Revision of the frigate tunas (Scombridae, *Auxis*), with descriptions of two new subspecies from the eastern Pacific

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Abstract.–Two cosmopolitan species of frigate tunas, *Auxis thazard* (Lacepède) and *A. rochei* (Risso), are differentiated primarily by the width of the corselet under the origin of the second dorsal fin and by the anterior extent of the dorsal scaleless area above the pectoral fin. *Auxis thazard* has five or fewer scales in the corselet under the second dorsal fin, and the dorsal scaleless area extends anterior to the tip of the pectoral fin; *A. rochei* has six or more scales and the dorsal scaleless area does not reach the tip of the pectoral fin. Of nine morphometric characters examined with ANCOVA, four body depth measurements were significantly different between the species. *Auxis rochei* is a slender species with each of the four body depth measurements approximately equal, whereas *A. thazard* is more tuna-shaped, with a deeper, more robust body and with more unequal body depth measurements. For both species, eastern Pacific populations differ from Atlantic and Indo-West Pacific populations at what we consider the subspecific level. The eastern Pacific *A. thazard brachydorax* new subspecies has more gill rakers, usually 43–48 vs. usually 38–42 in *A. t. thazard*. Body depth at anal-fin origin, pectoral-fin length, and corselet width were also significantly different between *A. thazard brachydorax* and *A. t. thazard*. The eastern Pacific *A. rochei eudorax* new subspecies has an even wider corselet than that of *A. rochei rochei*, usually more than 20 scales wide compared with 6–19 scales.

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It is not clear whether there are one or two species of frigate tunas of the genus *Auxis*. In the Indo-West Pacific region, several investigators have distinguished a narrow-corseleted species (N) from a wide-corseleted species (W): Bleeker (1854, 1855) from the East Indies as *A. tapeinosoma* (N) and *A. thynnoides* (W); Kishinouye (1915, 1923) from Japan as *A. hira* (N) and *A. maru* (W); Wade (1949) from the Philippines and Jones (1958) from India as *A. thazard* (N) and *A. tapeinosoma* (W); and Matsumoto (1960a) from Hawaii as *A. thazard* (N) and *A. thynnoides* (W). However, most Atlantic-based workers have considered the frigate tunas to be a single worldwide species which they have identified as *Auxis thazard* (Dresslar and Fesler, 1889; Jordan and Evermann, 1896; Fraser-Brunner, 1950; Rivas, 1951; Zavala-Camin, 1983). Fitch and Roedel (1963) have shown that there are two sympatric species of frigate tunas in the Indo-West Pacific: the narrow-corseleted *A. thazard* (Lacepède) and the wide-corseleted *A. rochei* (Risso) (Fig. 1). They used the name *A. rochei* for the wide-corseleted species on the supposition that only one species occurred in the Mediterranean Sea and Atlantic Ocean and that *rochei* was the earliest name for it. Richards and Randall (1967) have shown that both species occur in the Atlantic, reopening the question of the proper name for Atlantic *Auxis*.

Frigate tunas (*Auxis*) are the smallest members of the tribe Thunnini, the true tunas. *Auxis rochei* reaches a fork length (FL) of 600 mm and *Auxis thazard*, at least 420 mm. To date, frigate tunas have not been greatly exploited, partly because of their small size. Of the total world catch of tunas, bonitos, and billfishes in 1993 (4,654,750 metric tons (t), FAO, 1995), only 4.5% (208,305 t) was *Auxis*. The largest landings are by Asian countries (Philippines 110,357 t; Thailand 36,300 t; Japan 27,896 t; and India 15,684 t). *Auxis* has soft meat and is not suitable for sashimi (slices of raw fish) because of its strong astringent taste, probably due to the high level of free amino acids in the meat (Murata et al., 1994). At least as larvae, *Auxis* are widespread and very abundant (Yabe et al., 1963, fig. 15; Ahlstrom, 1971; Ramíriz-Estévez and Ornelas-

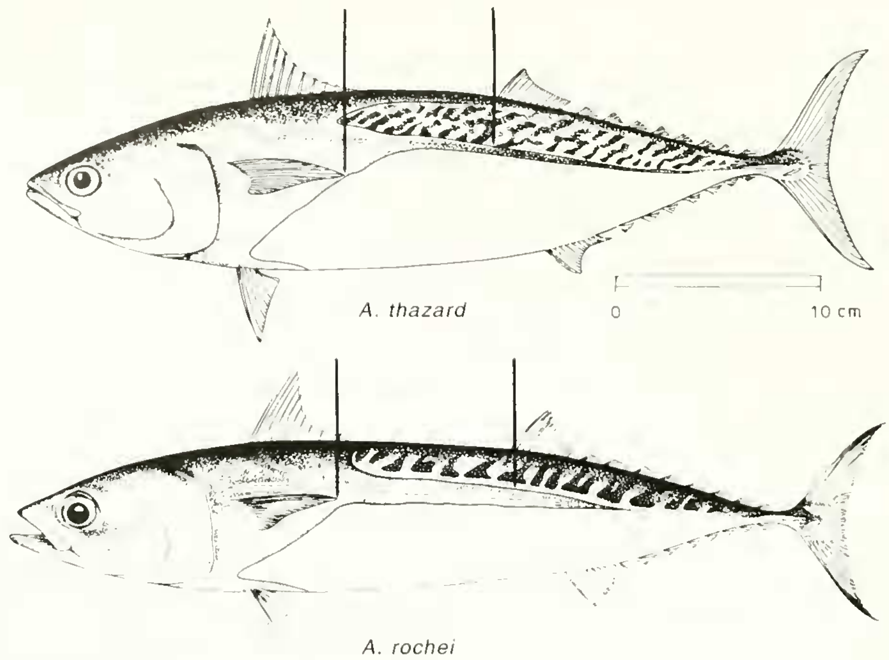

Figure 1

Auxis thazard (top) and *A. rochei* (bottom) showing anterior extent of dorsal scaleless area in relation to distal end of pectoral fin (left line) and width of corselet under origin of second dorsal fin (right line).

Roa, 1991). Richards (1984:28) concluded that *Auxis* "... is the most widely distributed and abundant scombrid in tropical seas." With stocks of other tuna species continually diminishing, there is increased potential for greater exploitation of *Auxis*. Before exploitation increases, it is necessary to establish how many species exist and what their correct names are, to determine how to identify them, and to obtain some idea of the major worldwide populations.

Fitch and Roedel (1963) also showed that the eastern Pacific populations of both species differed significantly from the Indo-West Pacific populations but did not name them pending further work. We confirm Fitch and Roedel's findings that the eastern Pacific population of *A. thazard* has more gill rakers (usually 43–48) than other populations (usually 38–42 in Atlantic and Indo-West Pacific populations), similar to the counts for *A. rochei*. The eastern Pacific population of *A. rochei* has an even wider corselet (usually more than 20 scales wide under the second dorsal fin) than other populations (8–19 scales in populations from the Indo-West Pacific).

This paper distinguishes the two species. We have located the type specimen of *rochei* and designate a neotype for *thazard* to stabilize current use of these names for these species. We evaluate the systematic status of eastern Pacific populations of the two species and describe them as new subspecies, *Auxis thazard* ***brachydorax*** and *Auxis rochei* ***eudorax***.

Materials and methods

Methods follow those used by Collette and Gillis (1992), in a revision of the double-lined mackerels *Grammatorcynus*, and by Collette and Russo (1985) in a revision of the Spanish mackerels *Scomberomorus*. Morphometric characters used in this study are as follows: FL (fork length); HdL (head length); P1L (pectoral-fin length); P1T (distance from pectoral-fin tip to anterior edge of dorsal scaleless area above lateral line); and CW (corselet width under second dorsal-fin origin). Owing to the different shapes of *A. rochei* and *A. thazard*, we postulated that four body depth measurements would illustrate these differences: 1Dor (body depth at origin of first dorsal); 1Dend (body depth at posterior end of first dorsal); 2Dor (body depth at origin of second dorsal); and Aor (body depth at anal-fin origin). *Auxis rochei* is a more slender species and the four body depth measurements are approximately equal, whereas *A. thazard* is more tuna-shaped, having narrow entering and departing wedges and more unequal body depths.

Morphometric data were analyzed with regression analysis, analysis of covariance (ANCOVA), and principal component analysis (PCA). Regression analysis was run on the combined morphometric data for all populations of *A. rochei* vs. the combined populations of *A. thazard* to determine whether morphometric differences exist between species. Regression analyses were also run on morphometric data for major populations of each species to look for intraspecific differences. The following combinations of geographic populations were tested: for *A. rochei*—western Atlantic (n=36) vs. Mediterranean (n=34) plus eastern Atlantic (n=64), western Pacific (n=82) vs. eastern Pacific (n=37); for *A. thazard*—Gulf of Guinea (n=20) vs. Indian Ocean (n=38), western Pacific (n=75) vs. central Pacific (n=17), and westcentral Pacific (n=92) vs. eastern Pacific (n=69).

PCA was performed with the character variables FL, 1Dor, 1Dend, 2Dor, and Aor to determine whether these characters supported species level separation of *A. rochei* from *A. thazard* and separation between the eastern Pacific population and the other populations for both species. Very little separation was observed with PCA because 97.9% of the variation is explained by principal component 1. This means that almost 98% of the variation can be explained by differences in size, whereas only a little more than 2% of the variation can be explained by character differences among the different populations.

ANCOVA was performed on the variables 1Dor, 1Dend, 2Dor, Aor, P1L, and CW with size (FL) as the covariate to determine whether these characters differentiated *A. rochei* from *A. thazard* and to see whether eastern Pacific populations of each species were different from other populations. ANCOVA showed that morphometric data for each species were the same for all populations, except for the eastern Pacific, and could be combined. For each species, the combined populations were run against the eastern Pacific population to test the level of differentiation of the eastern Pacific population. For *A. rochei*, the combined populations we tested against the eastern Pacific (n=30) were western Atlantic (n=36), Gulf of Guinea (n=64), Mediterranean (n=34), Indian Ocean (n=9), and western Pacific (n=82). For *A. thazard*, the combined populations we tested against the eastern Pacific (n=63) were Indian Ocean (n=38), western Pacific (n=71), central Pacific (n=17), and Australia (n=4).

Material examined is listed at the end of each subspecies account and includes 267 specimens of *A. thazard* and 291 specimens of *A. rochei*. Abbreviations of institutions housing the material examined follow Leviton et al. (1985). CMFRI is the Central Marine Fisheries Research Institute, Cochin, India. ZRC is the current institutional code for the Zoological Reference Collection at the National University of Singapore.

Systematics

Auxis Cuvier, 1829

Auxis Cuvier, 1829:199. Type-species: *Scomber rochei* Risso, 1810, by subsequent designation of Gill, 1862

Diagnosis (Modified from Collette, 1979.) *Auxis* lacks the prominent paired fronto-parietal fenestra in the top of the skull found in all the other tunas, tribe Thunnini (except *Allothunnus*). The dorsal and ventral branches of the cutaneous artery originate separately from the dorsal aorta in *Auxis* (Godsil, 1954); a common cutaneous artery divides into dorsal and ventral branches laterally from the dorsal aorta in the other Thunnini. The ventral branch is very poorly developed, less so than in other Thunnini. The dorsal cutaneous artery lies ventral to the corresponding vein in *Auxis;* it lies dorsal in *Euthynnus* (Godsil, 1954). The vertebral column differs from all other scombrids in having a long pedicel or epihaemal process (1.5–2 times the centrum depth) that forces the dorsal aorta to run much further ventrally from the vertebral column than in other tunas. The interpelvic process is single and very long, equal to or longer than the pelvic fins themselves; it is shorter than the pelvic fins in all other Scombridae.

Description Body robust, elongate, and rounded. Teeth small and conical, in a single series. Two dorsal fins, the first with 10–12 spines, separated from the second by a long interspace (at least equal to length of first dorsal-fin base), the second fin followed by 8 finlets; pectoral fins short; anal fin followed by 7 finlets. Gill rakers 36–49. Body naked except for the corselet, which extends posteriorly along the lateral line past the origin of the second dorsal fin. In *A. thazard*, the extension is only 1–5 scales wide beneath the second dorsal fin, in *A. rochei* it is six scales or more. A strong central keel is present on each side of the caudal-fin base between two smaller keels. Vertebrae: 20 precaudal plus 19 caudal, total 39. Color: dorsum bluish, turning to deep purple or almost black on the head; belly white, usually without stripes or spots, occasionally black spots present on belly between pectoral and pelvic fins as in *Euthynnus*; pectoral and pelvic fins purple, their inner sides black.

Relationships *Auxis* is related most closely to *Euthynnus* (Kishinouye, 1923; Collette, 1979, 1984; Finnerty and Block, 1995). It has been considered (Collette, 1979) to be the most primitive member (except for *Allothunnus*) of the Thunnini, the true tunas, because it lacks the frontoparietal fenestra present in *Euthynnus, Katsuwonus*, and *Thunnus*, because its subcutaneous circulatory system is more poorly developed than that of the more advanced tunas, and because *Auxis* shows no suturing of the first vertebra to the skull as is present in higher Thunnini. Tunas have a pair of lateral retia which serve the red muscle and act as heat exchangers enabling them to maintain body temperatures several degrees warmer than ambient water (3.5–9.5°C, mean 5.9°C, in the case of *Auxis*, Schaefer, 1985). In addition, *Auxis* and *Euthynnus* share a large central heat exchanger below the vertebral column in a series of enlarged haemal arches. *Auxis* is endothermic at sizes of 200 mm FL and larger (Dickson, 1994). The liver is similar to that in *Euthynnus* in having a very long right lobe running the length of the body cavity (Fig. 2). Prominent branches of the hepatic vein are present on the ventral surface of the liver lobes in both genera. *Auxis* differs from *Euthynnus* in having a greatly reduced left liver lobe; the left and middle lobes are of about equal length in *Euthynnus*. A swimbladder is present in larvae but degenerates by 20 mm as in *Euthynnus* and *Katsuwonus* (Richards and Dove, 1971).

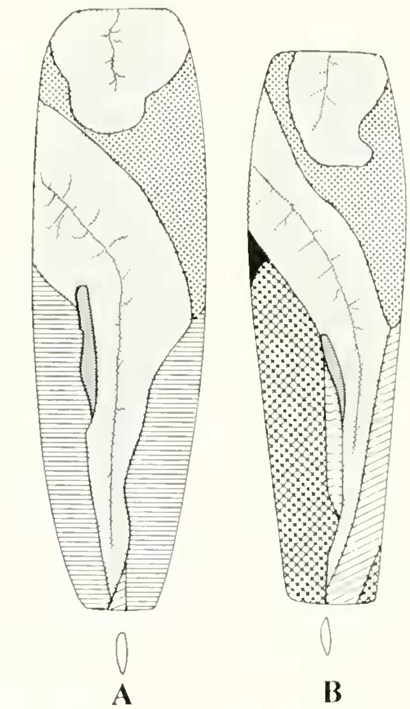

Figure 2

Viscera in ventral view. (**A**) *Auxis t. thazard*, USNM 339045, Philippine Is., 357 mm FL. (**B**) *Auxis r. rochei*, USNM 339044, Philippine Is., 262 mm FL.

Osteological comparisons Several authors (Kishinouye, 1923; Watanabe, 1962, 1964; Yoshida and Nakamura, 1965; Chi and Yang, 1972; Uchida, 1981; Zavala-Camin, 1983) have reported osteological differences between the species. Watanabe (1962, 1964) found that there were two types of *Auxis* based on long and short parapophyses. The differences were more prominent in specimens larger than 111 mm, especially on the 25th and 27th vertebrae. *Auxis thazard* had long free parapophyses, whereas *A. rochei* (as *A. tapeinosoma*) had short free parapophyses. In addition, in young *A. thazard* the first free parapophysis is developed mostly on the 23rd vertebra, and the first inferior foramen occurs on the 27th or 28th vertebra. In young *A. rochei*, however, the first free parapophysis is usually produced on the 21st or 22nd vertebra, and the first foramen occurs on the 29th or 30th vertebra. Other differences between the two species were the ratio of the caudal vertebral length to precaudal vertebral length and the ratio of body height at anal-fin origin to length from first dorsal to second dorsal origin. Yoshida and Nakamura (1965) found that in *A. thazard* the length of the anterior branch of the haemal process of the 24th to the 28th vertebra was longer and contacted the preceding arch. In *A. rochei* the anterior branches of the haemal processes were short, more fragile, and were never in contact with the preceding haemal arches. The angle between the temporal crests and a line parallel to the supraoccipital crest ranged from 0 to 2 degrees in *A. rochei* and from 3 to 7 degrees in *A. thazard*. In skulls of the same length, skulls of *A. thazard* were wider than those of *A. rochei*.

Larval differences In several geographic regions, workers have been able to divide their material of larval and juvenile *Auxis* into what appear to be two

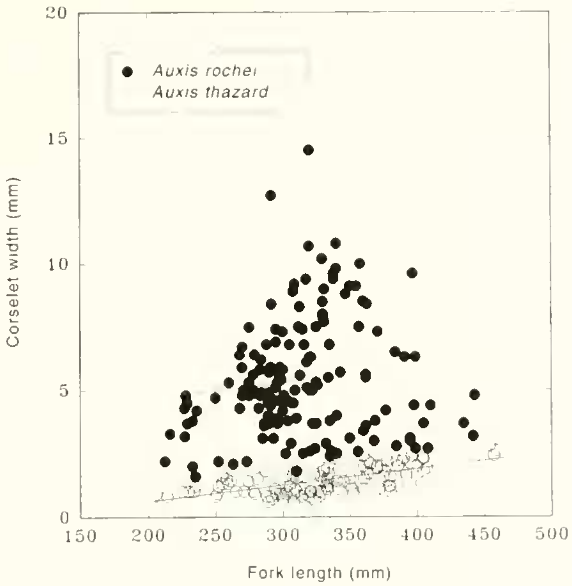

Figure 3

Corselet width under second dorsal-fin origin vs. fork length in *Auxis rochei* (closed circles, $y = 0.005x + 3.933$, r=0.09) and *A. thazard* (open circles, $y = 0.006 - 0.673$, r=0.62).

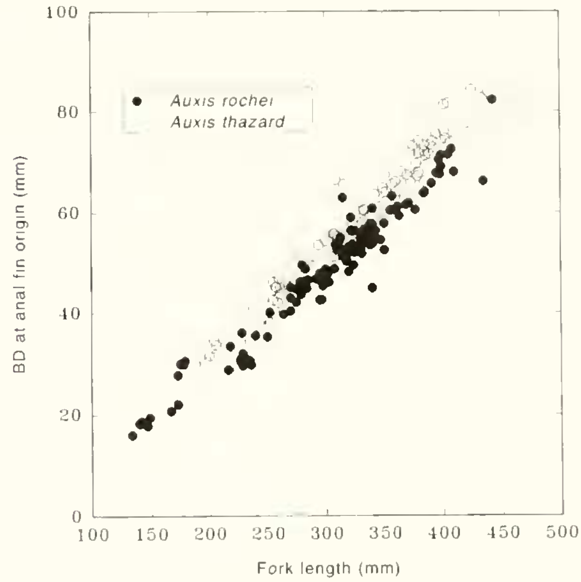

Figure 4

Body depth (BD) at anal-fin origin in *Auxis rochei* (closed circles, $y = 0.17x - 3.06$, r=0.92) and *A. thazard* (open circles, $y = 0.207x - 9.58$, r=0.96).

species (Wade, 1949, Philippines; Matsumoto, 1959; Gorbunova, 1969, 1974, Indian and Pacific oceans; Zhao et al., 1982, and Sun et al., 1986, China; Richards, 1989, western central Atlantic). Juveniles have been successfully identified (e.g. Wade, 1949), but larvae are more difficult to identify to species because the corselet scales and gill rakers that distinguish the adults are not fully developed in the larvae. For brief length intervals, pigment characters are useful in distinguishing two types of larvae.

Gorbunova (1974) distinguished between larvae of the two species. *Auxis rochei* is characterized by a seemingly slower rate of development and a shallower body depth. The relative size of the eye is smaller and the pigmentation on the caudal peduncle is less intense. *Auxis thazard* is distinguished by a more rapid rate of development, a greater body depth, a shorter caudal portion of the body, and more intense body pigmentation. Richards (1989) emphasized the presence of pigment along the lateral line in the posterior part of the body in *A. rochei* and its absence in *A. thazard*.

Biochemical differences The first attempts to separate the two species of *Auxis* biochemically were by Matsumoto (1960b) who found that Hawaiian specimens could be distinguished in a one-dimensional chromatogram. Taniguchi and Nakamura (1970) examined muscle protein of *A. thazard* and *A. rochei* by the cellulose acetate electrophoretic method. They found five components in the electropherograms of both species, but some components were not common to both. Electrophoretic patterns of the two species were clearly distinguishable from each other by the mobility and percentage of each component. Taniguchi and Konishi (1971) used starch gel electrophoresis to detect protein specificity between *A. thazard* and *A. rochei*. No individual variation occurred in the electropherograms of 11 specimens of *A. thazard*, whereas all 170 specimens of *A. rochei* fit into 1 of 3 phenotypic patterns. They hypothesized that these three phenotypes are controlled by two codominant alleles. Distribution of the three phenotypes was independent of age and sex.

Auxis thazard (Lacepède, 1800)

Frigate tuna

Diagnosis *Auxis thazard* has a narrow corselet that is 0.5–3.5 mm, usually 0.5–1.0 mm wide (Fig. 3) but no more than five scales wide under the second dorsal-fin origin (Table 1), a greater body depth at the anal-fin origin (Fig. 4), and the anterior margin of the scaleless area above the corselet extends anteriorly beyond the tip of the pectoral fins (Figs. 1 and 5) unlike that in *A. rochei*. Color pattern: 15 or more

Table 1

Number of corselet scales under second dorsal-fin origin in populations of *Auxis*.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	*n*	*x*
A. t. thazard																																
W. Atlantic	—	—	4	1	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7	4.0
E. Atlantic	1	2	10	1	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	14	2.9
Indian O.	1	3	23	7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	34	3.1
W. Pacific	14	7	25	5	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	53	2.5
C. Pacific	—	—	11	3	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	16	3.4
																															124	2.7
A. t. brachydorax																																
E. Pacific	13	8	42	2	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	68	2.6
Galapagos	—	—	1	1	—	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	5	5.6
																															73	2.8
A. r. rochei																																
W. Atlantic	—	—	—	—	2	8	4	7	4	1	—	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	30	7.9
Mediterranean	—	—	—	—	—	—	3	2	1	5	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13	9.2
E. Atlantic	—	—	—	—	—	—	—	4	3	2	2	9	6	6	3	4	4	3	3	2	1	2	—	1	—	—	—	—	—	—	55	14.3
Indian O.	—	—	—	—	—	—	1	—	—	3	2	3	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	—	10	11.5
W. Pacific	—	—	—	—	—	—	—	1	—	10	1	7	3	6	6	1	1	—	1	—	—	—	—	—	—	—	—	—	—	—	37	12.6
																															148	11.7
A. r. eudorax																																
E. Pacific	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	1	1	1	—	2	8	3	2	2	3	—	—	1	1	1	29	21.6

narrow, oblique to nearly horizontal, dark wavy lines in the scaleless area above the lateral line (Figs. 1 and 6). Spots sometimes occur between the pectoral and pelvic fins (see Robins and Ray, 1986: pl. 48), as they usually do in *Euthynnus*.

Geographical distribution Probably cosmopolitan in warm waters (Fig. 7) but there have been relatively few documented occurrences in the Atlantic Ocean. Although we did not examine specimens of either species from the southeastern Atlantic and although Zavalla-Camin (1983) concluded that there was only a single variable species, both species do occur there as can be seen from the anterior extent of the dorsal scaleless area (Fig. 8, 20 specimens of *A. thazard* and 33 specimens of *A. rochei*). On the basis of two specimens of *A. thazard* from Haifa, Israel (HUJ 17480, HUJ 17826) provided by Dani Golani, we believe both species occur in the Mediterranean Sea.

Habitat and biology (From literature summarized in Uchida, 1981, and Collette and Nauen, 1983:29.) An epipelagic, neritic, and oceanic species. In the eastern Pacific, mature fish occur throughout the

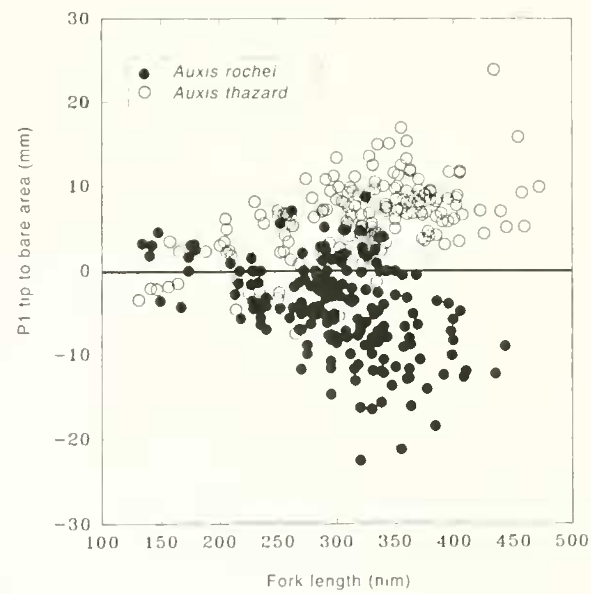

Figure 5

Distance from the tip of the pectoral fin (P1) to the bare area above the lateral line in *Auxis rochei* (closed circles) and *A. thazard* (open circles).

Figure 6

(**Upper photograph**) *Auxis rochei rochei*, 283 mm FL, Indonesia, Bali, Padang Bai; 28 Feb 1984; John E. Randall.
(**Lower photograph**) *Auxis thazard thazard*, 267 mm FL, Hawaii, Oahu; 11 Nov 1994; John E. Randall.

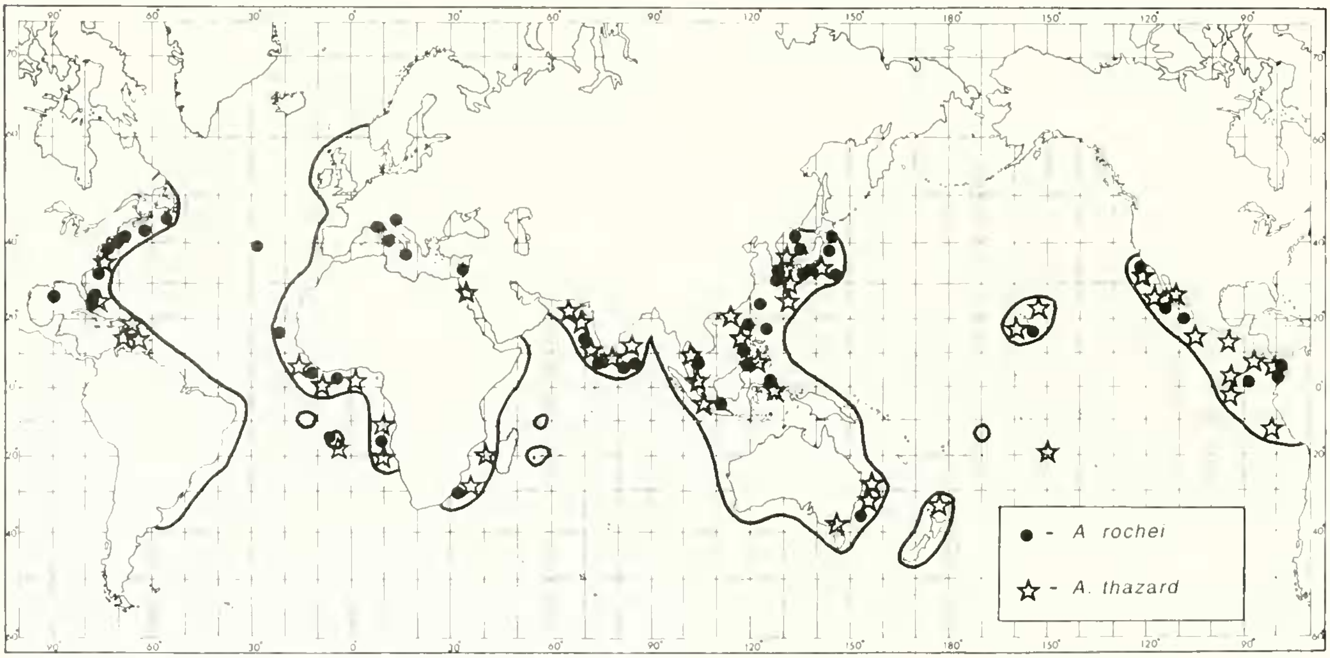

Figure 7

Distribution of *Auxis rochei* and *A. thazard*. Solid lines show approximate limits of distribution; symbols indicate localities of specimens examined.

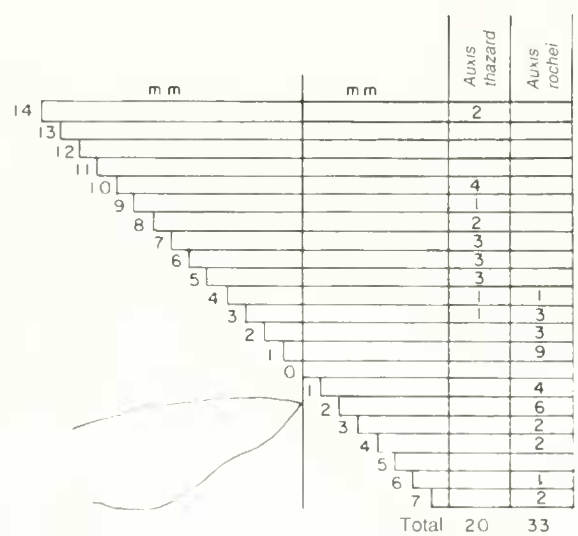

Figure 8

Distance from the tip of the pectoral fin to the anterior extent of the dorsal scaleless area above the lateral line in *Auxis* from southeastern Brazil (from Zavala-Camin, 1983: fig. 4). The scaleless area extends 3–14 mm anterior to the tip of the pectoral fin in 20 specimens of *A. thazard* but falls short of the pectoral-fin tip or extends slightly anterior to it in 33 specimens of *A. rochei*.

year; although off Costa Rica spawning is heaviest from December through April, whereas in Japanese waters it peaks in July as expressed by the index of sexual maturity. In the southern Indian Ocean, the spawning season extends from August to April; north of the equator it is reported from January to April. Fecundity was estimated at about 1.37 million eggs per year in a 44.2-cm-long female. Fecundity of fish in Indian waters ranged between approximately 200,000 to 1.06 million eggs per spawning in correlation with size of females.

Size Maximum fork length from drift net records in the Indian Ocean is 510 mm, but off Sri Lanka it is 580 mm; common lengths range between 250 and 400 mm FL depending on gear type and may also vary seasonally and by region. Size at first maturity is reported at about 290 mm FL in Japanese waters but at about 350 mm around Hawaii. *Auxis thazard* grows to be larger than *A. rochei*.

Subspecies The eastern Pacific population of *A. thazard* has more gill rakers, leading us to describe it as a separate subspecies. Linear regression analyses of morphometric characters for *A. thazard* showed significant differences between the eastern Pacific and the remaining combined populations in four char-

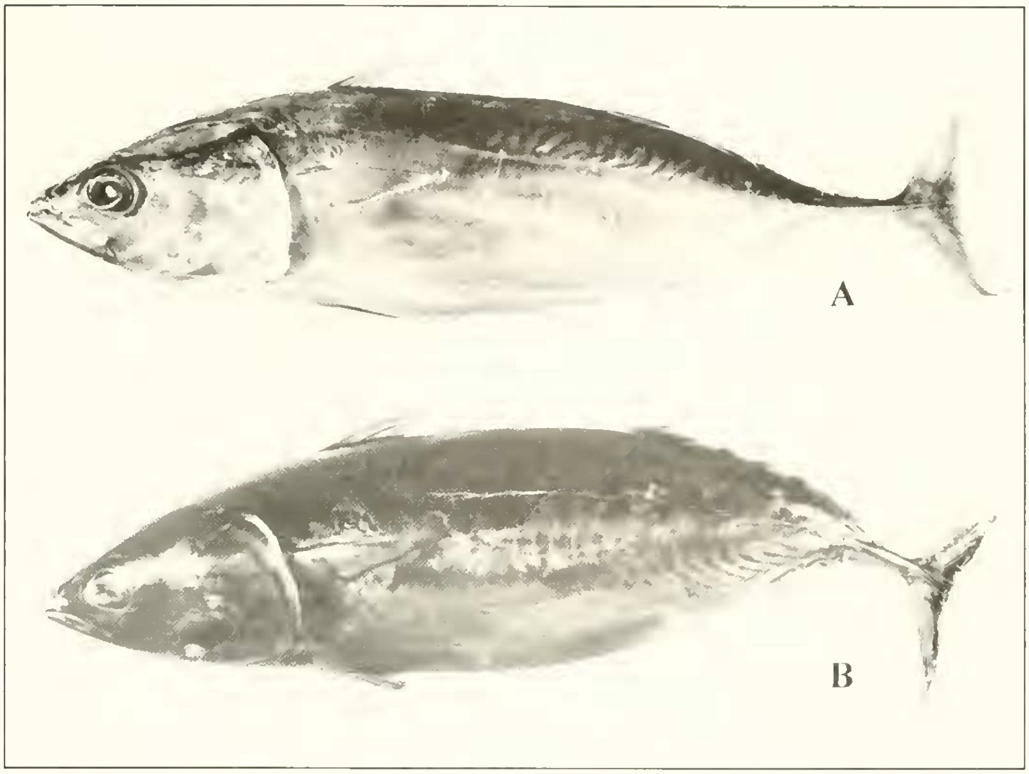

Figure 9

Type specimens of *Auxis thazard*. (**A**) Neotype of *Scomber thazard* Lacepède, 1800; USNM 265418; 274 mm FL; Indonesia, Moluccas, Halmahera I. (**B**) Holotype of *Auxis thazard brachydorax* n. ssp.; USNM 320406; 352 mm FL; 7°51'N, 99°51'W.

acters: CW, P1L, 2Dor, and Aor. ANCOVA showed differences that were significant at the 0.01 level of significance for three morphometric characters: AOR, P1L, and CW, further supporting recognition of an eastern Pacific subspecies of *A. thazard*.

Auxis thazard thazard (Lacepède, 1800)

Fig. 9A

Scomber thazard Lacepède, 1800:599 (original description) Lacepède, 1801:9–13 (description, off New Guinea); no type-specimens extant.

Auxis taso Commerson, 1831 *in* Cuvier and Valenciennes, 1831:146–148 (original description based on *Scomber taso* Commerson, New Guinea).

Auxis tapeinosoma Bleeker, 1854:408–409 (original description, Nagasaki, Japan); holotype: RMNH 6050 (see Boeseman, 1964:465, pl. 3, fig. 10).

Auxis thazard: Dresslar and Fesler, 1889:434 (synonymy, in part). Jordan and Evermann, 1896:867–868 (synonymy, in part). Wade, 1949:230–231, fig. 1 (comparison of both species, Philippines), figs. 3–6 (juveniles, 23.1–57.2 mm FL). Fraser-Brunner, 1950, synonymy, in part:152. Jones, 1958:190–192 (India). Matsumoto, 1960a:174–175, fig. 2 (comparison of both species, Hawaii). Jones and Silas, 1961:377–378, fig. 3. Fitch and Roedel, 1963:1329–1342, fig. 1 (generic review). Jones and Silas, 1963:1781–1786; 1964:20–22 (India). Tortonese, 1963 (Mediterranean population differs from Indo-Pacific populations of wide-corseleted *Auxis*). Richards and Randall, 1967:245–247, fig. 1 (first western Atlantic records). Chi and Yang, 1972 (osteology, morphology, Taiwan). Richards and Klawe, 1972:68–69 (references to eggs and young). Uchida, 1981 (species synopsis). Gorbunova, 1974:48–50 (description of larvae, Pacific and Indian oceans, fig. 12). Collette and Nauen, 1983:30–31 (synonymy, description, distribution, fig.). Robins and Ray, 1986:261 (W. Atlantic), pl. 48 (color fig.). Richards, 1989:32–33 (description of larvae, western central Atlantic; figs. of 7 larvae 4.5 mm NL to 25.0 mm SL).

Table 2
Number of gill rakers in populations of *Auxis*.

	36	37	38	39	40	41	42	43	44	45	46	47	48	49	*n*	$\bar{x}$
A. t. thazard																
Western Atlantic	—	—	1	1	2	2	1	—	—	—	—	—	—	—	7	40.1
Eastern Atlantic	—	—	1	4	6	5	5	—	1	—	—	—	—	—	22	40.6
Indian Ocean	1	2	6	8	7	7	3	1	—	—	—	—	—	—	35	39.6
Western Pacific	—	1	18	18	28	20	9	—	1	—	—	—	—	—	95	39.8
Central Pacific	—	—	—	3	9	7	9	—	—	—	—	—	—	—	28	39.3
Total															187	39.8
A. t. brachydorax																
Eastern Pacific	—	—	—	—	1	1	7	14	19	13	13	6	2	—	76	43.3
Galapagos	—	—	—	—	—	—	—	2	1	1	—	—	2	—	6	45.2
Total															82	43.4
A. r. rochei																
Western Atlantic	—	—	—	1	3	7	11	8	2	2	1	—	—	—	34	43.4
Eastern Atlantic	—	—	—	—	1	8	12	16	26	10	6	2	—	—	81	43.5
Mediterranean	—	—	—	—	1	10	8	8	6	3	—	1	—	—	37	42.6
Indian Ocean	—	—	—	—	—	—	—	1	3	—	1	3	2	—	10	45.8
Western Pacific	—	—	—	—	—	—	1	7	12	29	21	6	3	1	80	45.2
Central Pacific	—	—	—	—	—	—	—	3	3	5	1	1	—	—	13	44.5
Total															255	44.0
A. r. eudorax																
Eastern Pacific	—	—	—	—	—	—	—	1	5	11	5	5	3	—	30	45.6
Total																

Auxis hira Kishinouye, 1915:23–24, fig. 16 (original description, Japan); no type-specimens known. Kishinouye, 1923:462–463, pl. 31, fig. 55 (anatomy).

Diagnosis *Auxis thazard thazard* has fewer gill rakers, 36–44, usually 38–42 (Table 2); a greater body depth at the anal-fin origin (Fig. 10); a longer pectoral fin (Fig. 11); and a wider corselet (Fig. 12) than has *A. thazard brachydorax.*

Description Corselet narrow under second dorsal-fin origin (1–6 scales, usually 3, Table 1). Dorsal scaleless area extends anteriorly beyond P1 tip (1–16 mm, usually 3–12 mm, Fig. 5). Width of corselet under second dorsal-fin origin 0.5–3.5 mm, usually 0.5–1.0 mm (Fig. 3).

Types

Scomber thazard Lacepède, 1800. Neotype USNM 265418 (274 mm FL), Indonesia, Moluccas, Halmahera I., 0°58'N, 127°56'E; 12 Mar 1979; herein designated. Pectoral fin 41.2 mm, anterior extent of dorsal scaleless area 10.9 mm anterior to tip of pectoral fin, width of corselet under second dorsal-fin origin 1.4 mm, 3 scales in corselet under second dorsal-fin origin, gill rakers 10 + 31 = 41. Fig. 9A.

Auxis tapeinosoma Bleeker, 1854. Holotype RMNH 6050 (200 mm FL), Japan, Nagasaki; S.N. Wolff. Pectoral fin 20.5 mm; 2 scales in corselet under second dorsal fin origin; gill rakers 10 + 30 = 40. Photograph of type presented by Boeseman (1964, pl. 3, fig. 10).

Material examined 194 specimens (44.8–472 mm FL) from 94 collections.

Western Atlantic 10 specimens (240–471 mm FL) from 10 collections.

CAS SU 10874 (1, 305); Massachusetts; D.S. Jordan. USNM 23347 (1, 343); MA, Provincetown; Aug 1879; S.F. Baird. USNM 325226 (1, 449); NC, Oregon Inlet. UF 42693 (1, 344); NC, off Morehead City; 3 Jun 1973; G.F. Burgess. UF 38841 (1, 402); FL, Government Cut off Miami; 31 Jul 1971; T. Iwamoto. UF 98890 (1, 240); FL, Marquesas Keys, 24°29'N, 83°00'W; 23 Sep 1992; G.F. Burgess 92-5. UF 46979 (1, 253); Puerto Rico. USNM 325457 (1, 471); Caribbean, west of St. Vincent, 13°16'N, 62°32'W; 27 Mar 1966; RV *Undaunted*, cr. 2, sta. 114 (skeleton). USNM 325238 (1, 426); 10°47'N, 67°03'W; 24 Mar 1966; RV *Geronimo*, cr. 7, sta. 116. MNHN A.5792 (1, 248); Martinique; Plee; paralectotype of *Auxis vulgaris* Valenciennes.

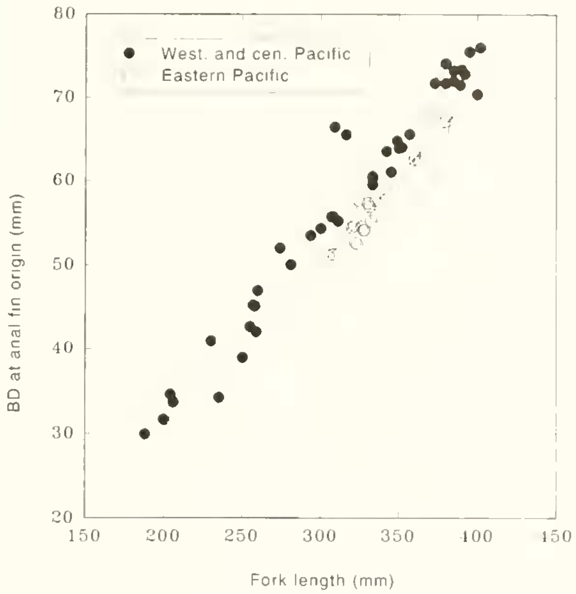

Figure 10

Body depth (BD) at anal-fin origin. Western and central Pacific *Auxis thazard thazard* (closed circles, $y = 0.216x - 10.683$, $r=0.98$) differ significantly ($F=52.06$, $P<0.00$) from eastern Pacific *A. t. brachydorax* (open circles, $y = 0.210x - 13.147$, $r=0.96$).

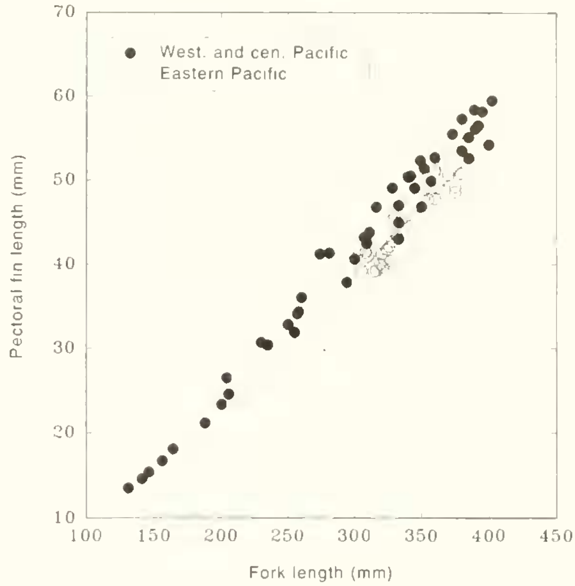

Figure 11

Pectoral-fin length. Western and central Pacific *Auxis thazard thazard* (closed circles, $y = 0.169x - 9.045$, $r=0.991$) differ significantly ($F=24.06$, $P<0.00$) from eastern Pacific *A. t. brachydorax* (open circles, $y = 0.165x - 11.11$, $r=0.95$).

Eastern Atlantic 24 specimens (261–472 mm FL) from 7 collections.

BMNH 1946.5.23.13–14 (2, 340–383); St. Helena; Colman. HUJ 17480 (1, 323); Mediterranean Sea, purchased in the market at Haifa, Israel; 8 Jun 1993; D. Golani. HUJ 17826 (1, 335); Haifa Bay; 2 Feb 1995; D. Golani. USNM 325237 (1, 442); 5°44'N, 14°28'W; 23 Feb 1965; RV *Geronimo*, cr. 5, sta. 124. USNM 325216 (10, 386–472); Gulf of Guinea; 15 Oct 1967; MV *Caribbean*, set 1. USNM 325956 (1, 261); Ghana; 5 Oct 1967. USNM 325224 (8, 370–439); off Lobito, Angola; fall 1968; MV *Bold Venture*.

Indian Ocean 38 specimens (216–416 mm FL) from 18 collections.

USNM 266918 (1, 310); Israel, Eilat; 21 May 1962. USNM 266919 (1, 330); Israel, Eilat; 1949. USNM 166908 (3, 310–338); Egypt, Ghardaqa; E. Clark. USNM 307773-5 (5, 351–373); north of Tulear, Madagascar, 22°10'S, 43°10'E; 4 Dec 1988; RV *Vityaz* 2657; B.B. Collette 1889. ANSP 93093 (1, 330); Natal coast; 1927; H.W. Bell Marley. CMFRI uncat (1, 415); India, Bombay, Sasson dock; 26 Oct 1979. CMFRI uncat (4, 325–387); India, Mangalore, Kaup; 15 Sep 1979. CMFRI uncat (2, 318–338); India, Vizhinjam; 17 Dec 1979. CMFRI uncat (2, 313–315); India, Veraval. CMFRI uncat (1, 368); India, Veerapandyan patnam, Tuticorin; 23 Oct 1979. CMFRI uncat (1, 416); India, Cochin fishing harbor; 1 Sep 1979. CMFRI uncat (5, 325–360); India, Calicut, off Vellayil; 25 Nov 1979; RSLM Haridas sta. 98. CMFRI uncat (1, 216); India, Cochin fish-

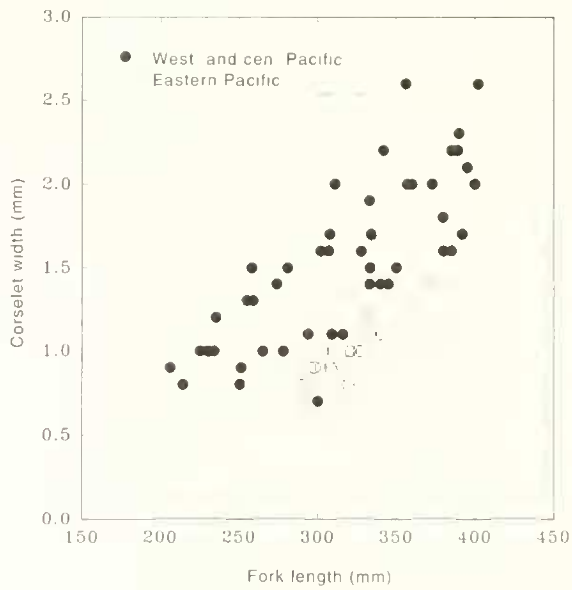

Figure 12

Corselet width under second dorsal-fin origin. Western and central Pacific *Auxis thazard thazard* (closed circles, $y = 0.007x - 0.606$, $r=0.79$) differ significantly ($F=65.94$, $P<0.00$) from eastern Pacific *A. t. brachydorax* (open circles, $y = 0.005x - 0.561$, $r=0.65$).

ing harbor; 22 Sep 1979. CMFRI uncat (1, 340); India. CMFRI uncat (1, 340); India, northwest Indian Ocean; 25 Mar 1977; MURAENA sta. 78. CMFRI uncat (1, 235); India, Cochin fishing harbor; 22 Sep 1979. USNM 218963 (1, 378); Ceylon, Trincomalee, St. John's market; 13 Sep 1969; P.C. Heemstra. USNM 215024 (6, 252–287); Ceylon; P.C. Heemstra.

Dissections 4 specimens (312–401 mm FL) from 4 collections.

USNM 307773-5 (3, 365–373); Madagascar, north of Tulear; 4 Dec 1988; RV *Vityaz* 2657; B.B. Collette 1889. CMFRI uncat (1, 401); India, Cochin fishing harbor.

Western Pacific 94 specimens (44.8–415 mm FL) from 50 collections.

RMNH 6050 (1, 200), Japan, Nagasaki; holotype of *Auxis tapeinosoma* Bleeker. ZUMT 2475 (1, 234); Japan, Nagasaki Pref.; Aug 1909. ZUMT 23751 (1, 251); Japan, Kagoshima Pref., Taniyama, Kagoshima City; 3 Jul–15 Aug 1930. ZUMT 31281 (1, 334); Japan, Shimane Pref., Matsue; 19 Oct 1935. ZUMT 31286 (1, 302); Japan, Shimane Pref.; 19 Oct 1935. ZUMT 50160 (1, 278); Japan, Nagasaki Pref., Nakadori I., Goto I., Arikawa; 17 Oct 1953. ZUMT 54923-4 (2, 225–250); Japan, Shizuoka Pref., Izu Peninsula; 12 Sep 1981; M. Aizawa. ZUMT 23979 (1, 214); Japan, Kagoshima Pref., Shibushi. CAS SU 24006 (1, 208); Japan, Wakanoura; 1900; Jordan and Snyder. USNM 325231 (1, 308); Japan, south of Tokyo (purchased in Tokyo market); 20 Sep 1966; R.H. Gibbs. USNM 44894 (1, 333); Japan. FMNH 57450 (1, 294); Japan, Sendai; D.S. Jordan. FMNH 57353 (2, 235–250); Japan, Osaka; D.S. Jordan. NMW 14528 (1, 300); Japan; 1900; D.S. Jordan. NMW 14530 (1, 309); Japan, Nagasaki; 1895. ZUMT 16740 (1, 265); Japan, Okinawa Island, Onnason. FMNH 55727 (1, 395); Korea, Fusan; 1911; D. S. Jordan. USNM 325230 (5, 349–402); Hong Kong; Nov 1967; CSM, cr. 10/67. ZRC 3736 (1, 370), South China Sea, 2°15'N, 104°45'E; 26 Mar 1973; RV *Changi*, SEAFDEC. CAS SU 13685 (2, 343–353); Philippine Is., Jolo; 1931; Herre. CAS SU 26430 (1, 238); Philippine Is., Culion; 1931. CAS SU 14524 (1, 263); Philippine Is., Luzon; 1934; Herre. CAS SU 28284 (1, 250); Philippine Is., Culion; Apr 1931; Herre. USNM 218964 (3, 307–342); Philippine Is.; 17 Sep 1963. USNM 150084 (3, 255–258); Philippine Is., Cebu; F. Baker. USM 325232 (1, 260); Philippine Is., Palawan; 25 May 1962; I. Ronquillo. USNM 325235 (3, 200–206); Philippine Is., Manila Bay; 27 May 1962. USNM 339045 (3, 265–357); Phillipine Is., Manila markets; 1–10 Oct 1995; B.B. Collette. CAS 53833 (3, 131–146); Philippine Is., Luzon, Batangas Prov., Batangas market; 24 Apr 1948; Herre. CAS 49634 (2, 156–164); Philippine Is., Batangas Prov., Batangas; 30 Jun 1948. LACM 45781-2 (14, 44.8–75.0); Philippine Is., Luzon, Batangas Bay, Bauan; 27 Mar 1949; M.A. Sabado and D. Leonicio. LACM 45782-2 (3, 62.7–69.2); Philippine Is., Luzon, Batangas Bay, Bauan; 12 Mar 1949; M.A. Sabado and D. Leonicio. LACM 45780-1 (3, 55.8–114); Philippine Is., Luzon, Batangas Bay, Bauan; 27 Sep 1949; M.A. Sabado and D. Leonicio. ZRC 3288 (1, 390); Singapore; Jun 1964; A.K. Tham. ROM 22971 (1, 188); Singapore; 1962–1963; C.C. Linsey. USNM 72629 (1, 230); Java, Batavia; 2 Apr 1909; Bryant and Palmer. SIO 61-735 (3, 206–215); Java Sea, Sunda Straits, 5°37'S, 106°02'E; 22 Mar 1961; Naga Expedition; T. Matsui. BMNH 1892.4.6.74 (1, 257); N. Celebes; Meyer. BMNH 1858.4.21.512 (1, 223); Amboina; Franks. USNM 265418 (1, 274); Moluccas, Kampung Loleba, Wasile district, Halmahera I., 0°58'N, 127°56'E; 12 Mar 1979; neotype of *Scomber thazard* Lacepède and USNM 330940 (1, 281), same data. USNM 215015 (1, 273); Australia, New South Wales, Sydney fish market; 17 Apr 1970; B.B. Collette 1469B. USNM 176970 (1, 300); Australia, New South Wales; Col. Howard. AMS IB 6430 (1, 403); Australia, Botany Bay, New South Wales; Mar 1963; D. Cleaver. AMS IB 845-6 (2, 282–290); Australia, Port Jackson; 3 Feb 1963; Stead. AMS I.21568-001 (1, 355); Australia, New South Wales, Sydney Harbour. AMS I.28544-001 (1, 415); Australia, New South Wales, Long Reef, 33°45'S, 151°19'E; D. Mercer. BMNH 1896.6.17.43 (1, 365); Melbourne market; Degen. NMNZ 9905 (2, 340–357), New Zealand, off Cape Brett, 35°10'S, 174°20'E. NMNZ 6939-42 (4, 290–350); New Zealand area; 16 Apr 1975. NMNZ 7326 (2, 370–372); New Zealand area.

Dissections 2 specimens (312–376) from 2 collections.

USNM 269056 (1, 312); Australia, Port Marquarie, New South Wales; 3 May 1970; B.B. Collette 1474E. USNM 269055 (1, 376); Australia, New South Wales; 17 Apr 1970; B.B. Collette 1469A.

Central Pacific 29 specimens (50.0–400 mm FL) from 10 collections.

LACM 6706-1 (4, 340–400), 6706-2 (4, 333–390), and 6706-3 (4, 345–385); Hawaiian Is. LACM 45778-1 (1, 93.0); Hawaii off Kona; 4 Oct 1962; RV *Charles M. Gilbert* 60-24. LACM 45779-2 (11, 50.0–60.3); Hawaiian Is.; 17 May 1969; RV *Townsend Cromwell* 43-30. CAS SU 12759 (1, 342); Hawaiian Is.; 1901; U.S. Fish Commission. USNM 52748 (1, 259); Hawaii; Bur. Fish. NMW 14529 (1, 316); Hawaii, Honolulu fish market; 1928; Pietschmann. BPBM 35799 (1, 267); Hawaii, Lanai, Cape Kaea; 30 Nov 1957; RV *John R. Manning*, cr. 38. MCZ 26298 (1, 392); Society Is.

Auxis thazard ***brachydorax*** Collette and Aadland, new subspecies

Fig. 9B

Diagnosis *Auxis thazard brachydorax* has more gill rakers, 40–48, usually 43–48 (Table 2), a shallower body depth at the anal-fin origin (Fig. 10), a shorter pectoral fin (Fig. 11), and a narrower corselet (Fig. 12) than *A. thazard thazard*.

Description Corselet narrow under second dorsal-fin origin (1–8 scales rows wide, usually 1–3, Table 1). Dorsal bare area extends anteriorly beyond tip of pectoral fins. Width of corselet under second dorsal 0.5–3.5 mm, usually 0.5–1.0 mm (Fig. 3).

Etymology We use the name that Fitch and Roedel used in their manuscript, *brachydorax* from the Greek *brachys* (short) and *dora* (hide) in reference to the narrow corselet. Carl L. Hubbs suggested this name in a memo dated 1 Feb 1951 to W.I. Follett, concerning an edition of their California fish list, with copies to Fitch and Roedel.

Material examined 73 specimens (205–400 mm FL) from 29 collections.

Holotype USNM 320406 (352 mm FL); 7°51'N, 99°51'W; Olympia; 16 Aug 1991. Pectoral fin 48.9 mm, anterior extent of dorsal scaleless area 10.0 mm anterior to tip of pectoral fin, width of corselet under second dorsal-fin origin 0.9 mm, 3 scales in corselet under second dorsal-fin origin, gill rakers 10 + 35 = 45. See Fig. 9B.

Paratypes from the eastern Pacific 48 specimens (205–400 mm FL) from 21 collections.

LACM 6711-2 (1, 335); CA, Orange Co., 1–2 mi off Huntington Beach; 19 Sep 1960. LACM 34069-1 (1, 330); CA, between Oceanside and San Clemente; 30 Sep 1972. LACM 34254-1 (1, 379); CA, off San Onofre; 20 Jul 1974; MV *Bonanza*. SIO 73-60 (1, 321); CA, La Jolla. SIO 60343 (1, 321); CA, San Diego, off Coronado Hotel. CAS 56979 (2, 355); Baja California, below Holcombe Point; 25 Jul 1958; IATTC. SIO 91-138 (10, 327–350); Baja California, 26°05'N, 113°22'W; 12 Sep 1991; W. Mesa. LACM 34022-1 (1, 205); Baja California, Morgan Bank; Apr 1969; MV *Beverly Lynn;* R. Chikami. LACM 6714-1 (10, 271–302); Baja California, Morgan Bank. SIO 61-257 (2, 312–328); Gulf of California, Ceralbo I., 24°08'N, 104°51.5'W; 22 Jun 1961; W. Baldwin. LACM 6708-1 (1, 335); Gulf of California, 450 Fathom Bank; 24 Mar 1950; MV *Nancy Rose*. CAS 56981 (3, 350–370); Mexico, Sinaloa, 30 mi off Mazatlan; Apr 1951; MV *Gaston Explorer;* field number W 51-151. ANSP 89064 (1, 363); Mexico, Tres Marias, Cleofa I.; 4 Jul 1941; Fifth Vanderbilt Expedition. LACM 6709-5 (2, 360–372); 20°16'N, 105°59'W; 24 Nov 1951; R.C. Wilson 51-S-87. ANSP 89066 (1, 350); Mexico, Colima, 18°00'N, 105°47'W; 29 Jun 1941; Fifth Vanderbilt Expedition. SIO 79-256 (2, 322–328); 15°30'N, 93°30'W; 10 Apr 1974. LACM 6709-2 (1, 376); Gulf of Panama, 9°48'N, 86°00'W; 13 Nov 1951; field number 51-S-82. SIO 80-172 (1, 342); 9°20'N, 94°27'W. LACM 6709-4 (1, 333); Gulf of Panama; field number 51-S-85. USNM 334062 (3, 303–310); 7°51'N, 99°51'W; Olympia; 16 Aug 1991. SIO 58-83-43A (2, 374–395); Peru; 1958; Tomlinson.

Other material examined 26 specimens (305–385 mm FL) from 4 collections.

LACM 6711-8 (4, 360–380); "California"; Jun–Jul 1951; MV *Courageous*. LACM 6711–9 (4, 355–385); "California." UMMZ 160954 (1, 375); "from Mexico"; 16 Sep 1927; L.E. Herr and L.A. Walford. USNM 325223 (17, 305–341); eastern Pacific, exchange from LACM, no other data.

Galapagos Islands 6 specimens (315–400 mm FL) from 4 collections.

LACM 6713-1 (3, 358–375); Isabella I., 5 mi south of Point Cristobal; 8 Mar 1954; MV *Mayflower;* H. Clemens. LACM 39622-1 (1, 385); Skipjack Bank, 01°11'N, 91°03'W; 7 Dec 1952; H. Clemens. ANSP 71417 (1, 315); Charles I.; Feb 1957; South Pacific Expedition; G. Vanderbilt. CAS 56980 (1, 400); Galapagos; Dec 1951; MV *Golden West*; Field Number W51-276.

Auxis rochei (Risso, 1810)

Bullet tuna

Diagnosis *Auxis rochei* has a wider corselet under the second dorsal-fin origin, 5 or more scales wide, usually 7–15 (Table 1), and the anterior margin of the scaleless area above the corselet does not reach the tip of the pectoral fin (Fig. 1). Color pattern: 15 or more fairly broad, nearly vertical dark bars in the scaleless area above the lateral line (Figs. 1 and 6).

Geographical distribution Cosmopolitan in warm waters (Fig. 7). Both species occur off southeastern Brazil (see distribution of *A. thazard*). Most confirmed records of *Auxis* from the Mediterranean Sea are *A. rochei,* with the exception of two specimens of *A. thazard* from Haifa, Israel.

Habitat and biology (From literature summarized in Uchida, 1981, and Collette and Nauen 1983:30.) An epipelagic, neritic, and oceanic species. The spawning season may vary regionally depending on the hydrographical regime. In many parts of the Mediterranean and in the Straits of Gibraltar, maturing fish are common from May onwards, and more than 30% are spent by September. In large areas of the Gulf of Mexico, peaks of batch spawning are reported from March to April and from June to August, whereas in coastal waters from Cape Hatteras to Cuba and in the Straits of Florida, the spawning season begins in February. Indirect evidence suggests that the season extends at least from June through July off Taiwan and from May through August off southern Japan, as indicated by gonad indices and larval counts, respectively. Fecundity ranges between 31,000 and 103,000 eggs per spawning according to size of the fish. Food consists largely of small fishes, particularly anchovies and other clupeids (Etchevers, 1976).

Size Maximum fork length is 500 mm in Japanese catches, commonly to 350 mm. Common fork lengths in the Indian Ocean range between 150 and 250 mm. Fork length at first maturity off Gibraltar is 350 mm for females and 365 mm for males (Rodríguez-Roda, 1966).

Subspecies The eastern Pacific population of *A. rochei* has more scales in the corselet under the second dorsal fin: therefore we describe it as a separate subspecies. ANCOVA on morphometric characters for populations of *A. rochei* were not significant, possibly because of the small size range (300–365 mm) for the eastern Pacific sample, but no significant differences were found between morphometric features for the eastern Pacific population and other populations.

Auxis rochei rochei (Risso, 1810)

Fig. 13, A and B

Scomber Rochei Risso, 1810:165–167 (original description, Nice); holotype MNHN A. 5808, Nice).

Scomber Bisus Rafinesque, 1810a:45, pl. II (upper fig.) (original description, Sicily); no type material. Rafinesque, 1810b:20 (Sicily).

Thynnus rocheanus: Risso, 1826:417–419.

Auxis vulgaris Cuvier, 1831, *in* Cuvier and Valenciennes, 1831:139–146, pl. 216 (original description, Mediterranean); syntypes: MNHN A. 5808, A. 5815, not located by Bauchot and Blanc, 1961:375, Blanc and Bauchot, 1964:453 or Collette, 1966, but recently located in the MNHN collections during transfer of fishes to the new storage building.

Auxis thynnoides Bleeker, 1855:301 (original description, Ternate, Indonesia); holotype: RMNH 6049 (see Boeseman, 1964:464–465, pl. 3 fig. 9). Jones 1958:192–193, fig. 2 (India). Matsumoto, 1960a:

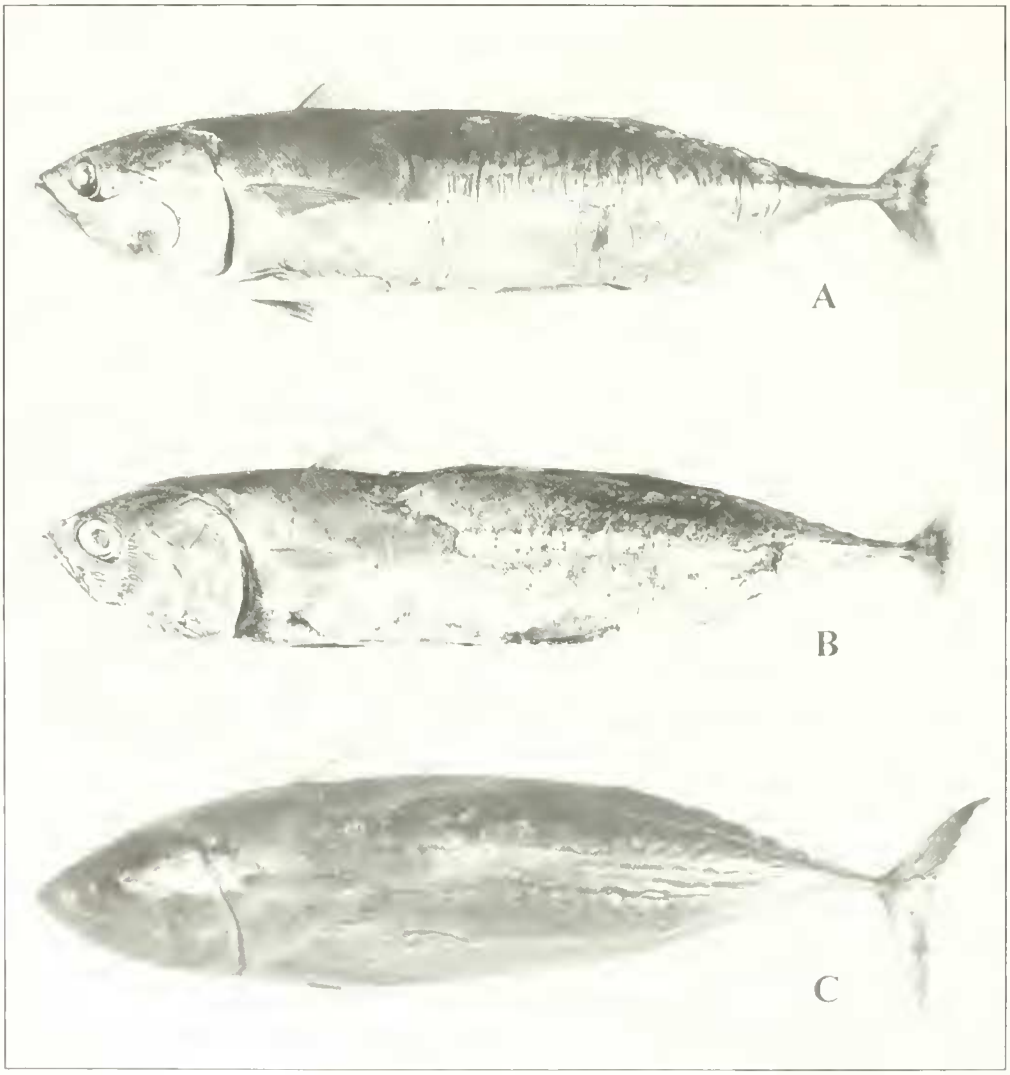

Figure 13

Type specimens of *Auxis rochei*. (**A**) Holotype of *Scomber rochei* Risso, 1810 and lectotype of *Auxis vulgaris* Cuvier, 1831; MNHN A.5808; 395 mm FL; Mediterranean Sea, Nice. (**B**) Holotype of *Auxis ramsayi* Castelnau, 1879; MNHN A.1241; 290 mm FL; Australia, Sydney. (**C**) Holotype of *Auxis rochei eudorax* n. ssp.; LACM 6712-1; 330 mm FL; California, 23 Fathom Bank.

173–174, fig. 1 (comparison of both species, Hawaii). Jones and Silas, 1961:378, fig. 4; 1963:1782–1786 (India). Jones, 1963:782–810 (species synopsis). Jones and Silas, 1964:23–24 (India).

Auxis Ramsayi Castelnau, 1879: 382 (original description, Port Jackson (Sydney), New South Wales, Australia); holotype MNHN A.1241.

Auxis rochei: Goode, 1880:808–810 and 1881:532–535 (first New England records). Fitch and Roedel, 1963:1331–1339, fig. 2 (generic review). Richards and Randall, 1967:245–247 (comparison with western Atlantic *A. thazard*). Chi and Yang 1972, (osteology, morphology, Taiwan). Richards and Klawe, 1972:67–68 (references to eggs and young). Gorbunova, 1974:50–52 (description, larvae, Pacific and Indian oceans, fig. 13). Rodríguez-Roda, 1980:169–176 (description, Spain). Uchida, 1981 (species synopsis). Collette and Nauen, 1983:29–30 (synonymy, description, distribution, fig.). Rodríguez-Roda, 1983 (age and growth, Spain). Richards, 1989:30–31 (description, larvae, western central Atlantic, figs. of 6 larvae, 3.5 mm NL to 39.0 mm SL).

Auxis thazard (*non* Lacepède, 1800): Dresslar and Fesler, 1889:434 (description, synonymy, in part), pl. 3 (USNM 25757, Rhode Island). Jordan and Evermann, 1896:867–868 (synonymy, in part). Fraser-Brunner, 1950: in part:152 (description; synonymy, in part). Rodríguez-Roda, 1966:279–291 (biology, eastern Atlantic).

Auxis maru Kishinouye, 1915:24 (original description, Japan); no type specimens known. Kishinouye, 1923:463464, pl. 31, fig. 56 (anatomy).

Diagnosis *Auxis rochei rochei* has fewer corselet scales, 5–24 (usually 6–19, Table 1), under the second dorsal-fin origin than *A. rochei eudorax*, 14–30 (usually 20–25).

Description Gill rakers 39–49, usually 41–47 in the Mediterranean, Gulf of Guinea, and Indo-West Pacific (Table 2); 39–46, usually 40–44 in the western Atlantic. The western Atlantic population has a narrower corselet (usually 6–9 scales wide under the second dorsal-fin origin compared with 8–19 in the eastern Atlantic and Indo-Pacific, Table 1) but appears best referred to as *A. r. rochei*. Corselet width under second dorsal-fin origin (Fig. 3) 2.0–10.0 mm, usually 3.0–7.0 mm, except in the western Atlantic where corselet width is only 1.0–4.0 mm, usually 1.5–3.5 mm. Dorsal scaleless area fails to reach pectoral-fin tip (Fig. 1) by up to 23.0 mm (Fig. 5); usually 3.0–17.0 mm in the Mediterranean, Gulf of Guinea, and Indo-West Pacific; may extend a little anterior to the pectoral-fin tip in the western Atlantic (Fig. 8).

Types

Scomber rochei Risso, 1810. Holotype MNHN A.5808 (395 mm FL), Mediterranean, Nice. Pectoral fin 50.1 mm; anterior extent of dorsal scaleless area extends 10.3 mm posterior to tip of pectoral fin; width of corselet under second dorsal-fin origin 3.7 mm; 12 scales in corselet under second dorsal-fin origin; gill rakers 9 + 33 = 42. Fig. 13A.

Auxis vulgaris Cuvier, 1831. Lectotype MNHN A.5808, herein selected. This specimen is also the holotype of *A. rochei*; thus *A. vulgaris* is an objective synonym of *A. rochei*.

Auxis thynnoides Bleeker, 1855. Holotype RMNH 6049 (260 mm FL), Indonesia, Ternate; C.F. Goldman. Pectoral fin broken, 27.2+ mm; dorsal scaleless area extends does not reach tip of pectoral fin; 5 scales in corselet under second dorsal-fin origin; gill rakers 11 + 36 = 47. Photograph of holotype in Boeseman (1964, pl. 3, fig. 9).

Auxis Ramsayi Castelnau, 1879. Holotype MNHN A.1241 (290 mm FL), Australia, New South Wales, Sydney. Pectoral fin 34.7 mm; anterior extent of dorsal scaleless area 12.7 mm posterior to tip of pectoral fin; width of corselet under second dorsal-fin origin 5.7 mm; 15 scales in corselet under second dorsal-fin origin; gill rakers 10 + 33 = 43. Fig. 13B.

Material examined 261 specimens (58.7–443 mm FL) from 102 collections.

Western Atlantic 37 specimens (96.4–442 mm FL) from 21 collections.

ROM 22066 (1, 292); off Nova Scotia, 41°06'N, 64°12'W; Jul 1955; Atlantic Bio Station. ROM 25064 (1, 350); Canada, Grand Bank; Aug 1967; E.O. Grandy. MCZ 39682 (1, 315); MA, Barnstable trap; 1 Aug 1954; F. Mather. USNM 35136 (1, 332); MA, Woods Hole; S.F. Baird. USNM 105002 (1, 285); MA, Woods Hole; 3 Jul 1936; H.M. Smith. ANSP 11335 (1, 283); RI, Newport; S. Powell. USNM 43717 (4, 322–340); RI, Newport; USFC. MCZ 26483 (1, 350); RI, Block I.; A. Agassiz. MCZ 40897 (1, 310); 20 mi S by E of No Man's Land; 30 Sep 1935; F.K. Schwomen. MCZ 123011 (1, 340); 40°05'N, 70°05'W; 29 Jun 1952; MV *Blue Dolphin*. USNM 50546 (1, 335); RI, off Block I.; H.C. Johnson. USNM 25973 (6, 420–442); RI, Newport; S.F. Baird. ANSP 119968 (1, 335); NJ, 29 mi ESE of Monasquain Inlet; 25 Jun 1966. ANSP 91791 (1, 340); NJ, Ventnor; 1946; C.B. Atkinson. USNM 127147 (9, 304–343); NJ. USNM 76694 (1, 324); MD, Ocean City; B.A. Bean. AMNH 3686 (1, 252); NC, Cape Lookout; summer 1910; R.J. Coles. USNM 325227 (1, 447); NC, Oregon Inlet. UF 38840 (1, 309); FL, Key Largo; A. Pflueger. USNM 325229 (1, 302); Florida; 20 Feb 1968. TU 6922 (1, 96.4); Gulf of Mexico, 28°27'N, 89°25'W; 9 Aug 1952; RV *Oregon*, R.D. Suttkus 2333.

Mediterranean 43 specimens (106–443 mm FL) from 22 collections.

USNM 266916 (1, 218); Israel, Haifa; 7 Jul 1960. HUJ 17073 (3, 318–328), Israel, purchased in Jaffa market; 17

June 1993; D. Golani. HUJ 17826 (1, 300); Haifa Bay; 8 Feb 1995; D. Golani. USNM 324234 (4, 134–147); Lebanon, St. George Bay; 10 Aug 1964; C. George. USNM 214659 (10, 119–155); Lebanon, St. George Bay; 28 Jul 1965; C. George. BMNH 1967.2.272–274 (3, 106–122); Lebanon, Antelias; C. George. NMW 14534 (1, 405); Yugoslavia, Fiume; 1881–1882; Steindachner. NMW 14531 (1, 443); Italy, Trieste; 12 Jun 1907; Steindachner. NMW 14532 (1, 408); Yugoslavia, Fiume; 1882; Steindachner. NMW 14533 (1, 399); Yugoslavia, Fiume; 1882; Steindachner. MNHN A.5808 (1, 395); Nice; Laurillard; holotype of *Auxis rochei* Risso. NMW 14537 (1, 335); France, Nizza; 1889. NMW 14538 (1, 395); France, Nizza; 1881. NMW 14527 (2, 297–303); Sicily; 9 Apr 1837. NMW 14536 (2, 149–228); France, Nizza; 1884.I.100; Steindachner. NMW 14535 (2, 108–113); France, Nizza; 1883; Steindachner. NMW 14551 (1, 435); Lissabon Dez; 1864; Steindachner. LACM 6707-1 (3, 377–410); Mediterranean Sea. MNHN A.5815 (1, 393); eastern Mediterrranean; Bory St. Vincent; paralectotype of *Auxis vulgaris* Cuvier. MCZ 58517 (1, 235); Straits of Messina; 10 Nov 1959; G. Arena. AMNH 5041 (1, 395); Italy, Naples; received Jun 1913. USNM 198207 (1, 362); Italy, Genoa; 1964; E. Tortonese.

Eastern Atlantic 69 specimens (212–399 mm FL) from 10 collections.

BMNH 1983.9.8.203 (1, 287); Azore Is.; Stonehouse. ISH 173/64 (2, 345–390); Cape Verde Is., 16°05'N, 22°45'W; RV *Walther Herwig* 81/64; 14 Mar 1964. USNM 325217 (15, 343–399); Gulf of Guinea; 15 Oct 1967; MV *Caribbean*, set 1. USNM 325955 (1, 212); Ghana; 5 Oct 1967. BMNH 1932.2.27.17 (1, 297); Ghana, Accra; Irvine. USNM 189004 (1, 279); Liberia; 27–29 Oct 1952; G.C. Miller 1789. USNM 218954 (1, 330); Angola, Baia Farta, 12°36'S, 13°12'E; 5 Apr 1968; RV *Undaunted* 68-279. USNM 325218 (32, 278–307); Angola, Benguela, 12°36'N, 13°12'E; 29 Mar 1968; RV *Undaunted* 68-273. USNM 325219 (14, 271–334); Angola, Baia Farta, 12°36'S, 13°12'E; 5 Apr 1968; RV *Undaunted* 68-279. BMNH 1868.6.15.11 (1, 390); St. Helena; Melliss.

Indian Ocean 9 specimens (175–273 mm FL) from 6 collections.

CMFRI uncat (1, 273); India, Cochin Harbor; 2 Oct 1979. CMFRI uncat (2, 198–267); India. CMFRI uncat (1, 198); India, Cochin Harbor; Oct 1979. CMFRI uncat (1, 175); India, Vellayil, Calicut; 31 Aug 1979. CMFRI uncat (1, 181); India, Cochin Harbor; 11 Sep 1979. USNM 215024 (3, 241–243); Ceylon; P.C. Heemstra.

Western Pacific 90 specimens (58.7–335 mm FL) from 41 collections.

MCZ 32422 (3, 295); Russia, Vladivostok market, Peter-the-Great Bay; 1925; Pacific Fisheries Institute. CAS SU 24121 (1, 262); Japan, Tokyo; 21 Oct 1932; D.S. Jordan. CAS SU 11763 (1, 213); Japan; 1895; K. Otaki. CAS SU 23788 (1, 235); Japan, Etcha; 1922; Ishikawa and Wakiya. MCZ 58514 (1, 173); Japan, near Tokyo; T. Abe. MCZ 58516 (1, 167); Japan, near Tokyo; T. Abe. AMNH 34877 (1, 240); Japan, Tokyo market; 31 Oct 1922; D.S. Jordan. AMNH 26893 (1, 216); Japan, Misaki; 1922; K. Aoki. AMNH 13025 (1, 250); Japan, Kyoto market; 1922; D.S. Jordan. UMMZ 142722 (1, 252); Japan, Tokyo market; 31 Oct 1922; D.S. Jordan. ZUMT 16380 (1, 270); Japan, Miyagi Pref., off Ishinomaki City; 10 Sep 1925. ZUMT 13758 (1, 311); Japan, Hokkaido, Muroran City; Sep 1924. ZUMT 20200 (1, 237); Japan, Wakayama Pref.; Jan 1920. ZUMT 46643 (1, 331); Japan, Niigata Pref.; Aug 1923. ZUMT 51365 (1, 250); Japan, Fukuoka fish market; 10 Dec 1959. ZUMT 41208 (1, 214), 41213 (1, 215), 41220-24 (5, 201–219), 41228 (1, 210), 41249-57 (9, 200–225), and 41282-84 (3, 206–216); Japan, Toyama Pref., Namerikawa. ZUMT 54922 (1, 214); Japan, Shizuoka Pref., Izu Peninsula; 12 Sep 1981; M. Aizawa. ZUMT 50407 (1, 243); Japan, Nagasaki Pref.; Motoura, Ikitsuki I.; 25 Oct 1953. CAS SU 49371 (1, 270); Taiwan; Chu. CAS SU 14524 (3, 230–240); Philippine Is., Luzon; 1934; Herre. CAS SU 28284 (1, 235); Philippine Is., Culion; Apr 1931; Herre. USNM 325236 (5, 227–233); Philippine Is., N. Palawan; 17 Sep 1963; I. Ronquillo. USNM 325233 (3, 217–236); Philippine Is., Almahon Bato; 17 Sep 1963. USNM 326677 (1, 209); Philippine Is., Manila Bay; 27 May 1962. USNM 339044 (6, 256–285); Philippine Is., Manila markets; 1–10 Oct 1995; B.B. Collette. LACM 45781-1 (17, 58.7–93.8); Philippine Is., Luzon, Batangas Bay, Bauan; 27 Mar 1949; M.A. Sabalo and Leonicio. SIO 75–149 (1, 156); 9°51.4'N, 117°32.5'W; 16 Nov 1970; F. Williams. SIO 61–736 (4, 173–179); Gulf of Thailand, 41 mi from Ban Laehn Pho, Pattani; 16 Nov 1960; RV *Stranger*. AMNH 15865 (2, 270–275); Java, Batavia; 5 Dec 1941; Inst. Zoevisch. RMNH 6049 (1, 260), East Indies, Ternate; C.F. Goldman; holotype of *Auxis thynnoides* Bleeker. MNHN A.1241 (1, 290); Australia, New South Wales, Sydney; F. Castelnau; holotype of *Auxis ramsayi*. AMS IB 4015 (1, 335); Australia, New South Wales, Sydney; G.P. Whitley. AMS IB 3227 (1, 325); Australia, New South Wales, Newcastle district; A. D'Ombrain. AMS IB 3535 (1, 318); Australia, New South Wales, off Port Stephens; A. D'Ombrain. AMS IB 1804 (1, 300); Australia, New South Wales, Shoal Bay. AMS I 15313 (1, 284); Australia, New South Wales, Shoal Harbor.

Central Pacific 13 specimens (50.5–283 mm FL) from 2 collections.

BPBM 27044 (6, 260–283); Hawaii, Cape Kaea, Lanai; 30 Nov 1957; RV *John R. Manning*, cr. 38. LACM 45779-1 (7, 50.5–59.2); Hawaiian Is., RV *Townsend Cromwell*, cr. 43, sta. 30; 17 May 1969.

Auxis rochei eudorax Collette and Aadland, new subspecies

Fig. 13C

Diagnosis *Auxis rochei eudorax* has more corselet scales under the second dorsal-fin origin (Table 1), 14–30 (usually 20–25) than *A. rochei rochei*, 5–24 (usually 6–19).

Description Gill rakers 43–48, usually 44–47 (Table 2). Corselet width under second dorsal-fin origin 5.0–11.0 mm, usually 7.0–10.0 mm (Fig. 3).

Etymology We use the name that Fitch and Roedel used in their manuscript, *eudorax* from the Greek *eu* (well) and *dora* (hide) in reference to the wide or well-developed corselet. Carl L. Hubbs suggested this name in a memo dated 1 Feb 1951 to W.I. Follett, concerning an edition of their California fish list, with copies to Fitch and Roedel.

Material examined 30 specimens (300–365 mm FL) from 17 collections.

Holotype LACM 6712-1 (330 mm FL); CA, 23 Fathom Bank; 13 Jan 1955; R.D. Collyer; field number SSY 1-2. Pectoral fin 41.7 mm; anterior extent of dorsal scaleless area extends 8.1 mm posterior to tip of pectoral fin; width of corselet under second dorsal-fin origin 10.2 mm; 25 scales in corselet under second dorsal-fin origin; gill rakers 11 + 36 = 47. See Fig. 13C.

Paratypes from the eastern Pacific 29 specimens (300–365 mm FL) from 17 collections.

LACM 6711-5 (1, 350); CA, Balboa Pier; 17 Sep 1960; J.P. Reed. LACM 6711-6 (1, 312); CA, off Newport Beach; 13 Dec 1961; A. Gronsky. LACM 6711-3 (1, 338); CA, outside of Newport Beach; 13 Dec 1961; A. Gronsky. LACM 6711-4 (1, 322); CA, off San Clemente; 15 Sep 1960. LACM 6711-1 (1, 355); CA, Los Coronados Is.; 4 Nov 1957; MV *Lo-An*. LACM 34069-2 (1, 318); CA, between Oceanside and San Clemente; 30 Sep 1972. CAS 56944 (1, 363); CA, between Half Moon and San Francisco bays; 29 Oct 1984; MV *Aries*. CAS 54921 (1, 335); CA, San Luis Obispo Co., 30 mi N of Morro Rock, 7 Sep 1983; MV *Mary Beth*. LACM 6711-11 (1, 340); California; Jun–Jul 1951; MV *Courageous*. LACM 6712-2 (6, 300–325); CA, 23 Fathom Bank; 13 Jan 1955; R.D. Collyer; field number SSY 1-2. LACM 6711-10 (1, 316); California. LACM 6711-7 (3, 320–340); Baja Calif., Cape San Lucas; May 1950; MV *Nancy Rose*. LACM 39621-1 (1, 308); Mexico, Pta. Pequera, San Juanico; 24 Nov 1953; J.E. Fitch. CAS 56978 (1, 365); Baja California, below Holcombe Pt.; 25 Jul 1958; Walker and Connolly. LACM 6708-2 (3, 313–338); Gulf of California, 450 Fathom Bank; 24 Mar 1950; MV *Nancy Rose*. LACM 6709-1 (3, 309–331); Panama Bay, N of Isla Chepillo, 8°58'N, 79°10'W; 27 Feb 1954; MV *Mayflower*. ANSP 89082 (2, 340–343); Galapagos, James I., Sullivan Bay; 4 Jul 1941; Fifth Vanderbilt Expedition.

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