

Early Life History of *Lutjanus vitta* (Lutjanidae) in Yuya Bay, the Sea of Japan

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Abstract The morphology and ecology of *Lutjanus vitta* in early developmental stages were studied. Materials were collected with plankton nets, seines and trawls from 1975 through 1977 in Yuya Bay located in the southwestern part of the Sea of Japan. Larvae and early juveniles of the fish are outstanding in having an elongate second dorsal spine, pelvic spines, and pelvic rays. The body is compressed, and the head is armoured with spines and bony projections on the maxillary, posttemporal, supracleithrum, postcleithrum and four opercular bones. The fish attain full fin ray counts at about 10 mm SL (=standard length) and specific coloration around 24 mm SL. Relative growth of the elongate fin elements consists of four stanzas delimited by three growth inflexions which occur at about 7, 16 and 32 mm SL. Close correlations between morphological and ecological changes were observed. Larvae less than 7 mm SL spend planktonic life in the open sea, showing rapid growth in fin elements, adapting to the life mode. At about 7 mm SL, a sharp downward inflexion occurs simultaneously in these fin elements, and the negative growth rate is maintained until the fish measure about 16 mm SL. In this growth stanza, the fish develop free-swimming ability gradually, migrate into bays and concentrate in shallow waters. In the third growth stanza (16~32 mm SL), relative growth is highly negative (the relative growth coefficients, $a \ll 1$) in these body parts and actually negative ($a < 0$) in some of them indicating a fast decrease of these parts in proportion to the length of the fish. In this growth stanza the fish move into grass beds, and the transition from pelagic to demersal life is completed at the end of the stanza. Over 32 mm SL, relative growth is slightly negative and stable until 20 cm SL, the size limit of the observations. Stomach contents of demersal young fish caught in grass bed were analyzed and a flexible feeding strategy was demonstrated. The fish is seemingly a random feeder which utilizes the most abundant food items available from more than one micro-habitat within grass beds. They take small fishes and crustaceans both at the sea bottom, on *Zostera* blades, and in the water column between *Zostera* blades.

Historical paucity of knowledge on the early life histories of lutjanid fishes has been partly filled by recent studies attempted on some western tropical Atlantic and eastern Pacific species (Starck, 1964, 1971; Heemstra, 1974; Fahay, 1975; Laroche, 1977; Collins et al., 1980; Rabalais et al., 1980; Richards and Saksena, 1980). In Japanese waters, however, little is known, probably because of the rare occurrence of their larvae and juveniles in conventional gear. Uchida (1937) illustrated a larva of *Lutjanus* sp., and Suzuki and Hioki (1979) described laboratory-reared eggs and early larvae of *Lutjanus kasmira*.

Lutjanus vitta (Quoy et Gaimard), typically Indo-West Pacific in its geographical distribution, has been recorded from Seychelles, India, Ceylon, New Guinea, Australia, the South China Sea, the Philippines, and as far north as

the Sado Straight in the Sea of Japan at 38°N Lat. (Day, 1875; Weber and de Beaufort, 1936; Herre, 1953; Munro, 1955, 1967; Kato, 1956; Honma, 1963; Smith and Smith, 1963; Shinohara, 1966). In Yuya Bay, located in the southwest of the Sea of Japan at 34°23'N, the larvae and juveniles of the species occur in considerable numbers every year, suggesting that it reproduces not far from the area, although the species is more abundant in the southern seas.

Materials and methods

Study field. Yuya Bay is located near the western tip of Honshu (the main island of Japan), and opens to the Sea of Japan to the west (Fig. 1). The north-south distance at the entrance to the bay is about 4 km, and about 10 km east-west. The depth of the water at

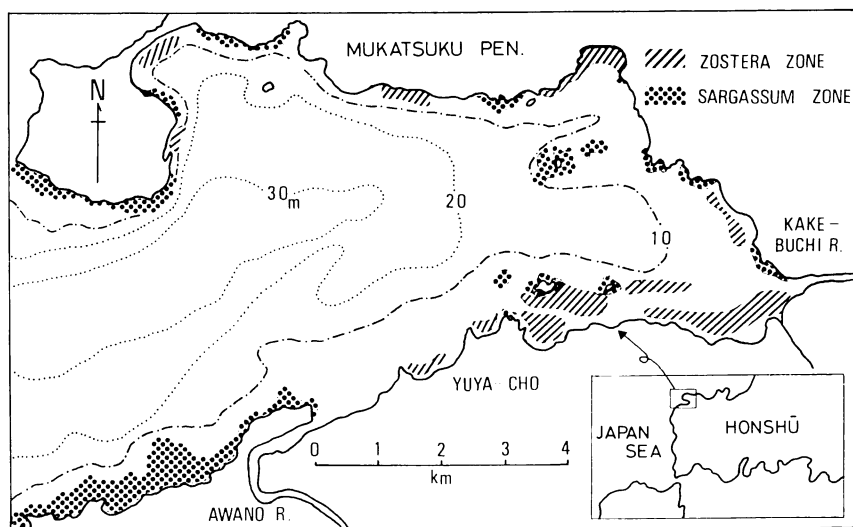


Fig. 1. Topography of Yuya Bay showing depth contours and vegetation in summer months (Mori, 1980).

the entrance to the bay is about 35 m, but it decreases gradually to the east forming a wide area less than 10 m deep along the southern and eastern coasts. The bottom sediments vary from sand to muddy sand in the major portion of the bay (Inoue, 1980). The bay is exposed to the influence of the Tsushima Current, which is a branch of the Kuroshio, and the seasonal fluctuations of temperature and salinity parallel that of the current; the lowest temperature, about 7°C, is observed in late January, and the highest, about 28°C, in late August (Tawara and Ouchi, 1980). Two major and several smaller rivers drain to the bay. *Zostera marina* beds are developed in shallow waters, especially in the southeastern part of the bay (see Fig. 1).

Methods of collection. Three kinds of gear were used; plankton net, seine, and trawl. The plankton net was a cylindrical-conical net of 113 cm in mouth opening, 4 m in length lined with 0.5 mm mesh nylon monofilament net, with an overall open area ratio measuring 7.7. The net was towed obliquely from near bottom to surface at 13 stations where water depth was greater than 15 m, and was towed horizontally below the surface at the other 12 stations with water-depths less than 15 m. All tows were made at about 2 knots for durations of 10 minutes during daytime.

The seine, called "funabiki-ami" locally, is a

huge net originally designed and used in commercial fishing for anchovy larvae and juveniles. In structure and in method of operation, the net is fundamentally identical to a beach seine, but in this district, it has been modified to operate from skiffs in the sea. It has long "wing" sections of large mesh on both ends, which are supposed to have a driving effects on fishes, accompanied by a "bag net" of 1.75 mm mesh minnow net which serves as the cod-end. The diameter of the bag-net on operation is about 10 m. The net catches fishes in the water column as well as on the bottom. The net was towed slowly from two anchored skiffs for 60 minutes during daytime, covering a distance estimated at about 500 m. The effectiveness of this gear in collecting juvenile fishes was shown by Dotsu (1961). The catch was sometimes as large as several hundred kilograms, and only a small portion of it could be brought back to laboratory. In such a case, the number of fish caught was estimated through the ratio of the subsamples to the entire catch.

The trawl was a kind of small-sized beam trawl equipped with a bamboo stretch of 8 m in length at the mouth. The net is used commercially for the prawn fishery in the district. The entire length of the net is 7.0 m, with the main part lined with 22 mm stretch mesh and the cod-end with 18 mm mesh. The cod-end

is covered by minnow net of 2.25~2.50 mm mesh in order to retain small specimens. The net was towed for 10 minutes at about 2 knots and the distance covered estimated at about 600 m. The entire catch was brought back to laboratory.

Method of measurements. Measurements in larvae and juveniles were made on the left side with an ocular micrometer, and with a dial caliper in larger specimens. Measurements include: Notochord length (NL)—distance from tip of snout to distal end of notochord (before hypural formation).

Standard length (SL)—distance from tip of snout to posterior end of the middle hypural bones.

Total length (TL)—distance from tip of snout to posterior margin of the upper lobe of caudal fin.

Head length (HL)—horizontal distance from tip of snout to cleithrum (before the formation of operculum), or to the posterior margin of the operculum (after opercular formation).

Body depth—vertical distance between dorsal and ventral surfaces, to the ventral tip of the cleithrum.

Eye diameter—maximum diameter of fleshy eye socket.

Spine and fin ray length—distance from point of entry of spine or ray into flesh to distal tip. Preopercular spine was measured from distal tip to the postero-ventral corner of preoperculum.

Other methods. Specimens were initially preserved in 10 percent buffered sea-water formalin, and transferred to 5 percent buffered formalin after the specimens were sorted. All the measurements and counts were done on preserved specimens. Osteological observations were made on specimens cleared and stained by Hollister's method (Hollister, 1934). For the observations of surface structures such as squamation, head spination, etc., specimens were lightly stained with solar cyanin, which was used also in counting meristic characters.

Identification was based on the morphology of juvenile specimens, and the larvae were linked to the juveniles by similarities of morphology and pigmentation. The species is virtually the only species of the family occurring in the area.

Spines were named after the bone from which they originated, as far as possible. Most of the spines observed on the present species were also observed on *Sebastes* spp. (Moser and Ahlstrom, 1978; Richardson and Laroche, 1979), hence, only minor modifications and additions were needed, including the maxillary spine and the postcleithral spine.

Terms of relative growth were taken after Martin (1949). As to the definitions of developmental stages, I followed Uchida and Dotsu (1958), which has been widely accepted by Japanese fishery biologists. The definitions are essentially similar to those by Hubbs (1943), but the commencement of the juvenile stage is defined by the completion of fin formation and acquirement of full fin ray counts.

Since the fish caught by seine are said to show a tendency of within-net feeding, probably because the fish are allowed to feed for considerable duration of time after being caught in the net (Omori, 1980), the diet problem was analysed based on those specimens caught by trawling but not others. Stomachs were removed from the fish which had been preserved in formalin, and the contents were identified and counted under a binocular microscope. Before contents weighed on an electronic balance, extra water was removed by pressing them lightly against filter paper several times.

Results

Meristic characters of juveniles. Since adult fish were not available, 100 juvenile specimens (53~110 mm SL) were examined to determine meristic variation. The meristic counts determined are: D. X, 12~13, A. III. 7~9, P. 14~17, C. 9+8, Branchiostegals 7. Numbers of dorsal spines, anal spines, principal caudal rays and branchiostegals are consistent, but there is some variation in the rays of dorsal, anal and pectoral fins (Table 1).

Morphology. The description given below was based on 6 specimens, each of which represents a characteristic stage in development. The data are shown in Table 2. The sequence of morphological change was determined using additional specimens.

Specimen A, 4.1 mm NL (4.2 mm TL) (Fig. 2A): Body heavily compressed. Head large (34% in NL), its dorsal contour concave antero-

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Table 1. Variation in fin ray counts of *Lutjanus vitta* made on 100 juvenile specimens from 53 to 110 mm SL (64~138 mm TL).

Counts	7	8	9	12	13	14	15	16	17	Sum
Dorsal fin rays				9	91					100
Anal fin rays	5	92	3							100
Pectoral fin rays						1	11	85	1	98

Table 2. Measurements (mm) and counts of larvae and juveniles of *Lutjanus vitta* illustrated in Fig. 2.

	Specimen					
	A	B	C	D	E	F
Developmental stage	larva	larva	juvenile	juvenile	juvenile	juvenile
Standard length	4.1	7.7	12.25	20.15	20.93	34.8
Total length	4.2	9.0	14.5	25.15	26.38	44.0
Body depth	1.4	2.8	4.3	7.2	7.85	12.38
Head length	1.4	3.15	5.75	8.35	8.68	14.10
Eye diameter	0.45	0.90	1.25	2.20	2.45	4.10
Length, second spine in dorsal fin	1.4	4.1	5.3	5.5	5.6	5.5
Length, pelvic fin spine	0.9	3.2	4.8	4.45	4.4	5.1
Length, first ray in pelvic fin	1.15	3.70	5.30	7.05	7.25	7.80
Length, preopercular spine	0.4	0.85	1.05	1.10	1.45	—
Dorsal fin	V+	X, 13	X, 13	X, 13	X, 13	X, 13
Anal fin	—	III, 9	III, 8	III, 8	III, 8	III, 8
Pectoral fin	—	13	16	16	16	16
Caudal fin	—	9+8	9+8	9+8	9+8	9+8

dorsally to the eye and round dorsally. Notochord straight. Nostril consists of a single pit situated on each side of the snout. Pelvic fin well developed in comparison with other fins; the spine long and slender; the outermost ray longer than the spine. Pectoral fin fan-shaped and membranous. Median fins membranous and continuous with each other. In dorsal fin anterior 5 spines well developed, the second one slender and longest, measuring 34% in SL; the rest still undeveloped, though, discernible. Anal fin and hypurals still in process of formation. Surfaces of both dorsal and pelvic spines smooth.

Head armed with spines and bony projections. Tip of maxillary extended anterolaterally to form a sharp spine. Preopercle armed with a strong spine on posteroventral corner, a spine dorsally and two shorter spines ventrally. Posterior to ear capsule, two bony projections originated from posttemporal, and one bifid spine from supracleithrum.

Pigmentation still scanty, except abdominal cavity densely pigmented. Head region lacking any pigment except eye. One conspicuous pigment spot on cleithral symphysis, and the other on ventral finfold anterior to anal opening. Two melanophores on each side of anal base, and four along ventral edge of caudal peduncle. One small melanophore on hypural and another stellate one on the future caudal fin. Fin membrane pigmented along second dorsal spine, and spine and rays of pelvic fin also pigmented.

Specimen B, 7.7 mm SL (9.0 mm TL) (Fig. 2B): Body shape similar to the former specimen in general, except contour of head straight. Notochord flexed, and caudal fin with full complement of principal rays. Nostril still single. Minute conical teeth on jaws. All the fins except pectoral formed with full complements of spines and rays. Second dorsal spine long, extending to one-third of caudal peduncle. Spine and the first ray of pelvic fin also long and

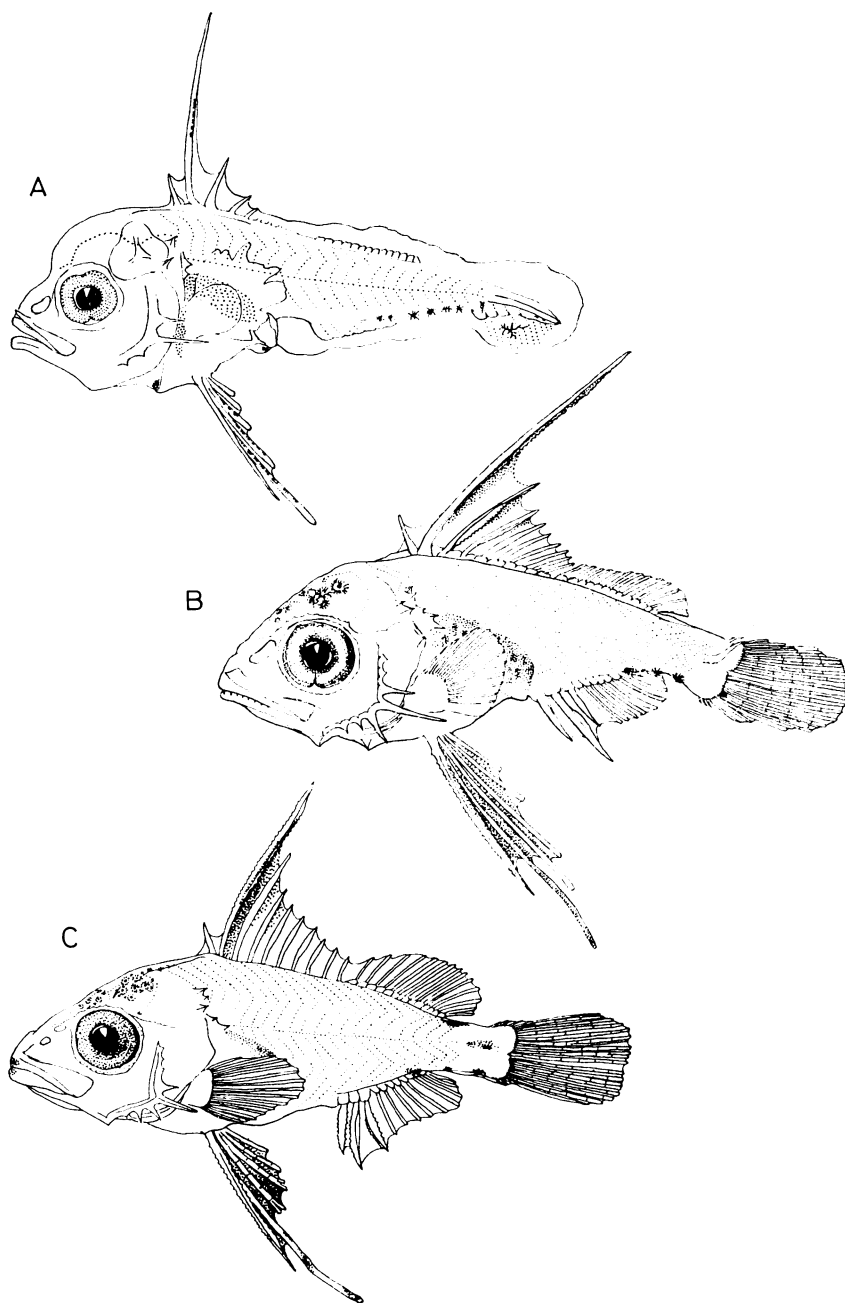
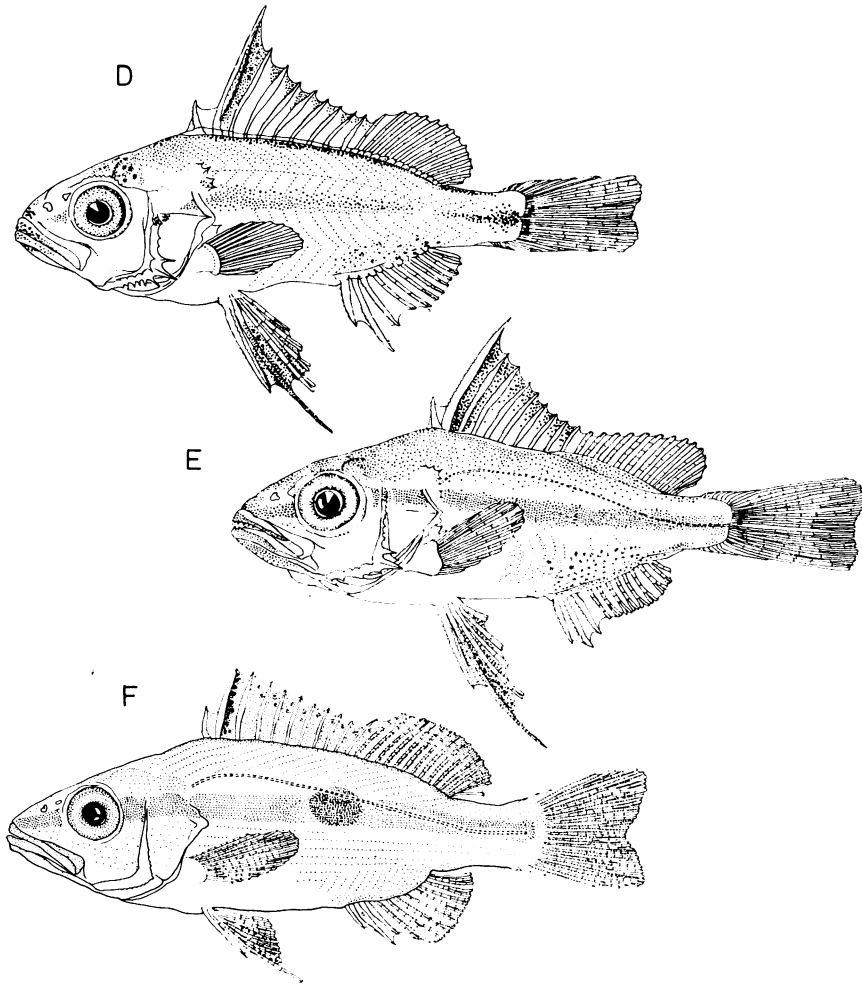


Fig. 2. Larvae and juveniles of *Lutjanus vitta*. A, larva 4.1 mm NL (4.2 mm TL); B, 7.7 mm SL (9.0 mm TL). C, pelagic juvenile 12.25 mm SL (14.5 mm TL); D, 20.15 mm SL (25.15 mm TL); E, 20.93 mm SL (26.38 mm TL). F, benthic juvenile 34.8 mm SL (44.0 mm TL). Measurements and counts shown in Table 2.

slender, reaching up to two-thirds of anal base and caudal peduncle respectively. Spines in dorsal, anal and pelvic fins V-shaped in cross

section, with the "V" open posteriorly. Posterior edges of second to fourth dorsal spines, and both anterior and posterior edges of pelvic



spine serrated finely. Distal end of caudal fin round.

In head, bony projections and spines becoming more conspicuous. The anterior tip of maxillary protruding anterolaterally to form a blunt projection. A bony ridge with fine serrations over the eye. In preoperculum, the spine at the angle increased in length, and three other spines both dorsally and ventrally. Preopercular crest with several spinules. Opercular margin with a flat spine. Temporal region armed by two bifid spines originating from posttemporal, and one trifid spine from supracleithrum.

Pigment present on top of head. Tail melanophores decreased in number, one along the anal base, two others on the ventral edge of

caudal peduncle. Dorsal fin membrane pigmented densely along the entire length of the second spine, and partially along the third and fourth spines. Pelvic fin membrane pigmented, heaviest between the spine and the neighbouring ray. Pigment on the base of caudal fin, but no other pigments on soft dorsal, anal or pectoral fins.

The smallest specimen showing full complements of dorsal and anal rays was 7.9 mm SL, but pectoral fins did not have full complements until 9.6 mm SL. Hence, the sequence of fin formation was pelvic—caudal—dorsal and anal—pectoral. Although dorsal fin attains full ray complement early, ossification is slow and specimens as large as 11.0 mm SL have not yet

begun ossification. Between 9.6 and 11.0 mm SL, pectoral fins attain full complement, thus the larval stage terminates at about 10 mm SL.

Specimen C, 12.25 mm SL (14.5 mm TL) (Fig. 2C): Body shape very close to the previous specimen. Nostrils isolated pits. Pectoral fin with full complement. Second dorsal spine the longest, but relative length decreased, extending to the posterior end of dorsal fin base. Both pelvic spine and outermost ray decreased in their relative length, the spine reaching up to one third of anal fin base, and the ray to posterior end. In pelvic and caudal fins, some of the rays segmented and branched. In addition to head spination observed in smaller specimens, one flat spine originated from postcleithrum. Pigmentation generally heavier. Melanophores present on the tips of snout and lower jaw. On caudal peduncle, melanophores on mid-lateral surface and on dorsal surface immediately posterior to the dorsal fin base, with considerable variation among specimens of similar length.

Specimen D, 20.15 mm SL (25.15 mm TL) (Fig. 2D): Body moderately compressed laterally. Scale pockets developed on almost entire lateral surface of body and on cheek. Lateral line discernible by staining. Head spination less conspicuous. Anterior portion of maxillary covered with flesh, and its tip not protruding externally. On preopercular margin, spines decreased in their relative length, but increased in number. Lower posttemporal spine not present. Second dorsal spine decreased in its relative length, reaching the origin of soft dorsal. First pelvic soft ray reaching midpoint of anal base. Soft dorsal and anal rays segmented, and some anal rays in the process of branching. Pectoral fin rays not segmented. Distal margin of caudal fin slightly concave.

Pigmentation developed on body surface. A thin stripe present along the mid-lateral surface of body, extending anteriorly onto operculum, preoperculum and snout. Pigments also increased in head region, and first appearance along the base of dorsal and anal fins. In spinous dorsal, pigments shown near the distal tip of fin membranes posterior to the third spine.

Specimen E, 20.93 mm SL (26.38 mm TL) (Fig. 2E): This specimen is similar in length

to Specimen D, but is considerably more advanced, demonstrating individual variation. Posterior margin of interopercle projects posteriad between preopercular spines. Lacrymal extending anteriorly to cover almost anterior half of maxillary. Scales formed on the entire surface of body, cheek, opercle and subopercle and extending onto caudal, dorsal and anal fin bases. Some of the scales on body surface ctenoid. Lateral line pores extend from the upper corner of opercle to the base of caudal fin. Scales appear as horizontal rows below lateral line, and oblique rows above lateral line.

Lateral stripe, broad, conspicuous and dark brown in color, extending from snout tip to the base of caudal fin. This specimen was the smallest with the stripe clearly formed, whereas the largest one without the stripe was 24.5 mm SL (30.9 mm TL).

Specimen F, 34.8 mm SL (44.0 mm TL) (Fig. 2F): Body form and coloration similar to adult, although head and eye are still relatively larger. Second dorsal spine and second anal spine reduced greatly in relative lengths measuring almost equal with succeeding spines. All of the head spines covered with scales except for the posttemporal which is flat, scale-like and quadricuspid. Preopercular spines are now a row of blunt serrations along the entire margin. Scales present on interopercle.

Specific color pattern present; oblique, narrow stripes above, and horizontal, narrow stripes below the pronounced mid-lateral stripe. Within the mid-lateral stripe, a circular blotch is present below the origin of soft dorsal. The blotch was observed on a specimen as small as 27.9 mm SL (32.1 mm TL). Melanophores, brownish in color, cover the entire head region and all the fins, but relatively scarce in the anal and pectoral fins. On the posterior half of mid-lateral stripe and all fins except for pectoral of juveniles larger than this specimen, some of the melanophores are replaced by brilliant yellow-orange xanthophores, although this was evident only in newly preserved specimens.

Osteology. Since larval specimens in good condition were not available, osteological observations were restricted to juveniles of two size groups; 21 of 13.6~22.5 mm SL, and 12 of 78~96 mm SL.

Shoulder girdle (Fig. 3): Shoulder girdle

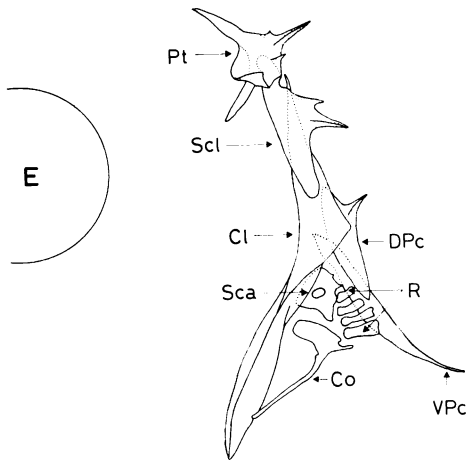


Fig. 3. Shoulder girdle of juvenile *Lutjanus vitta*, 16.2 mm SL, illustrating a part of head spinations. Stippled portions exposed out of skin. Cl, cleithrum; Co, coracoid; DPc, dorsal postcleithrum; E, eye; Pt, posttemporal; R, radials; Sca, scapula; Scl, supra-cleithrum; VPc, ventral postcleithrum.

bears part of head spinations. Posttemporal with three broad spines, superior, median, and inferior; superior and median ones sometimes bicuspid or tricuspid; median posttemporal spine not always distinct and sometimes located closely to the base of the superior, appearing as one of the cusps of the latter. Supracleithrum bearing one broad spine with sometimes as many as four cusps. Dorsal postcleithrum with one broad spine.

Dorsal fin supports (Fig. 4): Three predorsal bones anterior to the first pterygiophore in all twelve specimens (78~96 mm SL). Pterygiophores count 21 in number in 11 specimens and 20 in one specimen. Anterior pterygiophores broad and stout, the first one carrying first and second dorsal spines, and in their relation to vertebral column, together with predorsal bone, presenting typical "*Lutjanus* configurations"

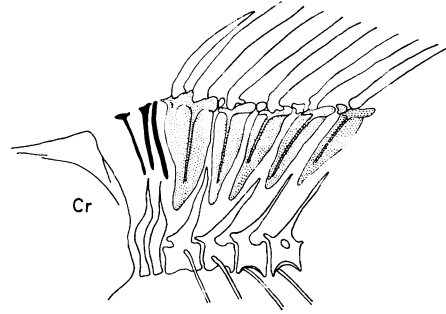


Fig. 4. Anterior portion of dorsal fin support of *Lutjanus vitta*, 16.6 mm SL, illustrating the relationships of dorsal pterygiophores (stippled) and predorsal bones (black) against the vertebral column. Cr, cranium.

(Heemstra, 1974) in eight specimens out of 12 examined. In the four other specimens the arrangement is slightly modified. When all the predorsal and pterygiophores are taken into account, five specimens out of 12 showed a common arrangement denoting "*Lutjanus* configurations" for the anterior part (Fig. 5), although seven other specimens showed slight modifications from the arrangement above in various ways.

Anal fin supports (Fig. 6): Total number of anal pterygiophores highly consistent; all 12 specimens (78~96 mm SL) having 9 elements. In their arrangement in relation to the vertebral column, a consistent pattern (Fig. 5) was found in 6 specimens out of 12, the rest showing slight variations. First pterygiophore broad and stout carrying the first and second spines and part of the third. In 21 smaller (13.6~22.5 mm SL) specimens, the first pterygiophores are inserted between the last pair of ribs, which are attached to the parapophyses of the 10th vertebrae, thus, the first pterygiophores are connected to the parapophyses through the last ribs. The feature seems to be exclusively juvenile, because the first pterygiophore is free from the rib without

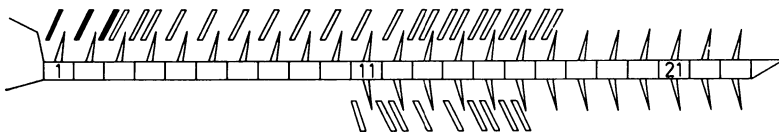


Fig. 5. Schematic presentation of the typical relationships of dorsal and anal pterygiophores against the vertebral column in young (78~96 mm SL) *Lutjanus vitta*. Black bar indicates a predorsal bone.

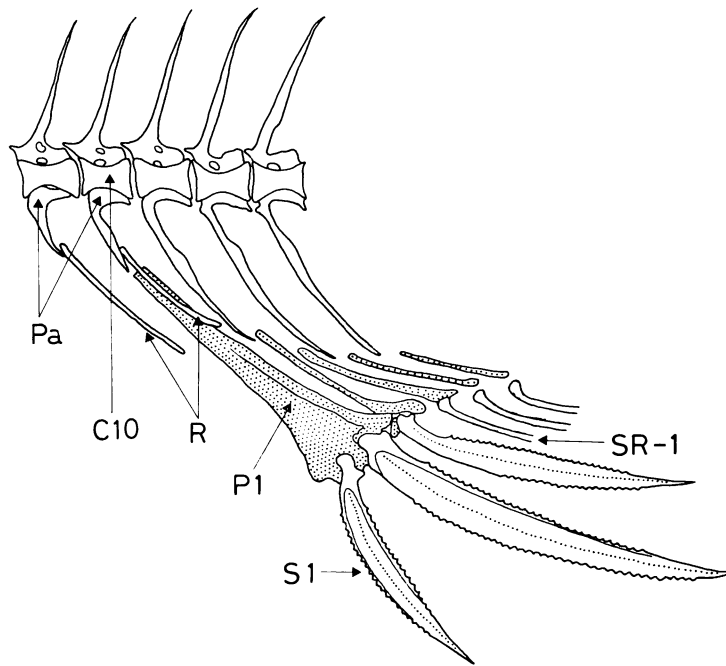


Fig. 6. Anterior portion of anal fin support of juvenile *Lutjanus vitta*, 16.1 mm SL, illustrating the relations of pterygiophores to the vertebral column. C10, tenth centrum or the last precaudal centrum; Pa, parapophyses; P, pterygiophore; S, anal fin spine; R, ribs; SR, soft ray.

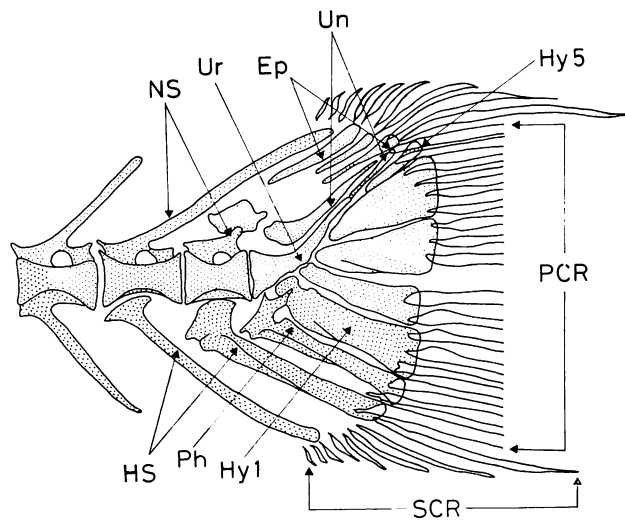


Fig. 7. Caudal complex of juvenile *Lutjanus vitta*, 17.3 mm SL. Ep, epurals; HS, haemal spines; Hy, hypurals; NS, neural spines; PCR, principal caudal rays; Ph, parhypural; SCR, secondary caudal rays; Un, uroneurals; Ur, urostyle.

exception in larger (78~96 mm SL) specimens.

Caudal fin (Fig. 7): The caudal complex is the typical percoid arrangement of three epurals, one parhypural and two paired

uroneurals. Secondary rays vary in number from 7 to 9 dorsally, from 6 to 8 ventrally in 13.6~22.5 mm SL group, from 8 to 10 dorsally and 8 to 9 ventrally in 78~96 mm SL group.

Relative growth. In the previous section, it was demonstrated that some of the fin elements grow rapidly only in early developmental stages. In order to verify this, relative growths of some of the fin elements were examined. Relative growths of body depth and head length were also examined to detect possible changes in body form (Fig. 8 and Table 3).

Relative growth plots for the second dorsal and pelvic spines and the first pelvic ray (Fig. 8A, B, C) indicate four growth stanzas (term adopted from Martin, 1949) delimited by three inflexions, respectively. The inflexions occur at about 7, 16 and 30 mm SL, simultaneously in these three parts. These parts are outstanding in the sense that the relative growth rates (a) in the first stanzas (less than 7 mm SL) are extremely high. Consequently, these parts become disproportionately long at the ends of the stanzas. In the second stanzas (7 ~ 16 mm SL), the allometry changes from positive to negative. In the third stanza (16 ~ 30 mm SL) the relative growth coefficients are either almost zero or negative indicating that these parts do not grow in spite of the increase in body length or actually degenerate. In the fourth stanzas (30 mm SL and

over) the relative growths of these parts are slightly negative.

The relative growth plots of the third dorsal and the second anal spines (Fig. 8D, E) have two inflexions which occur at about 16 mm and 30 mm SL. In the first stanza (less than 16 mm SL), these parts show positive growth, but the relative growth rates are not extraordinarily high. In the second stanza (16 ~ 30 mm SL), the relative growths are highly negative showing the actual growth of these parts very slow. In the third stanza (30 mm SL and over), the relative growths are slightly negative. Thus, the relative growth patterns are not similar between neighbouring fin elements, but are similar among those which show similar intensity of the earliest growth. The synchronized inflexions suggest a possibility of behavioural changes of the fish at these lengths.

No growth inflexion was observed in the relative growth plots of the third anal spine (Fig. 8F), body depth and head length, but the relative growth rates are constantly negative (Table 3), indicating that these parts decrease gradually with the increase in body length.

Seasonal occurrence and horizontal movement

Table 3. Statistics for the relative growths in 9 body parts of *Lutjanus vitta*. a, the slope; b, y-intercept; r, correlation coefficient in the equation, $\text{Log } Y = a \text{ Log } X + b$.

Body parts	Size range (mm)	a	b	r
Total length	4.1 ~ 193.5	0.998	0.095	0.999
Head length	4.1 ~ 193.5	0.956	-0.337	0.998
Body depth	4.1 ~ 193.5	0.978	-0.423	0.998
Second dorsal spine	4.1 ~ 7.0	1.906	-1.055	0.960
	7.0 ~ 16.0	0.647	-0.011	0.835
	16.0 ~ 30.0	-0.266	1.098	-0.509
	30.0 ~ 193.5	0.697	-0.346	0.965
Third dorsal spine	4.3 ~ 16.0	1.177	-0.864	0.981
	16.0 ~ 30.0	0.288	0.230	0.647
	30.0 ~ 193.5	0.859	-0.592	0.978
	4.1 ~ 7.0	1.867	-1.142	0.941
Pelvic spine	7.0 ~ 16.0	0.607	-0.080	0.907
	16.0 ~ 30.0	-0.175	0.906	-0.481
	30.0 ~ 193.5	0.824	-0.578	0.982
	4.1 ~ 7.0	2.035	-1.195	0.966
First pelvic ray	7.0 ~ 16.0	0.909	-0.246	0.945
	16.0 ~ 30.0	0.130	0.689	0.430
	30.0 ~ 193.5	0.904	-0.479	0.990
	6.6 ~ 16.0	1.238	-0.991	0.954
Second anal spine	16.0 ~ 30.0	0.239	0.217	0.540
	30.0 ~ 193.5	0.827	-0.607	0.986
Third anal spine	11.3 ~ 193.5	0.892	-0.720	0.992

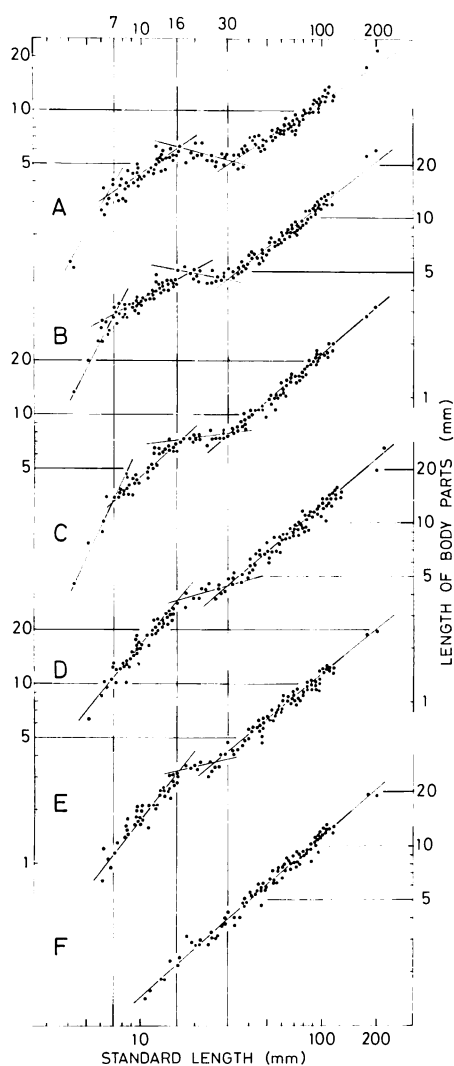


Fig. 8. Relative growth of six body parts, and synchronism in growth inflexions in *Lutjanus vitta*. A, second dorsal spine; B, pelvic spine; C, first pelvic ray; D, third dorsal spine; E, second anal spine; F, third anal spine.

in the bay. The season and the fish size at first migration into the bay had been expected to be deduced from plankton-net surveys. However, it produced only 6 larvae less than 4.8 mm NL (5.3 mm TL) in 25 tows in September, 1976. The poor catch did not allow determination of whether the fish did not migrate into the bay at this length or whether the poor catch simply reflected poor migration during the

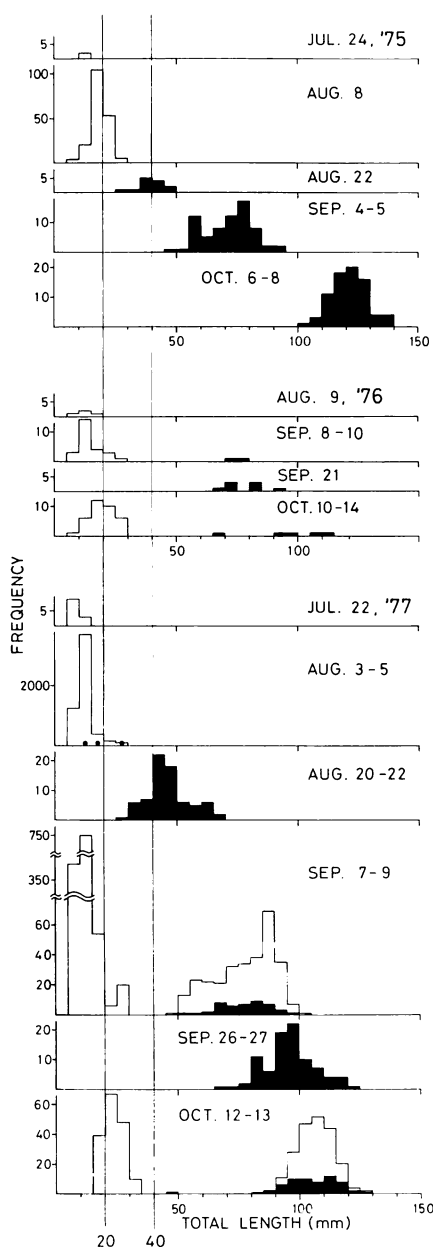


Fig. 9. Length frequency distributions of *Lutjanus vitta* captured by seine (open polygons) and by trawl (solid polygons). Solid circles in August 1977 indicating small number of catches by trawl. In polygons for seine, number of fish in each length class was back-calculated to the number of fish caught.

year.

The smallest fish caught by seine was 4.6 mm

SL (6.6 mm TL), but the majority of the catch was composed of fish from 6.5 to 16 mm SL (9.0~20 mm TL) (Fig. 9). The earliest catch of this size group was either in late July or early August. The catch of this size group in considerable quantity was observed only once in early August in 1975, but twice in 1976, and three times in 1977. The latest catch of this size group in 1976 and 1977 was in October. Thus, considerable annual fluctuation was suggested concerning both the frequency and the resulting amount of migration.

Larvae were caught by plankton net only at those stations near the entrance of the bay. From the distribution of catch by seine, the fish appeared to move eastward along the southern coast of the bay (Fig. 10A, B) as observed for *Pagrus major* in the same bay (Mori, 1980). The distribution of trawl catches indicated heavy concentration of fish larger than 30 mm TL in the *Zostera marina* bed in shallow waters less than 5 m deep along the south coast of the bay from late August to early September (Fig. 10C). Along the northern coast of the bay, where the sea grass bed is sparse, the catch was negligible. The entering of juvenile fish into sea grass beds corresponds well to that of *Lutjanus griseus* in the tropical west Atlantic (Starck, 1971).

The heavy concentration in the grass bed became less intense in mid October (Fig. 10E), suggesting that dispersion had taken place, and this may mark the movement of the fish to a new habitat in rocky areas. First catches by sport fishermen are reported from about this period in rocky areas and around wharves and jetties in the bay. In November the fish were not caught any more, indicating either that they left the bay for a new habitat or they moved to rocky reefs within the bay, not sampled during this survey. Fish of one year old and older are seldom caught in the bay with other gear such as gill nets and hook-and-line, suggesting that most of the fish migrate out of the bay and never return in succeeding years. Thus, the fish utilized the bay as a nursery in their early stages for about three months, localized to grass beds during the latter half of the period. The virtual absence of large-sized fish in the bay reduces the possibility of spawning within the bay, but regular occurrence of larvae and

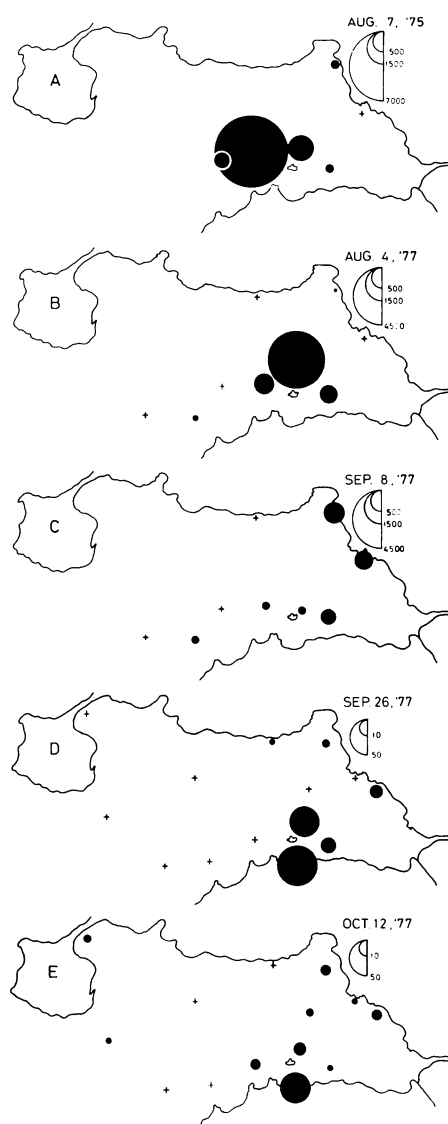


Fig. 10. Records for catches of larvae and pelagic juveniles by seine (A~C) and benthic juveniles by trawl (D, E) in Yuya Bay on given dates and localities. Crosses indicating stations with no catch; size of circles showing the number of fish caught.

juveniles in quantity suggest that spawning occurs nearby.

Growth. The heavy concentration of the fish in the southeastern corner of the bay excluded the possibility of intermingling of bay residents with fish from outside the bay, and permitted the tracing of the growth through

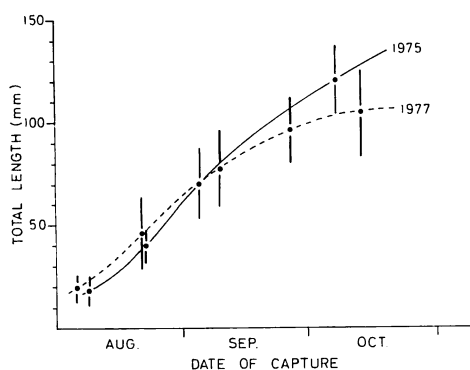


Fig. 11. Growth of *Lutjanus vitta* in 1975 and 1977 in Yuya Bay. Solid circles indicating the mean length of catch, and vertical lines 2 S.D.

the increase in mean length (Fig. 11). Fish which arrived late in 1977 were omitted. From August 8 to October 8, 1975, the mean length increased from 18.34 mm to 120.80 mm TL; 102.7 mm of increase in 61 days or 1.68 mm of increase per day. In 1977, it increased from

19.03 mm to 105.72 mm TL from August 4 to October 13; 85.69 mm of increase in 70 days or 1.22 mm per day. In 1977, the growth seemed to slow down after late September. This may not reflect slow growth itself, because it is quite probable that fast-growing fish leave the bay earlier than slow-growing or late-arriving fish (Oshima, 1954). The growth rate above is comparable with that of a reared grouper, *Epinephelus tauvina*, which showed 70 mm of increase within 50 days (Chen et al., 1977).

Diet and feeding habit of benthic young fish.

Composition of diet: Many of the organisms in the stomachs were in good condition, and some of them were almost intact allowing positive identification and accurate measurement. Diversity of the diet was rather poor (Table 4); it consisted of only several species of fishes and several species of crustaceans, where identification was possible. Besides these two categories, only one polychaet was recognized. In weight, known to be a better indicator of the significance as food, the totals of fishes and

Table 4. Organisms found in the stomachs of *Lutjanus vitta* caught in *Zostera marina* bed. Both frequencies and weights converted into those per hundred stomachs.

Lot No.	S-127		S-509		S-519		S-533	
Date of capture	Oct. 8, 1975		Sep. 8, 1977		Sep. 26, 1977		Oct. 12, 1977	
Time of capture	13: 18		20: 31		22: 24		21: 45	
Size range (TL mm)	106~138		64~98		82~133		92~123	
Nos. of specimens	51		29		15		30	
	Freq.	Weight	Freq.	Weight	Freq.	Weight	Freq.	Weight
1) <i>Acentrogobius pflaumi</i>	92.2	12.669	48.3	4.144	13.3	1.407	63.3	13.363
2) <i>Chaenogobius heptacanthus</i>	37.3	7.798	24.1	4.469	66.7	15.440	36.7	8.370
3) Gobies, not identified	2.0	0.176	—	—	—	—	—	—
Sum of gobies (1~3)	131.4	20.643	72.4	8.614	80.0	16.847	100.0	21.733
4) <i>Engraulis japonica</i> , larva	2.0	0.306	—	—	—	—	—	—
5) <i>Syngnathus schlegeli</i> , larva	17.6	0.014	—	—	—	—	—	—
6) <i>Sillago japonica</i> , juvenile	2.0	0.049	—	—	—	—	—	—
7) Fishes, unidentified	13.7	2.137	20.7	0.831	33.3	1.447	23.3	1.353
8) Fish remains	33.3	1.802	6.9	0.172	—	—	—	—
Sum of all fishes (1~8)	200.0	24.951	100.0	9.617	113.3	18.293	123.3	23.086
9) <i>Alpheus brevirostratus</i>	64.7	19.045	10.3	0.773	6.7	3.607	26.7	11.567
10) Hippolytid shrimps	458.8	4.037	17.2	0.476	13.3	0.633	436.7	4.343
11) <i>Crangon affinis</i>	—	—	3.4	0.455	13.3	1.467	3.3	0.397
12) Unid. macrurans	27.5	1.627	241.4	7.369	66.7	0.893	36.7	1.070
13) Macruran remains	15.7	2.155	6.9	0.479	13.3	0.607	6.7	0.577
Sum of macrurans (9~13)	566.7	26.865	279.3	9.552	113.3	7.206	510.0	17.954
14) Mysidaceans	23.5	0.069	6.9	0.455	—	—	53.3	0.037
15) Amphipods	2.0	0.912	3.4	0.010	—	—	—	—
Sum of all crustaceans (9~15)	592.2	27.845	289.7	9.700	113.3	7.206	563.3	17.990
16) Polychaets	—	—	—	—	—	—	3.3	0.015

crustaceans were nearly equal in three out of four lots of material. Among fishes, two species of gobies, *Acentrogobius pflaumi* and *Chaenogobius heptacanthus* comprised the major portion of fishes both in weight and frequency, and the remaining fish species were almost negligible. *Acentrogobius pflaumi* is a small fish, a permanent resident of the bay, the most dominant in number of all benthic fishes in the bay, and spawns from June to September (Mori, unpublished). Another goby, *Chaenogobius heptacanthus*, is also a small fish of about one year's life span and a resident of the *Zostera* bed (Nakamura, 1944 and personal observations). This goby spawns from February through April and is the most dominant fish species within *Zostera* beds in the bay, and is frequently observed to hover in the water column over the vegetation (Mori, unpublished). Length compositions of the above two species of gobies found in the stomachs (Fig. 12) reflect the length compositions of these species in September and October and show that most of *Acentrogobius pflaumi* were juveniles of the year, but rarely one year old individuals were present.

Among macrurans, *Alpheus brevicristatus* was the most dominant food item and comprised a significant portion in the weight of total crustaceans in all four lots. This snapping shrimp is benthic and has burrowing behaviour (Harada, 1968, 1969). Hippolytid shrimp, the majority of them *Latreutes acicularis*, were quite high in frequency, although they were not significant in weight, due to their small sizes. This shrimp is abundant in the *Zostera* beds in the bay all year round (Kojima and Hanabuchi, 1981). The microhabitat of this and other hippolytid shrimps is the surface of *Zostera* blades, where they feed on detritus and sessile microalgae (Kikuchi, 1966).

Feeding habit: Food organisms found in the stomachs of day-caught fish were in much better condition in general than those found in night-caught fish. The ratio of almost intact food organisms was higher in daytime specimens, suggesting that the fish feed actively during daytime, but not during the night.

The high frequencies of occurrence of *Acentrogobius pflaumi* and *Alpheus brevicristatus*, both benthic in habit, indicate the fish feed on

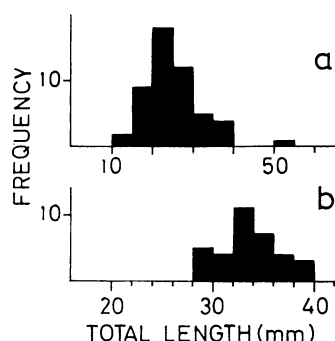


Fig. 12. Length frequency distributions of *Acentrogobius pflaumi* (a) and *Chaenogobius heptacanthus* (b) found in the stomachs of *Lutjanus vitta* caught in *Zostera* bed.

the sea bottom. Fragments of rotten leaves of *Zostera marina* found in 13 stomachs also support this. High frequencies of occurrence of *Latreutes acicularis* indicate feeding among the blades of *Zostera marina*. In contrast, high frequencies of *Chaenogobius heptacanthus* suggest feeding in the water column. Thus, the diversity in the microhabitat of major prey species suggests that the fish is flexible in its feeding strategy, and that the fish covers more than one feeding site or microhabitat.

Discussion

Larval characters of genus *Lutjanus* and their similarities with those of subfamily Epinephelinae. Larvae and juveniles of several species of *Lutjanus* have been illustrated and described. Uchida (1937) illustrated a larva of *Lutjanus* sp. (5.0 mm TL) from Japan but did not provide a description. Starck (1964) described juveniles of *L. griseus* from the western North Atlantic, and Richards and Saksena (1980) described laboratory-reared larvae and juveniles of the same species. Collins et al. (1980) described larvae and juveniles of *L. campechanus* from the Gulf of Mexico, and Rabalais et al. (1980) described eggs and early larvae of the same species. Heemstra (1974) re-examined Fowler's (1944) specimens from the eastern Pacific and the Caribbean, and identified juveniles of *L. jordani* (19.9 mm), *L. aratus* (18.2 mm), and *L. synagris* or *L. mahogani*. Fahay (1975) illustrated a "postlarva" of *Lutjanus* sp. (14.2 mm FL) from the western north Atlantic. Fourmanoir (1976) described an early juvenile of *Lutjanus* sp.

(probably *L. bohar*) from the western South Pacific. Musiy and Sergiyenko (1977) described juveniles of *Lutjanus* sp. from the Gulf of Aden.

All these descriptions show that the larvae and early juveniles of *Lutjanus* are similar, and most of the characters observed in *L. vitta* are shared by those other species in the genus. They all possess stout, elongate second dorsal and pelvic spines, and a long second anal spine. In some species these elongate spines are serrated. Dorsal and pelvic fins form early, with the anterior-most several spines forming first in the dorsal fin. The first pelvic ray is much longer than the spine in many species (*L. vitta*, *L. campechanus*, *L. aratus*, *L. jordani*, and *L. synagris* or *L. mahogani*). In *L. bohar* and *L. griseus*, the rays are not elongate but subequal to the spine in length. In the head region, spines are developed on the posttemporal, supracleithrum, postcleithrum, preoperculum, operculum and interoperculum. Some species have serrate bony ridges above the eyes. In larvae and early juveniles, the body is deep and heavily compressed. Pigment is scarce in general and confined to the surface of the skull, cleithral symphysis, vicinity of anal opening, ventral edge and lateral surface of the caudal peduncle, abdominal cavity lining and some portions of the fin membranes.

It may be pointed out that the larvae of the above species are also similar to those of subfamily Epinephelinae of Serranidae. Kendall (1979) made a comprehensive review of epinepheline larvae and pointed out precise similarities within the subfamily (genera *Paranthias*, *Epinephelus*, and *Mycteroperca*). Later publications on larvae of *Epinephelus tauvina* (Chen et al., 1977; Hussain and Higuchi, 1980) and observations on reared *E. microdon* (Mori, unpublished) agree with Kendall's conclusion. Larvae of the genus *Lutjanus* and the subfamily Epinephelinae are different in the following characters. Elongate spines in the fins are either smooth or finely serrate in *Lutjanus* whereas they are either finely or deeply serrate in Epinephelinae. The supraorbital ridge forms a triangle only in early larvae of Epinephelinae. Preopercular spines are smooth in *Lutjanus*, but are serrate in Epinephelinae. Pelvic rays are extremely elongate or at least subequal to the spine in *Lutjanus*, whereas they are much shorter than

the spine in Epinephelinae. All of these differences seem relatively minor, and the strong resemblance of larvae of *Lutjanus* to those of Epinephelinae are believed to be an example of convergence which occurred independently in relation to ecological adaptations to prolonged planktonic lives, since phyletic closeness of these two groups were not suggested by an extensive taxonomic study on lutjanid fishes (Johnson, 1980). The diversity in the degree of larval development of fin spines in *Lutjanus* may support this conclusion.

Inter-relation between morphological and ecological changes. The largest specimen caught by larva net was 4.8 mm NL (5.3 mm TL), thus the fish of this size and smaller are planktonic and are distributed in the open sea, mainly. The scarcity of the fish in the plankton net catch may support this speculation. The rapid growth in some of the spines and rays in fish smaller than 7 mm SL are believed to provide them with protection from predation (Moser, 1981), which also might help in the dispersion of the fish by allowing it to cover some distance, drifting in the water current and using the elongate fin elements as a sea-anchor. But their rapid growth also results in an excess at the end of the growth stanza. Extremely elongate spines and rays may act as a drag for the free swimming fish and thus hinder shoreward migration.

The smallest fish caught by seine was 5.3 mm SL (6.6 mm TL), but the bulk of the fish thus caught were larger than 7.0 mm SL (ca. 9.0 mm TL) (Fig. 9). It is highly probable that the fish acquire free-swimming ability gradually from about this length (7.0 mm SL) and migrate into the bay. The growth inflexion at 7 mm SL and successive negative growths in some of the fin elements until fish reach 16 mm SL (20 mm TL) reduce these parts proportionally and streamline the fish during its migration to shallow waters.

Fish over 16 mm SL (20 mm TL) appear to become less vulnerable to the seine, and fish over 24 mm SL (30 mm TL) were virtually absent in the catch except in rare cases. The big catches of fish larger than 40 mm TL by seine (in early September and October 1977) occurred when the seine happened to hit the edges of the grass beds where the fish were abundant. Horizontal movement of the fish out of the area

sampled by the seine is a plausible explanation for this, because the seine would have caught them if they were present there whether they are pelagic or demersal. At about 16 mm SL an inflexion occurs and reduction of the spines accelerates until 32 mm SL, producing a body form suitable for demersal life.

Within the grass bed, however, the trawl did not catch fish smaller than 24 mm SL (30 mm TL). Considering the facts that the same gear caught a quantity of *Pagrus major* larger than 15 mm TL and also that *L. vitta* has a deeper body and is equipped with elongate fin spines, its absence in the catch can not be explained from the size-selectivity of the gear. It is a more plausible interpretation that the fish remained pelagic even after moving into the grass beds.

The trawl caught fish larger than 24 mm SL (30 mm TL), which indicates that the fish become benthic, at least partly, at this size. At about this length the fish attain the specific pigmentation pattern including the stripe with a prominent blotch.

Fish caught by trawl most often measured about 32 mm SL (40 mm TL) or larger, and they become fully benthic at this size. This length also coincides with another growth inflexion or the completion of the growth stanza in which the rapid growth in the fin elements is reduced.

As shown above, the changes in morphology, especially the relative growths of the spines, coincide with ecological changes such as the

mode of swimming and the horizontal and vertical movement of the fish as summarized (Table 5). This will partly support the statements of Martin (1949) and Ochiai (1970) that growth inflexions are approximately coincident with either ecological or physiological changes in fishes. It is not plausible, however, to associate gradual processes which take time, such as transition from a planktonic to a free-swimming mode, and from a pelagic to a benthic mode with growth inflexions which are somewhat instantaneous. Instead, these gradual processes will be interpreted as associated with growth stanzas. In this case each growth inflexion is thought to indicate the onset and completion of an ecological change.

At about 10 mm SL (ca. 12 mm TL) the fish grow to the juvenile stage from the larval stage. This falls in the midst of the second growth stanza and no apparent ecological change was observed at this length. A similar discrepancy was observed also in *Scomber japonicus* (Watanabe, 1970). The facts suggest that the relative growth of swimming apparatus is a better indicator for detecting ecological changes of fish than the criteria for developmental stages which are based on the attainment of adult complements in fin ray counts (Uchida and Dotsu, 1958).

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Table 5. Possible correlations between the relative growths of fin elements (Fig. 8 and Table 3) and ecology in *Lutjanus vitta*.

Length (mm) SL (TL)	Direction of growth inflexion	Relative growth coefficient	Mode of swimming or vertical movement	Habitat or horizontal distribution
		Highly positive	Planktonic	Open sea
7 (9)	Downward	Negative	Semi-planktonic to free swimming	Migrate into bay, accumulate in shallow waters
16 (20)	Downward	Highly negative	Free-swimming, semi- benthic at over 24 mm SL (30 mm TL)	Move into grass bed
32 (40)	Upward	Slightly negative	Benthic	Grass bed

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日本海・油谷湾におけるヨコスジフエダイの初期生活史

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山口県西部, 日本海側の油谷湾において稚魚網, 船曳網, 底曳網により採集された材料にもとづき, ヨコスジフエダイの仔・稚・幼魚期における形態変化, 体各部位の相対成長, 生態, 食性について記載した。本種の仔・稚魚では背鰭第2棘, 腹鰭棘および腹鰭第1

軟条が著しく伸長し，若干の頭部棘も発達する．これらの部位はむしろ仔魚期に発達し，その後相対的に縮少，あるいは絶対値が減少する．これらの部位の相対成長における変化は生態の変化とよく対応している．全長 20 mm 前後で浅所のアマモ場に移動し，30 mm 前後で底棲となる．幼魚は海底，アマモ葉上，水中で

小型ハゼ類，小型甲殻類を食う．

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