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A Biochemical and Morphological Review of the Lizardfish Genus *Saurida* in Hawaii, with the Description of a New Species[1]

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ABSTRACT: Electrophoretic and morphological analysis of lizardfishes in the genus *Saurida* (Pisces: Synodontidae) confirms the presence of three species in Hawaii, where a single species (*S. gracilis*) has previously been recognized. *Saurida flamma*, new species, is described, and *S. nebulosa* is removed from the synonomy of *S. gracilis*. The three species are found in different habitats, and *S. nebulosa* commonly enters brackish water. Fixed allelic differences were found between each pair of species at 10 or more of the 29 presumptive gene loci surveyed electrophoretically. Morphological characters for separating the three Hawaiian *Saurida* include counts of lateral-line scales and pectoral fin rays, length of upper jaw and pectoral fin ray, position of dorsal fin, dentition, and pigmentation. Patterns of allometric growth that affect certain characters' usefulness in systematics are discussed. Relevant type specimens were examined, and the assignment of names was aided by the use of discriminant function analysis of morphometric and meristic data.

SPECIES HAVE TRADITIONALLY BEEN DEFINED primarily on the basis of morphology. However, separating the variability within species from that between species has been a recurring problem for systematic biologists. The concept of a species as an evolutionary unit isolated reproductively from other such units is more satisfying theoretically. The challenge has been to apply this biological species concept to real situations involving natural populations. One technique that has proved to be very useful in this respect is the electrophoretic analysis of proteins. By sampling variability in gene products, protein electrophoresis provides an estimate of genetic differences, and hence the degree of reproductive isolation, between populations. In the present study, a combination of electrophoretic and morphological data has been used to separate three cryptic species in the lizardfish genus *Saurida* in Hawaii.

The lizardfishes (family Synodontidae, but see Dutt 1973) are circumtropical in distribution and are represented in Hawaiian waters by the genera *Synodus* and *Trachinocephalus* in addition to *Saurida*. A single species in the latter genus, *S. gracilis* (Quoy and Gaimard 1824), is recognized from Hawaii (Gosline and Brock 1960, Jordan and Evermann 1905, Tinker 1978). *Saurida gracilis* is a commonly reported inhabitant of shallow coral reef areas from Hawaii to the Red Sea. Gosline and Brock (1960) noted substantial differences between Hawaiian specimens from sandy and muddy or brackish habitats, but they apparently judged the differences to be too inconsistent to allow the definition of another species. Presented here is evidence that three species of *Saurida* occur in Hawaii: *S. gracilis*; *S. flamma*, a new species described below; and *S. nebulosa* Valenciennes in Cuvier and Valenciennes (1849), previously placed in the synonomy of *S. gracilis* (Jenkins 1904). The relatively minor morphological

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differences among the three *Saurida*, compared to the substantial differences that separate them from other members of the genus, may explain why they have traditionally been considered to be a single species.

MATERIALS AND METHODS

Field collections were made as follows (number of specimens in parentheses): *Saurida gracilis*: Oahu (3), northwest Hawaiian Islands (NWHI) (15), Fiji (1); *Saurida flamma*: Oahu (22), NWHI (1); *Saurida nebulosa*: Oahu (22). Complete collection data are given with the species descriptions. Type specimens and other material were kindly loaned by the following institutions: Muséum National d'Histoire Naturelle (MNHN); Academy of Natural Sciences, Philadelphia (ANSP); Bernice P. Bishop Museum (BPBM); California Academy of Sciences (CAS); Scripps Institution of Oceanography (SIO); United States National Museum (USNM).

Specimens captured in the field were iced immediately, transferred as soon as possible to a freezer, and stored at approximately −10°C until sampled. Samples of skeletal muscle were taken from every fish to make certain of species identification, and samples of liver, eye, and heart tissue were taken from certain individuals to examine additional enzyme systems. After homogenization in approximately an equal volume of 0.1 *M* potassium phosphate buffer (pH 7.0), tissue extracts were centrifuged for 20–30 min at 5°C and 40,000 × **G**.

Extracts from all tissues were loaded on 12.5 percent starch gels prepared from Electrostarch lot 307 (Electrostarch Co., Madison, Wisconsin). Vertical electrophoresis (at Hawaii Institute of Marine Biology, HIMB) using the discontinuous *tris*-borate-EDTA (EBT) and *tris*-citrate (TC) buffer systems described by Shaklee, Kepes, and Whitt (1973) lasted 16–20 hr at 250 V. Slicing and staining were as described by Shaw and Prasad (1970), with minor modifications. Horizontal electrophoresis (at SIO) followed the procedures of Graves and Rosenblatt (1980). The following enzyme systems (and loci scored) were analyzed on slab starch gels: aspartate aminotransferase (Aat-1, Aat-2); adenosine deaminase (Ada); creatine kinase (Ck-A, Ck-B); alpha-naphthyl acetate esterases (Est-1, Est-3); glyceraldehyde-phosphate dehydrogenase (Gapdh-2); glycerol-3-phosphate dehydrogenase (G3pdh); glucosephosphate isomerase (Gpi-A, Gpi-B); isocitrate dehydrogenase (Idh-1, Idh-2); lactate dehydrogenase (Ldh-A, Ldh-B, Ldh-C); malate dehydrogenase (Mdh-A, Mdh-B); mannosephosphate isomerase (Mpi); leucyl-tyrosine peptidase (Pep); phosphogluconate dehydrogenase (Pgdh); phosphoglucomutase (Pgm); superoxide dismutase (Sod); xanthine dehydrogenase (Xdh).

Skeletal muscle extracts only were run on vertical slab polyacrylamide gels (7.5 percent, 0.8 mm thick). Each slot contained 5 μl supernatant mixed with 5 μl 10 percent sucrose solution containing bromphenol blue as tracking dye. After 2–3 hr of electrophoresis at 250 V in a discontinuous EBT buffer system (Shaklee et al. 1973), the gels were stained for general proteins (Gp-1, Gp-2, Gp-3, Gp-4) and 4-methylumbelliferyl acetate esterases (Umb-3).

Counts and measurements follow Hubbs and Lagler (1958) and were made after specimens had been preserved in isopropyl alcohol. Standard length and preanal length were measured to the nearest millimeter with a steel ruler; all other measurements were made with dial calipers reading to 0.05 mm and were recorded to the nearest 0.1 mm. Vertebral counts were made from X rays and include the urostyle. All normal, pored lateral-line scales were counted, but the one or two elongated scales on the caudal base were not. I have followed Norman (1935) and others in referring to the inner row of teeth on the palate as palatine teeth, because they arise from a shelf of bone partially fused to the palatine. Sulak (1977) refers these teeth to the endopterygoid in his examination of Atlantic species in the genus.

RESULTS AND DISCUSSION

All individuals examined expressed identical electromorphs at 10 of the 29 presump-

TABLE 1

RELATIVE MOBILITIES OF ISOZYMES IN HAWAIIAN *Saurida* FOR THE 19 PRESUMPTIVE GENE LOCI AT WHICH INTERSPECIFIC DIFFERENCES WERE OBSERVED

LOCUS	BUFFER	*S. gracilis*	*S. nebulosa*	*S. flamma*
Ada	EBT	97	97	100
Ck-A	EBT	88	88	100
Ck-B	EBT	96	100	96
Est-1	EBT	92	100	(0.75)100, (0.25)92
Est-3	EBT	(0.94)93, (0.06)92	100	96
Gapdh-2	TC	100	(0.82)100, (0.18)38	100
G3pdh	TC	85	85	100
Gpi-A	EBT	70	70	100
Gpi-B	EBT	89	89	100
Idh-2	TC	90	100	100
Mdh-A	TC	96	96	100
Mdh-B	TC	95	95	100
Mpi	EBT	90	100	90
Pgdh	EBT	85	100	95
Pgm	TC	84	100	84
Xdh	TC	(0.75)88, (0.25)76	100	76
Gp-2	EBT	100	96	100
Gp-3	EBT	97	100	100
Gp-4	EBT	89	89	100
Average number of individuals sampled per locus (29 loci)		9	12	9

NOTE: The fastest anodally migrating allele is labeled 100; smaller numbers indicate relative mobilities of slower alleles. Numbers in parentheses are estimated allelic frequencies at loci polymorphic within a species.

tive gene loci surveyed. These monomorphic loci were Aat-1, Aat-2, Idh-1, Ldh-A, Ldh-B, Ldh-C, Pep, Sod, Gp-1, and Umb-3. However, each individual could be assigned unequivocally to one of three groups on the basis of its electrophoretic mobilities at the remaining loci (as shown in Table 1, which uses the specific names for these groups, as determined below). Four loci (Est-1, Est-3, Gapdh-2, Xdh) were found to be polymorphic within one group. At each of the remaining 15 loci fixed allelic differences were found between at least two of the groups. The data in Table 1 suggest that each pair of groups is separated by fixed allelic differences at 10 or more loci.

The occurrence of multiple fixed allelic differences among the groups indicates a corresponding lack of gene flow. Because the three groups are sympatric (on Oahu, at least) but clearly do not interbreed, they must be considered to be distinct biological species. Several enzyme and protein systems (CK, EST, GP, PGDH) by themselves separate the three species, and thus, each serves as a biochemical key to the Hawaiian species of *Saurida*. The enzyme creatine kinase, for example, was surveyed for two loci, A (skeletal muscle) and B (eye), that are well documented in other teleosts (Fisher and Whitt 1978). Figure 1 shows that the three species exhibit distinctive phenotypes for the Ck-A_2 and Ck-B_2 isozymes, respectively: *S. flamma* is fast, slow; *S. gracilis* is slow, slow; *S. nebulosa* is slow, fast.

Estimates of genetic similarity among the Hawaiian *Saurida*, computed according to Nei's (1978) method for small sample sizes, are shown in Table 2. The values range from $I = 0.47$ for *S. flamma–S. nebulosa* to $I = 0.66$ for *S. nebulosa–S. gracilis*; that is, the two most closely related species still differ at about one-third of the loci surveyed. Although caution must be exercised in interpreting such indices in terms of formal taxonomy, it is noteworthy that the similarity values found for the Hawaiian *Saurida* are lower than those found between most traditionally recognized fish species (Shaklee, Tamaru, and Waples, in press.).

Studies of gene frequencies among populations of a single species generally require

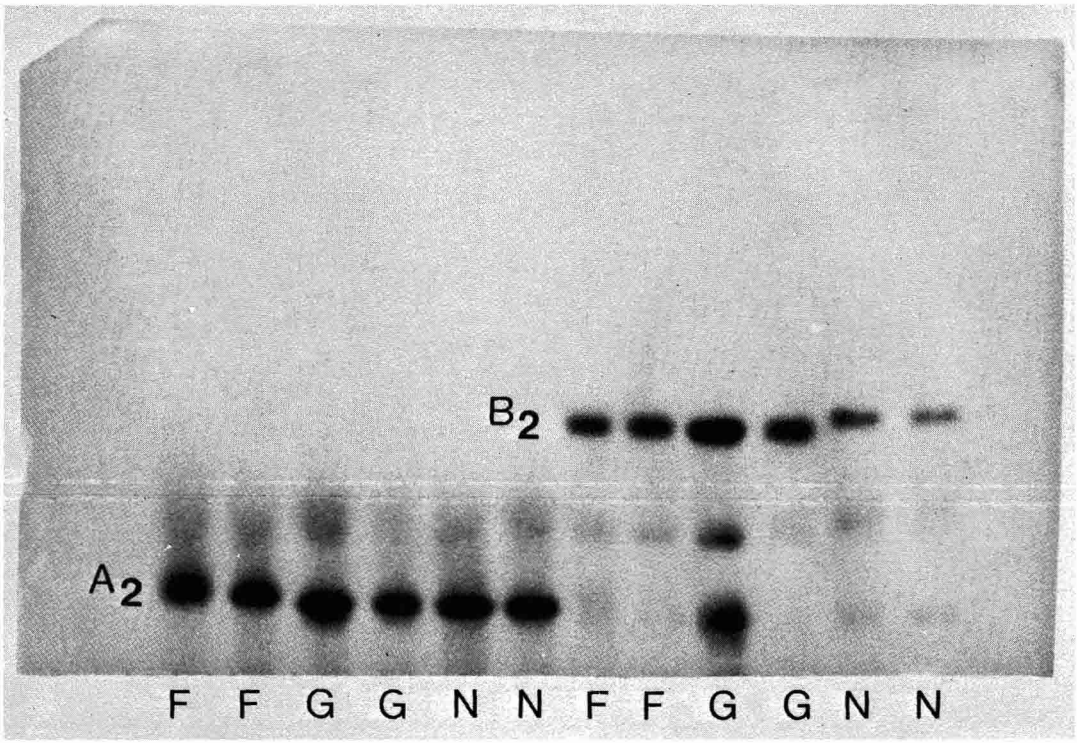

FIGURE 1. Creatine kinase isozymes of Hawaiian *Saurida*, visualized on a starch gel electrophoresed horizontally. Two individuals of each species have been scored as follows for the A_2 (muscle) and B_2 (eye) isozymes, respectively: *flamma* (F) = fast, slow; *gracilis* (G) = slow, slow; *nebulosa* (N) = slow, fast. The anode is toward the top of the figure.

TABLE 2

ESTIMATES OF NEI'S (1978) GENETIC SIMILARITY (*I*, ABOVE DIAGONAL) AND GENETIC DISTANCE ($D = -\ln I$, BELOW DIAGONAL) FOR HAWAIIAN *Saurida*, BASED ON THE ELECTROPHORETIC SURVEY OF 29 PRESUMPTIVE GENE LOCI

	S. nebulosa	*S. gracilis*	*S. flamma*
S. nebulosa	—	0.66	0.47
S. gracilis	0.42	—	0.54
S. flamma	0.75	0.61	—

large sample sizes. The sample sizes in this study are relatively small; the average number of individuals scored per locus was 9 for *Saurida gracilis* and *S. flamma* and 12 for *S. nebulosa*. For the four polymorphic loci mentioned above, the number of alleles sampled was too small for a chi-square test of expected Hardy–Weinberg genotype frequencies. Accordingly, the frequencies reported at these loci should be considered approximations. Estimates of average heterozygosity are not reported for similar reasons. However, the limited data available do suggest that, in contrast to the large interspecific differences, populations of *S. flamma* and *S. gracilis* may be fairly uniform genetically over substantial geographic ranges. No unique alleles were found in the single *S. flamma* taken in NWHI or in the single *S. gracilis* from Fiji. The Oahu population of *S. gracilis* contains only one allele (92 at the Est-3 locus) not found in other populations. Although the data merely suggest patterns of intraspecific variability, the sample sizes used are more than adequate for a taxonomic study. Species that have been compared electrophoretically tend to share either virtually all their alleles ($I \approx 1$) or virtually no alleles ($I \approx 0$) at most of the loci surveyed.

TABLE 3

MORPHOMETRIC DATA, EXPRESSED AS PERCENTAGE OF STANDARD LENGTH, FOR HAWAIIAN *Saurida*, INCLUDING HOLOTYPE OF *S. flamma*, NEW SPECIES

CHARACTER	*S. nebulosa* (n = 22)	*S. gracilis* (n = 19)	*S. flamma* (n = 22)	*S. flamma* (holotype, BPBM 25942)
Standard length, SL (mm)	75–165 (111 ± 26)	125–254 (180 ± 36)	78–290 (194 ± 62)	290
Head length, H	22.0–24.8 (23.5 ± 0.7)	24.6–27.9 (26.1 ± 1.0)	23.3–27.0 (25.3 ± 0.9)	25.7
Snout, SN	4.4–5.7 (5.1 ± 0.4)	5.7–6.8 *	5.6–6.6 (6.1 ± 0.2)	6.0
Bony orbit, EYE	3.7–5.2 (4.4 ± 0.4)	4.4–5.4 *	4.3–6.1 *	4.6
Bony interorbit, IOD	2.9–4.5 *	4.0–5.4 *	3.6–5.3 *	5.1
Upper jaw length, JAW	14.1–16.2 (15.4 ± 0.5)	16.7–19.5 (18.0 ± 1.0)	15.7–18.5 (17.4 ± 0.7)	17.8
Body depth at dorsal origin, DEPTH	11.2–15.3 *	11.1–16.6 (13.5 ± 1.2)	12.1–18.7 *	16.4
Least depth caudal peduncle, PED	5.0–6.0 (5.5 ± 0.2)	5.5–6.5 (6.0 ± 0.3)	5.5–6.7 *	6.5
Longest ray, of pectoral fin, P1L	10.1–11.8 (10.8 ± 0.5)	12.1–13.2 (12.5 ± 0.4)	11.9–13.7 *	12.0
of pelvic fin, P2L	15.5–18.9 (17.3 ± 0.8)	17.9–20.5 (18.9 ± 0.8)	17.9–21.2 (20.1 ± 0.8)	20.4
of dorsal fin, DRL	16.0–19.2 *	17.5–19.6 *	18.2–21.4 *	18.2
Last dorsal ray, LDRL	6.7–8.7 (7.6 ± 0.5)	6.9–8.7 (7.7 ± 0.5)	7.5–9.7 *	7.7
Dorsal base, DB	12.0–14.0 (13.2 ± 0.5)	13.5–15.4 (14.4 ± 0.6)	13.9–16.1 (14.9 ± 0.6)	14.2
Anal base, AB	8.2–10.4 *	8.5–10.6 (9.4 ± 0.6)	9.0–11.4 (10.0 ± 0.5)	9.8
Prepectoral length, SNP1	22.0–24.7 (23.3 ± 0.7)	24.9–27.6 (26.1 ± 0.7)	23.5–26.5 *	25.6
Prepelvic length, SNP2	30.5–34.7 (33.0 ± 1.3)	32.7–37.0 (34.9 ± 1.2)	32.3–37.1 (34.4 ± 1.2)	34.1
Preanal length, SA	72.3–86.3 *	72.8–79.1 *	72.7–76.5 *	74.8
Distance from pectoral origin to pelvic origin, P1P2	11.9–16.3 (13.3 ± 1.1)	11.5–14.0 (12.4 ± 0.8)	10.9–14.5 (12.1 ± 0.9)	11.4
Predorsal length, SNDO	40.6–44.7 (42.3 ± 1.2)	40.1–43.3 (41.4 ± 0.8)	38.3–41.1 (39.8 ± 0.8)	39.1
Distance from dorsal origin to adipose origin, DOAD	35.9–41.0 (38.9 ± 1.2)	37.4–40.9 *	38.6–42.2 *	40.1
SNDO/DOAD	1.04–1.19 (1.09 ± 0.04)	1.02–1.11 (1.06 ± 0.02)	0.94–1.04 (0.98 ± 0.03)	0.98

NOTE: Standard length given in millimeters; morphometric data are expressed as percentage of standard length. Ranges are given first, followed by means ± standard deviation in parentheses. Characters marked with an asterisk showed substantial allometric growth; see Table 6 for parameters describing these growth patterns.

Unless heterozygosity is extremely high, the polymorphic loci contribute very little to the estimate of genetic similarity, and a small sample yields essentially the same estimate as would the entire population. Nei (1978) showed this theoretically, and Gorman and Renzi (1979:242) demonstrated empirically that genetic distance estimates "are hardly

TABLE 4

MERISTIC DATA FOR HAWAIIAN *Saurida*

	DORSAL FIN RAYS			PECTORAL FIN RAYS					ANAL FIN RAYS			PREDORSAL SCALES				LATERAL-LINE SCALES					VERTEBRAE					PECTORAL FIN REACHES PREDORSAL SCALE ROW:						
SPECIES	10	11	12	11	12	13	14	15	9	10	11	15	16	17	18	50	51	52	53	54	49	50	51	52	53	0	1	2	3	4	5	6
S. nebulosa	5	17		2	19	1			6	16			4	9	3	7	12	2			5	16								3	12	5
S. gracilis		17	2		3	15	1		6	13		2	6	5	2	3	9	6			3	14	2					14	5			
S. flamma		22	1			3	17	3	4	18	1	4	4	6					1	18		1	2	17	3		2	11	9	1			

affected by sample size. A single individual may be used to represent a species for interspecific comparisons."

The electrophoretic data described above provided an independent guideline to use in the morphological analysis of specimens. Because each fish was identified unequivocally as belonging to one of the three electrophoretic phenotype classes, the species could be analyzed separately and contrasted to discern differences that had not been apparent previously.

Counts and measurements for specimens phenotyped electrophoretically are presented in Tables 3 and 4. A close inspection of these data reveals that there is no single character that separates the Hawaiian *Saurida* with certainty. The number of pectoral fin rays is the best discriminator in this respect; most *nebulosa* have 12 rays, most *gracilis* have 13 rays, and most *flamma* have 14 rays, but several exceptions were found. A number of characters more reliably separate one species from the other two, and by a combination of these an accurate diagnosis can be made (see key, below). The greatest separation, morphologically as well as genetically, is found between *S. flamma* and *S. nebulosa*. The former has generally higher counts, and most of its body parts are also relatively larger than those of *S. nebulosa*. *Saurida gracilis* is similar to *S. flamma* in body proportions, but has vertebral and lateral-line scale counts nearly identical to those of *S. nebulosa*.

The most distinctive feature of *Saurida gracilis* is the patch of vomerine teeth that bridges the gap between the outer rows of palatine teeth. In the other two species, the outer palatine teeth form rows on either side of the mouth that narrowly approach each other anteriorly, but there is always a toothless channel between them. All the specimens of *S. gracilis* from NWHI and the single specimen from Fiji have this patch of vomerine teeth, but the condition is more variable in specimens from Oahu. One individual has a distinct patch, a second has only a single tooth on the vomer, and a third has no separate vomerine teeth, but the outer palatine rows are nearly continuous over the vomer. The inner series of palatine teeth consists of about three poorly defined rows in *S. gracilis* and *S. flamma*, but is present as two quite distinct rows in *S. nebulosa*.

All specimens of *Saurida nebulosa* examined also have dark pigmentation on the peritoneum and on the gill filaments that is rarely found in the other two *Saurida*. This pigment persists in alcohol and may be seen on specimens over 100 years old. The peritoneum of *S. nebulosa* is darkly colored by a dense aggregation of chromatophores extending about halfway down the abdominal cavity. This pigmentation is usually restricted to a narrow band over the kidney in *S. gracilis* and *S. flamma*. The exceptions are the Makua specimens of *S. flamma* and the Oahu specimens of *S. gracilis*, in all of which the pigment is present as sparsely scattered chromatophores extending about halfway down the cavity. Darkly pigmented gill filaments were found in only a few *S. gracilis* and in no *S. flamma*.

Saurida nebulosa is further distinguished by the large gap between the tip of its pectoral fin and its dorsal origin, which is the result of a shorter pectoral fin, more anterior pectoral insertion, and longer predorsal length compared with the other two species. In *S. nebulosa*, a vertical line through the tip of the longest pectoral ray passes through the fourth to sixth row of predorsal scales; in *S. gracilis*, this line passes through the second or third row; and in *S. flamma*, this line generally passes through the first or second row (Table 4). Because the dorsal origin is so far posterior in *S. nebulosa*, the predorsal length is always greater than the distance from the dorsal origin to the adipose fin origin; this ratio ranges from 1.04 to 1.19. In *S. gracilis*, this ratio is similar (1.02–1.11), although somewhat less extreme. The dorsal fin is typically inserted more anteriorly in *S. flamma*; the observed ratio ranges from 0.94 to 1.01, with the smallest (78 mm standard length) individual having the value 1.04.

The striking reddish-orange coloration on the mouth and body of *Saurida flamma* readily identifies fresh specimens of this species. The colors in alcohol of the three *Saurida* are similar, but *S. flamma* can be

distinguished by its higher lateral-line scale count, as well as by other characters given in the key (below).

Saurida

Saurida Valenciennes in Cuvier and Valenciennes, 1849:499; type species *Salmo tumbil* Bloch, 1795, by subsequent designation (Jordan, Tanaka, and Snyder 1913)

DIAGNOSIS: A synodontid with the following combination of characters: 9 pelvic rays (8 in *Synodus* and *Trachinocephalus*); a double band of teeth on each side of the palate (single band in other genera); pelvic bones with short, laminar posterior processes (more slender in other genera).

ABBREVIATED KEY TO THE GENUS *Saurida*
(after Shindo and Yamada 1972)

1a. Lower jaw shorter than or equal in length to upper jaw and not visible from above when mouth closed 2
1b. Lower jaw longer than upper and visible from above when mouth closed ..... most Atlantic species and *isarankurai*
2a. Longest ray of dorsal fin more than two but less than three times as long as last ray; scale in axil of pectoral fin short and broad; all fins with series of dark bars or spots ... 3
2b. Longest ray of dorsal fin more than three times as long as last ray; scale in axil of pectoral fin long and pointed; no fins (except first dorsal and caudal rays in some species) with dark bars or spots ..... Indo-West Pacific species

KEY TO THE HAWAIIAN SPECIES OF *Saurida*

3a. Lateral-line scales 52 or fewer and vertebrae 51 or fewer; dorsal origin inserted behind midpoint of distance from snout to adipose fin origin; usually 13 or fewer pectoral rays; no bright-orange coloring on mouth or body 4
3b. Lateral-line scales 54 or more (rarely 53) and vertebrae 52 or more (rarely 50 or 51); dorsal origin inserted anterior to or near midpoint of distance from snout to adipose fin origin; usually 14 or 15 pectoral rays; fresh specimens with bright-orange bars on mouth and orange or rose tint on fins and body ..... *flamma*, new species
4a. Pectoral fin short; longest ray $\leq$ 11.8 percent of standard length, tip of which just reaches pelvic insertion and reaches no closer to dorsal origin than fourth predorsal scale row; upper jaw $\leq$ 16.2 percent of standard length; usually 12 pectoral rays (rarely 11 or 13); vomer toothless; inner palatine teeth in two distinct rows; dark pigment always present on gill filaments and upper half of peritoneal cavity ..... *nebulosa*
4b. Pectoral fin long; longest ray $\geq$ 12 percent of standard length, tip of which extends clearly past pelvic insertion to within two or three scale rows of dorsal origin; upper jaw $\geq$ 16.7 percent of standard length; usually 13 pectoral rays (rarely 12 or 14); small patch of teeth present on vomer, often reduced in specimens from Oahu; inner palatine teeth in about three poorly defined rows; gill filaments often without pigment; peritoneal pigment usually restricted to a narrow band over the kidneys ..... *gracilis*

Descriptions are based on specimens phenotyped electrophoretically. Morphometric data for these specimens (including the holotype of *Saurida flamma*) are given in Table 3. Descriptions of *S. nebulosa* and *S. gracilis* omit details that do not differ significantly from the description of *S. flamma*. Complete synonomies are not given, because

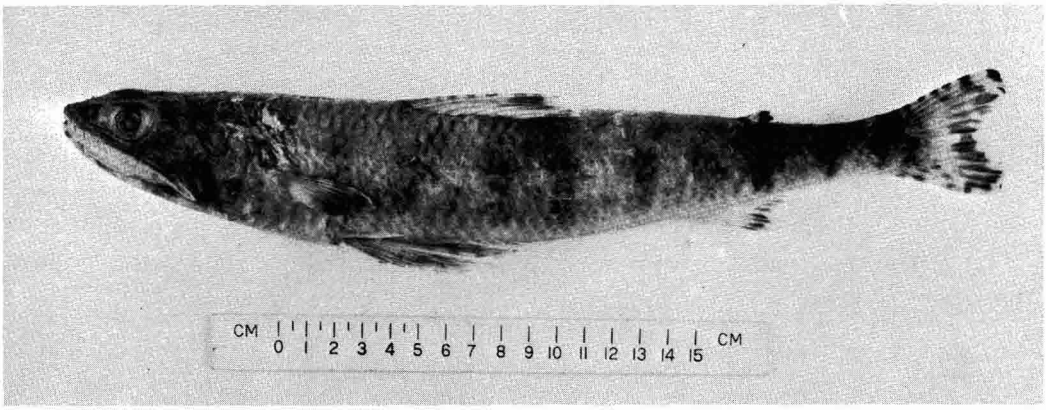

FIGURE 2. *Saurida flamma*, holotype, BPBM 25942; 290 mm SL, Oahu, Hawaii (preserved specimen).

most references are too brief to permit an accurate identification.

Saurida flamma, new species

Figure 2

Description of the holotype follows in parentheses where it departs from the norm.

DESCRIPTION: Lateral-line scales 54 (rarely 53); vertebrae 52–53 (rarely 50 or 51) (52 in type); dorsal rays 11 (rarely 12); pectoral rays 13–15, usually 14 (14); anal rays 9–11 (10); pelvic rays 9; predorsal scales 15–17 (15); scale rows above lateral-line $3\frac{1}{2}$; vertical line through tip of pectoral fin passes through first through third predorsal scale row, occasionally just reaching the dorsal origin (second); body elongate and cylindrical, somewhat depressed in head and caudal peduncle, the latter with distinct keel continuing forward as slight ridge on scales of the lateral line; scales large, cycloid, very deciduous; scales present on cheek and opercle; teeth on jaws numerous, caninelike, generally in three rows, visible when mouth closed; palatine teeth in two separate series: outer series long and usually in two rows, with anterior teeth longer, inner series short, in about three poorly defined rows; outer palatine series converge anteriorly but always separated by a toothless gap on vomer; minute teeth on tongue; lower jaw slightly shorter and fits into groove between teeth at tip of upper jaw; gill rakers numerous, seen as series of mostly discrete plates, 4–5 on upper limb, 5–6 on lower limb, with a small patch at the angle; adipose eyelid in two parts: posterior part well developed, but anterior part narrow and usually absent from upper margin of orbit; flap over anterior naris broad at base with more slender protrusion that may extend about one naris diameter past naris; origin of dorsal fin anterior to or near midpoint of distance from snout to adipose fin origin; pectoral fin extends well past pelvic insertion; adipose fin over middle of anal base; axillary scale of pectoral short and broad, that of pelvic long and pointed; gill filaments pale; pigment on peritoneum usually restricted to narrow band over kidneys, but occasionally seen as series of scattered chromatophores extending halfway down body cavity; dark spots running longitudinally along peritoneum 0–5 (usually 2) (type not examined internally).

COLOR IN ALCOHOL: Dark mottled brown on back, pigment continuing to two or three scale rows below lateral line; pale white below; broad darker bands on back behind dorsal and adipose fins; about nine distinct blotches along sides, vertically oriented and most intense along lateral line; second dorsal ray with about eight dark bars alternating with bands of lighter color; remainder of fin with broad, dark bar near tips of rays and

scattered spots elsewhere; first pectoral ray with about four dark bands; remainder of fin pale near base and darker near edges; 2–4 dark spots on each pelvic ray, not aligned as continuous bars; single dark band on anal fin; broad, pale-yellow, vertical band near base of caudal fin; remainder of fin with series of spots or single dark band near tips (as in the type); 3–5 dark bars under the chin (3); gums with some dark pigment but no distinct bars; outer margins of scales on back darker.

COLOR OF FRESH OR FRESHLY FROZEN SPECIMENS: Mottled brown above, pale or pale rose (as in the type) below; all fins with spots and bars of dark pigment; series of 8–9 bright-orange bands on gums on each side of mouth; opercle, lower jaw, and bases of pectoral, pelvic, and caudal fins also tinged orange or red, particularly in larger specimens (as the type).

DISTRIBUTION: Collected from Oahu and French Frigate Shoals, NWHI.

HABITAT: Apparently, *Saurida flamma* prefers deep reef areas where sandy channels or pockets adjoin rock and coral ledges. *Saurida flamma* typically hides in a rock crevice or under a ledge and was not observed to bury itself in sand as do many lizardfishes. I did not see this species in water less than 5 m deep. Museum specimens from Hawaii identified as this species were taken in 9–30 m of water. The specimen from NWHI was speared at a depth of 9–12 m, deeper than any *S. gracilis* collected there.

ETYMOLOGY: Named *flamma*, from the Latin for "fire," a noun in apposition referring to the striking coloration on the mouth and body. Suggested common name, orangemouth lizardfish.

REMARKS: Most descriptions of *Saurida gracilis* cite 12 or 13 pectoral rays, so it is not certain whether *S. flamma*, usually with 14 or 15 rays, was among the material examined. The striking orange mouth has gone unmentioned by authors. Whether *S. flamma* occurs outside the Hawaiian Islands remains to be determined.

One specimen from Oahu (CAS 24997) has an abnormally high count of 56 lateral-line scales, but its vertebral count (52) is normal for the species. The paratype with only 50 vertebrae has two pairs of fused centra, so this low count is probably aberrant for *S. flamma*.

MATERIAL EXAMINED: 23 specimens; HOLOTYPE: BPBM 25942, 290 mm SL, off Kewalo Basin, Oahu, Hawaii, over sand adjacent to coral ledges, in 10 m, spear, R. Waples, 11 July 1980.

PARATYPES: BPBM 25943, 3 (119–285 mm SL), same data as holotype; ANSP 146525, 5 (179–255 mm SL), 25 May 1979, other data same as holotype; CAS 47763, 1 (255 mm SL), same locality as holotype, spear, R. Waples and D. Davis, 25 August 1978; USNM 226489, 4 (194–270 mm SL), same data as preceding; MNHN 1981–614, 1 (107 mm SL), same data as preceding; BPBM 25944, 1 (150 mm SL), off Three Tables Beach, Oahu, sand and coral bottom, at night, in 8 m, spear, R. Waples and M. Krochina, 7 July 1978; MNHN 1981–615, 1 (152 mm SL), off Makua Beach, Oahu, sand and coral bottom, in 8–10 m, spear, R. Waples, 21 June 1979; BPBM 25946, 1 (114 mm SL), 18 June 1979, other data same as preceding; CAS 47761, 1 (125 mm SL), 7 July 1979, other data same as preceding; CAS 47762, 1 (165 mm SL), 15 July 1980, other data same as preceding; BPBM 25945, 1 (78 mm SL), Waimea Bay, Oahu, on sand near rocks at west side of bay, in 5 m, spear, R. Waples, 8 July 1980; BPBM 25947, 1 (243 mm SL), French Frigate Shoals, NWHI, sand channel adjacent to coral and rock ledges, in 9–12 m, spear, personnel from Hawaii Cooperative Fisheries Unit, 28 May 1980.

ADDITIONAL MATERIAL: One specimen (146 mm SL), dissected and stained with alizarin, same data as CAS 47763; morphometric data not included in Table 3.

Saurida gracilis

Saurus gracilis Quoy and Gaimard, 1824: 224 (Hawaii and Mauritius).

Saurus minutus Lesueur, 1825:118, pl. v. (Mauritius).

Saurida nebulosa Valenciennes in Cuvier

and Valenciennes, 1849:504, in part (Mauritius).

Saurida gracilis Jenkins, 1904 (1902):433 (Hawaii).

DESCRIPTION: Lateral-line scales 50–52; vertebrae 49–51; dorsal rays 11 (rarely 12); pectoral rays 13 (rarely 12 or 14); anal rays 9–10; pelvic rays 9; predorsal scales 15–18; scale rows above lateral line $3\frac{1}{2}$; vertical line through tip of pectoral fin passes through second or third predorsal scale row; scales very deciduous; inner palatine teeth in about three short, indistinct rows; outer palatine series converge anteriorly and are joined by a patch of teeth on vomer, which may be reduced in specimens from Oahu; origin of dorsal fin inserted behind the midpoint of distance from snout to adipose fin origin; pectoral fin extends clearly beyond pelvic insertion; gill filaments pale or dark; pigment on peritoneum restricted to narrow band over kidney, except in specimens from Oahu, where scattered chromatophores may be found extending halfway down the body cavity.

COLOR IN ALCOHOL: Mottled shades of brown and white above, pale yellowish or white below; blotches along sides generally distinct but sometimes present only as dark spots along lateral line; all fins with dark bands or spots; broad, pale, vertical band at base of caudal fin; 6–9 dark, vertical bands on gums on each side of mouth.

COLOR OF FRESH OR FRESHLY FROZEN SPECIMENS: As above; pigmentation of this species is little changed by preservation.

DISTRIBUTION: Its presence at Fiji as well as Oahu and the NWHI indicates a wide distribution for this species. The holotype of *Saurus minutus* and two of the syntypes of *Saurida nebulosa*, all from Mauritius, appear to be this species as well (see below).

HABITAT: NWHI specimens were found at depths of 1–6 m over sandy or partly sandy bottom. They were commonly taken on small patch reefs rising out of deeper water. Two Oahu specimens were taken at night on a similar patch reef in Kaneohe Bay. The third Oahu specimen was taken with *Saurida flamma* in 10 m and is the deepest record for this species. The Fiji specimen was taken in 1 m inside a fringing reef. *Saurida gracilis* appears to favor a sandy reef habitat shallower than *S. flamma* generally is found.

REMARKS: I have examined more than 50 museum specimens catalogued as *Saurida gracilis*. Most are clearly separable from *S. flamma* and *S. nebulosa*, but few agree with the present description of *S. gracilis* in all details. Work in progress may help to determine whether *S. gracilis* is variable enough morphologically to explain these results, or whether additional species of *Saurida* exist.

MATERIAL EXAMINED: 19 specimens, all taken by spear: Midway, NWHI, 8 (125–224 mm SL), March–April 1980; French Frigate Shoals, NWHI, 7 (141–254 mm SL), May 1980; off Kewalo Basin, Oahu, 1 (145 mm SL), July 1980; Kaneohe Bay, Oahu, 2 (126–235 mm SL), December 1980; south coast of Viti Levu, Fiji, 1 (235 mm SL), July 1979.

Saurida nebulosa

Saurida nebulosa Valenciennes in Cuvier and Valenciennes, 1849: 504, pl. 648, in part (Mauritius).

Synodus sharpi Fowler, 1901: 497, pl. xix (Hawaii).

Saurida gracilis Gosline and Brock, 1960: 99, in part (Hawaii).

DESCRIPTION: Lateral-line scales 50–52; vertebrae 49–50; dorsal rays 10–11; pectoral rays 12 (rarely 11 or 13); anal rays 9–10; pelvic rays 9; predorsal scales 16–18; scale rows above lateral line $3\frac{1}{2}$; vertical line through tip of pectoral fin passes through fourth through sixth predorsal scale row; scales somewhat deciduous; inner palatine teeth in two short, distinct rows; outer palatine series converge anteriorly but always separated by distinct, toothless gap on vomer; origin of dorsal fin behind the midpoint of distance from snout to adipose fin origin; pectoral fin just reaches pelvic insertion; gill

TABLE 5

MORPHOMETRIC AND MERISTIC DATA FOR TYPE SPECIMENS REFERABLE TO *Saurida gracilis* AND *S. nebulosa*

CHARACTER	*Saurus gracilis* (holotype, MNHN A7616)	*Saurus minutus* (holotype, MNHN B1030; =*gracilis*)	*Saurida nebulosa* (syntype, MNHN B2918; =*gracilis*)	*Saurida nebulosa* (lectotype, MNHN B1029)	*Synodus sharpi* (lectotype, ANSP 16084; =*nebulosa*)
Standard length, SL (mm)	109	43	112	117	67
H	26.1	26.0	26.3	24.0	24.6
SN	6.4	5.5	6.0	5.0	5.2
EYE	5.3	5.5	5.3	4.6	5.1
IOD	4.2	3.5	4.1	3.3	3.0
JAW	18.3	15.4	18.2	15.7	16.4
PED	5.8	6.2	5.5	5.1	5.7
P1L	12.3	12.2	12.0	10.5	10.9
P2L	18.8	18.2	20.1	17.2	18.2
DRL	18.2	17.5	18.9	17.7	20.1
LDRL	7.9	6.7	8.5	7.9	8.1
DB	13.4	11.0	13.8	12.7	12.7
AB	9.8	8.5	8.9	9.0	10.0
SNP1	26.9	25.8	27.1	24.0	24.5
SNDO	42.6	42.6	42.2	41.9	43.3
DOAD	37.6	40.1	39.1	37.8	38.2
SNDO/DOAD	1.13	1.06	1.08	1.11	1.13
Dorsal rays	11	11	11	10	10
Pectoral rays	13	13	13	12	12
Lateral-line scales	49	49	51	50	51
Vertebrae	49	48	48	49	50
Pectoral fin reaches predorsal scale row:	3	2	3	5	4

NOTE: Abbreviations follow those in Table 3. Standard length given in millimeters; morphometric data are expressed as percentage of standard length.

filaments dark; peritoneum darkly pigmented on upper half of body cavity.

COLOR IN ALCOHOL: Mottled brown above, yellow, cream, or silver below; blotches along side generally quite indistinct, often seen only as series of dark spots along lateral line; all fins with dark bands or spots, which may be faint or missing on pelvic and anal fins; pale, vertical band at base of caudal fin; about 6–8 vertical bars on gums on each side of mouth.

COLOR OF FRESH OR FRESHLY FROZEN SPECIMENS: Mottled greenish-brown above, pale below; pale or bright silver along the sides and on cheek, broken by small patches of dull gray; other markings as above, often more distinct.

DISTRIBUTION: Only specimens from Oahu have been phenotyped electrophoretically, but the lectotype (from Mauritius) and other museum specimens from Yap, Guam, Palau, Tahiti, India, and Australia are clearly conspecific with the Hawaiian material, indicating a wide Indo-Pacific distribution for *Saurida nebulosa*.

HABITAT: Hawaiian specimens were taken in less than 2 m of dirty water over muddy bottom, often at the mouth of a freshwater stream. Data for most museum specimens indicate a similar depth range and an association with sand and mud bottoms with partial eel grass cover, but two Tahiti specimens were taken in 6 m at a rotenone station inside a lagoon.

REMARKS: *Saurida nebulosa* appears to be quite uniform morphologically over its range. This species apparently does not attain as large a size as do *S. flamma* and *S. gracilis*; the largest Hawaiian specimen is 165 mm SL,

and the largest museum specimen examined (CAS 47315, from Tahiti) is 172 mm SL.

MATERIAL EXAMINED: 22 specimens: Kaneohe Bay, Oahu, adjacent to mangrove stand near Kaneohe Marine Corps Naval Air Station, 17 (75–157 mm SL), beach seine, August 1978; near mouth of Kaalakei Stream, Oahu, 5 (122–165 mm SL), spear and dip net, August 1979–June 1980.

ASSIGNMENT OF NAMES

Quoy and Gaimard's (1824) description of *Saurus gracilis* is based on the holotype (from an unspecified locality in the Hawaiian Islands) and two paratypes (from Mauritius). The holotype was examined; data for it and other type specimens examined are given in Table 5.

The holotype of *Saurus gracilis* is clearly distinguishable from *Saurida flamma* by its vertebral and lateral-line scale counts. For the following characters, the type exceeds the observed range of *S. nebulosa* but agrees with the material here referred to *S. gracilis*: head length, snout, bony orbit, upper jaw length, pectoral fin length, and prepectoral length (compare data in Tables 3 and 5). The type also has 13 pectoral rays, a rare condition in *S. nebulosa*. The inner palatine teeth are in three rows (not two, as in *S. nebulosa*) and the outer palatine rows are nearly continuous over the vomer, a condition similar to that found in one of the Oahu specimens here referred to *S. gracilis*. Because the type is from the Hawaiian Islands, as is most of the comparative material, there is little doubt that *S. gracilis* is the valid name for the species collected in this study from Oahu, the NWHI, and Fiji.

Saurida nebulosa and *S. flamma* are sufficiently well separated from all other Indo-Pacific *Saurida* by characters given in the key that it is unlikely either has been confused with a species other than *S. gracilis*. Norman (1935) has provided the most complete synonomy of *S. gracilis*, among which there are four potentially valid names: *Saurus minutus* Lesueur (1825); *Saurus ferox* Eydoux and Souleyet (1842); *Saurida nebulosa* Valenciennes (1849); *Synodus sharpi* Fowler (1901).

No measurements or locality are given for *Saurus ferox*, nor, apparently, does a type specimen exist, but the description and figure both indicate 8 pelvic rays, a character consistent with species of *Synodus* but not of *Saurida*, which have 9.

All the remaining type specimens can be distinguished from *Saurida flamma* by their low vertebral and lateral-line scale counts and the posterior insertion of their dorsal fin. The holotype of *Saurus minutus* (from Mauritius) is a juvenile (43 mm SL), much smaller than any of the comparative material. As might be expected from the comparison of a juvenile with adult specimens, morphometric data for the type do not agree completely with those of any of the Hawaiian *Saurida*. The dentition, like that of other *Saurida* spp. of this size range examined, is poorly developed; only one row of inner palatine teeth is apparent and there are no vomerine teeth. However, other details agree best with *S. gracilis*; the type has 11 dorsal and 13 pectoral rays (despite the description, which cites 10 and 12) and a long pectoral fin that extends nearly to the dorsal origin. Therefore, I here consider *Saurus minutus* to be a synonym of *Saurida gracilis*.

The next available name is *Saurida nebulosa*, also described from Mauritius. The largest of the eight syntypes (MNHN B1029) matches the description (10 dorsal and 12 pectoral rays) and has been selected as the lectotype. It agrees with the Hawaiian material here referred to *S. nebulosa* in every respect and is outside the observed range of *S. gracilis* for a number of morphometric characters. For these reasons, *S. nebulosa* is here removed from the synonomy of *S. gracilis* and is resurrected as a valid species.

The largest of three Hawaiian syntypes of *Synodus sharpi*, which I have selected as the lectotype (ANSP 16084), was examined and is clearly referable to *Saurida nebulosa*. *Synodus sharpi* is therefore placed in the synonomy of this species. No available name remains for the orangemouth lizardfish, which is given the new name, *Saurida flamma*.

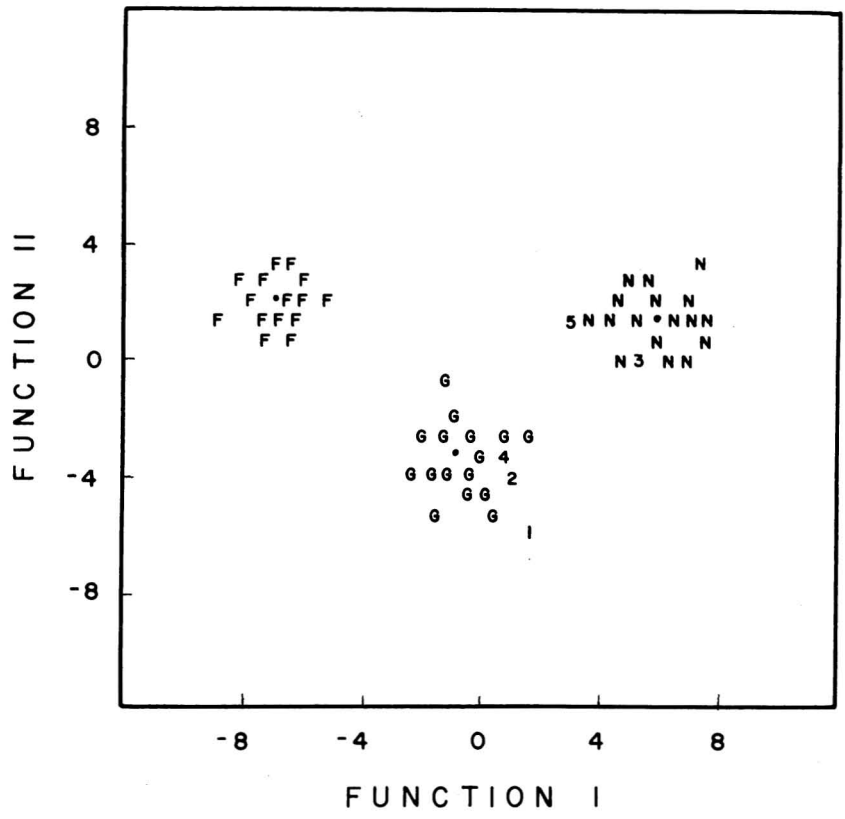

FIGURE 3. Scattergram of discriminant function scores for *Saurida* specimens. Letters represent individuals phenotyped electrophoretically; numbers are type specimens. A letter may represent more than one case. Discriminant function units appear on the axes. F = *flamma*; G = *gracilis*; N = *nebulosa*; 1 = *Saurus gracilis* holotype (MNHN A7616); 2 = *Saurus minutus* holotype (MNHN B1030); 3 = *Saurida nebulosa* lectotype (MNHN B1029); 4 = *S. nebulosa* syntype (MNHN B2918); 5 = *Synodus sharpi* lectotype (ANSP 16084); • denotes a group centroid.

DISCRIMINANT FUNCTION ANALYSIS

All the Hawaiian *Saurida* examined in this study can be identified with the use of the key (above). However, variability in anatomical features, particularly among *S. gracilis*, has been noted, and natural variation in meristics and morphology within species makes it likely that characters that appear to be diagnostic from an initial sample will prove to be poor discriminators if new individuals are examined. In this event, it is necessary to consider a number of characters, no one of which is a perfect discriminator. Such a multivariate technique is discriminant function analysis, in which the linear combination of variables is selected that best discriminates among any given groups. The *Saurida* data are well suited to a discriminant analysis, because the groups can be defined independently on the basis of electrophoretic phenotype. All specimens that had been phenotyped and for which complete morphometric and meristic data were available (variables used are those in Table 5) were entered in the SPSS discriminant function analysis computer program (Nie 1975). These specimens supplied the data base from which the discriminant functions were computed. Data for type specimens and other museum specimens were entered as unclassified cases and were placed according to their scores on the discriminant functions. Raw, unstandardized data were used, and all variables were entered at the

same level. Anatomical features not easily quantified (e.g., pigmentation) were not used.

The results of the analysis are seen in Figure 3. It is clear that meristic and morphometric data alone easily separate the three species when all variables are considered. Each individual is closely associated with the species group defined by its electrophoretic phenotype and is clearly separated from the other two groups ($p < 0.001$; multivariate F test). In addition, the placement of each type specimen agrees with the conclusions discussed above. The holotype of *Saurus gracilis* and the lectotype of *Saurida nebulosa* are placed with the Hawaiian material that has been referred to them. Although the small size of the *Saurus minutus* holotype makes its identification via the key somewhat difficult, this specimen is clearly placed with *Saurida gracilis* by the discriminant analysis. As expected, none of the type specimens is identified with *S. flamma*.

In addition to the lectotype, one of the syntypes of *Saurida nebulosa* was included in the analysis because it and another syntype (both MNHN B2918) have 13 pectoral rays and the generally larger body proportions characteristic of *S. gracilis*. The clear placement of this syntype and the lectotype in different groups indicates that the type series of *S. nebulosa* contains two different species. Although all eight *nebulosa* syntypes lack any vomerine teeth, the two in lot B2918 agree with *S. gracilis* in other respects and are provisionally identified as that species. As noted above, most museum specimens that I have examined from localities other than Hawaii depart from the present description of *S. gracilis* in some way; most lack vomerine teeth, for example, and many have the dorsal fin inserted midway between the snout and the adipose origin, as in *S. flamma*. A number of these specimens were also entered as unclassified cases in the analysis (not shown in Figure 3), and their scores on the discriminant functions generally did not place them clearly with any of the groups. Although *S. gracilis* from Oahu, NWHI, and Fiji appear to be quite similar genetically, specimens from Oahu are known to be morphologically variable. Differences noted among specimens from throughout the Indo-Pacific region may thus be part of the natural variation of the species. However, biochemical analysis has already demonstrated the existence of two morphologically cryptic species of *Saurida* in Hawaii alone, and it is probable that more undetected species exist in the remainder of the Indo-Pacific.

ALLOMETRIC GROWTH

Effects of allometric growth (understood here as changes in body proportions correlated with changes in size of the organism) must be considered in systematics work involving organisms of different sizes. The specimens of *Saurida nebulosa* examined in this study were generally smaller than those of the other two species. Part of this size difference is real, since *S. nebulosa* apparently does not reach as large a size as do the other two *Saurida*. But sampling bias undoubtedly contributed to the differences, because *S. flamma* and *S. gracilis* were collected by spear, making large specimens the easiest to obtain, while many small *S. nebulosa* were collected by beach seine and dip net. Because of this size differential, each character in Table 3 was examined to determine whether some characters were merely reflecting differences in absolute size.

Allometry is commonly described in terms of the equation $y = bx^a$. Thompson (1942) showed that many trends can be represented equally well by a linear regression. Linear plots fit the *Saurida* data very well, and those of characters showing substantial allometric growth are given in Table 6; the closeness of fit can be seen in the magnitude of the correlation coefficients (all $r \geq 0.95$). Simple power functions provided generally poorer fits, and although more complex functions might be fitted to the data, their practicality for routine systematics work is questionable. Regression parameters have been computed using the functional (GM) method of Ricker (1973). This method is recommended when neither variable can be regarded as independent and is specifically indicated for studies of allometry (Teissier 1948). The slope of the GM

TABLE 6

PARAMETERS DESCRIBING REGRESSION ON STANDARD LENGTH FOR THOSE CHARACTERS SHOWING SUBSTANTIAL* ALLOMETRIC GROWTH IN HAWAIIAN *Sauridae*

CHARACTER	SPECIES	CORRELATION COEFFICIENT	SLOPE	INTERCEPT
SN	*gracilis*	0.99	0.069	−1.2
EYE	*gracilis*	0.98	0.042	1.2
	flamma	0.98	0.040	1.8
IOD	*nebulosa*	0.97	0.049	−1.5
	gracilis	0.99	0.066	−3.3
	flamma	0.99	0.058	−2.5
DEPTH	*nebulosa*	0.95	0.162	−3.4
	flamma	0.96	0.186	−6.5
PED	*flamma*	0.99	0.067	−1.1
DOAD	*gracilis*	0.99	0.417	−4.2
	flamma	0.99	0.418	−1.9
DRL	*nebulosa*	0.98	0.147	3.4
	gracilis	0.99	0.167	3.5
	flamma	0.99	0.178	3.0
LDRL	*flamma*	0.98	0.074	1.7
AB	*nebulosa*	0.97	0.076	1.7
SA	*nebulosa*	0.99	0.856	−9.6
	gracilis	0.99	0.815	−9.6
	flamma	0.99	0.763	−4.1
P1L	*flamma*	0.99	0.121	1.1
SNP1	*flamma*	0.99	0.262	−2.1

NOTE: All measurements are in millimeters. Sample sizes were: *nebulosa* (22); *gracilis* (19); *flamma* (21). Abbreviations follow those in Table 3. Regression parameters were computed using the functional regression of Ricker (1973).

*See text for explanation.

line is the geometric mean of the regression of Y on X and the reciprocal of the regression of X on Y.

Table 6 gives regression parameters for those characters showing substantial allometric growth in at least one species. Gould (1966) and others have noted that any line (describing the regression of one body part on another) with a significantly nonzero intercept defines a pattern of allometric growth. However, some equations with small nonzero intercepts may be of little use in systematics; allometric effects are important taxonomically only for those characters for which the regression equation explains a substantial portion of the observed variation. Characters meeting this latter (admittedly subjective) criterion, and for which inspection of scattergrams verified the consistency of the allometric growth patterns, are included in Table 6. For example, the regression on standard length (SL) of bony orbit (EYE) in *Saurida flamma* predicts a decrease in size from 6.3 to 4.6 percent of SL over the observed size range of 78–290 mm. From Table 3, the observed range of EYE in *S. flamma* is 6.1 to 4.3 percent of SL, so allometric growth accounts for most of the observed variation in this character. Note that sampling over a large size range increases the likelihood of being able to separate allometric effects from natural variation; this explains in part the large number of characters displaying significant allometric growth in *S. flamma*. It should be stressed that the parameters in Table 6 describe growth patterns only within certain size ranges, and caution should be exercised in extrapolating outside these ranges, particularly for small or juvenile specimens whose shape may be quite different from that of adults.

Although linear regressions only approximate the growth patterns of the three *Saurida*, they clearly are improvements over more traditional presentations of the data (Table 3). This is easily shown if characters standardized to SL are plotted against SL. When interorbital distance (IOD) is plotted this way

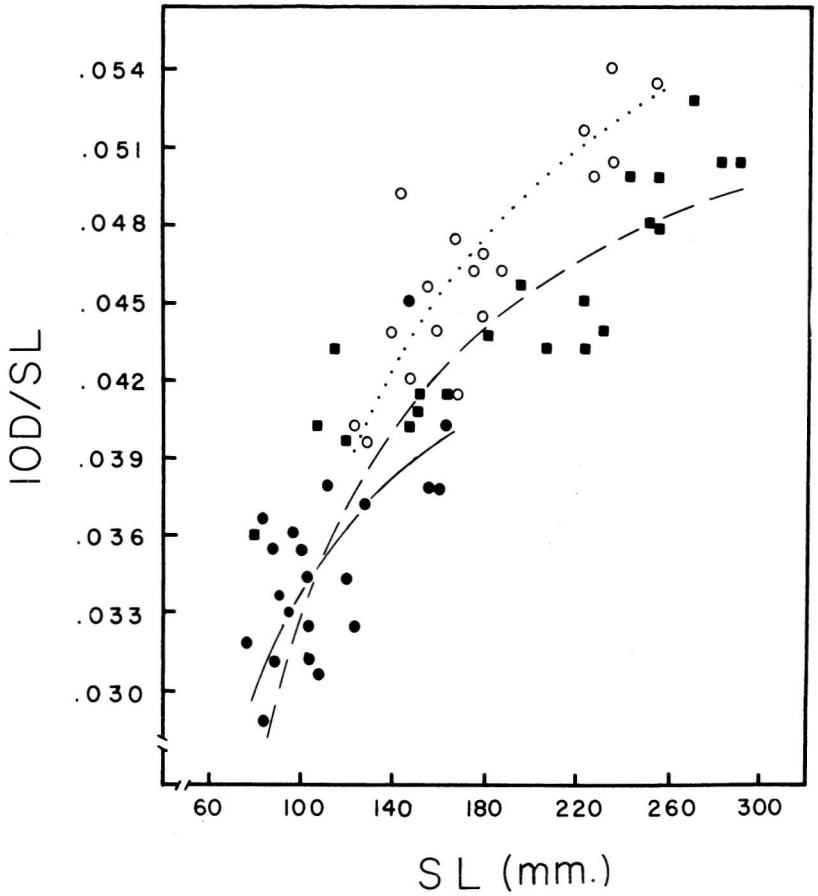

FIGURE 4. Scattergram of standardized interorbital distance (IOD/SL) versus standard length (SL) for Hawaiian *Saurida*. Squares and broken line = *flamma*; open circles and dotted line = *gracilis*; closed circles and solid line = *nebulosa*. Lines represent regression equations from Table 6 transposed to these coordinates. For example, regression of IOD on SL for *S. nebulosa* is described by the equation IOD = 0.049 SL − 1.5 (from Table 6). Thus IOD/SL = 0.049 − 1.5/SL (solid line in this figure).

(Figure 4), two points emerge. First, all three species show marked positive allometry; that is, large individuals have relatively large IOD. Second, the patterns of the three species are similar enough that IOD/SL is highly correlated with SL regardless of the species. IOD/SL can be estimated very closely from SL and represents largely redundant information. Thus, this character, which appears from Table 3 to differ markedly between *S. nebulosa* and the other two species, is in fact chiefly useful for discriminating between large and small fish. Other characters for which apparent interspecific differences can be largely attributed to allometric growth patterns are DEPTH, DOAD, and SNP2.

A very different pattern is seen when longest dorsal ray length (DRL) is plotted in the same manner (Figure 5). All species show negative allometric growth for this character, but the patterns are so distinct that there is no single relationship between DRL/SL and SL. For any given SL, *Saurida nebulosa* has the shortest dorsal ray, *S. gracilis* one of intermediate length, and *S. flamma* the longest. Thus, an unidentified specimen can be placed to species with a good deal of confidence if only its DRL and SL are measured. Data as traditionally reported do not yield as much information.

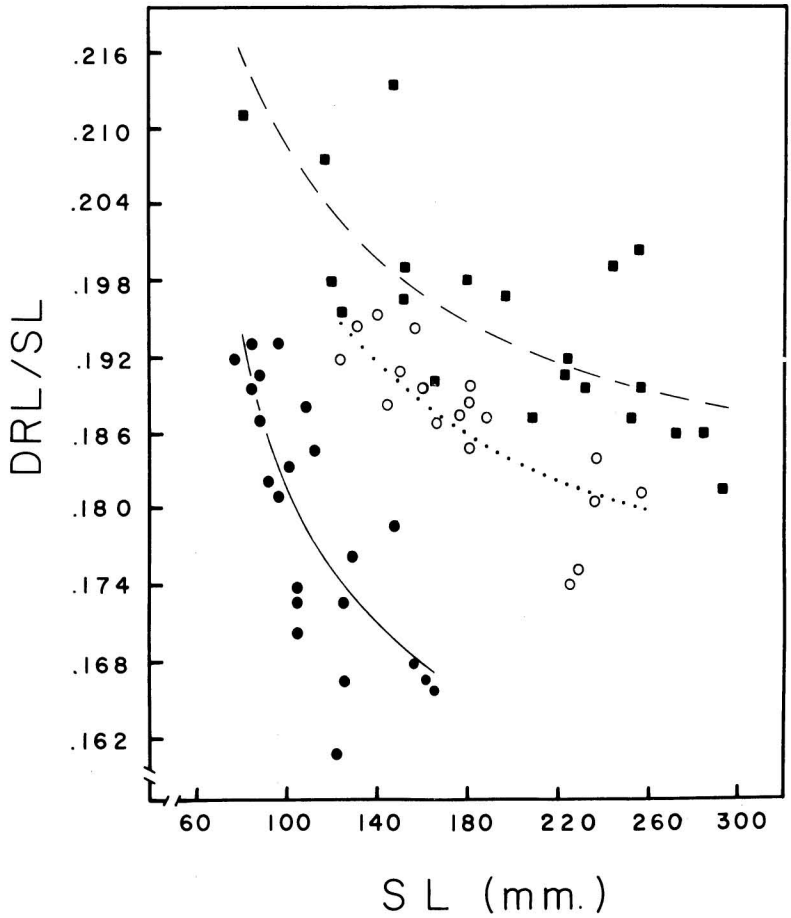

FIGURE 5. Scattergram of standardized dorsal ray length (DRL/SL) versus standard length (SL) for Hawaiian *Saurida*. Symbols are explained in Figure 4.

Although mean values for the three species differ, there is a broad area of overlap from DRL = 17.5–19.6 percent of SL where the observed ranges of at least two species coincide. Anal base (AB) and preanal length (SA) are other characters whose discriminatory power increases when allometric effects are taken into consideration.

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LITERATURE CITED

CUVIER, B., and A. VALENCIENNES. 1849. Histoire naturelle des poissons. Vol. 22. Pitois-Levrault, Paris.

DUTT, S. 1973. Synodidae: Correct name for lizardfish family. J. Mar. Biol. Assoc. India 15(1):450–451.

EYDOUX, F., and L. F. A. SOULEYET. 1842. Zoologie. Vol. 1. *In* A. N. Vaillant. Voyage autour du monde exécuté . . . sur la corvette la Bonite . . . . Arthus Bertrand, Paris.

FISHER, S. E., and G. S. WHITT. 1978. Evolution of isoenzyme loci and their differential tissue expression. J. Mol. Evol. 12:25–55.

FOWLER, H. W. 1901. Contributions to the ichthyology of the tropical Pacific. I. The Sandwich Islands. Proc. Acad. Nat. Sci. Philadelphia (1900):493–528.

GORMAN, G. C., and J. RENZI, JR. 1979. Genetic distance and heterozygosity estimates in electrophoretic studies: Effects of sample size. Copeia 1979:242–249.

GOSLINE, W. A., and V. E. BROCK. 1960. Handbook of Hawaiian fishes. University of Hawaii Press, Honolulu.

GOULD, S. J. 1966. Allometry and size in ontogeny and phylogeny. Biol. Rev. 41: 587–640.

GRAVES, J. E., and R. H. ROSENBLATT. 1980. Genetic relationships of the color morphs of the serranid fish *Hypoplectrus unicolor*. Evolution 34:240–245.

HUBBS, C. L., and K. F. LAGLER. 1958. Fishes of the Great Lakes region. Cranbrook Inst. Sci. Bull. 26:1–213.

JENKINS, O. P. 1904. Report on collections of fishes made in the Hawaiian Islands, with descriptions of new species. U.S. Bur. Fish. Bull. 22:417–511.

JORDAN, D. S., and B. W. EVERMANN. 1905. The aquatic resources of the Hawaiian Islands. Part I. The shore fishes. U.S. Bur. Fish. Bull. 23:1–575.

JORDAN, D. S., S. TANAKA, and J. O. SNYDER. 1913. A catalogue of the fishes of Japan. J. Coll. Sci. Tokyo 33(1):1–497.

LESUEUR, C. A. 1825. Description of a new species of the genus *Saurus* (Cuvier.) J. Acad. Nat. Sci. Philadelphia 5:118–119.

NEI, M. 1978. Estimation of average heterozygosity and genetic distance from a small number of individuals. Genetics 89:583–590.

NIE, N. H., ed. 1975. SPSS: Statistical package for the social sciences. 2d edition. McGraw-Hill, New York.

NORMAN, J. R. 1935. A revision of the lizardfishes of the genera *Synodus*, *Trachinocephalus*, and *Saurida*. Proc. Zool. Soc. London 1935:99–135.

QUOY, J. R. C., and P. GAIMARD. 1824. Voyage autour du monde . . . exécuté sur les corvettes de S. M. "L'Uranie" et "La Physicienne" pendent les années 1817–20. Poissons. Pillet Aîné, Paris.

RICKER, W. E. 1973. Linear regressions in fishery research. J. Fish. Res. Board Can. 30:409–434.

SHAKLEE, J. B., K. L. KEPES, and G. S. WHITT. 1973. Specialized lactate dehydrogenase isozymes: The molecular and genetic basis for the unique eye and liver LDHs of teleost fishes. J. Exp. Zool. 185:217–240.

SHAKLEE, J. B., C. S. TAMARU, and R. S. WAPLES. Speciation and evolution of marine fishes studied by the electrophoretic analysis of protein polymorphisms. Pac. Sci. (in press).

SHAW, C. R., and R. PRASAD. 1970. Starch gel electrophoresis of enzymes—A compilation of recipes. Biochem. Genet. 4: 297–320.

SHINDO, S., and U. YAMADA. 1972. Descriptions of three new species of the lizardfish genus *Saurida*, with a key to its Indo-Pacific species. Uo 11:1–13, 12:1–14.

SULAK, K. J. 1977. The systematics and biology of *Bathypterois* (Pisces, Chlorophthalmidae) with a revised classification of benthic myctophiform fishes. Pages 49–108 *in* T. Wolff, ed. Galathea Report. Vol. 14. Scandinavian Science Press, Copenhagen.

TEISSIER, G. 1948. La relation d'allométrie: sa signification statistique et biologique. Biometrics 4:14–48.

THOMPSON, D. W. 1942. On growth and form. University Press, Cambridge.

TINKER, S. W. 1978. Fishes of Hawaii. Hawaiian Service, Honolulu.