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Osteology of Bluegill Sunfish, *Lepomis macrochirus* RAFINESQUE

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(Figs. 1–5; Tables 1–6; Plates 1–3)

Bluegill sunfish, *Lepomis macrochirus* RAFINESQUE, has 'distributed widely' in the various districts of Japan since the time The Crown Prince Akihito transplanted it into this country from the United States in October, 1960[1].

Recently, at several research institutions in Japan, bluegill is being used as an experimental animal. The idea is to make it a standard experimental animal in the fisheries research[2]. The use of bluegill in fisheries research, in fact, has several obvious reasons. It is a freshwater fish, has a handy size and its maintenance in the experimental tanks or aquaria is easy. Moreover, being a member of the Centrarchidae family, it represents a typical example of teleostean fish.

Bluegill, as an experimental animal now, necessitates a thorough investigation to be made upon its morphological, physiological and biological normalities. In other words, there is a need to know what a normal bluegill actually is. In the literature while basic informations regarding biology of bluegill are available in considerable detail, morphological and physiological informations are scarce. In response to this need, therefore, the present authors decided to make a comprehensive study upon its various morphological and physiological aspects. This illustrated and statistically analysed description of the osteology of bluegill, is a part of such studies.

That the osteology has a great value in determining the relationships of fishes, is a too well known fact to need elaboration. The present authors are of the opinion that apart from its taxonomical value, osteological knowledge based on statistical analysis is of immense importance in securing the needed insight in the problem of natural coordination formed between the skeleton and the other organs in the fish. In the case of experimental animals particularly, such insight is rather obligatory to facilitate their meaningful surgery in the research laboratories. It was in this frame of mind that the present study was initiated.

Detailed osteology of bluegill has not been attended in particular as yet. Even upon the Centrarchidae as a whole, there is a considerable paucity of osteological informations. Researchers, working on the systematics of centrarchid fishes, have felt a need to make a comparative osteological study based upon statistical analysis in order to depict the relationship of all members of the Centrarchidae family[3]. The following account is supposed to fulfil a part of all such needs.

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MATERIAL AND METHODS

A total of 100 specimens of bluegill, ranging from 3.22 to 17.02 cm in standard lengths, were used for the detailed study of osteology. These specimens were obtained from the Osaka Prefectural Freshwater Fish Experiment Station, Hiroshima Prefectural Fisheries Experimental Station, and from the experimental tanks of the Aquaculture laboratory of our department. Gross studies on the skeletal structure were made by the commonly used boil-and-clean technique. Dissection and disarticulations were performed under the dissection microscope. To study the orientation of smaller osseous elements, specimens were stained in toto by the alizarine method of HOLLISTER (1934)[4] as modified by EVANS (1948)[5]. X-ray photographs of all the individual specimens were taken by Softex, Model-CM (Nippon Softex Co., Ltd.). Fuji X-ray films (Kx) 12×16.5 cm, were used. In general, X-ray exposure conditions of 56 kV and 6.2 mAS for bigger specimens (body width about 2.70 cm), 46 kV and 3.2 mAS for medium sized specimens (body width about 1.30 cm), and 42 kV and 0.8 mAS for very small specimens (body width about 0.50 cm) at a focus-film distance of 45 cm, gave satisfactory results. MURACHI (1966)[6], however, stated different exposure conditions for more or less similar body widths of rainbow trout which might be due to the differences in the materials and the X-ray films used in the two studies. Measurements were made from the X-ray photographs on the lines shown in Plate 1(a) by using a caliper, the vernier of which allowed us to measure the fractional parts of a centimeter up to two decimal figures. Meristic measurements were made by the standard methods described by HUBBS and LAGLER (1964)[7]. Popularly used nomenclatures have been used to describe the details. To avoid confusion, terms are indicated in the figures and plates. X-ray photographs of some other centrarchid fishes (Table 1) were also taken for comparison. These specimens were procured from Michigan in the year 1969.

OBSERVATIONS

Except for otoliths, neither the components of cranium nor the components of post-cranial axial skeleton were found to be heavily ossified. Orbital cavity was moderately large with anterior and posterior portions of cranium fairly abbreviated. Cranium was observed to be broadest between the tips of the lateral line element of pterotics which represents the cranium width of the present study.

The percentage mean values of various skeletal proportions of bluegill with their standard deviations are presented in Table 1. It can be seen there that some proportions have a significantly high range of standard deviations. More obvious among them, the proportions of cranium height and cranium width to the cranium length revealed to bear correlation with the size of the fish. For instance, in smaller specimens (SL about 5.00 cm), the cranium height was found to be about 30% of the cranium length, whereas, in bigger specimens (SL about 15.00 cm), the same went upto 60%. Similarly, in the case of cranium width, such range of percentage was found to fluctuate from 40 to 60%. Plots of these measurements (Fig. 1b&c) further confirmed these findings to be true by showing the lines of regressions intercepting the Y-axis on the negative sides at significantly low levels of -0.38 and -0.37 cm for cranium height and width respectively. From these findings it can be construed that height and width of the cranium become more

Table 1. Mean values of various skeletal proportions of bluegill and some other centrarchid fishes. Values are expressed in percentage with their standard deviations.

Common name-	Bluegill	Pumpkin seed	Green sunfish	Northern longear sunfish	Warmouth	Black crappie
Species-	(*Lepomis macrochirus*)	(*Lepomis gibbosus*)	(*Lepomis cyanellus*)	(*L. megalotis peltastes*)	(*Chaenobryttus gulosus*)	(*Pomoxis nigromaculatus*)
Number of specimens-	100	13	2	2	1	2
Cranium length/Standard length	27.47±2.11	29.31±1.11	31.00	28.00	32.00	30.00
Cranium height/Cranium length	48.32±9.57	54.23±2.20	36.50	50.00	37.00	33.00
Crest height/Cranium height	61.97±5.47	—	—	—	—	—
Cranium width*/Cranium length	50.30±6.69	—	—	—	—	—
Interorbital width/Cranium width	76.65±7.22	—	—	—	—	—
Preorbital length/Cranium length	27.95±1.62	29.08±1.32	30.50	32.00	27.00	26.50
Eye-socket diameter/Cranium length	37.30±2.77	34.69±3.07	37.00	37.50	35.00	40.50
Postorbital length/Cranium length	34.22±2.39	35.46±2.23	33.00	36.00	37.00	33.00
Maxillary length/Cranium length	34.96±3.47	34.08±2.78	41.00	42.00	48.00	45.50
Mandible length/Cranium length	48.21±4.02	44.46±2.29	55.00	52.50	55.00	59.50
Standard length/Total length	78.89±2.22	81.00±0.00	—	82.00	—	—
Furcal length/Total length	95.27±1.37	—	—	—	—	—
Skeletal height in caudal peduncle/ Caudal peduncle height	67.98±3.95	61.62±4.66	62.50	62.50	73.00	63.00
Predorsal length/Standard length	41.52±1.18	43.08±1.22	47.50	44.50	47.00	48.00
Preventral length/Standard length	42.74±1.47	44.15±1.57	42.00	43.00	43.00	39.50
Prepectoral length/Standard length	34.39±2.79	34.69±0.77	38.50	36.50	40.00	35.50
Preanal length/Standard length	64.52±1.61	65.38±0.83	63.50	65.00	69.00	54.50
Length dorsal fin base/Standard length	46.54±3.59	47.69±1.45	47.00	47.00	43.00	35.50
Length anal fin base/Standard length	23.66±2.71	21.54±1.03	19.50	21.50	—	—
Skeletal height of the body**/Standard length	44.86±4.58	46.15±1.46	43.50	46.50	42.00	40.50

* Cranium widths were calculated using a correction factor, 0.86 of head width, which was found out from the data available for cranium widths.

** Skeletal height of the body can also be referred to as body height, for there is hardly any difference between the heights of two.

pronounced as bluegill grows. To find out which component actually influences the height of the cranium to grow at a faster rate, a doubt was thrown upon the supraoccipital crest. Measurements of the crest (from the tip of the epiotic to the dorsal tip of the supraoccipital crest) were taken and analysed. It was found out that the crest contributes to the cranium height proportionately (Fig. 1f).

Fluctuations observed in the mean values of other proportional measurements did not appear to indicate any correlation with the size or sex of the individuals. Plots of some of the measurements with formularized expressions of their relationships are presented in Fig. 1a-f.

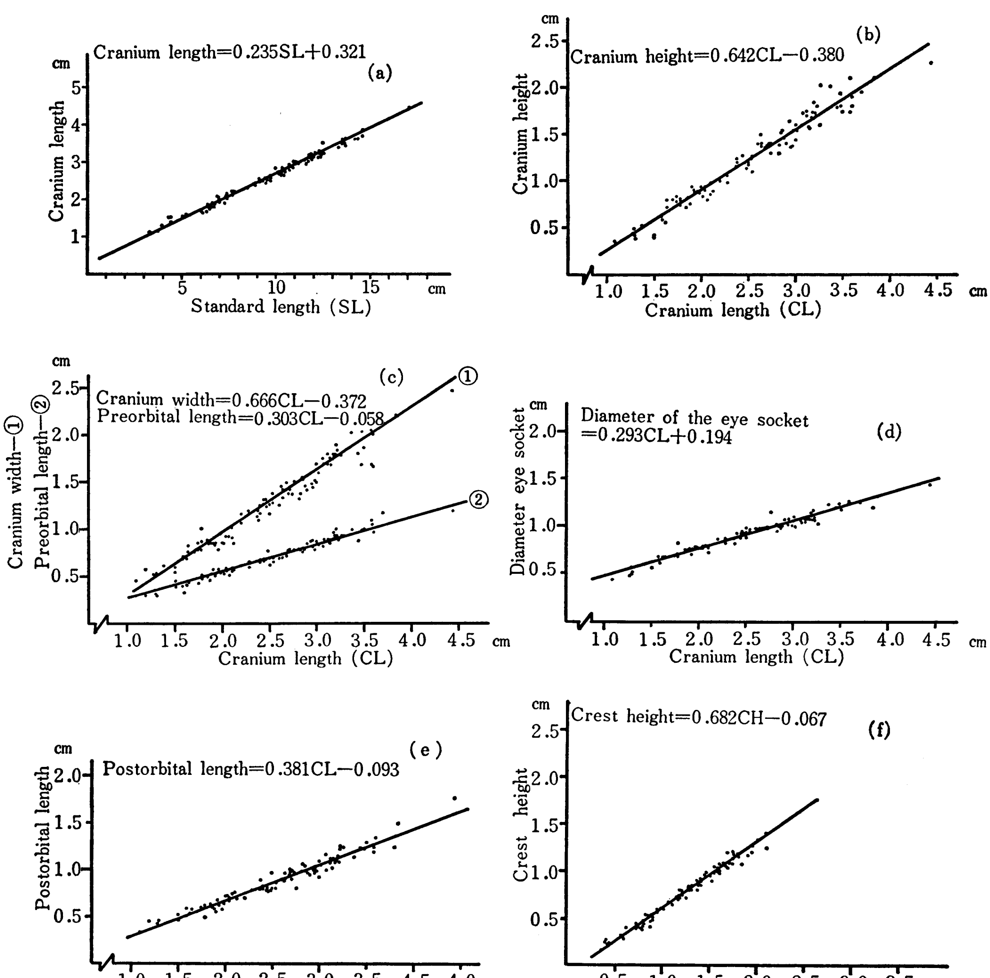

Fig. 1. Plots showing relationships between various skeletal proportions of bluegill, with their formularized expressions. (a), standard length and cranium length; (b), cranium length and cranium height; (c), cranium length and cranium width (1), cranium length and preorbital length (2); (d), cranium length and eye-socket diameter; (e), cranium length and postorbital length; (f), cranium height and crest height.

1. CRANIUM (Neurocranium)

Dorsal, ventral, lateral, and posterior aspects of the cranium of bluegill have been delineated in Fig. 2A-D. In the following description, abbreviations used to indicate the cranium components in Fig. 2 have been referred. Unless stated otherwise all the bones described in the account are paired. Details regarding the sensory canal system have been omitted from the account since our findings stay in agreement with those stated by BRANSON and MOORE (1962)[8].

Olfactory region:

The **nasal** (Plate 1b, NA) is a tubular structure loosely bound to the cranium by connective tissue lying on either side of the ascending process of permaxillary. Posteriorly, it is trimmed in a manner to receive the sensory canal coming from the frontal.

The **vomer** (V), an unpaired bone forming the front contour of the cranium, consists of a long ventral and two short lateral processes. These processes together form a hollow concavity to cap the anterior tip of the rostral-cartilage lying between mesethmoid and vomer. The ventral long process, forming the anterior floor of the cranium, reaches approximately upto 1/3 of the length of parasphenoid. Conical teeth are borne on its anteroventral edge.

The unpaired **mesethmoid** (ME) is largely cartilagenous with only a small ossified portion at its anterodorsal exposed surface. The posterior 2/3 part of its dorsal surface remains concealingly accommodated beneath the anterior edge of frontals. It bears two wing-like lateral expansions covering the posterior tips of respective prefrontals. Ventrally, it bears anterior myodome for eye-muscles.

The rostral-cartilage (RC) serves as a key-stone between vomer, mesethmoid and prefrontals. Its anterior tip is capped by the hollow concavity of vomer, laterally, it is attached to the inner borders of prefrontals, and posterodorsally, it bears a shallow depression upon which rests the ossified portion of mesethmoid. Ventrally, it has a fine groove for the dorsal ridge of parasphenoid.

The **prefrontals** (PF) are irregularly-shaped bones with wide inner borders capping the posterolateral edges of the rostral-cartilage. Anteriorly, they form the rear margins of the olfactory capsules and posteriorly, a part of the anterior rims of eye-sockets. Their posterior tips are hidden beneath the overhangings of frontals. Anterolateral tips have condyles to fit into the sockets of lachrymals. A formamen passes through each prefrontal for the olfactory nerve.

Orbital region:

The **frontals** (F) form the entire roof of the skull above the orbit. Anteriorly, they overlap the mesethmoid and prefrontals. The lateral edges form the upper rims of the eye-sockets. The posterolateral extentions are united to the sphenotics and posteriorly, they attach to the parietals. Two frontals unite medially forming a V-shaped notch posteriorly to receive the anterior tip of the supraoccipital. A ridge runs across the frontals starting from their posterolateral corners and joining in the middle in front of the supraoccipital. This ridge, which in fact runs over the course of the sensory canal (OSC I-OSC IV), actually depicts the extent to which the musculus lateralis is extended over the cranium in bluegill. Altogether the first three myomeres of the musculus lateralis fall upon the cranium, of which the first two start from this ridge of the frontal.

The **alisphenoids** (AS) are small triangular structures descending from the frontals into the posterodorsal region of the eye-sockets. They articulate laterally, with the

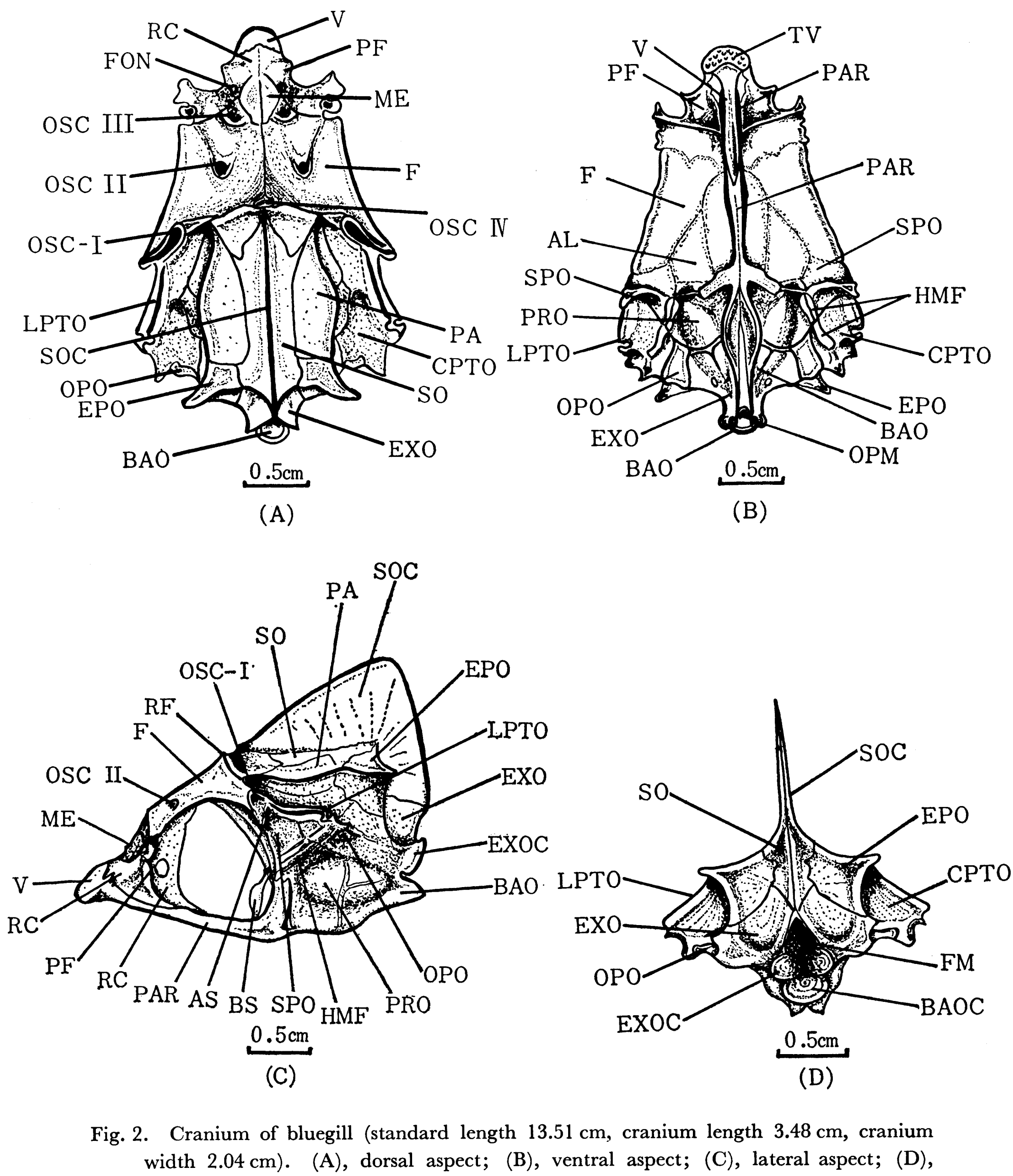

Fig. 2. Cranium of bluegill (standard length 13.51 cm, cranium length 3.48 cm, cranium width 2.04 cm). (A), dorsal aspect; (B), ventral aspect; (C), lateral aspect; (D), posterior aspect.

AL, alisphenoid; BAO, basioccipital; BAOC, basioccipital condyle; BS, basisphenoid; CPTO, cranial element of pterotic; EPO, epiotic; EXO, exoccipital; EXOC, exoccipital condyle; F, frontal; FM, foramen magnum; FON, foramen for olfactory nerve; HMF, hyomandibular facet; LPTO, lateral line element of pterotic; ME, mesethmoid; OPM, opening in the posterior myodome; OPO, opisthotic; OSC I–IV, openings of sensory canal; PA, parietal; PAR, parasphenoid; PF, prefrontal; PRO, prootic; RC, rostral cartilage; RF, ridge across frontals; SO, supraoccipital; SOC, supraoccipital crest; SPO, sphenotic; TV, toothed anteroventral border of vomer; V, vomer.

sphenotics and ventrally, with the prootics.

The **basisphenoid** (BS) is an unpaired Y-shaped bone. The two arms articulate with the anterolateral edges of the floor of the cranium cavity i.e. with the prootics. The median ventral leg is connected to the parasphenoid. The triangular space left between the two oblique arms and the floor of the cranium cavity, is lined by a thin cartilagenous membrane.

The **lachrymals** (Plate 1b, LR) are rectangular bones neatly patched at the dorsolateral spaces of the snout concealing the lateral accessory pouch of the olfactory capsule. The posterior edges are involved in forming the anterior rims of the eye-sockets. The anteroventral margins are gently serrated and the upper posterior corners are markedly pronounced. At the posterodorsal corners, they bear sockets to receive the condyles of the prefrontals.

Following the lachrymals, are **suborbitals** (Plate 1b, SO) varying from six to seven in number. When only six, fusion was found to be formed between the 1st and the 2nd ones. The 1st one of the series, also referred to as jugal, is a very small bone. The other suborbitals following it, gradually increase in size posteriorly forming the lower rim of orbit of fairly tubular nature. The flanges of the suborbitals, in fact, hardly unite to form the true tubes. The last suborbital, also referred to as dermosphenotic, is a funnel-shaped bone. It rests on the sphenotic.

Alizarine preparations revealed the presence of ossified saucer-like **sclerotic plates** imbedded in the sclera of each eye ball, one on the anterior surface and an other on the posterior.

Otic region:

The **parietals** (PA), lying behind the frontals, form the major portion of the temporal crest. Two parietals remain apart from each other due to the intervention of the supraoccipital. Posteriorly, parietals are firmly fused to the epiotics.

The **sphenotics** (SPO), attached to the posterolateral edges of the frontals, form the posterodorsal rims of the eye-sockets. Ventrally, they are united to the prootics and complete the anterior portion of the hyomandibular facets of each side. The ventromesial surfaces are bounded by the alisphenoids and the posterior surfaces, by the pterotics.

The **prootics** (PRO) are fairly large bones attached dorsally to the sphenotics and the pterotics and posteriorly to the basioccipital and the exoccipitals. The prootic of each side sends off bony projections inward which meet medially forming the anterior floor of the cranium cavity. Ventrally directed flanges of prootics are overlapped by the dorsal outgrowths of the parasphenoid. Anteriorly, the prootics are attached to the oblique arms of the basisphenoid and bear foramen for the trigeminal nerve. Anterior and lateral faces of the prootics are partially divided by a vertical bony strut hanging from the lower corner of the hyomandibular facet and joining below at the root. The prootics are swollen posteriorly forming the anterior halves of the auditory capsules. Together with the parasphenoid and the basioccipital, the prootics form a portion of the posterior myodome.

The cone-shaped **epiotics** (EPO) foming the end portions of the temporal crest, provide attachment surfaces to the anteriorly directed prongs of posttemporals. Anteriorly, they are united to the parietals and posteriorly to the exoccipitals. The two epiotics are separated from each other through the supraoccipital. The epiotics touch the pterotics at the tripartite junction of the epiotic, the pterotic, and the exoccipital. Their direct contact is prevented by a cartilagenous line.

The **pterotics** consist of two elements: a lateral line element (LPTO) and a cranial element (CPTO). The former, immovably fused with the latter, remains open throughout its entire length forming the lateral aspect of the pterotic complex. The latter articulates with the sphenotic anteriorly, the prootic anteroventrally, the opisthotic and the exoccipital posteriorly. The pterotics bear facets at the ventrolateral surface forming the posterior half of the hyomandibular facet of each side. Internally, they have deep sockets for the lateral semicircular canal.

The **opisthotics** (OPO) rest on the anterolateral flanges of the exoccipitals and remain concealed dorsally by the posterior projections of the pterotics which meet with the exoccipitals. Posteriorly, they have a prominent notch where the ventral prongs of the posttemporals are attached to them by strong ligaments.

The **supraoccipital** (SO) is an unpaired bone covering the posterodorsal surface of the cranium. A crest ascends steeply from the anterior tip of it and ends above the opening of the foramen magnum (FM). Anteriorly, it is attached to the frontals, laterally, to the parietals and posteriorly, to the epiotics and the exoccipitals. Out of the three myomeres of the musculus lateralis extended over the cranium of bluegill, the 3rd one is attached to the crest of the supraoccipital.

The **exoccipitals** (EXO) are large strongly convoluted bones forming the greater part of the rear of the cranium. Dorsal wing from each, unite over the foramen magnum but the complete fusion is prevented by a cartilagenous line. Ventrally, however, they are in complete fusion forming a pair of articular surfaces (EXOC) for the articulation with the atlas of the 1st vertebra. Dorsally, they are attached to the epiotics, and the pterotics, anteriorly, to the opisthotics and the prootics and ventrally, to the basioccipital. At the dorsolateral angle and anteroventral space, they bear prominent foramina for the vagus and glossopharyngeal nerves respectively.

The **basioccipital** (BAO) is an unpaired bone which forms the rear side of the floor of the cranium cavity. Its ventral flanges, covered by the rear portion of the parasphenoid, constitute the rear end of the posterior myodome. Together with the exoccipital, it forms the posterior half of the auditory capsule. Posteriorly, it is modified (BAOC) in order to articulate with the 1st vertebra.

The **parasphenoid** (PAR) is a long gently curved unpaired bone extending along the entire mid line of the ventral surface of the cranium. The anterior 2/3 length rests on the ventral process of the vomer supporting the roof of the mouth. Its paired dorsal outgrowth overlaps the ventrally directed flange of the prootic. Posteriorly, it goes over the ventral flage of the prootics and basioccipital forming the floor of the posterior myodome. It has a bifurcated rear tip which leaves an opening in the posterior myodome.

2. BRANCHIOCRANIUM

The hyoid arch (Plate 1c):

The hyoid arch is articulated to the hyomandibular and symplectic through the intermediation of samll **interhyal** (IH). Alizarine preparations revealed that in smaller individuals, interhyal is largely cartilagenous.

The **epihyal** (EH) is a fairly large triangular bone with a facet at the posterior end to receive the thickened lower extrimity of interhyal. Its broad anterior margin bears bony processes to interdigitate with bony processes borne on the posterior margin of the ceratohyal.

The **ceratohyal** (CH) is an hour-glass-shaped bone bearing a big fenestra dorsally. Complete fusion by interdigitation between the ceratohyal and the epihyal is prevented by a cartilagenous line. Bony processes are borne on its anterior margin also to interdigitate with the hypohyal.

The **hypohyal** (HH) is a small roughly rectangular bone divided into upper and lower halves by means of a distinct suture. The upper half bears bony processes to interdigitate with the ceratohyal and the lower half is modified to receive the bony projections of the ceratohyal.

The **basihyal** (Plate 1d, BH) is an unpaired bone supporting the tongue. It serves as a key-stone where the upper halves of the hypohyals on two sides join. The basihyal bears no teeth, representing one of the characteristic features of the genus *Lepomis*[7].

The **branchiostegals** (BS) were observed to be mostly six in number. However, a variation ranged from 5 to 7 indicating no correlation to the size or sex of the fish. The branchiostegals are all sabre-shaped increasing in length and width posteriorly. The most posterior one is rooted in the facet slightly lateral to the anteroventral margin of the epihyal. The preceeding two find their places at the junction of the caratohyal and the epihyal. The rest of the anterior ones are attached to the ventral margin of the ceratohyal.

The **urohyal** (Plate 1d, UH) is a large unpaired bone providing common bases for the attachment of the hypobranchials and the ligaments from the lower hypohyals.

The branchial arch (Plate 1e):

Three unpaired **basibranchials** (BBR) lie in the midventral line of the pharynx tightly articulated to each other. The 1st one is a small, laterally flattened bone lying between the hypohyals. The 2nd one is more or less like a tubular rod and the 3rd one, the longest of all, has a broad anterior and pointerd posteior extrimities. None of the basibranchials bear teeth.

Three **hypobranchials** (HBR) are tiny bones belonging to the 1st three branchial arches. The 1st one fits into a notch at the lateral edge of the 2nd basibranchial. The 2nd one is attached in a similar manner between the 2nd and the 3rd basibranchials. The 3rd one is the shortest of all and bears a marked basal extention anteroventrally. It is attached to the posterolateral edge of the 3rd basibranchial.

Four slender **ceratobranchials** (CBR) together with three hypobranchials, form the lower half of the branchial arch. They have longitudinal grooves along the ventral surfaces to room branchial arteries. The 1st three ceratobranchials are attached to the respective hypobranchials but the 4th one is attached to a cartilagenous mass.

The **infrapharyngeals** (IPH) are roughly triangular bones bearing heavy patch of teeth dorsally. These toothed surfaces are contiguous with each other at mid line. The teeth towards the mid line are generally larger than the remaining portion.

The 1st of the four **epibranchials** (EBR) is the longest and bears a branch-like process which extends over the upper portion of the 2nd epibranchial. The 2nd one is slightly smaller than the 1st one bearing no such marked process. The 3rd one is smaller than the preceeding two and has marked branching which goes over the lower portion of the 4th epibranchial. Smallest of all is the 4th epibranchial which bears a blunt protuberance at its lower tip pointing posteriorly. The epibranchials are completely devoid of any tooth plate. They bear deep grooves dorsally to room branchial arteries.

The **suprapharyngeals** (SPH) are four in number. The 1st one is a thin rod-shaped bone attached dorsally to the cranium at the ventrolateral margin of the prootic.

The 2nd one bears about 10–12 teeth arranged in two rows on its ventral surface. The 3rd one is a broad, roughly triangular tooth plate bearing about seven rows of teeth ventrally. The 4th one is a round tooth plate bearing numerous sharp teeth ventrally. The tooth plates of the 2nd, 3rd, and 4th suprapharyngeals together form a congtiuous patch of teeth just opposite to the tooth plates of the infrapharyngeals.

The **gill rakers** are attached in two rows on the outer and inner edges of the first four branchial arches. Those on the outer row of the 1st one, are long being longest at its distal half. The remaining rows have small gill rakers. Gill raker counts in the present study, ranged from 8 to 11 on the lower half and 3 to 5 on the upper, revealing no relation with the sex or size of the fish. Gill teeth, observed on gill rakers were found to be too short to form effective sieves to strain minute organisms suggesting that bluegill does not depend much on planktonic diet.

Opercular series (Plate 2a):

The **preopercular** (PO) is a crescentric bone lying anterior to the opercular. The anterior margin of its upper limb which is deflected from its lower part at an angle of about 95 degrees, remains tightly articulated with the posterior edge of the shaft of the hyomandibular. The lower limb which is shorter than the upper one, extends forward as far as the suspensory angle of mandible. Anteriorly, at the angle of lower and upper limbs, it has a thin bony sheet overlying the ventral end of the shaft of the hyomandibular. Serrations at the posteroventral margin revealed no relation with sex or size of the fish.

The **opercular** (O) is the largest bone of the opercular series. Posteriorly, it extends almost up to the margin of the ear flap being very flexible and ragged at its caudal margin depicting one of the identifying characters of this species[7]. It bears a marked facet for the opercular process of the hyomandibular. This facet is supported by two bony struts, one of which extends posteriorly and the other runs ventrally along the anterior rim of the opercular.

The **interopercular** (IO), bearing smooth margin, is almost completely overlapped by the preopercular except for a little ventral portion forming the anteroventral margin of the opercular series. Anteriorly, it is attached to the mandible by means of a ligament and posteriorly, it slightly overlies the anteroventral portion of the subopercular.

The **subopercular** (SO), lying internal to the opercular, forms the posteroventral margin of the opercular series. The posterodorsal tip is flexible and ragged like that of the opercular. It bears a small process extending anteriorly in front of the opercular.

Bones of the opercular series, when nicely cleaned, present clear growth rings formed by alternate translucent and transparent zones. The rings are remarkably clear on the interopercular.

Suspensorium (Plate 2a):

The **hyomandibular** (HY) srves as the key bone of the suspensorium. It is a flat wedge-shaped structure with wide uncondyled upper margin attached to the cranium in a facet formed by a fusion of the sphenotic, the prootic, and the pterotic (Fig. 2B, HMF). Below this margin, it has a condyle to fit into the facet of the opercular. Slightly below this, opens a small foramen for the hyomandibular branch of the facial nerve. It runs ventrally into a bony tube that traverses along the entire shaft of the hyomandibular, opening ultimately through a small pore near the ventral tip. Posteriorly, it is tightly attached to the preopercular and anteriorly, to the metapterygoid. Ventrally, it is connected to the symplectic and the interhyal by means of connective tissues and cartilage.

The **symplectic** (SY), a tiny pin-shaped bone, joins the hyomandibular dorsally. Its lower end fits into a notch of the quadrate.

The **quadrate** (Q) is a fan-shaped bone with solidly ossified upper and lower rims. The stout base remains ankylosed with the articular. The upper rim is attached to the pterygoid and the lower rim receives the lower limb of the preopercular and the symplectic. Posteriorly, it is attached to the mesopterygoid and the metapterygoid through a cartilagenous line.

The **metapterygoid** (MET) articulates posteriorly to the hyomandibular leaving a tubular space along the shaft of the latter to make room for the hyoidean artery. Ventrally, it is bound by the quadrate, the symplectic, and the mesopterygoid.

The **mesopterygoid** (MES) forms the major portion of the floor of the eye-socket and joins in the middle with its counterpart through a membrane, forming the roof of the buccal cavity. Ventrally, it is attached to the pterygoid and the quadrate through the intermediation of a cartilagenous line. Posteriorly, it is slightly overlapped by the metapterygoid. The mesopterygoid bears no teeth in bluegill.

The **pterygoid** (PT), a tiny sickle-shaped structure completely devoid of any teeth, attaches to quadrate and the mesopterygoid. It meets the palatine dorsally.

The **palatine** (PAL), devoid of any teeth, is a narrow bone which sends off a process dorsally for maxillary. Posteriorly, it is attached to the prefrontal and ventrally, to the pterygoid and the mesopterygoid.

The **premaxillary** (Plate 2b, PM), conjoined in mid line through their ascending process, make a half moon-shaped upper margin of the mouth bearing villiform teeth along their oral border. The ascending process is about half the length of the body of the premaxillary and is deflected from it at an angle of about 95 degrees. At this angle, it bears an attachment surface for the maxillary.

The **maxillary** (Plate 2b, M) bears no teeth and takes no part in the formation of the edge of the mouth. Dorsally, it is attached to the premaxillary and the palatine by its modified processes. The attachment to the lachrymal is through a membrane to facilitate mouth protrusion. The maxillary of the two sides are connected to each other through a strong ligament. The greatest width of the maxillary, in the present study, was found out to be $28.66 \pm 3.25\%$ of its length.

The supramaxillary is absent in bluegill.

The **dentary** (Plate 2b, D) bears sharp teeth along its thin oral edge. Between the two broad flexures of V-shaped dentary, there is a deep space where anterior process of articular and Meckel's cartilage are inserted. The two dentaries join medially. Ventral margins of dentary and articular are in straight continuation and there is hardly any space left in between.

The **articular** (Plate 2b, AR) has a prominent anterior extention penetrating into the deep space of the dentary. Posteriorly, it provides an articulating surface for the quadrate.

The **angular** (Plate 2b, AN) is a small triangular structure attached to the postero-ventral angle of the articular. Posteriorly, it provides surface to a ligament which binds it with the interopercular. The adaxial margin of the angular is longer than that of the abaxial one.

3. PECTORAL GIRDLE (Fig. 3)

The **supratemporal** (Plate 1b, ST) is an inverted Y-shaped tubular canal lying upon the flesh between the lateral line element of the pterotic and the posttemporal. Its anterior and posterior limbs actually form the connecting canal between the cephalic canal and the lateralis proper of the acoustico lateralis system. Dorsally, the canal of its median limb is further continued by another slender tubular canal (also referred to as second supratemporal) which ultimately opens on to the skin depicting one of the ends of the lateralis system. The two supratemporals are not covered over by scales except for a slight overlap upon the dorsal limb of the 1st one.

The **posttemporal** (PT) is a small forked structure through which the pectoral girdle is attached to the cranium. Dorsal prong which is broader and a little longer than the ventral one, is attached to the posterodorsal surface of the epiotic. The spine-like ventral prong is attached to the opisthotic by a strong ligament. At the junction of the prongs, runs a canal in continuation to the canal of the supratemporal which opens immediately on to the supracleithrum.

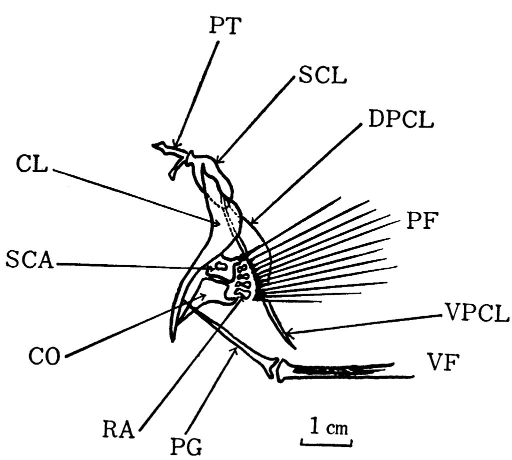

Fig. 3. Pectoral end Pelvic girdles of bluegill, left half, (SL 13.76 cm) as traced from the X-ray photograph.
CL, cleithrum; CO, coracoid; DPCL, dorsal postcleithrum; PF, pectoral fin; PG, pectoral girdle; PT, posttemporal; RA, four radials; SCA, scapula; SCL, supracleithrum; VF, ventral fin; VPCL, ventral postcleithrum.

The **supracleithrum** (SCL) is a flat bone thickened along its anterior margin. Dorsally, it is attached to the posttemporal. It connects the sensory canal coming from the cranium to the 1st scale of the lateral line canal. Its ventral expansion overlaps enough of the dorsal tip of the cleithrum.

The **cleithrum** (CL) is the largest component of the pectoral girdle. Its long, broad dorsal end terminates in a sharp process. The ventral folded extention curves craniad and joins its counterpart by a ligament forming a part of the branchial apparatus. Posteriorly, this folded extention provides surface for the scapular and coracoid articulations.

The **postcleithrum** are two: a dorsal (DPCL) and a ventral (VPCL). The dorsal one is a thin, flat bone thickened along its anterior edge. Dorsally, it is overlapped by the cleithrum. The ventral postcleithrum is a gently curved spine. Dorsally, it is tightly attached to the thickened margin of the dorsal postcleithrum and ventrally, it is embeded in muscle underneath the pectoral fin.

The **scapula** (SCA) is a roughly triangular bone attached to the cleithrum anteriorly and the coracoid ventrally. It bears a large foramen. The 1st pectoral ray articulates directly with the scapula in a facet provided at its posterodorsal tip. Other rays find their attachment through the intermediation of radials. Three and a half of the total four radials, articulate with the posterior margin of the scapula.

The anterior margin of the **coracoid** (CO) in continuation with the scapula, fits into the groove of the folded ventral portion of the cleithrum. Its elongated ventral process extends anteriorly upto the cleithral symphysis. At its posterodorsal edge, it contributes surface to the ventral half of the last radial.

The four **radials** (RA) are roughly hour-glass-shaped increasing in size ventrally. The number of pectoral rays, in the present study, varied from 12 to 14 (Table 2).

4. PELVIC GIRDLE (Plate 2c)

The pelvic girdle consists of paired basal elements (basipterygia) each associated with one spiny and five soft branched fin rays. The basipterygium of each side approximates each other at mid ventral surface leaving a narrow interosseous space. The conjoined anterior tips of the basipterygia are attached to the cleithral symphysis by means of a ligament. Posteriorly, the two shafts are united to each other by their distinct processes (processus medialis and processus medialis posterior) originating from the posteromedial corner. Each basipterygium has a lateral ridge (rachis)running longitudinally along its full length, obvious only in the ventral view. Medial to this ridge arises another ridge which runs about half the length of the rachis. The extent of the longitudinal run of this ridge in two basipterygia of the same specimen may not strictly be same. The nomenclatures used here are bases on SHELDEN (1937)[9] and SEWERTZOFF (1934)[10].

5. VERTEBRAL COLUMN

Vertebral count including the urostyle, in the present study, was almost constantly 29 with only two exceptions out of the 100 observed specimens, where the count showed 28 and 30 (Table 2). Following SCHULTZ (1958)[11], the 1st vertebra with fully developed hemal spine was considered as the 1st caudal vertebra. In the observed specimens, the fully developed hemal arch and spine appeared abruptly on the 13th vertebra presenting no gradual transition stages between typical trunk and typical caudal vertebrae. The number of trunk vertebrae was found to be constantly 12 depicting a typical character of genus *Lepomis*[7].

Unless stated otherwise the descriptive part of the vertebral axis stays in agreement with the account presented by STOKELY (1952)[12]. X-ray photographs revealed the extent of the posterior extention of the air bladder going as far as the 5th caudal vertebra. The body cavity making room for this posterior extention of air bladder, was found receiving support from the ribs sometimes from the 2nd caudal vertebra apart from the usual 1st one. Extra transverse process was found to be borne by the 2nd caudal vertebra in such specimens.

Observations were made to correlate certain external characters of the fish with those of the skeletal characters in an attempt to provide a key to know ahead the position of certain skeletal components in the body of fish. These observations were made solely through the help of 100 X-ray photographs of bluegill. The results of the observations are as follows:

i) A line connecting the 1st dorsal spine and the ventral spine (C to D of Plate la) in about 90% of the cases, crosses the centrum of 5th vertebra which can be located right above the height of 61.40±1.58% upon this line (Fig. 4, A).

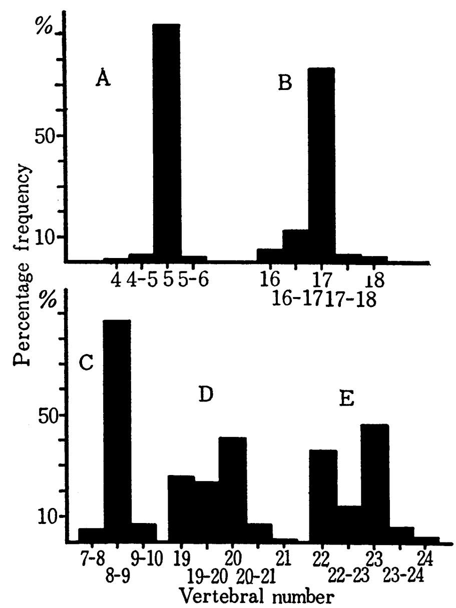

Fig. 4. Histograms depicting the percentage frequencies of the crossings made on vertebrae by the lines connecting, (A), first dorsal spine and ventral spein, C to D of Plate Ia; (B), last ray of the soft dorsal and ventral spine, G to D of Plate Ia; (C), first anal spine and 8–9 dorsal spine, E to F of Plate Ia; (D), first anal spine and last ray of the soft dorsal, F to G of Plate Ia; (E), last ray of the soft dorsal and last ray of the soft anal, G to H of Plate Ia, of bluegill.

ii) A line joining the last dorsal soft ray and the ventral spine (G to D of Plate la) in about 75% of the cases, crosses the 17th vertebra which falls right above the body axis of the fish (Fig. 4, B).

iii) The position of the 1st caudal vertebra can be predicted right above the height of 58.20±1.27% upon a line connecting the 1st anal spine and 8–9 dorsal spine (E to F of Plate la and Fig. 4, C).

iv) A line connecting the 1st anal spine and the last dorsal soft ray (F to G of Plate la) crosses mostly through the centra of 19th or 20th vertebrae which fall more or less on the body axis of the fish (Fig. 4, D).

v) The 1st hemal spine appears at 58.25±1.04% of the standard length.

vi) The hemal spine of the 17th vertebra which represents the extent of air bladder's extention in bluegill, can be predicted at 67.44±1.05% of the standard length.

vii) A line connecting the last dorsal soft ray and the last anal soft ray (G to H of Plate la) has almost equal chance to cross through the centra of the 22nd or 23rd vertebrae which fall on the proper body axis (Fig. 4, E).

Further, to ascertain the differences in the size of centra, possibly causing the deviation in the aforesaid measurements, heights and lengths of 10th and 20th centra were measured. The heights were found to be 4.4±0.6% and 4.2±2.1% of the body height for the 10th and 20th centra respectively while lengths were 3.0±0.0% and 2.4±0.5% of the standard length.

6. UNPAIRED APPENDAGES

Dorsal fin:

The number of dorsal spines, in the present study, varied from 9 to 11 with 10 being the most common number, and soft rays from 11 to 13 with 11 and 12 being the numbers of common occurrence. Table 2 presents the mean values of these counts. The spines gradually increase in size posteriorly. Soft rays are all branched gradually increasing in length till the 6th and then decrease. Often the last soft ray was found branched from the base. In general, one pterygiophore was found associated with each dorsal spine and their number varied according to the variation in the number of dorsal spines. However, in three specimens, a vestigial spine was found associated with the 1st pterygiophore which has not been included in the counts of dorsal spine in the present study. Such vestigial spines were not found in other specimens of genus *Lepomis* observed during

Table 2. Comparison of mean meristic counts among bluegill and some other centrarchid fishes.

Common name-	Bluegill	Pumpkin seed	Green sunfish	Northern longear sunfish	Warmouth	Black crappie
Species-	(*Lepomis macrochirus*)	(*Lepomis gibbosus*)	(*Lepomis cyanellus*)	(*L. megalotis peltastes*)	(*Chaenobryttus gulosus*)	(*Pomoxis nigromaculatus*)
Number of specimens-	100	13	2	2	1	2
Dorsal spines	9.98±0.29	10.00±0.00	10.00	10.00	10.00	7.00
Dorsal soft rays	11.47±0.52	11.31±0.58	11.00	12.00	10.00	16.00
Anal spines	2.99±0.10	2.92±0.28	3.00	3.00	3.00	6.00
Anal soft rays	11.05±0.54	10.15±0.38	9.50	9.50	10.00	18.00
Pectoral fin rays	12.83±0.42	12.31±0.48	12.00	12.50	14.00	14.00
Vertebrae:						
Total	29.00±0.14	30.00±0.00	29.00	30.00	29.00	33.00
Trunk	12.00±0.00	12.00±0.00	12.00	12.00	12.00	14.00
Caudal	16.99±0.17	18.00±0.00	17.00	18.00	17.00	19.00
Scales in lateral line	40.82±1.65	39.46±1.13	43.50	34.00	—	—
Scales above lateral line	6.34±0.56	6.00±0.00	7.00	5.50	—	—
Scales below lateral line	13.58±0.76	13.00±0.58	15.00	12.00	—	—
Cheek scales	5.32±0.70	5.00±0.00	—	—	—	—

Table 3. Variation-range in the insertion of dorsal spine pterygiophores between neural spines.

	Neural spines										
PTERYGIOPHORES	1–2	2–3	3–4	4–5	5–6	6–7	7–8	8–9	9–10	10–11	11–12
I	1	96									
II		44	53								
III		1	96								
IV			3	92	2						
V				3	94						
VI					3	90	4				
VII						3	91	3			
VIII							3	64	30		
IX								2	7	85	
X										3	89
XI											3

Note: Tabulated figures indicate the number of specimens.

Table 4. Variation-range in the insertion of dorsal soft ray pterygiophores between neural spines.

	Neural spines									
PTERYGIOPHORES	11–12	12–13	13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21
1	6	90								
2		7	89							
3			15	81						
4			1	85	10					
5				6	90					
6					39	57				
7					3	90	3			
8						13	83			
9						2	81	13		
10							7	89		
11							1	33	6	
12									1	

Note: Tabulated figures indicate the number of specimens.

the present study. The morphology of pterygiophores conforms to the conditions in Sacramento prech[3].

The number of interneurals was found to be three with only one exception where it was two. In 66% of the specimens the trend of their insertion was uniform being one to one. In the rest of the percentage, the 1st one being regular, 2nd and 3rd both together, were inserted between the 1st and 2nd neural spines.

The range of variation in the insertion of dorsal pterygiophores between neural spines has been presented in Table 3 and 4. Similar degrees of variations were noticed in the X-ray photographs of other observed centrarchid fishes.

Anal fin:

The number of anal spines was found to be three with only one exception where it was two. This specimen, standing in exception, revealed no sign of damage. The number of anal soft rays varied from 9 to 12 with 11 being the most common number which occurred in as many as 72% of the specimens. Bulegill possesses stout anal spines increasing in length posteriorly. The 1st spine is slightly more than half the length of 2nd. Soft rays are all branched in decreasing length posteriorly. The last ray was found branched from the base in quite a few specimens.

Table 5. Variation-range in the insertion of anal soft ray pterygiophores between hemal spines.

		Hemal spines							
		13–14	14–15	15–16	16–17	17–18	18–19	19–20	20–21
PTERYGIOPHORES	1	94							
	2	2	92						
	3		55	39					
	4	1	93						
	5			14	80				
	6				88	6			
	7				6	88			
	8					88	6		
	9					4	90		
	10						67	6	
	11							9	

Note: Tabulated figures indicate the number of specimens.

The pterygiophores of the 1st and 2nd anal spines are fused together. These plus one associated with the 3rd anal spine, fit together into a groove at the anterior margin of the 1st hemal spine giving a firm support to the anal fin. Variations in the insertion of anal pterygiophores between the hemal spines have been presented in Table 5.

Caudal fin:

Bluegill has a gently forked caudal fin with the lower lobe slightly shorter than the upper. In all the specimens, the number of fin rays constantly numbered 17 with 9 in the upper lobe and 8 in the lower. Save the one above and one below, all other rays are branched. Vestigial rays were observed to be 7 to 9 dorsally and 6 to 9 ventrally.

Details regarding the last three vertebrae which are further modified in relation to the caudal fin of bluegill, have been discussed in detail by STOKELY (1952)[12]. The only difference which has been observed in the present study, is the presence of two uroneurals instead of one which he described under the nomenclature of 'extra neural arch'. As has been indicated in Plate 3a, a 2nd uroneural was discovered in the present study. It is, in fact, a very thin slender bone which lies in continuation with the dordsal deflection of the slender projection of the 1st one. Its existence can be noticed only when a complete disarticulation of bones is made. A better way to investigate its existence is to make an alizarine preparation of the whole caudal skeleton.

7. OTOLITHS (Plate 3b)

The sacculith is the largest of three otoliths presenting clear growth rings. To ascertain the constant relationship between the sacculith and the cranium length, measurements of the horizontal diameter of the sacculith (taken from the X-ray photographs) were plotted against the cranium length of the fish. The relationship which was found

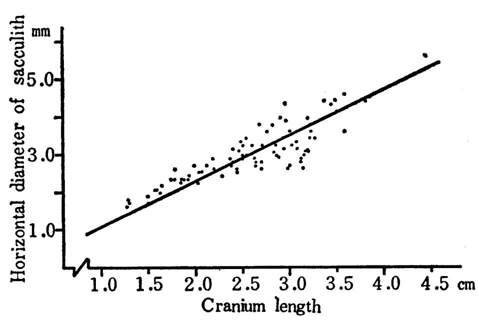

Fig. 5. Linear regression of the horizontal diameter of the sacculith upon the cranium length of bluegill.

to be linear (Fig. 5) can be expressed as follows:

Sacculith diameter$=1.21\times$cranium length -0.15 (Saccuith diameter in mm and cranium length in cm)

The sacculith is roughly an oval structure having a concave outer and a convex inner side. Anteriorly, it is pointed and posteriorly, rounded. While its dorsal margin is serrated markedly, serrations on ventral are feeble. The horizontal sulcus opens on the anterodorsal margin. Posteriorly, it does not reach up to the margin. The sulcus has a narrow cauda and a wide osteum.

The utriculith and lagenolith are very small in comparison to the sacculith. The utriculith is rectangular and the lagenolith is triangular with smooth margins.

8. SCALES

REGIER (1962)[13] has presented the photographs of bluegill scales and reviewed the description of their characteristics published by earlier researchers and has prepared a list of critaria by which the annuli on bluegill scales may be identified. Observations made during the present study agree with the descriptions of earlier researchers. Scale counts have been presented in Table 2.

DISCUSSION

Statistical analyses of the skeletal system of bluegill revealed that significant fluctuations in its skeletal proportions are not many. This fact suggests that the data upon the proportional measurements, presented in the account, can be of immense help in finding out the coordination formed between the skeleton and the other organs in bluegill.

To make further studies on the disposition of various organs, the vertebral column can be considered as the key point to correlate with, since knowledge of the location of several vertebrae is now made so easy by the results of observations made upon the correlation between external and skeletal characters, already described in the text. In the case of the abdominal cavity, for instance, the extent of its height can be determined at $61.40 \pm 1.58\%$ upon a line connecting the 1st dorsal spine and the ventral spine (C to D of Plate la); the 13th vertebra i. e. the posterodorsal extent of the abdominal cavity proper can be determined right above a height of $58.20 \pm 1.27\%$ upon a line connecting the 1st anal spine and the 8–9th dorsal spine (E to F of Plate la); and its posterior extent i. e. the 1st hemal spine can be predicted at $58.25 \pm 1.04\%$ of standard length. Deviations accounted in the aforesaid measurements are of little or no significance since they are covered within the limits of height ($4.4 \pm 0.6\%$ of the body height) and length ($3.0 \pm 0.0\%$ of the standard length) measurements of one centrum. In the case of cranium cavity, although there are limitations to fix any key point with so much accuracy, yet its extents can roughly be determined by locating the ridge across the frontals (easy to observe externally), which depicts the position of the olfactory bulb in the cranium cavity anteriorly. The posterior extent i. e. foramen magnum can be predicted by the measurements of the cranium length and the cranium height. Since the axis of the cranium length, considered in the present study, does not fall on the proper body axis, for practical purposes, a line can be drawn from the tip of the snout passing through the center of the eye ball to depict this axis. Further anatomical observations considering the measurements of the skeletal proportions, are expected to yield interesting results.

The basic scheme of arrangement of bones in bluegill, except for their shapes and sizes, was found to be more or less the same as has been observed in Sacramento perch by DINEEN and STOKELY (1956)[3], the only complete report available on the osteology of any centrarchid to compare our observations with. Sacramento perch is thought to be a survivor of an ancient fauna according to MILLER (1946)[14], probably revealing the more generalized structural patterns of the centrarchid stock. Comparison revealed some reductions in the number of certain skeletal components in bluegill.

Certain osteological characters were observed to be of some importance, viz. the palatine was found to bear no teeth in the present study. BOULENGER (1895)[15] in the 'Catalogue of Fishes in the British Museum', however, has stated 'teeth on palatine' as one of the characteristic features of the genus *Lepomis*. As far as the authors' knowledge goes, newer references on the classification do not include it amongst the characteristic features of this genus. A 2nd uroneural was discovered in bluegill by the present study which hither-to had not been reported from any other centrachid. STOKELY (1952)[12] who has made certain observations on the vertebral axis of bluegill, described the existence of only one under the nomenclature of 'extra neural arch'. The authors find no plausible explanation for this than to state that the 2nd uroneural, a too small structure to be readily visible to the naked eye, has probably been overlooked in the observations made by STOKELY[12].

Upon the meristic measurements of bluegill, some references are available. Comparison of these meristic counts (Table 6) reveals some differences particularly in the

Table 6. Comparison of the meristic counts of bluegill as stated by various authors.

Authors-	BOULENGER[14] (1895)	MORGAN[15] (1951)	STOKELY[11] (1952)	SMITHERMAN[16] and HESTER (1962)	HUBBS &[6] LAGLER (1964)	Authors
Number of specimens-	—	—	18	100	—	100
Dorsal spines	10–11*	10	—	9.94	10(usually)*	9.98 (9–11)
Dorsal soft rays	10–12*	10–12	—	12.15	—	11.47 (11–13)
Anal spines	3*	3	—	3	3(very rarely 2 or 4)*	2.99 (2–3)
Anal soft rays	8–10*	10–12	—	11.57	10–12(typically)	11.05 (9–12)
Pectoral fin rays	13–15*	—	—	12.76	—	12.83 (12–14)
Vertebrae:						
Total	30*	—	29.06 (29–30)	—	—	29.00 (28–30)
Trunk	14*	—	12.11 (12–13)	—	12(typically)*	12.00 (12)
Caudal	16*	—	—	—	—	16.99 (16–18)
Scales in lateral line	—	—	—	45.29	55(or fewer)*	40.82 (36–45)
Scales above lateral line	—	—	—	7.44	—	6.34 (5–8)
Scales below lateral line	—	—	—	15.40	—	13.58 (12–15)
Cheek scales	—	—	—	5	—	5.32 (4–6)
Gill rakers	—	—	—	11.79	—	13.68 (12–15)

* These characters have been indicated as the distingushing features of genus *Lepomis*.

counts of dorsal soft rays, trunk vertebrae, scales, and gill rekers. The number of dorsal soft rays, observed in the present study, is more than those observed by BOULENGER (1895)[15] and MORGAN (1951)[16] but a little less than SMITHERMAN and HESTER (1962)[17]. These differences, in all possibilities, might have resulted from some racial differences in the stocks of bluegill. The count of tunk vertebrae in bluegill as well as in the other species of genus *Lepomis* observed in the present study (Table 2) showed no variation in the number depicting one of the typicalities of this genus as stated by HUBBS and LAGLER (1964)[7]. STOKELY (1952)[12], however, found out extra trunk vertebrae in bluegill accounted for by the occurrence of the 1st hemal arch on the 14th rather than on 13th vertebra. Reduction in the number of scales which was observed in the present study, suggests that our specimens probably had bigger scales than those observed by SMITHERMAN and HESTER (1962)[17]. It might be holding some biological significance which, for the lack of informations at present, the authors are unable to explain. The number of gill rakers is significantly higher than that stated by SMITHERMAN and HESTER (1962)[17]. This has happened probably because in the present study, counts were made under the dissection microscope and it included even those protuberances that are too small to be visible to the naked eye.

SUMMARY

The present study was undertaken in order to provide information upon the normal skeletal structure of bluegill sunfish, *Lepomis macrochirus* RAFINESQUE, to the researchers using it as an experimental animal and to the taxonomists trying to work out the relationship between the members of the Centrarchidae family.

This study is based upon the examination of 100 bluegill specimens made by cleaning, staining, and roentgnography. The observations can be summarized as follows:

i) Statistical analyses of various skeletal proportions revealed small fluctuations except for the cranium height and width which were observed to be size-dependent.

ii) Correlation between external and skeletal characters have been made to predict the position of several skeletal components on the body of fish without subjecting it to the troubles of scissors and forceps.

iii) Basic scheme of the arrangement of bones except for their shapes and sizes, has been found out to be more or less the same as that of Sacramento perch studied by DINEEN and STOKELY (1956)[3]. However, reduction in the number of certain skeletal components has been observed in bluegill.

iv) A second uroneural has been discovered in bluegill which hither-to had not been reported from any other centrarchid including bluegill.

v) Comparison of meristic measurements as stated by various authors presented some difference in the number of dorsal soft ray, trunk vertebrae, scales, and gill rakers.

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ブルーギルサンフイッシュの骨格に関する研究

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Bluegill sunfish (*Lepomis macrochirus* RAFINESQOE) を実験動物として使用するために必要な基礎的知見を得，さらにその所属するクロマス科 Centrarchidae の魚類の分類に資する目的で，その骨格を精査した．

100 尾の標本につき，常法，骨格染色法，X線写真により，骨の形状，配列，大きさ等を観察し次の結果を得た．

(1) 頭蓋骨の長さに対する高さ，巾の比率は魚の成長に伴って変化するが，他の骨格要素の大きさは，標準体長又は頭蓋骨長に比し略々一定の値を示し，魚の成長に伴い変化しない．

(2) 魚体の外形に対応して骨格の構成が一定している所から，数種の骨は位置を外形から容易に決定出来る．

(3) 骨の基本的配列は同科の Sacramento perch (DINEEN and STOKELY, 1956) と略々同様であるが，個々の骨の大きさ，形状は異なり，bluegill sunfish では若干の骨が省略されている.

(4) bluegill sunfish を含む Centrarchidae の魚の骨格について行なわれた従来の研究では，1ケしかないとされていた尾神終骨が2ケ存在することが確認される.

(5) 体節性構造の内，背鰭軟条，腹椎，鱗及び鰓耙の数が，従来得られていた結果と若干相違している.

EXPLANATIONS OF PLATE 1

a) *X*-ray photograph of bluegill (standard length 11.82 cm, body width 2.24 cm under the exposure conditions of 54 kV and 6.2 mAS at a focus-film distance of 45 cm) showing lines of measurements: A–B, body axis; C–D, body height I; E–F, body height II; A–I, cranium length; I–J, cranium height; A–L, preorbital length; L–K, eye-socket diameter; K–I, postorbital length; D–M, height of the abdominal cavity I; F–N, height of the abdominal cavity II.

b) Nasal, lachrymal, suborbitals, and supratemporals of bluegill (SL 13.51 cm).

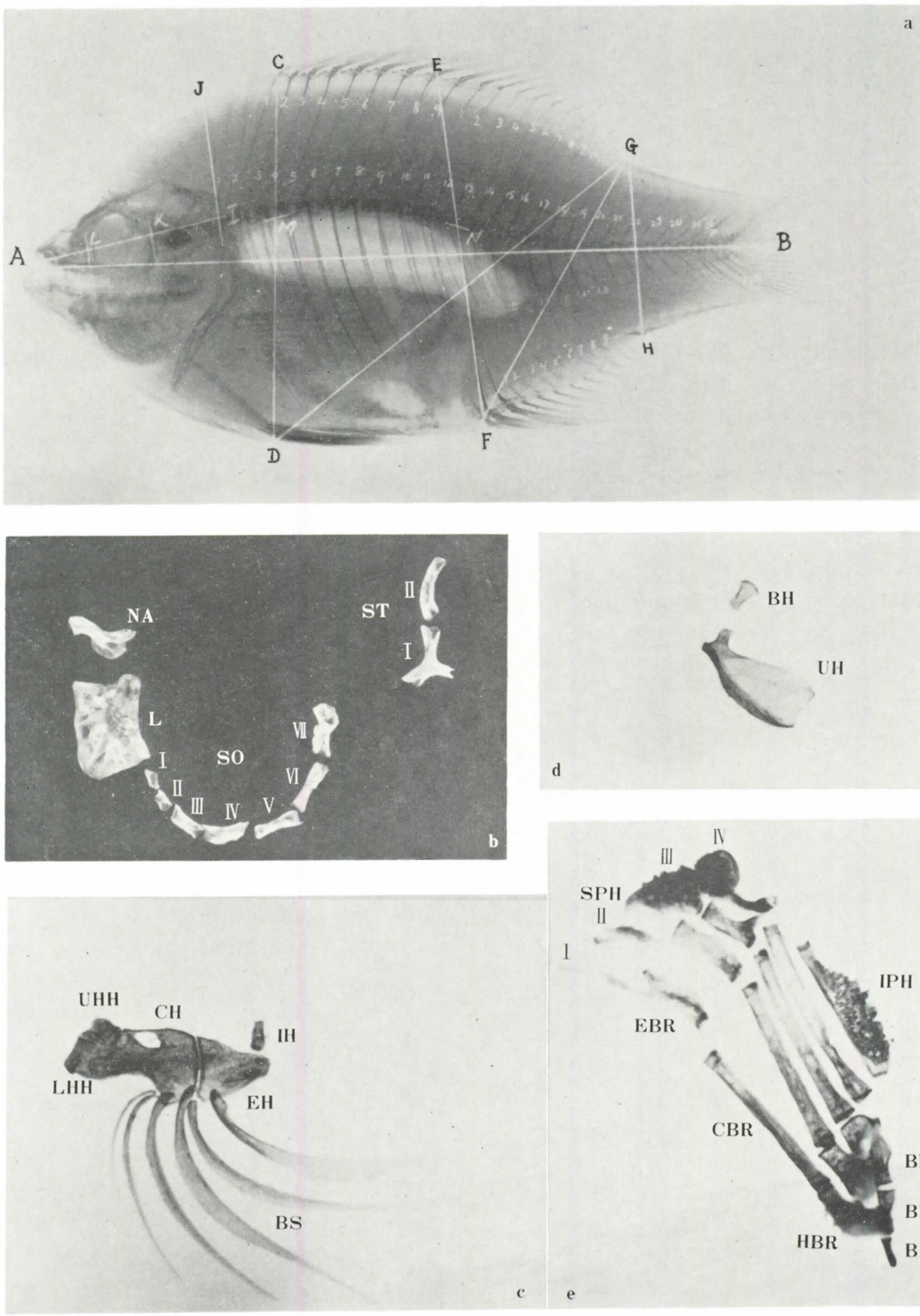
c) Photograph of the alizarine stained hyoid arch of the left half of bluegill (SL 12.60 cm).

d) Photograph of the alizarine stained urohyal and basihyal of bluegill (SL 12.60 cm).

e) Photograph of the alizarine stained branchial arch of the left half of bluegill (SL 12.60 cm).

Abbreviations:

BBR, basibranchial; BH, basihyal; BS, branchiostegals; CBR, ceratobranchial; CH, ceratohyal; EBR, epibranchial; EH, epihyal; HBR, hypobranchial; IH, interhyal; IPH, infrapharyngeal; L, lachrymal; LHH, lower hypohyal; NA, nasal; SO, suborbitals; SPH, suprapharyngeal; ST, supratemporal; UH, urohyal; UHH, upper hypohyal.


a
A
B
C
D
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F
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NA
ST
II
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IV
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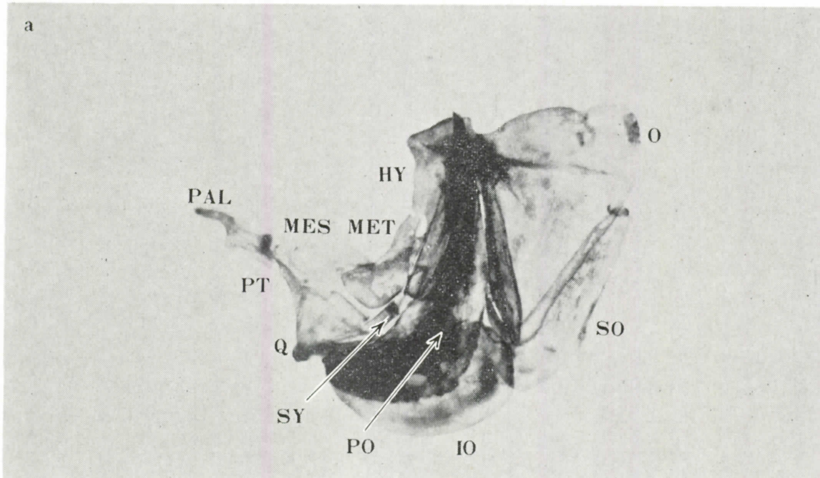
VI
VII
b
UHH
CH
IH
LHH
EH
BS
c
BH
UH
d
IV
III
SPH
II
I
IPH
EBR
CBR
BBRIII
BBRII
HBR
BBRI
e

EXPLANATIONS OF PLATE 2

a) Photograph of the alizarine stained suspensorium and opercular bones of the left half of bluegill (SL 13.51 cm).
b) Photograph of the alizarine stained bones of the upper and lower jaws of the left half of bluegill (SL 13.51 cm).
c) Pelvic girdle of bluegill (SL 13.51 cm).

Abbreviations:

AN, angular; AR, articular; D, dentary; HY, hyomandibular; IO, interopercular; M, maxillary; MES, mesopterygoid; MET, metapterygoid; O, opercular; PAL, palatine; PM, premaxillary; PO, preopercular; PT, pterygoid; Q, quadrate; SO, subopercular; SY, symplectic.


a
HY
O
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PT
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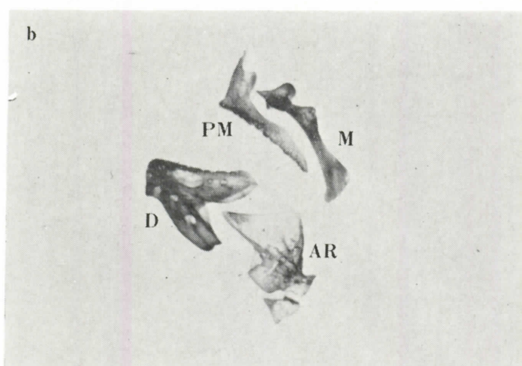
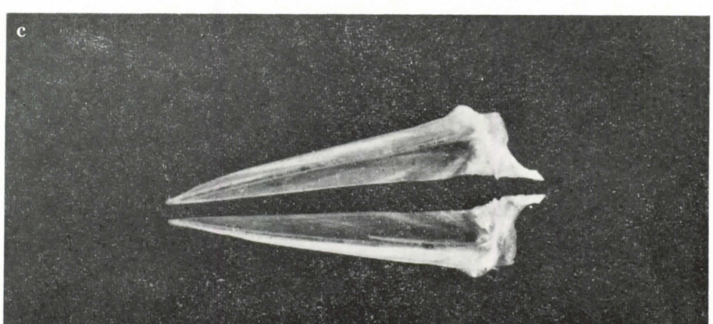
PO
IO


b
PM
M
D
AR

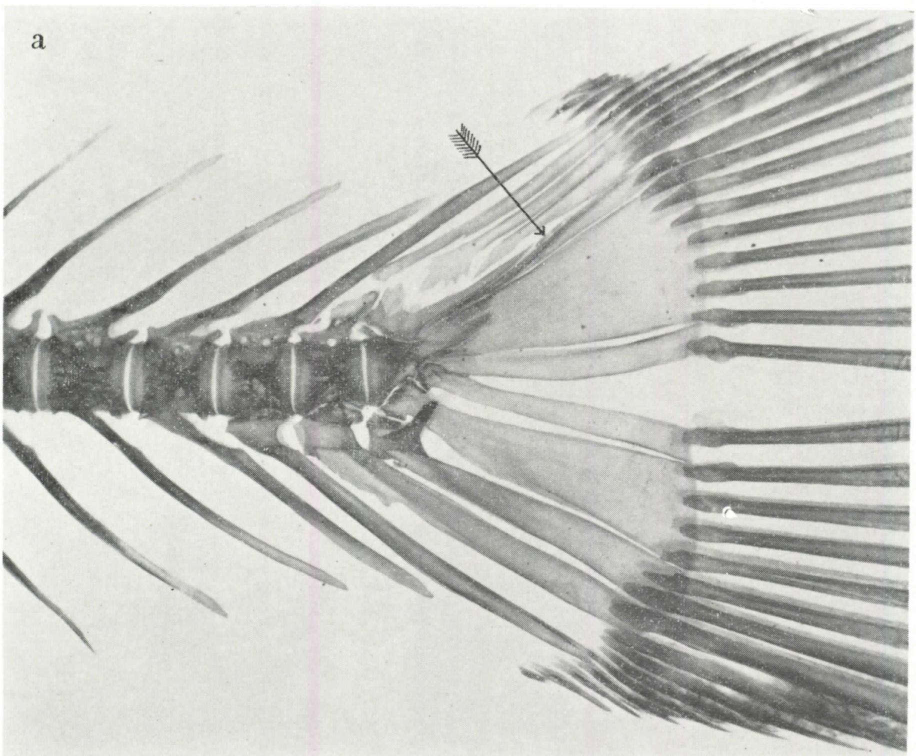

c

EXPLANATIONS OF PLATE 3

a) Photograph of the alizarine stained caudal fin skeleton with last five vertebrae of bluegill (SL 11.76 cm) indicating the existence of second uroneural.

b) Otoliths of bluegill (SL 14.51 cm). From left to right: lagenolith, sacculith, and utriculith.

a



b