Identification Guide to Scombrid Fishes and Larvae of Southeast Asia

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FOREWORD

Marine capture fishery is an important fisheries subsector in the regional and national economy of the Southeast Asian countries, particularly pelagic fisheries targeting the family Engraulidae and Scombridae. In the last decade, the demand for these pelagic fishes had continuously increased within and outside the region. However, the remarkable increase in number of fishing vessels and the introduction of more efficient fishing gears had led to the great decline of these pelagic fish populations in some waters in Southeast Asia. Therefore, it is necessary to have proper management and conservation of the stock to sustain its fisheries.

Generally, limiting the number of operating fishing vessels and banning fishing activities around spawning and nursery grounds seasonally are being undertaken as part of the management measures. Ichthyoplankton surveys were conducted to determine the spawning ground and season and to monitor the stock status of the targeted fishery resources.

However, the number of researchers on ichthyoplankton in the Southeast Asian region is scarce, and their skills in larval fish identification is limited. As such, the Southeast Asian Fisheries Development Center, Training Department (SEAFDEC/TD) in collaboration with the SEAFDEC-Sweden Project organized in 2015 the training workshop on the identification of larval fishes, particularly families Scombridae and Engraulidae. During the training workshop, it was realized that one of challenges of ichthyoplankton research is the lack of an identification guide to fish larvae commonly found in Southeast Asia. As alternative, we used reference books and other sources on other areas such as in the waters of Australia, Japan, Western and Central Pacific, California Current region. Therefore, it is my hope that the compilation of this book will boost the conduct of ichthyoplankton research in the Southeast Asian region.

On behalf of SEAFDEC, I wish to express my appreciation to authors and contributors who worked hard to compile and edit this book. I would like also to express my appreciation to the Japanese Trust Fund for the support to publish of this book.

Ms. Malinee Smithrithee
SEAFDEC Secretary-General

PREFACE

The high-yielding pelagic fishes such as anchovies, mackerels, and tuna-like fishes are the major target of fisheries in the world. They are an important fishery resources in terms of food production and economic benefits. However, in recent years, the fish stocks had been exposed to high fishing pressure coupled with the use of efficient fishing gear. Therefore, it is necessary to manage such resources for sustainable use and clarify the underlying ecological parameters.

Ecological research for resource management needs to be investigated throughout the life cycle of the target resources. In particular, conducting research on the spatiotemporal aspects including the spawning season and spawning ground of the target resources provides basic and essential knowledge to formulate biological management measures.

In order to advance the research on early life history of anchovies (Family Engraulidae), mackerels, tunas, and tuna-like fishes (Family Scombridae), the Training Department of the Southeast Asian Fisheries Development Center (SEAFDEC/TD) in collaboration with the SEAFDEC-Sweden Project organized a workshop on larval fish identification in 2016 in Samut Prakan, Thailand participated by young researchers from Cambodia, Malaysia, Myanmar, Thailand, and Viet Nam.

This Identification Guide to Scombrid Fishes and Larvae of Southeast Asia is published as an outcome of the Workshop. Unfortunately, due to the lack of information on in the region, the morphological development of the Engraulidae larvae was not included in this Guide.

Konishi, Y., Chayakul, R. & Punsri, R.

ACKNOWLEDGMENTS

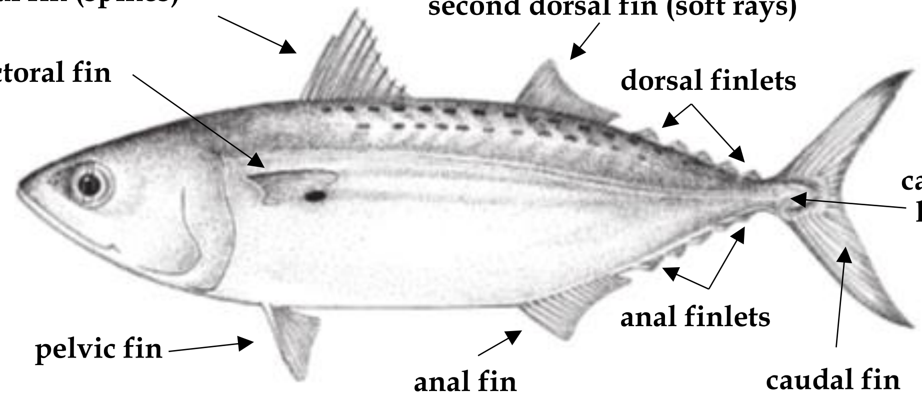
We acknowledge the publishers, authors, and editors of the references used in this Guide for the permission to reproduce the illustrations, namely: Food and Agriculture Organization of the United Nations (FAO), The American Society of Ichthyologists and Herpetologists (ASIH); Australia – G. P. Jenkins (University of Melbourne), J. M. Leis (Australian Museum and University of Tasmania); China – R. Z. Zhang (Yellow Sea Fisheries Research Institute); Japan – Y. Nishikawa and S. Ueyanagi (former National Research Institute of Far Seas Fisheries), T. Ozawa (Kagoshima University); USA – B. B. Collette (NOAA National Systematics Laboratory), H. G. Moser (NOAA Southwest Fisheries Science Center), late H. G. Moser (NOAA Southwest Fisheries Science Center), W. J. Richards (NOAA Southeast Fisheries Science Center), W. Watson (NOAA Southwest Fisheries Science Center).

We thank the researchers from Thailand including P. M. Hussadee and W. Boonyoung (Department of Fisheries, Thailand), K. Aiemsomboon (Chulalongkorn University), S. Siriraksophon and Y. Prarinthorn (UNEP/GEF), S. Arnupapboon and S. Pangsorn (SEAFDEC/TD) for their valuable comments to improve this Guide.

PART 1

ADULTS

DIAGNOSTIC CHARACTERS OF SCOMBRID FISHES



- **Two dorsal fins (the first fin is usually short and separated from the second)**
- **Four to twelve dorsal and anal finlets behind dorsal and anal fins**
- **Caudal fin deeply forked**
- **Pectoral fins placed high**
- **At least two small keels on each side of caudal peduncle**
- **31 to 64 vertebrae**

REFERENCES: Collette and Nauen (1983), Collette (2001), Collette and Graves (2019)

SPECIES COMPOSITION OF SCOMBRID FISHES

Tribe	Genus	Species	English name
Scombrini	*Rastrelliger*	*R. brachysoma*	short mackerel
		R. faughni	island mackerel
		R. kanagurta	Indian mackerel
	Scomber	*S. australasicus*	spotted chub mackerel
		S. japonicus	Pacific chub mackerel
Scombero-morini	*Acanthocybium*	*A. solandri*	wahoo
	Grammatorcynus	*G. bilineatus*	double-lined mackerel
	Scomberomorus	*S. commerson*	narrow-barred Spanish mackerel
		S. guttatus	Indo-Pacific king mackerel
		S. koreanus	Korean seerfish
		S. lineolatus	streaked seerfish
		S. sinensis	Chinese seerfish
Sardini	*Gymnosarda*	*G. unicolor*	dogtooth tuna
	Sarda	*S. orientalis*	striped bonito
Thunnini	*Auxis*	*A. rochei*	bullet tuna
		A. thazard	frigate tuna
	Euthynnus	*E. affinis*	kawakawa
	Katsuwonus	*K. pelamis*	skipjack
	Thunnus[1]	*T. alalunga*	albacore
		T. albacares	yellowfin tuna
		T. obesus	bigeye tuna
		T. tonggol	longtail tuna

[1] *Thunnus maccoyii* and *T. orientalis* distribute in the adjacent waters of Southeast Asia: the former is in the east Indian Ocean, and the latter in the west Pacific Ocean.

REFERENCES: Collette (2001)

[2]KEYS TO THE SPECIES OF SCOMBRID FISHES

1a. Two small keels and no large median keel on each side of caudal peduncle (Fig. 1a); usually five dorsal and five anal finlets (Fig. 1a); adipose eyelids cover front and rear of eye (Fig. 2) - - - - - - - - - - - - - 2

1b. Two small keels and a large median keel between them on each side of caudal peduncle (Fig. 1b); 6 to 11 dorsal and 5 to 12 anal finlets; adipose eyelids absent - 6

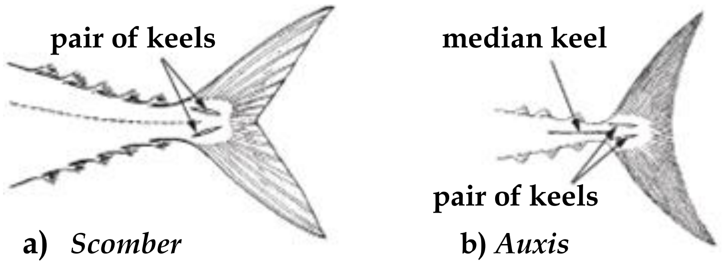


Fig. 1 Keels

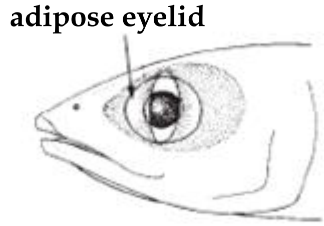


Fig. 2 *Scomber*

2a. Vertically zigzag or wavy lines on back; first anal-fin spine fairly stiff and strong (Fig. 3); teeth present on roof of mouth -- (*Scomber*) - - - - - - - - - - - 3

2b. One or two horizontal rows of spots on each side of back; first anal fin spine thin, rudimentary (Fig. 4); no teeth on roof of mouth -- (*Rastrelliger*) - - - - - - - - - 4

Fig. 3 *Scomber*

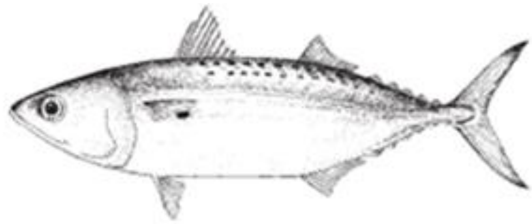


Fig. 4 *Rastrelliger kanagurta*

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[2] modified from Collette (2001).
REFERENCES: Collette and Nauen (1983), Collette (2001), Collette and Graves (2019)

3a. First dorsal-fin spines 9 or 10; distance from tenth (or ninth if it is last spine) dorsal-fin spine to origin of second dorsal fin less than distance between first and tenth (or ninth if it is last spine); 12–15 interneural bones[3] under first dorsal fin - - - - - - *Scomber japonicus*

3b. First dorsal-fin spines 10 to 13; distance from tenth dorsal-fin spine to origin of second dorsal fin greater than distance between first and tenth spine; 15–20 interneural bones under first dorsal fin - *Scomber australasicus*

4a. Gill rakers not visible from side of head when mouth is open, 34 to 40 on first gill arch; body moderately slender, its depth at posterior margin of opercle from 4.9 to 6 times in fork length; length of intestine equal to or less than fork length - - - - - *Rastrelliger faughni*

4b. Gill rakers visible from side of head when mouth is open (Fig. 5), 47 to 73 on first gill arch; body moderately deep, its depth at posterior margin of opercle from 3.7 to 5.2 times in fork length; length of intestine from 1.4 to 3.6 times the fork length - - - - - - - - - - - - - - - - - 5

5a. Body depth at posterior margin of opercle from 3.7 to 4.3 times in fork length; length of intestine from 3.2 to 3.6 times the fork length - *Rastrelliger brachysoma*

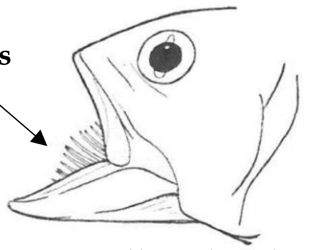

Fig. 5 *Rastrelliger brachysoma*
(after Collette and Nauen 1983)

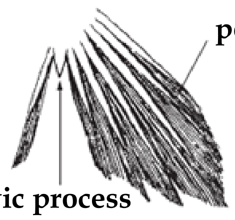

Fig. 6 *Grammatorcynus*

[3] Interneural bones are the proximal element of the pterygiophores which support fin ray, and insert between the neural spines of the vertebral columns.

5b. Body depth at posterior margin of opercle from 4.3 to 5.2 times in fork length; length of intestine from 1.4 to 1.8 times the fork length - *Rastrelliger kanagurta*

6a. Two lateral lines, the lower joining the upper behind pectoral-fin base and at caudal-fin base; interpelvic process single and small (Fig. 6); vertebrae 31 - *Grammatorcynus bilineatus*

6b. One lateral line; interpelvic process single (Figs. 6 and 12) or double (Fig. 13); vertebrae 38 to 64 - 7

7a. Teeth in jaws strong; compressed, almost triangular or knife-like; corselet of scales obscure; vertebrae 41 to 64 - - - - - - - - - - - - - - - - - - 8

7b. Teeth in jaws slender, conical, hardly compressed; corselet of scales well developed; vertebrae 38 to 45 - 13

8a. Snout as long as rest of head (Fig. 7); gill rakers absent; first dorsal fin with 23 to 28 spines; vertebrae 62 to 64 - - - - - *Acanthocybium solandri*

8b. Snout much shorter than rest of head (Fig. 8); at least one gill raker present; first dorsal fin with 14 to 18 spines; vertebrae 41 to 52 - (*Scomberomorus*) - - - - - - 9

9a. Lateral line with a deep dip below first or second dorsal fin; vertebrae 41 to 46 - 10

9b. Lateral line straight or descending gradually backwards. Vertebrae 44 to 52 - 11

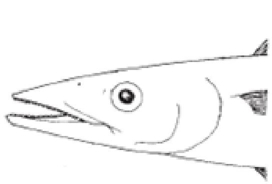

Fig. 7 *Acanthocybium*

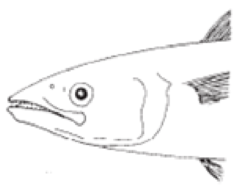

Fig. 8 *Scomberomorus*

10a. Dip in lateral line below first dorsal fin; total gill rakers on first gill arch 11 to 15; vertebrae 41 or 42 - - - - - - - - - *Scomberomorus sinensis*

10b. Dip in lateral line below second dorsal fin; total gill rakers on first gill arch 1 to 8; vertebrae 42 to 46 - - - - - *Scomberomorus commerson*

11a. Lateral line without auxillary branches anteriorly; vertebrae 44 to 46 - *Scomberomorus lineolatus*

11b. Lateral line with many small auxillary branches anteriorly (Fig. 9); vertebrae 46 to 52 - 12

12a. Dorsal-fin spines 15 to 18 (usually 16 or more); intestine with two loops and three limbs; head longer, from 20.2 % to 21.5 % of fork length; body depth less, 22.8 % to 25.2 % of fork length; vertebrae from 47 to 52- - - - - - - - - - - - - - - *Scomberomorus guttatus*

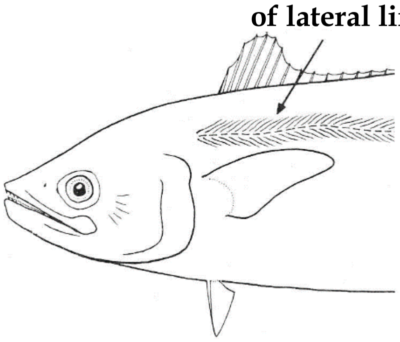

Fig. 9 *Scomberomorus koreanus* (after Collette and Nauen, 1983)

12b. Dorsal-fin spines from 14 to 17 (usually 14 or 15); intestine with four loops and five limbs; head shorter, from 19.7 % to 20.4 % of fork length; body depth greater, from 24.4 % to 26.7 % of fork length; vertebrae 46 or 47 - - - - - - - - - - - - - - - - - - *Scomberomorus koreanus*

13a. Upper surface of tongue without cartilaginous longitudinal ridges (Fig. 10a) - 14

13b. Upper surface of tongue with two longitudinal ridges (Fig. 10b) - - 15

14a. Six to eight narrow, dark longitudinal stripes on upper part of body (Fig. 11); no teeth on tongue; vertebrae 44 or 45 - - - - ***Sarda orientalis***

14b. Body either without stripes or with dark spots above lateral line and longitudinal dark stripes below; two patches of teeth on tongue; vertebrae 38 - ***Gymnosarda unicolor***

Fig. 10 *Sarda orientalis* (left), *Katsuwonus pelamis* (right)

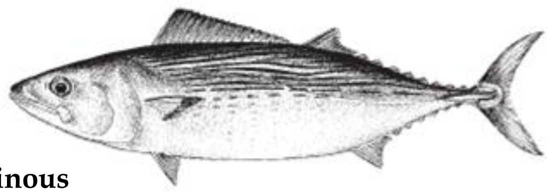

Fig. 11 *Sarda orientalis*

15a. First and second dorsal fins widely separated, the space between them at least equal to length of first dorsal-fin base (Fig. 12); first dorsal-fin spines from 10 to 12; interpelvic process single and large, longer than longest pelvic-fin ray (Fig. 12); vertebrae 39 -(***Auxis***)- - 16

15b. First and second dorsal fins barely separated, at most by a space equal to eye diameter (Figs. 13 to 15); first dorsal-fin spines from 12 to 18; interpelvic process bifid and short, shorter than shortest pelvic-fin rays (Fig. 13); vertebrae 39 or 41 - 17

16a. Posterior extension of corselet[4] narrow, only from one to five scales wide under second dorsal-fin origin; dorsal naked area extends anterior to tips of pectoral fins; gill rakers from 38 to 42 on first gill arch - ***Auxis thazard***

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[4] The large thick scales that cover the anterior part of the body in advanced scombrids (see Fig. 14).

16b. Posterior extension of corselet wide, usually from 10 to 15 scales wide under origin of second dorsal fin; dorsal naked area does not extend anterior to tips of pectoral fins; gill rakers from 37 to 47 on first gill arch - ***Auxis rochei***

17a. Four to 6 prominent dark longitudinal stripes on belly (Fig. 13); total gill rakers on first gill arch from 50 to 65; vertebrae 41 - ***Katsuwonus pelamis***

17b. No dark longitudinal stripes on belly; total gill rakers on first gill arch from 19 to 34; vertebrae 39 - 18

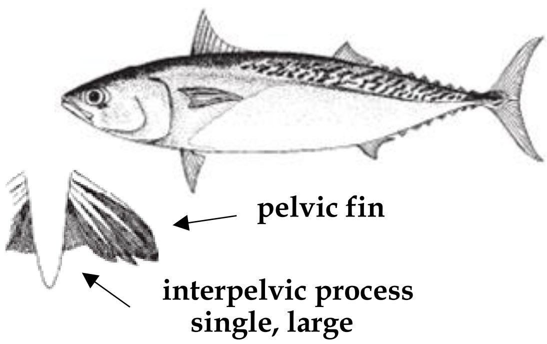

Fig. 12 *Auxis thazard*

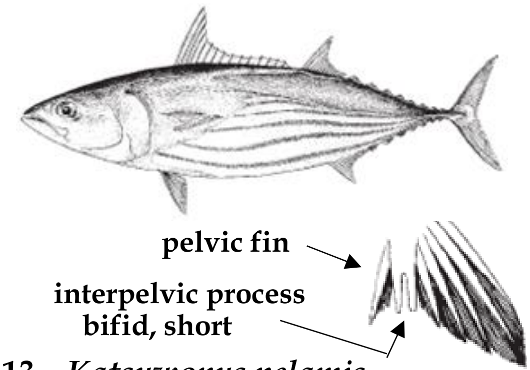

Fig. 13 *Katsuwonus pelamis*

18a. Body naked behind corselet; several black spots usually present between pectoral- and pelvic-fin bases (Fig. 14); pectoral-fin rays from 25 to 27 - ***Euthynnus affinis***

18b. Body covered with very small scales behind corselet; no black spots on body (Fig. 15); pectoral-fin rays from 30 to 36 - - (***Thunnus***) - - - 19

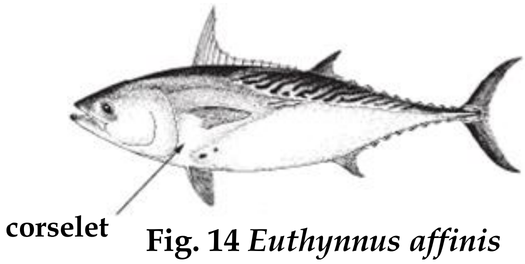

Fig. 14 *Euthynnus affinis*

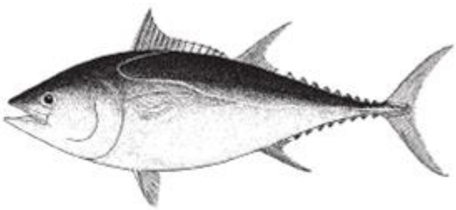

Fig. 15 *Thunnus*

19a. **Ventral surface of liver with prominent striations; center lobe of liver equal to or longer than left and right lobes (Fig. 16a) - - - - - - - - - 20[5]**

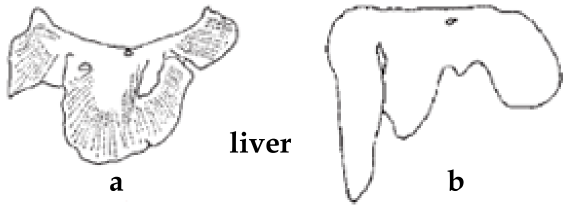

Fig. 16 ***T. alalunga, T. obesus*** **(a) and** ***T. albacares, T. tonggol*** **(b)**

19b. **Ventral surface of liver without prominent striations; right lobe of liver much longer than left or central lobes (Fig. 16b) - - - - - - - - - - 21**

20a. **Caudal fin with a narrow white posterior border; pectoral fins very long, reaching well past end of second dorsal-fin base; greatest body depth at or slightly before level of second dorsal fin -** ***Thunnus alalunga***

20b. **Caudal fin without white posterior border; pectoral fins short or moderate in length, not reaching end of second dorsal-fin base (except in small individuals); greatest body depth about middle of body, near middle of first dorsal fin - - - - - - - - - - - -** ***Thunnus obesus***

21a. **Total gill rakers on first gill arch from 26 to 34 (usually 27 or more); second dorsal and anal fins of larger individuals (120 cm fork length or larger) elongate, more than 20 % of fork length; maximum size is over 200 cm fork length -** ***Thunnus albacares***

21b. **Total gill rakers on first gill arch from 19 to 27 (usually 26 or fewer); second dorsal and anal fins never greatly elongate, less than 20 % of fork length at all sizes; maximum size 130 cm fork length -** ***Thunnus tonggol***

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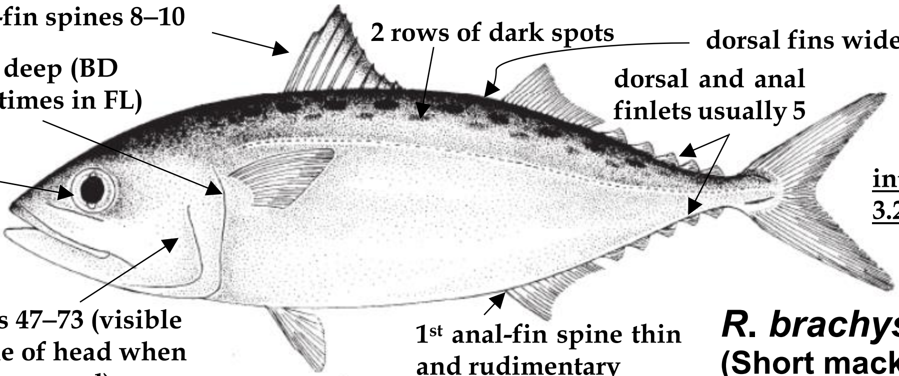
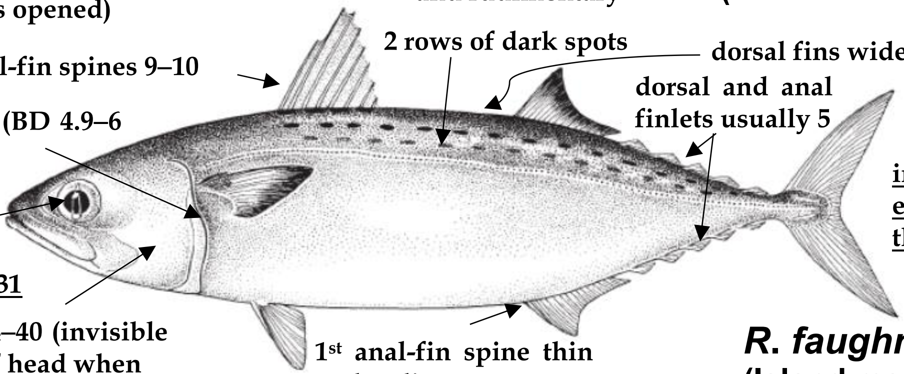
[5] This type liver is shared with the neighboring-water species of *Thunnus orientalis* and *T. maccoyii*. *Thunnus orientalis* are distinguished from *T. maccoyii* by median caudal keel and pectoral-fin size (dark vs yellow, less than 20 % of fork length vs more than 20 % of fork length, respectively).

PICTORIAL KEYS TO THE SPECIES OF SCOMBRID FISHES

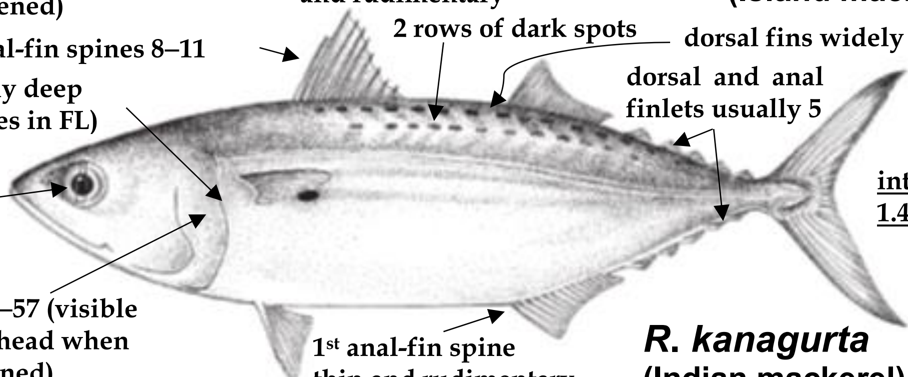
Rastrelliger



R. brachysoma
(Short mackerel)

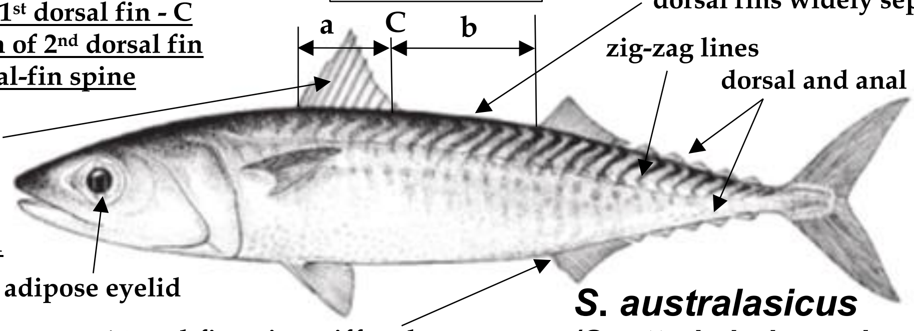


R. faughni
(Island mackerel)



R. kanagurta
(Indian mackerel)

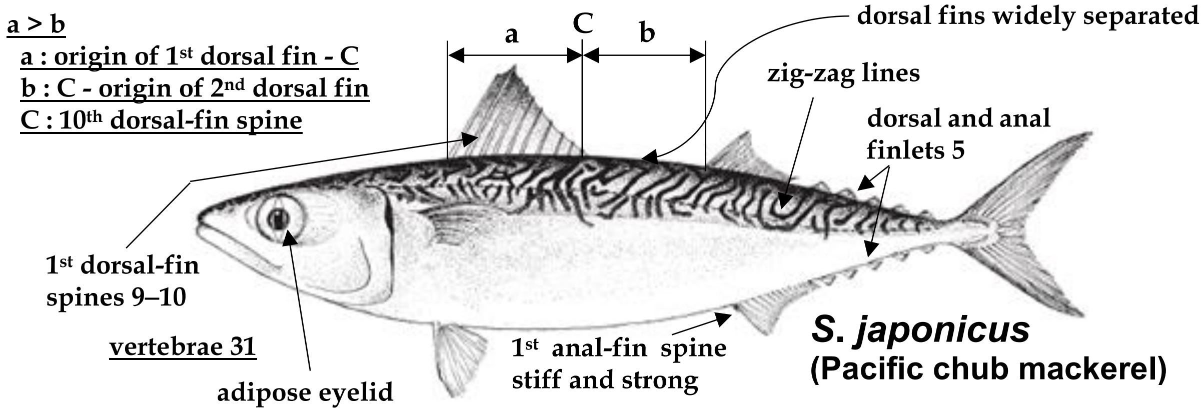
Scomber



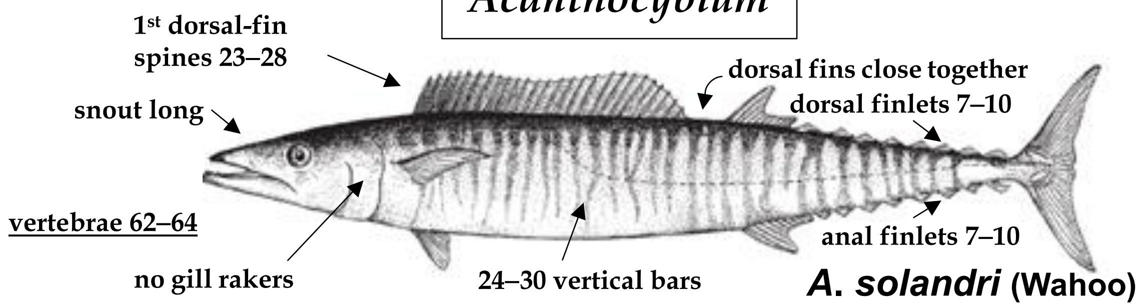
S. australasicus
(Spotted chub mackerel)

Selected distinguishing characters are shown (the same hereafter).
REFERENCES: Collette and Nauen (1983), Collette (2001), Nakabo and Doiuchi (2013), Collette and Graves (2019)

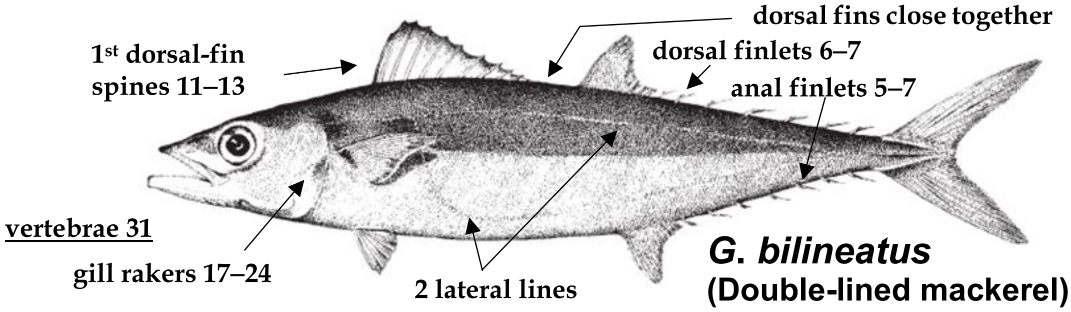
Scomber (cont'd)



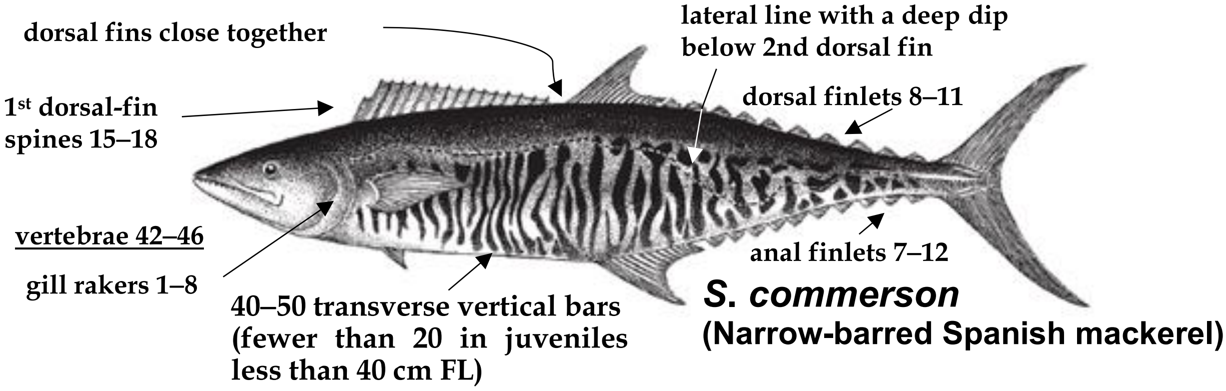
Acanthocybium



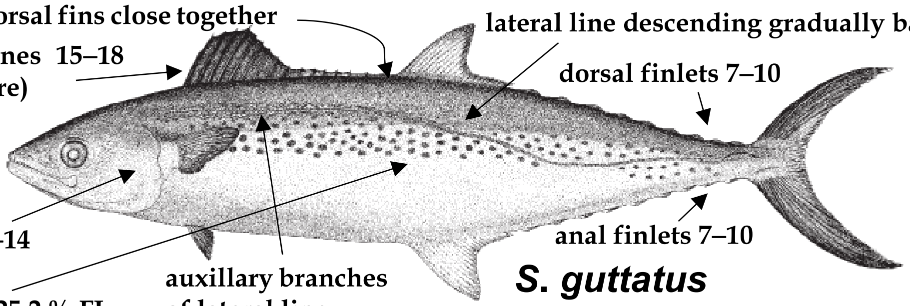
Grammatorcynus



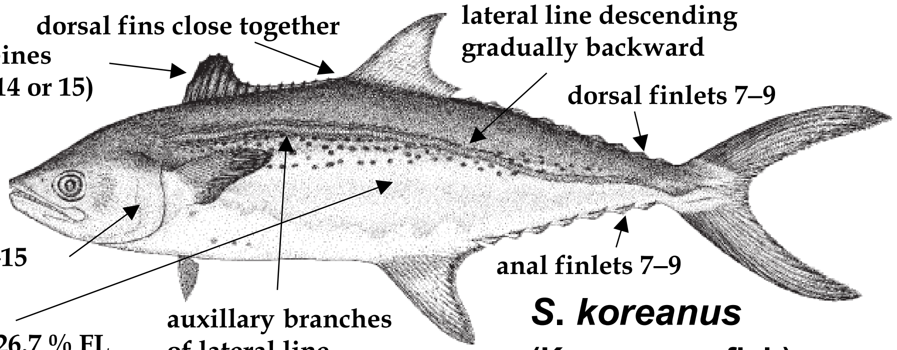
Scomberomorus



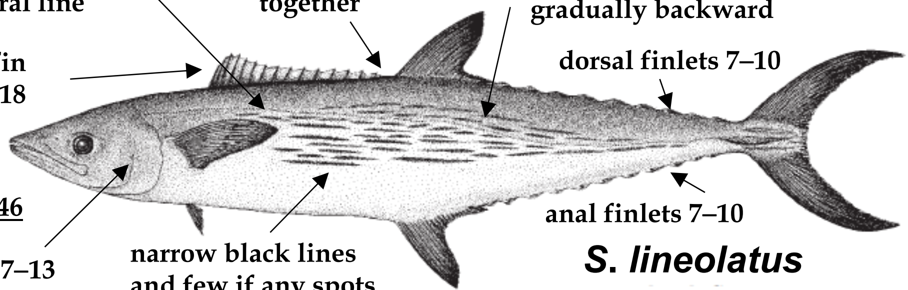
Scomberomorus (cont'd)



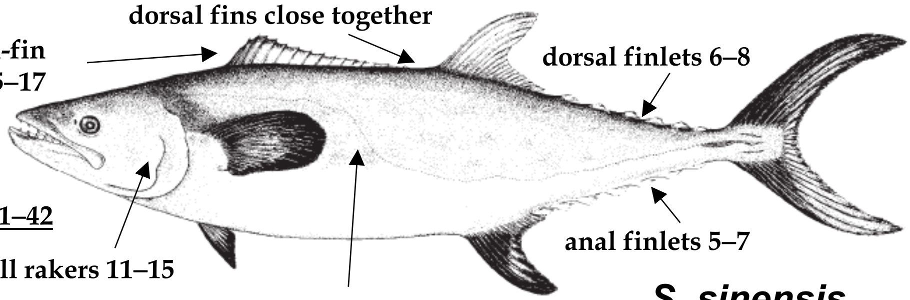
S. guttatus
(Indo-Pacific king mackerel)



S. koreanus
(Korean seerfish)

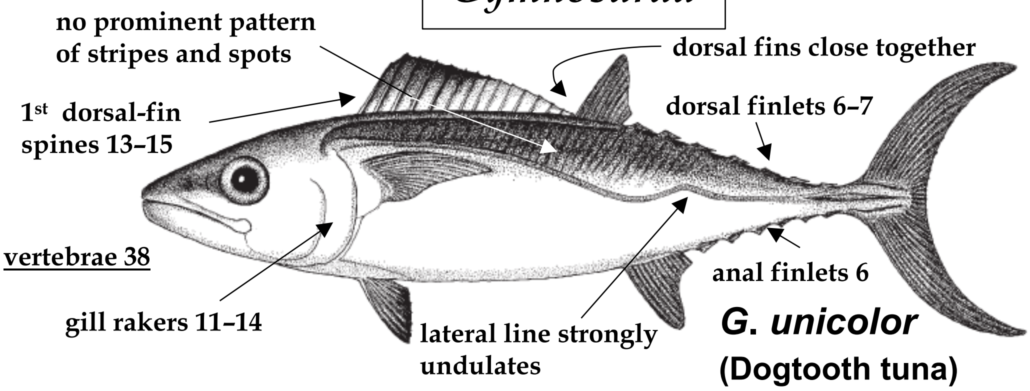


S. lineolatus
(Streaked seerfish)



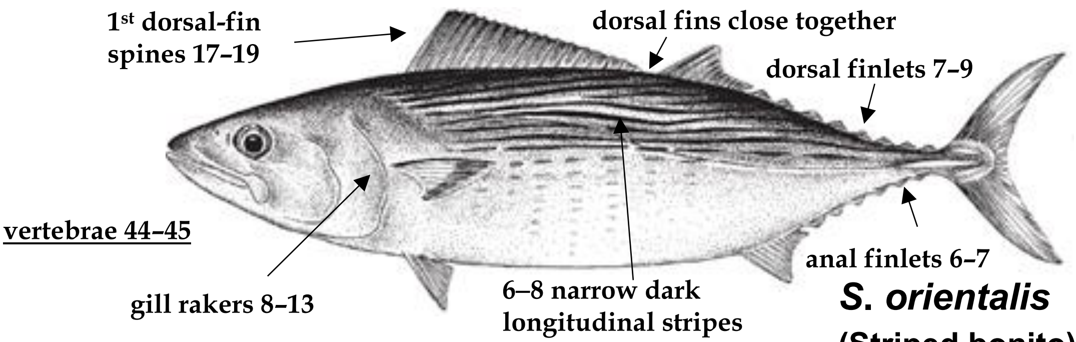
S. sinensis
(Chinese seerfish)

Gymnosarda



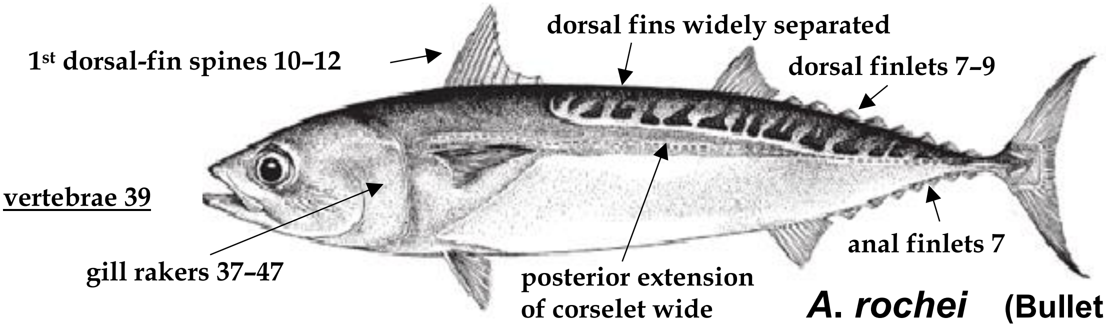
G. unicolor
(Dogtooth tuna)

Sarda

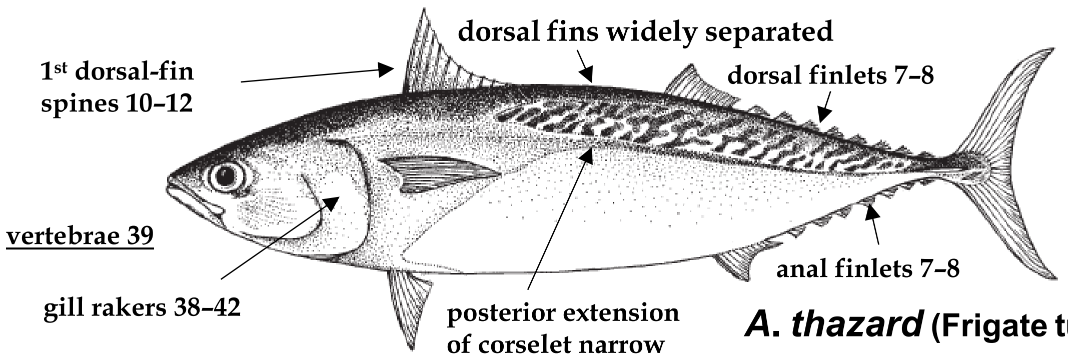


S. orientalis
(Striped bonito)

Auxis

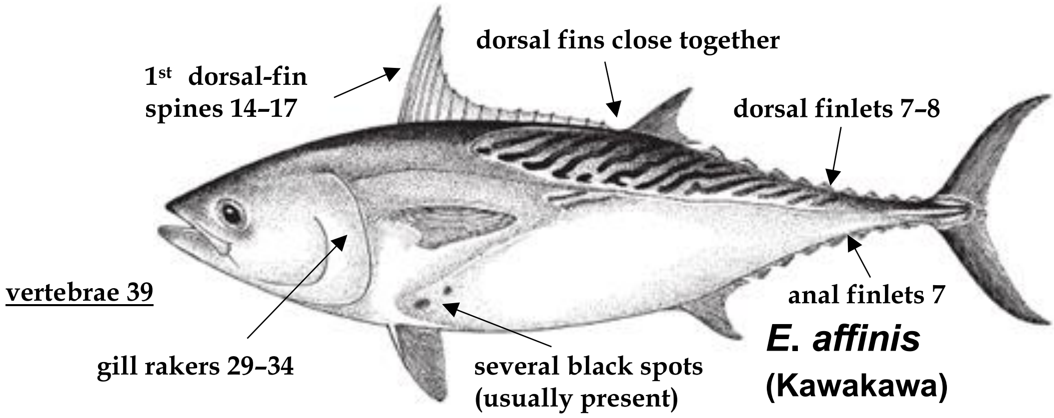


A. rochei **(Bullet tuna)**

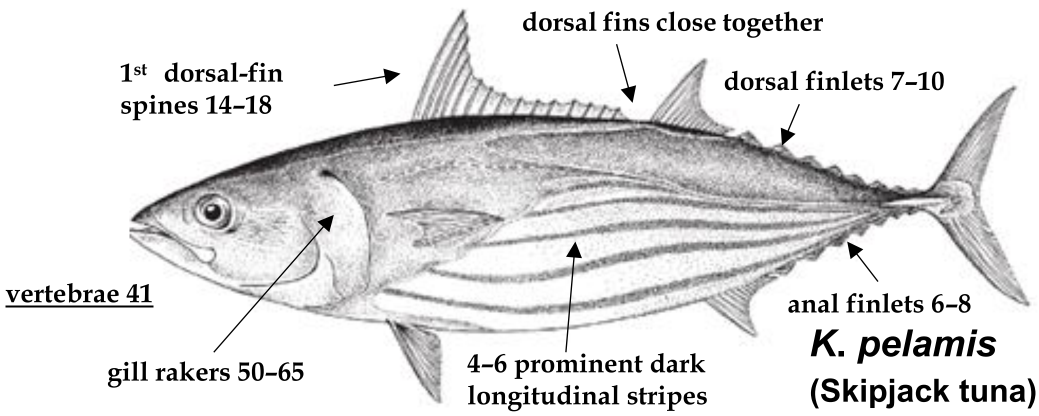


A. thazard **(Frigate tuna)**

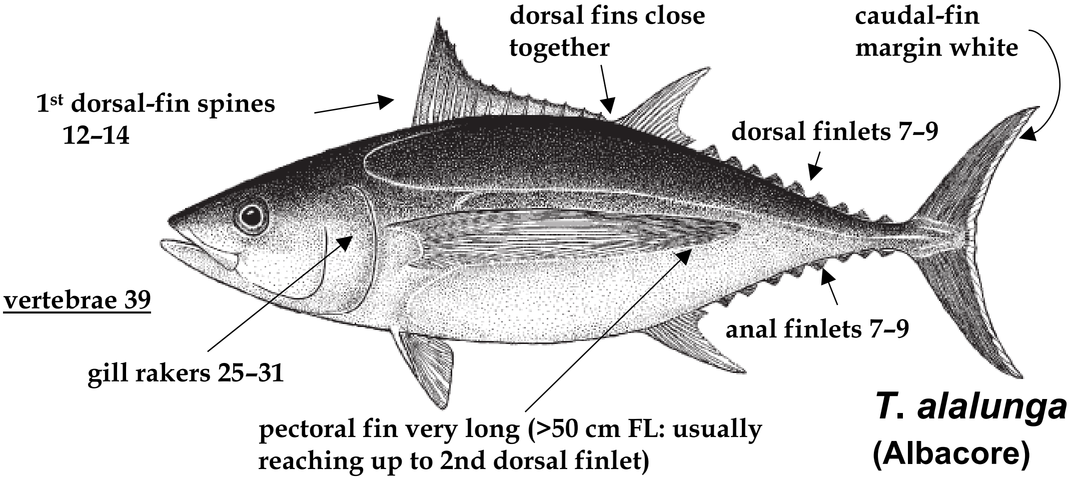
Euthynnus

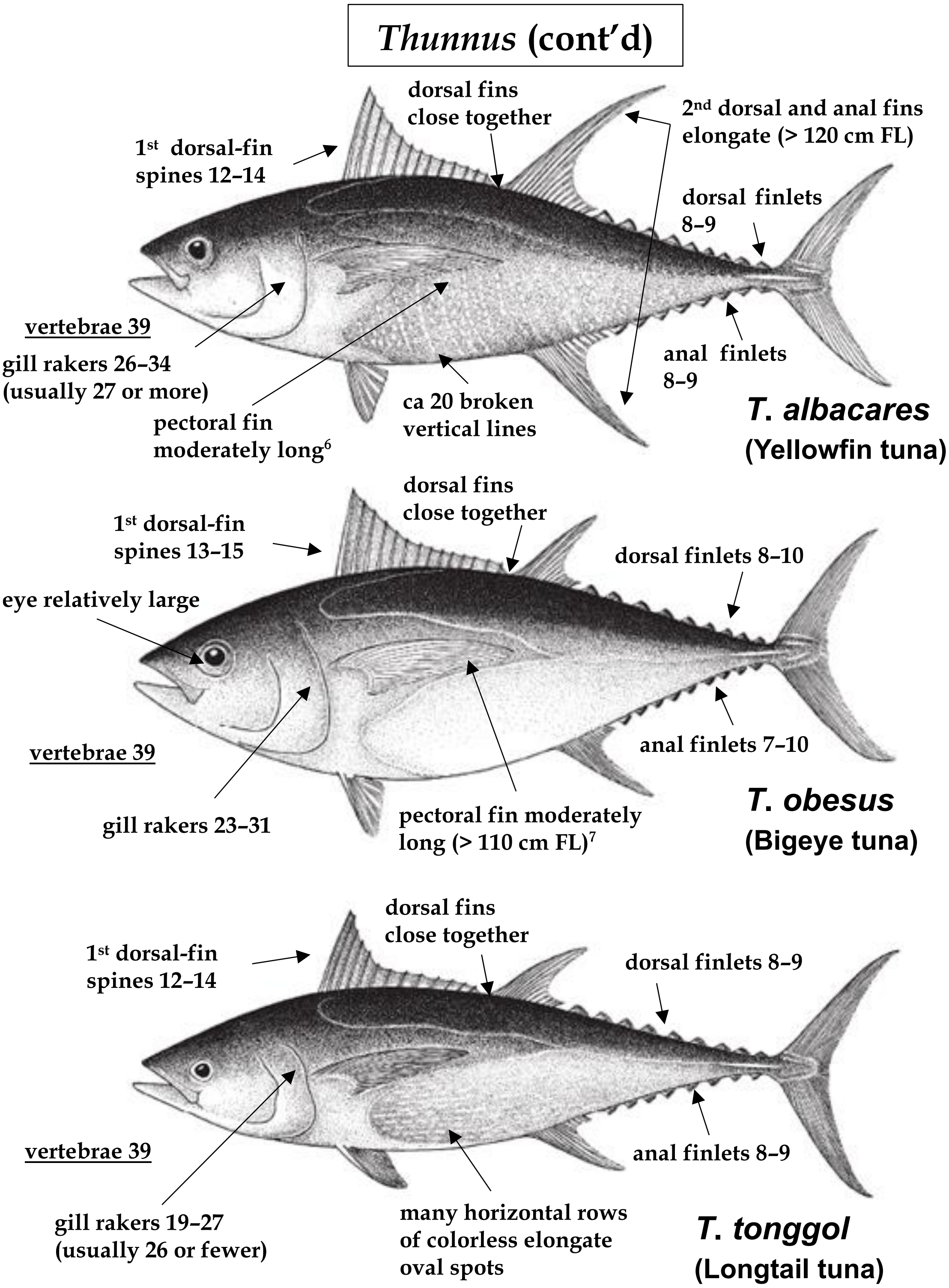


Katsuwonus



Thunnus





[6] Pectoral fins reach usually beyond origin of 2nd dorsal fin but not beyond the end of its base.
[7] Pectoral fins of smaller individuals (> 40 cm) are very long (reaching to end of 2nd dorsal fin).

Table 1. Distributions of scombrid fishes in Southeast Asian countries

Species	Brunei Darussalam	Cambodia	Indonesia				Malaysia			Myanmar	Philippines		Thailand		Viet Nam	
	SCS	GOT	EID	CID	WID	IND[a]	SCS (E)	SCS (W)	SOM	ADM	SCS[b]	PCF	GOT	ADM[c]	SCS (S)	SCS (N)
Rastrelliger brachysoma	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	×
R. faughni	○	○	△	△	○	△	○	○	○	○	○	○	○	○	○	○
R. kanagurta	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Scomber australasicus	×	×	△	×	×	×	×	×	×	×	○	○	×	×	×	×
S. japonicus	×	×	×	×	×	×	×	×	×	×	△	○	×	×	×	×
Acanthocybium solandri	×	×	○	△	×	○	△	×	×	×	○	○	×	×	×	×
Grammatorcynus bilineatus	○	?	○	△	○	○	○	?	○	○	○	○	?	○	?	?
Scomberomorus commerson	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
S. guttatus	○	○	△	△	○	×	○	○	○	○	×	×	○	○	○	○
S. koreanus	×	×	×	×	○	×	×	○	○	○	×	×	×	○	○	○
S. lineolatus	×	×	×	△	○	△	×	○	○	○	×	×	△	○	×	×
S. sinensis	×	×	×	×	×	×	×	×	×	×	×	×	×	×	○	○
Gymnosarda unicolor	×	×	×	×	×	×	×	×	×	×	○	○	×	×	×	×
Sarda orientalis	×	×	△	×	×	△	×	×	×	?	△	○	×	×	×	?
Auxis rochei	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
A. thazard	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
Euthynnus affinis	○	×	○	○	○	○	○	○	○	○	○	○	△	○	○	△
Katsuwonus pelamis	○	×	○	○	○	○	○	△	○	○	○	○	×	○	△	×
Thunnus alalunga	×	×	×	×	×	○	△	×	×	×	△	△	×	×	△	×
T. albacares	○	×	○	○	○	○	○	△	△	○	○	○	×	○	△	×
T. obesus	○	×	○	△	×	○	○	△	×	△	○	○	×	△	○	×
T. tonggol	○	×	○	○	○	○	○	○	△	△	○	○	△[d]	△[d]	△	×

ADM: Andaman Sea; GOT: Gulf of Thailand; IND: Indian Ocean; PCF: Pacific Ocean; SCS: South China Sea; SCS (E): South China Sea (East Malaysia including Sulu and Celebes Seas); SCS (W): South China Sea (West Malaysia); SCS (N): South China Sea (Vietnam, north of Danang); SCS (S): South China Sea (Viet Nam, south of Danang including GOT); SOM: Strait of Malacca; EID: Eastern Indonesia (Celebes, Molucca, Halmahera, Seram, Banda and Arafura Seas, PCF); CID: Central Indonesia (SCS, Natuna, Karimata, Java, Makassar, Flores Seas); WID: Western Indonesia (SOM).

[a] From western Sumatra Island to southern Java-Nusa Tenggara Islands; [b] including Sulu and Celebes Seas; [c] including Strait of Malacca; [d] Information from the Department of the Fisheries, Thailand (personal communication).

○: present; △: partly present; ×: not present; ?: no available information.

REFERENCES : Collette (2001), Collette and Graves (2019)

Table 2. Meristic data of scombrid fishes

Tribe	Genus	Species	D_1	D_2	D finlets	A	A finlets	P_1	GR	V
Scombrini	*Rastrelliger*	*R. brachysoma*	8–10	11–13	4–6	10–13	5	18–21	47–73	31
		R. faughni	9, 10	11–13	4–6	12–13	5	18–21	34–40	31
		R. kanagurta	8–11	11–13	4–6	10–13	5	18–22	48–57	31
	Scomber	*S. australasicus*	10–13	12–13[c]	5	10–14[c]	5	18–21	33–40	31
		S. japonicus	9, 10	12–13[c]	5	12–14[c]	5	20–21	37–47	31
Scomberomorini	*Acanthocybium*	*A. solandri*	23–28	11–16	7–10	10–14	7–10	22–26	0	62–64
	Grammatorcynus	*G. bilineatus*	11–13	10–14	6, 7	10–15	5–7	22–26	17–24	31
	Scomberomorus	*S. commerson*	15–18	15–20	8–11	16–21	7–12	21–24	1–8	42–46
		S. guttatus	15–18	18–24	7–10	19–23	7–10	20–23	8–14	47–52
		S. koreanus	14–17	20–24	7–9	20–24	7–9	20–24	11–15	46, 47
		S. lineolatus	15–18	15–22	7–10	17–22	7–10	20–24	7–13	44–46
		S. sinensis	15–17	15–17	6–8	16–19	5–7	21–23	11–15	41, 42
Sardini	*Gymnosarda*	*G. unicolor*	13–15	12–14	6, 7	12–13	6	25–28	11–14	38
	Sarda	*S. orientalis*	17–19	14–17	7–9	14–16	6, 7	23–26	8–13	44, 45
Thunnini	*Auxis*	*A. rochei*	10–12	10–12	7–9	12–13	7	22, 23	37–47	39
		A. thazard	10–12	10–12	7, 8	12–14	7, 8	22–25	38–42	39
	Euthynnus	*E. affinis*	14–17	10–13	7, 8	13–14	7	25–27	29–34	39
	Katsuwonus	*K. pelamis*	14–18	13–16[d]	7–10	13–17[d]	6–8	24–32	50–65	41
	Thunnus	*T. alalunga*	12–14	13–16	7–9	11–15	7–9	31–36	25–31	39
		T. albacares	12–14	14–15	8, 9	14–15	8, 9	32–35	26–34	39
		T. obesus	13–15	13–16	8–10	11–15	7–10	31–35	23–31	39
		T. tonggol	12–14	14–15	8, 9	13–14	8, 9	30–35	19–27	39
		T. maccoyii[a]	12–14	13–15	8–10	13–15	7–9	31–36	31–40	39
		T. orientalis[b]	13–15	13–15	8, 9	13–15	7, 8	31–38	32–43	39

D_1: first dorsal fin (spines); D_2: second dorsal fin (soft rays); D finlets: dorsal finlets; A: anal fin (soft rays); A finlets: anal finlets; P_1: pectoral fin; GR: gill rakers on first gill arch; V: vertebrae.

[a] Southern bluefin tuna is distributed throughout the Southern Oceans mainly between 30°S and 50°S.

[b] Pacific bluefin tuna is distributed in the west Pacific Ocean.

[c] First ray is described as spine and [d] first two rays as spines (Nakabo & Doiuchi, 2013).

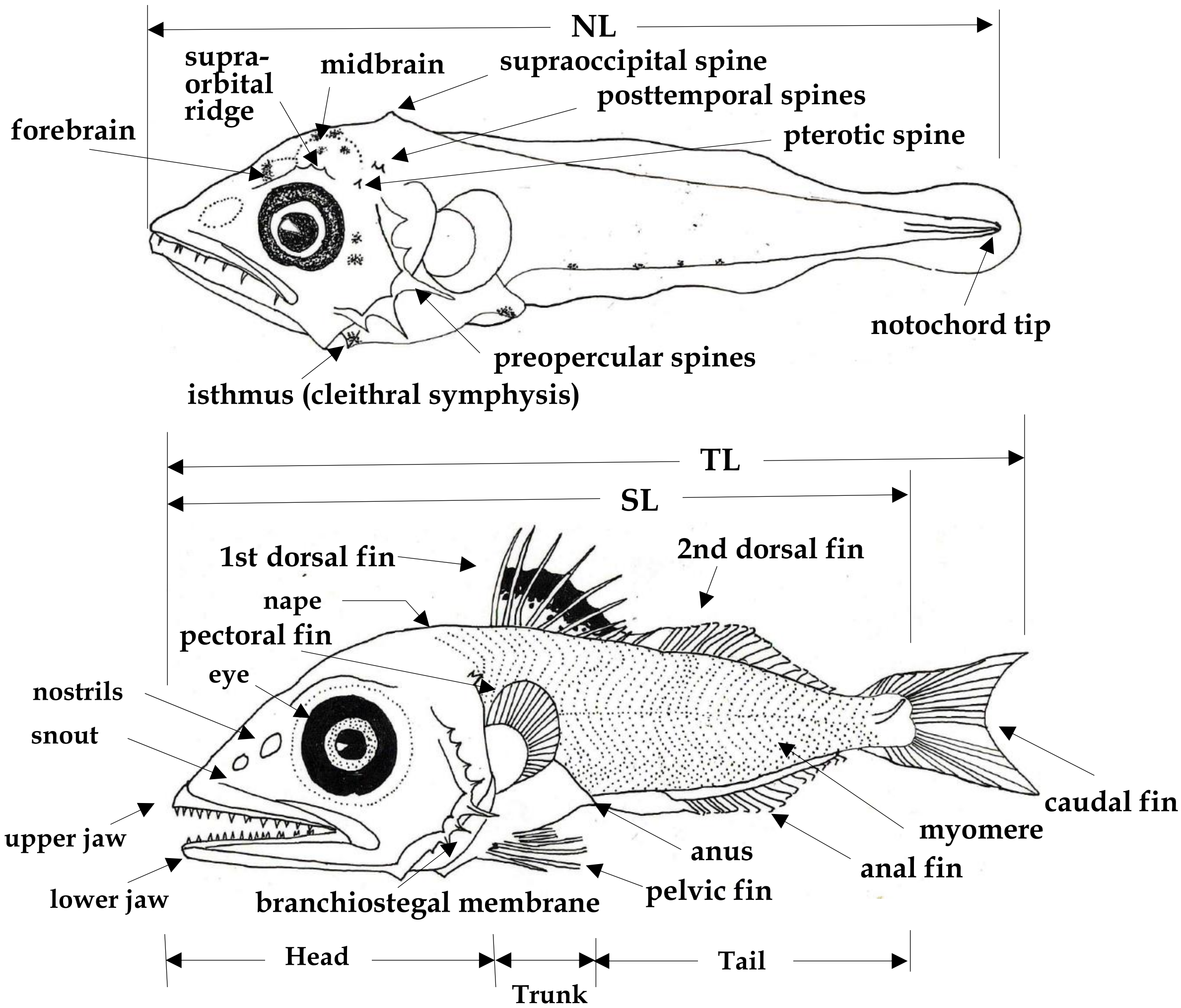
Pelvic fins of all species: one spine and five soft rays.

REFERENCES: Nakabo and Doiuchi (2013), Collette and Graves (2019)

PART 2

LARVAE

MORPHOLOGICAL CHARACTERS AND MEASUMENTS OF SCOMBRID FISH LARVAE



Hypothetical larvae (upper: preflexion; lower: postflexion)

NL: notochord length (distance from tip of snout to posterior margin of notochord)

SL: standard length (distance from tip of snout to posterior vertical margin of hypural plate)

TL: total length (distance from tip of snout to posterior edge of caudal fin)

Head: portion from anterior tip of snout to posterior margin of opercle

Trunk: portion between head and anus

Tail: portion of body posterior to anus

[8]KEYS TO THE SPECIES OF SCOMBRID FISH LARVAE

1a. Second dorsal fin develops prior to first dorsal fin. Preopercular spines absent. Vertebrae (myomeres) 31 - 2

1b. First dorsal fin develops prior to second dorsal fin. Preopercular spines present. Vertebrae (myomeres) from 31 to 64 - - - - - - - - - - - - 3

2a. Pigment present heavily over brain, and on nape[9]. Pigment spots on ventral gut and preanus invisible or small at preflexion and flexion. Upper jaw tip projecting at postflexion - - - - - - - - - - - - - - - - (*Scomber*)

2b. Pigment present sparsely over brain and absent on nape. Pigment spots on ventral gut and preanus distinct at preflexion and flexion. Both jaw tips nearly meet at postflexion - - - - - - - - - - - - - (*Rastrelliger*)

3a. Snout round and short. Preopercular spines small in same size. Vertebrae (myomeres) 31 - - - - - - - - - - - - *Grammatorcynus bilineatus*

3b. Snout pointed or elongate. Preopercular spines formed usually well and elongate at angle. Vertebrae (myomeres) ≧ 39 - - - - - - - - - - - - 4

4a. Supraoccipital spine present - 5

4b. Supraoccipital spine absent - 6

5a. Snout elongate and its length about two times of eye diameter. Supraoccipital spine distinct. No pigment appears on pelvic fin. Vertebrae (myomeres) from 41 to 52 - - - - - - - - - - - - (*Scomberomorus*)

5b. Snout moderately elongate and its length 1.5 times of eye diameter. Supraoccipital spine weak. Pigment appears on pelvic fin. Vertebrae (myomeres) 44 or 45 - *Sarda orientalis*

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[8] modified from Nishikawa (2014). This key is applied to larvae less than 10 mm BL.
[9] Development of pigment on nape is depend on body size (see page 25 and 26).

REFERENCES: Nishikawa and Rimmer (1987), Richards and Jenkins (2000), Richards (2006), Fahay (2007), Nishikawa (2014)

6a. Body elongate. Gut very long and anus position considerably beyond half body. Snout extremely elongate and mouth quite large. Vertebrae (myomeres) from 62 to 64 - - - - - ***Acanthocybium solandri***

6b. Body moderate and tail tapering. Gut compact and anus position anterior to or near half body. Snout pointed or elongate. Mouth moderate or large. Vertebrae (myomeres) 38 to 41 - - - - - - - - - - - - - - 7

7a. Snout very elongate. Upper jaw tip greatly projecting. Branchiostegal membrane and opercular area well pigmented - ***Gymnosarda unicolor***

7b. Snout pointed. Both jaw tips nearly meet or upper jaw tip slightly projecting at postflexion stage. Branchiostegal membrane and opercular area sparsely pigmented - 8

8a. Internal pigment present on anterior margin of forebrain - - - - - - - - 9

8b. Internal pigment absent on anterior margin of forebrain - - - - - - - - 11

9a. Cleithral symphysis and preanus pigmented - - - - - ***Euthynnus affinis***

9b. Cleithral symphysis and preanus unpigmented - - - - - - - - - - - - - - - 10

10a. Pigment appears early on lower jaw tip at about 3.5 mm NL. First dorsal fin pigmented late at about 6 mm SL. Pigment appears late on upper jaw tip at about 7.5 mm SL. Vertebrae (myomeres) 41 - ***Katsuwonus pelamis***

10b. Pigment appears late on lower jaw tip at about 9 mm SL[10]. First dorsal fin pigmented early at about 5 mm SL. Pigment appears early on upper jaw tip at about 5 mm SL. Vertebrae (myomeres) 39 - ***Thunnus tonggol***

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[10] Nishikawa and Ueyanagi (1992)

11a. Pigment present on cleithral symphysis and preanus. First dorsal fin pigmented late at about 11 mm SL - - - - - - - - - - - - (*Auxis*) - - - - - - 12

11b. No pigment present on cleithral symphysis and preanus. First dorsal fin pigmented early at 5–6 mm SL - 13

12a. 3.5–5 mm NL: melanophore on lateral midline of tail (MLM) absent, and pigment on lower jaw tip (PLJ) present; 5–6 mm BL: MLM 0 or 1, and PLJ present; 6–7 mm SL: MLM usually from 0 to 2, if more than 3, the melanophores present on caudal peduncle and/or anterior to caudal peduncle - *Auxis rochei*[11]

12b. 3.5–5 mm NL: melanophores on lateral midline of tail (MLM) present, or MLM and pigment on lower jaw tip (PLJ) absent; 5–6 mm BL: MLM usually equal to or more than 2, if a single, the PLJ absent; 6–7 mm SL: MLM usually equal to or more than 3, and the pigment present mostly on caudal peduncle - - - - - - - - - - - - - - - *Auxis thazard*[11]

13a. One or two very small melanophores present on ventral midline of tail - *Thunnus obesus*

13b. No melanophores present on tail - 14

14a. Pigment on lower jaw tip appears late at about 8 mm SL - *Thunnus alalunga*[12]

14b. Pigment on lower jaw tip appears early at about 4 mm NL - *Thunnus albacares*

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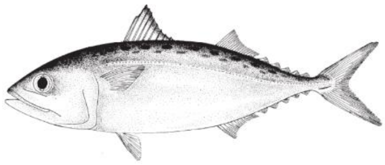
[11] modified from Sato et al. (2020). This key is applied to larvae less than 7 mm BL (NL or SL). Completion of notochord flexion occurs around 6 mm BL.

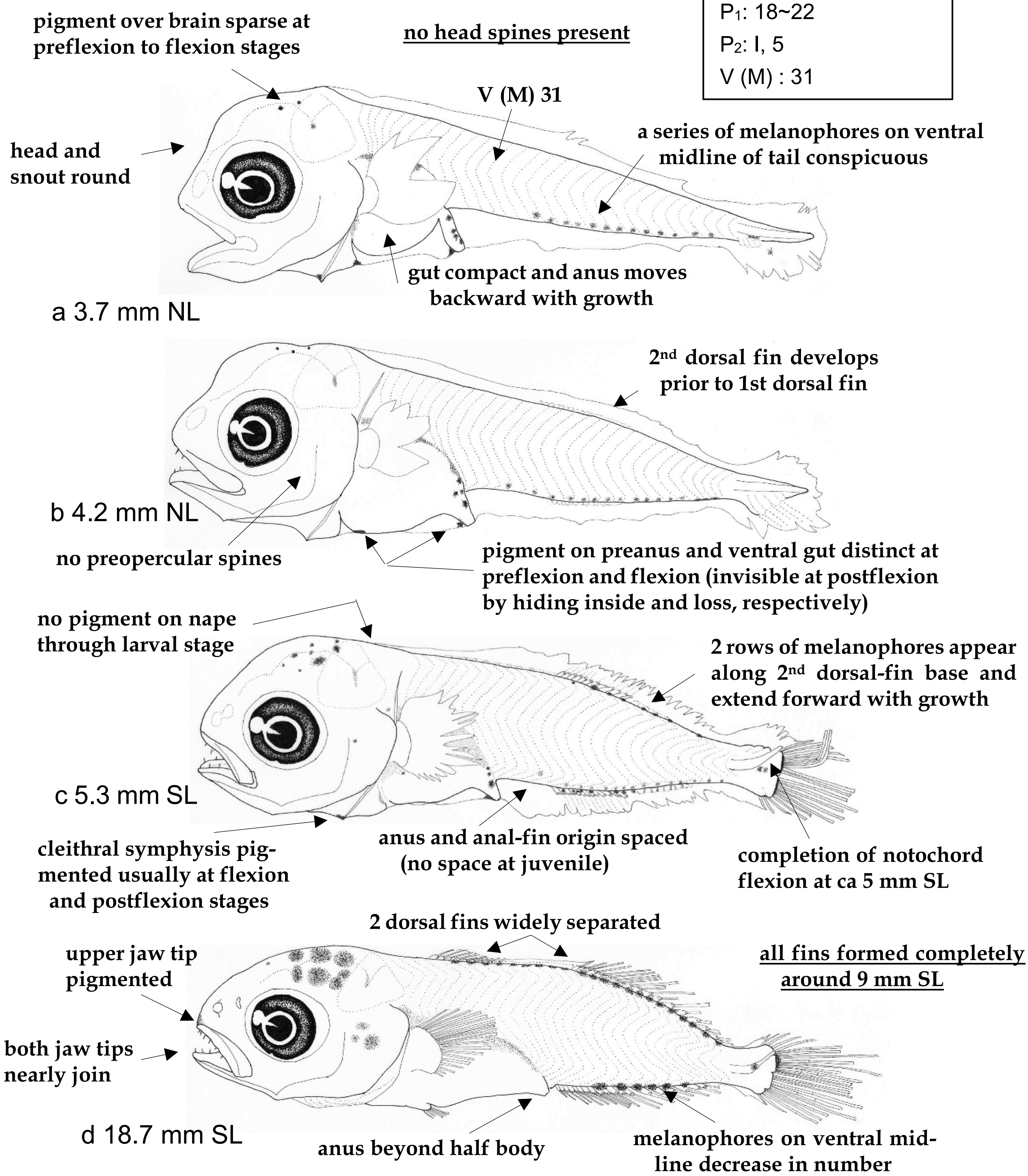
[12] Spawning grounds are formed mainly in the tropical and subtropical waters out the Southeast Asian waters: Central Indian Ocean (10°S–26°S, 50°E–120°E); northern Central & West Pacific Ocean (10°N–30°N, 128°E–150°W); southern Pacific Ocean (8°S–25°S, 150°E–105°W) (Ueyanagi, 1969).

PICTORIAL KEYS TO THE SPECIES OF SCOMBRID FISH LARVAE

Rastrelliger[13]



D : VIII~XI-11~13+4~6
A : 10~13+5
P_1: 18~22
P_2: I, 5
V (M) : 31



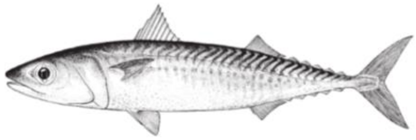
***Rastrelliger* sp. or spp. (a∼d: Konishi 2014)**

Selected characters with an arrow are shown (the same hereafter).

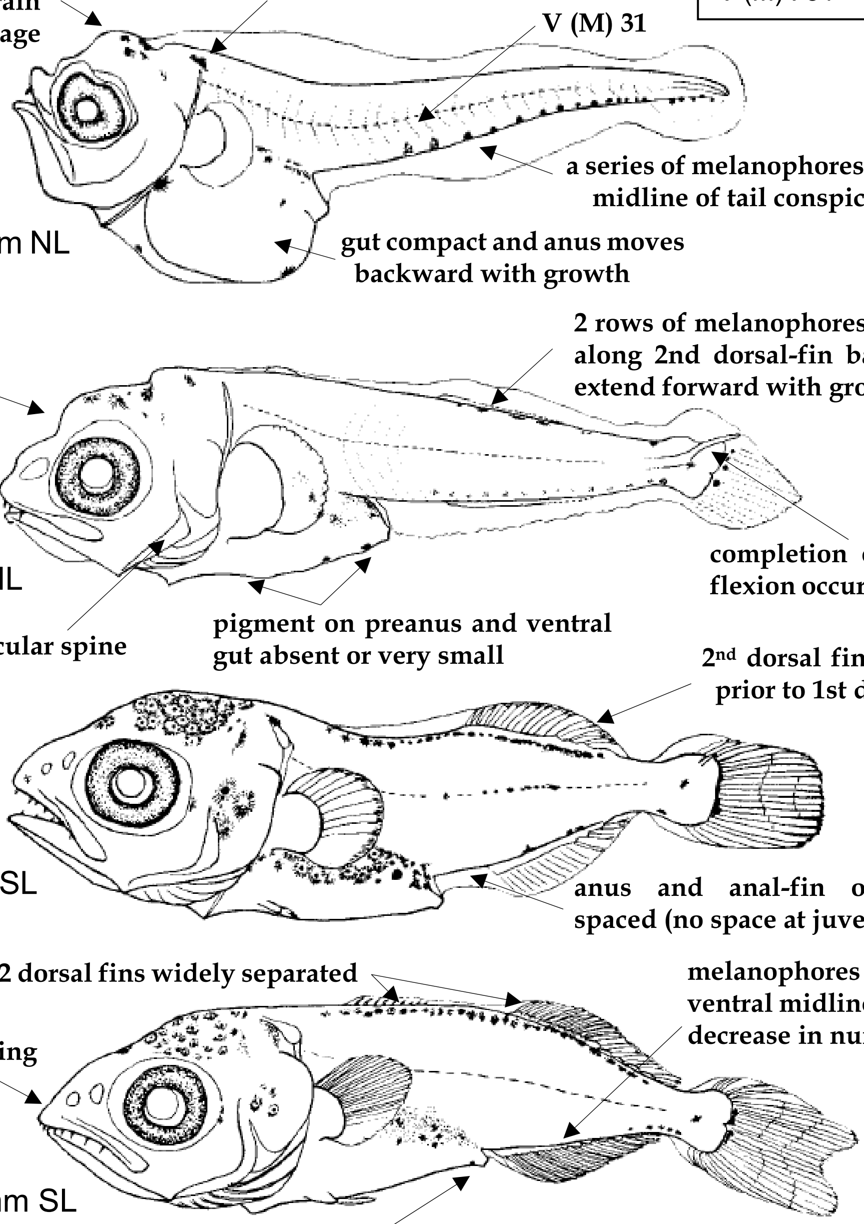
[13] Species identification of *Rastrelliger brachysoma*, *R. faughni* and *R. kanagurta* larvae is impossible by morphological characters.

REFERENCES: Chayakul (1996), Konishi (2014)

Scomber



D : X~XIII-12~13+5
A : 10~14+5
P_1: 18~21
P_2: I, 5
V (M) : 31



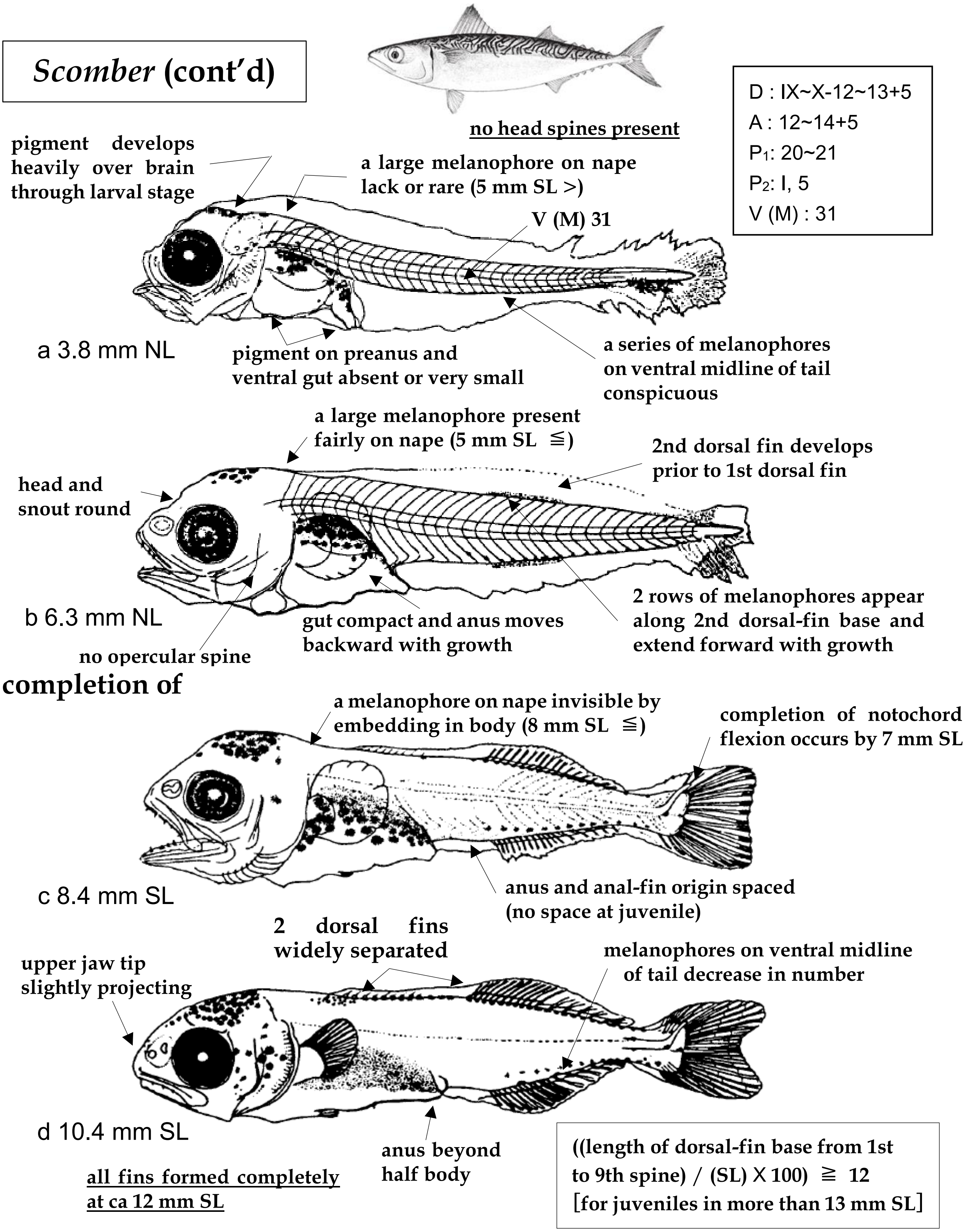
((length of dorsal-fin base from 1st to 9th spine) / (SL) X 100) < 12
[for juveniles in more than 13 mm SL]

Scomber australasicus (a～d：Ozawa 1984)

REFERENCES: Ozawa (1984), Sassa and Konishi (2014)

Scomber (cont'd)

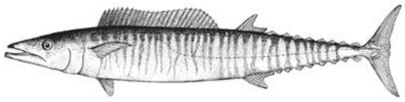
D : IX~X-12~13+5
A : 12~14+5
P_1: 20~21
P_2: I, 5
V (M) : 31



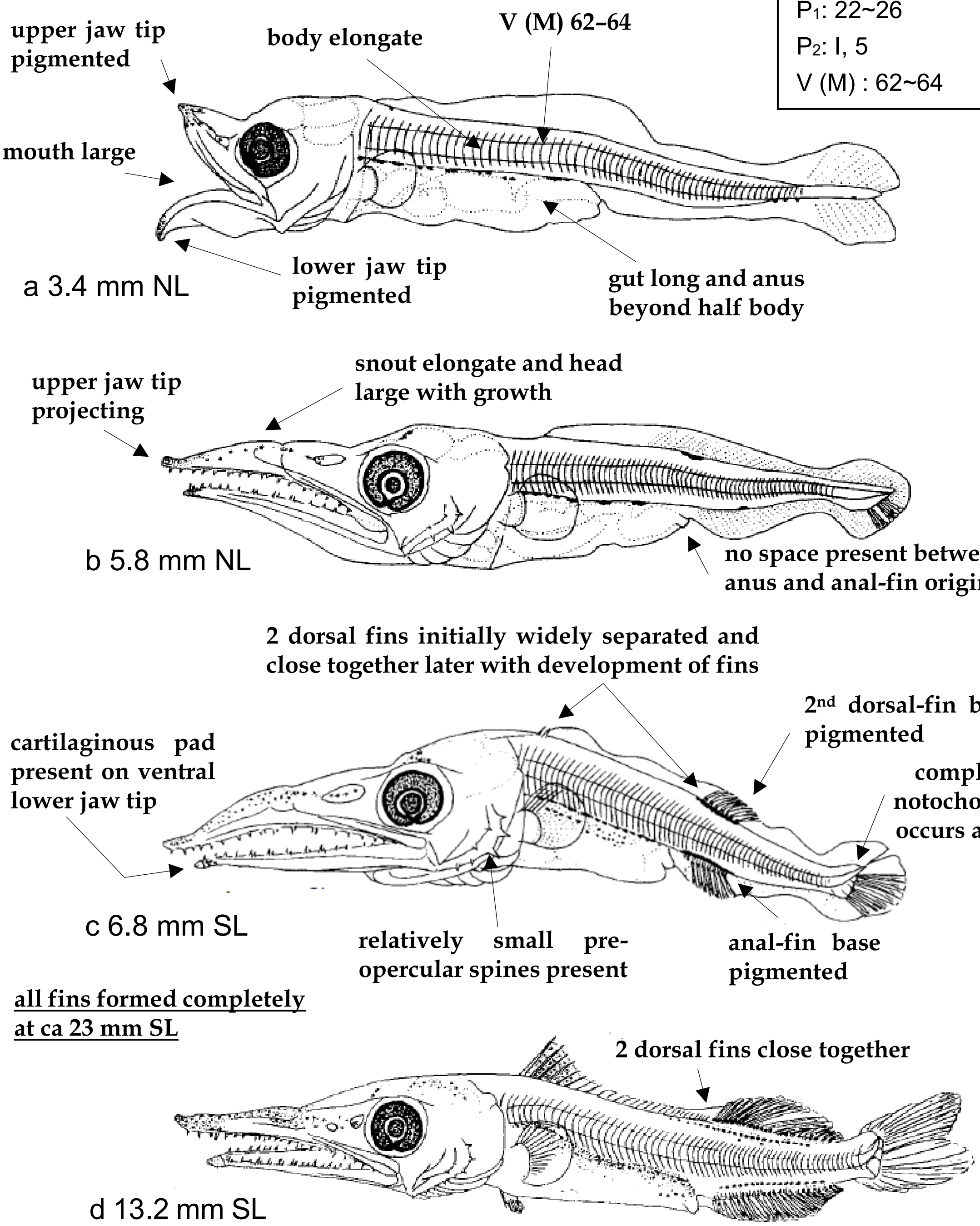
Scomber japonicus (a～d : Uchida et al. 1958)

Total length is converted to notochord length (NL) or standard length (SL).
REFERENCES: Uchida et al. (1958), Sassa and Konishi (2014)

Acanthocybium



D : XXIII~XXVIII-11~16+7~10
A : 10~14+7~10
P_1: 22~26
P_2: I, 5
V (M) : 62~64

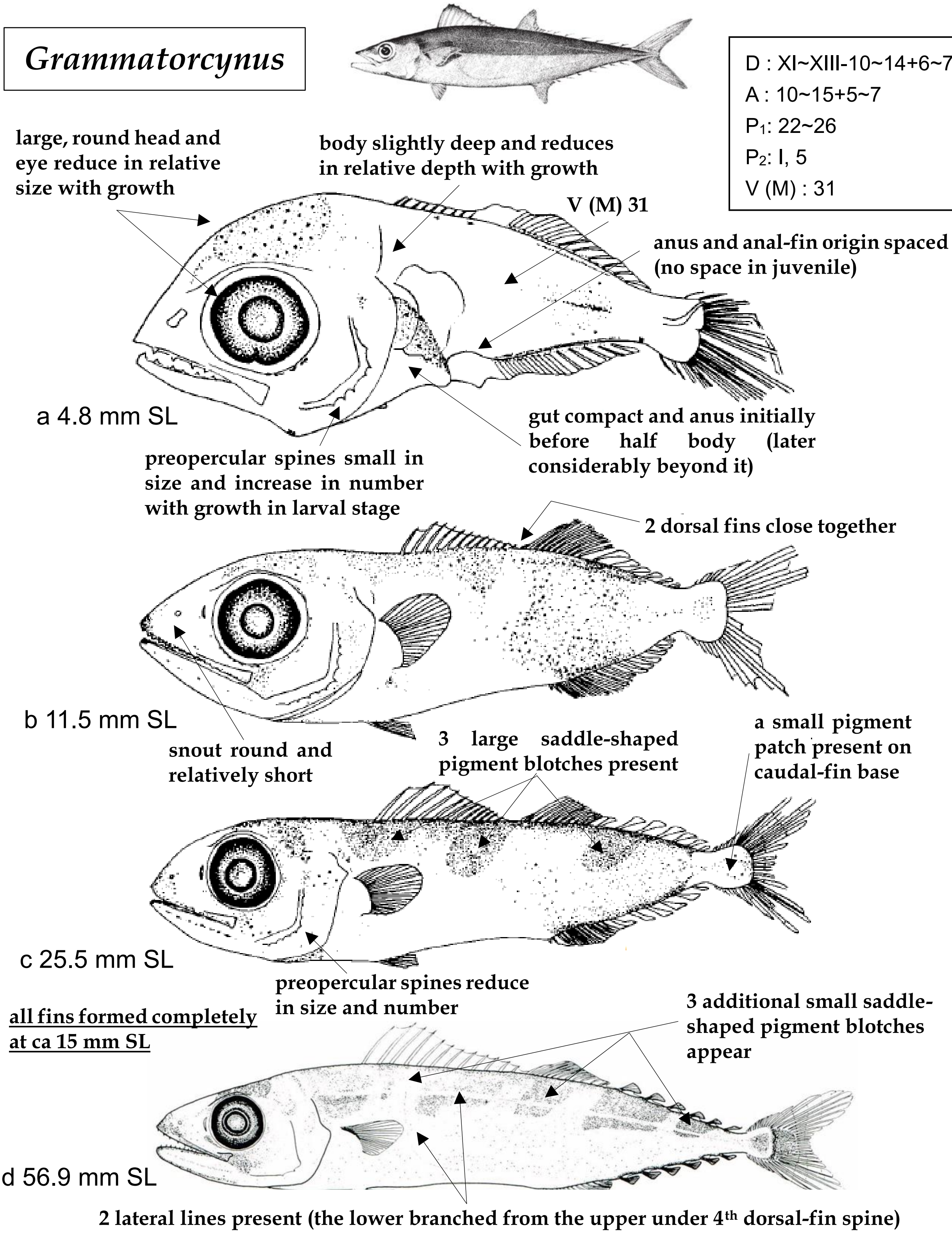


Acanthocybium solandri **(a～d: Matsumoto 1967)**

REFERENCES: Matsumoto (1967), Richards (2006), Fahay (2007), Nishikawa (2014)

Grammatorcynus

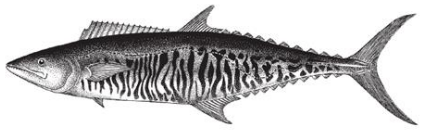
D : XI~XIII-10~14+6~7
A : 10~15+5~7
P_1: 22~26
P_2: I, 5
V (M) : 31



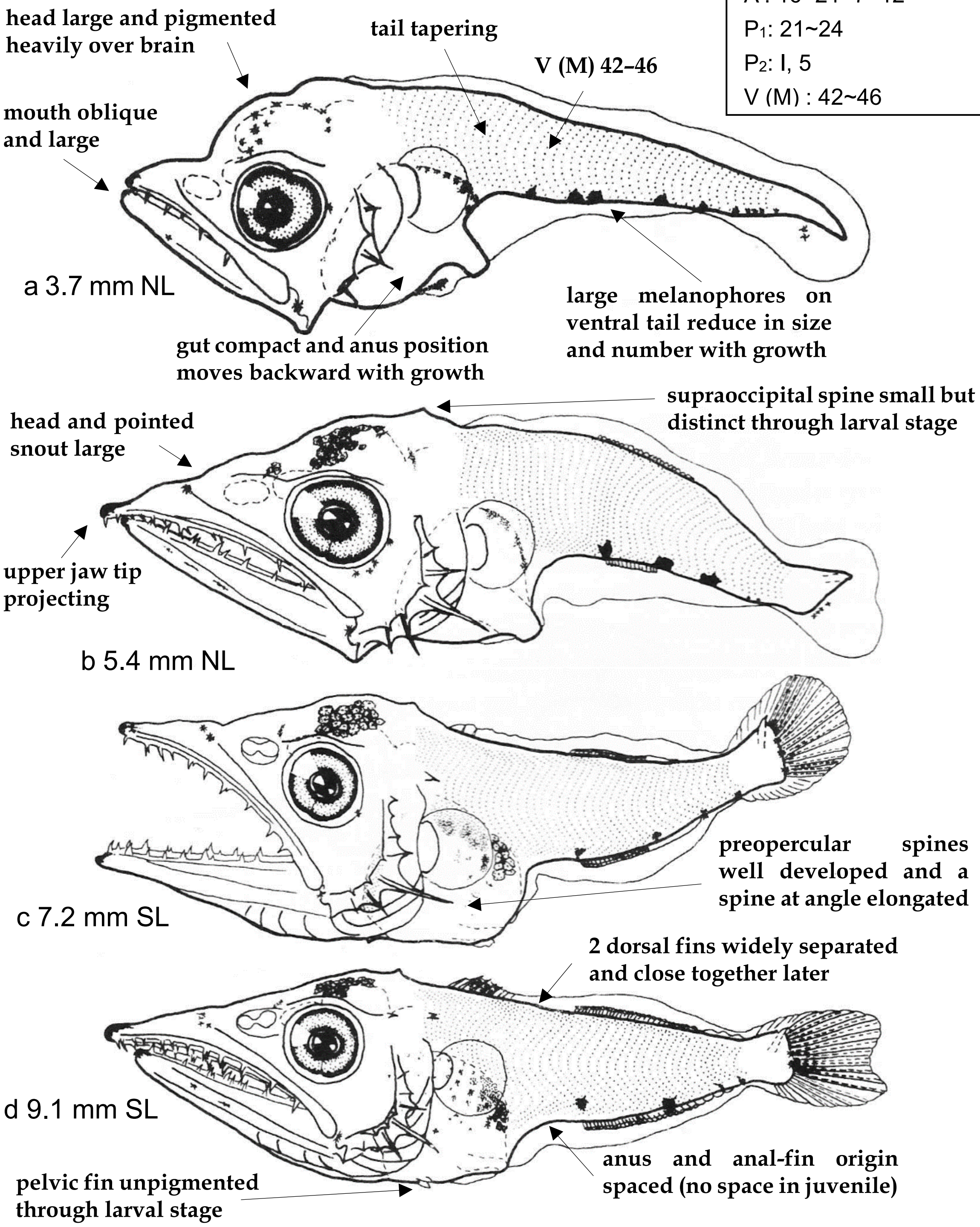
Grammatorcynus bilineatus **(a～d: Nishikawa 1979)**

REFERENCES: Wade (1951), Nishikawa (1979), Richards and Jenkins (2000), Nishikawa (2014)

Scomberomorus[14]



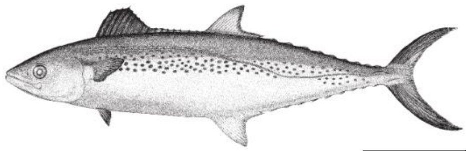
D : XV~XVIII-15~20+8~11
A : 16~21+7~12
P_1: 21~24
P_2: I, 5
V (M) : 42~46



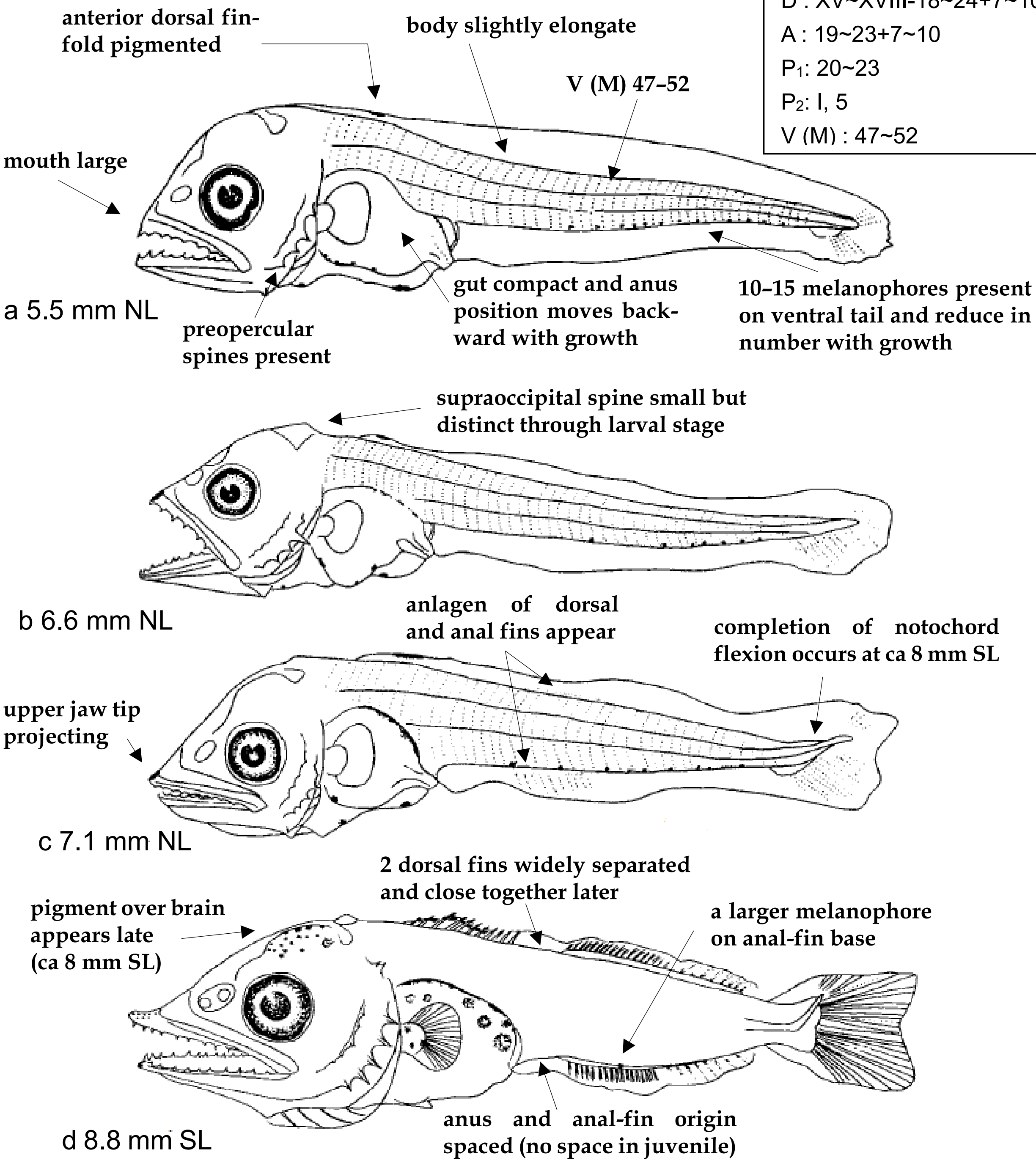
Scomberomorus commerson **(a～d: Richards and Jenkins 2000)**

[14] Larvae of *S. koreanus*, *S. lineolatus* and *S. sinensis* are unreported.
REFERENCES: Jenkins et al. (1984), Chayakul (1996), Richards and Jenkins (2000), Nishikawa (2014)

Scomberomorus (cont'd)



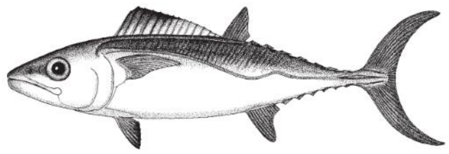
D : XV~XVIII-18~24+7~10
A : 19~23+7~10
P_1: 20~23
P_2: I, 5
V (M) : 47~52



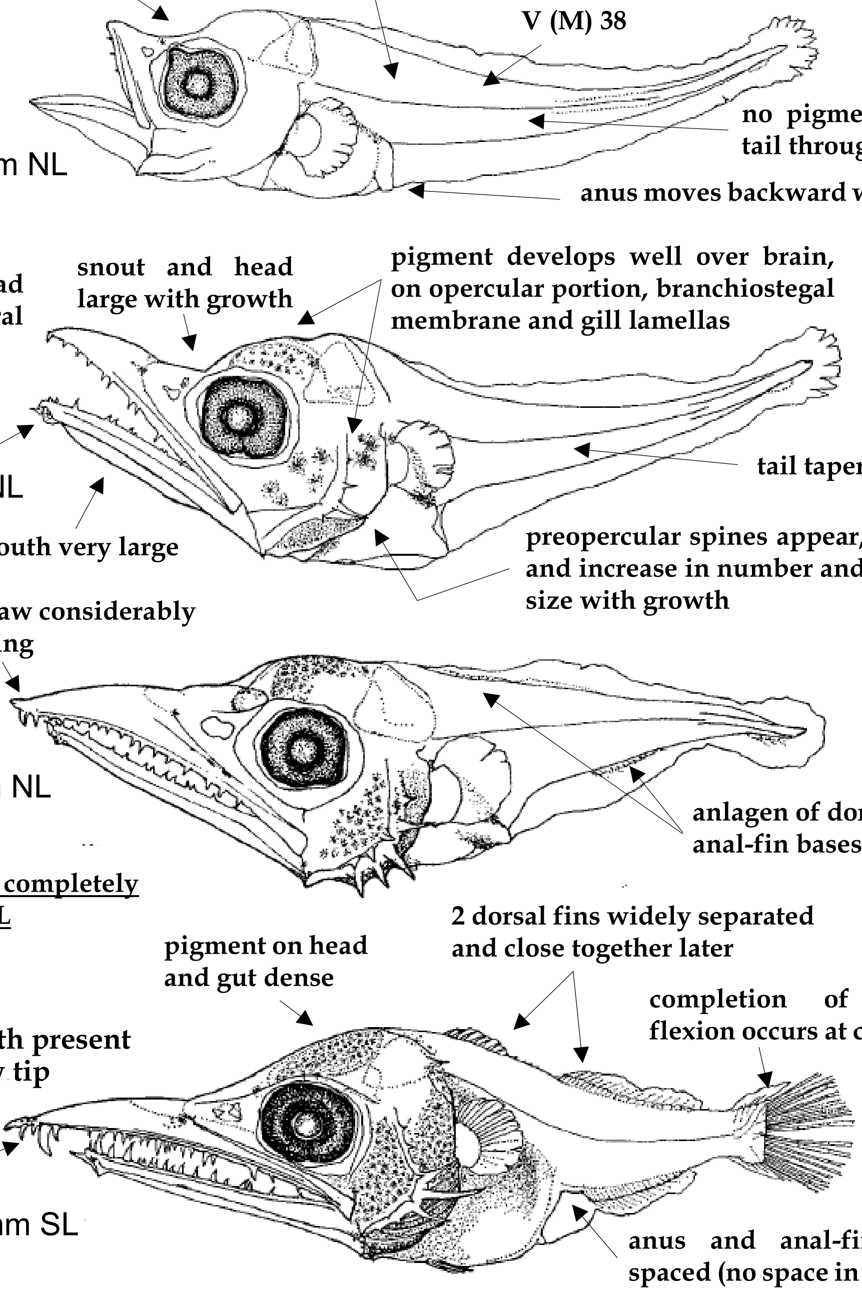
Scomberomorus guttatus **(a～d : Zang 1985)**

REFERENCES: Zang (1985), Chayakul (1996), Nishikawa (2014)

Gymnosarda



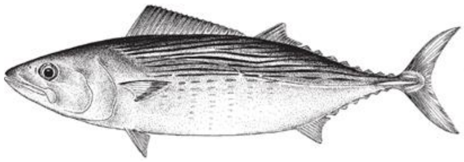
D : XIII~XV-12~14+6~7
A : 12~13+6
P_1: 25~28
P_2: I, 5
V (M) : 38



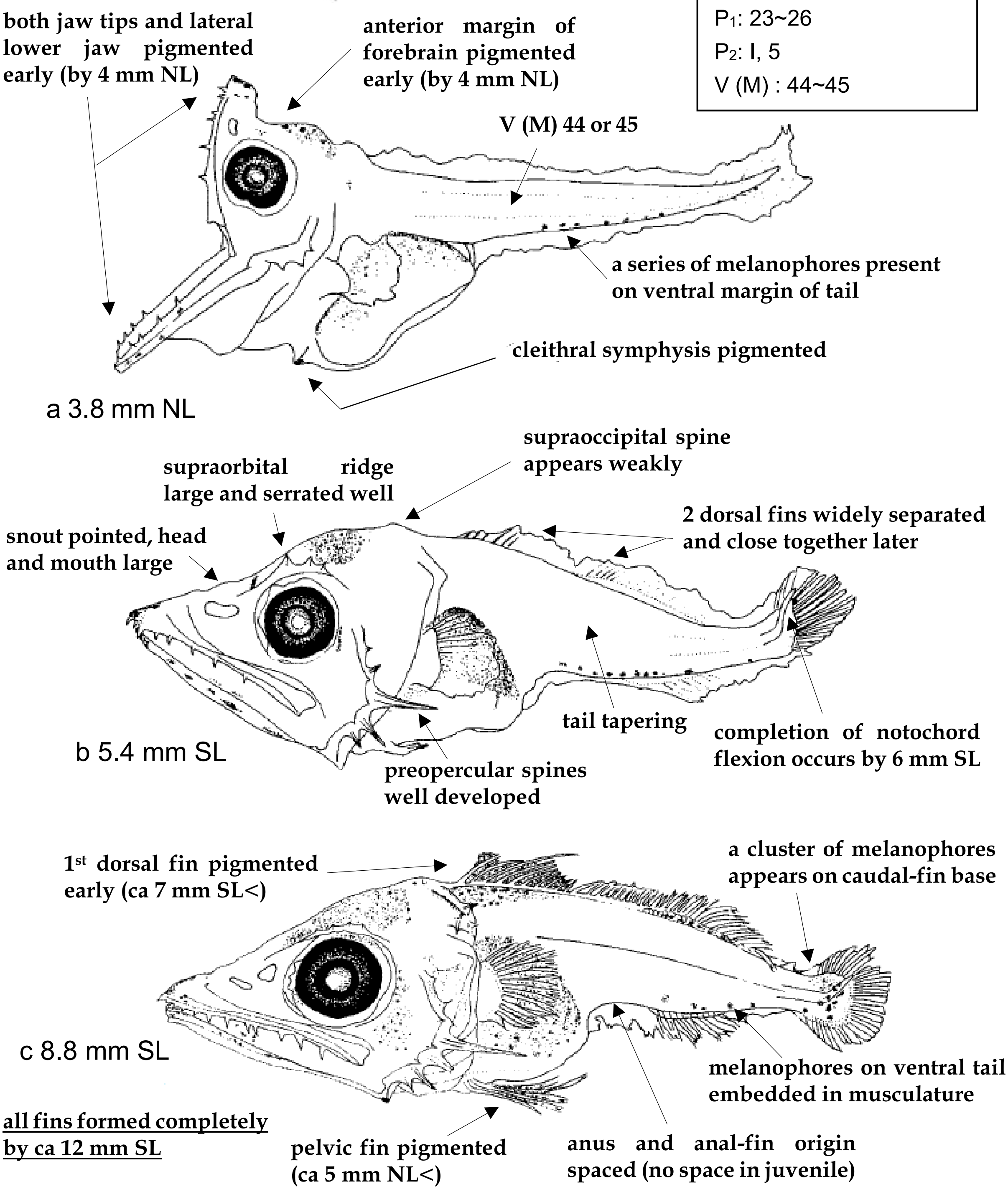
Gymnosarda unicolor **(a～d: Okiyama and Ueyanagi 1977)**

REFERENCES: Okiyama and Ueyanagi (1977), Nishikawa (2014)

Sarda



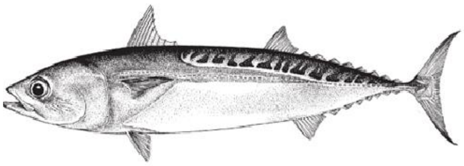
D : XVII~XIX-14~17+7~9
A : 14~16+6~7
P_1: 23~26
P_2: I, 5
V (M) : 44~45



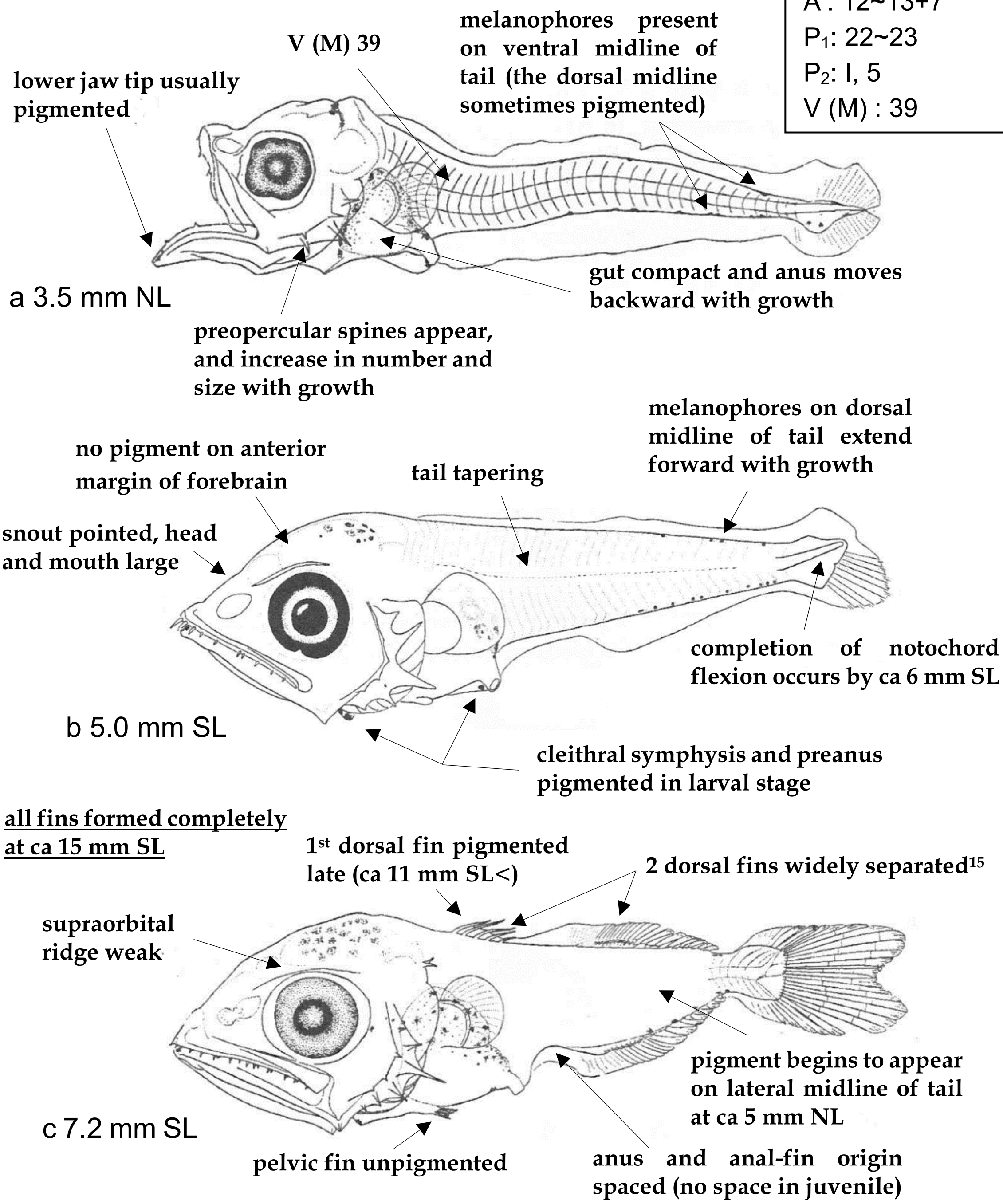
Sarda orientalis (a~c: Nishikawa 2014)

Total length is converted to notochord length (NL) or standard length (SL).
REFERENCES: Ambrose (1996), Richards (2006), Fahay (2007), Nishikawa (2014)

Auxis



D : X~XII-10~12+7~9
A : 12~13+7
P_1: 22~23
P_2: I, 5
V (M) : 39



Auxis rochei **(a, c : Matsumoto 1959 ; b : Collette et al. 1984)**

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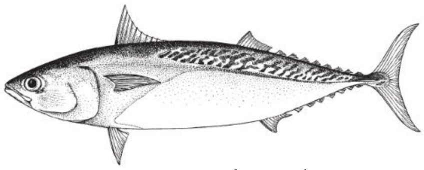
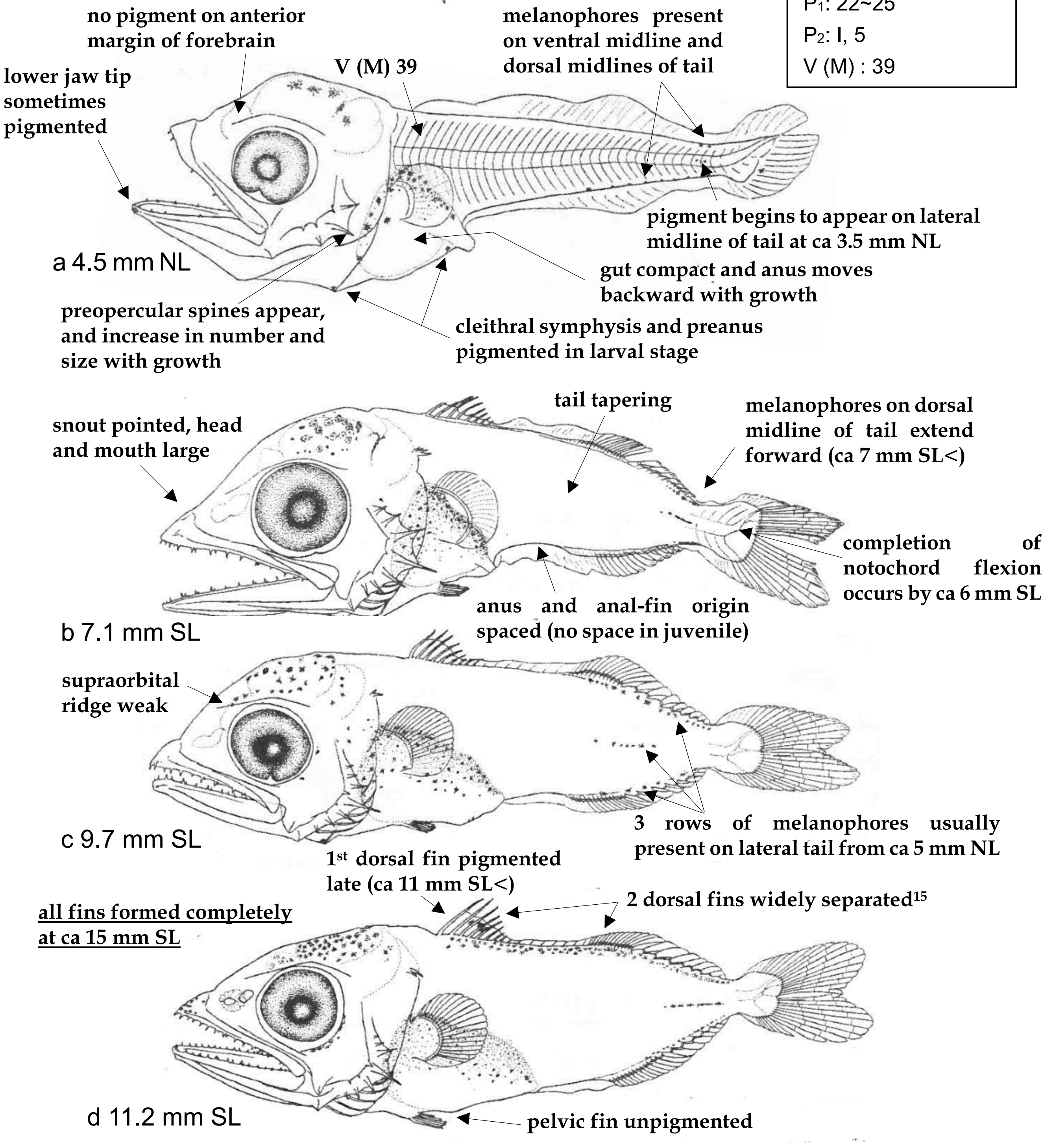
[15] Several small spines are noticeable between 1st and 2nd dorsal fins and embedded in body after ca 50 mm SL.

REFERENCES: Matsumoto (1959), Collette et al. (1984), Ambrose (1996), Richards (2006), Fahay (2007), Nishikawa (2014), Sato et al. (2020)

Auxis (cont’d)



D : X~XII-10~12+7~8
A : 12~14+7~8
P_1: 22~25
P_2: I, 5
V (M) : 39



Auxis thazard (a～d : Matsumoto 1959)

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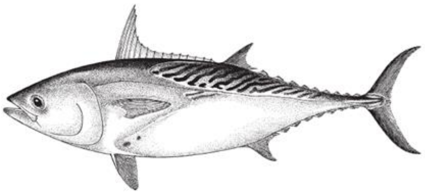
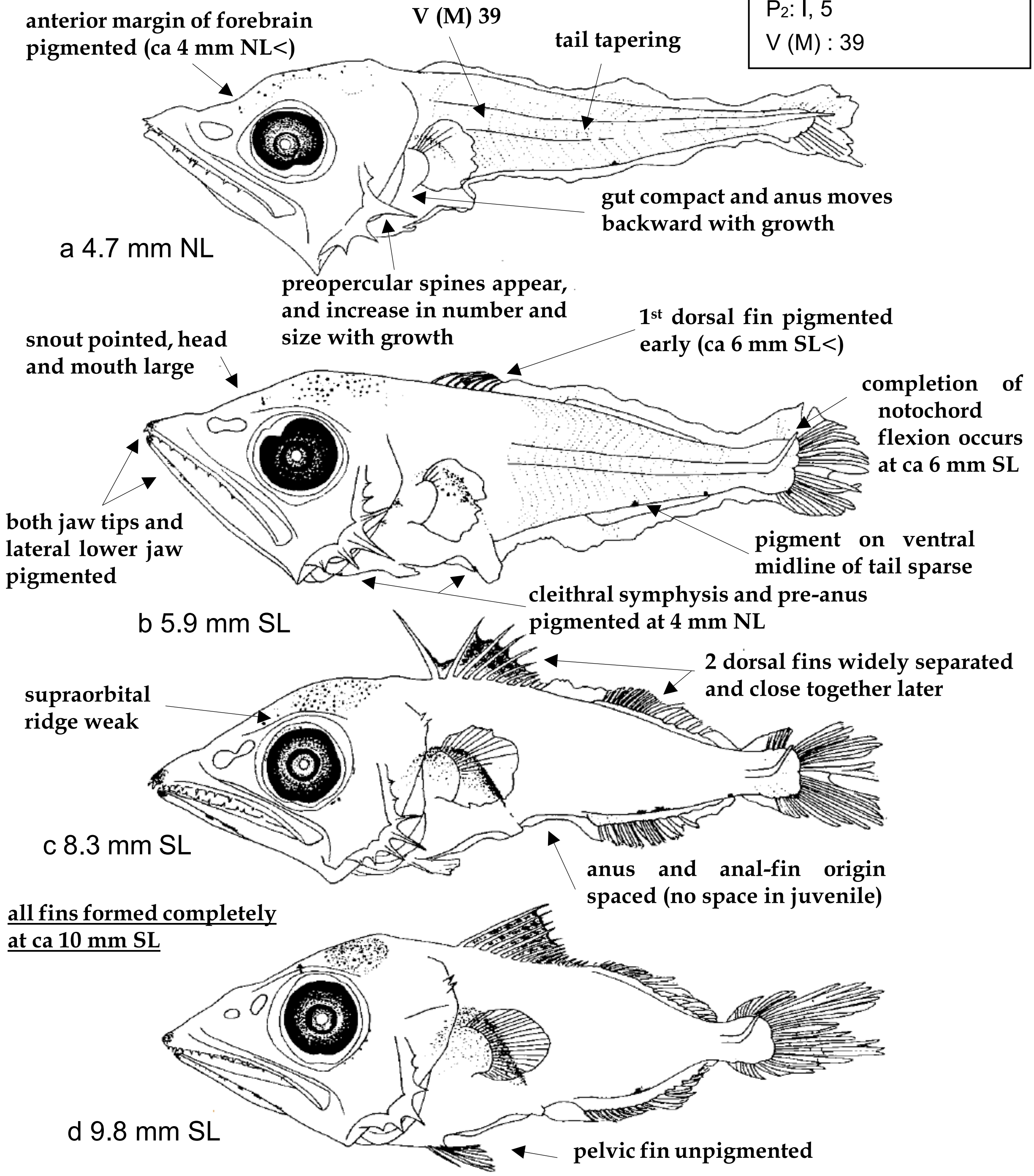
[15] See *Auxis rochei* in page 33.

REFERENCES: Matsumoto (1959), Ambrose (1996), Chayakul (1996), Richards (2006), Fahay (2007), Nishikawa (2014), Sato et al. (2020)

Euthynnus



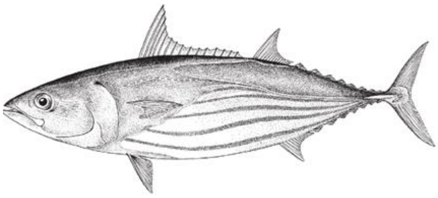
D : XIV~XVII-10~13+7~8
A : 13~14+7
P_1: 25~27
P_2: I, 5
V (M) : 39



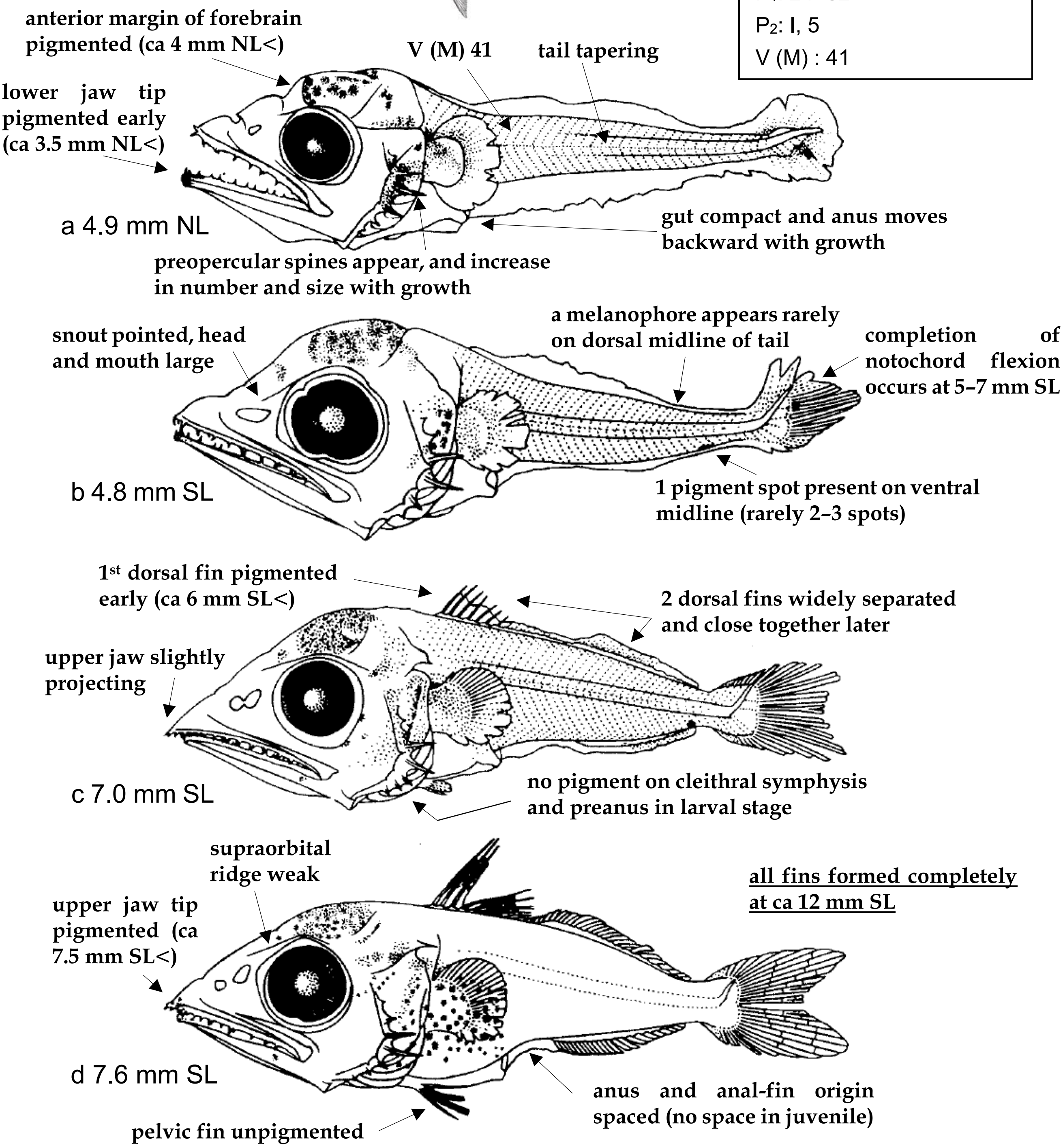
Euthynnus affinis **(a～d : Nishikawa 2014)**

Total length is converted to notochord length (NL) or standard length (SL).
REFERENCES: Matsumoto (1959), Ambrose (1996), Richards (2006), Fahay (2007), Nishikawa (2014)

Katsuwonus



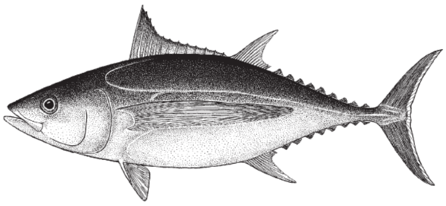
D : XIV~XVIII, 13~16+7~10
A : 13~17+6~8
P_1: 24~32
P_2: I, 5
V (M) : 41



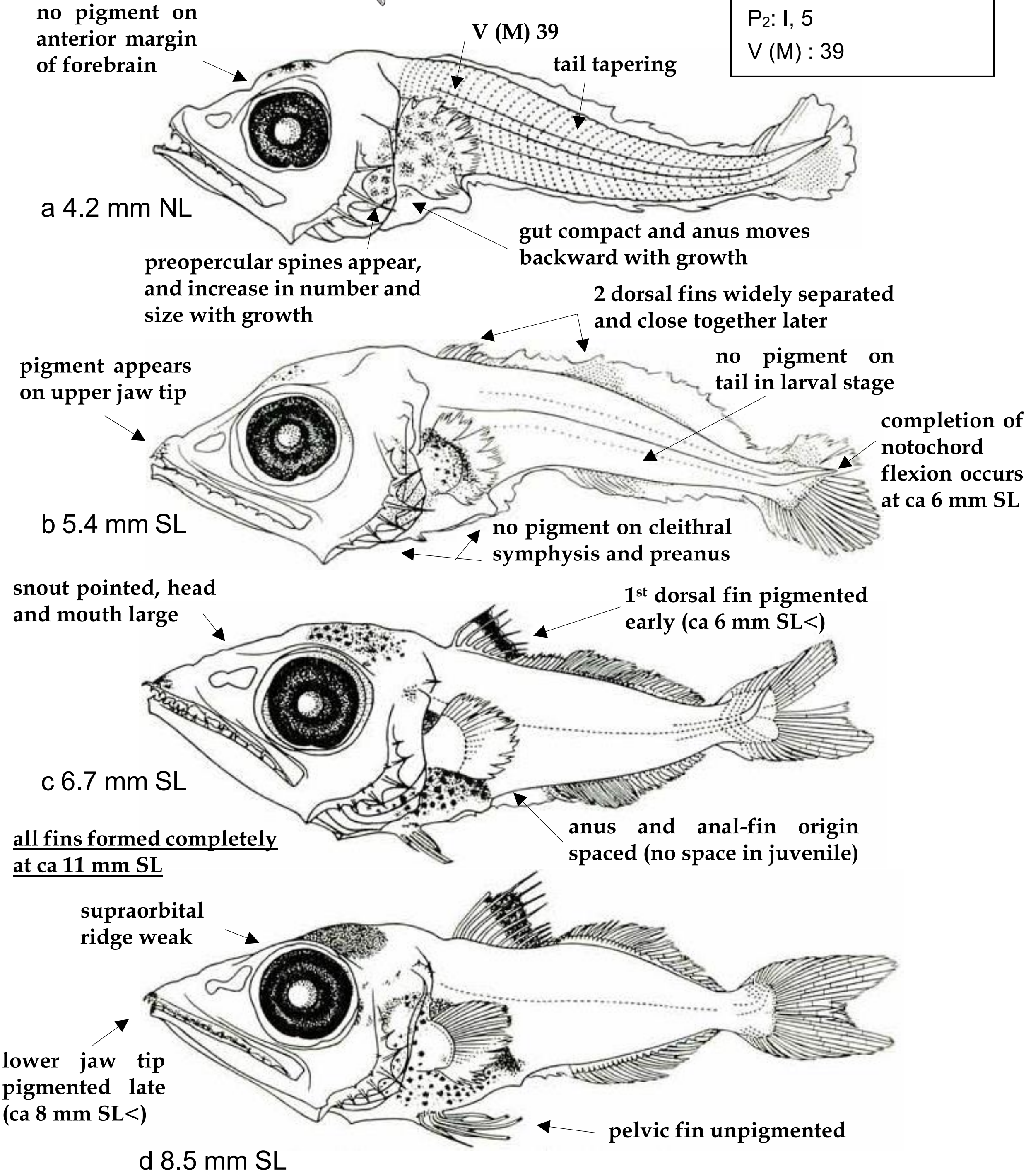
Katsuwonus pelamis **(a〜d : Yabe 1955)**

Total length is converted to notochord length (NL) or standard length (SL).
REFERENCES: Yabe (1955), Matsumoto (1958), Ambrose (1996), Richards (2006), Fahay (2007), Nishikawa (2014)

Thunnus



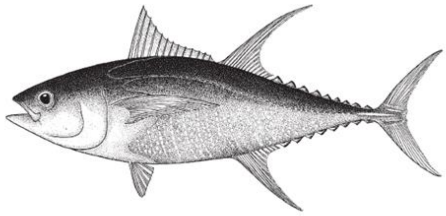
D : XII~XIV-13~16+7~9
A : 11~15+7~9
P_1: 31~36
P_2: I, 5
V (M) : 39



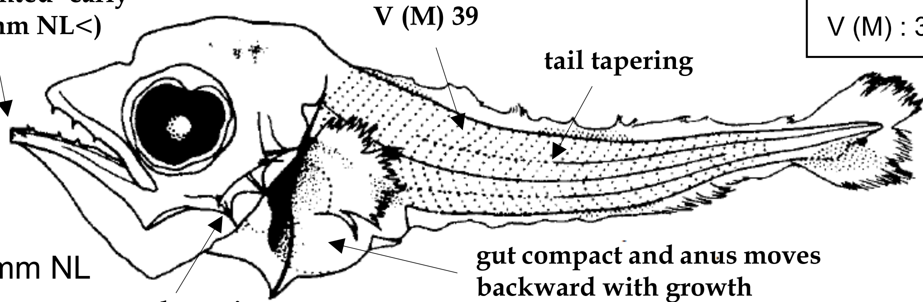
Thunnus alalunga **(a～d: Ueyanagi 1969)**

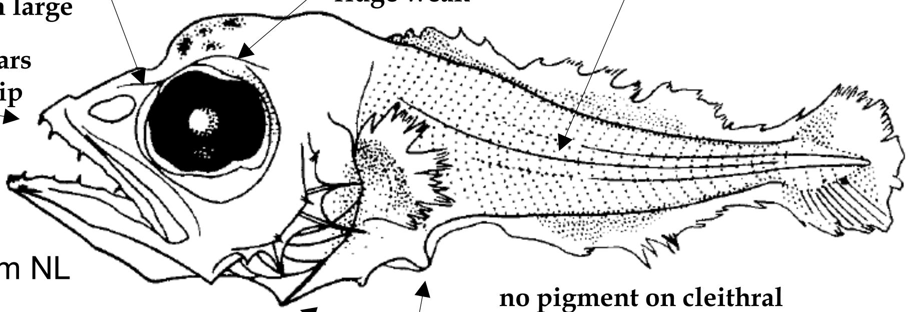
Total length is converted to notochord length (NL) or standard length (SL).
REFERENCES: Ueyanagi (1969), Richards (2006), Fahay (2007), Nishikawa (2014)

Thunnus (cont'd)

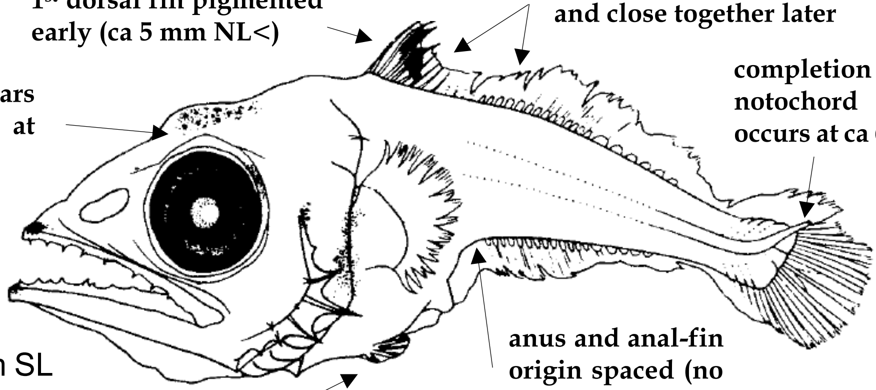


D : XII~XIV-14~15+8~9
A : 14~15+8~9
P_1: 32~35
P_2: I, 5
V (M) : 39





all fins formed completely at ca 12 mm SL

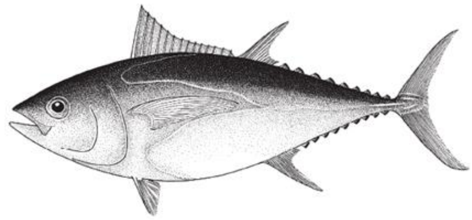


Thunnus albacares **(a～c : by Ueyanagi in Nishikawa (2014))**

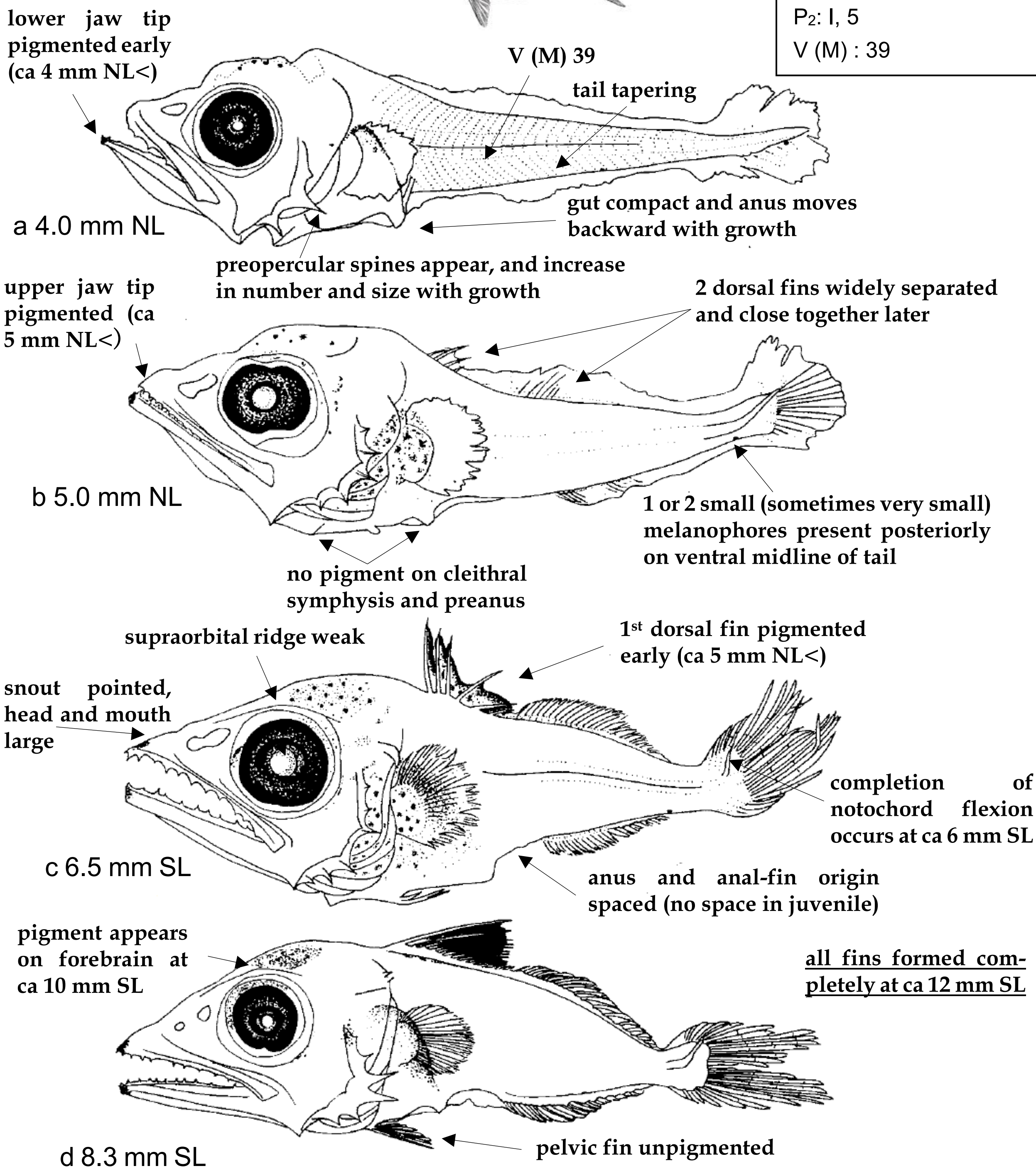
Total length is converted to notochord length (NL) or standard length (SL).

REFERENCES: Matsumoto (1958), Ambrose (1996), Richards (2006), Fahay (2007), Nishikawa (2014)

Thunnus (cont'd)



D : XIII~XV-13~16+8~10
A : 11~15+7~10
P_1: 31~35
P_2: I, 5
V (M) : 39



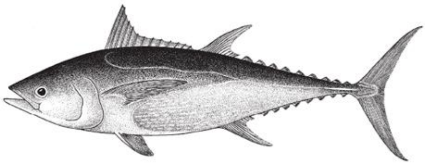
Thunnus obesus **(a～d : by Ueyanagi in Nishikawa (2014))**

Total length is converted to notochord length (NL) or standard length (SL).

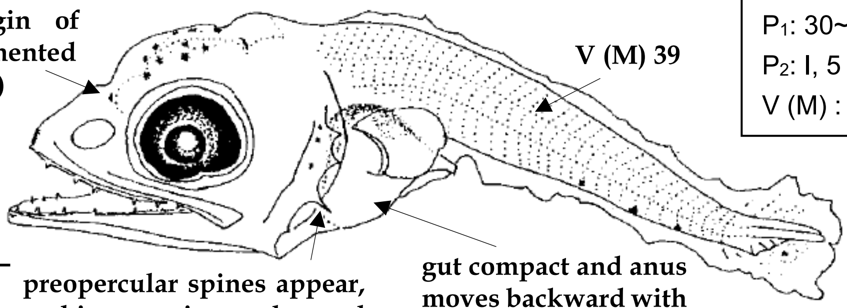
※Larvae of *T. orientalis* in the west Pacific and *T. maccoyii* in the east Indian are similar to those of *T. obesus*. See Table 3 in page 41.

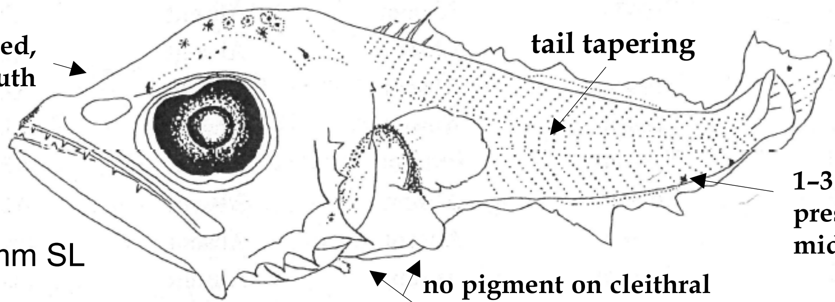
REFERENCES: Richards (2006), Fahay (2007), Nishikawa (2014)

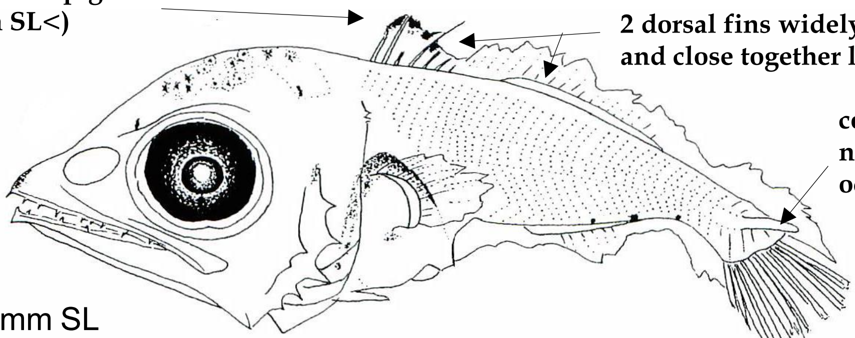
Thunnus (cont'd)

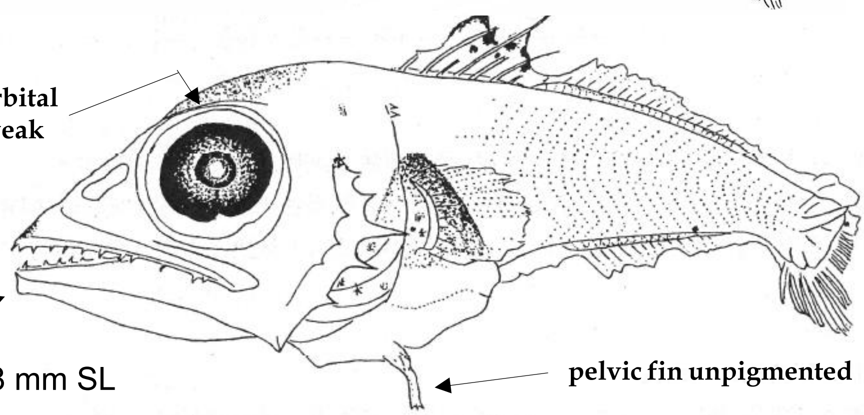


D : XII~XIV-14~15+8~9
A : 13~14+8~9
P_1: 30~35
P_2: I, 5
V (M) : 39









Thunnus tonggol **(a～d: Nishikawa and Ueyanagi 1991)**

REFERENCES: Nishikawa and Ueyanagi (1991, 1992), Chayakul (1996), Nishikawa (2014)

Table 3. Distinguishing pigment patterns among resemble three *Thunnus* larvae

Species (English name)	Distribution[a]	Spawning area and (season)[a]	Melanophores					
			Tail		Caudal fin		Others in tail	
			Dorsal midline	Ventral midline	Dorsal	Ventral	Lateral midline	Dorsolateral[b]
Thunnus obesus (bigeye tuna)	central South China Sea, Sulu, Celebes, Banda and Arafura Seas, Indian and Pacific Ocean	same as on the left (peak: Apr–Sept in north hemisphere; Jan–Mar in south hemisphere)	absent	1 or 2 (very small)	absent (rarely 1)	0–2 (usually 1)	absent	absent
Thunnus maccoyii (southern bluefin tuna)	east Indian Ocean between 30°S and 10°S	possible in the waters between Indonesia and northwest Australia (all year except July: peak in Oct–Feb)	0–4[c] (usually 1)	1–4 (usually 1)	0–2 (usually 0 or 1)	1–4 (usually 2)	sometimes present (1 or 2)	sometimes present
Thunnus orientalis (Pacific bluefin tuna)	western Pacific (southern Okhotsk to northern Philippines)	northeast of Philippines to southern Japan (Apr–Jun)	1–4 (usually 2)	1–5 (usually 2)	absent	0 or 1 (usually 0)	sometimes present (1–3)	rarely present

[a] Information on distribution, and spawning areas and season only in the Southeast Asia and its adjacent waters is shown (Collette & Nauen, 1983; Collette, 2001; Collette & Graves, 2019).

[b] Internal pigment.

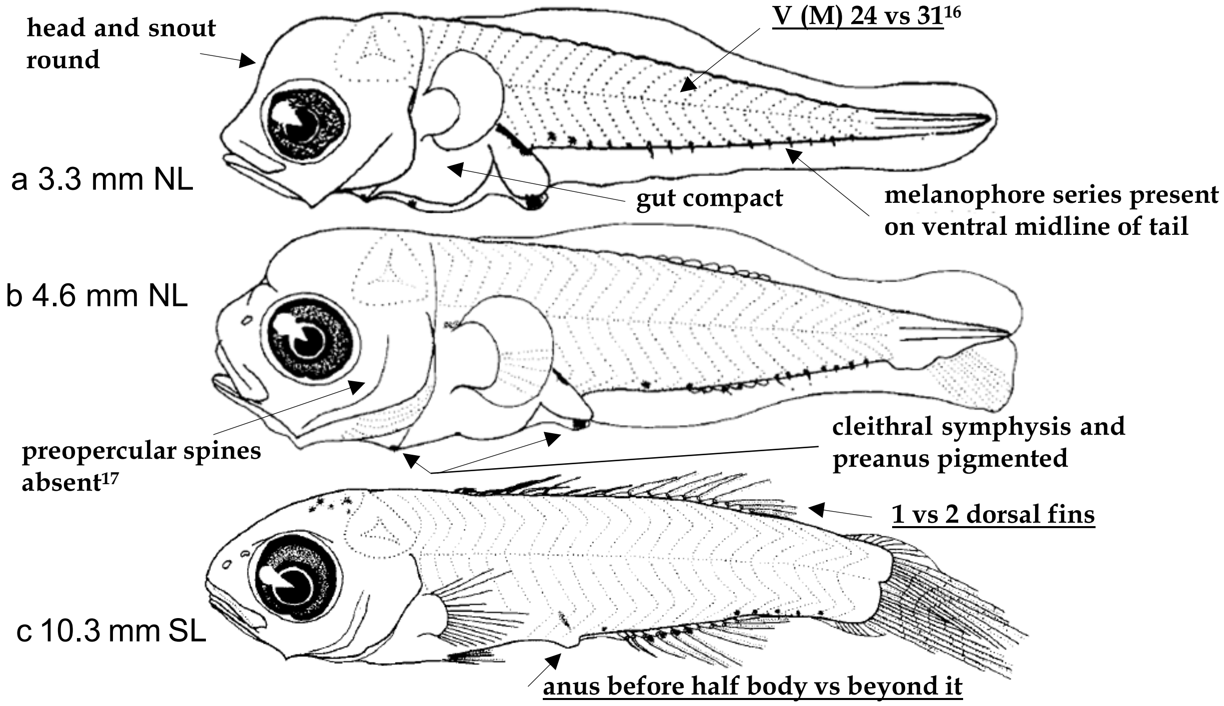
[c] The melanophore(s) is smaller than those of *Thunnus orientalis*.

Number of specimens examined for pigmentation, collection sites, and size range of each species: *Thunnus obesus*, 301, from southern Japan, 2.7 mm NL-10.0 mm SL; *T. maccoyii*, 516, from northeast Australia, 2.6 mm NL-11.1 mm SL; *T. orientalis*, 486, from south Japan, 3.2 mm NL-8.2 mm SL.

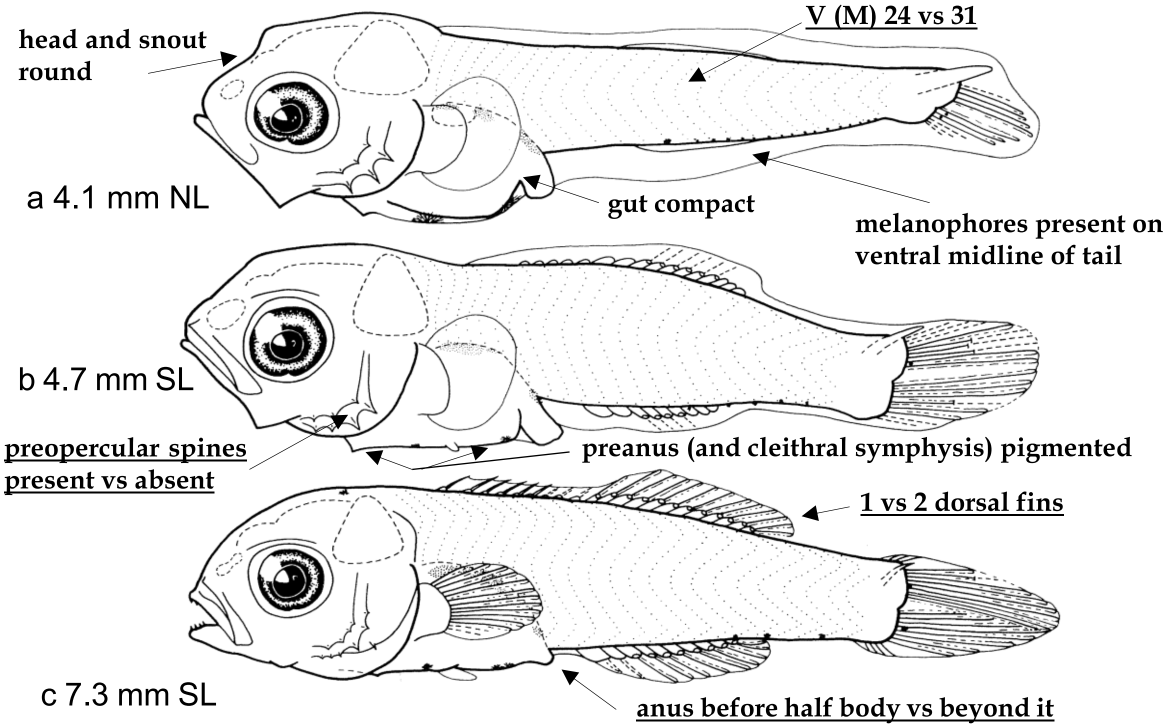
REFERENCES: Collette and Nauen (1983), Nishikawa (1985), Collette (2001), Collette and Graves (2019)

SIMILAR LARVAE TO SCOMBRID FISH LARVAE

Similar larvae to Scombrini and *Grammatorcynus*



Family Nemipteridae *Nemipterus bathybius* (a～c：Konishi 2014)



Family Sparidae *Acanthopagrus* sp. (a～c：Trnski and Leis 2000)

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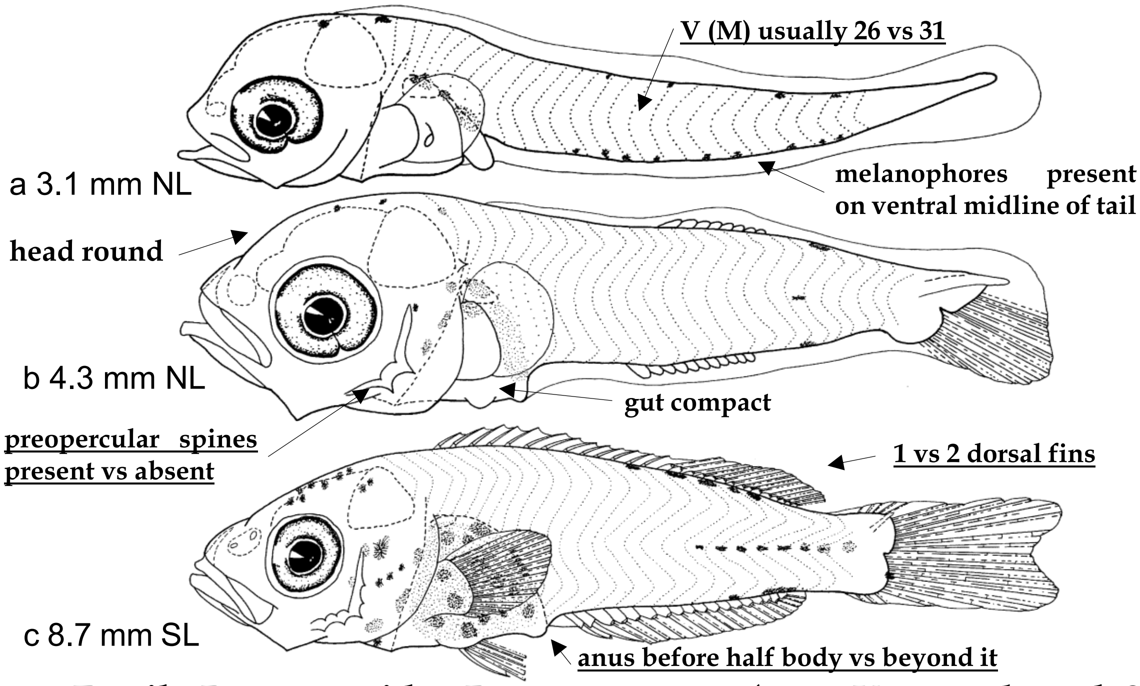
[16] Similar larvae vs concerning scombrid larvae (the same hereafter).

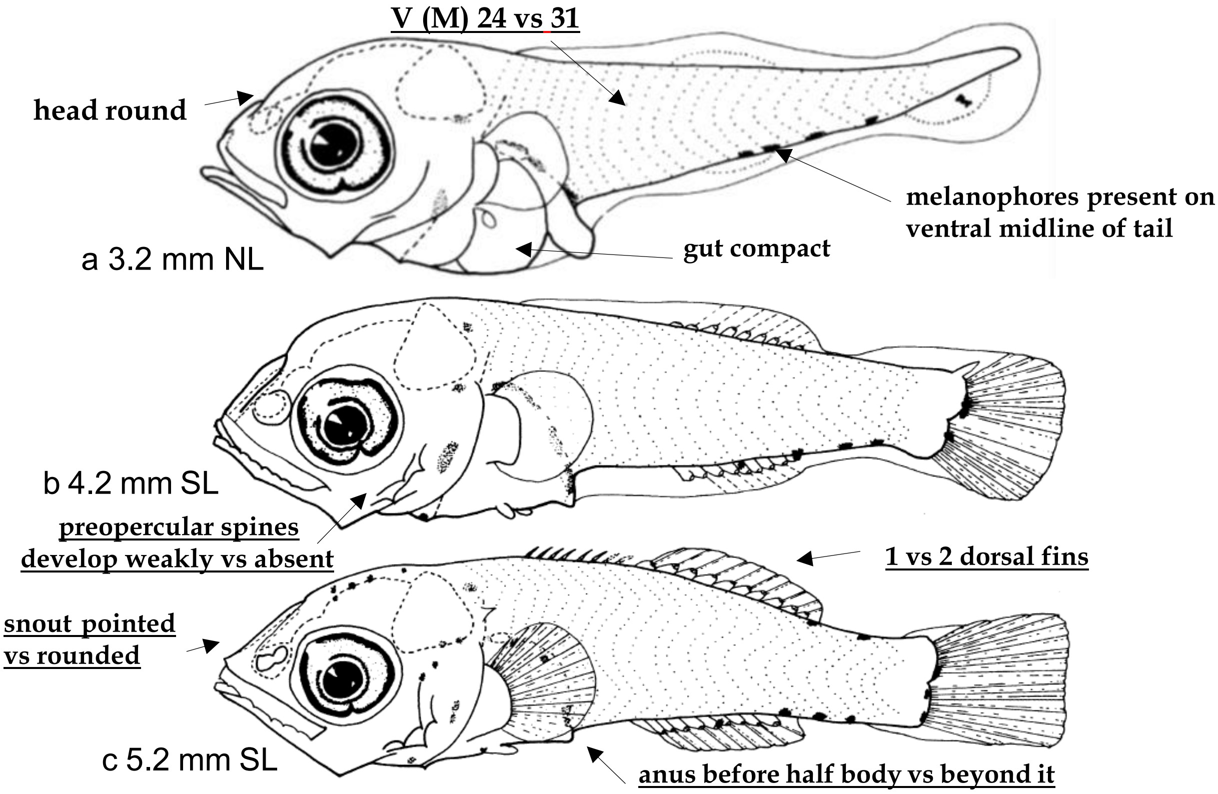
[17] Nemipterid *Parascolopsis* and scombrid *Grammatorcynous* larvae have small preopercular spines.

REFERENCES: Leis and Trnski (1989), Leis and Rennis (2000), Richards and Jenkins (2000), Trnski and Leis (2000), Konishi (2014)

Similar larvae to Scombrini and *Grammatorcynus* (cont'd)



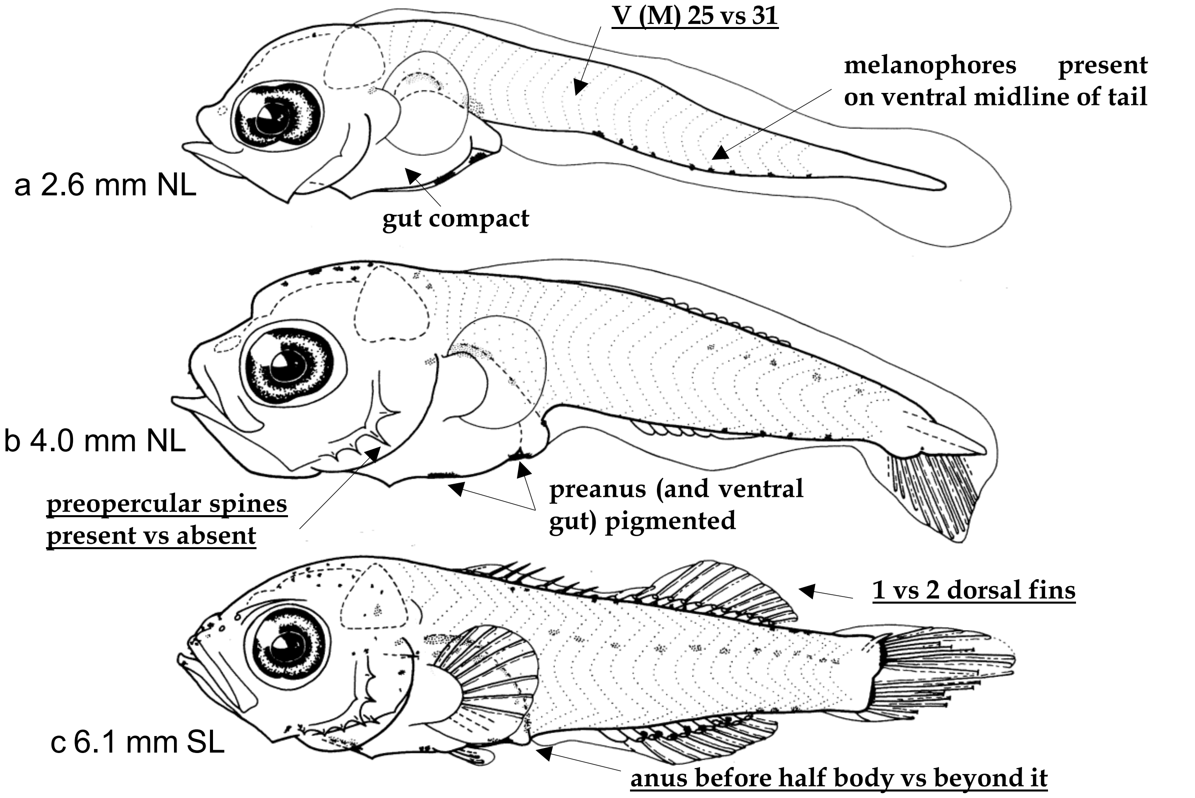
Family Pomacentridae *Pomacentrus* sp. (a～c：Kavanagh et al. 2000)



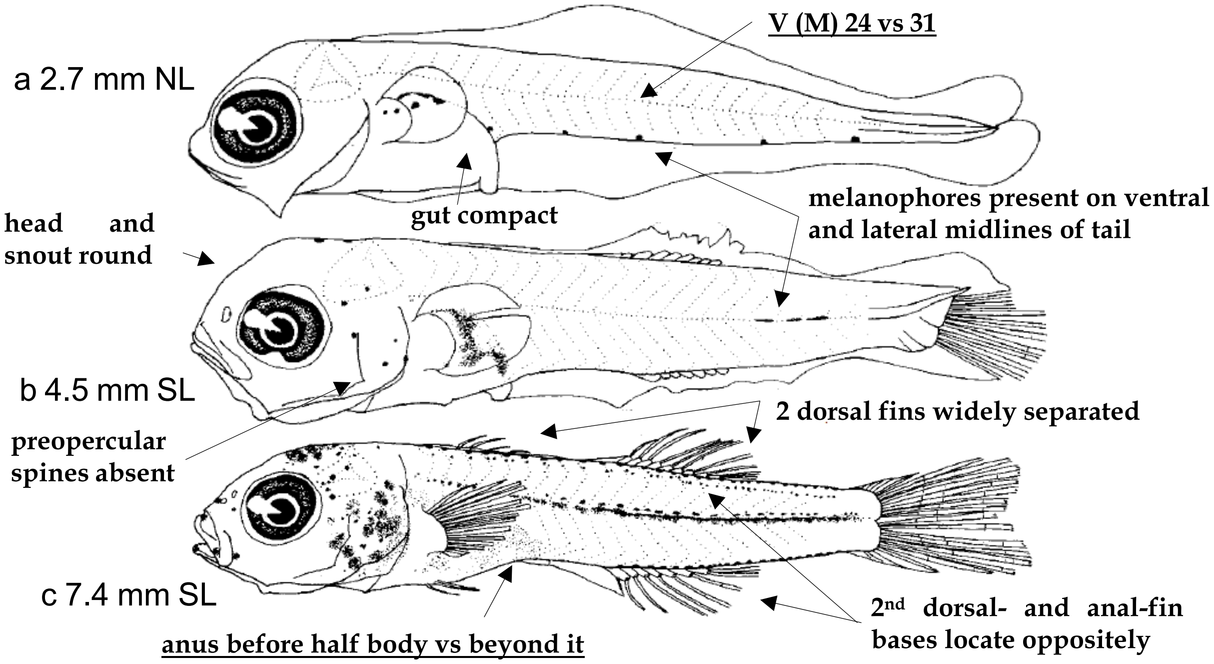
Family Gerreidae *Gerres* sp. (a～c：Leis and Rennis 2000)

REFERENCES: Kavanagh et al. (2000), Leis and Rennis (2000), Richards and Jenkins (2000)

Similar larvae to Scombrini and *Grammatorcynus* (cont'd)



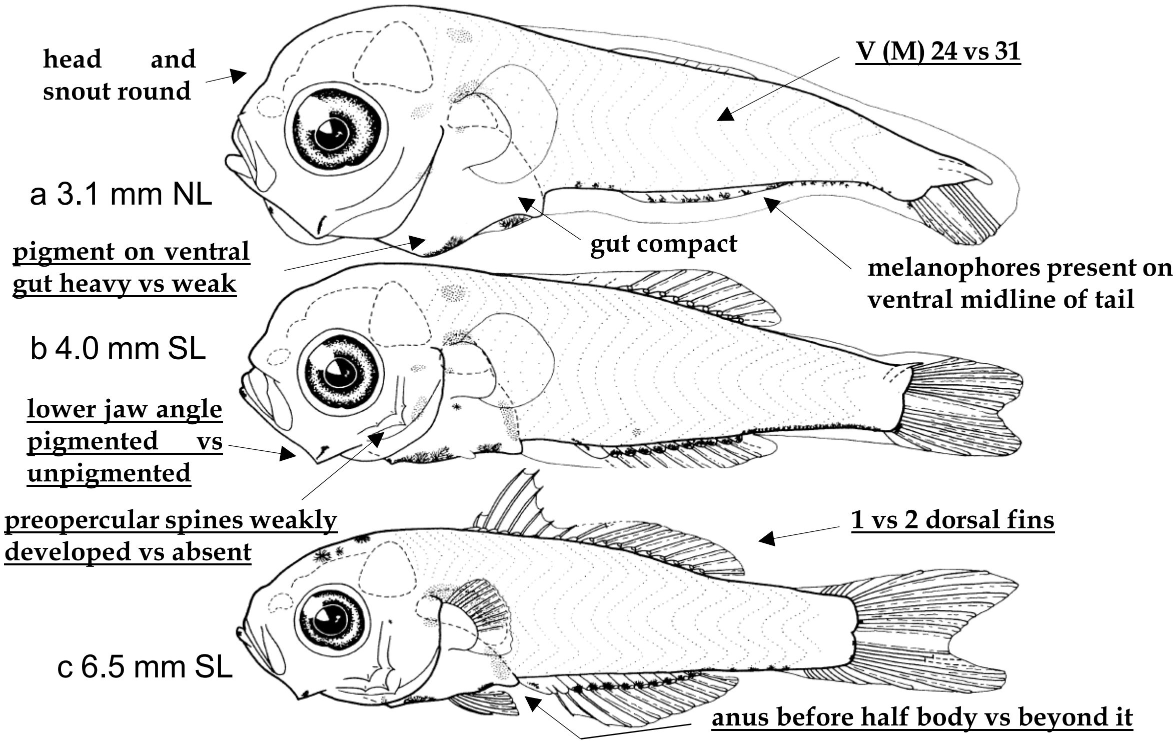
Family Terapontidae *Terapon theraps* (a～c: Trnski and Leis 2000)



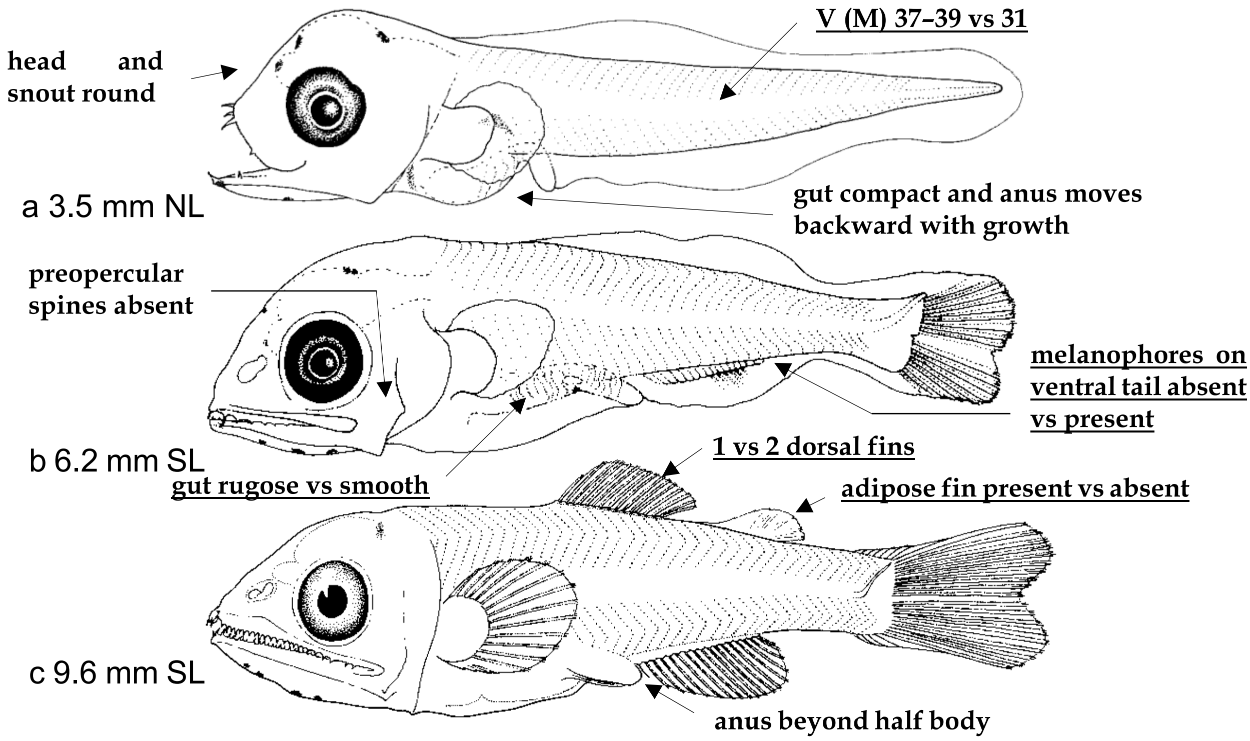
Family Mullidae *Upeneus japonicus* (a～c: Konishi 2014)

REFERENCES: Leis and Trnski (1989), Leis and Schmitt (2000), Richards and Jenkins (2000), Trnski and Leis (2000), Konishi (2014)

Similar larvae to Scombrini and *Grammatorcynus* (cont'd)



Family Ambassidae *Ambassis* sp. (a〜c : Trnski and Leis 2000)

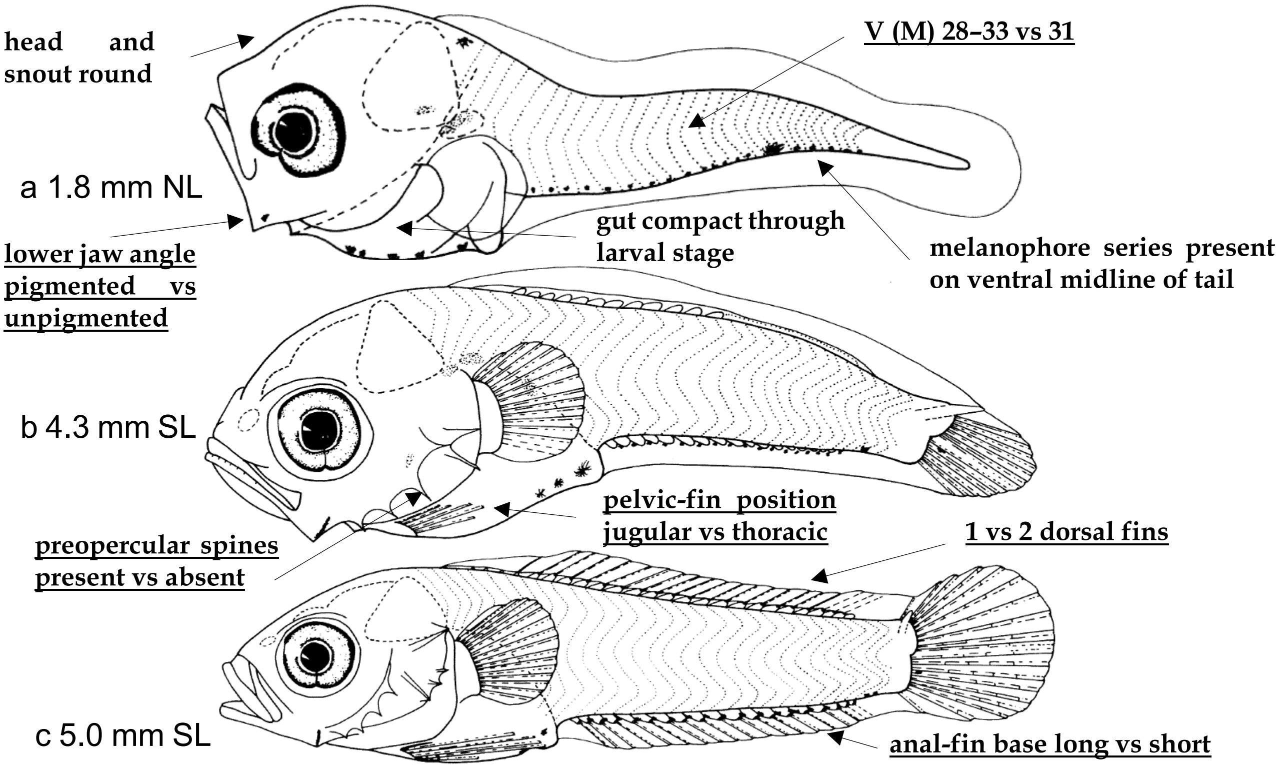


Family Myctophidae[18] *Lampanyctus nobilis* (a〜c : Moser and Ahlstrom 1996)

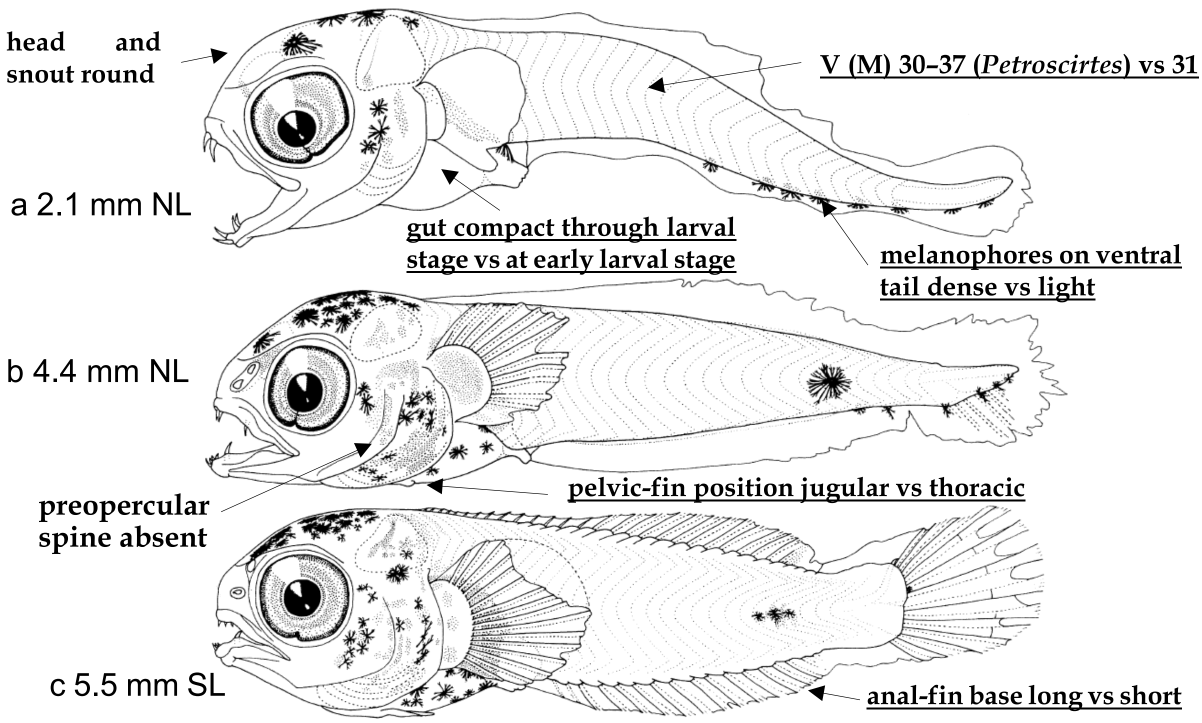
[18] Other genera of the similar larvae: *Nannobrachium* and *Notoscopelus*.

REFERENCES: Leis and Trnski (1989), Moser and Ahlstrom (1996), Richards and Jenkins (2000), Trnski and Leis (2000)

Similar larvae to Scombrini and *Grammatorcynus* (cont'd)



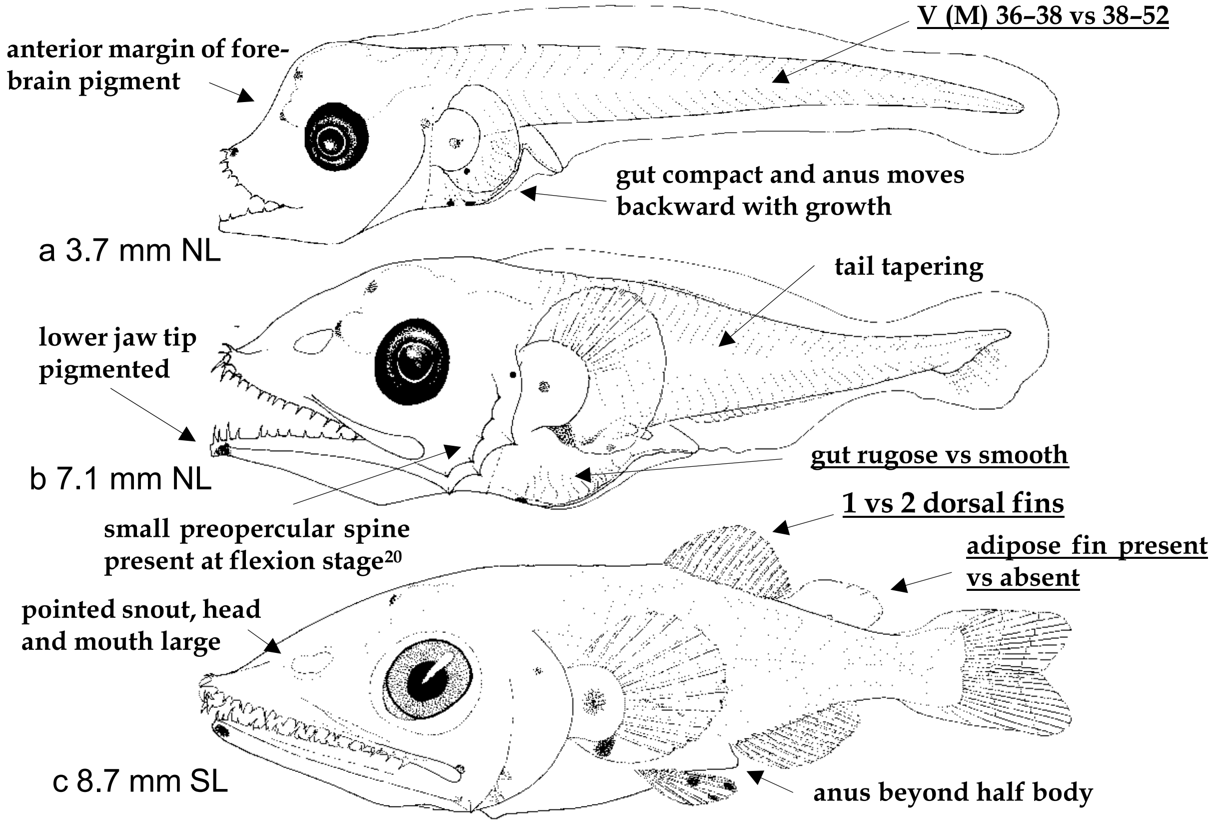
Family Pinguipedidae *Parapercis* sp. (a～c：Leis and Rennis 2000)



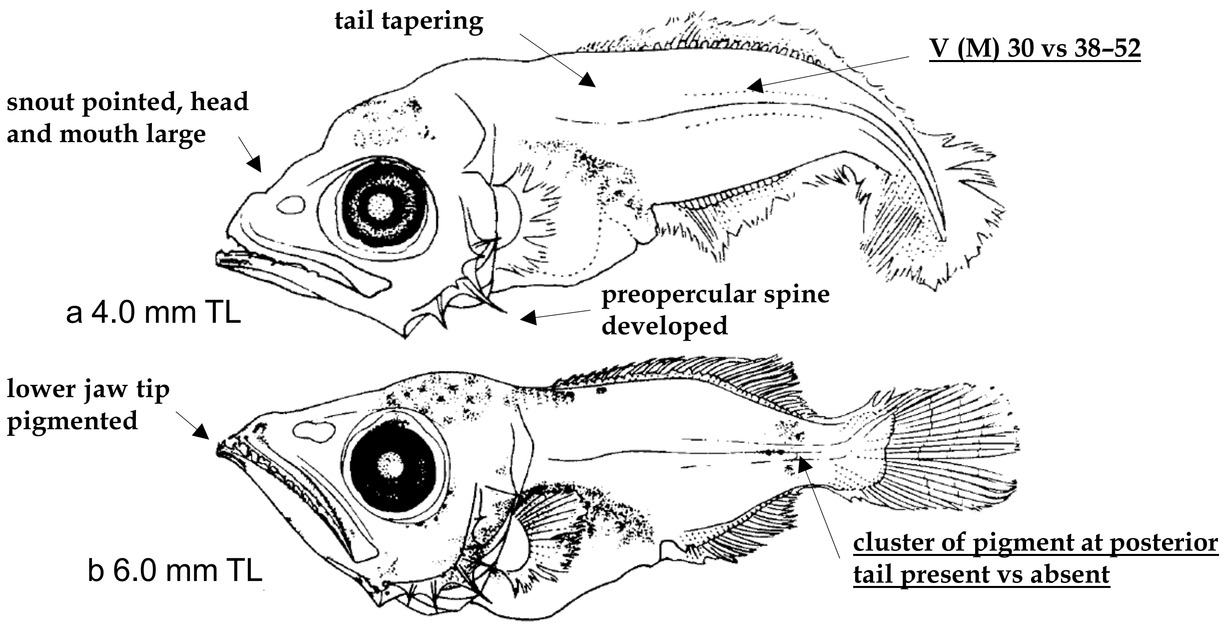
Family Blenniidae *Petroscirtes mitratus* (a～c：Watson 2000)

REFERENCES: Leis and Rennis (2000), Richards and Jenkins (2000), Watson (2000)

Similar larvae to Sardini, Scomberomorini[19] and Thunnini



Family Myctophidae *Nannobrachium bristori*[21] (a〜c：Moser and Ahlstrom 1996)



Family Scombrolabracidae *Scombrolabrax heterolepis* (a〜b：Nishikawa 2014)

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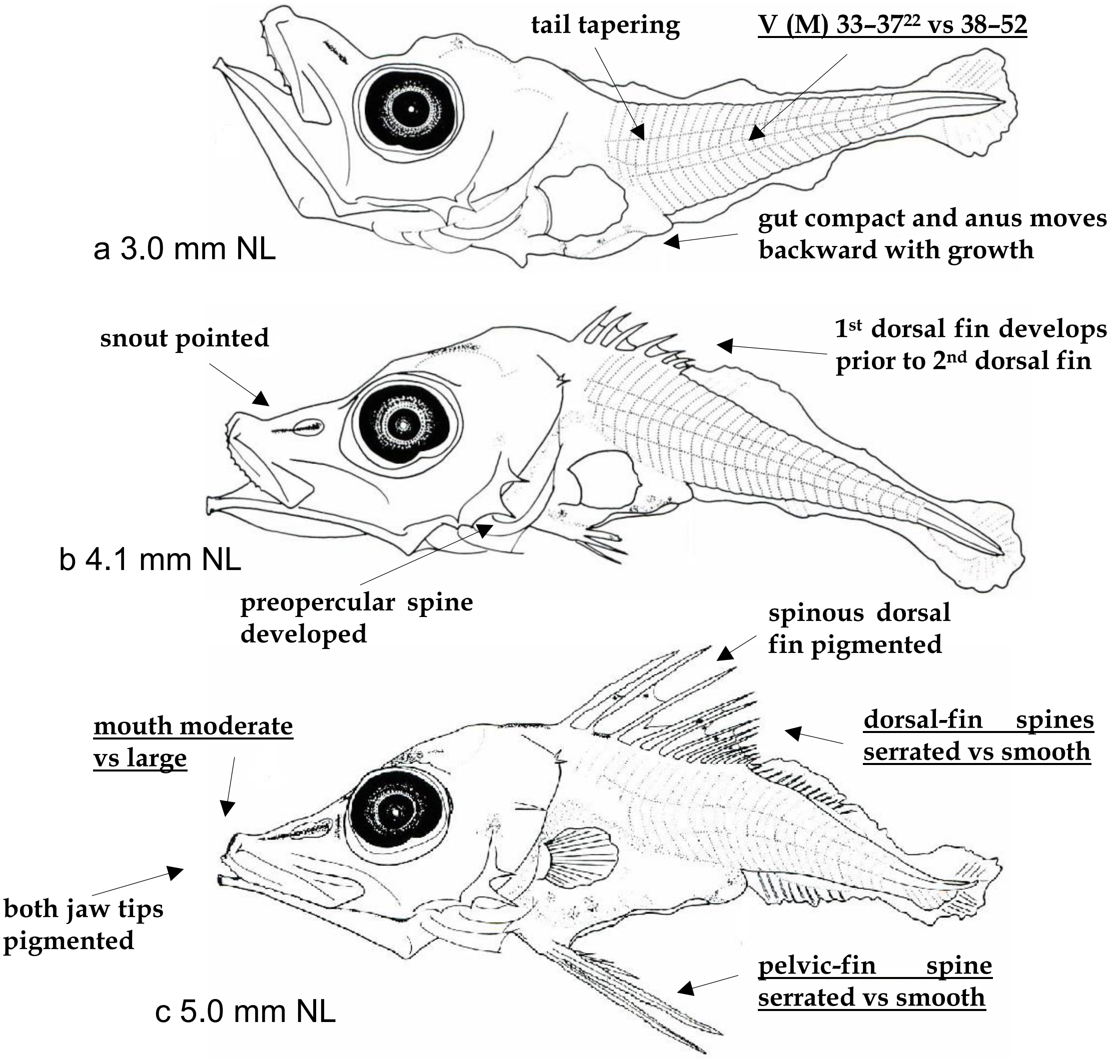
[19] The Genera *Acanthocybium* and *Grammatorcynous* are excluded.
[20] Preopercular spines do not appear usually in myctophid larvae.
[21] Tropical and subtropical species in the North Pacific (Zahuranec, 2000)
REFERENCES: Moser and Ahlstrom (1996), Richards and Jenkins (2000), Nishikawa (2014)

Similar larvae to Sardini, Scomberomorini and Thunnini (cont'd)



Family Gempylidae[23] *Neciarchus nasutus* (a～c: Nishikawa 1987)

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[22] Collette et al. (1984).

[23] Larvae of *Lepidocybium flavobrunneum* have two small supraoccipital spines (Nishikawa 1987).

REFERENCES: Collette et al. (1984), Nishikawa (1987, 2014), Richards and Jenkins (2000)

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