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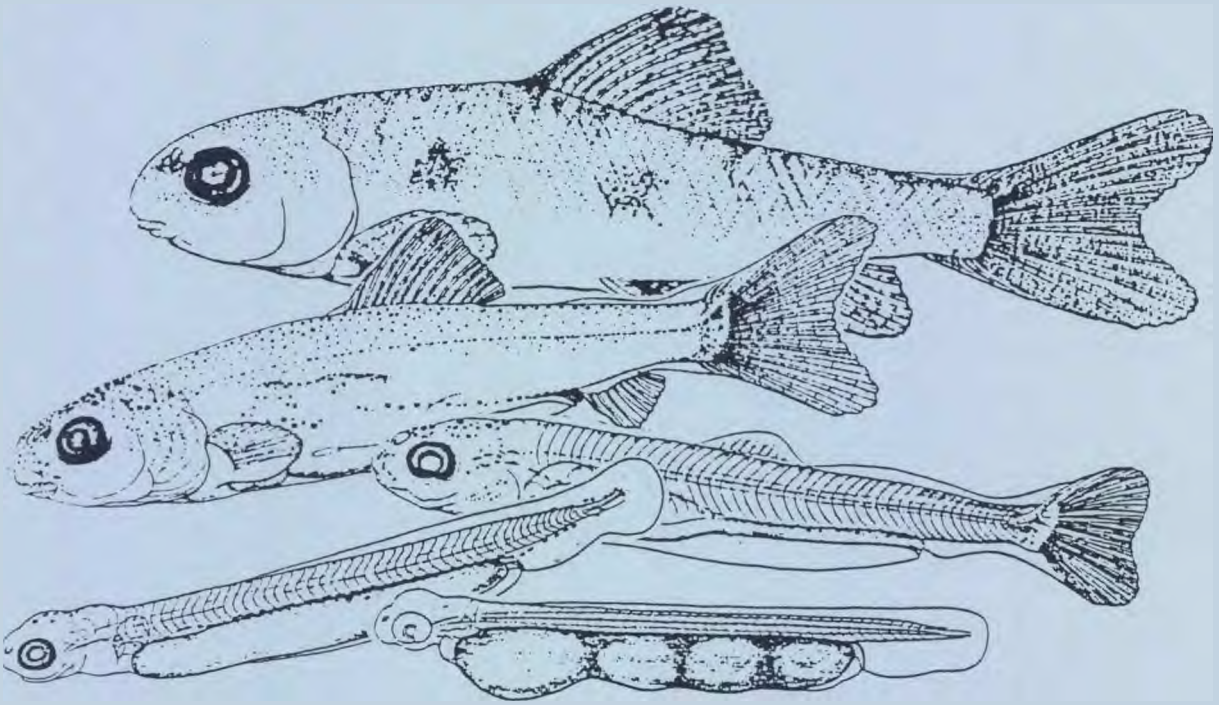
DESCRIPTION AND IDENTIFICATION OF JUNE, UTAH, AND MOUNTAIN SUCKER LARVAE AND EARLY JUVENILES



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DESCRIPTION AND IDENTIFICATION OF JUNE, UTAH, AND MOUNTAIN SUCKER LARVAE AND EARLY JUVENILES

by

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Some material herein was previously published. Much of the text and illustrations preceding results are modified from Snyder (1981) and a draft manual for catostomid larvae of the Upper Colorado River Basin prepared for the Colorado Division of Wildlife. Some data and illustrations for mountain sucker larvae were prepared originally for Snyder (1981 and 1983a) and a report for the U. S. Fish and Wildlife Service in Reno. Illustrations of adult suckers at the beginning of species accounts are copied from Sigler and Sigler (1987; permission granted by John F. Stetter, director, University of Nevada Press, and William F. Sigler, author).

DESCRIPTION AND IDENTIFICATION OF JUNE, UTAH, AND MOUNTAIN SUCKER LARVAE AND EARLY JUVENILES

ABSTRACT

The endangered June sucker (Chasmistes liorus mictus) is endemic to Utah Lake Basin. The more widespread Utah sucker (Catostomus ardens) shares the lake, while the mountain sucker (Catostomus platyrhynchus, subgenus Pantosteus) inhabits major tributaries. Sucker larvae and early juveniles must be collected and accurately identified to evaluate June sucker reproductive, spawning, and nursery requirements. To facilitate identification, reared or known series of each species were studied. Most mountain sucker protolarvae and mesolarvae are distinguished from the other species by a continuous line of melanophore pigment on the ventral midline from heart to vent. On the dorsal midline, another nearly solid line of pigment usually extends from head to tail, often with pigment scattered to either side thereof. Metalarvae are characterized by lateral peritoneal pigmentation and early folding of the gut. Young-of-the-year juveniles have a dark peritoneum, extensive gut folding, and fewer dorsal fin rays. They also have more and later-forming scales, unique mouth characters, and distinctive skeletal features. Separation of June and Utah suckers is more difficult and, in many cases, might not be possible. June sucker larvae are usually a bit smaller relative to developmental state. For protolarvae and flexion mesolarvae, the origin of the dorsal finfold is often more posterior on June suckers. Early juveniles sometimes have more advanced gut folding, longer dorsal and caudal fins, and more pelvic fin rays than Utah suckers.

INTRODUCTION

Despite the information explosion and technological advances of the past few decades, knowledge of the biology of many North American fishes remains inadequate for either evaluation of potential environmental impacts on aquatic ecosystems or optimal management of fisheries. Knowledge of early-life stages (eggs, larvae, and early juveniles) is especially weak. For most species, the larvae and early juveniles represent several life-intervals that are ecologically distinct from each other and from their later juvenile and adult counterparts. Knowledge of habitat requirements and limitations, population dynamics, and behavior of these early-life intervals will improve our understanding of aquatic ecosystems and communities and facilitate more effective monitoring and management of fish populations and habitats. Such knowledge is particularly valuable in evaluation of environmental impacts and recovery of endangered species such as the June sucker (Chasmistes liorus mictus).

The early-life stages of fishes are or should be a principal focus of many ecological studies (Snyder 1976a). Their distributions and densities are indicative of spawning and nursery areas, spawning seasons, larval behavior, and year-class strength. Even in baseline surveys designed to determine the presence and relative abundance of fishes, larval collections can often provide information on certain species that because of gear selectivity, behavior, or habitat are difficult to collect or observe as adults. Studies of fish larvae can also provide information on morphological development, systematics, growth rates, survival rates, food habits, predation, and various other ecological relationships.

Research on ecology of early-life stages and subsequent management efforts depend on accurate identification of collected specimens. Inland fishery managers and researchers often exclude potentially critical larval-fish investigations specifically because they "haven't done it before" or they don't have the taxonomic tools needed for the job. Unfortunately, the acquisition of this vital taxonomic information is a very time-consuming and expensive process. While such information is slowly building, the many individual efforts are piecemeal, uncoordinated, and often "a labor of love" on the part of the researchers involved.

Of approximately 775 species of freshwater and anadromous fishes in North America (Lee et al. 1980), less than 20% are adequately described as larvae for identification purposes (extrapolated from 15% reported by Snyder 1976a). In a relatively comprehensive listing of regional guides, keys, and comparative descriptions of larval fishes by Simon (1986), only about 80 of 230 citations (35%) pertain to freshwater species. Snyder (1983b) listed 11 regionally oriented larval fish identification manuals for or including freshwater species (some of these are for the same regions and all are incomplete in coverage). Since 1983 only two small freshwater guides have been published, both for Southeastern waters.

The purpose of this study was to document the morphological development and distinguishing characteristics of larval and early-juvenile June, Utah, and mountain suckers (Chasmistes liorus, Catostomus ardens, and Catostomus platyrhynchus, respectively). All three species belong to the same subfamily (Catostominae) and tribe (Catostomini) of the family Catostomidae. These are the only three catostomids currently recognized in Utah Lake and its tributaries. Although the webug sucker (Catostomus fecundus), which was described only from Utah Lake in the late 1800s, is still listed as a species by Robins, et al. (1980), Sigler and Miller (1963) and Miller and Smith (1981) consider it to be a localized hybrid of June and Utah suckers and not a distinct species. Utah Lake and its fishes are described by Radant and Sakaguchi (1981).

The June sucker is endemic to Utah Lake and its tributaries and is protected as an endangered species by Utah and the federal government (United States Fish and Wildlife Service 1986). However, according to Holden et al. (1974) and Miller and Smith (1981), the present population in Utah Lake differs from that originally described by Jordan (1878). Miller and Smith concluded that the current June sucker is the product of introgressive hybridization with Utah sucker originating during a period of severe environmental stress in the 1930s. They also agreed with Tanner (1936) that the true or pure June sucker (Chasmistes liorus liorus) has probably been extinct since the 1930s and accorded the current form unique subspecific status (Chasmistes liorus mictus). The genus Chasmistes (for which the true June sucker is the type species) is often referred to as lakesuckers; adults are generally not found in tributary rivers or streams except during the spawning season. The most current information on the distribution and ecology of June sucker is provided by Radant et al. (1987) and Radant and Shirley (1987).

Shirley (1983) described the spawning ecology (summarized by Sigler and Sigler 1987) and larval development of the June sucker. His illustrations and data for protolarvae, mesolarvae, and possibly some metalarvae were based on reared specimens of known parentage, but that for other metalarvae and juveniles was based on collected specimens assumed to be June sucker. Unfortunately, subsequent examination of some of the collected metalarvae and juveniles by the senior author revealed that nearly all are mountain suckers. At least some of the earlier collected material are also suspected to be misidentified. Shirley's conclusion (reiterated by Sigler and Sigler 1987) that young June suckers remained in the Provo River (his study area) from summer 1982 through at least January 1983 was probably also based largely on mountain sucker larvae and juveniles.

The Utah and mountain suckers are both of broader distribution (Lee et al. 1980, Sigler and Sigler 1987). The Utah sucker belongs to the subgenus of valley suckers (Catostomus) and the mountain sucker to the subgenus of mountain suckers (Pantosteus). Adult mountain suckers are relatively small and seldom exceed 20 cm in total length, while both Utah and June suckers may attain lengths greater than 60 cm. The Utah sucker is highly adaptable to a variety of habitats from deep, cold lakes to small, warm streams with rapid to slight currents and turbid to clear waters (Sigler and Miller 1963); young are usually found in tributary streams or near shore (Sigler and Sigler 1987). In contrast, the mountain sucker is typically found in cold, clear rivers and mountain streams and (except possibly as larvae) is rarely collected in lakes (Sigler and Miller 1963). The young are found in relatively quiet, shallow waters, while older juveniles and adults are often collected in moderate to swift currents. Breeding habits of both species were summarized by Sigler and Sigler (1987). The early life stages of Utah sucker have not been previously described. Snyder (1981) included mountain sucker in a key to metalarvae in the Upper Colorado River Basin and sumniarized morphometric, meristic, and size relative to developmental state data based on relatively few specimens. Snyder (1983a) added illustrations of two protolarvae and a recently transformed mesolarva and compared mountain sucker larvae to the larvae of cui-ui (Chasmistes cuius) and Tahoe sucker (Catostomus tahoensis) in Pyramid Lake and the Truckee River, Nevada. These data and illustrations are included herein as part of the results for mountain sucker.

A COMBINED DEVELOPMENTAL INTERVAL TERMINOLOGY

It is often convenient and desirable to divide the ontogeny of fish into specifically defined intervals. If the intervals selected are used by many biologists as a frame of reference, such division can facilitate communication and comparison of independent results. The largest intervals, periods (e.g. embryonic, larval, juvenile, and adult), are often subdivided into phases and sometimes into steps (Balon 1975 and 1984); the word "stage", although commonly used as a synonym for period or phase (e.g., Kendall et al. 1984), should be reserved for instantaneous states of development.

The larval phase terminologies most commonly used in recent years, particularly for descriptive purposes, are those defined by Hardy et al. (1978 -- yolk-sac larva, larva, pre juvenile), Ahlstrom et al. (1976 -- preflexion, flexion, postflexion; expanded upon by Kendall et al. 1984), and Snyder (1976b and 1981 -- protolarva, mesolarva, metalarva). Definitions for all three terminologies were presented by Snyder (1983b). During a workshop on standardization of such terminologies, held as part of the Seventh Annual Larval Fish Conference (Colorado State University, January 16, 1983), it became obvious that these are not competing terminologies, as they often are treated, but rather complementary options with subdivisions or phases defined for different purposes. As such, it is possible to utilize all three terminologies simultaneously to: (1) facilitate comparative descriptions and preparation of keys based on fish in similar states of development with respect to the morphogenesis of finfold and fins; (2) segregate, for fishes with homocercal tails, morphometric data based on standard lengths measured to the end of the notochord prior to and during notochord flexion from those measured to the posterior margin of the hypural plates following notochord flexion; and (3) approximate the transition from at least partially endogenous nutrition (utilization of yolk material) to fully exogenous nutrition (dependence on ingested food) based on the presence or absence of yolk material.

The combined terminology presented below and utilized herein effectively integrates the principal subdivisions and functions of the three component terminologies. In doing so, Ahlstrom's "preflexion-flexion-postflexion" terminology is treated, for fishes with homocercal tails, as a subset of Snyder's mesolarva phase. Since notochord flexion in the caudal region usually begins when the first caudal fin rays appear and is essentially complete when all principal caudal rays are well defined, and since presence of fin rays can be more precisely observed than the beginning or end of actual notochord flexion, fin rays are used as transition criteria. As a result, all protolarvae are preflexion larvae, and all metalarvae are postflexion larvae. Although most fish pass sequentially through all the phase subdivisions designated, some pass pertinent points of transition prior to hatching or birth and begin the larval period in a later phase or possibly skip the period entirely.

The definition for the end of the larval period is necessarily a compromise deleting all requirements (some taxon-specific, others difficult to determine precisely) except acquisition of the full complement of fin rays in all fins and loss of all finfold (last remnants are usually part of the preanal finfold). Provision for taxon-specific prejuvenile (or transitional) phases are also deleted. In some cases, finfold persists through the end-point for such special intervals, and the intervals are effectively included in the larval period.

Timing of complete yolk absorption varies from well before notochord flexion and initial fin ray formation, as in most fishes with pelagic larvae, to postflexion stages after all or most of the fin rays are formed, as in many salmonids. Accordingly, the interval during which fish larvae bear yolk should not be represented generally as a separate phase preceding phases based

on fin formation as it has been treated by Kendall et al. (1984). The Hardy et al. terminology effectively distinguishes between larvae with and without yolk by modifying the period name with the adjective "yolk-sac" when yolk material is present. Any period or phase name of the combined terminology can be similarly modified to indicate presence or absence of yolk material (e.g., yolk-bearing larva, yolk-sac metalarva, postflexion mesolarva with yolk, protolarva without yolk).

The combined terminology is designed to be relatively simple but comprehensive, precise in its transition criteria, applicable to nearly all teleost fishes, and flexible. It can be utilized in part (essentially as one of its component terminologies) or its entirety depending on the purposes of the user. For example, if it is necessary to acknowledge only that the fish is a larva and whether it bears yolk, the terms "yolk-sac larva" and "larva without yolk" are all that is needed. Biologists who formerly utilized one of its component terminologies should have no difficulty in adapting to the combined terminology -- the essential features and terms of the original terminologies have been retained.

Larva: Period of fish development between hatching or birth and (1) acquisition of adult complement of fin rays in all fins, including spines, soft and hardened rays, and rudimentary rays, and (2) loss beyond recognition of all finfold not retained by the adult.

Protolarva: Phase of larval development characterized by absence of dorsal, anal, and caudal fin spines and rays. (Standard length measured to end of notochord.)

Mesolarva: Phase of larval development characterized by presence of at least one dorsal, anal, or caudal fin spine or ray but either lacking adult complement of principal soft rays in all median (dorsal, anal, and caudal) fins or lacking pelvic fin buds or fins (if present in adult). (Standard length measured to posterior margin of notochord or, once developed, axial skeleton.)

Preflexion Mesolarva: Among fishes with homocercal tails, phase of mesolarval development characterized by absence of caudal fin rays. (Posterior portion of notochord remains essentially straight and standard length measured to end of notochord. When first median fin ray is a caudal ray, larva progresses directly from protolarva to flexion mesolarva.)

Flexion Mesolarva: Among fishes with homocercal tails, phase of mesolarval development characterized by incomplete adult complement of principal caudal fin rays. (Posterior portion of notochord flexes upward and standard length measured to end of notochord.)

Postflexion Mesolarva: Among fishes with homocercal tails, phase of mesolarval development characterized by adult complement of principal caudal fin rays. (Notochord flexion essentially complete and standard length measured to posterior-most margin of the hypural elements or plates.)

Metalarva: Phase of larval development characterized by presence of (1) adult complement of principal soft rays in all median fins and (2) pelvic fin buds or fins (if present in adult). (Standard length measured to posterior end of axial skeleton, the hypural elements or plates in fishes with homocercal tails.)

Yolk-sac, Yolk-bearing, With Yolk, Without Yolk: Examples of modifiers used with any of the above period or phase designations to indicate presence or absence of yolk material, including oil globules.

CHARACTERISTICS USEFUL IN IDENTIFICATION OF CYPRINIFORM FISH LARVAE

The following discussion of taxonomically useful characters is reprinted with minor modification from Snyder (1981). Cyprinids and catostomids are closely related and morphologically similar. Together the two families account for at least a nine species in Utah Lake and its tributaries (Radant and Sakaguchi 1981, Radant and Shirley 1987) and over one-third of all species in the Great Basin (Sigler and Sigler 1987). Generalizations with respect to the order Cypriniformes refer specifically to North American species of these two families. Figures 2 and 3 identify the more obvious morphological features and structures of catostomid (and cyprinid) eggs and larvae.

Identification of fish larvae is in part a process of elimination. Even before examination of a single specimen, the number of candidate species can be substantially reduced by a list of known or likely species based on adult captures in the study area or connected waters. However, the first documentation of some species in a particular body of water, especially species that are elusive as adults, can certainly be based on the identification of their larvae. Incidental transport of eggs or larvae from far upstream or distant tributaries must also be considered. Knowledge of spawning seasons, temperatures, habitats, and behavior coupled with information on egg deposition and larval nursery grounds and behavior are also useful in limiting the possibilities.

Berry and Richards (1973) noted that "although species of a genus may vary from one geographical area to another, generally the larval forms of closely related species look alike. At the same time, the larvae of distantly related forms may be closely similar in gross appearance." Cypriniform larvae as a group are distinctive and generally easy to distinguish from larvae of other families. The beginning worker is advised to become familiar with the general larval characteristics of each family likely to be encountered. The various guides and keys cited in Snyder (1983b) are most useful in this respect. Auer (1982) is particularly recommended since it covers most of the families and many of the species in the Great Basin. Discussions of taxonomic characters by Berry and Richards (1973) and Kendall et al. (1984) are also recommended.

In the Great Basin, cypriniform larvae are readily categorized as cyprinids or catostomids. But elsewhere, if members of the cyprinid subfamily Cyprininae (the carps) and the catostomid subfamily Ictiobinae (the carpsuckers and buffalofishes) or tribe Erimyzontini (chubsucker, Catostominae), are present, identification at the family level may become more difficult for the inexperienced.

Within their respective families, and especially at the subfamily level, cypriniform larvae are very homogeneous in gross structure and appearance and, therefore, may be especially difficult to discriminate at the genus or species levels. This is particularly true of Great Basin catostomids. For the latter, specific identification relies on dorsal fin ray counts, size at which certain developmental events occur, form of the gut, melanistic (brown or black) pigment patterns, osteological characters, and to a limited extent, morphometrics and other meristics.

There is often a noticeable amount of intra- as well as inter-regional variability in many of the characters to be discussed. Awareness of this variability or its possible presence, and confirmation with several diagnostic characters, if possible, will increase confidence in identification and reduce the probability of error.

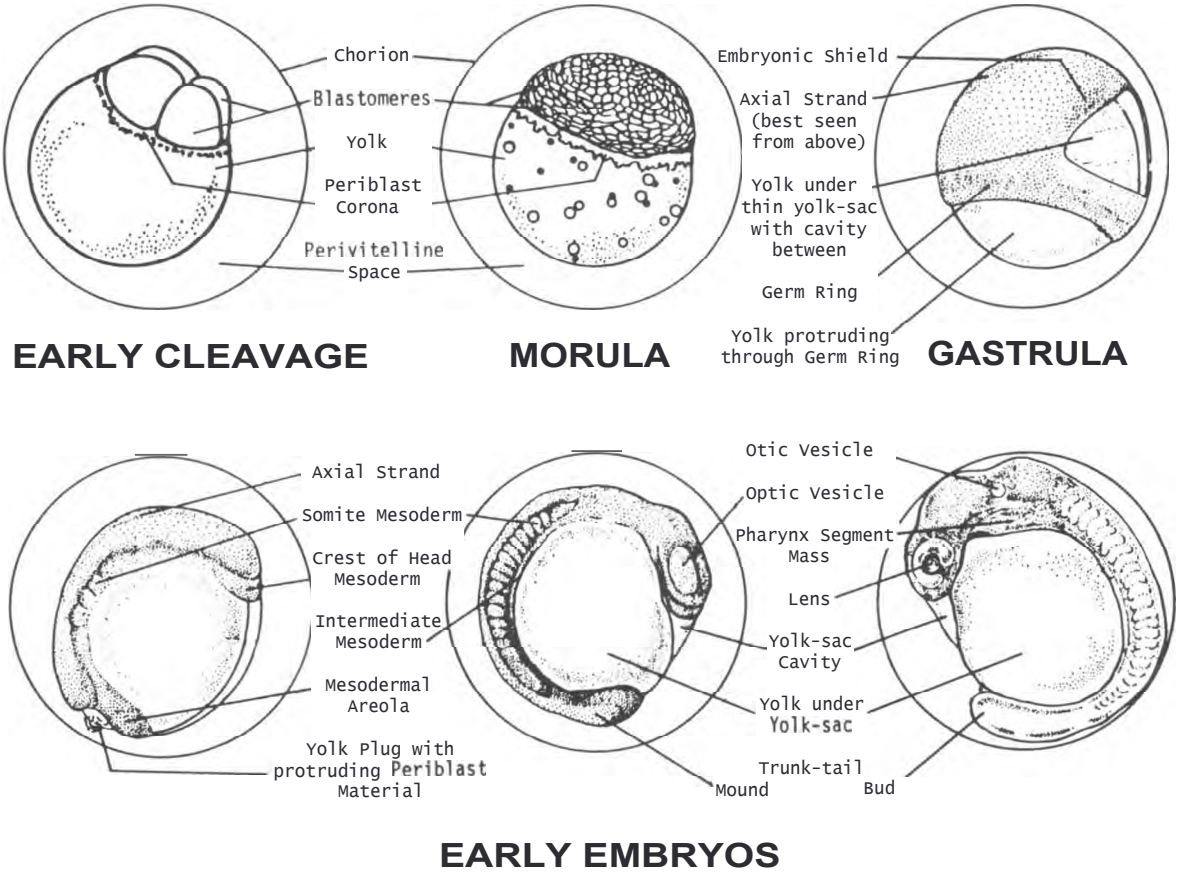


Figure 1. Selected anatomical features of cypriniform fish eggs and embryos. (From Snyder 1981; based on drawings from Long and Ballard 1976.)

Myomeres

Myomeres, because they are obvious morphological features and relatively consistent in number and position, are one of the most useful characters available for identification of larvae above (and sometimes at) the specific level, especially for protolarvae and mesolarvae. They begin as part of the embryonic somites and are usually formed in their full complement prior to hatching. Throughout the protolarval and much of the mesolarval phase, myomeres are chevron-shaped but by the beginning of the metalarval phase they evolve to their typical three-angled adult form. Fish (1932) and many subsequent authors indicated that there is a nearly direct, one-to-one correlation between total myomeres and total vertebrae (including the Weberian ossicles in cypriniforms. Snyder (1979) summarized considerable data on cypriniform fishes in support of this generalization.

The most anterior and posterior myomeres are frequently difficult to distinguish. The most anterior myomeres are apparent only in the epaxial or dorsal half of the body; the first is often deltoid in shape and is located immediately behind the occiput. The most posterior myomere is defined as lying anterior to the most posterior complete myoseptum. Siefert (1969) describes a "false (partial) myoseptum" posterior to the last complete myoseptum which adds to the difficulty

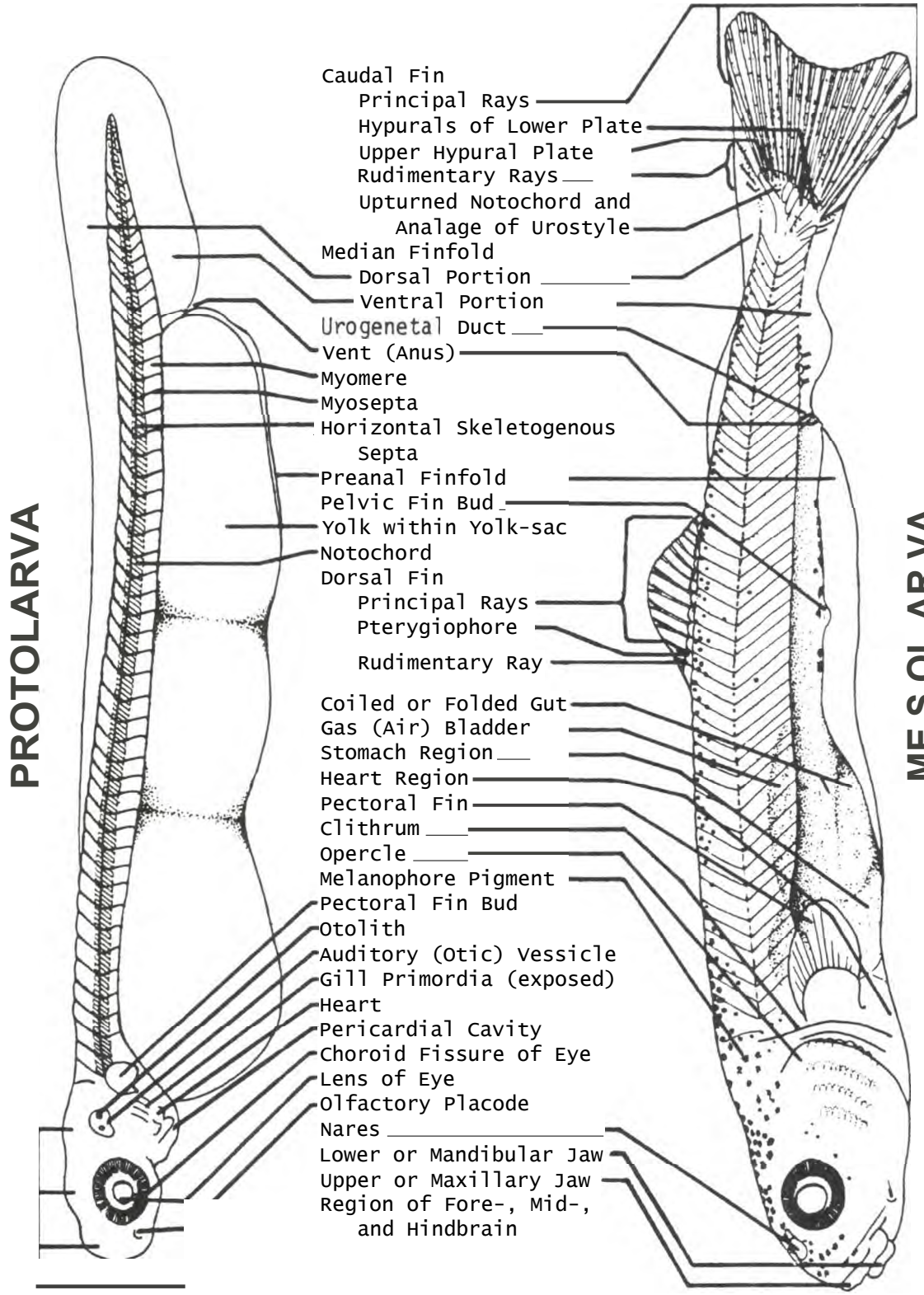


Figure 2. Selected anatomical features of cypriniform fish larvae. (From Snyder 1981.)

of discerning the last myomere. Early in the larval period, myomeres are most readily observed using transmitted light. Polarizing filters, depending on thickness and certain other qualities of the preserved tissues, can often be used to dramatically increase the contrast between the muscle tissue of the myomeres and the myosepta that separate them. The myomeres of some metalarvae and most juveniles are difficult to observe even with polarizing filters; reflected light at a low angle from one side and higher magnification sometimes facilitates observation.

Typical counts used in taxonomic work include total, preanal, and postanal counts. Partial counts are frequently used to reference the location of various structures in addition to the vent. The most generally accepted method of making partial counts is that described by Siefert (1969) for distinguishing preanal and postanal myomeres: "postanal myomeres include all [entire] myomeres posterior to an imaginary vertical line drawn through the body at the posterior end of the anus . . . Remaining myomeres, including those bisected by the line, are considered preanal." The technique is equally applicable to other structures or points of reference such as the origins of fins or finfolds. Another approach used by Snyder et al. (1977), Snyder and Douglas (1978), Loos and Fuiman (1977) and, according to the latter authors, Fish (1932), is essentially the opposite; only entire myomeres are included in the count anterior to the structure of reference. As counts resulting from Siefert's method are expected to more nearly approximate the number of vertebrae to the point of interest, that approach is recommended as standard procedure.

Snyder (1979) reported: "The range of total vertebra and/or myomere counts for 70 cyprinid species, 28 to 51, is larger and essentially includes that for 27 catostomids, 32 to 52. Preanal and postanal myomere counts range from 19 to 31 and 10 (9?) to 18, respectively, for cyprinids and 25 to 42 and 5 (3?) to 12 (14?) for catostomids. The two families can be readily distinguished by the proportion of postanal to preanal myomeres, about 1/2 or greater for cyprinids and 1/3 or less for catostomids; or preanal to total myomeres, about 2/3 or less for cyprinids and 3/4 or more for catostomids. The genera of each family are characterized by distinctive ranges of total myomeres or vertebrae which can be used to help determine the identity of unknown cypriniform larvae."

Fins and Finfolds

Fin ray meristics and fin positions, usually determined from older juveniles and adults or gleaned from published descriptions of adults, are among the most useful characters for later mesolarvae and metalarvae, especially among the cyprinids. The sequence and timing (relative to larval length) of fin development, fin lengths, and basal lengths of the dorsal and anal fins are also useful.

The median finfold, one of the most obvious of larval structures in protolarvae and early mesolarvae, is a continuous structure originating on the dorsal surface, usually well behind the head, and extending posteriorly to and around the end of the notochord then anteriorly along the ventral surface to the posterior margin of the vent. During the mesolarval phase, this finfold differentiates at the sites of the future median fins. As the median fins develop, the finfold recedes or diminishes before and between the fins until it is no longer apparent, usually at or near the end of the metalarval phase.

The preanal finfold, a second median finfold, may or may not be present upon hatching, depending upon the size and shape of the yolk sac. In the burbot (Lota lota) and its marine relatives (Gadidae), the preanal finfold is initially continuous with the ventral portion of the median finfold, the vent opening to one side of the finfold; they later separate. In cypriniforms, the preanal finfold is typically absent or barely apparent upon hatching. As yolk is consumed and the yolk sac is reduced in size, either during the late embryonic phase or the

protolarval phase, a small finfold appears just anterior to the vent. As more yolk is consumed and the larva grows, the preanal finfold enlarges and extends anteriorly, usually well in advance of the origin of the dorsal finfold. The preanal finfold remains prominent throughout the mesolarval phase and slowly diminishes in a posterior direction during the metalarval phase. It is typically the last of the finfolds to completely disappear.

The caudal fin is the first fin to differentiate from the median finfold in many fishes. Such is always the case in cypriniforms. The portion involved first thickens along the ventral side of the posterior end of the notochord and begins to differentiate into the hypural elements of the caudal skeleton. Immediately thereafter, the first caudal rays become apparent, marking the beginning of the mesolarval phase, and the posterior portion of the notochord begins to bend or flex upward. Care must be taken not to confuse striations or folds in the finfold with developing rays. As the fin develops and the notochord continues to flex upward, the hypurals and developing caudal rays, all of which are ventral to the notochord, are moved to a posterior or terminal position. The first principal rays are medial; subsequent principal rays are progressively added posteriorly above and anteriorly below. The principal caudal rays, which are the first to attain their full adult complement, articulate with the hypural bones of the caudal structure and include all branched rays plus one unbranched ray on each side. Branching and segmentation can be observed as or shortly after the full complement of rays becomes evident.

The number of principal caudal rays is typically very consistent within major groupings of fish. Cyprinids, for example, generally have 19 principal rays (ten based on the superior hypurals), and catostomids usually have 18 principal rays.

Rudimentary caudal rays, which appear sequentially in an anterior direction, begin forming immediately after the principal rays are formed or nearly formed. They are often the last group of fin rays among all fins to be established in full adult complement. Accordingly, they are often ignored in larval fish identification, but may be of taxonomic value for juveniles and adults.

The dorsal and anal fin, which typically form either simultaneously (many cyprinids) or dorsal first (most catostomids), usually begin development prior to the attainment of the full complement of principal caudal rays. Tissue first aggregates in the vicinity of the future fin, and the basal structures or pterygiophores soon become evident. The latter structures permit limited use of dorsal and anal fin position and meristics about midway through the mesolarval phase. The anterior principal rays develop first with subsequent rays added in a posterior direction. The first of the rudimentary rays (anterior to the principal rays) are frequently evident before all the principal rays are formed; rudimentary rays are added in an anterior direction.

The first or most anterior principal ray in both dorsal and anal fins remains unbranched, while all others branch shortly after or as segmentation becomes evident. The last or most posterior principal ray in each fin is considered to be divided at the base and therefore usually consists of two elements that, except for their close proximity and association with the same pterygiophore, might be mistaken for separate rays.

Principal dorsal and anal ray counts between and within certain genera vary sufficiently to often be of use in identification at the specific level, especially the anal rays of cyprinids and the dorsal rays of catostomids. The position of the dorsal fin origin (anterior insertion) and insertion (posterior insertion) relative to the origin of the pelvic fins or fin buds and the vent varies considerably among the cyprinids and is useful in identification at the genus or species levels. These position characters are relatively more constant among the catostomids (e.g.,

dorsal fin origin is always well in advance of the pelvic fins), especially at the subfamily level, and therefore of less value in larval identification.

The pelvic fins begin as buds at some stage prior to or at the very beginning of the metalarval phase. In cypriniform fishes, they originate in an abdominal position along each side of the preanal finfold. They may erupt shortly after dorsal and anal fin development begins or be delayed until just before or shortly after all principal rays are present in the median fins. Pelvic rays begin to form shortly after the buds make their appearance; the adult complement of segmented rays quickly ensues. Within the cypriniform fishes, pelvic ray counts are seldom used diagnostically. However, both the position of the pelvic fin or fin bud relative to other structures and its position in the sequence of developmental events can be useful in identification, especially in the family Cyprinidae.

The pectoral fins typically begin as buds immediately behind the head during the late embryonic phase. However, pectoral buds are not evident on some species (including some cypriniform fishes) until shortly after hatching. Though strongly striated and occasionally with membranous folds and breaks, they typically remain rayless in cypriniforms until late in the mesolarval phase when most of the principal median fin rays are present. With the exception of rudimentary caudal rays, the rays of the pectoral fins are often the last to establish their full complement. For this reason and because the number of pectoral rays is usually relatively large and difficult to count without excision (especially the smaller ventral rays), pectoral ray counts are generally of little value in larval identification.

Other Countable Structures

Other structures that may be treated meristically (and in some cases morphologically) include branchiostegals, gill rakers, pharyngeal teeth, and scales. Branchiostegals form early in larval development, but counts are usually constant within major taxon groups. Within the order Cypriniformes, all members of the superfamily Cyprinoidea, which includes the Cyprinidae and Catostomidae, have three branchiostegals (McAllister 1968). Due to later development, small size and/or internal location, the other characters are seldom used, and then usually only on later metalarvae and juveniles. Gill rakers form gradually with numbers increasing throughout much of the larval period and the early portion of the juvenile period. Pharyngeal teeth form relatively early but may not be sufficiently well developed to be readily removed and observed until late in the larval period or early in the juvenile period. Detailed study of gill rakers and pharyngeal teeth might reveal some useful diagnostic qualities, including size, shape, and number; however, in most cases, species can be more easily distinguished by use of external characteristics. Scales typically become apparent late in the larval period or early in the juvenile period, but all are not typically present until a short time later. First scales on cypriniforms typically appear mid-laterally on the posterior half of the body and from there spread anteriorly, dorsally and ventrally toward adult coverage. The scales of larger-scaled species are sometimes obvious by late in the metalarval phase and may be used to separate or help distinguish certain species or genera.

Morphology

The shape or form of larvae and specific anatomical structures (e.g., the gut, air bladder, yolk sac, and mouth) change as fish grow and develop and provide some of the most obvious characters for identification, particularly at family and subfamily levels. At the species level, morphological differences are usually much more subtle, but may still be of diagnostic value. Much of this shape or form-related information can be quantified to some degree via proportional measurements or morphometrics.

Morohometric data emphasize the relative position and relative size of various body components and dimensions and may be critical to species identification. Such measurements may be allometric, changing in proportion as the fish grow; thus morphometric data should be related to size, at least for protolarvae and mesolarvae. Some morphometric data, particularly body depths and widths, may be directly affected by the condition of individual specimens and the volume and form of food items in their digestive tracts. The source of the specimens and the nature of the solution in which they are stored should also be considered in the use of this data. Shrinkage and deformation are greater in alcohol than in formalin.

Morphometric data in this guide are reported as a percentage of standard length. Use of standard length avoids the allometric influence of caudal fin growth included in percentages based on total length. As explained later (Methods), conversion of certain data to percent total length for comparison with other works is relatively simple. Prior to hypural plate formation and completion of notochord flexion, herein correlated with the acquisition of the adult complement of principal caudal fin rays, standard length is defined as notochord length (snout to the posterior end of the notochord). Thereafter, it is defined as the length from the anterior margin of the snout to the most posterior margin of the hypural plates (usually the superior plate or hypurals). Use of notochord length for protolarvae and early mesolarvae gives the appearance of greater allometric growth differences than may really exist, at least in comparison with subsequent measures based on the posterior margin of the hypural plates. This undesirable effect is a result of the upward bending or flexing of the notochord and the switch from use of the end of the notochord to the posterior margin of the hypurals as the basis for length measurement. These factors must be taken into account when reviewing the morphometric data given herein.

Measurement of body lengths and various parts thereof, in contrast to the procedures recommended by Hubbs and Lagler (1958) for larger juveniles and adults, is generally done along a line parallel to the horizontal axis of the fish. Exceptions are fin lengths, which in studies conducted for this guide were measured from the origin of the fin base to the most distal margin of the fin rays. Typical measures include total, standard, snout-to-vent preanal, predorsal, prepelvic, head, eye, snout and fin lengths.

Snout-to-vent length, which is measured to the posterior margin of the vent or anus, reflects the position of the vent. The term preanal length should be reserved specifically for the length measure from the snout to the origin of the anal fin; in many fishes, including the cypriniforms, the latter point is often the same or nearly the same as the posterior margin of the vent. The snout-to-vent length is a primary diagnostic character for many species, especially at the family and sometimes subfamily level. Except for most larvae of the common carp (Cyorinus carpio) and an occasional mesolarva of the Colorado squawfish (Ptychocheilus lucius), cyprinid larvae in the Upper Colorado River System are readily differentiated from catostomid larvae by snout-to-vent lengths of less than 72% SL.

Head length is typically measured to the posterior margin of the operculum in juveniles and adults, but the operculum may be absent or incomplete throughout much of the larval period. Accordingly, many biologists have redefined head length to be measured to the posterior end of the auditory vesicle or the anterior or posterior margin of the cleithrum, one of the first bones to ossify in fish larvae (Berry and Richards 1973). Unfortunately, the auditory vesicle and cleithrum are not always easily observed, especially later in larval development. Also, resultant measures from the auditory vesicle are considerably anterior to the eventual posterior margin of the operculum. Snyder et al. (1977) and Snyder and Douglas (1978) measured larval head length to the anterior insertion or origin of the pectoral fin. The base of the pectoral fin is readily observed throughout the larval period (except in the few species that hatch prior to pectoral

bud formation), somewhat approximates the position of the cleithrum (part of its supporting structure), and more nearly approximates the posterior margin of the operculum than does the posterior margin of the auditory vesicle. Accordingly, head length is defined herein as the length from the anterior margin of the snout to the anterior-most margin or origin of the base of the pectoral fin and is used, for purposes of consistency, for juveniles as well as larvae. The measure is most precisely determined while examining the specimen from above or below and, if necessary, holding the fin away from the body.

Body depths and widths are measured in planes perpendicular to the horizontal axis of the fish. Many biologists report these as maximum or minimum measures (e.g., greatest head depth, greatest body depth, and least caudal peduncle depth). However, it seems more logical for comparative purposes to specify specific locations as standard reference points for such measures, as per Moser and Ahlstrom (1970), Fuiman (1978), and Snyder and Douglas (1978). Five specific locations, four corresponding to specific length measurements, are used herein: 1) immediately posterior to the eyes, 2) origin of the pectoral fin, 3) origin of the dorsal fin, 4) immediately posterior to the vent and 5) at the anterior margin (mid-lateral apex) of the most posterior myomere. Neither fins nor finfolds are included in depth measurements.

Other morphological characters such as the position, size, and form of the mouth and the gut, and related changes, can be among the more useful characters for identification to the species level. The size of the mouth, as well as its position and angle of inclination, and the form of specific mouth structures are diagnostic for some cypriniforms, especially later in the larval period. The timing of mouth migration from a terminal to an inferior position is particularly useful during a portion of the metalarval period in catostomids. The length, timing of the occurrence of the first loop, and eventual degree and form of the loops, folds, or coils of the gut can be important diagnostic characters for many fish. They are among the more obvious characters used to distinguish the postflexion mesolarvae, metalarvae and early juveniles of certain catostomids.

Pigmentation

The basic patterns of chromatophore distribution, and changes in these patterns as fish grow and advance developmentally, are characteristic at the species level (for some fishes at the subspecies level). Used with caution, preferably in combination with other characters if feasible, and with an awareness of both intra- and inter-regional variation, the chromatophore distribution and patterns of many fishes are among the most useful characters available for identification at the species level. However, in some instances, differences are so subtle that use of pigmentation is impractical and may be misleading.

For a specific developmental stage within a species, pigmental variation is largely a function of the number of chromatophores exhibiting pigment, either in general or in specific areas, and not a change in chromatophore pattern or distribution. Complete loss of pigment in an area, of course, eliminates that portion of the visible pattern. In addition, pigment in chromatophores can be variously displayed from tight, contracted spots, giving a relatively light appearance, to widely expanded, reticular networks which gives a dark or more brilliant appearance to the area affected. Differences in environmental conditions and food can significantly affect the appearance of pigmentation. Accordingly, the pigmentation of cultured specimens can appear quite different from that of field-collected material.

In cypriniform fishes, as well as most other fishes, chromatophores other than melanophores have not been sufficiently studied for identification purposes because they typically are neither as numerous nor as obvious and because of difficulty in preserving these pigments

over a period of time. Melanin, the amino acid breakdown product responsible for the dark, typically black, appearance of melanophores (Lagler et al. 1977), remains relatively stable in preserved specimens. Melanophores are, however, subject to fading and loss of pigment if specimens are stored or studied extensively in bright light or if subjected to changing concentrations in the fluids in which they are stored or studied. To minimize the latter effects, as well as shrinkage and deformation, dilute formalin solutions (3-5%, preferably buffered) are strongly recommended over alcohol solutions as storage media. Most of the following discussion refers to chromatophores in general, but in this guide, as well as previous guides to freshwater species in North America, pigmentation typically refers to melanophores only.

According to Orton (1953), pigment cells originate in the neural crest region (dorsal portion of body and tail) and migrate in amoeboid fashion in waves to their eventual position. The first wave of chromatophores occurs late in the embryonic period or early in the larval period and establishes a relatively fixed basic or primary pattern of chromatophore distribution. In a few (mostly marine) species, the cells become pigmented prior to migration, and the actual migration can be observed and documented. But in cypriniform fishes, as in most other freshwater species, pigment is not present (or appears not to be present) in the chromatophores until some time after the cells have reached their ultimate destinations.

Pigmentation often changes considerably as fish grow and develop. Most of the change is due to the increased numbers and spread of chromatophores. Observable pigmentation might also be lost from certain areas, usually through either a loss of the pigment or chromatophores themselves, or, in the case of subsurface or internal chromatophores, by the thickening and increasing opacity of covering tissues. Peritoneal melanophore pigmentation is an obvious character for the later stages of some larvae but can be obscured by overlying tissues incorporating silvery iridophores in the latest stages (the silvery pigment often dissipates over time in preservative). Internal melanophore pigmentation can be observed more readily by careful clearing of the larva.

Osteology

When externally visible characters fail to conclusively segregate species, osteological characters may come to the rescue. While whole-specimen clearing and cartilage- and bone-staining techniques are relatively simple (see Methods), they require much time (a few days, mostly waiting) and a fair amount of attention (monitoring progress and changing fluids). Soft (longwave) X-ray techniques (Tucker and Laroche 1984) may be faster and easier, especially when working with a large number of specimens, but require appropriate X-ray equipment and a darkroom.

Dunn (1983) reviewed the utility of developmental osteology in taxonomic studies and Dunn (1984) provided a brief overview of use of skeletal structures. Among the first bones to ossify are those associated with feeding, respiration, and orientation (e.g., the jaws, bones of the branchial region, cleithrum, and otoliths). The axial skeleton follows with formation of the vertebrae and associated bones. Once the axial skeleton is sufficiently established, median- and pelvic-fin supports and then the fins develop. Presence, number, position, and shape of certain bones in many parts of the skeleton can have diagnostic value, even for closely related species. Use of osteological characters for identification of fish larvae has received little attention, but its potential value is great, at least for confirmation of questionable identities and for some species for which external characters are diagnostically inadequate.

SPECIMENS EXAMINED

Cultured specimens were studied for each species. Developmental series of June sucker were reared from artificially-fertilized eggs at the Springville Fish Hatchery (Utah Division of Wildlife Resources) in 1982 (plus yearlings from 1984-1985) and at Brigham Young University and the Larval Fish Laboratory in 1987. Series of Utah sucker and mountain sucker were reared at Utah State University in 1987 and the Larval Fish Laboratory in 1981, respectively. Parental stock for the series of June sucker was collected from the Provo River, principal tributary to Utah Lake; Utah sucker from Bear Lake along the west shore and in the mouth of Swam Creek; and mountain sucker from Willow Creek and Ways Gulch, headwater tributaries to the Elk River (Yampa River System) northwest of Steamboat Springs, Colorado.

Wild or field-collected larvae and juveniles of certain identity were available only for the mountain sucker. Mountain suckers were collected in 1966 and 1967 from Rocky Creek, Madison River (near Cherry Creek), and Flathead Creek (all headwaters of the Missouri River) in south-central Montana; in 1973-1982 from Pyramid Lake and the lower Truckee River, Nevada; in 1981 from Willow Creek and Ways Gulch, headwater tributaries of the Yampa River System near Steamboat Lake in northwestern Colorado; and in 1982-1986 from the lower portions of the Provo and Spanish Fork Rivers, tributaries to Utah Lake.

In addition to the early life stages, adults of all three species were examined for meristics and to verify certain diagnostic characters reported in the literature. A solitary 420 mm SL (495 mm total length) June sucker was collected from the Provo River during the spawning season in 1987 and provided to us on loan. Utah suckers collected from Bear Lake, Utah, were available in the Colorado State University teaching collection. Adult mountain suckers were collected from Willow Creek and Ways Gulch in northwestern Colorado.

Most of the collected and reared specimens were killed and fixed in 10% formalin, then stored in 3% buffered formalin. Some mountain sucker specimens from Montana were preserved in ethyl or isopropyl alcohol solutions. Due to excessive dehydration and shrinkage, none of the latter specimens were analyzed for measures or size relative to developmental state.

All specimens used for morphometric and skeletal analysis, and most of the other specimens on which this study is based are maintained in the collections of the Larval Fish Laboratory and are available for examination by other researchers. Individual specimen data (counts and measures) are stored in computer files (IBM compatible, Lotus 123 files).

METHODS

Specimen Data and Observations

Specimens were analyzed for counts, measures, developmental state, and pigment distribution. Figure 3 illustrates the various measurements, fin ray counts, and myomere counts that were made on at least two specimens, if available, in each 1-mm TL (total length) interval throughout the larval period of each species. Thereafter, to a length of about 50 mm TL, one or more specimens were similarly processed for each 5-mm interval, if available. Specimens were studied under low-power stereo-zoom microscopes with measuring eyepiece reticles and various combinations of reflected, transmitted, and polarized light. Magnification was adjusted before each series of measurements to calibrate the scale in the eyepiece against a stage micrometer for direct measurement. Measurements were made to the nearest 0.1 mm and occasionally to half that unit. Re-measurement of selected specimens by a second observer indicated that most measurements are repeatable to within 0.1 mm. Most measurements are reported as a percentage of standard length (%SL) but are readily converted to percent total length by dividing the length of interest (as %SL) by total length (AS to PC, as %SL), and multiplying by 100. Meristic data were also obtained from specimens cleared and stained for skeletal study and from available adults.

Size at the apparent (visible under low-power magnification without special preparation) onset of selected developmental events was documented for all specimens analyzed for morphometric and meristic data and for as many additional specimens as time permitted. The selected events were hatching, attainment of *eye* pigment, formation of pectoral and pelvic fin buds, loss of yolk and preanal finfold, formation of first and last principal fin rays in each of the median fins, formation of first and last fin rays in the paired fins, formation of the first and last rudimentary rays of the caudal fin, and initial and complete formation of lateral surface scales on the body. For each specimen developmental phase (e.g., Protolarva) and extent of gut folding were also determined. The latter was classified as one of five gut phases (Fig. 4). Changes in other structures were only casually noted.

Drawings, including dorsal, lateral, and ventral views, were prepared for beginning and middle of each larval phase (flexion and postflexion mesolarvae treated as one phase) and the juvenile period (young-of-the-year portion) of all three species to document typical body form and pigmentation. Enlarged photographs of typical specimens were traced to assure accurate body proportions. Various structures were checked and additional detail was added to drawings while specimens were examined under a microscope. Final drawings were idealized (e.g., closed or frayed fins opened and smoothed and curved bodies straightened). If necessary, melanophore distribution was modified using additional reference specimens to represent a more typical pattern. In addition, pigmentation variation was studied by sketching observed patterns and loosely noting their frequency.

Selected postflexion mesolarvae, metalarvae, and juveniles were cleared and stained for examination of potential osteological characters and vertebra counts as well as to verify fin meristics. Based on our study of other catostomids, emphasis during examination was placed on the shape and size of the interneurals, frontoparietal fontanelle, and anterior-dorsal maxillary projections; position of the mandibles relative to the maxillae; and the angles at which the base of the postcleithra extend from the cleithra (Fig. 5). Mesolarvae were stained with alcian blue for cartilage and metalarvae and juveniles with alizarin red for bone. The following tissue clearing and skeletal staining procedures were slightly modified from techniques described by Pothoff (1984) and Taylor and Van Dyke (1985).

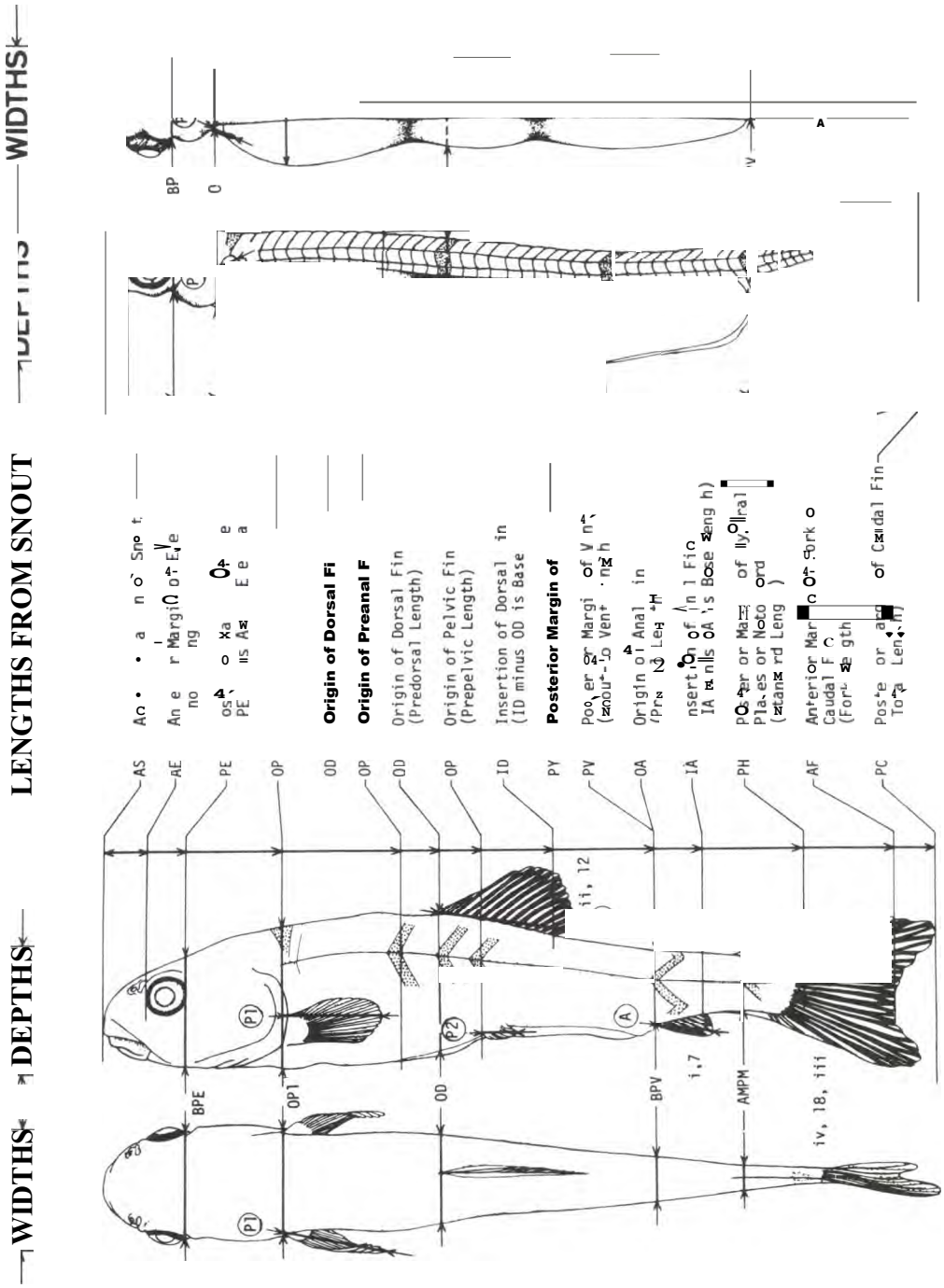


Figure 3. Measures and counts for larval and early juvenile fishes. Yolk-sac and pterygiophores are included in width and depth measures but fins and finfolds are not. "B" in BPE and BPV means immediately behind. AMPM is anterior margin of most posterior myomere. Location of width and depth measures at OD prior to D formation is approximated to that of later larvae. PHP is measured to end of notochord until adult complement of principal caudal rays are observed. Fin lengths (D, A, P1, and P2, encircled) are measured along plane of fin from origin to most distal margin. When reported together, rudimentary median fin rays (outlined above) are given in lower case Roman numerals, while principal median fin rays (darkened above) are given in arabic numerals); rudimentary rays are not distinguished in paired fins. Most anterior, most posterior and last myomeres in counts to specific points of reference are shaded above. (From Snyder 1981.)

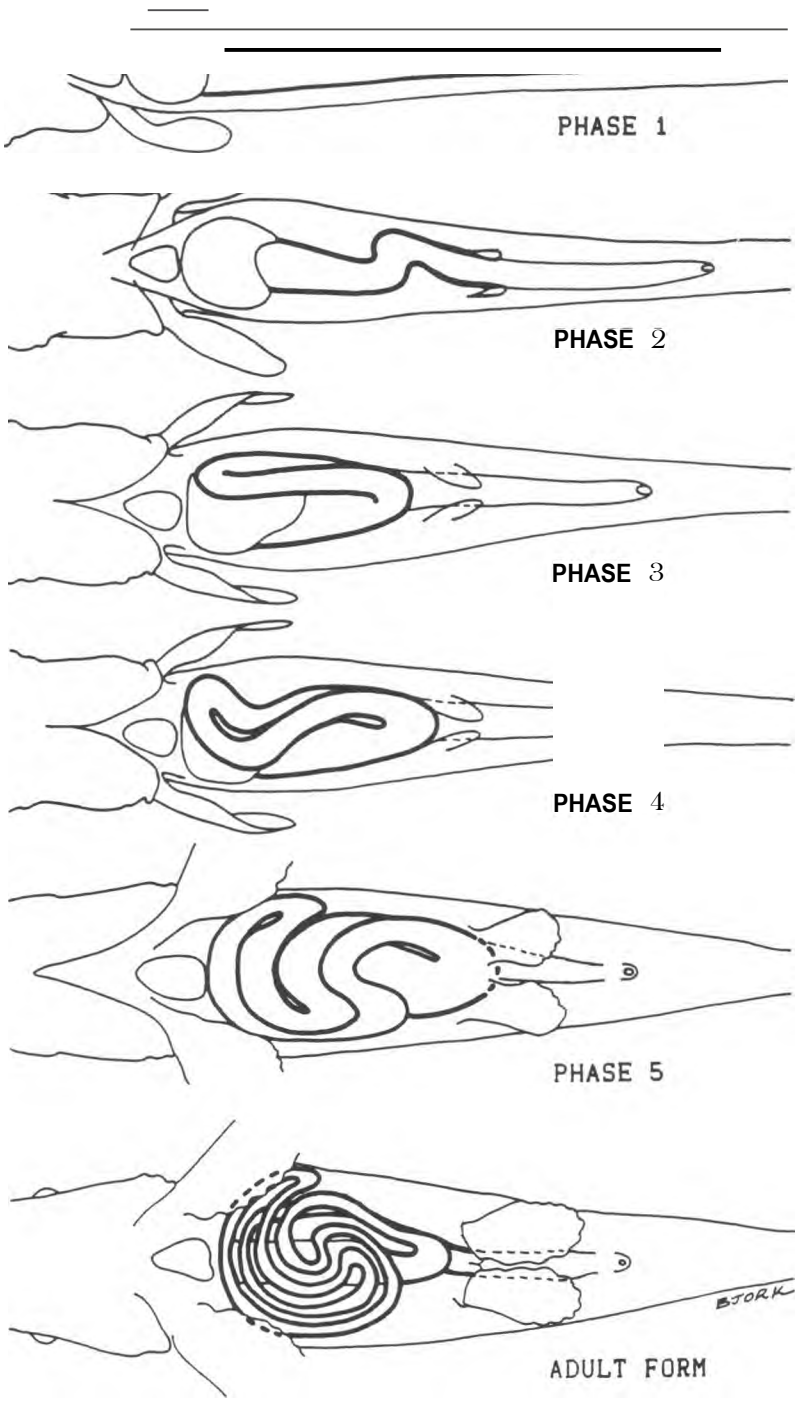


Figure 4. Phases of gut coil development in catostomid fish larvae and early juveniles with comparison to adult form in Catostomus commersoni (latter modified from Stewart 1926). Phase 1 -- essentially straight gut. Phase 2 -- initial loop formation (usually on left side), begins with 90° bend. Phase 3 -- full loop, begins with straight loop extending to near anterior end of visceral cavity. Phase 4 -- partial fold and crossover, begins with crossing of first limb over ventral midline. Phase 5 -- full fold and crossover, begins with both limbs of loop extending fully to opposite (usually right) side, four segments of gut cross nearly perpendicular to the body axis. Later in Phase 5 and in adult form, outer portions of gut folds or coils extend well up both sides of visceral cavity.

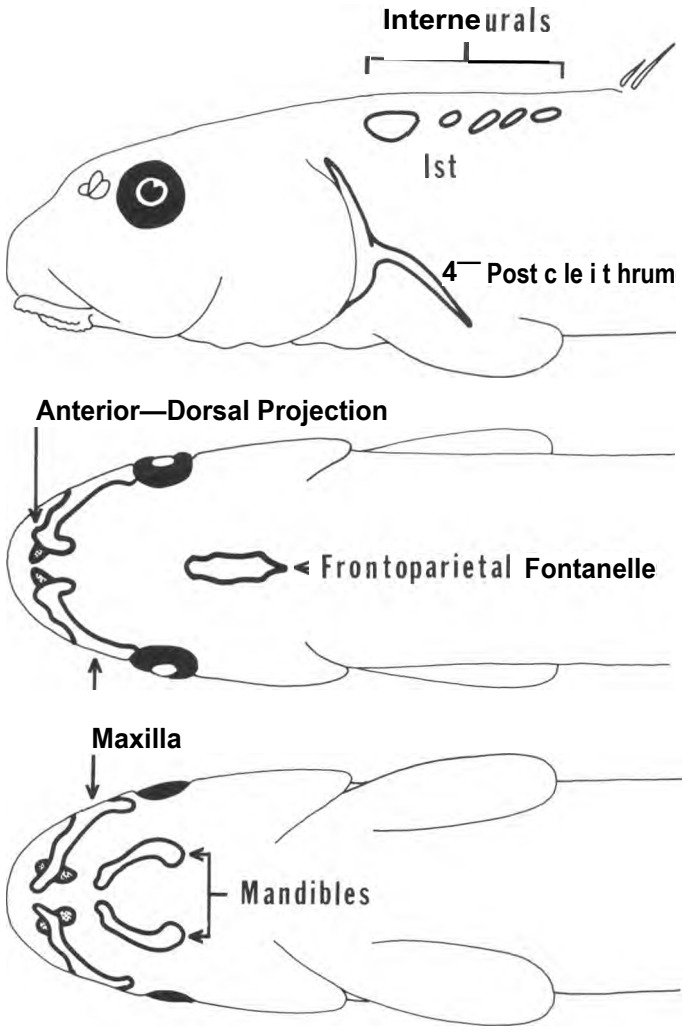


Figure 5. Location of selected skeletal features of metalarval and early-juvenile catostomids. Top -- lateral view. Middle -- dorsal view. Bottom -- ventral view.

Clearing and Staining Procedures

Chemicals:

Alcian blue (powder)
Alizarin red S (powder)
Distilled water
Ethanol (absolute ethanol preferred, denatured will suffice)
Formalin (saturated formaldehyde solution)
Glacial acetic acid
Glycerin (glycerol)
Potassium hydroxide
Sodium borate (powder)
Sodium phosphate monobasic
Sodium phosphate dibasic
Trypsin (At least 1-100 activity)
Thymol (crystals)

Stock solutions:

Fixative -- 10% solution of formalin in distilled water; buffer with 1.8 g sodium phosphate monobasic and 1.8 g sodium phosphate dibasic per liter of formalin solution.
Preservative -- 3% solution of formalin in distilled water; buffer with 1.8 g sodium phosphate monobasic and 1.8 g sodium phosphate dibasic per liter of formalin solution.
Ethanol solution -- 50% solution of ethanol in distilled water.
Saturated sodium borate solution -- Excess sodium borate powder in distilled water; mix well and allow excess sodium borate powder to settle.
Enzyme buffer solution -- 30% solution of supernate from saturated sodium borate solution in distilled water.
Potassium hydroxide (KOH) solution -- 1% solution KOH in distilled water.
Alcian blue stain solution -- 30% glacial acetic acid in ethanol; to every 100 ml add 20 mg alcian blue powder (solution will keep at room temperature for 3-4 weeks).
Saturated alizarin red solution -- Excess alizarin red powder in small amount (e.g., 20 ml) of distilled water; mix well and allow excess alizarin red powder to settle.
Alizarin red stain solution -- To every 100 ml of 1% KOH solution add 1-2 ml of supernate from saturated alizarin red solution (solution will keep for 1 week).
Glycerin solutions -- 25, 50, and 75% solutions of glycerin in distilled water.
Trypsin solution -- To every 500 ml of enzyme buffer solution, add about 1 g of trypsin powder; mix well but do not allow to froth (make just prior to use).

Cartilage staining procedure:

1. Place live or freshly killed specimens in fixative (10% buffered formalin) for at least 24 hr; transfer specimens to preservative (3% buffered formalin) for storage.

2. Place preserved specimens directly in 50% ethanol solution for 24 hr, then in absolute (or denatured) ethanol for another 24 hr.
3. After alcohol dehydration, place specimens in alcian blue stain solution for 24 hr.

4. After staining, place specimens in supernate from saturated sodium borate solution for 12 hr.

5. Remove specimens from saturated sodium borate solution and place in trypsin solution (volume of 10-40 times that of specimens) and leave until 80-90% of the muscle tissue is cleared (typically 2-5 days for specimens <21 mm TL, 5-12 days for specimens >20 mm TL). Completely change trypsin solution every 3 days.

6. After clearing, place specimens in distilled water for 1 hr.

7. Work specimens through glycerin series (25-50-75%); 24 hr in each solution. Store specimens in 100% glycerin with a few thymol crystals to prevent fungus growth.

Bone staining procedure:

1. Place live or freshly killed specimens in fixative (10% buffered formalin) for at least 24 hr; transfer specimens to preservative (3% buffered formalin) for storage.

2. After preservation, the skin of juveniles with scales or thick integument should be carefully removed using fine-pointed forceps.

3. Place in trypsin solution (volume of 10-40 times that of specimens) and leave until 80-90% of the muscle tissue is cleared (typically 2-5 days for specimens <21 mm TL, 5-12 days for specimens >20 mm TL). Completely change trypsin solution every 3 days. Larger specimens may require more trypsin. Clearing time depends on specimen size and will typically range from 5-12 days.

4. After clearing, place specimens in distilled water for 1 hr.

5. Place specimens in alizarin red stain solution. Staining time depends on specimen size and will typically range from 1-5 days (remove specimens from stain solution periodically and check on progress).

6. After staining, soak specimens in distilled water for 1-2 hr. If after 2 hr specimens still retain much stain in the soft tissues, place specimens back in trypsin solution for about 2 hr (periodically check on progress) then soak again in distilled water for 1 hr.

7. Work specimens through glycerin series (25-50-75%); 24 hr in each solution. Store specimens in 100% glycerin with a few thymol crystals to prevent fungus growth.

Note: If semitransparent soft tissue covers structures to be studied for either staining procedure, it can be removed by carefully cutting and picking away the soft tissue with fine-pointed scissors and forceps.

RESULTS AND CONCLUSIONS

Results are divided into three interrelated sections -- Comparative Summary, Keys, and Species Accounts. While 151 specimens were intensively analyzed for morphometrics and meristics, and several hundred more were documented for size, developmental state, and pigmentation patterns, there are undoubtedly rare specimens with character extremes beyond those we observed. Some buffer (usually range extension by one unit) has been built into the keys to minimize this problem.

Because of the similarity between larvae, especially June and Utah suckers, many specimens may be difficult to identify or remain questionable after applying the diagnostic criteria provided herein. The identity of such specimens is tentative and should be designated as such by using a question mark (?) after the taxon name, appending an appropriate footnote, or leaving the identity at the family level (e.g., "unidentified Catostomidae"). Some of these specimens will represent character extremes not observed in this study. Others may be hybrids.

Hybridization between June and Utah suckers has been documented and, as noted in the introduction, apparently had a significant impact on the current population of June sucker in Utah Lake (Miller and Smith 1981). Under unusual conditions, hybrids of either June or Utah sucker with mountain sucker also might be possible. Using the keys and diagnostic characters that follow, the larvae of hybrids will likely be identified as the parental species they most closely resemble.

Radant and Sakaguchi (1981) reported that Utah suckers spawn earlier in the spring than June suckers. If such temporal differences are great enough and can be adequately documented for the years in which larvae to be identified were collected, those differences can be used as criteria for tentatively segregating otherwise indistinguishable larvae.

Shirley's (1983) illustrations and data (morphometrics and size relative to state of development) for reared June sucker protolarvae and mesolarvae are generally similar to comparable illustrations and data given herein. However, our preanal and total myomere counts averaged 2 and 3 myomeres greater, respectively, than Shirley's counts. Those differences are due to methodology since our counts for some of Shirley's specimens matched counts for June sucker larvae specifically reared for this study. As mentioned in the introduction, Shirley's illustrations and data for metalarvae and juveniles were based largely on collected mountain suckers.

Comparative Summary

Size relative to state of development (Table 1) -- Although egg size is similar, Utah suckers tend to hatch at a larger size than June suckers. Generally, mountain sucker eggs are smaller and yield smaller larvae than either Utah or June suckers. At least through transition to the metalarval phase, Utah suckers maintain their greater size relative to developmental state. However developmental processes for Utah suckers appear to advance more rapidly, relative to size, during the metalarval phase and, with the exception of some June suckers, Utah suckers transform to the juvenile state before either of the other species. Care must be taken when treating the latter and related observations as diagnostic criteria since the reared larvae on which they are based were slow growing and may have been developmentally stunted (Appendix I); verify with other criteria if possible. The same situation could apply to the smallest juvenile June suckers. All species initiated formation of the gut loop (90 bend or kink, phase 2, Fig. 4)

Table 1. Comparison of diagnostically useful differences in size relative to state of development for Chasmistes liorus, Catostomus ardens, and Catostomus platyrhynchus larvae and early juveniles. SL = standard length, TL = total length. Rare or questionable extremes in parentheses.

Character	Chasmistes liorus		Catostomus ardens		C. platyrhynchus	
	mm SL	mm TL	mm SL	mm TL	mm SL	mm TL
Phase/period transitions						
Embryo to larva:	(7)8-10	(7)8-10	(8)9-11	(8)9-11	7-8	7-8
Proto- to mesolarva:	11-13	11-14	12-13	12-14	11	11-12
Flexion to post-flexion mesolarva:	12-13	13-14	13-14	14-15	13-14	15
Meso- to metalarva:	14-16	16-19	15-17	17-20	16-17	18-19
Larval to juvenile:	18-22	22-25(27)	19-20	23-23	21-22	25-27
Gut phase transitions						
2 to 3:	17-19	22-23	18-19	(19)22-24	16-17	20-21
3 to 4:	19-20	24-25	20-22	26-27	18-20	22-24
4 to 5:	24-28	31-35	27-28	34-35	21-23	25-28
Yolk absorbed:	11-13	11-14	12-13	12-14	10-11	10-12
Preanal finfold absorbed:	18-21	22-25(27)	19	23	21-22	25-27
Onset of first fin rays						
Dorsal, principal:	12-13	13-14	13-15	14-16	13	14
Pelvic:	(13)14-15	16-17	14-17	17-19	16	18
Caudal, rudimentary:	12-14	13-15	14-15	15-17	14	15-16
Onset of full ray counts						
Dorsal, principal:	14-15	16-17	14-16	17-19	14-17	16-19
Anal, principal:	14-16	16-19	15-17	17-19	16-17	18-19
Pectoral:	18-20	22-24	15-18	17-22	18-20	22-23
Pelvic:	18-19	23	18-19	(19)22	18-20	22-23
Caudal, rudimentary:	18-21	22-25	19-20	23	20-21	24-25
Scales, lateral series						
First observed:	19-22	25-27	21-23	26-28	23-24	28-30
Onset of full series:	24-27	29-35	24	29-38	32-36	38-43

at about the same size. Thereafter, gut loop and fold transitions occurred at notably smaller sizes for mountain suckers and somewhat larger sizes for Utah suckers than for June suckers. By the metalarval phase, mountain suckers were in at least gut phase 2. By the juvenile period all species were in at least gut phase 4. The presence of scales on the earliest juveniles examined was difficult to observe. Accordingly, the lengths reported herein for presence of first lateral scales and the establishment of the full lateral series may be greater than is the actual case. Even so, at least the full lateral series certainly appears much earlier in June and Utah suckers (<30 mm SL) than in mountain suckers (>30 mm SL).

Meristics and morphometrics (Table 2; Appendix II) -- Principal dorsal fin, pectoral fin, and pelvic fin ray counts tended to be highest for June sucker and least for mountain sucker juveniles and adults (also principal dorsal rays for metalarvae). Lateral line (or series) scale counts and dorsal rudimentary rays of the caudal fin tended to be the reverse, least for June sucker and greatest for mountain sucker. Utah sucker tended to be intermediate in all cases but generally closer to the counts for June sucker. Although gill raker counts (and form) are diagnostic for the adults of these fish, the adult count is not set until much later in the juvenile period than covered herein. There is a tendency for total vertebra and myomere counts to be slightly greater in Utah suckers and slightly less in mountain suckers than in June suckers; however, vertebra counts for June and Utah suckers are based on only reared specimens cleared and stained for this study and the differences, especially in myomere counts, are not consistent enough to warrant treatment as useful diagnostic characters (see species accounts). As reflected by myomere counts and lengths, the origin of the dorsal finfold was generally more anterior on Utah sucker protolarvae and mesolarvae than on the others. Similarly, origin of the preanal finfold was usually more posterior on mountain sucker mesolarvae and metalarvae (except near transition to the juvenile period) than on the others.

Table 2. Comparison of diagnostically useful differences in meristics and morphometrics for Chasmistes liorus, Catostomus ardens, and Catostomus platyrhynchus larvae and early juveniles (<40 mm standard length, <50 mm total length). See Figure 3 for abbreviations and methods of measurement and counting. F = flexion, Pf = postflexion.

Character	Chasmistes liorus		Catostomus ardens		platyrhynchus	
	Mean	Range	Mean	Range	Mean	Range
Fin Ray Counts						
D, principal:	12	(11)12-13(14)	12	(10)11-13(14)	10	(8)9-11-(13)
P1:	17	16-18(19)	16	(14)15-17	15-16	14-16
P2:	11	10-11	10	10	9-10	9-10
C, dorsal rudimentary:	9	(4)7-11	10	(8)9-11	11	(9)-11-12
Scales, Lateral Series:	55-61	54-70	62	(54)-57-72(79)	75-92	(60)75-100(108)
Myomere Counts						
To ODF						
Protolarvae:	15	14-16(+?)	12	10-13(+?)	14	12-21
F Mesolarvae:	15	13-16	12	11-12	14	13-16
Pf Mesolarvae:	15	13-16	13	12-14	15	13-17
To OPAF						
Pf Mesolarvae:	7	5-7	6	5-7	9	7-13
Metalarvae:	13	7-25(+?)	12	6-17(+?)	18	9-28
Lengths, as % Standard Length						
AS to ODF						
Protolarvae:	38	35-40(+?)	33	29-36(+?)	41	36-55
F Mesolarvae:	38	35-42	35	31-36	41	38-43
Pf Mesolarvae:	43	36-47	39	37-41(+?)	44	41-47
AS to OPAF						
F Mesolarvae:	25	23-28	25	22-26	28	26-31
Pf Mesolarvae:	30	28-35	28	25-31	35	30-44
Metalarvae:	42	31-61(+?)	41	30-51(+?)	50	35-68

continued.

Table 2. Continued.

Character	Chasmistes liorus Mean	Range	Catostomus rdens Mean	Range	C. platyrhynchus Mean	Range
AS to OD						
Pf Mesolarvae:	48	47-49	49	47-50	50	49-52
Metalarvae:	49	48-50	50	49-52	51	50-53
Juveniles:	48	46-51	49	48-51	50	48-52
As to ID						
Metalarvae:	65	64-67	65	64-67	63	62-65
Juveniles:	66	65-69	65	64-68	63	60-64
OD to ID						
Metalarvae:	16	15-18	15	14-16	12	11-14
Juveniles:	18	15-19	16	14-17	13	12-14
D						
Metalarvae:	22	19-25	19	18-20	17	15-19
Juveniles:	27	23-29	24	21-26	20	18-21
A						
Juveniles:	16	13-20	15	12-18	14	12-15
C						
Metalarvae:	22	18-26	20	18-22	18	15-20
Juveniles:	27	24-31	25	23-28	21	19-23
P1						
Juveniles:	21	17-24	20	15-22	18	15-19
P2						
Metalarvae:	11	8-14	11	8-12	8	6-11
Juveniles:	16	14-19	14	12-16	12	10-13
D+P2						
Metalarvae:	33	27-39	30	26-32	25	22-29
Juveniles:	43	37-46	38	33-42	32	28-34
D+C						
Metalarvae:	43	37-51	40	34-43	35	30-38
Juveniles:	54	48-57	48	44-53	41	38-43
Yolk						
Protolarvae:	62	57-67	57	49-64	47	0-70
F Mesolarvae:	17	0-49	16	0-43	3	0-14
Depths, as % Standard Length						
At BPE						
Juveniles:	19	17-21	18	17-18	16	15-17
At BPV						
Juveniles:	15	13-17	12	10-14	13	11-14
Widths, as % Standard Length						
At BPV						
Juveniles:	10	9-12	8	6-10	9	8-10
Eye Diameter (AS-PE minus AS-AE)						
As % Head Length (AS-OP1)						
Metalarvae:	29	27-33	30	28-33	26	25-28
Juveniles:	29	27-36	30	27-32	24	22-25
As % Snout Length (AS-AE)						
Metalarvae:	114	92-144	132	107-171	100	76-122
Juveniles:	103	86-133	112	95-133	76	63-93

As indicated by yolk length data, mountain suckers tended to assimilate most if not all of their yolk as protolarvae, while June and Utah suckers retained notable amounts of yolk at the beginning of the mesolarval phase. For metalarvae and especially juveniles, eye diameter (AS to PE minus AS to AE) is notably smaller in mountain suckers than the others. Also, the origin of the dorsal fin tended to be slightly more posterior and the insertion of the dorsal fin more anterior on mountain suckers than on the others. As a result, the length of the base of the dorsal fin (OD to ID) was always less on mountain suckers than on June suckers and usually less than on Utah suckers. Fin lengths, especially dorsal, pelvic, and caudal, were notably greater for metalarval and juvenile June suckers than for mountain suckers and were intermediate for Utah suckers. Head depth immediately behind the eyes (BPE) and body depth and width immediately behind the posterior margin of the vent (BPV) were greater for June sucker juveniles than for the others; head depth was least for mountain suckers and the body width least for Utah suckers. Since data for body depths and widths at other points are affected by the amount of yolk present in protolarvae and flexion mesolarvae and amount of food material in the guts and general condition of later developmental stages, the diagnostic value of those data is limited.

Mouth (Figs. 14, 15, 28, 29, 42 and 43) -- Mouth characters are important in the diagnosis of adults of these catostomids (Smith 1966; Miller and Smith 1981). Unfortunately, the mouths are insufficiently developed in all but the latest larvae and certain characters may remain indistinct in the earliest juveniles. Juvenile mountain suckers are characterized by lips with notches at the corners of the mouth and, by about 30-40 mm SL, by a cartilaginous ridge or "scraper" at the anterior margin of the lower jaw, sometimes extending beyond the lower lip. The lips of juvenile June and Utah suckers are not notched at the corners of the mouth, and neither species has a prominent scraper. Adult June suckers are distinguished by lip lobes that are well separated and nearly smooth (papillae are not very prominent). The lower lip of adult Utah suckers also is medially divided to the base of the lip, but the lobes tend to be adjacent without a distinct gap between them; papillae are more evident. The lower lip of adult mountain suckers is only shallowly divided at the middle, and the well connected lobes typically bear prominent papillae. But these criteria are not applicable to early juveniles. The lower lips of late metalarvae and juveniles (at least through 40 mm SL) are characterized by distinct and generally well-separated lobes in all three species (the lobes of some juveniles over 30 mm SL may be adjacent, even for June suckers). For June and especially Utah sucker juveniles over 30 mm SL, the papillae on both upper and lower lips tend to align in perpendicular rows, giving the appearance of plicae (ridges or folds).

Pigmentation (Figs. 8-15, 22-29, and 36-43) -- The most distinctive pigmentation patterns on catostomid larvae are usually those of the dorsum and the ventrum. Recently hatched larvae of all species typically bear no body pigmentation (melanophore, or black or brown pigments), and the eyes may or may not be pigmented. Larvae hatching at sizes less than 8 mm SL for mountain suckers, 9 mm for June suckers, and 10 mm for Utah suckers lack pigment in their eyes. Body pigment first appears (usually on the dorsal surface) on mountain suckers at 8 mm SL, June suckers between 9 and 10 mm, and Utah suckers between 11 and 12 (rarely 10) mm.

Once dorsal pigmentation is sufficiently developed, mountain sucker protolarvae can be distinguished by a distinct and usually complete dorsal midline of pigment. The midline pigment on the others usually consists of anterior and posterior segments well separated by a pigmentless segment at midbody (especially in vicinity of the future dorsal fin). Pigment to either side of this midline is predominately in a parallel row on June and Utah suckers and more random on mountain suckers. Dorsal pigmentation remains similar for flexion mesolarvae, except that midline pigment sometimes submerges (disappears) immediately under the future dorsal fin of mountain suckers and additional pigment is scattered to either side of the midline in all species

(rows of pigment parallel to either side of the midline remain the predominate pattern in June and especially Utah suckers). On postflexion mesolarvae, dorsum pigmentation is mostly scattered on all species but with emphasis on the midline or parallel rows as before. Thereafter, pigmentation on the dorsum of all species is evenly scattered with mottling and scales outlined on some juveniles; some juveniles of all three species display a more or less prominent spot of pigment at the origin of the dorsal fin.

For most mountain sucker protolarvae (once pigmentation forms) and mesolarvae, the midline of the ventral surface is characterized by a nearly solid line of pigment from heart (between pectoral fins or fin buds) to vent. Ventral midline pigmentation is usually lacking, sparse, or in short segments on June and Utah suckers. Unfortunately, the reverse and intermediate conditions have been observed in enough specimens to require verification of identity by other criteria. However, mountain suckers always have at least a couple spots of melanin along the ventral midline, and Utah suckers have not been observed with more than 18 spots of melanin along the midline. Generally, June suckers display more midventral pigmentation than Utah suckers, but this is not sufficiently consistent for purposes of identification. By the metalarval phase, midventral pigmentation on typical mountain suckers begins to appear broken or incomplete, and some portions broaden to a narrow band. Ventrum pigmentation on juveniles of all species is gradually submerged or lost, resulting in white undersides of the head and body except for peritoneal pigmentation in the mountain sucker. Pigmentation on the undersurface of the head is variable for larvae of all three species. Pigment along the lower margins of the preopercles is more common on mountain and Utah suckers than June suckers.

Lateral pigmentation is generally similar on all species through the larval period. The protolarvae (once pigment forms) and flexion mesolarvae of all species bear almost no lateral pigment except along the midline (horizontal septa). During the postflexion mesolarval phase, the scattered pigmentation of the dorsal surface expands down the sides to, and in rare instances for June and mountain suckers, below the lateral midline. On the head of postflexion mesolarvae, pigmentation scattered on the operculum seldom extends below eye level for June suckers but often extends below eye level for the others. Pigmentation below the lateral midline is usually light for the metalarvae of June suckers and light to moderately heavy for the others (rarely absent). On most early juveniles of all species, scattered pigmentation extends below the lateral midline to about bottom eye level. On mountain suckers the line separating lateral pigment from the white ventro-lateral and ventral surfaces is often very distinct.

Once scales are well formed (under 30 mm SL for June and Utah suckers; over 30 mm SL for mountain suckers), they are often, but not always, strongly outlined with pigment, and the relative size of the scales (smaller in mountain suckers) becomes obvious. Also, two large mid-lateral spots of pigment, one midway between the head and dorsal fin and the other above the base of the pelvic fin, characterize most (obscure on some and apparently absent on others) June suckers and at least some Utah suckers (very few juvenile Utah suckers with well formed scales were available for examination). There are also hints of an obscure third lateral spot at the base of the tail on some specimens. These lateral spots, reminiscent of the three lateral spots typical of early juvenile white suckers (Catostomus commersoni), are not present on juvenile mountain suckers.

Peritoneal pigmentation is usually sufficient to distinguish mountain sucker metalarvae and juveniles from the others. In mountain suckers, pigmentation begins to extend from dorsolateral to lateral surfaces of the peritoneum by late in the mesolarval or early in the metalarval phase (at least by 19 mm SL, 22 mm TL). By the latter portion of the metalarval phase, pigmentation extends to the ventro-lateral surfaces of the peritoneum. Much and often

all of the ventral surface is pigmented in juveniles. Pigmentation of the Utah sucker peritoneum proceeds more slowly and is generally lighter or less dense. Ventrolateral surfaces are essentially unpigmented until the juvenile period. Even in juveniles through 40 mm SL (50 mm Tl), pigmentation on the ventral surface is sparse or absent. Pigmentation of the visceral peritoneum is restricted to the dorsal to lateral surfaces of June suckers, at least through 40 mm SL.

Osteological features (Figs. 16-19, 30-33 and 44-47; Tables 7, 12, and 17) -- Although some of the emphasized structures are observable in postflexion mesolarvae and metalarvae, their diagnostic value for these catostomids is restricted to juveniles that have been cleared and stained for bone. Size and shape of the frontoparietal fontanelle (opening between the frontal and parietal bones covered with connective tissue) are the skeletal characters of greatest diagnostic value for these catostomids. In mountain suckers, the fontanelle is a narrow, elongate rectangle in the earliest juveniles (width between 20 and 30% of length for specimens <30 mm SL) which gradually narrows until it is no longer present (absent in the largest specimen cleared and stained, 76 mm SL). The fontanelle in Utah suckers is notably wider in the earliest juveniles (width between 35 and 45% of length) and does not narrow much thereafter (at least up to 40 mm SL). The fontanelle of June sucker is still wider in the earliest juveniles (width between 45 and 65% of length) but thereafter narrows to less than that of Utah sucker (to about 40% at 35 mm SL and less than 30% at 54 mm SL). In actual dimensions, width of the fontanelle in mountain sucker was less than 0.7 mm, while that of Utah sucker ranged between 0.9 and 1.2 and June sucker between 1.1 and 1.4.

The remaining structures serve well to separate mountain sucker from the others but are of no value in distinguishing between Utah and June suckers. The first interneurals tend to be smaller and more blocky in shape in mountain sucker than in the others, which have an anvil shape with a notably longer posterior extension. The anterior-dorsal maxillary projections are notably longer and more pointed in mountain suckers but much smaller and blunt in the others. The base of the postcleithrum of mountain suckers extends from the cliethrum at approximately a 90° angle, while the angle for the others was variable but usually much less than 90°. Position of the mandibles was distinctly posterior in juvenile mountain suckers (anterior margins near the base of the maxillae) and distinctly anterior in the others (anterior margin of mandibles just behind anterior portion of maxillae).

Keys

The continual change in available characters and character states and similarity of species during larval and early juvenile development are accommodated by keys for each of the five developmental intervals used in analysis. The keys are necessarily long and complex, often with multiple paths leading to the same conclusion. Users must begin by determining the developmental phase of the specimen in question: protolarva, flexion mesolarva, postflexion mesolarva, metalarva, or early (young-of-the-year) juvenile. For each key, developmental phase criteria are abbreviated for the species of concern and given with the heading.

Definitions for larval phases, discussions of characters useful in cypriniform identification, and diagrams of anatomical features, methods of counts and measures, gut loop phases, and selected skeletal structures precede the results section. A comparative summary of diagnostic characters and species accounts immediately precede and follow this section. The species accounts include full sets of dorsal, lateral, and ventral view drawings. These drawings are frequently referenced in the keys, especially to illustrate specific patterns of melanophore pigmentation (each dot of black or brown pigment, melanin, represents a single melanophore). Users of the keys should be familiar with this material before proceeding.

These keys require the use of a low-power microscope and some means of measuring to the nearest 0.1 mm, e.g., pointed dial calipers, graduated mechanical stage, or measuring eyepiece reticle with a stage micrometer disc or slide for calibration. If using the latter, be sure to set focus before calibration; any subsequent changes in focus or magnification will require recalibration. If using a zoom microscope and eyepiece reticle, the scale can be calibrated for direct millimeter measurement. A 10 mm reticle scale in a 10X eyepiece focused on the specimen (or stage micrometer) with precisely 1X of objective magnification will measure 10 mm (note that zoom control magnification scales may not be accurate). At 0.5X objective magnification, the reticle scale will measure 20 mm (each 0.1 division then equals 0.2 mm). If the specimen is not too large, adjustment of magnification to calibrate the reticle scale to standard length (Fig. 3) of the specimen will allow direct measurement of specific structures or dimensions as a percentage of standard length.

Except for fin lengths, measurements are made parallel or perpendicular to the body axis (Fig. 3). Specimens must be completely submerged in fluid (usually water) and positioned such that their body axis is horizontal. Flat pieces of glass can be used to prop or hold-down a specimen. For fish which taper from head to tail or have a pectoral fin preventing it from lying flat on the bottom of a dish, try suspending the head and part or most of the body over the edge of a sufficiently thick piece of glass. Lay another, smaller, and thinner piece of glass over the tail to hold the specimen in position. Curved or bent specimens that can't be straightened or gently flattened under a cover slip or thicker piece of glass can be measured in sections along the horizontal axis. Specimens larger than the range of the measuring devise also can be measured in sections. Measurement units are the nearest whole or tenth of a millimeter (e.g., a 12 mm specimen covers the range 11.50 to 12.49 mm, and a measure of 6.5 more precisely measures between 6.450 and 6.549).

Some keys require myomere counts (lateral muscle segments; Fig. 2). For accurate counts, the first myomere must be identified and included. It is partial (epaxial, dorsal only), sometimes deltoid or triangular in shape, and located above and often slightly anterior to the cleithrum or base of the pectoral fin (Fig. 3). To observe myomeres, experiment with both reflected (from above) and transmitted (from beneath) light. For small, somewhat translucent specimens, bright transmitted light will pass through the larva and make myomeres more visible. In many cases, the addition of a pair of polarizing filters will actually highlight individual myomeres, including

the first. One polarizing lens is placed between the light source and specimen (under the dish) and the other is positioned or held between the specimen and the objective lens of the microscope. The highlighting effect is achieved by rotating the upper lens until the background is black or as dark as possible. Only light waves that are turned 90 as they pass through the larva are observed. The position of the specimen relative to the plane of light passed by the lower filter is important as well. Once background light is minimized, rotate the specimen itself, or the dish, for optimal effect. For larger and more opaque specimens, reflected light at a low to near-horizontal angle casts shadows that help define individual myomeres.

Fin ray counts also are required for some keys. Developing fin rays must not be confused with folds or creases in the finfold or membrane, or with the skeletal structures that precede and support median fin rays, i.e., the hypural elements of the caudal fin and pterygiophores of the dorsal and anal fins (Fig. 3). The hypural elements eventually fuse and form the hypural plates. Externally, the upper or articulating ends of pterygiophores appear as small nodules at the base of the developing dorsal and anal fins. Since pterygiophores appear before the rays they support and since there is a one to one correspondence between pterygiophores and principal fin rays, pterygiophore counts can substitute for principal dorsal and anal fin ray counts near the end of the mesolarval phase. Also use them to determine presence of all principal dorsal or anal rays (a requirement for transition to the metalarval phase).

For median fins, principal rays also must be distinguished from rudimentary rays (Figs. 2 and 3). Principal dorsal and anal fin rays include all branched rays and the long unbranched ray preceding them. Principal caudal rays include all branched rays and the long unbranched rays immediately above and below them. Terminal branching for some principal fin rays might not be evident until late in the metalarval phase, but the association of principal rays with pterygiophores immediately anterior to them is obvious on close examination. The most posterior principal ray for dorsal and anal fins consists of two elements that articulate with the last pterygiophore. By convention, these elements are said to branch at the base and are counted together as one principal ray. In early metalarvae, the most posterior element of the last ray is often difficult to observe. Again, rely on the association between principal dorsal and anal fin rays and their pterygiophores to confirm counts. All fin rays are included in pectoral and pelvic fin ray counts. Do not mistake the spine-like pelvic splint at the leading edge of the pelvic fin for a fin ray. Transmitted light and polarizing filters are useful in observing pterygiophores and fin rays.

Keys are seldom perfect. When a specimen is near the boundary between developmental phases, use the adjacent key to help confirm results of the proper key. Similarly, within keys, if a character state is nearly borderline or if the user is unsure which of the criteria the specimen meets, try both branches of the key. In either of these situations, if the conclusions are different, and remain so after review, either the identity via the more appropriate key or branch should be considered tentative (noting the alternative possibility) or the identity of the specimen should be left in question. When character states are so similar between species that positive diagnosis is not possible (based on characters studied), the keys conclude with two or all three possible species. In such cases and when justified, an asterisk (*) is used to denote the more likely species. Use both the comparative summary and species accounts to help confirm conclusions reached through these keys. Sometimes, non-morphological data, such as collection date and location, can be used to delimit possible species. However, such data must be used cautiously. Positively identified fish larvae are often the basis for revision of previous assumptions regarding spawning seasons, spawning grounds, larval drift or migration, and nursery habitat. The authors appreciate notification of errors, misleading criteria, or problems uncovered by users and suggestions for revisions.

Eggs

Diameter

a. <2.7 mm — C. platyrhynchus
b. >2.8 mm. ..... C. ardens or C. liorus

Protolarvae (no caudal fin rays; Figs. 2 and 9)

1. Standard length (anterior margin of snout to end of notochord, AS-PHP; Fig. 43)
   a. <7 mm ..... C. platyrhynchus or C. liorus
   b. 8-12 mm 2
   c. ≥13 mm 19

2. Body pigmentation
   a. absent (eyes may be pigmented; Fig. 8) 3
   b. sparse, <12 dots of melanin, black or brown pigment, on dorsal surface (Fig. 36, top) 8
   c. moderate to extensive, ≥13 dots of melanin on dorsal surface (Fig. 9, top) 9

3. Standard length
   a. 8 mm 4
   b. 9-10 mm 6
   c. 11-12 mm ..... C. ardens

4. Length from anterior margin of snout to origin (beginning) of dorsal finfold (AS-ODF; Fig. 3)
   a. <33% of standard length ..... C. ardens
   b. >34% of standard length 5

5. Myomere count to origin of dorsal finfold (including myomeres transected by an imaginary vertical line from that point; Fig. 3)
   a. ≤10 ..... C. ardens
   b. >11 ..... C. liorus, C. ardens, or C. platyrhynchus

6. Length from anterior margin of snout to origin (beginning) of dorsal finfold (AS-ODF; Fig. 3)
   a. <33% of standard length ..... C. ardens
   b. >34% of standard length 7

7. Myomere count to origin of dorsal finfold (including myomeres transected by an imaginary vertical line from that point; Fig. 3)
   a. <11 ..... C. ardens
   b. >12 ..... C. liorus or C. ardens

8. Standard length
   a. 8 mm — C. platyrhynchus
   b. 9 mm ..... C. liorus* or C. platyrhynchus
   c. 10-12 mm 21

Most probable species.

9. Standard length
   a. 8 mm ..... platyrhynchus
   b. 9 mm 10
   c. 10 mm 13
   d. 11-12 mm 14

10. Length of yolk (spanning all segments if divided; Fig. 3)
   a. <49% of standard length — C platyrhynchus
   b. >50% of standard length 11

11. Dots of pigment (melanin) on midline of ventral surface between heart and vent
   a. absent (Figs. 8, bottom, and 23, bottom) — C liorus
   b. present but ≤19, sparse or in short to long lines or segments (Figs. 9, bottom, and 10, bottom) 12
   c. ≥20, usually in a continuous, or nearly continuous, line from heart to vent (Figs. 37, bottom, and 38, bottom) 15

12. Dots of pigment on midline of dorsal surface between head and last myomere (near future base of caudal fin)
   a. ≤24, discontinuous in short to long lines or segments, or sparse, especially at midbody (Figs. 9, top, 10, top, and 24, top) — C liorus
   b. >25 in a discontinuous or broken line from head to last myomere (Fig. 23, top) . . — C platyrhynchus or C. liorus
   c. >25 in a continuous line from head to last myomere (Figs. 37, top, and 38, top) — C platyrhynchus

13. Length of yolk (spanning all segments if divided; Fig. 3)
   a. <29% of standard length (most or all yolk absorbed; Fig. 10 -- note small amount of yolk below gut posterior to air bladder) — C platyrhynchus
   b. >30% of standard length 14

14. Dots of pigment (melanin) on midline of ventral surface between heart and vent
   a. absent (Fig. 23, bottom) 21
   b. present but ≤19, sparse or in short to long lines or segments (Figs. 9, bottom, and 10, bottom) 16
   c. ≥20, usually in a continuous, or nearly continuous, line from heart to vent (Figs. 37, bottom, and 38, bottom) 15

15. Dots of pigment on midline of dorsal surface between head and last myomere (near future base of caudal fin)
   a. ≤24, discontinuous in short to long lines or segments, or sparse, especially at midbody (Figs. 9, top, 10, top, and 24, to0 . . . . C. platyrhynchus or C. liorus
   b. >25 in a discontinuous or broken line from head to last myomere (Fig. 23, top) . . . . C. platyrhynchus* or C. liorus
   c. >25 in a continuous line from head to last myomere (Figs. 37, top, and 38, top) — C platyrhynchus

16. Dots of pigment on midline of dorsal surface between head and last myomere (near future base of caudal fin)
    a. <24 or ≥25, discontinuous in short to long lines or segments, or sparse, especially at midbody (Figs. 9, top, and 23, top) 17

    b. ≥25 in a continuous line from head to last myomere (Figs. 37, top, and 38, top) C platyrhynchus

17. Length from anterior margin of snout to origin (beginning) of dorsal finfold (AS-ODF; Fig. 3)
    a. ≤33% of standard length ..... C. ardens
    b. 34-37% of standard length 18
    c. ≥38% of standard length ..... C liorus* or C. platyrhynchus

18. Myomere count to origin of dorsal finfold (including myomeres transected by an imaginary vertical line from that point; Fig. 3)
    a. <10 ..... C. ardens
    b. 11-14 ..... C liorus*, C. ardens*, or C. platyrhynchus
    c. ≥15 ..... C liorus* or C platyrhynchus

19. Length of yolk (spanning all segments if divided; Fig. 3)
    a. <49% of standard length 20
    b. >50% of standard length ..... C. ardens

20. Dots of melanin, black or brown pigment, on midline of ventral surface between heart and vent
    a. ≤19, absent, sparse, or in short to long lines (Figs. 9, bottom, and 10, bottom) 21
    b. ≥20, usually in a continuous or nearly continuous line from heart to vent (Figs. 37, bottom, and 38, bottom) ..... C. liorus

21. Length from anterior margin of snout to origin (beginning) of dorsal finfold (AS-ODF; Fig. 3)
    a. <33% of standard length ..... C. ardens
    b. 34-37% of standard length 22
    c. >38% of standard length C liorus

22. Myomere count to origin of dorsal finfold (including myomeres transected by an imaginary vertical line from that point; Fig. 3)
    a. <11 ..... C. ardens
    b. 12-13 ..... C liorus or C. ardens
    c. ≥14 ..... C. liorus

Flexion Mesolarvae (caudal fin rays present but less than 18; Figs. 2 and 10)

1. Standard length (anterior margin of snout to end of notochord, AS-PHP; Fig. 3)
    a. <12 mm 2
    b. >13 mm 3

2. Length of yolk (spanning all segments if divided; Fig. 3)
   a. <39% or completely absorbed (Fig. 10 -- note small amount of yolk below gut just posterior to air bladder) 4
   b. >40% of standard length 9

3. Yolk
   a. absent (Fig. 24) 4
   b. present (Fig. 10 -- note small amount of yolk below gut just posterior to air bladder) 9

4. Dots of black or brown pigment (melanin) on midline of ventral surface between heart and vent
   a. absent 10
   b. present but ≤19, sparse or in short to long lines or segments (Fig. 10, bottom) 6
   c. ≥20, usually in a continuous, or nearly continuous, line from heart to vent (Fig. 38, bottom) 5

5. Dots of pigment on midline of dorsal surface between head and last myomere (near future base of caudal fin)
   a. <24 in a discontinuous line, especially at midbody (Figs. 24, top) ..... C. platyrhynchus or C. liorus
   b. >25 in a discontinuous or broken line from head to last myomere (Fig. 23, top). . . .. C. platyrhynchus* or C. liorus
   c. >25 in a continuous line from head to last myomere (Figs. 38, top) ..... platyrhynchus

6. Dots of pigment on midline of dorsal surface between head and last myomere (near future base of caudal fin)
   a. <24 or ≥25, discontinuous in short to long lines or segments, or sparse, especially at midbody (Figs. 10, top, and 24, top) 7
   b. >25 in a continuous line from head to last myomere (Figs. 38, top) ..... C. platyrhynchus

7. Length from anterior margin of snout to origin (beginning) of dorsal finfold (AS-ODF; Fig. 3)
   a. <33% of standard length ..... C. ardens
   b. 34-37% of standard length 8
   c. ≥38% of standard length ..... C. liorus* or C. platyrhynchus

8. Myomere count to origin of dorsal finfold (including myomeres transected by an imaginary vertical line from that point; Fig. 3)
   a. <10 ..... C. ardens
   b. 11-14 ..... C. liorus*, C. ardens*, or C. platyrhynchus
   c. >15 ..... C. liorus* or C. platyrhynchus

9. Dots of melanin, black or brown pigment, on midline of ventral surface between heart and vent
   a. ≤19, absent, sparse, or in short to long lines (Figs. 10, bottom) 10
   b. ≥20, usually in a continuous or nearly continuous line from heart to vent (Fig. 38, bottom) C. liorus

10. Length from anterior margin of snout to origin (beginning) of dorsal finfold (AS-ODF; Fig. 3)
    a. ≤33% of standard length ..... C. ardens
    b. 34-37% of standard length 11
    c. >38% of standard length ..... C liorus

11. Myomere count to origin of dorsal finfold (including myomeres transected by an imaginary vertical line from that point; Fig. 3)
    a. <11 ..... C. ardens
    b. 12-13 ..... C. liorus or C. ardens
    c. >14 ..... C liorus

Postflexion Mesolarvae (18 principal caudal rays, but less than 7 anal rays; Figs. 2 and 11)

1. Dots of black or brown pigment (melanin) on midline of ventral surface between heart and vent
    a. absent 12
    b. present but ≤19, sparse or in short to long lines or segments (Figs. 11, bottom, and 25, bottom) 2
    c. ≥20, usually in a continuous, or nearly continuous, line from heart to vent (Fig. 39, bottom) 19

2. Principal dorsal fin ray complement (Fig. 3)
    a. incomplete (some or all rays unformed; more pterygiophores than observable rays; Figs. 11 and 25) 4
    b. complete (adult count as evidenced by an equal number of pterygiophores, Fig. 39, and/or presence of most posterior ray which is branched at the base and appears as two separate elements that articulate with the last pterygiophore) 3

3. Principal dorsal fin rays
    a. <9 ..... C platyrhynchus
    b. 10 28
    c. 11-13 4
    d. >14 12

4. Length from anterior margin of snout to origin (beginning) of dorsal finfold (AS-ODF; Fig. 3)
    a. <39% of standard length 12
    b. >40% of standard length 5

5. Length from anterior margin of snout to origin (beginning) of preanal finfold (AS-OPAF; Fig. 3)
    a. <28% of standard length 12
    b. 29-36% of standard length 6
    c. >37% of standard length ..... C platyrhynchus

6. Myomeres to origin of preanal finfold (count to OPAF; Fig. 3)
    a. <5 12
    b. 6-8 7
    c. >9 ..... C. platyrhynchus

7. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
   a. 12 mm ..... C. liorus,* C. ardens, or C. platyrhynchus
   b. 13 mm 8
   c. 14 mm 10
   d. >15 mm 9

8. Pelvic fin rays
   a. absent ..... C. liorus*, C. ardens*, or C. platyrhynchus
   b. present ..... C. liorus* or C. ardens

9. Pelvic fin buds
   a. absent ..... C. ardens
   b. present 10

10. Peritoneum (membrane that lines the visceral cavity with lateral and ventral portions just under the skin) at least partially pigmented between pectoral and pelvic fins from above the gut (internal, below gas bladder) to
   a. dorsolateral surfaces only (Figs. 11, middle, and 25, middle) 11
   b. lateral surfaces (Fig. 39) ..... C. platyrhynchus

11. Principal dorsal fin rays
   a. 11 ..... C. ardens*, C. liorus, or C. platyrhynchus
   b. 12-13 or complement incomplete ..... C. liorus*, C. ardens*, or C. platyrhynchus

12. Principal dorsal fin ray complement (Fig. 3)
   a. incomplete (some or all rays unformed; more pterygiophores than observable rays; Figs. 11 and 25) 14
   b. complete (adult count as evidenced by an equal number of pterygiophores, Fig. 39, and/or presence of most posterior ray which is branched at the base and appears as two separate elements that articulate with the last pterygiophore) 13

13. Principal dorsal fin rays (Fig. 3)
   a. 10 ..... C. ardens
   b. >11 or complement incomplete 14

14. Length from anterior margin of snout to origin (beginning) of preanal finfold (AS-OPAF; Fig. 3)
   a. <32% of standard length 15
   b. ≥33% of standard length ..... C. liorus

15. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
   a. 12 mm ..... C. liorus* or C. ardens
   b. 13 mm 16
   c. 14 mm 18
   d. ≥15 mm 17

16. Pelvic fin rays
   a. absent ..... C. ardens or C. liorus
   b. present ..... C. liorus* or C. ardens

17. Pelvic fin buds
    a. absent ..... C. ardens
    b. present 18

18. Principal dorsal fin rays (Fig. 3)
    a. 11 ..... C. ardens* or C. liorus
    b. >12 or complement incomplete ..... C. ardens or C. liorus

19. Principal dorsal fin ray complement (Fig. 3)
    a. incomplete (some or all rays unformed; more pterygiophores than observable rays; Figs. 11 and 25) 21
    b. complete (adult count as evidenced by an equal number of pterygiophores, Fig. 39, and/or presence of most posterior ray which is branched at the base and appears as two separate elements that articulate with the last pterygiophore) 20

20. Principal dorsal fin rays
    a. <10 ..... C platyrhynchus
    b. 11-13 21
    c. >14 ..... C liorus

21. Length from anterior margin of snout to origin (beginning) of dorsal finfold (AS-ODF; Fig. 3)
    a. <39% of standard length ..... C liorus
    b. >40% of standard length 22

22. Length from anterior margin of snout to origin (beginning) of preanal finfold (AS-OPAF; Fig. 3)
    a. <28% of standard length ..... C liorus
    b. 29-36% of standard length 23
    c. >37% of standard length ..... C platyrhynchus

23. Myomeres to origin of preanal finfold (count to OPAF; Fig. 3)
    a. <5 ..... C liorus
    b. 6-8 24
    c. >9 ..... C platyrhynchus

24. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
    a. 12 mm ..... C. liorus* or C platyrhynchus
    b. 13 mm 25
    c. >14 mm 26

25. Pelvic fin rays
    a. absent ..... C. platyrhynchus* or C. liorus
    b. present ..... C liorus

26. Peritoneum (membrane that lines the visceral cavity with lateral and ventral portions just under the skin) at least partially pigmented between pectoral and pelvic fins from above the gut (internal, below gas bladder) to
    a. dorsolateral surfaces only (Figs. 11, middle, and 25, middle) 27
    b. lateral surfaces (Fig. 39) ..... C platyrhynchus

27. Principal dorsal fin rays
    a. 11-12 or complement incomplete ..... C. platyrhynchus* or C. liorus
    b. 13..... C. liorus* or C platyrhynchus

28. Length from anterior margin of snout to origin (beginning) of dorsal finfold (AS-ODF; Fig. 3)
    a. <39% of standard length ..... C. ardens
    b. >40% of standard length 29

29. Length from anterior margin of snout to origin (beginning) of preanal finfold (AS-OPAF; Fig. 3)
    a. <28% of standard length ..... C. ardens
    b. 29-32% of standard length 30
    c. >33% of standard length C platyrhynchus

30. Myomeres to origin of preanal finfold (count to OPAF; Fig. 3)
    a. <5..... C. ardens
    b. 6-8 31
    c. >9 C platyrhynchus

31. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
    a. <13 mm ..... C. platyrhynchus or C. ardens
    b. 14 mm 33
    c. >15 mm 32

32. Pelvic fin buds
    a. absent (Fig 25). ..... C. ardens
    b. present (Fig 39) 33

33. Peritoneum (membrane that lines the visceral cavity with lateral and ventral portions just under the skin) at least partially pigmented between pectoral and pelvic fins from above the gut (internal, below gas bladder) to
    a. dorsolateral surfaces only (Figs. 11, middle, and 25, middle) .....
    ..... C. platyrhynchus or C. ardens
    b. lateral surfaces (Fig. 39) C platyrhynchus

Metalarvae (7 anal rays and preanal finfold present; Figs. 2 and 12)

1. Peritoneum (membrane that lines the visceral cavity with lateral and ventral portions just under the skin) at least partially pigmented between pectoral and pelvic fins from above the gut (internal, below gas bladder) to
    a. dorsolateral (Figs 12, middle, and 13, middle) or lateral surfaces only (Figs. 26, middle, and 27, middle) 2
    b. ventrolateral and sometimes ventral surfaces (Figs. 40 and 41) . . . C. platyrhynchus

2. Principal dorsal fin rays (Fig. 3)
    a. <9 C platyrhynchus
    b. >10 3

3. Dots of black or brown pigment (melanin) on midline of ventral surface between heart and vent
   a. absent 15
   b. present but ≤19, sparse or in short to long lines or segments (Fig. 12, bottom) .4
   c. ≥20, usually in a continuous, or nearly continuous, line from heart to vent (Fig. 41, bottom)..... 22

4. Principal dorsal fin rays (Fig. 3)
   a. 10..... 33
   b. 11-13 5
   c. 14..... 16

5. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
   a. <14 mm 17
   b. 15-21 6
   c. ≥22 mm 24

6. Gut
   a. straight or with less than 90° bend (gut phase 1; Fig. 4) 17
   b. looped or folded (gut phases 2-4; Fig. 4) 7

7. Horizontal *eye* diameter (AS-PE minus AS-AE; Fig. 3)
   a. <80% of snout length (AS-AE; Fig. 3) C platyrhynchus
   b. 81-99% of snout length 26
   c. 100-129% of snout length 8
   d. 130-149% of snout length 18
   e. ≥150% of snout length ..... C. ardens

8. Horizontal eye diameter
   a. <25% of head length (AS-OP1; Fig. 3) C platyrhynchus
   b. 26-29% of head length 9
   c. >30% of head length 18

9. Dorsal fin length from origin to most distal margin of fin rays (greatest length from anterior base of first ray, D; Fig. 3).
   a. <16% of standard length C platyrhynchus
   b. 17-21% of standard length 10
   c. 22% of standard length..... 19
   d. ≥23% of standard length C liorus

10. Length of base of dorsal fin (origin to insertion, AS-ID minus AS-OD; Fig. 3)
   a. <12% of standard length C platyrhynchus
   b. 13-15% of standard length 11
   c. 16-17% of standard length 20
   d. ≥18% of standard length C liorus

11. Caudal fin length (total length minus standard length, AS-PC minus AS-PHP; Fig. 3)
   a. <16% of standard length C platyrhynchus
   b. 17-24% of standard length 12
   c. ≥25% of standard length 20

12. Depth immediately behind posterior margin of vent (at BPV; Fig. 3)
    a. <13% of standard length 13
    b. >14% of standard length ..... C. liorus

13. Myomeres to origin of preanal finfold (Fig. 3)
    a. <7 21
    b. >8 14

14. Principal dorsal fin rays
    a. 11 ..... C. ardens*, C. liorus, or C. platyrhynchus
    b. 12-13 ..... C. ardens*, C. liorus*, or C. platyrhynchus

15. Principal dorsal fin rays (Fig. 3)
    a. 10 ..... C. ardens
    b. >11 16

16. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
    a. <21 mm 17
    b. >22 mm ..... C. liorus

17. Horizontal eye diameter (AS-PE minus AS-AE; Fig. 3)
    a. <99% of snout length (AS-AE; Fig. 3 ..... C. liorus
    b. 100-149% of snout length 18
    c. >150% of snout length ..... C. ardens

18. Dorsal fin length from origin to most distal margin of fin rays (greatest length from anterior base of first ray, D; Fig. 3).
    a. <22% of standard length 19
    b. >23% of standard length ..... C. liorus

19. Length of base of dorsal fin (origin to insertion, AS-ID minus AS-OD; Fig. 3)
    a. <17% of standard length 20
    b. >18% of standard length ..... C. liorus

20. Depth immediately behind posterior margin of vent (at BPV; Fig. 3)
    a. <13% of standard length 21
    b. >14% of standard length ..... C. liorus

21. Principal dorsal fin rays
    a. 11 ..... C. ardens* or C. liorus
    b. >12 ..... C. ardens or Q. liorus

22. Principal dorsal fin rays (Fig. 3)
    a. <10 ..... C. platyrhynchus
    b. 11-13 23
    c. >14 ..... C. liorus

23. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
    a. 14 mm — C liorus
    b. ≥15 mm 24

24. Gut
    a. straight or with less than 90° bend (gut phase 1; Fig 4) — C liorus
    b. looped or folded (gut phases 2-4; Fig. 4) 25

25. Horizontal eye diameter (AS-PE minus AS-AE; Fig. 3)
    a. <80% of snout length (AS-AE; Fig. 3) — C platyrhynchus
    b. 81-129% of snout length 26
    c. >130% of snout length — C liorus

26. Horizontal eye diameter
    a. <25% of head length (AS-OPI; Fig. 3) — C platyrhynchus
    b. 26-29% of head length 27
    c. >30% of head length ..... C. liorus

27. Dorsal fin length from origin to most distal margin of fin rays (greatest length from anterior base of first ray, D; Fig. 3)
    a. <17% of standard length — C platyrhynchus
    b. 18-21% of standard length 28
    c. >22% of standard length — C liorus

28. Length of base of dorsal fin (origin to insertion, AS-ID minus AS-OD; Fig. 3)
    a. <13% of standard length — C platyrhynchus
    b. 14-15% of standard length 29
    c. >16% of standard length — C liorus

29. Caudal fin length (total length minus standard length, AS-PC minus AS-PHP; Fig. 3)
    a. <24% of standard length 30
    b. >25% of standard length — C liorus

30. Myomeres to origin of preanal finfold (Fig. 3)
    a. <7 — C liorus
    b. >8 31

31. Depth immediately behind posterior margin of vent (at BPV; Fig. 3)
    a. <13% of standard length 32
    b. >14% of standard length — C liorus

32. Principal dorsal fin rays (Fig. 3)
    a. 11-12 ..... C. platyrhynchus* or C. liorus
    b. 13 ..... C. liorus* or C. platyrhynchus

33. Gut
    a. straight or with less than 90° bend (gut phase 1; Fig. 4) ..... C ardens
    b. looped or folded (gut phases 2-4; Fig. 4) 29

34. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
    a. <21 mm 30
    b. >22 mm ..... C platyrhynchus

35. Horizontal eye diameter (AS-PE minus AS-AE; Fig. 3)
    a. ≤99% of snout length (AS-AE; Fig. 3) ..... C. platyrhynchus
    b. 100-129% of snout length 36
    c. ≥130% of snout length ..... C. ardens

36. Horizontal eye diameter
    a. ≤26% of head length (AS-OP1; Fig. 3) ..... C platyrhynchus
    b. 27-29% of head length 37
    c. >30% of head length ..... C ardens

37. Dorsal fin length from origin to most distal margin of fin rays (greatest length from anterior base of first ray, D; Fig. 3).
    a. <17% of standard length ..... C platyrhynchus
    b. 18-21% of standard length 38
    c. >22% of standard length ..... C ardens

38. Length of base of dorsal fin (origin to insertion, AS-ID minus AS-OD; Fig. 3)
    a. <12% of standard length ..... platyrhynchus
    b. 13-15% of standard length 39
    c. >16% of standard length ..... C ardens

39. Caudal fin length (total length minus standard length, AS-PC minus AS-PHP; Fig. 3)
    a. <16% of standard length ..... C platyrhynchus
    b. 17-24% of standard length 40
    c. >25% of standard length ..... C ardens

40. Myomeres to origin of preanal finfold (Fig. 3)
    a. <7 ..... C. ardens
    b >8 ..... C ardens* or C. platyrhynchus

Juveniles (<50 mm TL) (7 anal rays but no preanal finfold; Figs. 2 and 14)

1. Peritoneum (membrane that lines the visceral cavity between pectoral and pelvic fins)
    a. pigmented (black or brown pigment, melanin) including most of ventral surface (Fig. 43) ..... C platyrhynchus
    b. pigmented but either sparse or lacking on ventral surface (do not mistake any remaining dots of melanophores along the midline of the ventral surface as peritoneal pigmentation; Figs. 28, 29 and 42) 2
    c. unpigmented or pigmented laterally (sometimes lightly with very fine dots of melanin) but not on ventrolateral or ventral surfaces, except occasionally with several widely scattered dots of melanin (Figs. 14, 15, and 27) 17

2. Horizontal eye diameter (AS-PE minus AS-AE; Fig. 3)
    a. <90% of snout length (AS-AE; Figs 3, 42, and 43) ..... C platyrhynchus
    b. 91-99% of snout length 3
    c. >100% of snout length (Figs 28 and 29) ..... C ardens

3. Horizontal eye diameter
   a. <25% of head length (AS-OP1; Fig. 3) — C platyrhynchus
   b. 26% of head length 4
   c. >27% of head length ..... C. ardens

4. Principal dorsal fin rays (Fig. 3)
   a. 9 — C platyrhynchus
   b. 10-13 5
   c. 14..... C. ardens

5. Upper and lower lips
   a. distinctly notched or divided at the corners (Figs. 42 and 43 . . . C. platyrhynchus
   b. distinctly continuous at corners (Figs. 28 and 29) ..... C ardens
   c. indistinct at corners, divided or continuous nature not certain 6

6. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
   a. <24 7
   b. >25 12

7. Gut loop
   a. forming, full and straight, or (from ventral view) beginning to cross over stomach but with neither limb fully across the ventral midline (gut phases 2 and 3; Figs. 4 and 27 — C ardens
   b. partially folded over stomach with at least one limb across ventral midline (gut phase 4; Figs. 4, 28, 29, and 42) 8
   c. fully folded over stomach with four segments of gut nearly perpendicular to body axis (gut phase 5; Figs 4 and 43) — C platyrhynchus

8. Dots of black or brown pigment (melanin) on midline of ventral surface between heart and vent
   a. absent or <19 (Figs. 28, bottom, and 42, bottom) 9
   b. ≥20, (Fig. 41, bottom) — C platyrhynchus

9. Dorsal fin length from origin to most distal margin of fin rays (greatest length from anterior base of first ray, D; Fig. 3)
   a. <19% of standard length — C platyrhynchus
   b. 20-22% of standard length 10
   c. >23% of standard length ..... C ardens

10. Caudal fin length (total length minus standard length, AS-PC minus AS-PHP; Fig. 3)
   a. <21% of standard length — C platyrhynchus
   b. 22-24% of standard length 11
   c. >25% of standard length ..... C ardens

11. Principal dorsal fin rays
   a. 10 — C platyrhynchus* or C. ardens
   b. 11-12 ..... C. ardens or C. platyrhynchus
   c. 13 — C ardens* or C. platyrhynchus

12. Two or three eye-size spots or patches of black or brown pigment (melanin) on the lateral surface of the body (over the lateral line), one midway between the head and dorsal fin, another above the base of the pelvic fins, and sometimes a third at the base of the caudal fin over the hypural plates
    a. distinctly present (Fig. 15) ..... C. ardens
    b. absent or indistinct (Figs. 29 and 43) 13

13. Gut loop
    a. partially folded over stomach with at least one limb across ventral midline (gut phase 4; Figs. 4, 28, 29, and 42) ..... C. ardens
    b. fully folded over stomach with four segments of gut nearly perpendicular to body axis (gut phase 5; Figs 4 and 43) 14

14. Lateral series of scales (lateral line scales if distinguishable)
    a. <58 (Figs. 15 and 29). ..... C. ardens
    b. 59-80, incomplete, or indistinct and uncountable (Fig. 43) 15
    c. >81 ..... platyrhynchus

15. Dorsal fin length from origin to most distal margin of fin rays (greatest length from anterior base of first ray, D; Fig. 3)
    a. <21% of standard length C platyrhynchus
    b. 22% of standard length..... 16
    c. >23% of standard length ..... C. ardens

16. Caudal fin length (total length minus standard length, AS-PC minus AS-PHP; Fig. 3)
    a. <22% of standard length C platyrhynchus
    b. >23% of standard length ..... C. ardens

17. Pelvic fin rays (total count, Fig. 3; do not mistake pelvic splint at leading edge as a fin ray, Fig. 41, bottom)
    a. 11 C liorus
    b.10..... 18

18. Standard length (anterior margin of snout to posterior margin of hypurals plates, AS-PHP; Fig. 3)
    a. <25 mm 20
    b. >26 mm 19

19. Sum of lengths of dorsal and pelvic (one) fins, origin to most distal margin of fin rays (greatest length from anterior base of first ray, D and P2; Fig. 3)
    a. <40% of standard length ..... C. arc is
    b. 41-43% of standard length 22
    c. >44% of standard length C liorus

20. Gut loop
    a. forming, full and straight, or partially folded over stomach with at least one limb across ventral midline (gut phases 2-4; Figs. 4, 13, 14, and 28) 21
    b. fully folded over stomach with four segments of gut nearly perpendicular to body axis (gut phase 5; Figs 4 and 43) C liorus

21. Sum of lengths of dorsal fin and (one) pelvic fin, origin to most distal margin of fin rays (greatest length from anterior base of first ray, D and P2; Fig. 3)
    a. <37% of standard length ..... C. ardens
    b. 38-43% of standard length 22
    c. >44% of standard length ..... C liorus

22. Caudal fin length (total length minus standard length, AS-PC minus AS-PHP; Fig. 3)
    a. <29% of standard length 23
    b. >30% of standard length ..... C liorus

23. Length of base of dorsal fin (origin to insertion, AS-ID minus AS-OD; Fig. 3)
    a. <18% of standard length 24
    b. >19% of standard length ..... C liorus

24. Body depth immediately behind posterior margin of vent (at BPV; Fig. 3)
    a. <11% of standard length ..... C. ardens
    b. 12-14% of standard length 25
    c. >15% of standard length ..... C liorus

25. Standard length
    a. <27 mm 26
    b. >28 mm ..... C ardens or C. liorus

26. Width of frontoparietal fontanelle (specimens should be cleared and skeletons stained with alizarin red to observe and measure fontanelle; Fig. 5)
    a. <45% of its length (elongate rectangle even on smaller specimens; Fig. 33, top) ..... C. ardens
    b. >46% of its length (greater width and somewhat oval shape on smaller specimens; Fig. 19, top) ..... C liorus

Species Account -- Chasmistes liorus mictus

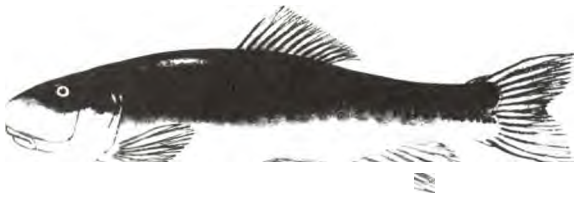


Figure 6. Chasmistes **liorus,** adult (from Sigler and Sigler, **1987).**

Adult Diagnosis: Mouth **subterminal** and usually somewhat oblique. Lobes of lower lip widely separated; papillae on lips weak to absent. No cartilaginous ridges at leading edge of jaws. Nodules of gill rakers strongly branched. Total length to **60** cm. (Also, Table **3.)**

Reproduction: Non-guarding, open-substrate **lithophil.** Late spring, early summer; daily mean water temperatures **12-13 C;** descending limb of discharge curve in **1982.** Tributary streams, predominately **0.3-0.8 m** deep over coarse gravel to small cobble with bottom velocities well under **0.3** m/sec. Eggs **2.8-3.3(+) mm** diameter (water hardened), **demersal,** adhesive.

Young: Hatch in **4** days at **21 ° C, 5-8** days at **19-20 ° C, 8** days at **18 ° C,** and **10** days at **11 ° C;** swim-up about *5-*10 days after hatching depending on temperature.

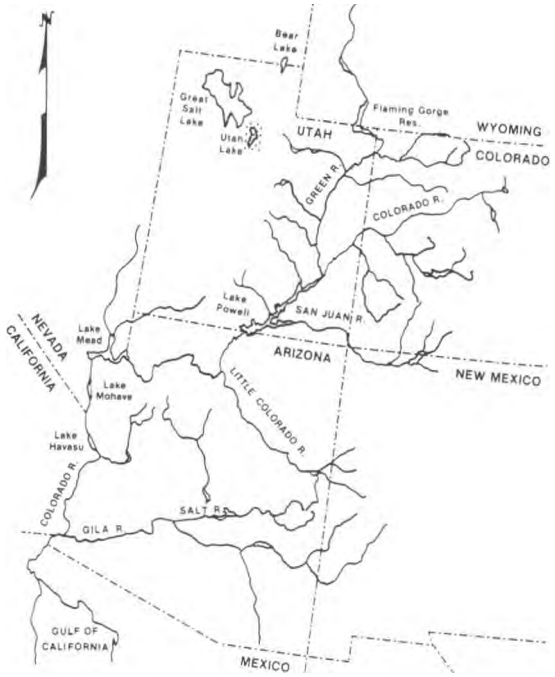


Figure 7. Distribution of Chasmistes **liorus.**

Table 3. Selected juvenile and adult **meristics** for Chasmistes liorus. **P** = principal rays; **R** = rudimentary rays; **D** = dorsal; **V** = ventral. Scales are lateral series or line when complete. Four added to vertebral count for **Weberian** complex. Gill rakers for exterior row of first arch, adults only. Mean or modal values underlined if known and noteworthy; rare or questionable extremes in parentheses.

Character	Original	Literature	Character	Original	Literature
Dorsal Fin Rays - **P:**	(11)12-13(14)		Dorsal Fin Rays - **R:**	**(1)2-4(5)**	
Anal Fin Rays - **P:**	**7**		Anal Fin Rays - **R:**	**(1)2-3**	
Caudal Fin Rays - **P:**	**18**		Caudal Fin Rays – RD:	**(4)7-10**	
Pectoral Fin Rays:	**16-17-18(19)**		Caudal Fin Rays – RV:	**(4)6-8**	
Pelvic Fin Rays:	**10-11**		Lateral Scales:	**54-63(70)**	**60-70 ***
Vertebrae:	**45-46-47**		Gill Rakers:	**38**	37-43-47 *

Table 4. Size at apparent onset of selected developmental events for Chasmistes **liorus,** as observed under low power magnification. **P** = principal rays; **R** = rudimentary rays; Scales are lateral series. Rare or questionable extremes in parentheses. Includes selected data from Shirley **(1983).**

Event or Structure	Onset or Formation mm SL	mm TL	Fin Rays or Scales	First Formed mm SL	mm TL	Last Formed mm SL	mm TL
Hatched:	**(7)8-10**	**(7)8-10**	Dorsal - **P:**	**12-13**	**13-14**	**14-15**	**16-17**
Eyes Pigmented:	**9**	**9**	Anal - **P:**	**(13)14-15**	**16-17**	**14-16**	**16-19**
Yolk Assimilated:	**11-13**	**11-14**	Caudal - **P:**	**11-13**	**11-14(15)**	**12-13**	**13-14**
Finfold Absorbed:	**18-21**	**22-25(27)**	Caudal - **R:**	**12-14**	**13-15**	**18-21**	**22-25**
Pectoral Fin Buds:	**8**	**8**	Pectoral:	(13)14-15	**16-17**	**18-20**	**22-24**
Pelvic Fin Buds:	**12-14**	**13-16**	Pelvic:	(13)14-15	**16-17**	**18-19**	**23**
			Scales:	**19-22**	**25-27**	**24-27**	**29-35**

References: Jordan **1878;** Jordan and **Evermann 1896;** Sigler and Miller **1963;** Moore **1968;** Miller and Smith **1981;** Shirley **1983;** Sigler and Sigler **1987.**

* For Chasmistes **liorus liorus** **D: 10-12,** A: **7-8,** Scales: **55-66,** Gill rakers: **45-48-53** (Miller and Smith **1981).**

Table 5. Size at developmental interval (left) and gut phase (right) transitions for Chasmistes liorus. See Figure 4 for phases of gut folding. Includes selected data from Shirley (1983). Rare or questionable extremes in parentheses.

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion Mesolarva:	11-13	11-14	2 - 90° bend:	14-16	16-18
Postflexion Mesolarva:	12-13	13-14(15)	3 - Full loop:	17-19	22-23
Metalarva:	14-16	16-19	4 - Partial crossover:	19-20	24-25
Juvenile:	18-22	22-25(27)	5 - Full cross over:	24-28	31-35

Table 6. Summary of morphometrics and myomere counts by developmental phase for Chasmistes liorus. *See* Figure 3 for abbreviations and methods of measurement and counting.

	Protolarvae (N=7)				Flexion Mesolarvae (N=6)				Postflexion Mesolarvae (N=12)				Metalarvae (N=12)				Juveniles (N=13)			
	Mean	±SD	Min	Max	Mean	±SD	Min	Max	Mean	±SD	Min	Max	Mean	±SD	Min	Max	Mean	±SD	Min	Max
SL,mm:	11	1	10	12	12	1	11	13	14	1	12	16	18	2	16	21	27	6	19	39
TL,mm:	11	1	10	12	13	1	12	14	16	2	13	19	22	2	19	25	34	8	25	51
Lengths %SL:																				
AS to AE	2	0	2	2	3	0	2	3	4	1	3	6	7	1	5	8	8	1	6	9
PE	8	0	8	9	9	1	8	10	12	1	9	13	14	1	13	15	15	1	13	18
OP1	15	1	14	16	18	1	16	20	22	2	20	26	25	1	24	27	26	1	25	29
OP2									52	1	50	55	55	1	52	57	55	1	54	58
PY	78	2	76	81	61	12[a]	49	73												
OPAF	43	21	23	71	25	2	23	28	30	2	28	35	42	11	31	61				
ODF	38	2	35	40	38	3	35	42	43	3	36	47	47	1	44	48				
OD									48	1	47	49	49	1	48	50	48	1	46	51
ID									64	1	61	65	65	1	64	67	66	1	65	69
PV	80	1	78	82	78	1	76	79	80	1	77	81	77	2	75	80	75	1	74	76
OA									79	2	76	80	77	1	75	79	75	1	74	76
IA									85	1	83	86	85	1	83	86	83	1	80	85
AFC									110	1	108	112	113	1	111	115	117	2	115	120
PC	104	1	103	105	106	2	104	110	115	3	110	119	122	2	118	126	127	2	124	131
Y	62	3	57	67	17	22	0	49												
P1	5	2	2	8	11	1	10	12	12	1	11	13	14	2	11	17	21	2	17	24
P2									4	2	0	8	11	2	8	14	16	2	14	19
D									17	1	15	17	22	2	19	25	27	1	23	29
A									8	0[c]	8	8	11	1	9	14	16	2	13	20
Depths %SL:																				
at BPE	9	1	8	11	11	1	10	12	14	1	12	17	17	1	15	18	19	1	17	21
OP1	11	1	9	13	12	2	10	14	16	2	13	19	19	1	17	21	21	2	19	25
OD	13	1	11	15	10	1	9	11	14	2	10	19	19	2	16	23	23	2	20	26
BPV	5	1	4	7	6	0	6	7	8	1	6	11	12	1	10	14	15	1	13	17
AMPM	3	0	2	3	4	1	3	5	6	1	5	8	8	1	7	9	8	0	8	9
Max. Yolk	9	2	6	12	2	2	0	4												
Widths %SL:																				
at BPE	9	1	8	10	10	1	9	11	13	1	11	15	15	1	14	17	17	1	15	19
OP1	7	1	6	8	8	1	7	10	12	2	9	14	15	1	13	17	18	1	16	19
OD	8	2	5	10	5	1	4	6	9	2	6	12	13	2	10	16	18	1	15	20
BPV	4	0	3	4	4	0	3	4	5	1	5	7	8	1	6	9	10	1	9	12
AMPM	2	0	2	3	2	0	2	3	3	0	3	4	4	0	3	4	5	1	4	6
Max. Yolk	10	2	6	13	2	2	0	5												
Myomeres:																				
to PY	36	1	35	39	28	7[a]	22	35												
OPAF	17	10	7	31	7	0	7	7	7	1	5	7	13	7	7	25				
OP2									21	1	19	21	21	1	21	23	22	1	20	23
ODF	15	1	14	16	15	1	13	16	15	1	13	16	16	0	15	16				
OD									18	1	17	19	17	1	16	18	17	1	16	18
PV	38	1	36	40	38	1	37	38	37	0	36	37	36	1	35	38	36	1	35	36
Total	46	1	45	47	46	1	45	47	45	1	44	46	45	1	43	46	46	1	45	46

[a]N = 3; [b]N = 10; [c]N = 5; [d]N = 7; [e]N = 6

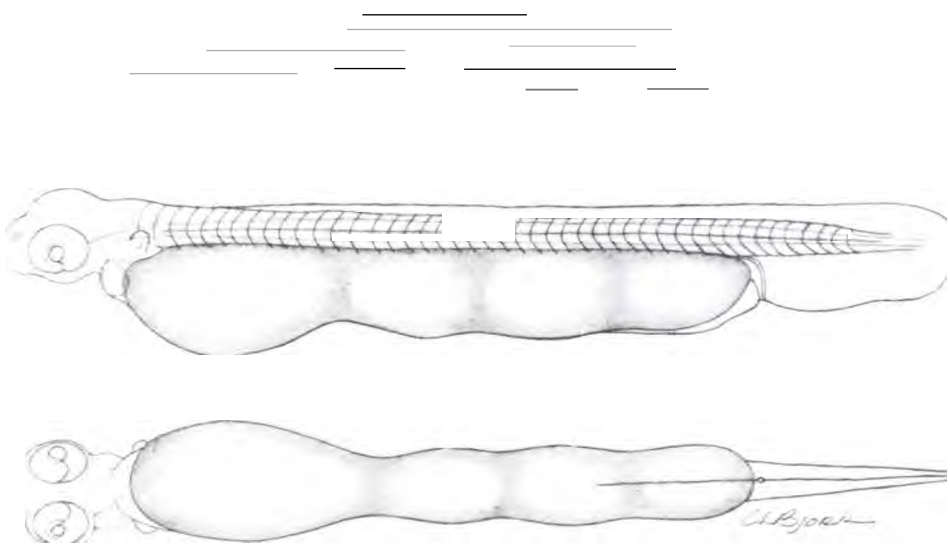


Figure 8. Chasmistes liorus protolarva, recently hatched, 9.6 mm SL, 9.9 mm TL. Cultured from Utah Lake, Utah.

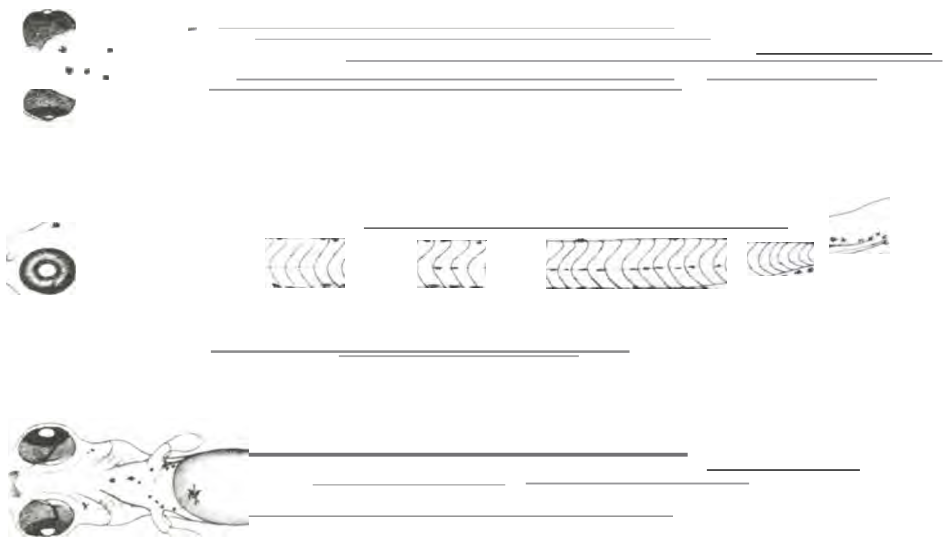


Figure 9. Chasmistes liorus protolarva, 11.1 mm SL, 11.6 mm TL. Cultured from Utah Lake, Utah.

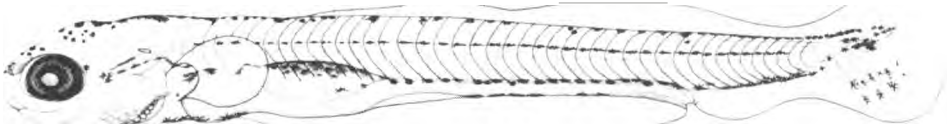


Figure 10. Chasmistes liorus flexion mesolarva, recently transformed, 11.9 mm SL, 12.5 mm TL. Cultured from Utah Lake, Utah.

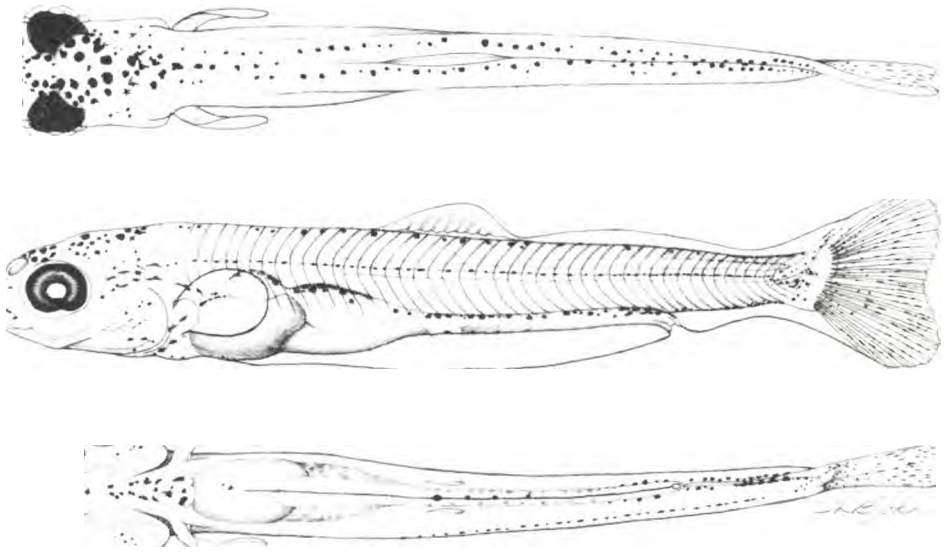


Figure 11. Chasmistes liorus postflexion mesolarva, 13.5 mm SL, 15.2 mm TL. Cultured from Utah Lake, Utah.

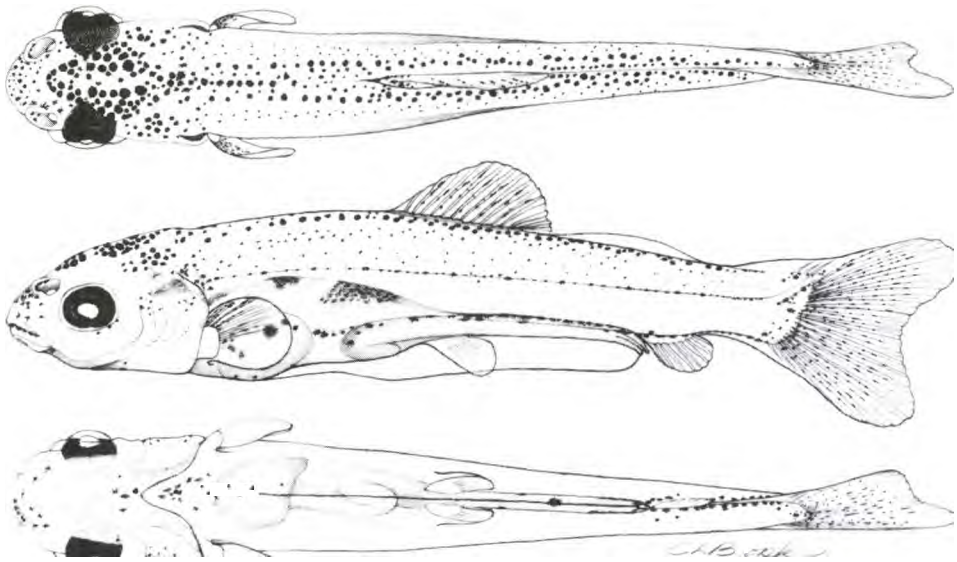


Figure 12. Chasmistes liorus metalarva, recently transformed, 15.8 mm SL, 18.7 mm TL. Cultured from Utah Lake, Utah.

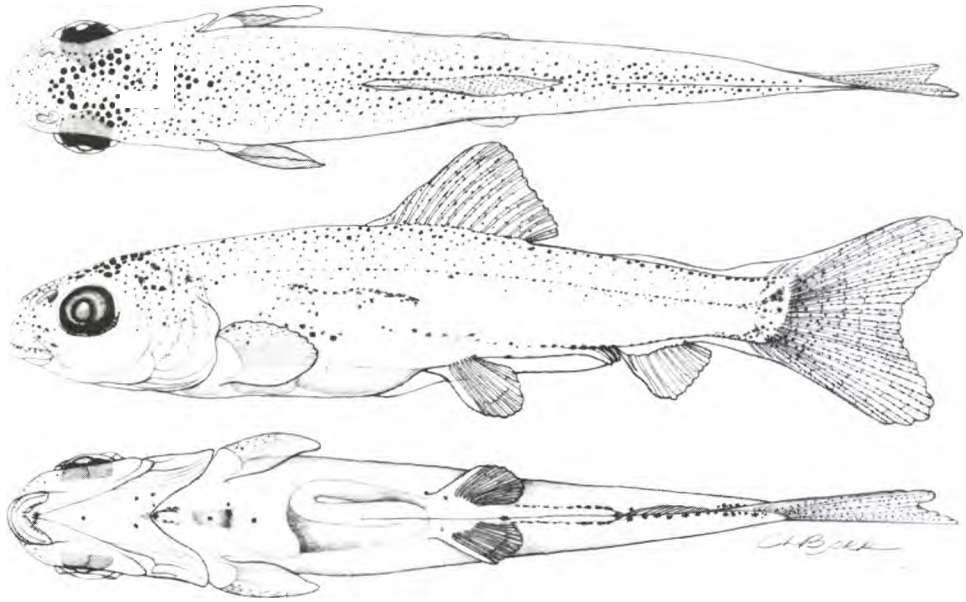


Figure 13. Chasmistes liorus metalarva, 18.1 mm SL, 22.0 mm TL. Cultured from Utah Lake, Utah.

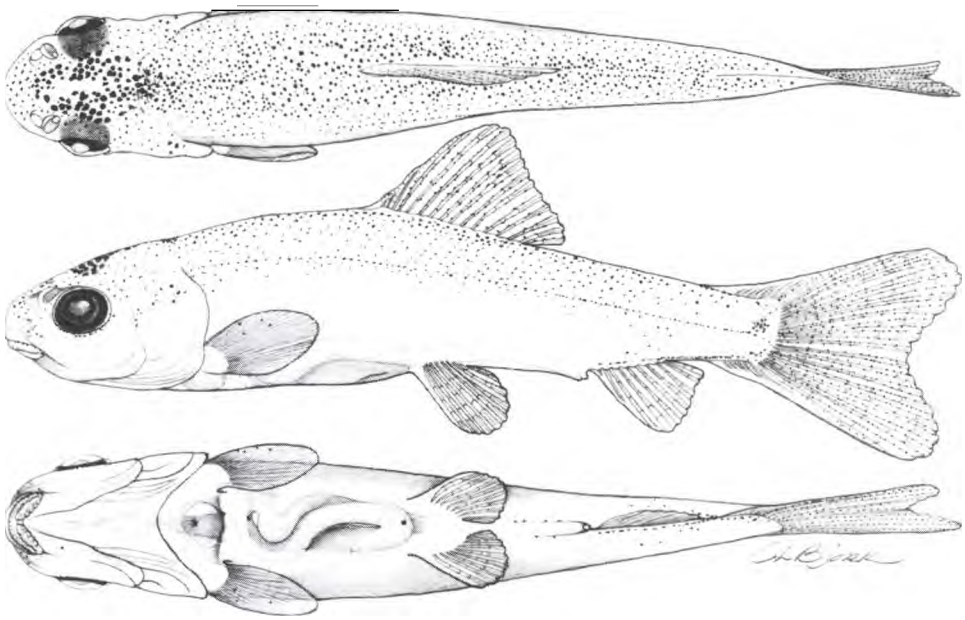


Figure 14. Chasmistes liorus juvenile, recently transformed, 21.8 mm SL, 27.1 mm TL. Cultured from Utah Lake, Utah.

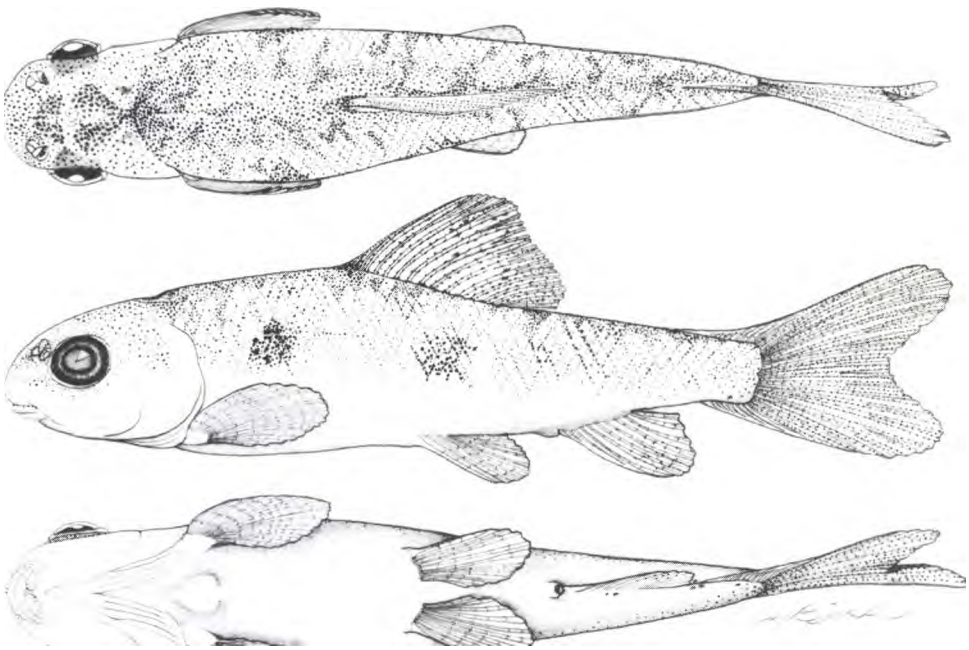
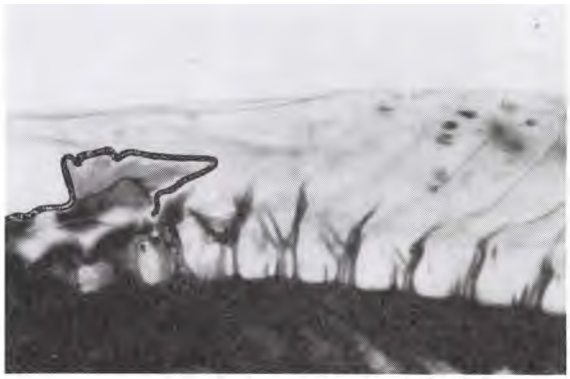


Figure 15. Chasmistes liorus juvenile, 31.7 mm SL, 40.0 mm TL. Cultured from Utah Lake, Utah.

Figure 16. Selected skeletal features of Chasmistes liorus, juvenile, 20.2 mm SL, 25.6 mm TL. Top -- postcleithrum. Middle -- anterior-dorsal maxillary projections. Bottom -- mandible position.

Figure 17. Selected skeletal features of Chasmistes liorus, juvenile, 35 mm SL, 45 mm TL. Top -- postcleithrum. Middle -- anterior-dorsal maxillary projections. Bottom -- mandible position.



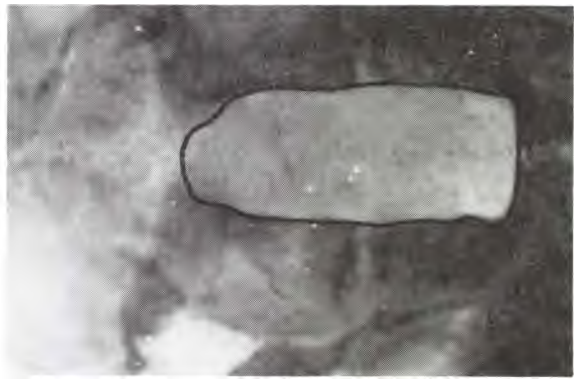


Figure 19. Frontoparietal fontanelle of Chasmistes liorus. Top -- juvenile, 20.2 mm SL, 25.6 mm TL. Bottom -- juvenile, 35 mm SL, 45 mm TL.

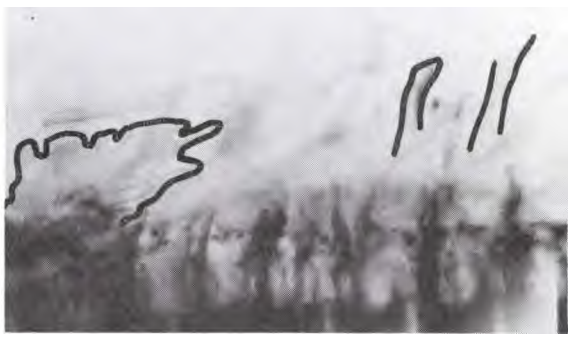


Figure 18. Interneurals of Chasmistes liorus. Top -- metalarva, 15.7 mm SL, 19.2 mm TL. Middle -- juvenile, 20.2 mm SL, 25.6 mm TL. Bottom -- juvenile, 35 mm SL, 45 mm TL.

Table 7. Dimensions of frontoparietal fontanelle for Chasmistes liorus early juveniles.

Specimens		Max. Width	Max. Length	Width as % of Length
mm SL	mm TL	(mm)	(mm)	
20.2	25.6	1.4	2.3	61
27.3	34.6	1.2	2.5	48
35	45	1.2	3.1	39
54	73	1.1	4.0	28

Figure 20. Catostomus ardens, adult (from Sigler and Sigler, 1987 .

Adult Diagnosis: Mouth inferior but well forward. Lower lip with deep medial cleft but lobes usually adjacent; no notches at outer corners; papillae on lips. No prominent cartilaginous ridge on anterior margin of lower jaw. Nodules of gill rakers slightly to unbranched. Fontanelle wide. Total length to 60 cm. (Also, Table 8.

Reproduction: Non-guarding, open-substrate lithophil. Mid to late spring. Tributary streams or rocky shoals near shore. Eggs 2.9-3.2 mm diameter (water hardened), demersal, adhesive.

Young: Hatch in 8-9 days at 17 ° C. Swim-up 7-8 days after hatching. Young mostly in tributary streams or near shore.

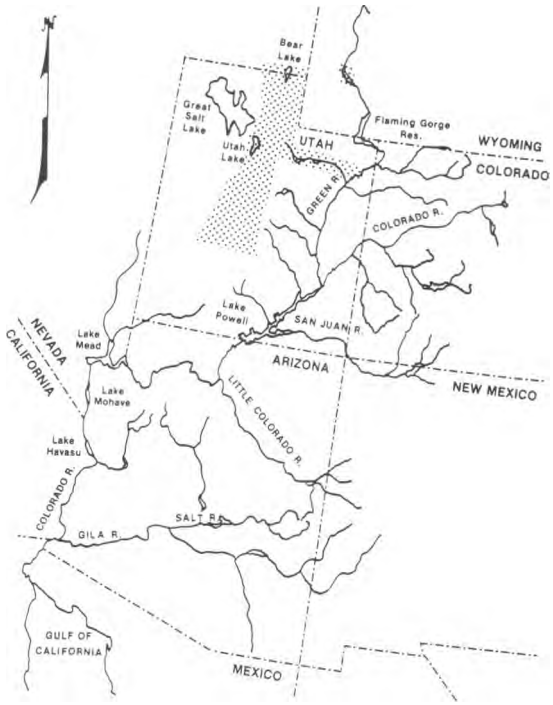


Figure 21. Regional distribution of Catostomus ardens.

Table 8. Selected juvenile and adult meristics for Catostomus ardens. P principal rays; R rudimentary rays; D dorsal; V ventral. Scales are lateral series or line when complete. Four added to vertebral count for Weberian complex. Gill rakers for exterior row of first arch, adults only. Mean or modal values underlined if known and noteworthy; rare or questionable extremes in parentheses.

Character	Original	Literature	Character	Original	Literature
Dorsal Fin Rays - P:	10 11-12-13 14	11-13	Dorsal Fin Rays - R:	2-5	
Anal Fin Rays - P:	7-8	7	Anal Fin Rays - R:	2-4	
Caudal Fin Rays - P:	17 18		Caudal Fin Rays - RD:	8 9-10-11	
Pectoral Fin Rays:	14 15-17		Caudal Fin Rays - RV:	6 7-8-9	
Pelvic Fin Rays:	10		Lateral Scales:	57 -62-68	54 60-72 79
Vertebrae:	47-48		Gill Rakers:		28-31-34

Table 9. Size at apparent onset of selected developmental events for Catostomus ardens as observed under low dower magnification. P principal rays; R rudimentary rays; Scales are lateral series. Rare or questionable extremes in parentheses.

Event or Structure	Onset or Formation mm SL	mm TL	Fin Rays or Scales	First Formed mm SL	mm TL	Last Formed mm SL	mm TL
Hatched:	8 9-11	8 9-11	Dorsal - P:	13-15	14-16	14-16	17-19
Eyes Pigmented:	8-9	8-9	Anal - P:	14-15	16-18	15-17	17-19
Yolk Assimilated:	12-13	12-14	Caudal - P:	12-13	12-14	13-14	14-15
Finfold Absorbed:	19	23	Caudal - R:	14-15	15-17	19-20	23
Pectoral Fin Buds:	9	9	Pectoral:	14-15	16-18	15-18	17-22
Pelvic Fin Buds:	13-15	14-16	Pelvic:	14-17	17-19	18-19	19 22
			Scales:	21-23	26-28	24	29-30

References: Jordan and Gilbert 1881; Jordan and Evermann 1896; Sigler and Miller 1963; Moore 1968; Baxter and Simon 1970; Simpson and Wallace 1978; Lee et al. 1980; Miller and Smith 1981; Tyus et al. 1982; Sigler and Sigler 1987; Modde (T. C., personal communication)

Table 10. Size at developmental interval left and gut phase right transitions for Catostomus ardens. See Figure 4 for phases of gut folding. Rare or questionable extremes in parentheses.

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion Mesolarva:	12-13	12-14	2 - 90° bend:	14-17	17-19
Postflexion Mesolarva:	13-14	14-15	3 - Full loop:	18-19	19 22-24
Metalarva:	15-17	17-19 20	4 - Partial crossover:	20-22	26-27
Juvenile:	19-20	23-23	5 - Full cross over:	27-28	34-35

Table 11. Summary of morphometrics and myomere counts by developmental phase for Catostomus ardens. See Figure 3 for abbreviations and methods of measurement and counting.

	Protolarvae N 10				Flexion Mesolarvae N 5				Postflexion Mesolarvae N 12				Metalarvae N 12				Juveniles N 12			
	Mean	±SD	Min	Max	Mean	±SD	Min	Max	Mean	±SD	Min	Max	Mean	±SD	Min	Max	Mean	±SD	Min	Max
SL,mm:	11	1	9	13	13	1	12	14	15	1	13	17	17	1	15	19	25	4	19	36
TL,mm:	11	1	9	14	13	1	12	15	16	2	14	19	21	2	17	23	32	6	24	45
Lengths %SL:																				
AS to AE	2	0	2	3	2	1	1	4	4	1	3	5	6	1	4	8	7	1	6	8
PE	8	1	7	9	8	1	7	10	11	1	10	12	14	1	12	16	15	1	14	16
OP1	15	1	12	17	17	2	15	19	20	1	19	23	26	1	23	27	26	1	25	28
OP2									52	1	50	53	56	1	53	57	56	1	55	58
PY	75	2	72	78	70	2[a]	69	72												
OPAF	41	19	22	67	25	1	22	26	28	2	25	31	41	7	30	51				
ODF	33	2	29	36	35	2	31	36	39	1	37	41	44	3[a]	42	47				
OD									49	1	47	50	50	1	49	52	49	1	48	51
ID									62	1	60	63	65	1	64	67	65	1	64	66
PV	78	1	76	80	76	1	75	77	79	1	76	80	77	1	76	78	75	1	73	76
OA									79	[e]	79	79	77	1	76	78	76	1	74	78
IA									84	[e]	84	84	84	1	84	86	83	1	82	85
AFC									109	1	107	110	112	1	111	114	116	1	114	118
PC	103	1	102	104	105	1	104	106	112	3	109	117	120	2	118	122	125	1	123	128
Y	57	5	49	64	16	22	0	43												
P1	5	3	1	8	10	1	8	11	11	1	9	13	14	2	12	17	20	2	15	22
P2									2	3	0	6	11	1	8	12	14	1	12	16
D									15	1[d]	14	16	19	1	18	20	24	2	21	26
A									7	[e]	7	7	10	1	9	12	15	2	12	18
Depths %SL:																				
at BPE	9	1	7	10	10	1	9	12	13	1	11	15	16	1	15	18	18	0	17	18
OP1	10	1	9	13	10	1	9	12	14	1	12	17	18	1	16	20	20	1	18	21
OD	11	1	10	12	9	1	8	9	12	2	9	15	17	1	16	20	20	1	16	22
BPV	5	1	4	6	5	0	5	6	7	1	6	9	10	1	9	12	12	1	10	14
AMPM	3	0	2	3	3	0	3	4	5	1	4	6	7	0	6	8	8	0	7	8
Max. Yolk	7	2	3	11	0	1	0	2												
Widths %SL:																				
at BPE	8	1	6	10	9	1	9	10	12	1	10	13	15	1	14	16	16	1	15	16
OP1	6	1	4	8	7	1	6	9	10	1	9	11	13	1	11	15	16	1	14	17
OD	7	1	5	9	5	0	5	6	7	1	5	10	12	1	9	13	15	1	12	17
BPV	3	0	3	4	3	0	3	4	5	1	4	6	6	1	5	7	8	1	6	10
AMPM	2	0	2	2	2	0	2	2	3	0	2	3	3	0	3	4	4	0	3	5
Max. Yolk	8	3	5	14	1	1	0	2												
Myomeres:																				
to PY	35	1	34	36	33	1	32	33												
OPAF	15	11	4	32	6	0	6	7	6	1[b]	5	7	12	4[c]	6	17				
OP2									21	1	19	22	21	1	20	22	22	0[d]	21	22
ODF	12	1	10	13	12	0	11	12	13	1	12	14	15	2[a]	13	16				
OD									18	1	17	19	17	1	16	18	17	1[d]	16	18
PV	37	1	36	38	36	1	36	37	37	1	35	38	36	1	34	37	35	1[d]	35	36
Total	46	1	45	47	46	1	45	47	46	1	45	48	45	1	43	47	46	1	45	47

[a]N = 2; [b]N = 10; [c]N = 11; [d]N = 5; [e]N = 1

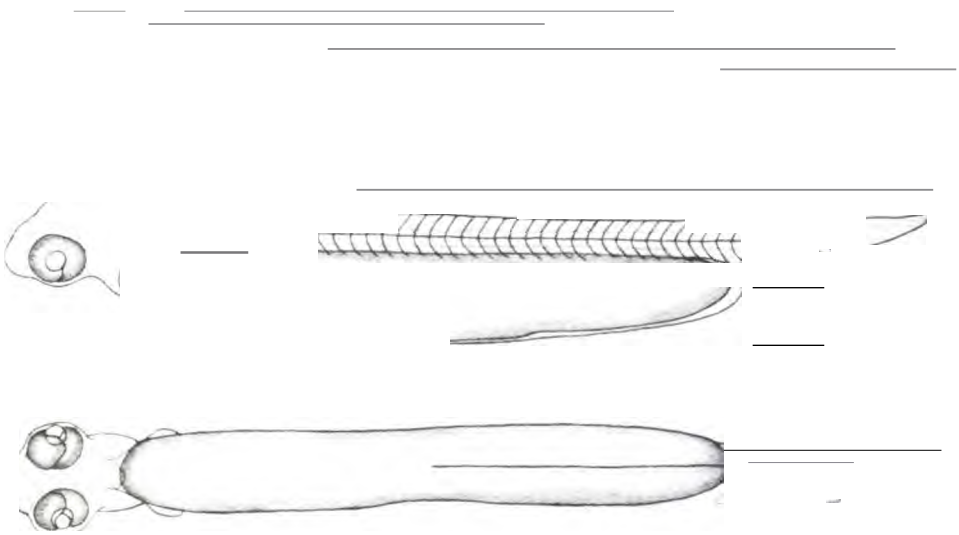


Figure 22. Catostomus ardens protolarva, recently hatched, 10.5 mm SL, 10.8 mm TL. Cultured from Bear Lake, Utah.

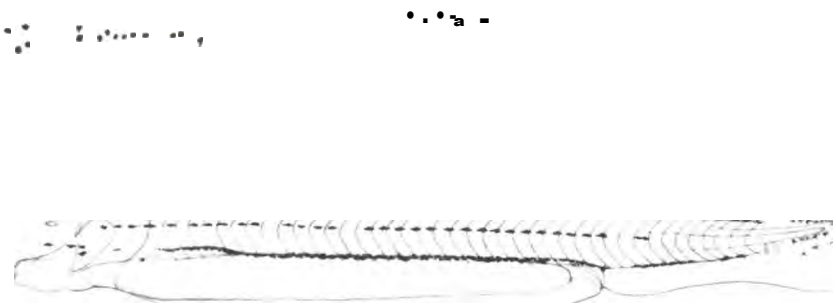


Figure 23. Catostomus ardens protolarva, 11.4 mm SL, 11.9 mm TL. Cultured from Bear Lake, Utah.

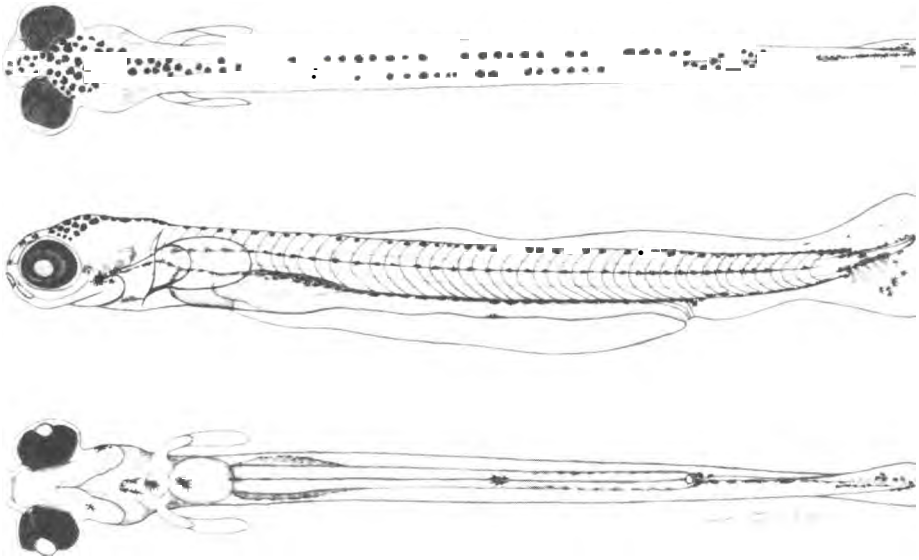


Figure 24. Catostomus ardens flexion mesolarva, recently transformed, 12.2 mm SL, 12.8 mm TL. Cultured from Bear Lake, Utah.

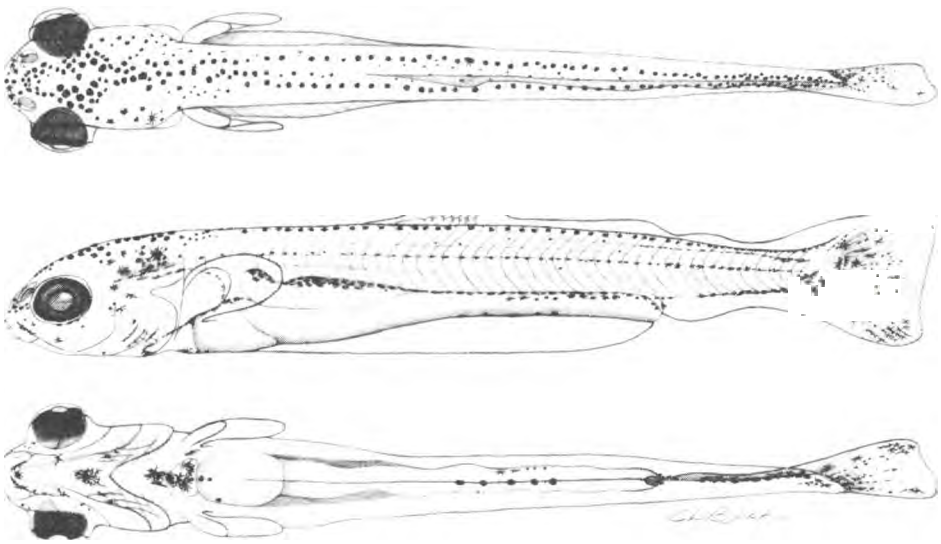


Figure 25. Catostomus ardens postflexion mesolarva, 14.2 mm SL, 15.7 mm TL. Cultured from Bear Lake, Utah.

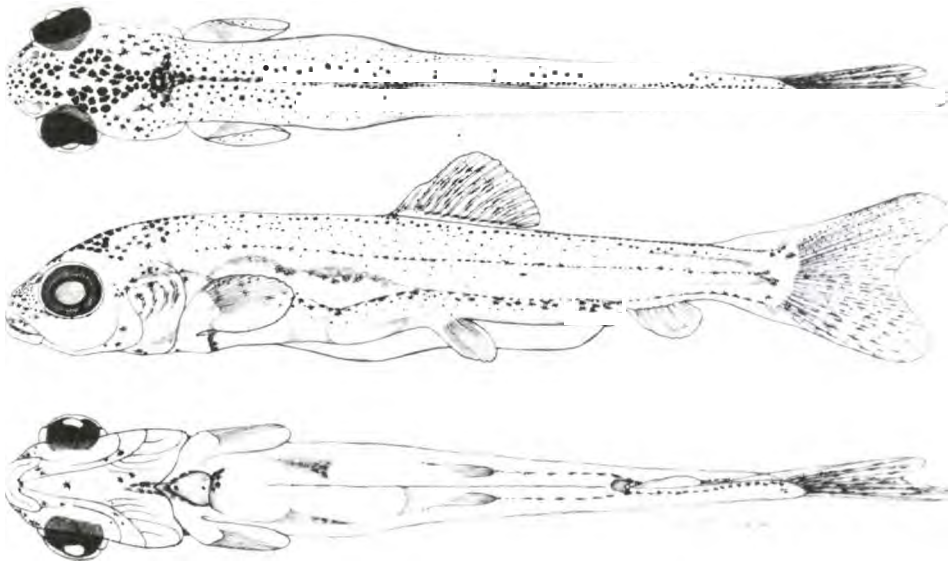


Figure 26. Catostomus ardens metalarva, recently transformed, 15.9 mm SL, 18.7 mm TL. Cultured from Bear Lake, Utah.

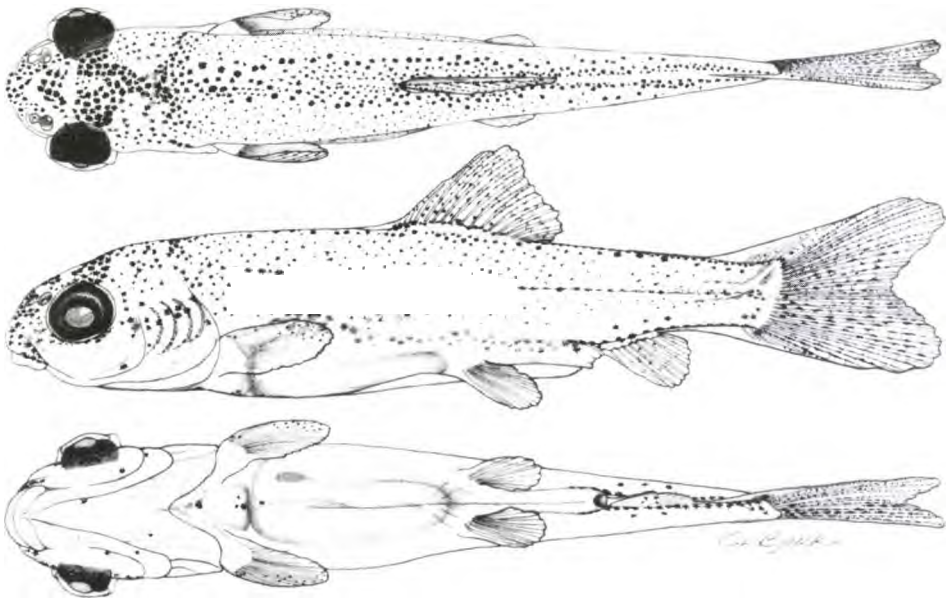


Figure 27. Catostomus ardens metalarva, 17.8 mm SL, 21.5 mm TL. Cultured from Bear Lake, Utah.

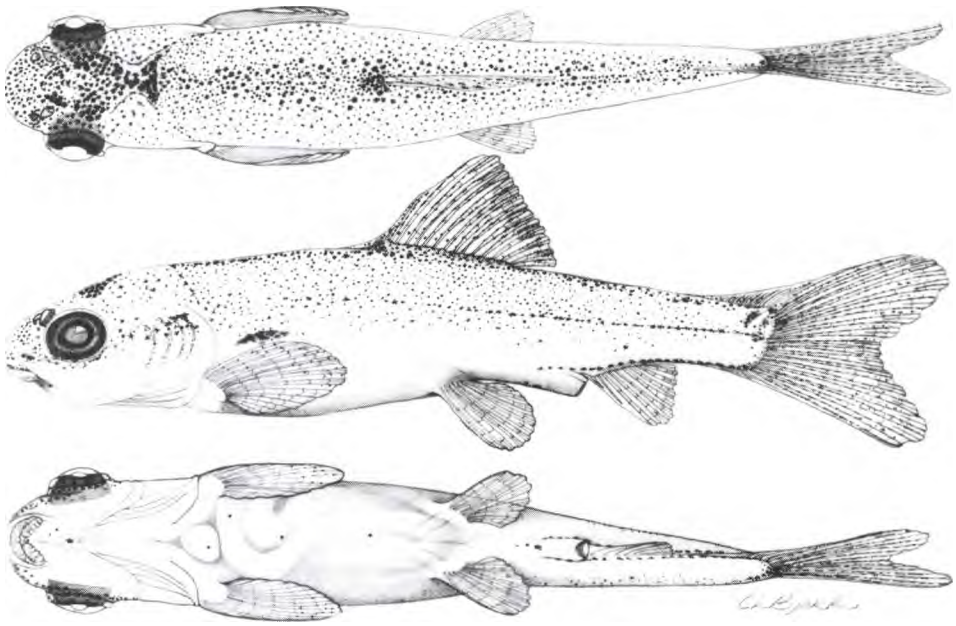


Figure 28. Catostomus ardens juvenile, recently transformed, 21.8 mm SL, 26.9 mm TL. Cultured from Bear Lake, Utah.

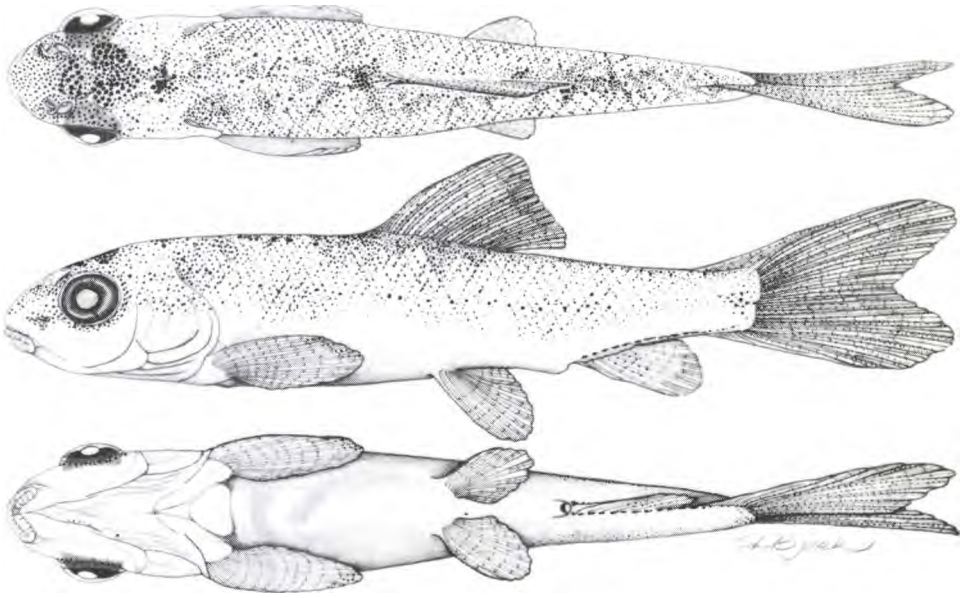
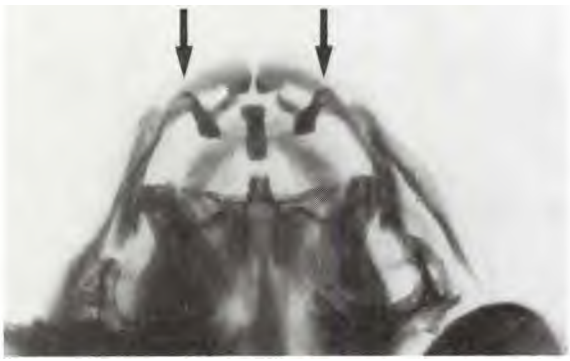


Figure 29. Catostomus ardens juvenile, 28.2 mm SL, 35.6 mm TL. Cultured from Bear Lake, Utah.



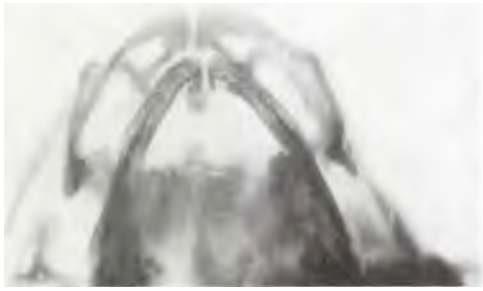


Figure 30. Selected skeletal features of Catostomus ardens, juvenile, 21.4 mm SL, 26.2 mm TL. Top -- postcleithrum. Middle -- anterior-dorsal maxillary projections. Bottom -- mandible position.

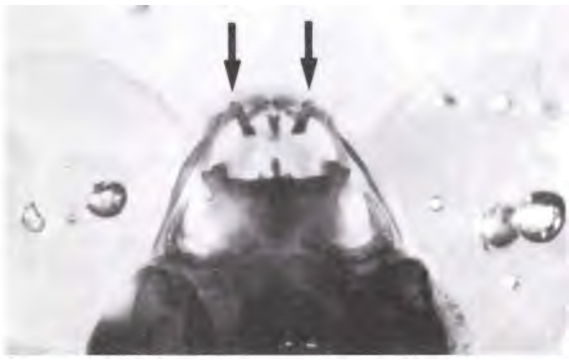


Figure 31. Selected skeletal features of Catostomus ardens, juvenile, 39.5 mm SL, 45.4 mm TL. Top -- postcleithrum. Middle -- anterior-dorsal maxillary projections. Bottom -- mandible position.

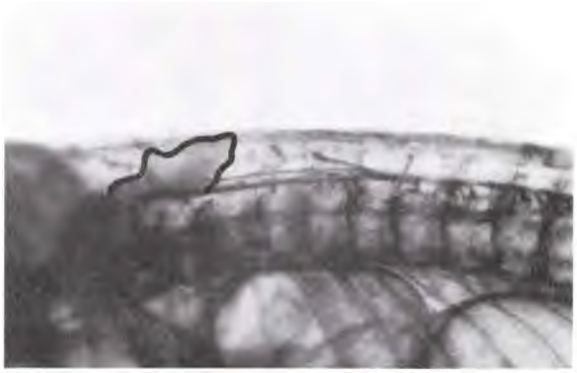


Figure 33. Frontoparietal fontanelle of Catostomus ardens. Top -- juvenile, 21.4 mm SL, 26.2 mm TL. Bottom -- juvenile, 39.5 mm SL, 45.4 mm TL.

Figure 32. Interneurals of Catostomus ardens. Top -- postflexion mesolarva, 16.8 mm SL, 19.2 mm TL. Middle -- juvenile, 21.4 mm SL, 26.2 mm TL. Bottom -- juvenile, 39.5 mm SL, 45.4 mm TL.

Table 12. Dimensions of frontoparietal fontanelle for Catostomus ardens, metalarva and early juveniles.

Specimens		Max. Width	Max. Width Length	as % of
mm SL	mm TL	(mm)	(mm)	Length
21.4	26.2	0.9	2.1	43
24.2	30.4	0.9	2.4	38
27.2	33.4	1.0	2.4	42
27.2	34.0	1.0	2.3	43
28.3	36.0	1.0	2.3	43
39.5	45.4	1.2	2.8	43

Species Account -- Catostomus platyrhynchus

Figure 34. Catostomus platyrhynchus, adult (from Sigler and Sigler, 1987 .

Adult Diagnosis: Mouth distinctly inferior and well back. Lobes of lower lip broadly connected, moderate median cleft; notched at outer corners of mquth; papillae on lips. Prominent cartilaginous ridge on anterior margin of lower jaw. Fontanelle narrow, rarely closed. Interradial membranes of caudal fin with little or no pigment. Total length to 25 cm. (Also, Table 13

Reproduction: Non-guarding, open-substrate lithophil. Late spring to early summer; between 11-19 ° C. Resident or tributary streams over gravel riffles. Eggs 2.3-2.7 mm diameter (water hardened), demersal.

Young: Hatch in 7-8 days at about 15 ° C. Young in streams, occasionally drift into lakes.

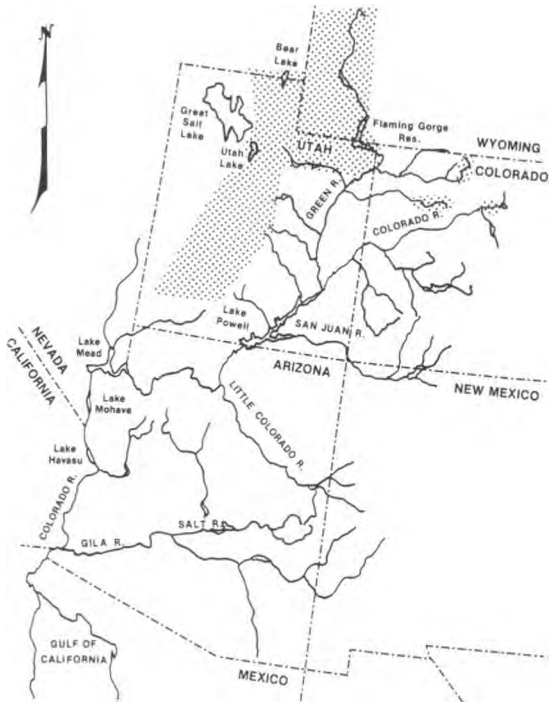


Figure 35. Regional distribution of C. platyrhynchus.

Table 13. Selected juvenile and adult meristics for Catostomus platyrhynchus. P principal rays; R rudimentary rays; D dorsal; V ventral. Four added to vertebral count for Weberian complex. Scales are lateral series or line when complete. Gill rakers for exterior row of first arch, adults only. Mean or modal values underlined if known and noteworthy; rare or questionable extremes in parentheses.

Character	Original	Literature	Character	Original	Literature
Dorsal Fin Rays - P:	9-10-11	8 9-11-12 13	Dorsal Fin Rays - R:	1 2-4	
Anal Fin Rays - P:	6 7	7	Anal Fin Rays - R:	2-3	
Caudal Fin Rays - P:	17 18		Caudal Fin Rays - RD:	9 -11-12	
Pectoral Fin Rays:	14-15-16	15	Caudal Fin Rays - RV:	7 8-9 11	
Pelvic Fin Rays:	9-10	9-10	Lateral Scales:	76-86	(60)-75-92-(108)
Vertebrae:	46	42 -44-47 48	Gill Rakers:		23-37

Table 14. Size at apparent onset of selected developmental events for Catostomus platyrhynchus, as observed under low power magnification. P principal rays; R rudimentary rays; Scales are lateral series. Rare or questionable extremes in parentheses.

Event or Structure	Onset or Formation mm SL	mm TL	Fin Rays or Scales	First Formed mm SL	mm TL	Last Formed mm SL	mm TL
Hatched:	7 8	7 8	Dorsal - P:	13	14	14-17	16-19
Eyes Pigmented:	8	8	Anal - P:	14-15	16-17	16-17	18-19
Yolk Assimilated:	10 11	10 11-12	Caudal - P:	11	11-12	13-14	15
Finfold Absorbed:	21-22	25-27	Caudal - R:	14	15-16	20-21	24-25
Pectoral Fin Buds:	8	8	Pectoral:	13-15	15-17	18-20	22-23
Pelvic Fin Buds:	13	14-15	Pelvic:	16	18	18-20	22-23
			Scales:	23-24	28-30	32-36	38-43

References: Cope 1872; Jordan and Evermann 1896; Baxter and Simon 1970; Sigler and Miller 1963; Smith 1966; Moore 1968; Scott and Crossman 1973; Moyle 1976; Simpson and Wallace 1978; Wydoski and Whitney 1979; Lee et al. 1980; Miller and Smith 1981; Tyus et al. 1982; Snyder 1983a; Woodling 1985; Sigler and Sigler 1987. Carlson and Muth (in press).

Table 15. Size at developmental interval (left) and gut phase (right) transitions for Catostomus platyrhynchus. See Figure 4 for phases of gut folding. Rare or questionable extremes in parentheses.

Transition to	mm SL	mm TL	Transition to	mm SL	mm TL
Flexion Mesolarva:	11	11-12	2 - 90° bend:	14-17	16-19
Postflexion Mesolarva:	13-14	15	3 - Full loop:	16-17	20-21
Metalarva:	16-17	18-19	4 - Partial crossover:	18-20	22-24
Juvenile:	21-22	25-27	5 - Full cross over:	21-23	25-28

Table 16. Summary of morphometrics and myomere counts by developmental phase for Catostomus platyrhynchus. See Figure 3 for abbreviations and methods of measurement and counting.

	Protolarvae (N=13)				Flexion Mesolarvae (N=9)				Postflexion Mesolarvae (N=11)				Metalarvae (N=9)				Juveniles (N=8)			
	Mean	±SD	Min	Max	Mean	±SD	Min	Max	Mean	±SD	Min	Max	Mean	±SD	Min	Max	Mean	±SD	Min	Max
SL,mm:	9	1	7	11	12	1	11	14	15	1	13	17	19	2	16	22	28	6	21	38
TL,mm:	10	1	8	12	13	1	11	15	16	1	15	19	22	3	18	27	34	7	25	45
Lengths %SL:																				
AS to AE	2	0	1	3	3	1	2	4	5	1	4	6	7	1	6	8	8	1	7	9
PE	9	1	8	10	9	1	8	11	12	1	10	13	13	1	12	14	14	1	13	15
OP1	17	1	16	18	19	1	17	21	23	2	20	26	25	1	23	26	25	1	24	26
OP2									54	1	52	56	56	2	53	58	57	2	55	60
PY	74	5[a]	62	82	51	1	50	52												
OPAF	36	20	25	82	28	2	26	31	35	4	30	44	50	12	35	68				
ODF	41	5	36	55	41	2	38	43	44	2[e]	41	47	49	[h]	49	49				
OD									50	1	49	52	51	1	50	53	50	1	48	52
ID									62	1	61	64	63	1	62	65	63	1	60	64
PV	78	2	75	84	77	1	75	78	79	1	77	80	77	1	75	78	75	1	74	78
OA									79	1	77	79	77	1	76	78	76	1	74	78
IA									83	83	83	84	1	82	85	84	1	83	85	
AFC									111	1	109	114	113	2	110	115	115	1	114	117
PC	104	1	101	106	107	1	105	109	113	2	110	118	118	2	115	120	121	1	119	123
Y	47	18	0	70	3	6	0	14												
P1	8	3	2	11	11	1	10	13	12	1	11	14	14	1	12	16	18	1	15	19
P2									4	2	1	8	8	1	6	11	12	1	10	13
D									13	1	11	15	17	1	15	19	20	1	18	21
A									8	1	7	8	10	2	8	13	14	1	12	15
Depths %SL:																				
at BPE	11	1	9	12	12	1	11	13	15	1	14	16	16	0	15	16	16	1	15	17
OP1	12	2	10	20	14	1[d]	12	15	17	1	15	18	18	1	16	20	20	1	17	21
OD	12	1	10	14	11	1	10	12	13	1[g]	12	16	17	1	15	19	20	1	18	21
BPV	6	1	3	7	7	0	6	7	8	1	7	9	10	1	9	12	13	1	11	14
AMPM	3	1	2	4	4	0	4	5	6	1	5	6	7	1	6	8	9	0	8	9
Max. Yolk	5	5	0	15	0	1	0	1												
Widths %SL:																				
at BPE	10	1	8	11	11	1	10	13	14	1	13	16	15	1	14	16	16	1	15	17
OP1	8	3	6	16	9	1	8	10	12	1	11	13	14	1	13	16	17	1	14	18
OD	8	2[b]	6	11	6	1	5	7	8	1[g]	7	10	12	1	10	14	15	1	13	17
BPV	4	0	3	4	4	0	4	4	5	1	4	5	7	1	6	9	9	1	8	10
AMPM	2	0	1	3	2	0	2	3	3	0	3	4	4	1	3	4	4	0	4	5
Max. Yolk	7	6	0	18	0	1	0	2												
Myomeres:																				
to PY	33	3[a]	26	35	23	1	22	23												
OPAF	12	9	5	34	7	1	6	9	9	2	7	13	18	7	9	28		[b]		
OP2									21	1	19	22	21	1[h]	20	22	22	0	21	22
ODF	14	2	12	21	14	1	13	16	15	1	13	17	15		15	15				
OD									19	1	17	19	18	1	16	19	18	1[c]	17	18
PV	36	1	35	37	36	1	35	37	36	1	34	37	35	1	32	36	34	1[c]	34	35
Total	45	1	44	46	46	1	44	47	45	1	43	46	45	1	43	45	45	1	44	45

Figure 36. Catostomus platyrhynchus protolarva, recently hatched, 8.1 mm SL, 8.2 mm TL (from Snyder 1983a). Cultured from Willow Creek, northwest of Steamboat Springs, Colorado.

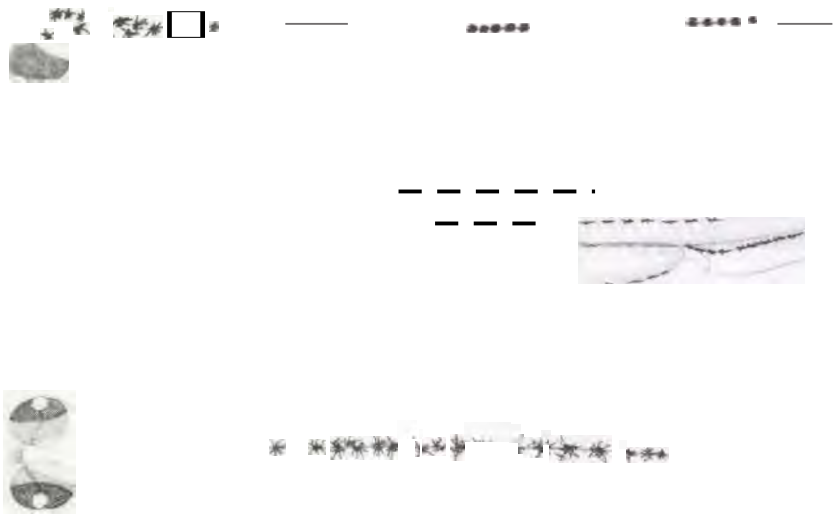


Figure 37. Catostomus platyrhynchus protolarva, 9.5 mm SL, 9.8 mm TL (from Snyder 1983a). Cultured from Willow Creek, northwest of Steamboat Springs, Colorado.

Figure 38. Catostomus platyrhynchus flexion mesolarva, recently transformed, 12.1 mm SL, 12.8 mm TL (from Snyder 1983a). Cultured from Willow Creek, northwest of Steamboat Springs, Colorado.

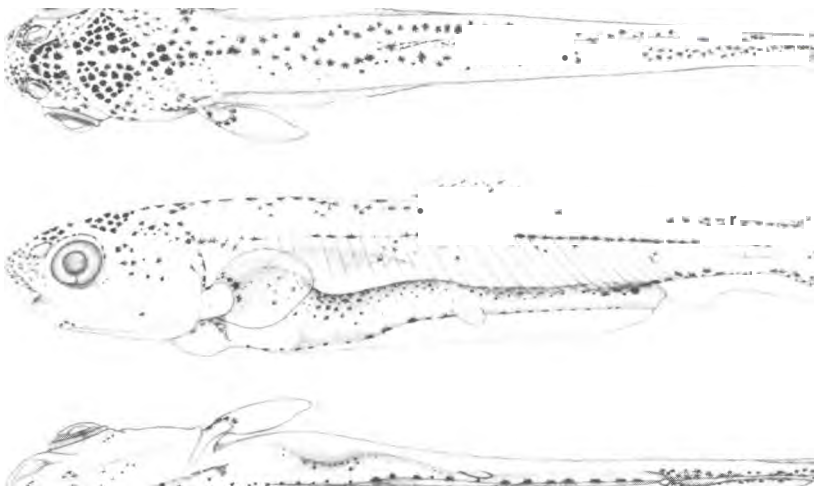


Figure 39. Catostomus platyrhynchus postflexion mesolarva, 13.7 mm SL, 15.6 mm TL. Collected from Willow Creek, northwest of Steamboat Springs, Colorado.

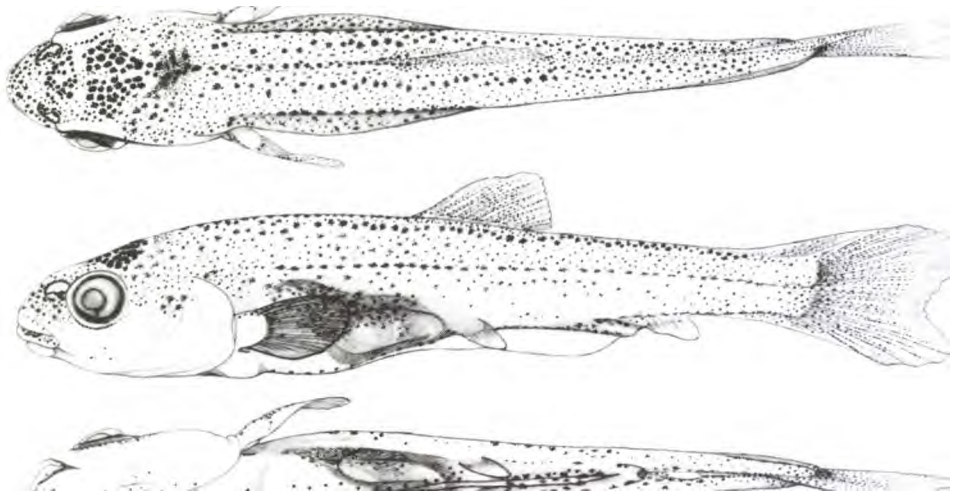


Figure 40. Catostomus platyrhynchus metalarva, recently transformed, 16.3 mm SL, 19.6 mm TL. Collected from Willow Creek, northwest of Steamboat Springs, Colorado.

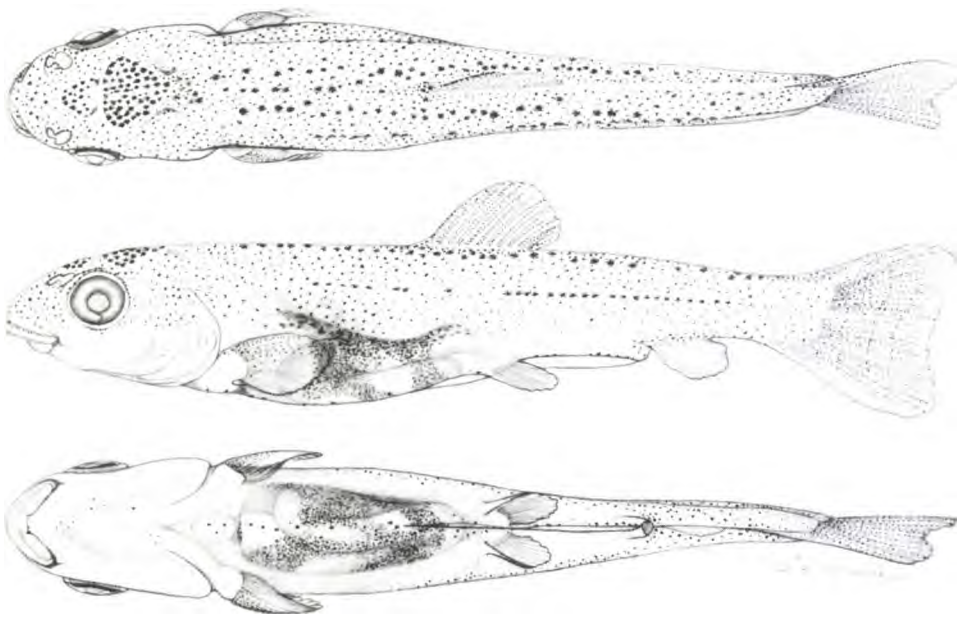


Figure 41. Catostomus platyrhynchus metalarva, 19.6 mm SL, 22.5 mm TL. Collected from Willow Creek, northwest of Steamboat Springs, Colorado.

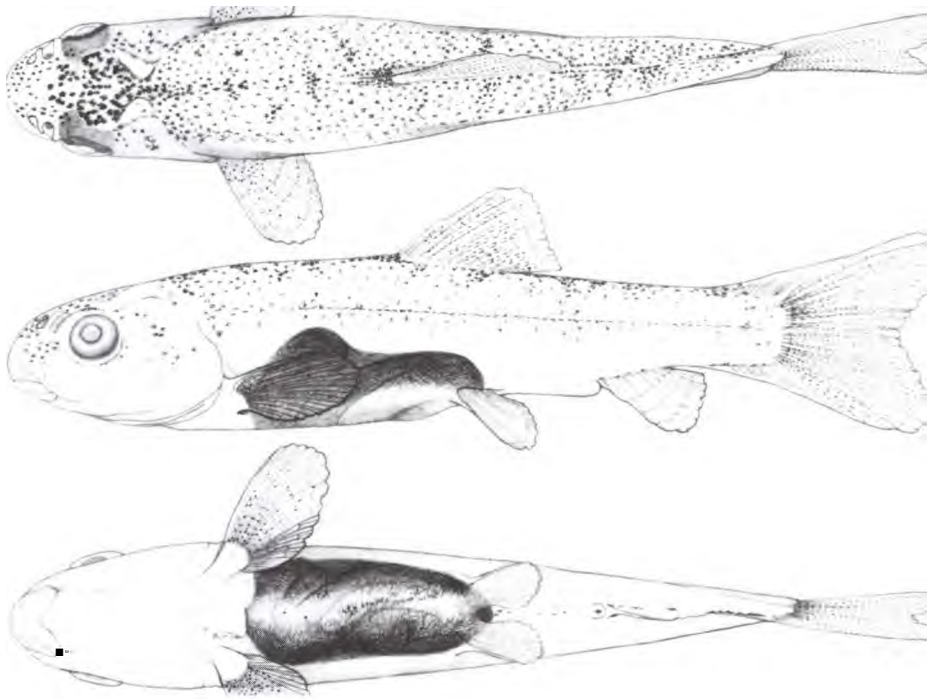


Figure 42. Catostomus platyrhynchus juvenile, recently transformed, 20.6 mm SL, 25.2 mm TL. Collected from Spanish Fork River, Utah Lake, Utah.

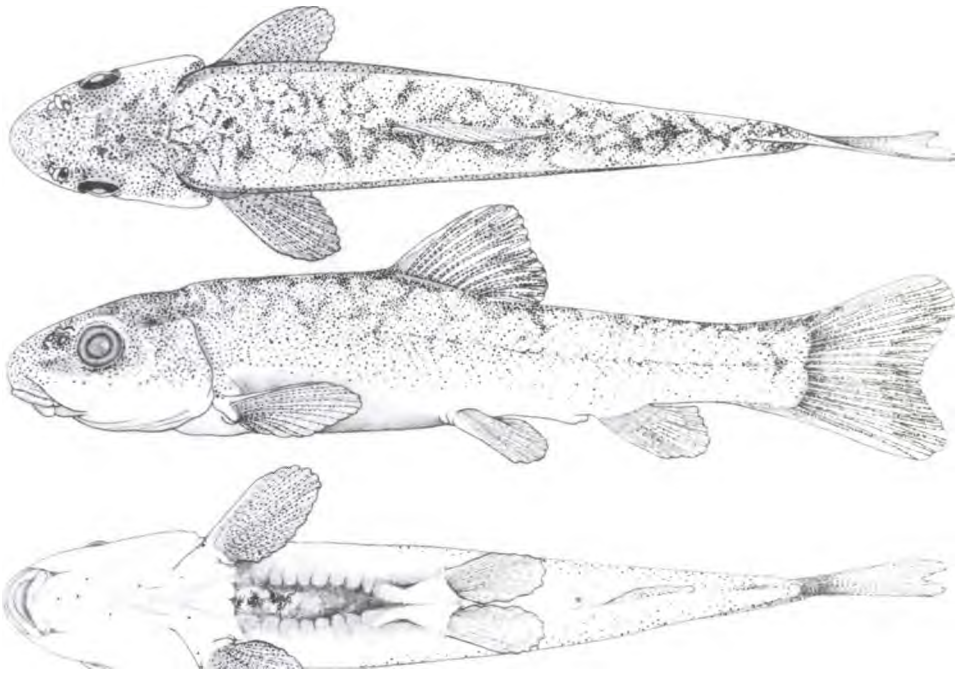


Figure 43. Catostomus platyrhynchus juvenile, 31.5 mm SL, 38.0 mm TL. Collected from Provo River, Utah Lake, Utah.

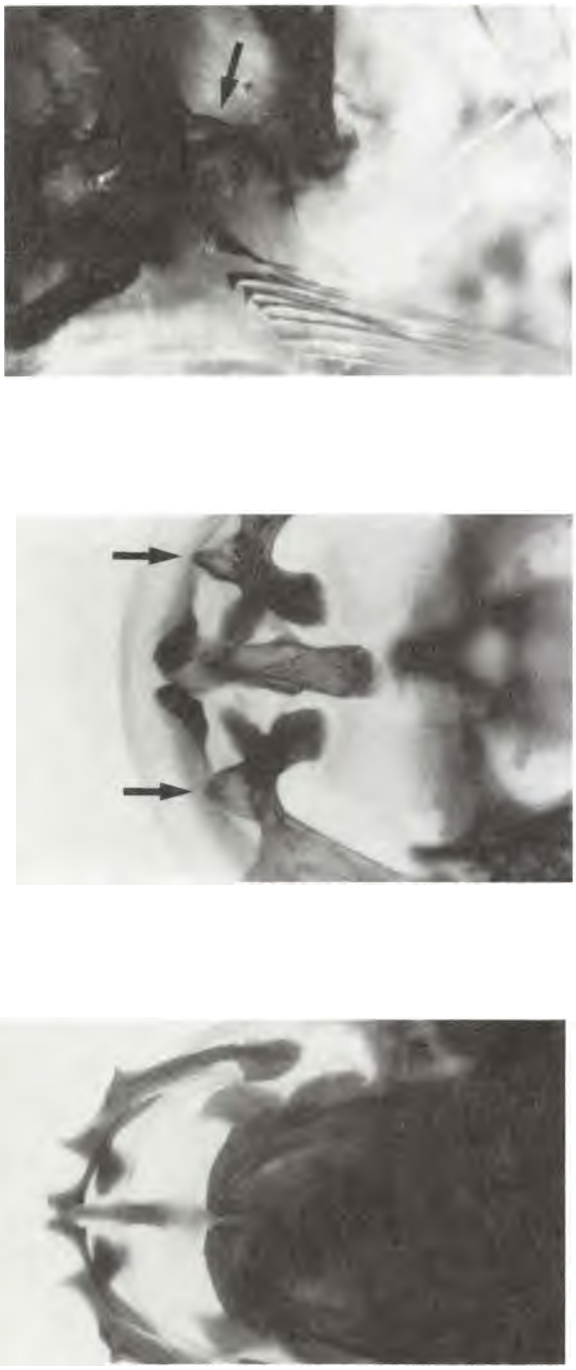


Figure 44. Selected skeletal features of Catostomus platyrhynchus, juvenile, 21.2 mm SL, 24.0 mm TL. Top -- postcleithrum. Middle -- anterior-dorsal maxillary projections. Bottom -- mandible position.

Figure 45. Selected skeletal features of Catostomus platyrhynchus, juvenile, 45 mm SL, 53 mm TL. Top -- postcleithrum. Middle -- anterior-dorsal maxillary projections. Bottom -- mandible position.

Figure 47. Frontoparietal fontanelle of Catostomus platyrhynchus. Top -- juvenile, 21.2 mm SL, 24.0 mm TL. Bottom -- juvenile, 45 mm SL, 53 mm TL.

Figure 46. Interneurals of Catostomus platyrhynchus. Top -- postflexion mesolarva, 15.0 mm SL, 17.0 mm TL. Middle -- juvenile, 21.2 mm SL, 24.0 mm TL. Bottom-- juvenile, 45 mm SL, 53 mm TL.

Table 17. Dimensions of frontoparietal fontanelle for Catostomus platyrhynchus, metalarva and early juveniles.

Specimens mm SL	mm TL	Max. Width (mm)	Length (mm)	Max. Width as % of Length
21.2	24.0	0.6	2.2	27
31.5	36.0	0.6	2.3	23
41.2	47.0	0.5	2.5	20
45	53	0.4	2.7	15
76	88	–	–	absent

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APPENDIX A

INDIVIDUAL MEASURES AND COUNTS FOR FULLY ANALYZED SPECIMENS

Table A-1. Individual measures and counts for fully analyzed Chasmistes liorus larvae and juveniles reared in 1987 by the Larval Fish Laboratory (LFL) at Colorado State University. Parents were captured from Utah Lake. "D" following specimen number denotes a specimen used as a model for drawings.

SPECIMEN #:	1 D	2	3	4	5 D	6	7	8	9	10 D	11 D	12	13	14	15	16 D
SOURCE:	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL
FERTILIZED:	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26
PRESERVED:	6/02	6/03	6/05	6/05	6/06	6/06	6/07	6/09	6/09	6/11	6/11	6/15	6/17	6/17	6/19	6/22
AGE, DAYS:	7	8	10	10	11	11	12	14	14	16	16	20	22	22	24	27
DEV. PHASE:	PY	PY	PY	PY	PY	PY	PY	MFY	MFY	MFY	MF	MF	MF	MP	MP	MP
LENGTHS, MM:																
AS TO AE	0.2	0.25	0.2	0.25	0.25	0.2	0.25	0.3	0.3	0.25	0.4	0.3	0.4	0.5	0.4	0.6
PE	0.8	0.85	0.8	0.9	0.9	0.9	0.95	1	1	1	1.2	1.1	1.3	1.35	1.25	1.55
OP1	1.4	1.5	1.45	1.7	1.8	1.8	1.7	1.9	2	2.05	2.3	2.25	2.4	2.5	2.6	2.9
OP2																6.9
PY	7.8	8.25	7.8	8.65	8.55	8.8	7.9	8.4	7.5	5.8						
OPAF	6.8	7.2	5	3.2	3.6	2.65	2.5	2.7	2.9	2.8	3.2	3.1	3.5	3.8	3.7	3.8
ODF	3.8	3.7	3.9	4	4.2	4.5	4	4.4	4.3	4.2	4.6	4.8	5.2	5.4	4.8	5.8
OD																6.5
ID																
PV	7.9	8.5	7.95	8.85	8.8	9.1	8.2	8.95	9.55	9.1	9.85	8.9	10	9.7	10.5	10.9
OA																
IA																
PHP	9.6	10.6	9.75	11	11.1	11.5	10.45	11.55	12.3	11.9	12.6	11.4	12.6	11.95	13.2	13.5
AFC														12.95	14.35	14.9
PC	9.9	10.9	10.15	11.55	11.6	12	10.9	12.2	12.8	12.5	13.3	12.25	13.8	13.1	14.7	15.2
	6.4	6.55	6.4	6.7	6.7	6.6	6.4	5.7	4.7	1.4						
P1	0.2	0.3	0.35	0.7	0.8	0.9	0.8	1.1	1.2	1.3	1.4	1.3	1.45	1.5	1.5	1.6
P2																0.5
A																
DEPTHS, MM:																
AT BPE	0.9	0.8	0.85	1.05	1.05	1.1	1.1	1.15	1.2	1.3	1.35	1.4	1.45	1.55	1.55	1.8
OP1	1.2	1	1.15	1.2	1.15	1.15	1.35	1.25	1.25	1.4	1.45	1.6	1.8	1.8	1.7	2.1
OD	1.4	1.4	1.45	1.35	1.35	1.25	1.3	1.2	1.1	1.1	1.3	1.3	1.3	1.4	1.3	1.65
BPV	0.35	0.4	0.4	0.6	0.7	0.65	0.7	0.65	0.75	0.75	0.8	0.75	0.85	0.85	0.85	0.95
AMPM	0.25	0.2	0.25	0.3	0.3	0.35	0.35	0.4	0.45	0.5	0.55	0.55	0.65	0.65	0.7	0.8
MAX YOLK	1.15	1.1	1.05	0.8	0.75	0.65	0.8	0.5	0.4	0.2						
WIDTHS, MM:																
AT BPE	0.8	0.8	0.85	0.95	1	1	1	1.05	1.1	1.2	1.25	1.3	1.4	1.4	1.4	1.6
OP1	0.6	0.6	0.7	0.75	0.75	0.7	0.8	0.8	0.8	0.85	0.95	1.1	1.1	1.2	1.15	1.3
OD	0.9	0.9	0.95	0.85	1	0.6	0.65	0.55	0.55	0.65	0.7	0.7	0.8	0.8	0.85	0.95
BPV	0.3	0.35	0.35	0.4	0.4	0.4	0.4	0.4	0.4	0.45	0.5	0.5	0.55	0.55	0.6	0.7
AMPM	0.15	0.2	0.2	0.25	0.25	0.3	0.25	0.25	0.25	0.25	0.3	0.3	0.3	0.3	0.35	0.4
MAX YOLK	1.25	1.15	1.1	0.85	1.05	0.7	0.9	0.6	0.5	0.2						
MYOMERES:																
TO PY	39	36	35	37	37	35	36	35	28	22						
OPAF	31	30	21	9	11	9	7	7	7	7	7	7	7	7	7	7
OP2																20
ODF	14	14	15	14	16	16	14	15	14	13	14	15	16	16	14	15
OD																18
PV	40	37	36	38	39	37	38	38	38	37	37	37	38	37	37	37
TOTAL	46	46	45	47	47	47	47	47	47	46	46	46	45	46	46	46
FIN RAYS P:																
								3	2	6	10	14	17	18	18	18
															3	8
A																
P1																
P2																
FIN RAYS S:																
CD																
CV																
A																

(continued)

Table A-1. Continued.

SPECIMEN #:	17	18	19	20	21	22	23	24	25	26 D	27	28	29	30 D	31	32	33
SOURCE:	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL
FERTILIZED:	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26
PRESERVED:	6/22	6/22	6/25	6/25	6/25	6/29	6/29	6/29	7/02	7/07	7/07	7/07	7/07	7/10	7/10	7/10	7/10
AGE, DAYS:	27	27	30	30	30	34	34	34	37	42	42	42	42	45	45	45	45
DEV. PHASE:	MP	MP	MP	MP	MP	MP	MP	MP	MP	MT	MT	MT	MT	MT	MT	MT	MT
LENGTHS, MM:																	
AS TO AE	0.6	0.6	0.5	0.7	0.9	0.5	0.6	0.7	1	1	1	0.9	1.3	1.1	1.1	1	1.3
PE	1.6	1.6	1.5	1.7	2.05	1.6	1.6	1.8	2.1	2.1	2.1	2.2	2.5	2.4	2.4	2.3	2.7
OP1	2.8	3.1	2.8	3.4	3.6	3.4	3.2	3.4	3.8	3.9	4	4	4.3	4.6	4.2	4.2	5
OP2	7	7.4	6.8	7.8	8	7.3	7.6	7.6	8.4	8.4	8.7	8.8	9.1	9.9	9.2	9.3	10.1
PY																	
OPAF	3.8	4.2	3.9	4.7	5	4.6	4.2	4.8	4.9	5.4	5.4	5.5	5.5	7.2	6.2	6.1	7.9
ODF	5.4	6.2	5.6	6.6	6.6	6.2	6.8	6.6	7.3	7	7.5	7.7	8.4	8.2	8.1	8.2	
OD	6.4	6.8	6	7.2	7.6	6.5	7.1	7.2	7.7	7.8	7.9	8.1	8.6	8.8	8.4	8.4	8.9
ID					9.8	8.6	9.3	9.5	10.2	10.3	10.6	10.8	11.3	11.6	11.2	11.4	11.9
PV	10.7	11.4	10.2	12.2	12.8	10.2	11.7	11.7	12.8	12.6	12.3	12.9	13.6	13.9	13.2	13.1	14
OA					12.7	10.15	11.6	11.6	12.8	12.5	12.3	12.9	13.6	13.9	13.2	13.1	14
IA					13.6	11.1	12.5	12.6	13.8	13.6	13.5	14.2	15	15.3	14.6	14.6	15.7
PHP	13.6	14.1	12.6	15.2	16	13.3	14.5	14.8	16	15.8	15.8	16.6	17.5	18.1	17	17	18.7
AFC	14.9	15.6	14.1	16.6	17.6	14.9	16	16.2	17.8	17.5	17.9	18.6	19.6	20.4	19	19.3	21
PC	15.4	16.1	14.6	17.3	18.3	15.8	16.9	17.3	18.7	18.7	19.4	19.7	21.2	22	20.3	20.8	23
P1	1.7	1.8	1.4	1.8	1.9	1.7	1.8	1.6	1.8	1.8	2	2.2	2.2	2.6	2	2.5	3
P2	0.45	0.6	0.6	0.8	0.9	1	0.9	1	1	1.2	1.6	1.4	1.7	2	1.6	2	2.4
					2.4	2.3	2.4	2.5	2.7	3	3.4	3.4	3.4	4	3.2	3.8	4.2
A					1.2	1.1	1.1	1.2	1.2	1.5	1.6	1.8	1.8	2	1.7	2	2.3
DEPTHS, MM:																	
AT BPE	1.9	2	1.9	2.1	2.35	2.2	2.1	2.2	2.4	2.4	2.8	2.6	2.8	3	2.8	2.8	3.2
OP1	2.1	2.4	2.2	2.5	2.7	2.5	2.5	2.5	2.8	2.8	3.3	2.9	3.2	3.4	3.1	3.4	3.6
OO	1.75	2	1.9	2.1	2.4	2.5	2.2	2.2	2.6	2.6	3.1	3	3	3.5	3	3.3	3.8
BPV	1	1.1	1.1	1.3	1.4	1.5	1.3	1.3	1.5	1.6	1.9	1.8	1.9	2.1	1.9	2	2.4
AMPM	0.85	0.9	0.8	0.9	1	1	0.9	1	1.1	1.1	1.4	1.2	1.3	1.4	1.3	1.3	1.4
MAX YOLK																	
WIDTHS, MM:																	
AT BPE	1.7	1.8	1.7	1.9	2	2	1.9	2	2.1	2.2	2.4	2.3	2.4	2.6	2.4	2.5	2.8
OP1	1.5	1.7	1.6	1.8	1.8	1.8	1.7	2	2	2.1	2.5	2.2	2.4	2.6	2.2	2.6	2.8
OD	1	1.1	1.2	1.3	1.45	1.6	1.4	1.4	1.6	1.6	2	1.8	1.9	2.2	2	2	2.5
BPV	0.8	0.7	0.7	0.8	0.9	0.9	0.8	0.8	1	1	1.2	1.1	1.2	1.3	1.2	1.3	1.4
AMPM	0.45	0.4	0.4	0.4	0.5	0.5	0.4	0.5	0.6	0.6	0.7	0.6	0.6	0.5	0.6	0.6	0.6
MAX YOLK																	
MYOMERES:																	
TO PY																	
OPAF	7	7	6	7	6	7	5	7	6	7	7	8	7	11	9	9	14
OP2	21	21	21	20	19	21	21	21	21	21	21	21	21	21	21	21	22
ODF	14	15	15	14	13	16	15	14	13	15	15	16	16	16	16	16	
OO	19	18	17	18	17	18	19	18	18	18	17	18	17	17	17	17	17
PV	37	37	36	37	37	37	37	37	37	38	35	36	37	36	36	36	36
TOTAL	45	44	45	45	45	45	45	45	46	46	43	45	45	44	45	46	45
FIN RAYS P:																	
	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	7	10	10	10	11	10	11	12	12	12	12	13	12	12	13	13	12
A					5	6		6	6	7	7	7	7	7	7	7	7
P1					3	3			5	8	9	8	9	11	8	10	12
P2					4	6		4	6	7	9	9	9	9	9	9	9
FIN RAYS S:																	
CD		1	1	1	2	2	1	2	2	4	3	3	4	4	3	4	5
CV		1			2	2	1	1	2	3	3	3	3	4	2	3	4
D					1	1	1	2	1	2	2	2	2	2	2	2	2
A										1	1	1	1	1	1	1	1

(continued)

Table A-1. Continued.

SPECIMEN #:	34	35	36	37	38	39 D	40	41	42	43	44	45	46	47 D	48	49	50
SOURCE:	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL
FERTILIZED:	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26	5/26
PRESERVED:	7/14	7/14	7/14	7/20	7/20	7/20	7/28	7/28	8/04	8/04	8/10	8/10	8/31	9/23	9/23	10/11	10/22
AGE, DAYS:	49	49	49	55	55	55	63	63	70	70	76	76	97	120	120	138	149
DEV. PHASE:	MT	MT	MT	MT	J	J	J	J	J	J	J	J	J	J	J	J	J
LENGTHS, MM:																	
AS TO AE	1.2	1.4	1.6	1.2	1.2	1.5	1.6	1.6	1.8	1.8	2.2	2	2.2	2.2	2.8	2.4	3.4
PE	2.6	2.8	3.1	2.7	2.8	3.1	3.2	3.3	3.6	3.6	4.2	4	4.4	4.6	5.2	4.9	6.9
OP1	4.6	5.1	5.3	5.2	5.6	5.6	5.5	6.2	6.2	6.5	6.7	7.2	7.4	7.8	8.8	8.4	9.8
OP2	9.8	10.6	11.3	11.3	11.7	11.7	11.2	12.8	12.6	13.3	14.4	15	15.9	17.1	19.4	18	22
PY																	
OPAF	6.8	11	12	12.2													
ODF																	
OD	8.7	9.2	10	9.6	10	10.6	9.7	11.5	10.9	11.7	12.9	13	13.7	14.6	17.2	15.3	18.7
ID	11.6	12.3	13.4	13	13.6	14.4	13.2	15	14.9	16.1	17.3	18.1	18.6	20.5	23.4	21.2	26.2
PV	13.3	14.1	15.4	14.9	15.6	16.2	14.5	17.2	17.2	18	19.4	20.4	21.3	23.5	26.4	24.5	29.2
OA	13.3	14.2	15.5	15	15.8	16.4	14.5	17.2	17.2	18.1	19.5	20.7	21.4	23.6	26.6	24.7	29.3
IA	14.7	15.7	17.2	16.6	17.5	18.1	16.2	19.1	18.3	20	21.6	22.7	23.8	26.4	30	27.4	32.8
PHP	17.4	18.8	20.5	20	20.9	21.8	19.2	23	22.8	24.2	25.8	27.3	28.6	31.7	35.7	32.3	38.6
AFC	19.9	21.4	23.4	23	24.2	25	22.6	26.5	26.8	28.1	30.4	32.1	33.8	37.4	41.8	38.5	46.4
PC	21.8	23	24.8	25.1	26.3	27.1	24.8	28.8	29.5	30.6	32.7	34.4	36.4	40	45.6	41.6	50.5
Y																	
P1	3	3	3.2	3.4	4	3.6	4.2	4.4	4.4	4.8	5.2	5.6	6.2	7	8.2	7.4	9.4
P2	2.3	2.4	2.4	2.8	3	3	3.2	3.2	3.6	3.8	4.2	4.6	5	5.6	6.1	5.8	7.5
D	4	4.4	4.7	5	5.5	5.4	5.4	5.3	6	6.6	6.9	7.3	7.8	9.1	9.4	9	10.2
A	2.2	2.3	2.6	2.8	3.2	2.9	3.1	3.2	3.4	3.6	4.2	4.4	4.6	5.5	6.2	5.4	7.8
DEPTHS, MM:																	
AT BPE	3.2	3.4	3.7	3.6	3.7	3.8	4	4.1	4.3	4.3	4.8	5.2	5.2	5.8	6.5	6.2	7.8
OP1	3.6	3.9	4.1	4.2	4.4	4.2	4.8	4.3	5.1	4.9	5.7	5.9	6	6.8	7.6	7	8.8
OD	3.9	3.9	4.1	4.5	4.6	4.5	4.9	4.8	5.4	5.2	6.2	6.3	6.2	7.4	7.8	6.6	9.4
BPV	2.4	2.6	2.6	2.8	3.1	2.9	3.2	3.3	3.2	3.6	4.2	4.2	4.2	4.8	5.1	4.1	5.8
AMPM	1.5	1.6	1.5	1.7	1.8	1.8	1.8	1.9	1.9	2	2.1	2.2	2.3	2.6	3	2.7	3.4
MAX YOLK																	
WIDTHS, MM:																	
AT BPE	3	2.9	3.1	3.3	3.4	3.3	3.6	3.7	4	3.8	4.4	4.4	4.8	5.3	6	5.6	7
OP1	3	3	3.3	3.4	3.6	3.5	3.6	3.9	4.2	4.2	4.8	5	5.2	5.4	6.6	6	7.2
OD	2.7	2.7	3.1	3.2	3.5	3.2	3.7	3.8	4	4.1	4.8	4.9	5	5.6	6.6	5.3	7.7
BPV	1.6	1.6	1.8	1.8	2	2	2.2	2.2	2.4	2.6	2.8	3	3	3	3.5	3.1	4.8
AMPM	0.7	0.7	0.7	0.8	0.8	0.9	1.1	1	1	1.1	1.4	1.1	1.4	1.3	1.8	1.5	1.8
MAX YOLK																	
MYOMERES:																	
TO PY																	
OPAF	10	23	23	25													
OP2	23	21	21	22	23	20	22	21	22	22							
ODF																	
OD	18	17	17	16	17	17	16	18	17	16							
PV	37	36	36	35	35	35	36	36	36	35							
TOTAL	46	45	45	44	46	45	46	46	45	45							
FIN RAYS P:																	
C	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
D	12	12	13	12	12	13	11	12	12	14	12	14	12	13	12	13	12
A	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
P1	15	15	16	16	17	16	16	17	16	17	17	17	17	17	16	17	17
P2	9	9	10	10	10	10	11	11	11	11	11	11	11	10	11	11	10
FIN RAYS S:																	
CD	5	6	6	8	8	10	7	9	8	10	8	10	9	9	7	9	8
CV	4	5	6	6	7	7	6	7	7	8	7	7	8	8	8	8	8
D	2	2	3	3	3	3	3	3	3	4	3	4	3	4	3	5	4
A	1	1	2	2	2	2	3	3	2	3	3	3	3	3	3	3	3

Table A-2. Individual measures and counts for fully analyzed Catostomus ardens larvae and juveniles reared in 1987 by the Utah Cooperative Fish and Wildlife Research Unit at Utah State University (USU). Parents were captured from Bear Lake. "D" following specimen number denotes a specimen used as a model for drawings.

SPECIMEN #:	1	2	3	4 D	5	6	7	8 D	9	10	11	12 D	13	14	15	16	17
SOURCE:	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU
FERTILIZED:	5/15	5/15	5/15	5/25	5/25	5/15	5/15	5/25	5/15	5/25	5/25	5/25	5/25	5/15	5/25	5/25	5/15
PRESERVED:	5/26	5/27	5/27	6/5	6/6	5/29	5/29	6/10	6/6	6/13	6/14	6/17	6/22	6/18	7/2	7/2	6/24
AGE, DAYS:	11	12	12	11	12	14	14	16	22	19	20	23	28	34	38	38	40
DEV. PHASE:	PY	PY	PY	PY	PY	PY	PY	PY	PY	MFY	MFY	MF	MF	MF	MP	MP	MP
LENGTHS, MM:																	
AS TO AE	0.2	0.3	0.25	0.2	0.25	0.25	0.2	0.2	0.3	0.3	0.2	0.2	0.5	0.3	0.5	0.5	0.4
PE	0.7	0.8	0.8	0.85	0.9	0.9	0.85	0.9	1	0.95	1	0.9	1.4	1.1	1.45	1.4	1.3
OP1	1.1	1.3	1.35	1.6	1.7	1.65	1.7	1.9	2	1.9	2.1	2	2.6	2.2	2.5	2.6	2.5
OP2															6.9		
PY	6.7	7.25	7.6	8.2	8.5	9.1	8.8	9.2	9.35	8.55	9.6						
OPAF	6	6.3	6.1	6	3.3	3.4	3.3	2.9	3.1	3.05	3	3	3.5	3	3.5	3.5	3.8
ODF	2.6	3.4	3.3	3.8	3.7	3.8	3.8	3.8	4.5	4.3	4.1	4.35	5	4.2	5	5.35	5
OD															6.4	6.9	
ID																	
PV	6.95	7.3	7.9	8.45	8.65	9.3	9.1	9.6	9.9	9.3	10.2	9.3	10.7	8.95	9.95	11	10.65
OA																	
IA																	
PHP	9	9.4	10.2	10.5	11	11.95	11.65	12.45	13.05	12.4	13.4	12.15	13.9	11.65	13.1	13.85	13.5
AFC															14.3	15.1	14.55
PC	9.15	9.6	10.4	10.8	11.3	12.3	12.1	13	13.55	13	14	12.8	14.8	12.2	14.3	15.1	14.7
Y	5.7	5.7	5.7	6.7	7	7	6.6	6.5	6.4	4.5	5.7						
P1	0.1	0.1	0.35	0.4	0.5	0.6	0.7	1	1	1.2	1.3	1.3	1.5	0.95	1.3	1.5	1.2
P2															0.05		
D																	
A																	
DEPTHS, MM:																	
AT BPE	0.7	0.9	0.7	1	1.05	1	1	1.25	1.35	1.25	1.2	1.15	1.6	1.3	1.7	1.65	1.55
OP1	1	1.2	1	1.1	1.2	1.1	1.1	1.2	1.25	1.2	1.25	1.1	1.7	1.25	1.8	1.85	1.65
OD	1	1.1	1.2	1.3	1.3	1.15	1.2	1.2	1.25	1.1	1.1	0.95	1.3	1	1.4	1.55	1.2
BPV	0.35	0.4	0.4	0.4	0.55	0.6	0.6	0.75	0.7	0.7	0.75	0.6	0.8	0.6	0.9	0.95	0.8
AMPM	0.25	0.25	0.25	0.25	0.25	0.35	0.3	0.4	0.35	0.4	0.4	0.35	0.55	0.4	0.55	0.6	0.6
MAX YOLK	0.85	1	0.8	0.8	0.8	0.75	0.7	0.4	0.45	0.2	0.1						
WIDTHS, MM:																	
AT BPE	0.6	0.6	0.7	0.85	0.9	0.95	0.95	1.05	1.15	1.1	1.2	1.1	1.4	1.2	1.5	1.45	1.5
OP1	0.75	0.7	0.4	0.7	0.75	0.55	0.6	0.8	0.8	0.8	0.9	0.75	1.2	0.8	1.2	1.3	1.25
OD	0.7	0.75	0.85	0.95	0.95	0.75	0.7	0.7	0.65	0.65	0.65	0.55	0.8	0.6	0.85	0.9	0.7
BPV	0.25	0.3	0.3	0.4	0.4	0.35	0.3	0.45	0.45	0.4	0.45	0.4	0.55	0.4	0.5	0.55	0.55
AMPM	0.15	0.2	0.2	0.25	0.25	0.2	0.2	0.25	0.25	0.25	0.3	0.25	0.3	0.25	0.3	0.3	0.3
MAX YOLK	0.95	1.3	0.95	1	0.9	0.9	0.75	0.6	0.7	0.3	0.2						
MYOMERES:																	
TO PY	36	36	34	35	36	36	36	36	35	32	33						
OPAF	32	30	26	24	9	7	9	7	6	6	6	7	6	6	6	5	7
OP2															21		
ODF	11	13	10	12	12	12	11	11	13	12	11	12	12	12	13	13	13
OD															19	19	
PV	38	37	36	36	37	37	37	38	38	36	36	36	37	37	35	38	37
TOTAL	46	47	45	46	46	46	46	46	47	46	46	45	46	47	45	48	47
FIN RAYS P:																	
C										3	5	6	16	14	18	18	18
D															4	3	
A																	
P1																	
P2																	
FIN RAYS S:																	
CD																	
CV																	
D																	
A																	

(continued)

Table A-2. Continued.

SPECIMEN #:	18	19	20 D	21	22	23	24	25	26	27	28 D	29	30 D	31	32	33	34
SOURCE:	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU
FERTILIZED:	5/25	5/25	5/25	5/25	5/25	5/15	5/15	5/15	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25
PRESERVED:	6/10	7/4	7/6	7/6	7/6	7/8	7/8	7/6	7/12	7/12	7/23	7/29	7/29	8/1	8/1	8/1	8/1
AGE, DAYS:	16	40	42	42	42	54	54	52	48	48	59	65	65	68	68	68	68
DEV. PHASE:	PY	MP	MP	MP	MP	MP	MP	MP	MP	MP	MT	MT	MT	MT	MT	MT	MT
LENGTHS, MM:																	
AS TO AE	0.2	0.5	0.55	0.55	0.6	0.7	0.75	0.7	0.8	0.9	0.7	0.75	1	1	1	1.2	1.1
PE	1	1.45	1.55	1.5	1.6	1.8	1.85	1.85	2	2	1.9	1.9	2.4	2.35	2.3	2.6	2.5
OP1	1.9	2.7	2.8	2.9	2.95	3.1	3.5	3.4	3.5	3.5	3.7	3.6	4.8	4.2	4.6	4.8	4.8
OP2		7.3	7.5	7.6	7.7	7.7	7.9	7.8	8.5	8.5	8.5	7.8	10.1	9.2	9.5	10.3	10.3
PY	8.3																
OPAF	2.5	3.9	4	4	4.05	4.4	4.7	4.8	4.7	4.6	4.7	4.6	7.2	5.6	8	7.5	6.8
ODF	3.9	5.3	5.8	5.6	5.5	6	6	6.1	6.2	6.8	6.6	6.8					
OD		6.75	7.1	7.2	7.2	7.4	7.6	7.45	7.7	7.85	7.8	7.1	9	8.1	8.5	9.3	9.3
ID						9.2	9.6	9.7	10	10	10.1	9.3	11.9	10.6	11	12	12.1
PV	8.65	10.95	11.1	11.25	11.8	11.9	12.3	12	13.1	13.25	12.3	11.4	13.6	12.9	12.9	14	14.1
OA										13.2	12.3	11.4	13.6	12.9	13.1	14.1	14.2
IA										14.1	13.4	12.4	15.1	13.9	14.2	15.4	15.6
PHP	11.4	13.85	14.2	14.4	14.8	14.95	15.4	15.45	16.35	16.7	15.85	14.6	17.75	16.5	16.9	18	18.6
AFC		15.05	15.4	15.45	16.05	16.4	16.7	16.9	17.95	18.4	17.7	16.2	20.2	18.6	19	20.5	20.8
PC	11.9	15.25	15.7	15.8	16.65	17.1	17.5	18	18.55	19.1	18.7	17.2	21.5	19.6	20.4	22	22.1
	5.8																
P1	0.95	1.8	1.65	1.6	1.8	1.6	1.75	1.8	1.7	1.8	2.2	2	2.6	2.1	2.2	2.5	2.6
P2		0.05	0.05	0.05	0.3	0.6	0.8	1	0.7	1	1.3	1.2	2.1	1.4	1.9	2.2	2
						2.1	2.1	2.45	2.5	2.5	2.9	2.6	3.6	3.1	3.3	3.6	3.6
A										1.2	1.4	1.6	2	1.5	1.8	2	2
DEPTHS, MM:																	
AT BPE	1.15	1.75	1.9	1.8	2	2.2	2.2	2.35	2.3	2.3	2.3	2.4	3.1	2.7	2.8	2.9	3
OP1	1.15	1.85	2	2	2.2	2.35	2.45	2.6	2.45	2.5	2.6	2.6	3.6	3	3.1	3.3	3.3
OD	1.2	1.7	1.55	1.7	1.9	2.1	2	2.3	2.4	2.3	2.6	2.3	3.5	2.9	3	3	3.1
BPV	0.7	1	1	0.95	1.05	1.1	1.05	1.35	1.25	1.3	1.35	1.4	2.2	1.6	1.8	1.85	1.9
AMPM	0.35	0.7	0.7	0.7	0.8	0.85	0.9	0.95	0.95	0.95	1	1	1.4	1.2	1.2	1.35	1.35
MAX YOLK	0.55																
WIDTHS, MM:																	
AT BPE	1.1	1.5	1.65	1.55	1.75	1.95	2	2.05	1.95	1.9	2.15	2	2.8	2.4	2.5	2.8	2.8
OP1	0.8	1.2	1.35	1.3	1.6	1.55	1.6	1.65	1.7	1.6	1.8	1.9	2.7	2.1	2.3	2.4	2.4
OD	0.7	0.9	1	0.9	1.1	1.1	1.15	1.5	1.35	1.4	1.45	1.4	2.3	2	1.9	2.2	2
BPV	0.45	0.6	0.65	0.65	0.7	0.7	0.7	0.9	0.8	0.8	0.75	0.8	1.25	0.9	1.1	1.1	1.15
AMPM	0.25	0.35	0.4	0.35	0.45	0.4	0.4	0.5	0.4	0.4	0.45	0.45	0.6	0.5	0.5	0.6	0.5
MAX YOLK	0.75																
MYOMERES:																	
TO PY	34																
OPAF	4	6	6	6	6	6	6	7	7	7	6	8	11	7	15	14	9
OP2		21	21	22	21	20	19	20	21	20	21	21	22	22	20	21	21
ODF	11	12	14	12	14	14	12	13	13	13	13	16					
OD		18	18	19	18	18	17	18	18	18	18	18	18	18	16	17	17
PV	36	36	36	37	36	38	37	37	38	37	37	37	37	37	34	36	37
TOTAL	46	45	46	46	45	45	45	46	45	45	46	45	45	46	43	45	47
FIN RAYS P:																	
		18	18	18	18	18	18	18	18	18	18	18	17	18	18	18	18
		4	5	4	6	9	9	12	11	11	12	12	12	13	12	12	12
A								3	3	4	7	7	7	7	7	7	7
P1						2	3	4	5	4	9	14	15	13	14	13	14
P2											7	8	9	8	9	10	9
FIN RAYS S:																	
CD						1	1	1	3	3	3	3	6	4	5	6	6
CV						1	2	1	2	2	3	3	5	3	5	5	5
						1	1	1	1	1	2	2	3	2	2	3	4
A											1	1	1	1	2	2	2

(continued)

Table A-2. Continued.

SPECIMEN #:	35	36	37	38	40	39	41	42	43	44	45	46	47	48	49	50	51
SOURCE:	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU	USU
FERTILIZED:	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25	5/25
PRESERVED:	8/1	8/7	8/7	8/13	8/10	8/7	8/10	8/10	8/10	8/13	8/20	8/20	8/20	8/28	8/28	9/11	9/11
AGE, DAYS:	68	74	74	80	77	74	77	77	77	80	87	87	87	95	95	109	109
DEV. PHASE:	MT	MT	MT	MT	MT	J	J	J	J	J	J	J	J	J	J	J	J
LENGTHS, MM:																	
AS TO AE	1.3	1.05	1	1.1	1.4	1.4	1.4	1.6	2.2	1.8	1.5	1.7	1.6	1.2	2.2	2.2	2.7
PE	2.7	2.5	2.4	2.4	2.9	3	3.1	3.4	4.5	3.7	3.3	3.6	3.6	2.8	4.3	4.4	5.4
OP1	4.9	4.6	4.3	4.4	5	5.4	5.6	6.2	7.2	6.3	6.6	6.7	7.1	5.2	6.9	7.4	9.2
OP2	10.6	10.2	9.7	9.8	10.6	11.6	12.2	12.6	15.8	13.6	13.4	13.9	15	10.8	15.6	16	20.3
PY																	
OPAF	9	8.6	7.8	8.7													
ODF																	
OD	9.6	8.9	8.8	8.7	9.3	10.35	10.5	10.9	13.7	11.5	11.6	12	12.8	9.8	13.7	14	17.6
ID	12.4	11.6	11.45	11.3	12.1	13.4	14.3	14.4	18.3	15.1	15.4	16.1	17.1	12.6	17.6	18.2	23.6
PV	15	13.7	13.5	13.3	14.1	15.8	16.5	16.9	20.8	17.4	17.7	18.2	19.7	14.5	20.4	21.2	26.9
OA	14.9	13.8	13.5	13.3	14.1	15.8	16.5	17	20.9	17.6	17.9	18.3	20	14.8	20.7	21.6	27.3
IA	16.2	15	14.8	14.5	15.5	17.4	18.1	18.7	23.1	19.4	19.7	20.1	22.2	16.2	22.6	23.5	29.9
PHP	19.4	17.8	17.6	17.1	18.5	21.1	21.8	22.5	27.8	23.5	24.1	24.6	26.5	19.05	27.2	28.15	35.9
AFC	damage	20.1	19.7	19.1	20.9	24.1	24.8	25.8	31.9	26.8	28	28.7	30.7	22	31.7	33	42.2
PC	23.4	21.8	21.2	20.6	22.6	26	26.9	28	34.6	28.8	30.2	31.4	33.2	23.9	34	35.6	45.4
Y																	
P1	2.4	3	2.3	2.4	3.2	3.2	4	4.3	5.2	4.4	5	4.8	5.6	3.6	6	6	8
P2	2.1	2	1.9	1.8	2.2	2.6	2.8	3.2	4.2	3	3.6	4	3.8	2.7	4.2	4.5	5.6
D	3.9	3.6	3.6	3.2	3.7	4.4	5	5	6.6	5.6	5.8	6.2	6.4	4	6.3	7	9.4
A	2	2	1.8	1.6	2.2	2.6	2.7	3.2	4.3	3.2	3.6	4	4.2	2.4	4.4	4.6	6.4
DEPTHS, MM:																	
AT BPE	3	3.1	2.9	2.7	3.3	3.6	3.8	4	5	4.3	4.2	4.4	4.8	3.2	4.8	4.8	6.3
OP1	3.6	3.4	3.1	3	3.7	4.1	4.2	4.6	5.7	4.9	4.9	5	5.6	3.4	5.2	5.2	7.4
OD	3.3	3.2	2.8	3.2	3.2	4	4.4	4.6	5.6	5.2	4.8	5	5.4	3.1	5.1	5.2	7.5
BPV	2	1.9	1.6	1.6	1.9	2.4	2.6	2.8	3.6	3.2	3.1	3.2	3.6	1.9	3.4	3.5	4.7
AMPM	1.4	1.3	1.1	1.1	1.3	1.55	1.7	1.8	2.3	1.9	1.8	2	2.2	1.4	2.1	2.1	3
MAX YOLK																	
WIDTHS, MM:																	
AT BPE	2.8	2.8	2.6	2.6	2.9	3.2	3.3	3.6	4.5	3.8	3.9	3.9	4.2	2.8	4.2	4.2	5.5
OP1	2.6	2.5	2.1	2.2	2.8	3.2	3.3	3.8	4.8	4.1	3.9	4.2	4.3	2.7	4.2	4.2	6
OD	2.3	2.3	1.8	2.1	2.4	3.1	3.2	3.6	4.5	3.9	3.8	4.2	4.2	2.3	4	4	6.2
BPV	1.2	1.2	1	1.1	1.2	1.5	1.6	1.8	2.6	2	2.1	2.2	2.1	1.2	2.2	2.3	3.7
AMPM	0.5	0.5	0.45	0.6	0.6	0.8	0.8	0.9	1.1	1	1.1	1	1.1	0.6	1.1	1.1	1.6
MAX YOLK																	
MYOMERES:																	
TO PY																	
OPAF	15	14	14	17													
OP2	21	21	21	22	21	21	22	22		22				22			
ODF																	
OD	18	17	17	17	16	17	17	16		16				18			
PV	37	35	35	35	35	36	35	35		35				36			
TOTAL	46	44	45	45	45	45	45	45		46				47			
FIN RAYS P:																	
C	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
D	12	13	13	12	12	12	13	12	13	12	12	13	12	11	11	12	13
A	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
P1	15	14	12	14	15	16	16	15	16	15	15	16	17	16	15	14	16
P2	10	9	9	9	10	10	10	10	10	10	10	10	10	10	10	10	10
FIN RAYS S:																	
CD	5	6	6	5	7	9	10	9	10	11	10	11	10	10	10	8	10
CV	5	5	4	4	6	7	9	8	8	8	8	8	8	8	8	6	8
D	3	3	3	3	3	4	4	4	4	4	5	4	4	4	5	4	5
A	2	2	1	1	2	3	3	3	3	3	3	3	3	3	4	3	4

Table A-3. Individual measures and counts for fully analyzed Catostomus platyrhynchus larvae reared in 1981 by the Larval Fish Laboratory (LFL) at Colorado State University. Parents were captured from Ways Gulch northwest of Steamboat Springs, Colorado (Yampa River System). "D" following specimen number denotes a specimen used as a model for drawings.

SPECIMEN #:	1	2 D	3	4 D	5	6	7	8	9 D	10	11	12	13	14	15	16
SOURCE:	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL	LFL
FERTILIZED:	6/06	6/06	6/06	6/06	6/06	6/06	6/06	6/06	6/06	6/06	6/06	6/06	6/06	6/06	6/06	6/06
PRESERVED:	6/13	6/14	6/16	6/18	6/19	6/20	6/23	6/24	6/26	6/27	6/29	7/02	7/05	7/08	7/11	7/18
AGE, DAYS:	7	8	10	12	13	14	17	18	20	21	23	26	29	32	35	42
DEV. PHASE:	PY	PY	PY	PY	PY	PY	MFY	MFY	MF	MF	MF	MP	MP	MP	MT	MT
LENGTHS, MM:																
AS TO AE	0.2	0.2	0.2	0.2	0.2	0.15	0.2	0.25	0.3	0.35	0.5	0.6	0.6	0.8	0.9	1.2
PE	0.7	0.7	0.8	0.8	0.8	0.8	0.9	1	1.1	1.15	1.35	1.55	1.55	1.8	1.95	2.45
OP1	1.35	1.45	1.5	1.6	1.5	1.7	1.9	2	2.2	2.3	2.35	2.7	3	3.2	3.7	4.5
OP2												6.9	7.2	7.5	8.3	10.05
PY	6.1	6.5	7	7.1	6.4	7.8	5.6	5.8								
OPAF	6.1	5.9	4.3	2.7	2.8	2.6	3	3.3	3.4	3.4	3.4	4	4.3	4.8	5.6	7.8
ODF	4.1	3.6	3.5	3.8	3.2	4.1	4.65	4.7	4.7	4.9	5	5.4	6.4	6.5	7.8	
OD												6.5	6.9	7.1	8.1	9.2
ID														8.8	10.1	11.8
PV	6.2	6.6	7.15	7.35	6.75	8.2	8.5	8.55	9.3	9.8	9.8	10.35	10.95	11.2	12.3	13.9
OA														11.2	12.3	14
IA															13.35	15.3
PHP	7.4	8.1	8.8	9.5	8.8	10.5	11.1	11.2	12.05	12.55	13	13.2	13.7	14.2	15.8	18.15
AFC												14.6	15.1	15.9	17.6	20.6
PC	7.5	8.2	9.1	9.8	9.25	10.95	11.7	11.8	12.8	13.45	13.7	14.6	15.2	16.1	18.1	21.2
Y	5.2	5.4	5.2	5.3	4.7	5.9	1.5	1.5	0	0	0					
P1	0.15	0.2	0.45	0.6	0.65	0.9	1.1	1.2	1.4	1.4	1.4	1.6	1.6	1.6	1.9	2.4
P2							0	0	0	0	0	0.4	0.5	0.6	0.9	1.5
D													1.6	1.9	2.5	3.5
A														1	1.2	1.9
DEPTHS, MM:																
AT BPE	0.9	0.7	0.8	0.95	1	1.1	1.2	1.3	1.35	1.4	1.5	1.9	2.1	2.25	2.5	2.8
OP1	1.45	1	1	1	1.05	1.1	1.3	1.3	1.6	1.65	1.8	2.2	2.3	2.5	2.9	3.35
OD	1	1.1	1.2	1.1	1.05	1.05	1.1	1.1	1.3	1.5	1.5	1.75	1.9	2.25	2.5	3.3
BPV	0.25	0.25	0.35	0.5	0.55	0.65	0.7	0.7	0.8	0.9	0.85	1.05	1.1	1.3	1.6	2.1
AMPM	0.15	0.2	0.2	0.25	0.25	0.3	0.4	0.4	0.45	0.55	0.55	0.7	0.7	0.8	1	1.3
MAX YOLK	1.1	1.05	0.85	0.6	0.8	0.7	0.15	0.1	0	0	0					
WIDTHS, MM:																
AT BPE	0.7	0.65	0.8	0.85	0.85	1	1.15	1.2	1.4	1.4	1.45	2.15	1.85	2	2.2	2.7
OP1	1.2	1	0.6	0.65	0.7	0.75	0.9	0.9	1.1	1.15	1.25	1.55	1.7	1.8	2.1	2.5
OD	0.7	0.9	0.9	0.6	0.55	0.65	0.6	0.6	0.8	0.85	0.8	1.05	1.2	1.4	1.6	2.6
BPV	0.25	0.25	0.3	0.35	0.35	0.4	0.45	0.4	0.45	0.45	0.5	0.5	0.7	0.7	0.9	1.1
AMPM	0.1	0.15	0.15	0.2	0.2	0.2	0.25	0.25	0.25	0.3	0.3	0.4	0.45	0.45	0.5	0.6
MAX YOLK	1.35	1.15	0.95	0.8	0.9	0.85	0.2	0.1	0	0	0					
MYOMERES:																
TO PY	34	35	35	33	33	35	22	23								
OPAF	34	29	18	7	9	7	7	9	8	8	7	10	9	9	10	14
OP2												22	21	21	20	21
ODF	21	14	13	13	12	15	16	16	13	15	14	15	17	15	15	
OD												19	19	19	18	18
PV	36	36	37	35	35	37	36	35	36	37	37	37	37	36	35	35
TOTAL	45	45	46	44	45	46	46	46	46	47	47	46	46	45	45	45
FIN RAYS P:																
C							5	8	10	16	12	18	18	18	18	18
D												5	7	10	11	11
A														4	7	7
P1														5	8	11
P2															3	8
FIN RAYS S:																
CD													1	1	3	6
CV													1	1	2	5
D														1	2	2
A															1	1

Table A-4. Individual measures and counts for fully analyzed Catostomus platyrhynchus larvae captured from Ways Gulch and Willow Creek northwest of Steamboat Springs, Colorado (Yampa River System). "D" following specimen number denotes a specimen used as a model for drawings.

SPECIMEN #:	17	18	19	20	21	22	23	24	25	26	27	28	29 D	30	31	32	33
SOURCE:	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC	WC
PRESERVED:	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981
DEV. PHASE:	PY	PY	PY	PY	PY	PY	P	MF	MF	MF	MF	MP	MP	MP	MP	MP	MP
LENGTHS, MM:																	
AS TO AE	0.1	0.2	0.2	0.25	0.3	0.2	0.2	0.3	0.35	0.5	0.5	0.5	0.7	0.7	0.6	0.8	0.7
PE	0.8	0.85	0.9	0.95	1	0.85	0.8	1	1.1	1.35	1.4	1.5	1.6	1.6	1.6	1.9	1.6
OP1	1.5	1.6	1.8	1.9	2	1.6	1.7	1.95	2.3	2.7	2.7	2.9	3.3	3.3	3.3	3.75	3.5
OP2										6.9	7.3	7.4	7.4	7.4	8	8	8.25
PY	5.3	6.6	7.3	7.9	8.4	6.3											
OPAF	2.15	2.3	2.7	2.9	3	2.2	2.5	2.9	3.3	4	4.1	4.2	4.6	6	5.1	5.7	5.2
ODF	3.9	3.5	4.1	4.1	4.2	3.8	3.8	4.4	5	5.5	5.9	5.8	6	6	6.65		7
OD										6.35	6.9	6.8	7	6.8	7.8	7.4	7.8
ID																9.3	9.6
PV	6.65	7	7.8	8.2	8.8	6.9	7.5	8	9.2	9.9	10.8	10.6	11	10.8	12.2	11.5	12.4
OA														10.8		11.5	12.4
IA																	
PHP	8.55	9.35	10.1	10.7	11.4	8.9	9.8	10.5	12	12.7	13.8	13.3	13.7	13.6	15.4	14.5	15.7
AFC												15.1	15.35	15.1	16.8	16.2	17.2
PC	8.95	9.8	10.6	11.3	12	9.4	10.3	11.2	12.8	13.9	14.95	15.1	15.6	15.6	17	17	17.7
	3	4.2	4.9	5.1	3.85	4.1											
P1	0.9	0.95	1.1	1.2	1.3	1	1.1	1.4	1.4	1.5	1.5	1.85	1.8	1.8	1.9	1.9	1.7
P2										0.05	0.05	0.1	0.25	0.25	0.4	1	0.8
													1.7	1.8	1.7	2.2	2.1
A																1	1
DEPTHS, MM:																	
AT BPE	1	1	1.15	1.25	1.2	1	1.05	1.25	1.4	1.7	1.7	1.8	2	2.1	2.2	2.3	2.2
OP1	0.95	1	1.2	1.3	1.3	1	1.15	1.6	1.65	1.95	1.9	2.2	2.5	2.5	2.3	2.6	2.5
OD	0.7	0.75	0.95	1.05	1.15	0.7	0.75	1	1.2	1.4	1.4	1.5	1.9	1.6	1.8	2.1	2
BPV	0.5	0.55	0.7	0.75	0.7	0.5	0.6	0.7	0.8	0.8	0.9	0.9	1	1	1.1	1.1	1.1
AMPM	0.25	0.35	0.35	0.4	0.4	0.35	0.3	0.4	0.5	0.6	0.6	0.7	0.8	0.8	0.7	0.9	0.8
MAX YOLK	0.1	0.2	0.3	0.3	0.2	0.05											
WIDTHS, MM:																	
AT BPE	0.8	0.9	1	1.1	1.2	0.9	0.9	1.2	1.4	1.6	1.6	1.7	1.9	1.9	2	2.2	2.1
OP1	0.6	0.6	0.7	0.8	0.85	0.6	0.65	0.85	1	1.2	1.1	1.5	1.6	1.6	1.7	1.9	1.8
OD	0.4	0.4	0.5	0.55	0.65	0.4	0.5	0.55	0.75	0.8	0.8	0.9	1.1	1.1	1.1	1.3	1.15
BPV	0.25	0.3	0.4	0.45	0.4	0.3	0.3	0.4	0.5	0.5	0.6	0.5	0.7	0.7	0.7	0.7	0.8
AMPM	0.15	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.3	0.35	0.3	0.4	0.5	0.5	0.4	0.5	0.5
MAX YOLK	0.1	0.2	0.4	0.4	0.4	0.1											
MYOMERES:																	
TO PY	26	32	33	34	34	31											
OPAF	6	7	7	7	6	5	8	7	6	7	7	8	8	13	7	9	9
OP2										20	21	22	21	19	20	21	21
ODF	16	13	14	14	13	15	14	15	13	13	14	14	16	13	14		14
00										18	19	19	19	17	18	18	18
PV	36	36	35	36	36	36	36	36	36	36	36	36	36	36	36	36	36
TOTAL	45	45	45	45	45	44	45	45	45	44	45	45	43	44	44	44	44
FIN RAYS P:																	
								6	8	17	15	18	18	18	18	18	18
										3	2	4	7	8	4	9	9
A														3		5	5
P1												3	3	5		12	8
P2																	
FIN RAYS S:																	
CD														1	1	3	2
CV														1	1	2	2
														1		2	1
A																1	1

(continued)

Table A-4. Continued.

SPECIMEN #:	34	35	36 D	37	38	39 D	40	41	42	43 D	44	45	46	47	48D	49	50
SOURCE:	WC	WC	WC	WC	WC	WC	WC	WC	SFR	SFR	SFR	WC	SFR	SFR	PR	WC	PR
PRESERVED:	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	6/21 -8/07 1981	7/19 1985	7/19 1985	7/19 1985	6/21 -8/07 1981	7/19 1985	7/19 1985	2/15 1983	6/21 -8/07 1981	10/19 1982
DEV. PHASE:	MP	MP	MT	MT	MT	MT	MT	MT	MT	J	J	J	J	J	J	J	J
LENGTHS, MM:																	
AS TO AE	0.8	0.9	0.9	1	1.2	1.4	1.2	1.7	1.8	1.4	1.65	1.8	1.9	2.4	2.4	2.9	3.4
PE	1.8	2	2	2.1	2.4	2.7	2.45	3	3.2	2.7	3.1	3.2	3.4	3.9	4.2	4.9	5.6
OP1	3.7	4	4.2	4.4	4.6	4.85	4.9	5.3	5.7	5.3	5.9	5.6	6.2	6.9	7.8	8.5	9.2
OP2	8.8	8.7	8.7	9.9	10	11.4	11.7	12.6	13	11.8	12.9	13.8	13.2	15.2	17.6	19.7	21.8
PY																	
OPAF	5.8	6.1	5.7	8	9	8.8	12.3	14.6	14.6								
ODF	7.8																
OD	8.4	8.2	8.6	8.8	9.2	10	10.4	10.8	11.4	10.3	11.3	11.9	12.2	13.6	15.2	17.6	18.9
ID	10.3	10	10.4	11.1	11.5	12.4	12.8	13.3	14	13.1	14.4	14.7	15.5	17.2	19	22.6	23.4
PV	13	12.25	12.7	13.3	14	15.3	15.55	16.4	16.8	15.6	17.2	17.8	18	20.9	23.2	26.6	28.4
OA	13	12.2	12.7	13.3	14	15.35	15.65	16.6	17	15.7	17.2	17.9	18.2	20.9	23.4	26.9	28.7
IA		13.2	13.9	14.5	15.2	16.5	17.1	17.9	18.4	17.3	18.9	19.5	20.1	23.2	26	29.8	31.4
PHP	16.7	15.85	16.3	17.45	18.1	19.6	20.3	21.6	22.4	20.6	22.8	22.9	24.1	27.5	31.5	35.6	37.6
AFC	18.4	17.8	18.4	19.8	20.6	21.5	23	24.4	25.8	23.6	26.3	26	28.1	31.6	36.5	41	43.6
PC	18.9	18.65	19.6	20.8	21.7	22.5	24.1	25.4	26.9	25.2	27.6	27.5	29.6	33.2	38	42.7	44.8
Y																	
P1	2.1	2	2.5	2.4	2.8	2.6	3	3.2	3.6	3.3	4	3.4	4.5	5.2	5.6	6.6	7
P2	0.9	1.2	1.5	1.5	1.8	1.5	1.6	1.8	2.4	2.6	2.8	2.4	3	3.4	4.1	4.4	5
D	2.3	2.4	2.6	2.7	3	3.1	3.2	3.5	4	4	4.7	4.1	4.8	5.4	6.4	7.6	7.05
A	1.1	1.3	1.5	1.8	1.8	1.55	2	2.3	2.9	2.7	3.2	2.8	3.5	3.8	4.7	4.6	5.7
DEPTHS, MM:																	
AT BPE	2.4	2.5	2.6	2.7	2.9	3.1	3.2	3.2	3.6	3.5	3.65	3.5	4.1	4.4	5.1	5.7	6.3
OP1	2.7	2.85	3	3.3	3.4	3.4	3.45	3.5	4.5	4.2	4.6	4	5	5.3	5.9	7.2	7.5
OD	2.2	2.1	2.4	2.9	2.9	3.3	3.4	3.7	4.3	4	4.6	4.1	4.9	5.1	6.2	7.2	7.9
BPV	1.3	1.3	1.4	1.6	1.8	2	2	2.3	2.7	2.5	2.8	2.5	3.2	3.4	4.2	4.9	5.3
AMPM	0.9	1	1.1	1.1	1.3	1.3	1.4	1.5	1.9	1.8	2	1.8	2.2	2.3	2.8	3.3	3.5
MAX YOLK																	
WIDTHS, MM:																	
AT BPE	2.1	2.4	2.5	2.6	2.8	2.9	3	3.1	3.5	3.5	3.6	3.4	3.9	4.4	5	5.5	6.2
OP1	2	1.9	2.2	2.3	2.6	2.6	2.9	2.9	3.5	3.4	4	3.2	4.1	4.5	5	6.1	6.8
OD	1.35	1.4	1.6	2.1	2.1	2.35	2.45	2.7	2.9	3	3.6	3	4.05	4.4	4.6	6	6.1
BPV	0.85	0.8	1	1.2	1.2	1.35	1.55	1.6	2	1.8	2.1	1.85	2.5	2.7	2.6	3.4	3.9
AMPM	0.5	0.5	0.5	0.6	0.6	0.7	0.9	0.9	1	0.85	1	0.9	1.1	1.2	1.2	1.6	1.6
MAX YOLK																	
MYOMERES:																	
TO PY																	
OPAF	10	10	9	15	17	13	25	28	28								
OP2	21	21	21	21	21	22	22	22	21	22	22	22	21	22	22		
ODF	15																
OD	19	19	19	19	18	18	18	18	16	17	17	17	18	18	18		
PV	35	34	36	34	34	35	35	35	32	35	34	34	34	35	34		
TOTAL	45	44	45	44	43	45	45	45	44	45	44	45	44	45	44		
FIN RAYS P:																	
C	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
D	8	9	9	10	10	10	10	9	10	10	10	10	10	10	10	10	10
A	3	5	7	7	7	7	7	7	7	7	7	7	7	6	7	7	7
P1	12	13	11	13	14	13	14	14	15	15	14	15	15	16	15	14	15
P2	6	2	5	7	8	9	10	10	9	9	10	9	10	9	9	9	10
FIN RAYS S:																	
CD	1	3	4	4	6	7	8	11	12	12	11	10	12	12	11	12	11
CV	1	2	3	3	6	6	7	8	8	7	8	8	8	8	9	9	9
D	1	2	2	1	2	2	2	3	4	4	4	4	4	4	3	4	4
A		1	1	1	2	1	2	3	2	2	3	2	3	3	3	2	2

APPENDIX B

COMPARATIVE GRAPHS OF SELECTED MORPHOMETRIC DATA

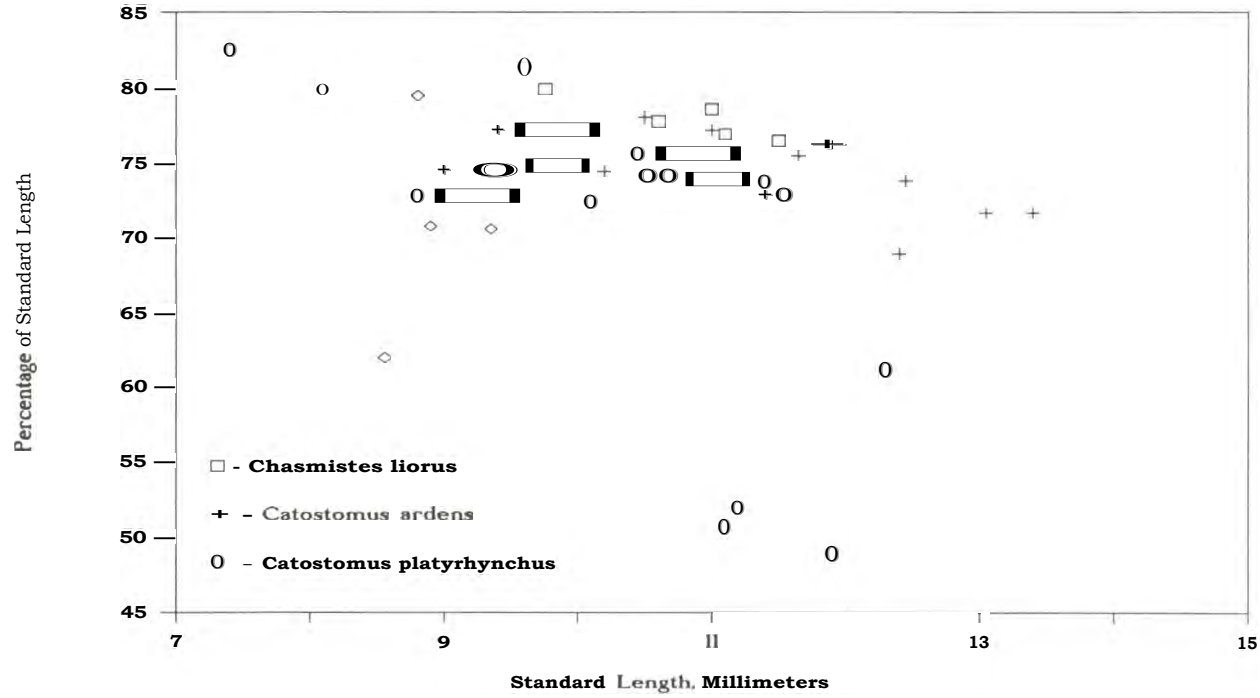


Figure B-1. Length from anterior margin of snout to posterior margin of yolk (AS-PY) as a percentage of standard length. See Figure 3 for method of measurement.

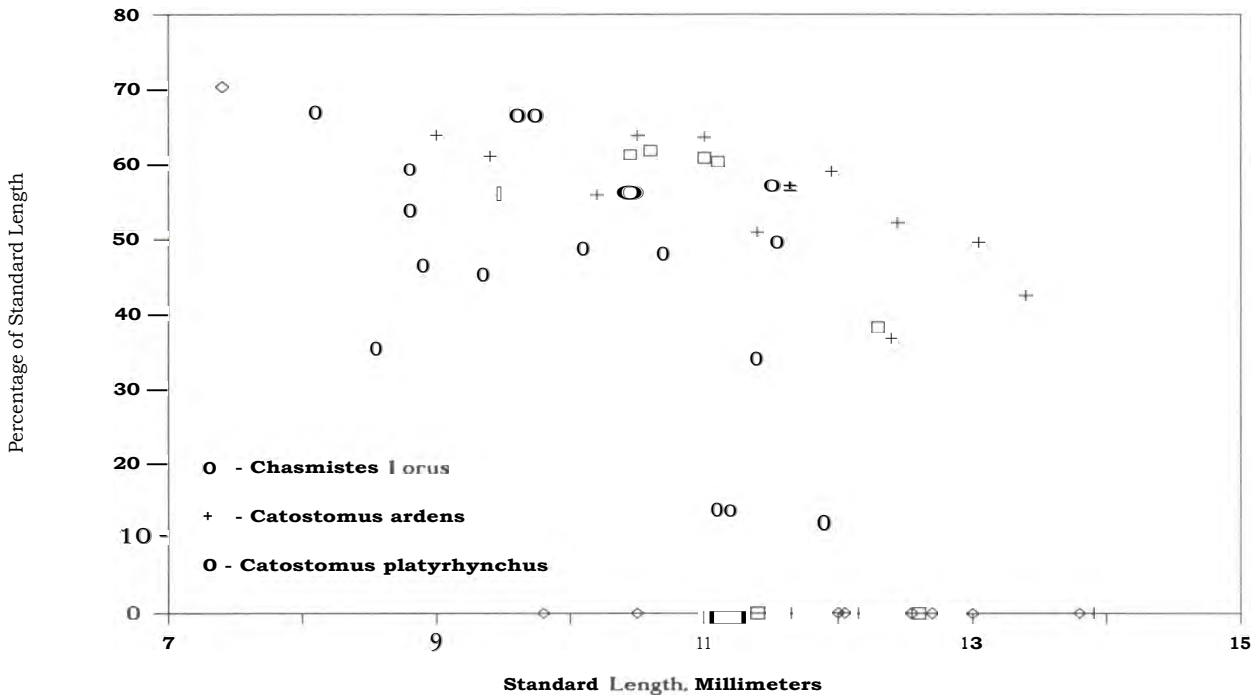
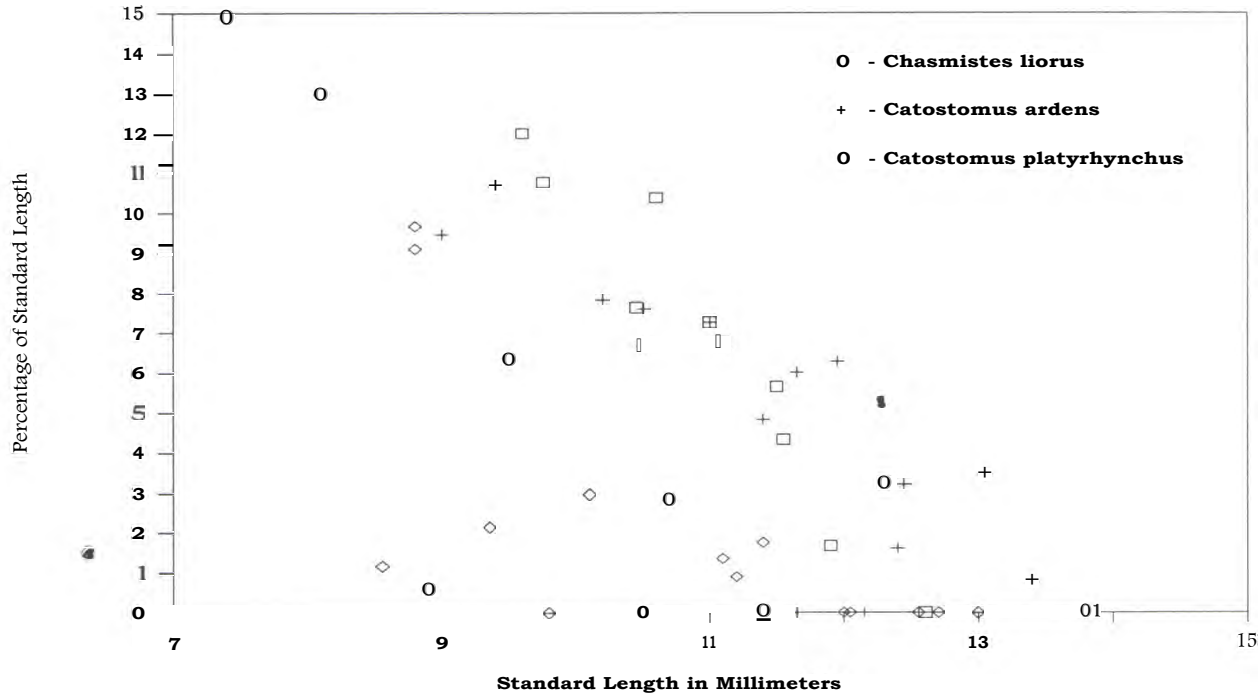


Figure B-2. Length of yolk (Y) as a percentage of standard length. See Figure 3 for method of measurement.



F[illegible] B-3. M[illegible] (Y) [illegible]. S[illegible] F[illegible] 3 [illegible].

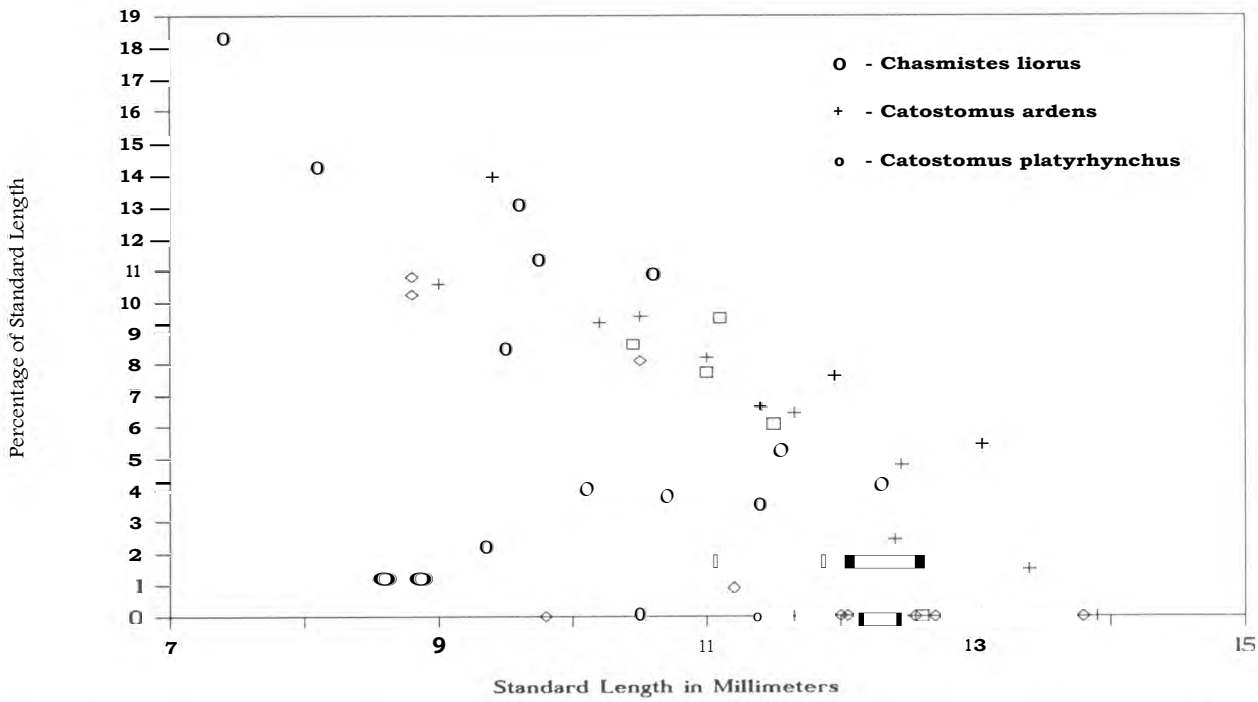
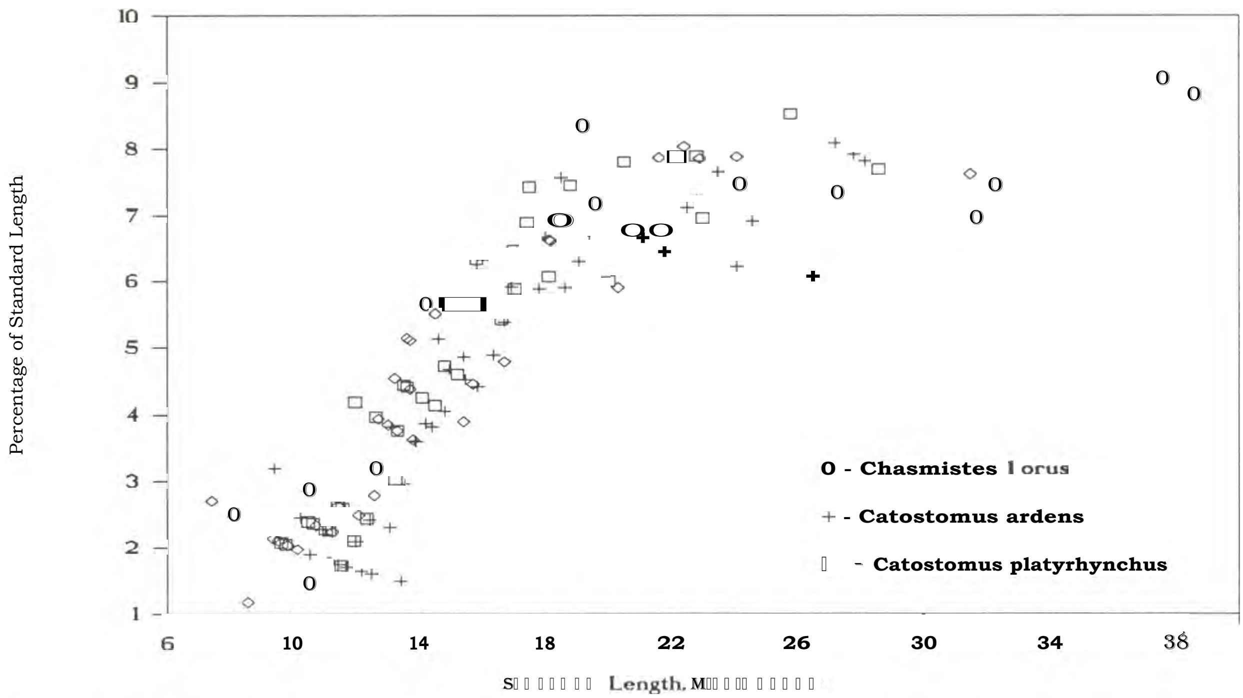
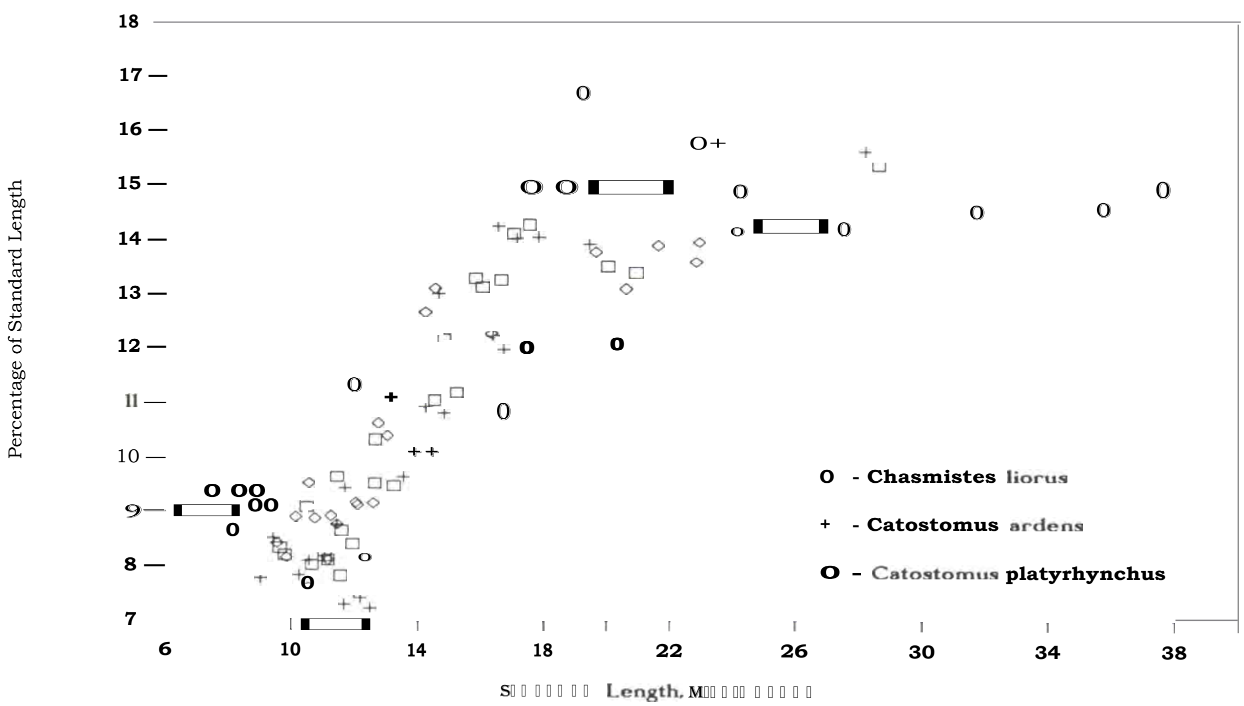


Figure B-4. Maximum width of yolk (Y) as a percentage of standard length. See Figure 3 for method of measurement.



F[illegible] B-5. L[illegible] (AS-AE) [illegible]. S[illegible] F[illegible] 3 [illegible].



F[illegible] B-6. L[illegible] (AS-PE) [illegible]. S[illegible] F[illegible] 3 [illegible].

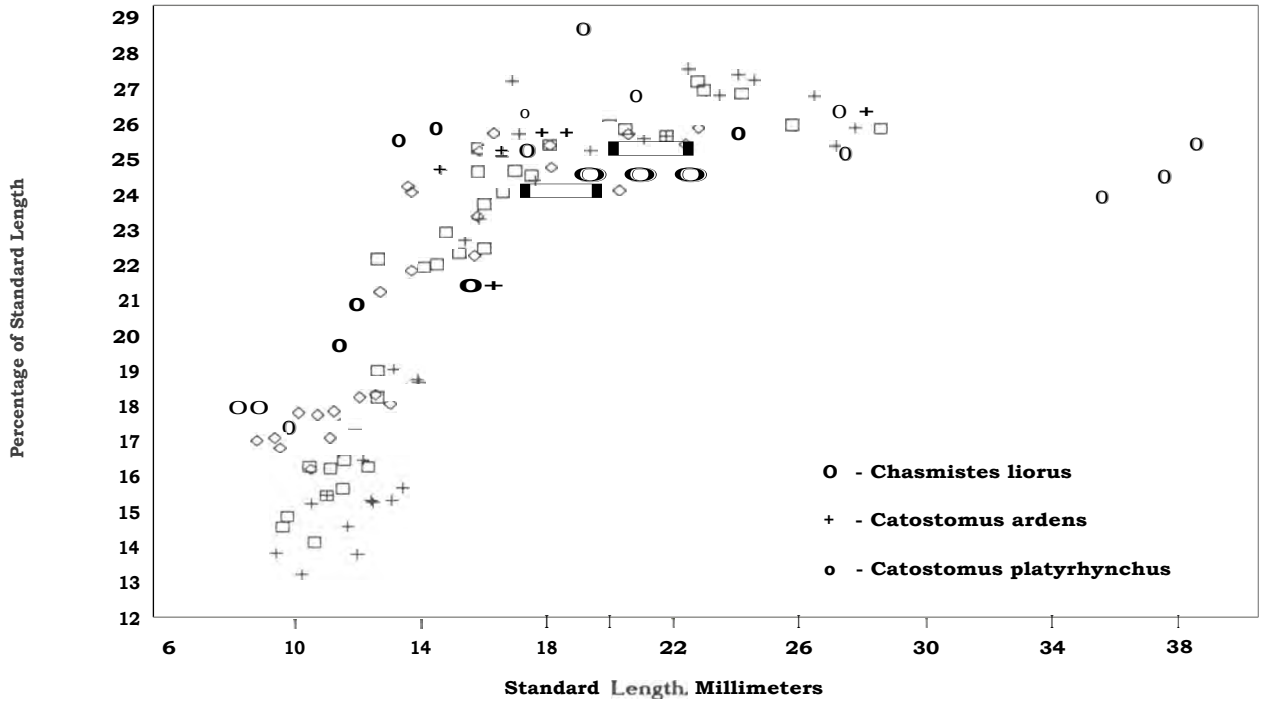


Figure B-7. Length from anterior margin of snout to origin of pectoral fin or fin bud (AS-OP1; head length) as a percentage of standard length. See Figure 3 for method of measurement.

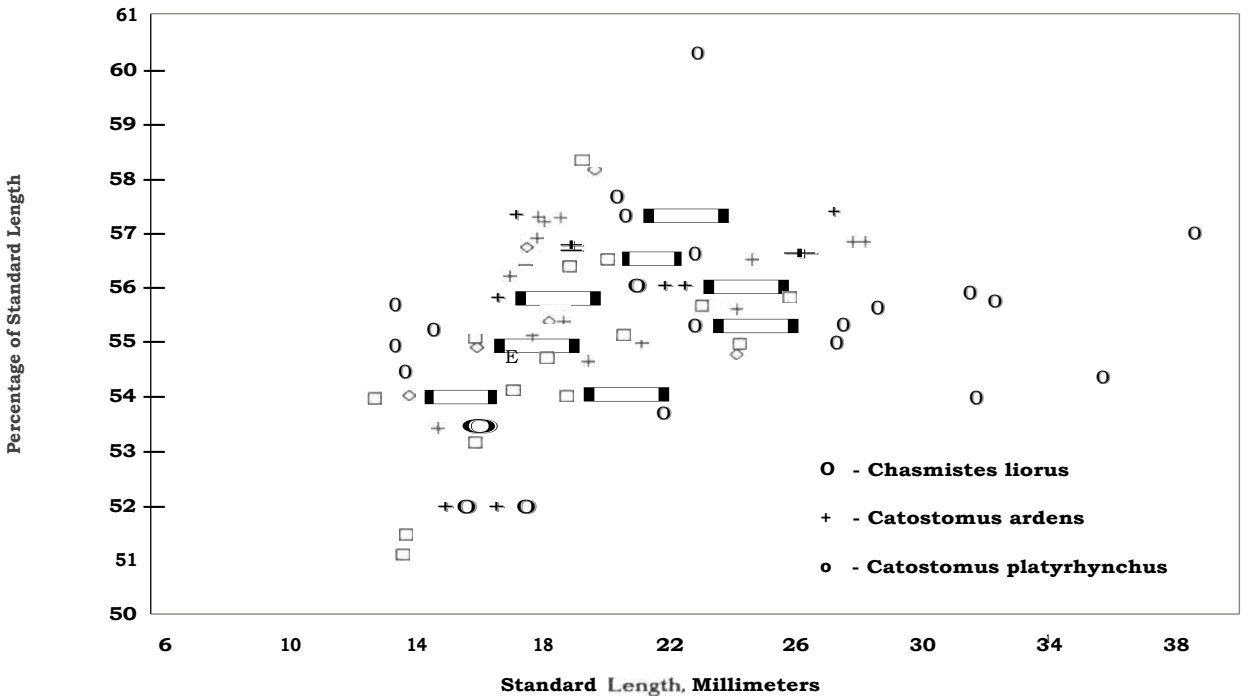


Figure B-8. Length from anterior margin of snout to origin of pelvic fin or fin bud (AS-OP2) as a percentage of standard length. See Figure 3 for method of measurement.

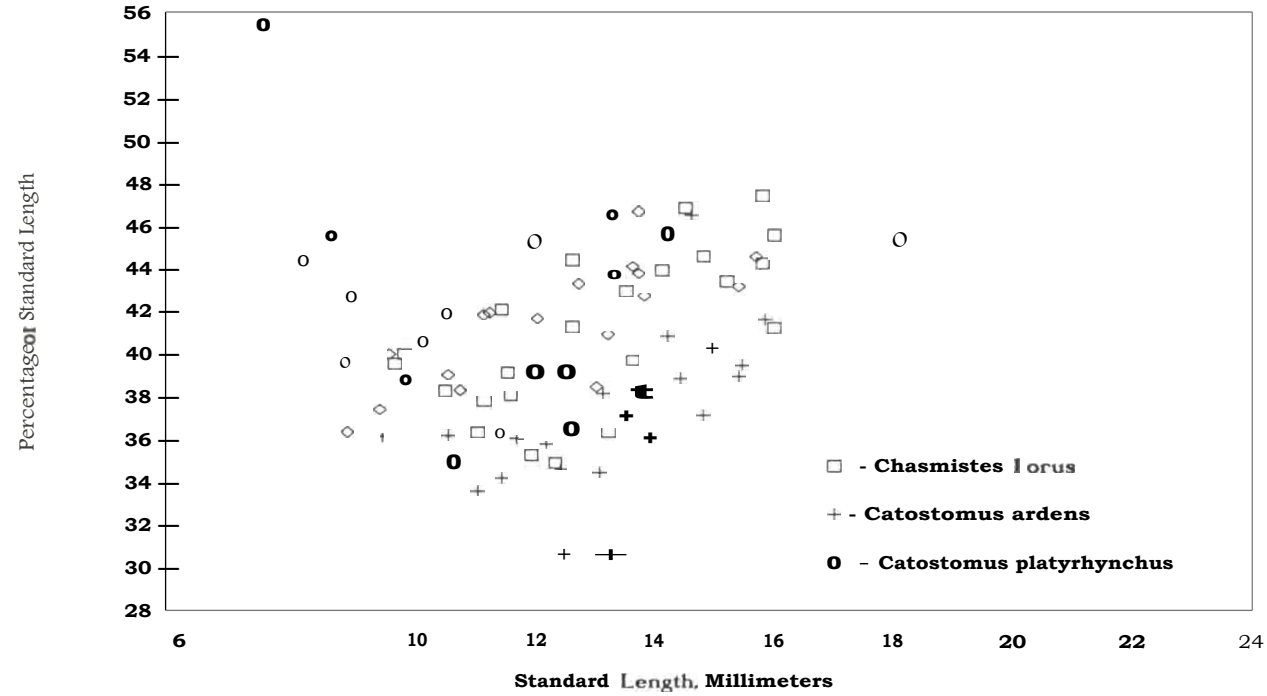


Figure **B-9.** Length from anterior margin of snout to origin of dorsal finfold (AS-ODF) as a percentage of standard length. See Figure 3 for method of measurement.

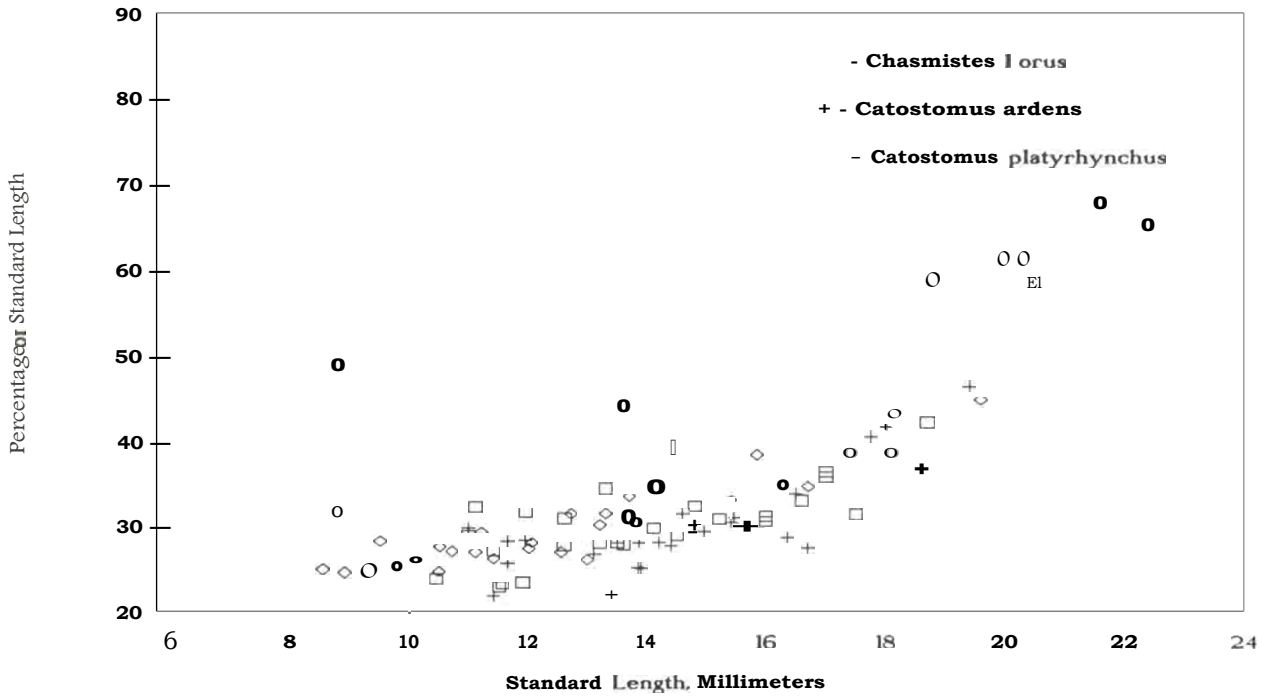


Figure **B-10.** Length from anterior margin of snout to origin of preanal finfold (AS-OPAF) as a percentage of standard length. See Figure 3 for method of measurement.

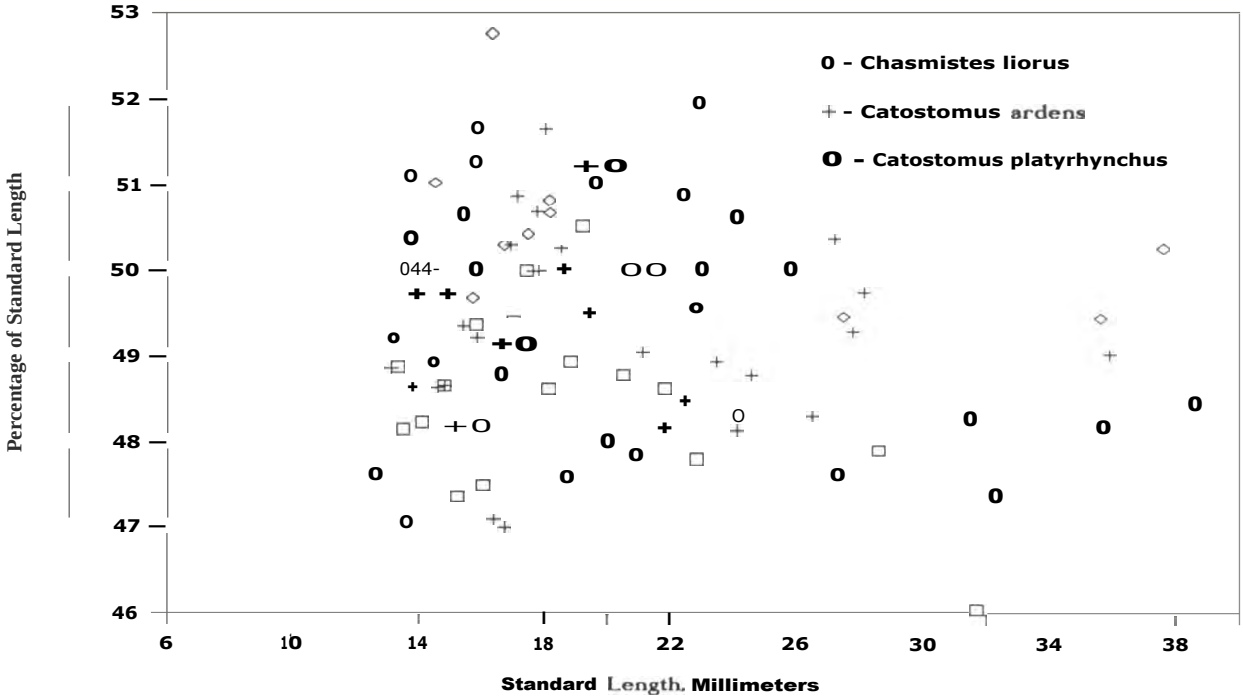


Figure B-11. Length from anterior margin of snout to origin of dorsal fin (AS-OD) as a percentage of standard length. See Figure 3 for method of measurement.

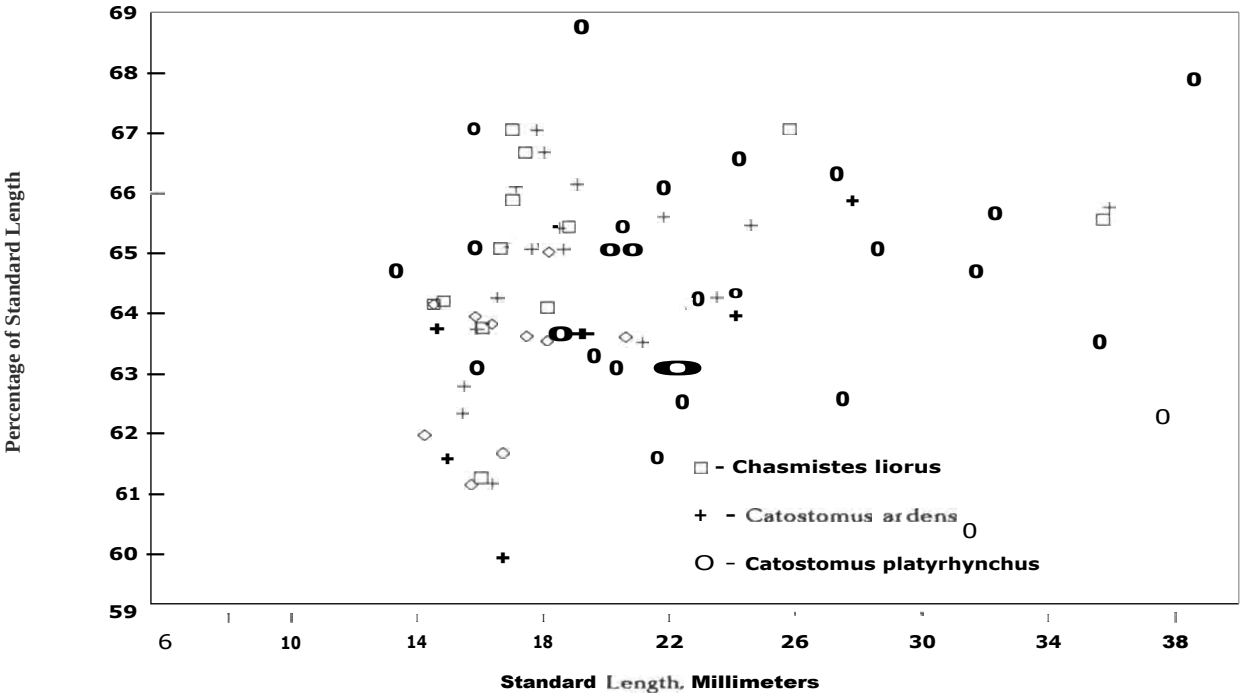


Figure B-12. Length from anterior margin of snout to insertion of dorsal fin (AS-ID) as a percentage of standard length. See Figure 3 for method of measurement.

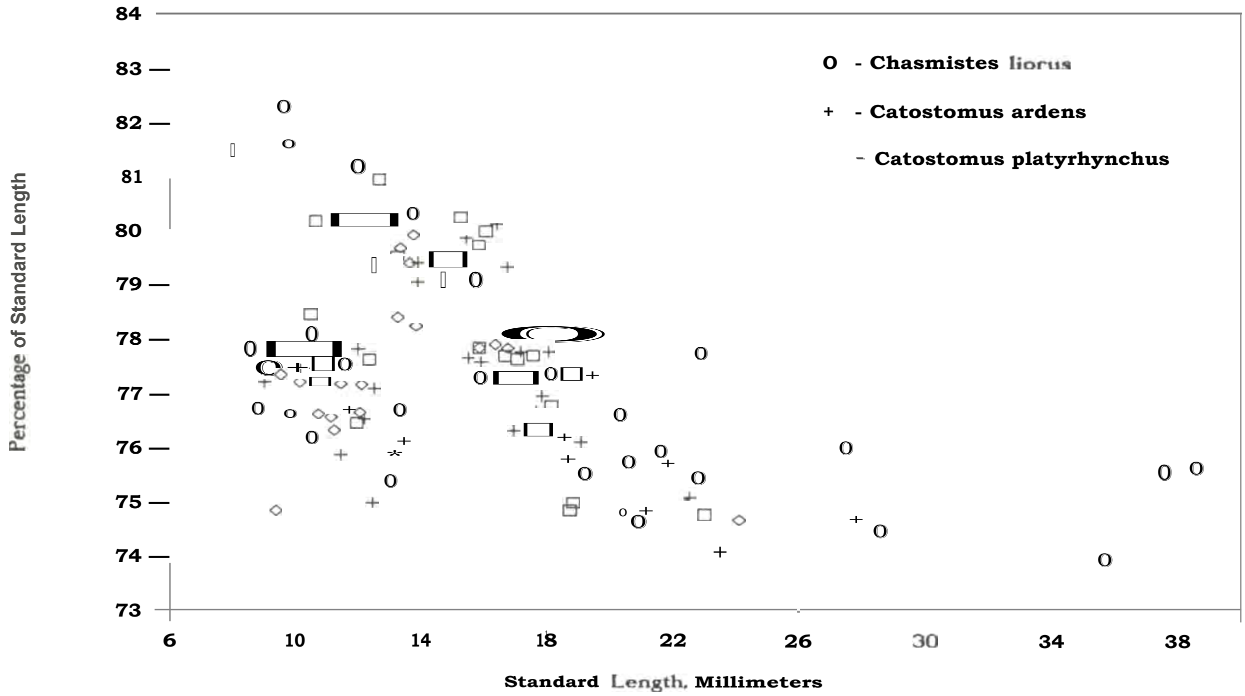


FIGURE B-13. LENGTH FROM ANTERIOR MARGIN OF SNOUT TO POSTERIOR MARGIN OF VENT (AS-PV; PREANAL LENGTH) AS A PERCENTAGE OF STANDARD LENGTH. SEE FIGURE 3 FOR METHOD OF MEASUREMENT.

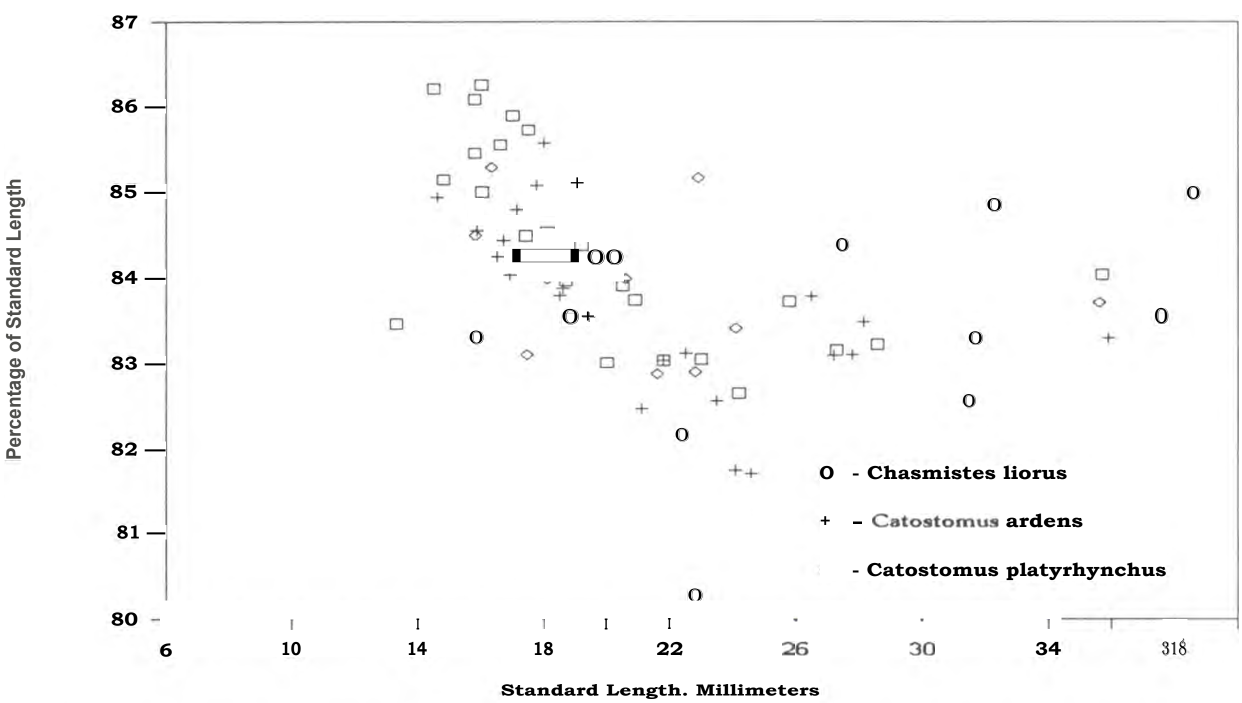


FIGURE B-14. LENGTH FROM ANTERIOR MARGIN OF SNOUT TO INSERTION OF ANAL FIN (AS-IA) AS A PERCENTAGE OF STANDARD LENGTH. SEE FIGURE 3 FOR METHOD OF MEASUREMENT.

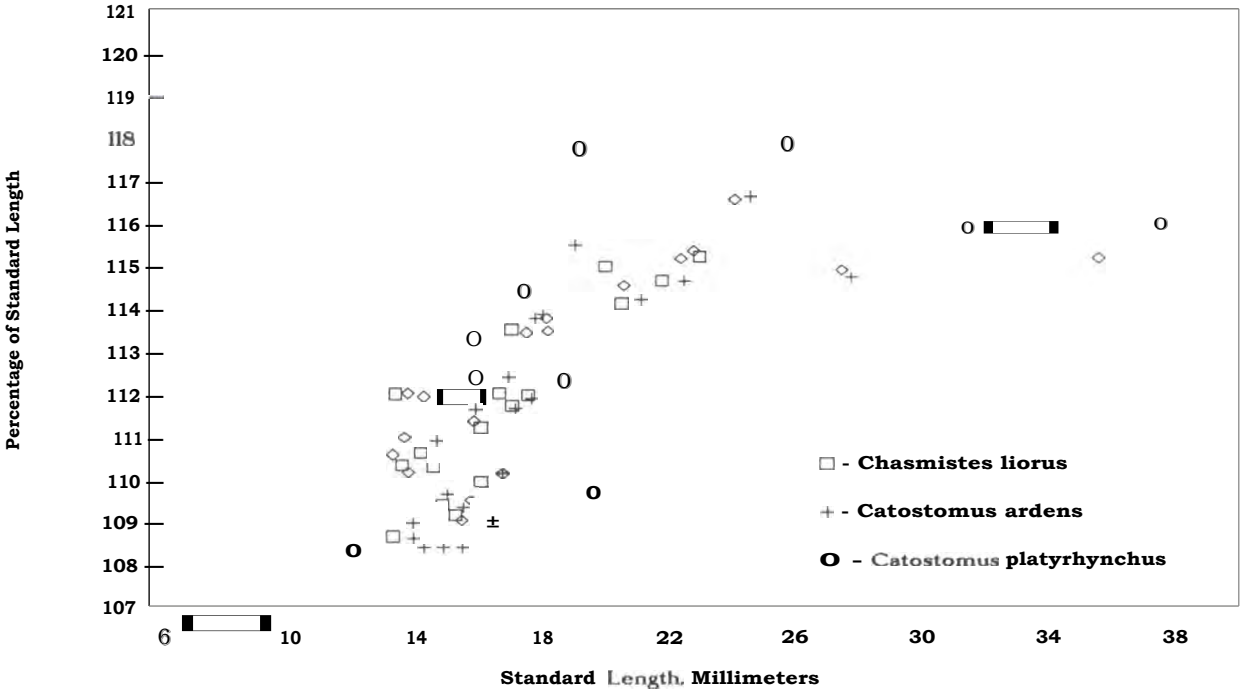


Figure B-15. Length from anterior margin of snout to anterior margin of fork of caudal fin (AS-AFC; fork length) as a percentage of standard length. See Figure 3 for method of measurement.

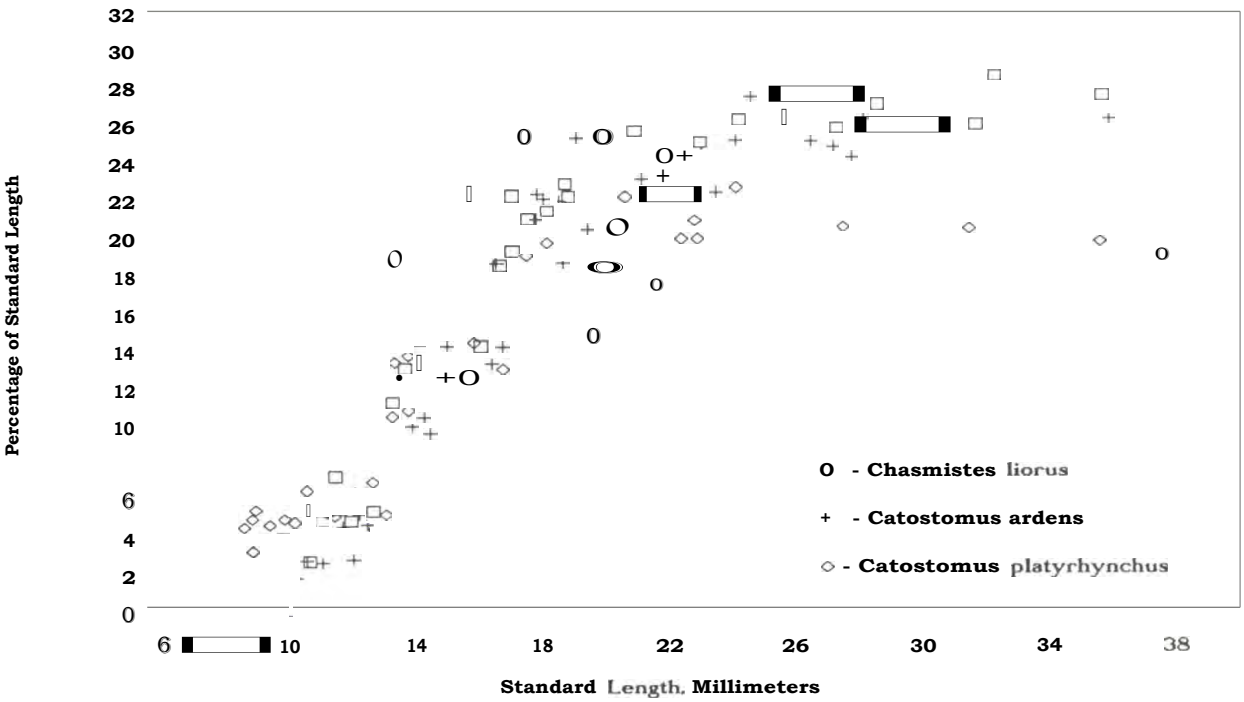


Figure B-16. Length of caudal fin (C) as a percentage of standard length. Calculated (AS-PC minus AS-PHP; total minus standard length); see Figure 3 for method of measurement.

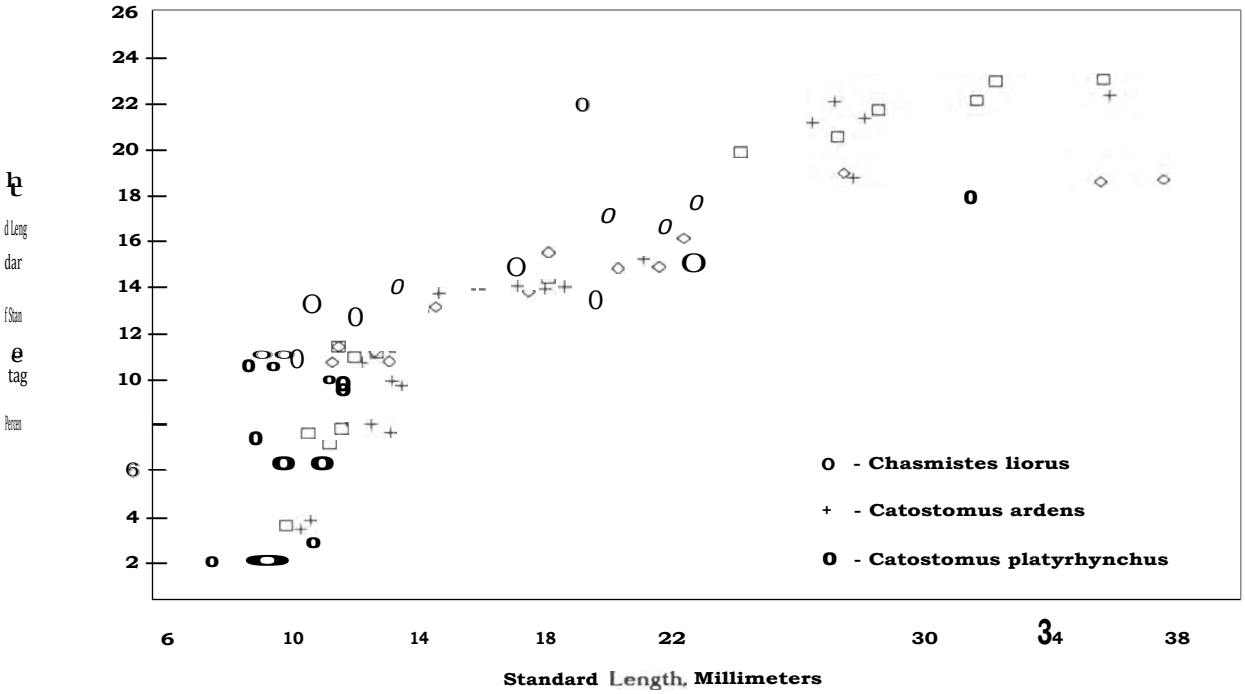
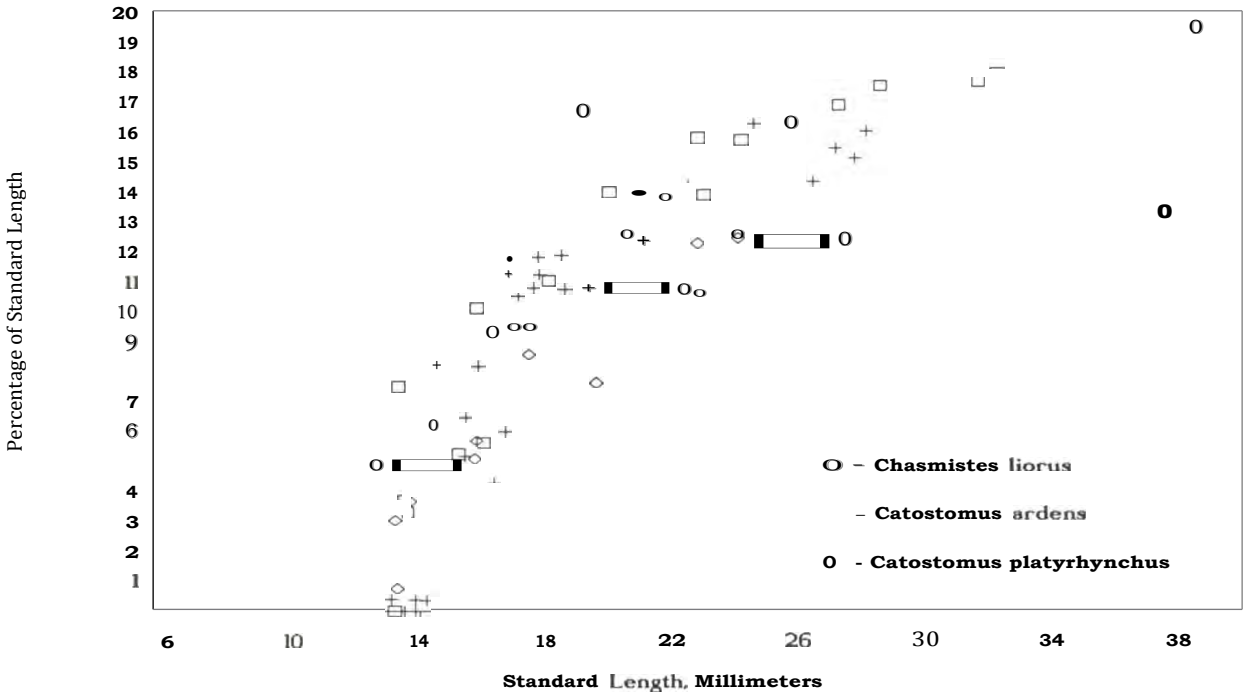
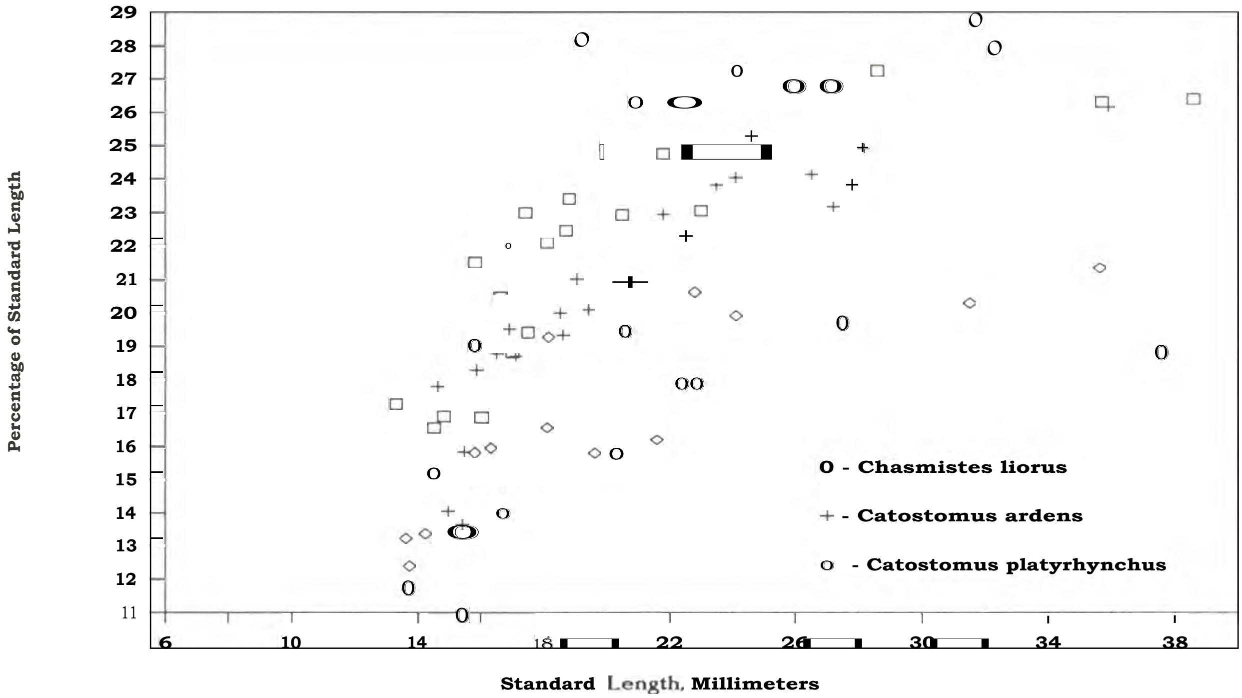


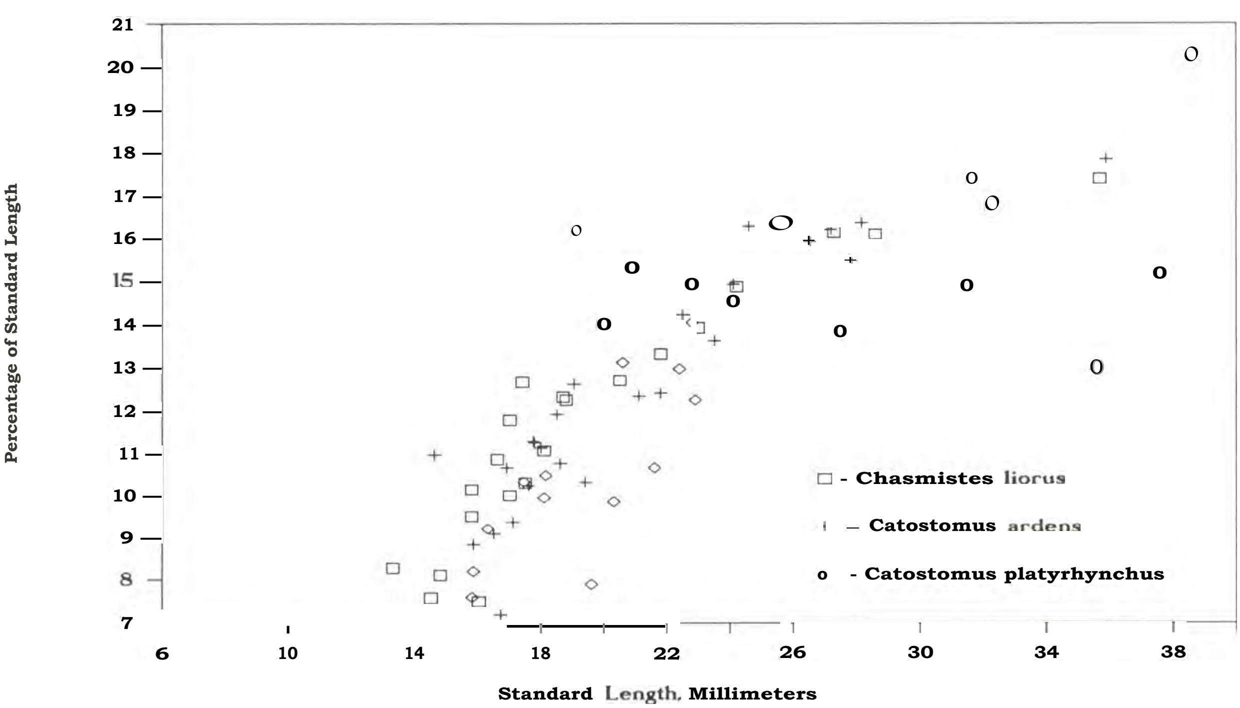
Figure B-17. Length of pectoral fin (P1) as a percentage of standard length. See Figure 3 for method of measurement.



F□□ □ □ □ **B-18.** Length of pelvic fin (P2) as a percentage of standard length. See Figure 3 for method of measurement.



F B-19. L (D) . S F 3 .



F B-20. L (A) . S F 3 .

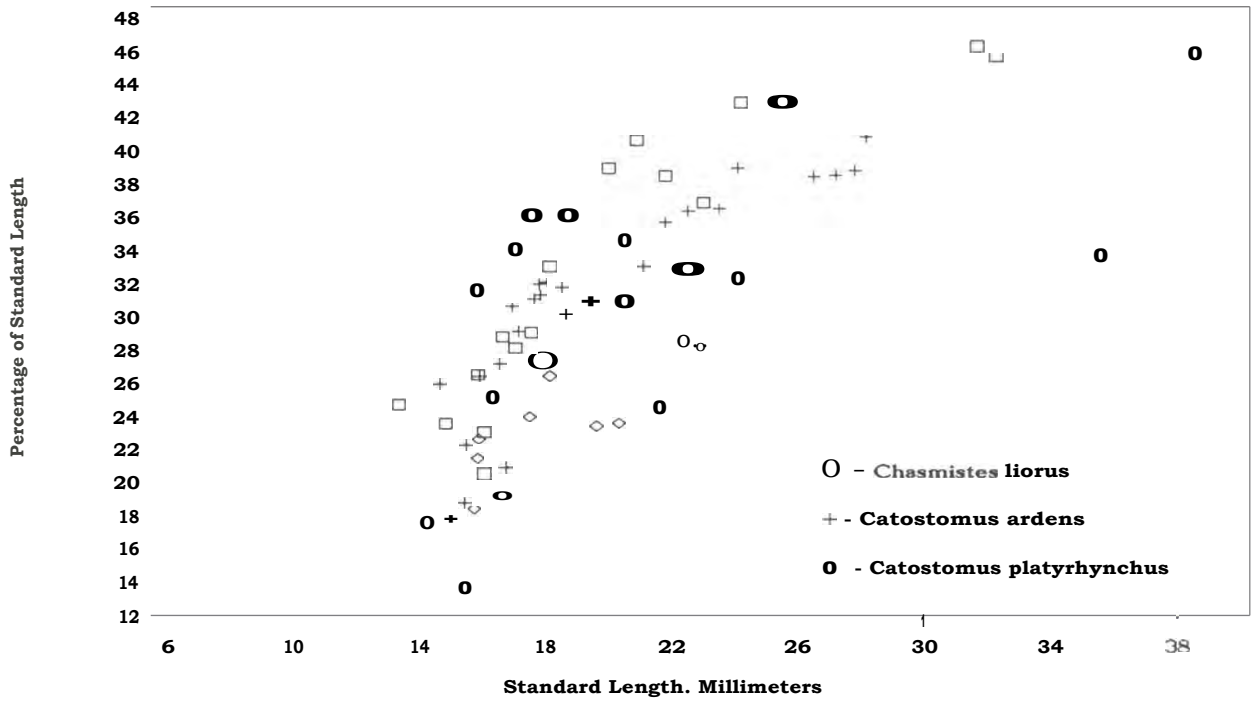


Figure B-21. Sum of lengths of dorsal and (one) pelvic fins (D plus P2) as a percentage of standard length. See Figure 3 for methods of measurement.

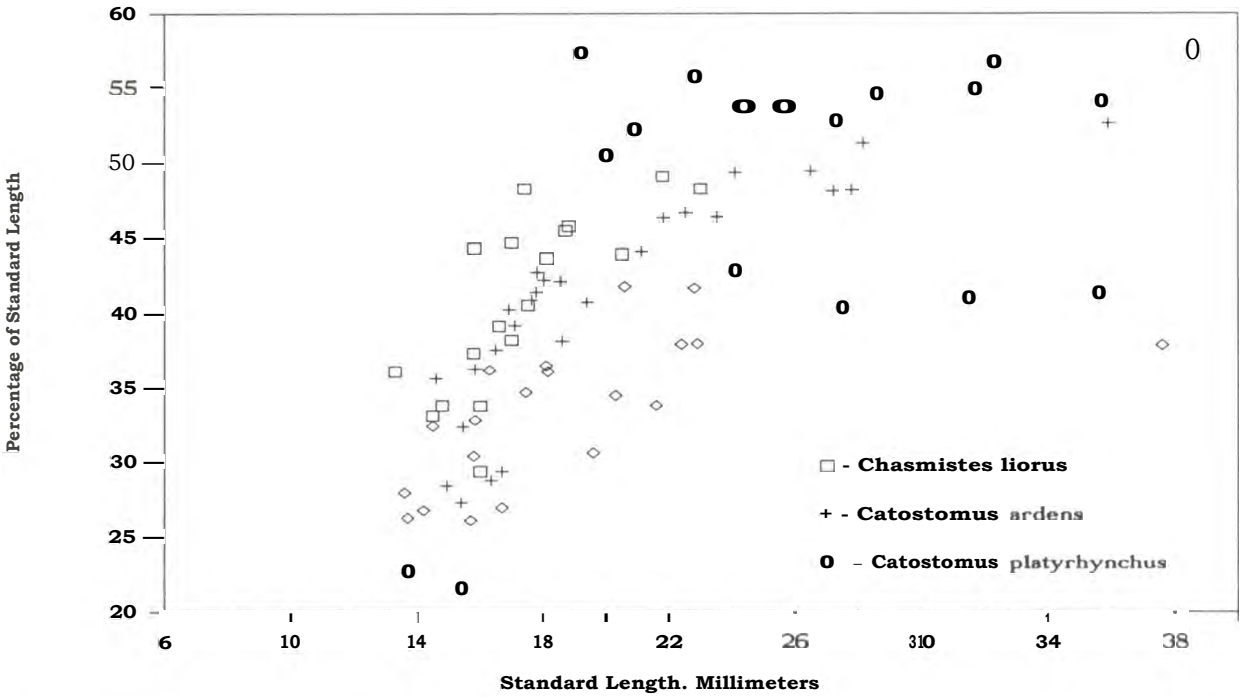


Figure B-22. Sum of lengths of dorsal and caudal fins (D plus C) as a percentage of standard length. See Figure 3 for methods of measurement.

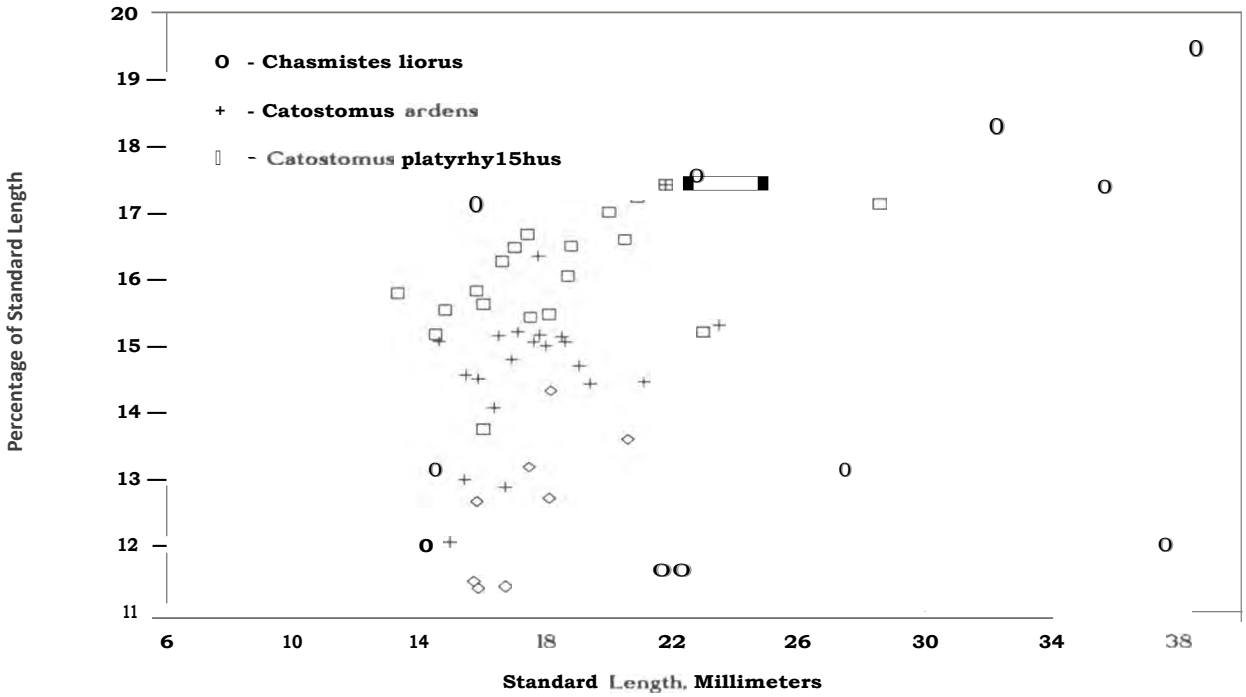


Figure B-23. Length from origin to insertion of dorsal fin (OD-ID) as a percentage of standard length. Calculated (AS-ID minus AS-OD); see Figure 3 for methods of measurement.

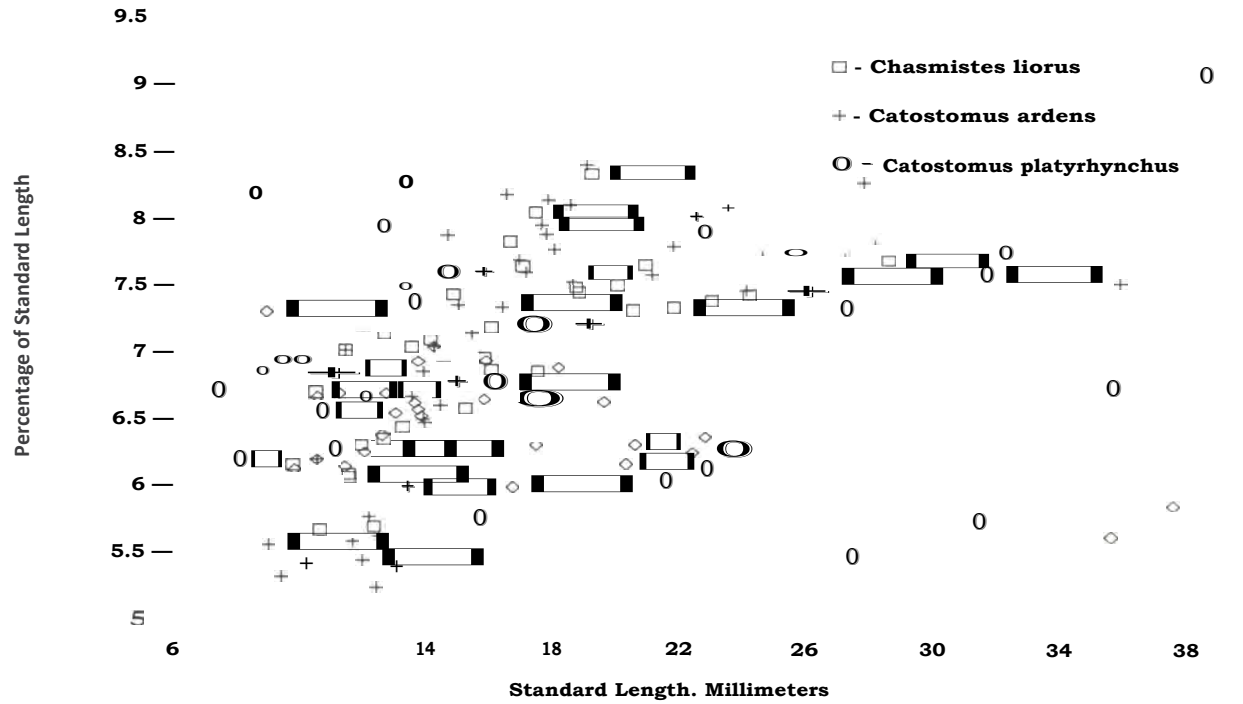


Figure B-24. Eye diameter as a percentage of standard length. Calculated (AS-PE minus AS-AE); see Figure 3 for method of measurement.

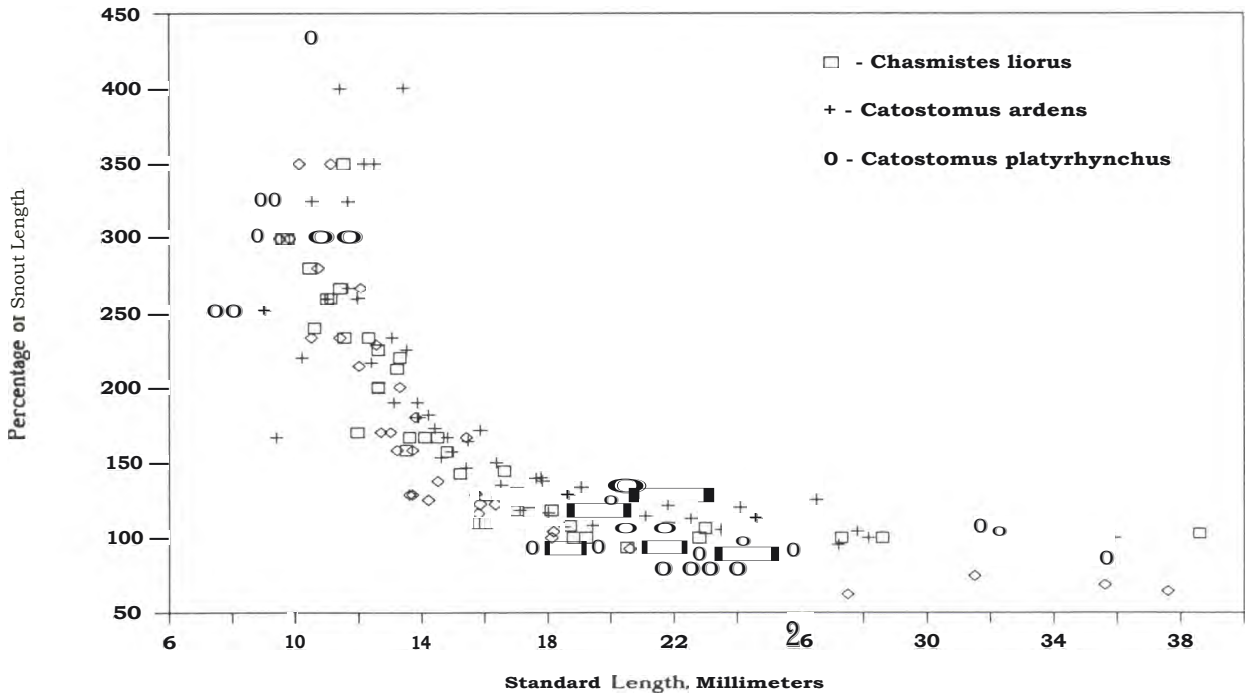


Figure B-25. Eye diameter as a percentage of snout length (AS-AE). Calculated (AS-PE minus AS-AE); see Figure 3 for method of measurement.

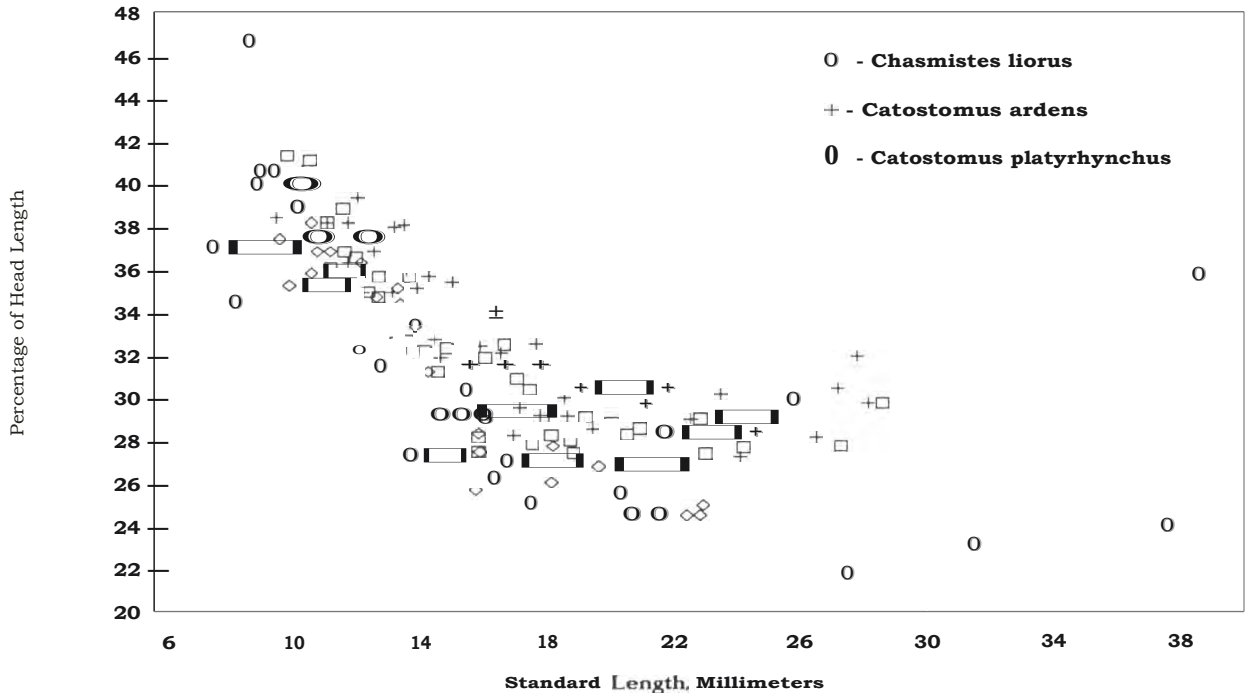


Figure B-26. Eye diameter as a percentage of head length (AS-OP1). Calculated (AS-PE minus AS-AE); see Figure 3 for method of measurement.

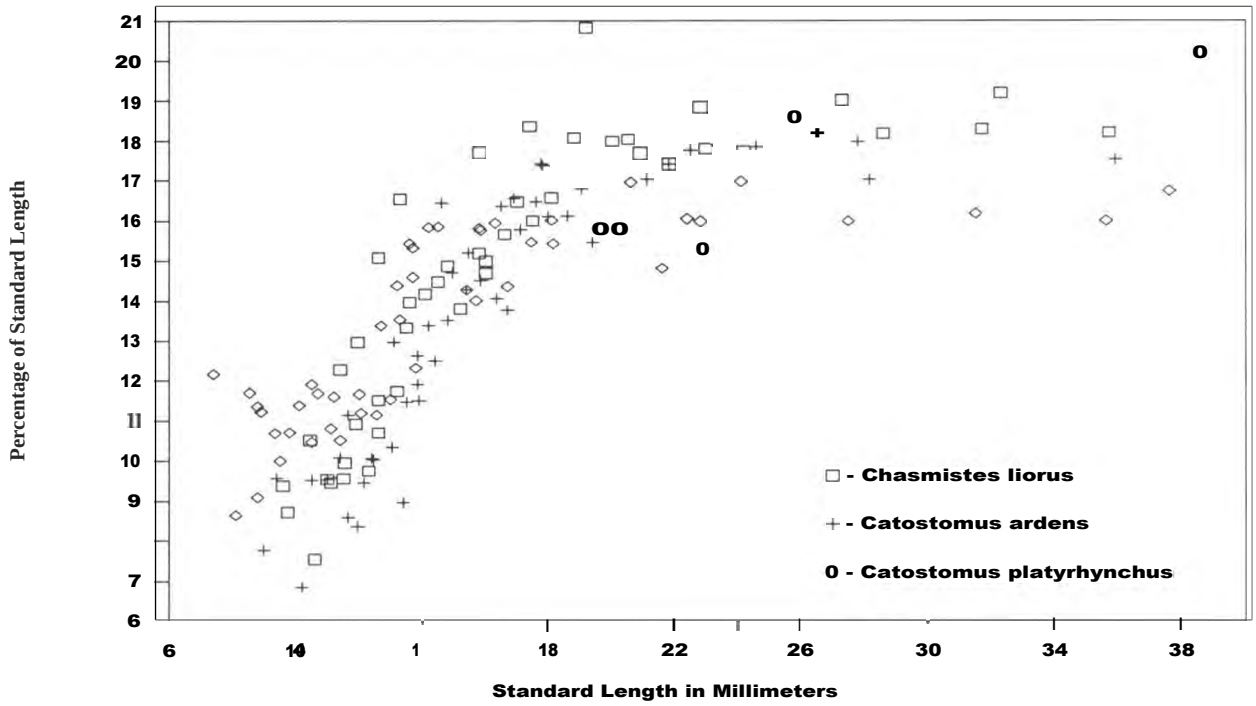


Figure B-27. Head depth immediately behind posterior margin of eye (at BPE) as a percentage of standard length. See Figure 3 for method of measurement.

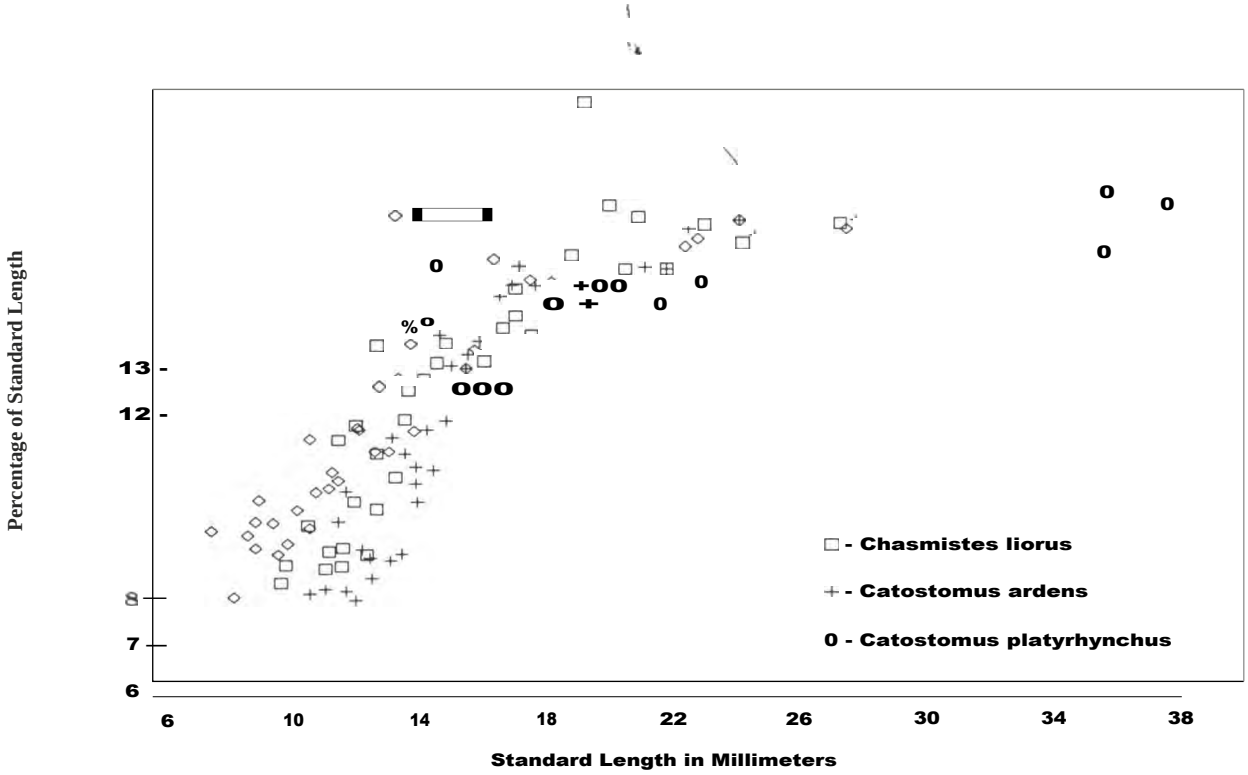


Figure B-28. Head width immediately behind posterior margin of eyes (at BPE) as a percentage of standard length. See Figure 3 for method of measurement.

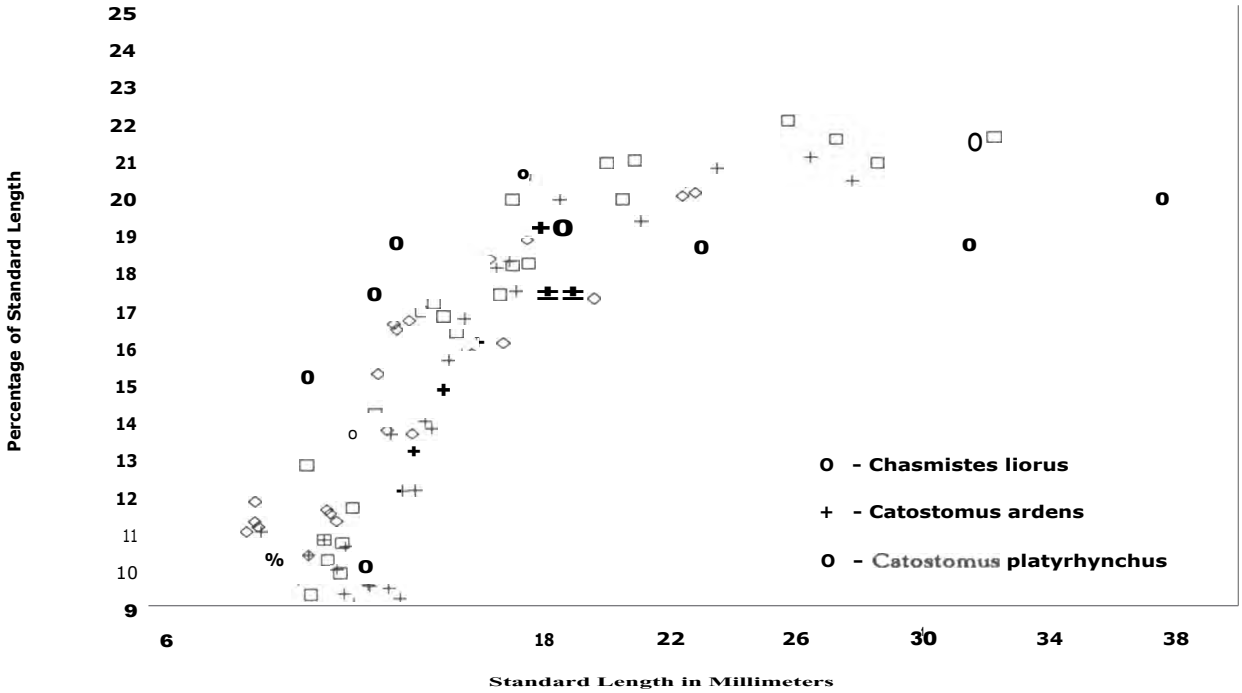


Figure B-29. Body depth at origin of pectoral fin (OP1) as a percentage of standard length. See Figure 3 for method of measurement.

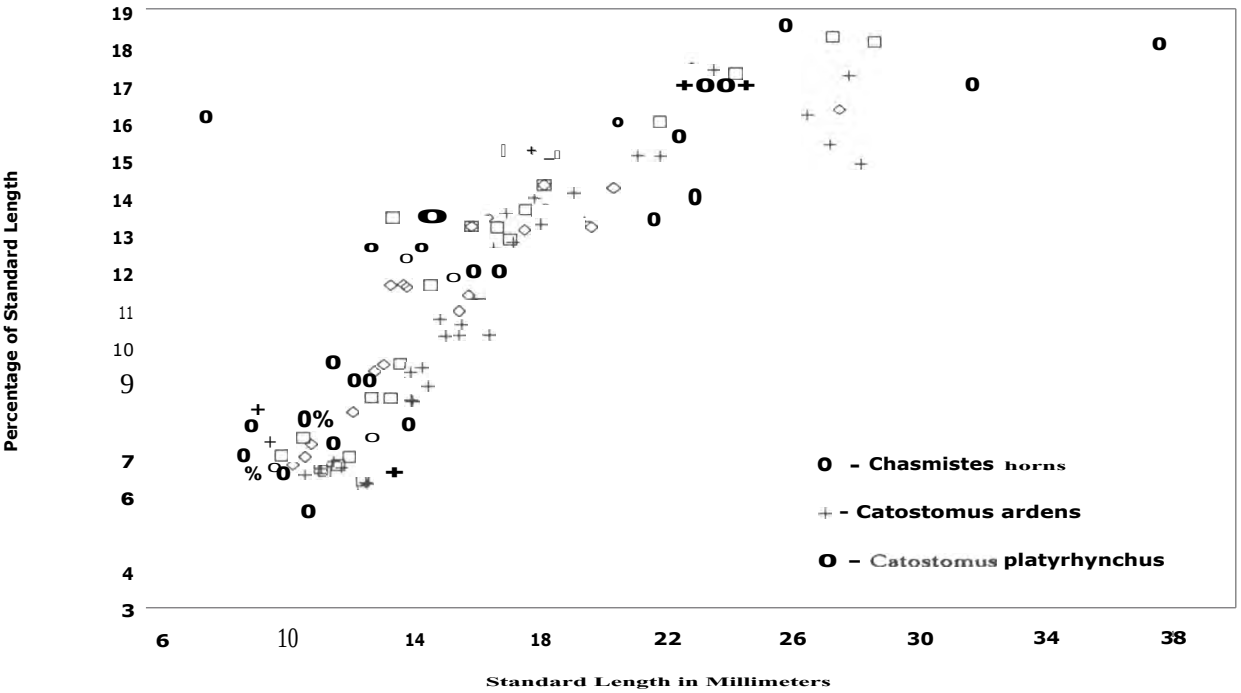


Figure B-30. Body width at origin of pectoral fins (OP1) as a percentage of standard length. See Figure 3 for method of measurement.

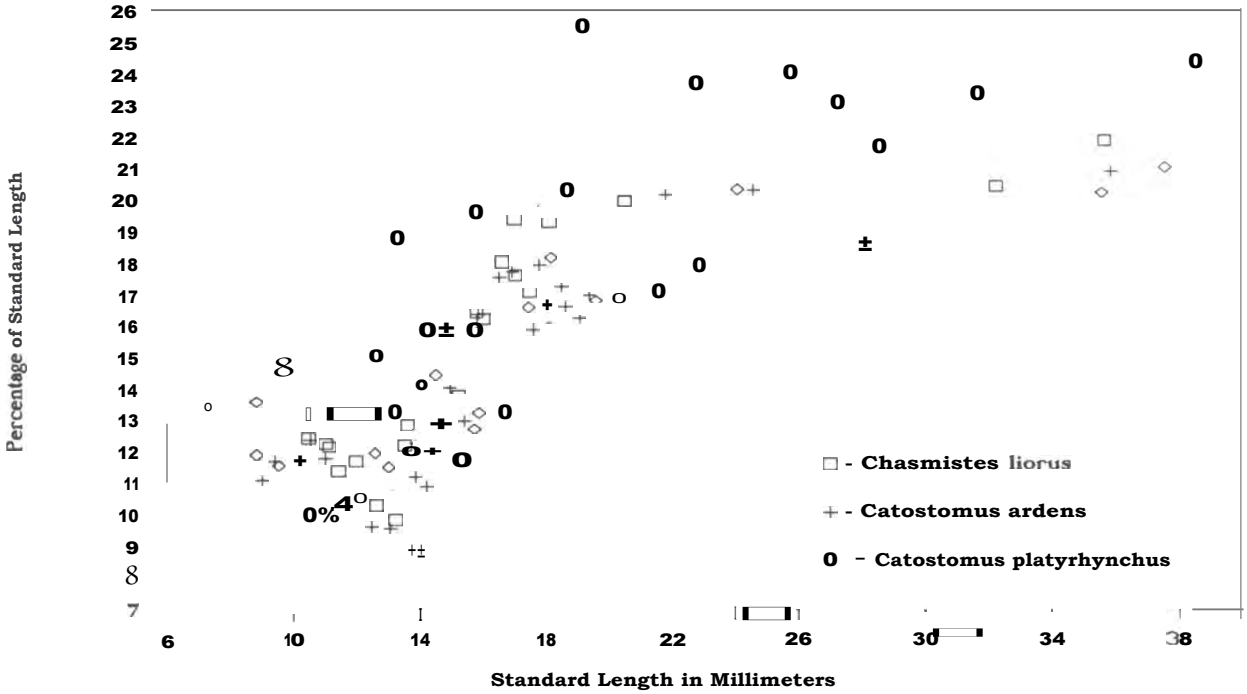


Figure B-31. Body depth at origin of dorsal fin (OD) as a percentage of standard length. See Figure for method of measurement.

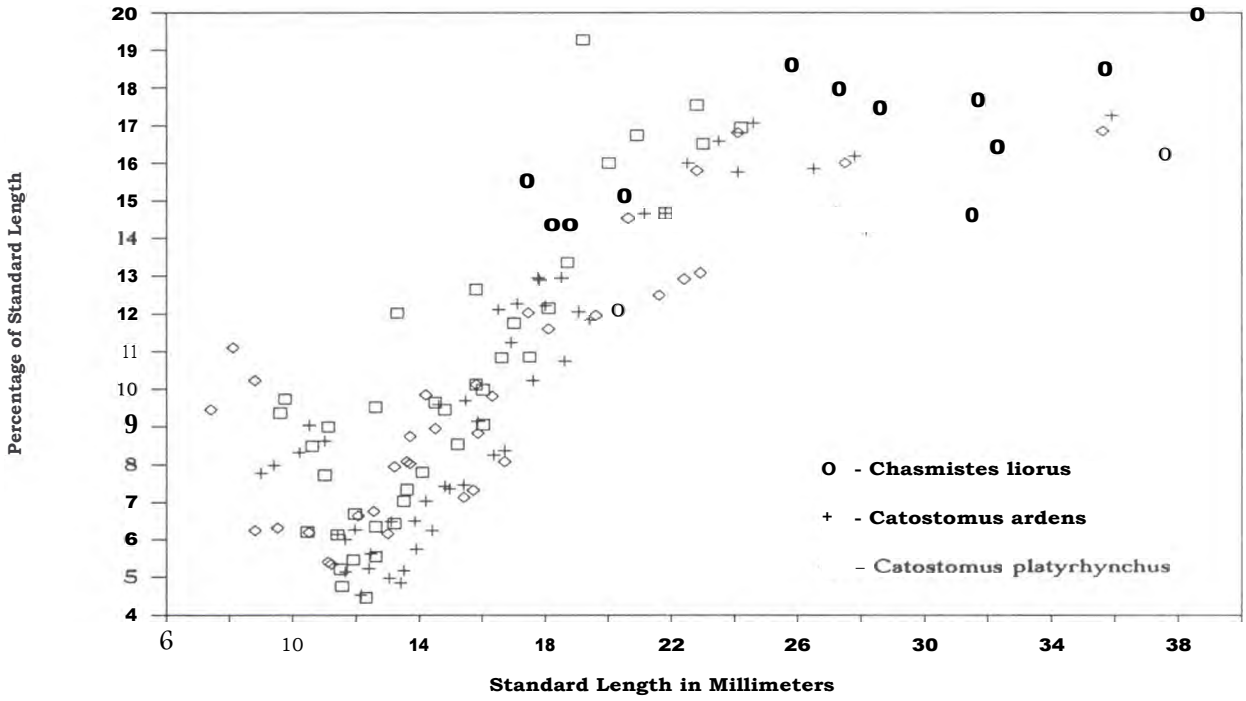
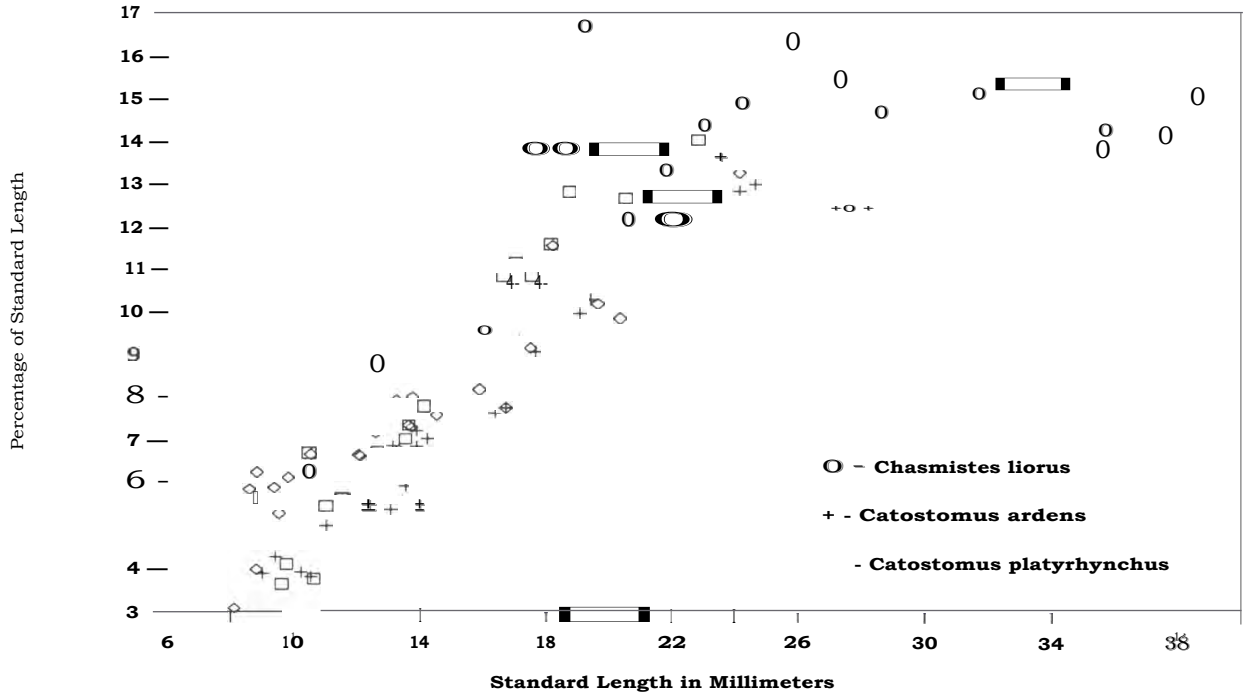
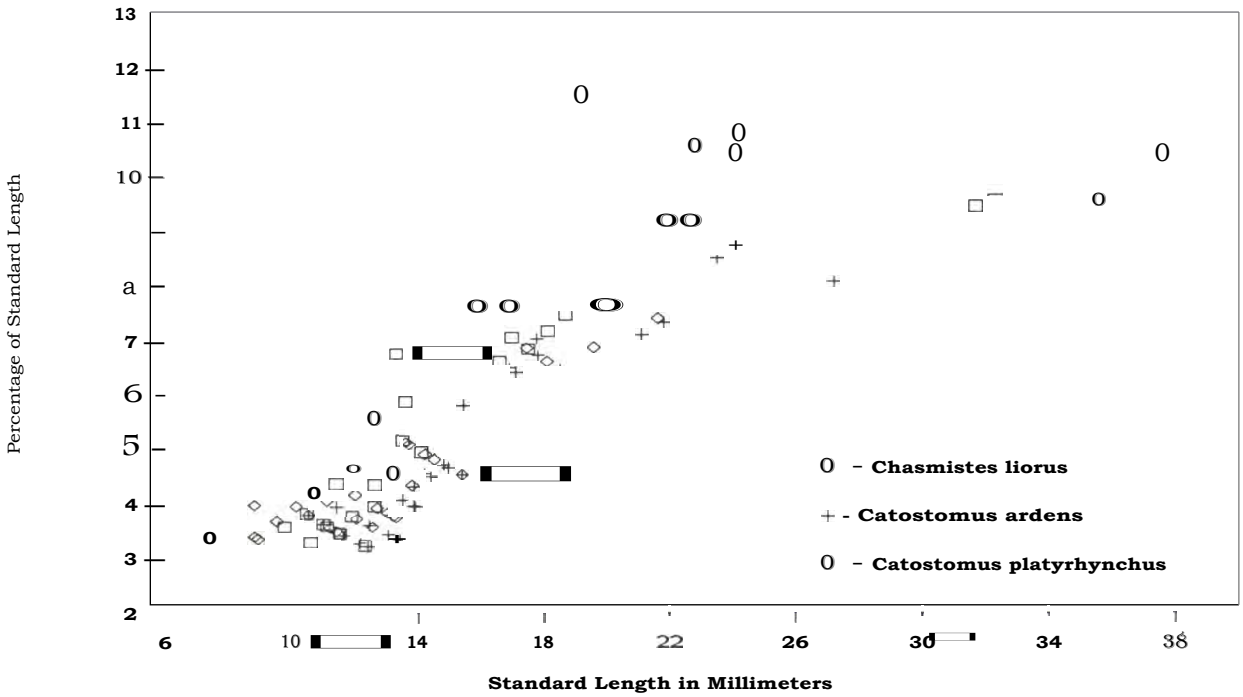


Figure B-32. Body width at origin of dorsal fin (OD) as a percentage of standard length. See Figure 3 for method of measurement.



F **B-33.** Body depth immediately behind posterior margin of vent (at BPV) as a percentage of standard length. See Figure 3 for method of measurement.



F **B-34.** Body width immediately behind posterior margin of vent (at BPV) as a percentage of standard length. See Figure 3 for method of measurement.

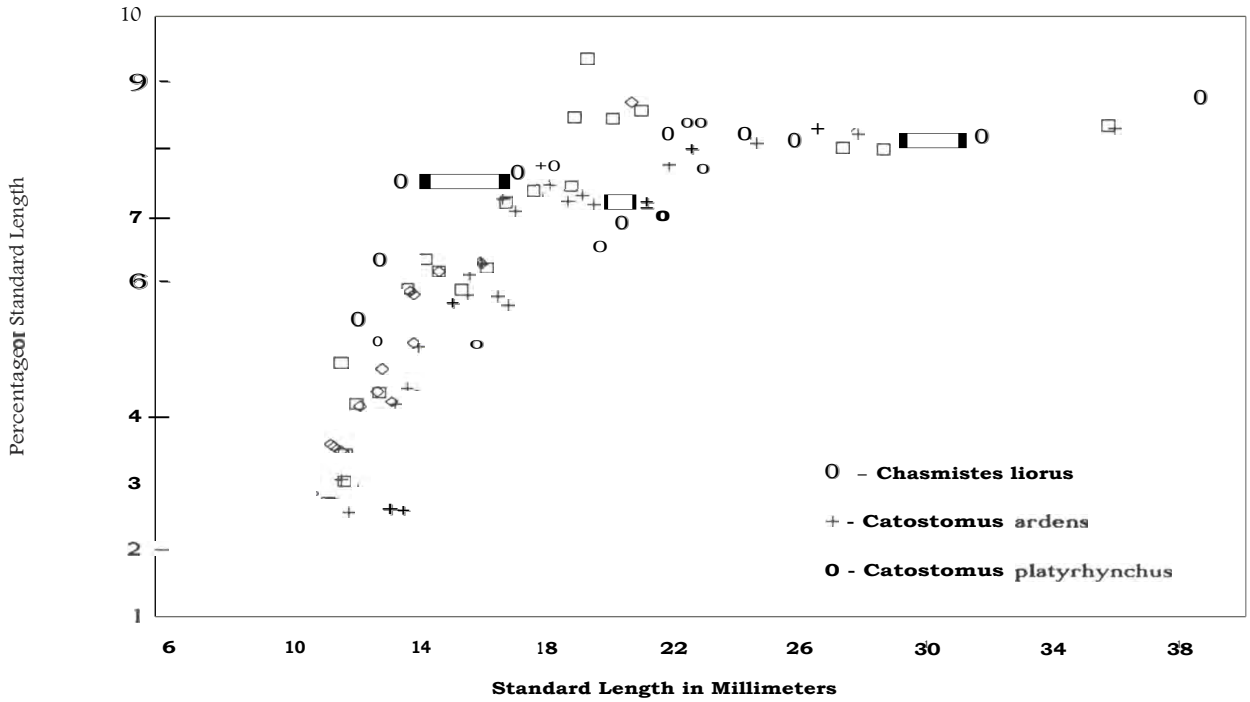


Figure B-35. Body depth at anterior margin of most posterior [illegible] (AMPM; caudal peduncle depth) as a percentage of standard length. See Figure 3 for method of measurement.

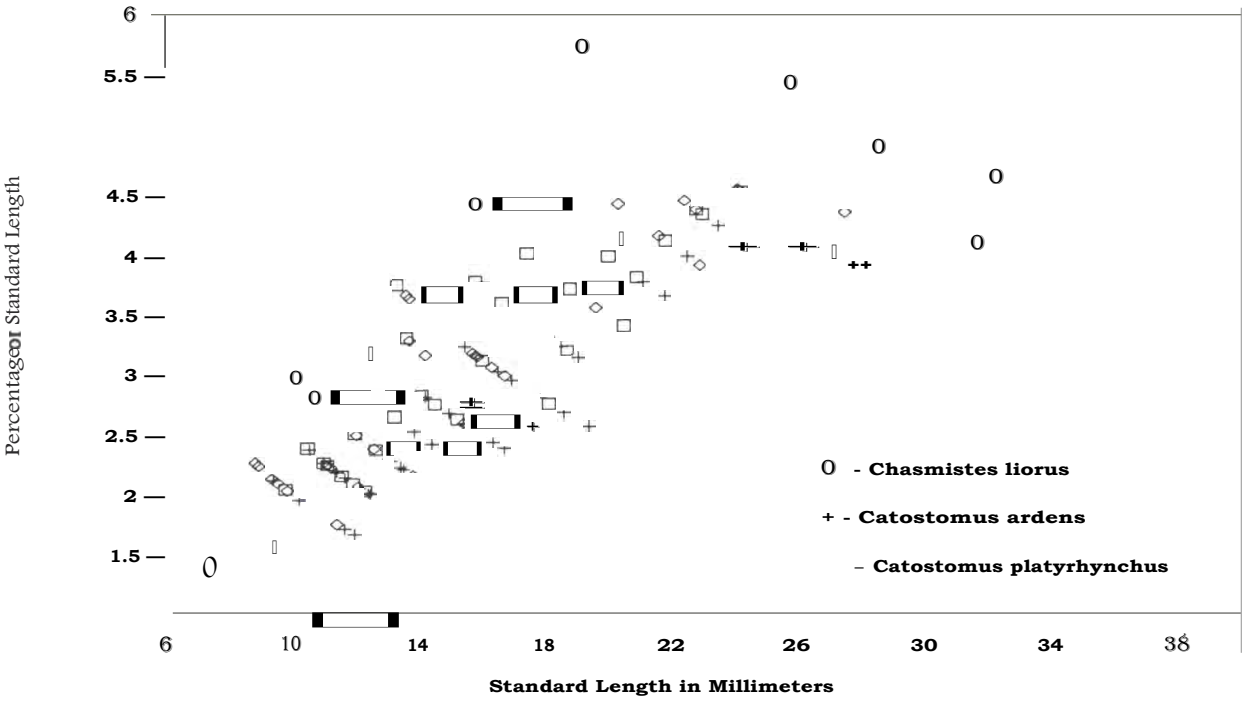


Figure B-36. Body width at anterior margin of most posterior [illegible] (AMPM; caudal peduncle width) as a percentage of standard length. See Figure 3 for method of measurement.

APPENDIX C

GROWTH CURVES FOR REARED SPECIMENS

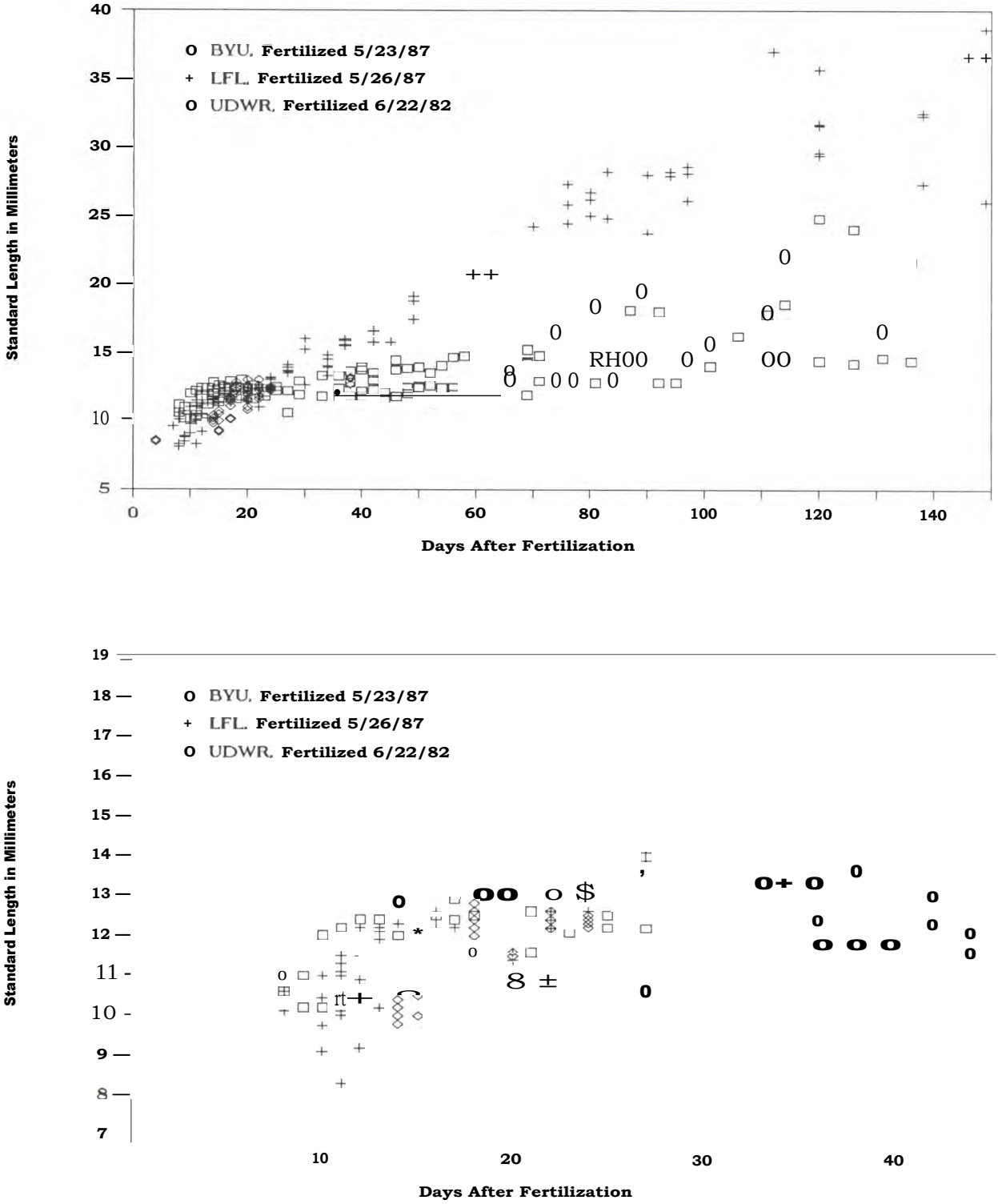
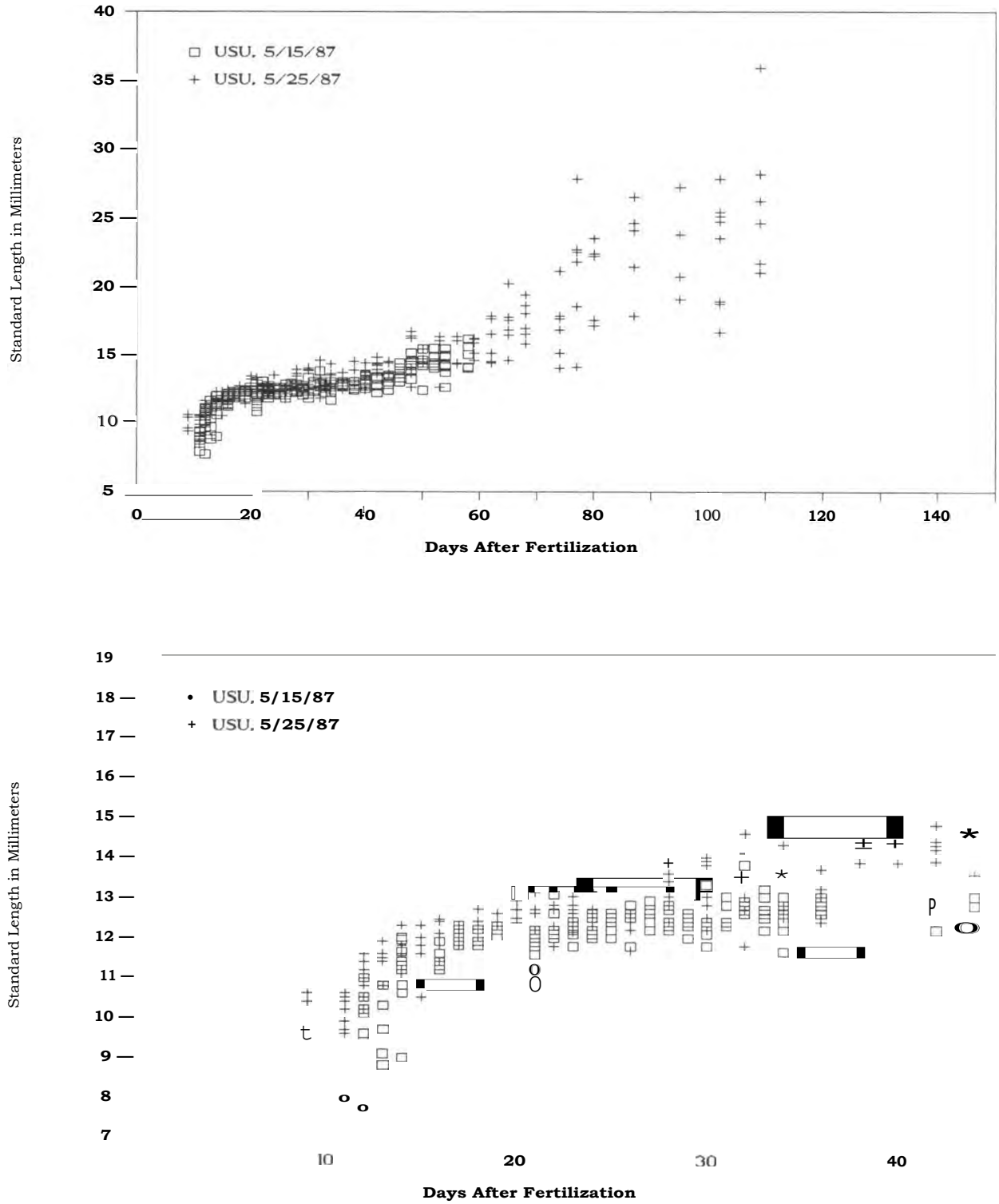


Figure C-1. Growth curves for Chasmistes liorus reared by Utah Division of Wildlife Resources (UDWR), Department of Zoology at Brigham Young University (BYU), and Larval Fish Laboratory at (LFL) Colorado State University. Based on specimens available for examination and measurement by Larval Fish Laboratory. Bottom graph is an enlarged subset of top graph.



F **C-2.** Growth curves for Catostomus ardens reared by Utah Cooperative Fish and Wildlife Research Unit at Utah State University (USU). Based on specimens available for examination and measurement by Larval Fish Laboratory. Bottom graph is an enlarged subset of top graph.

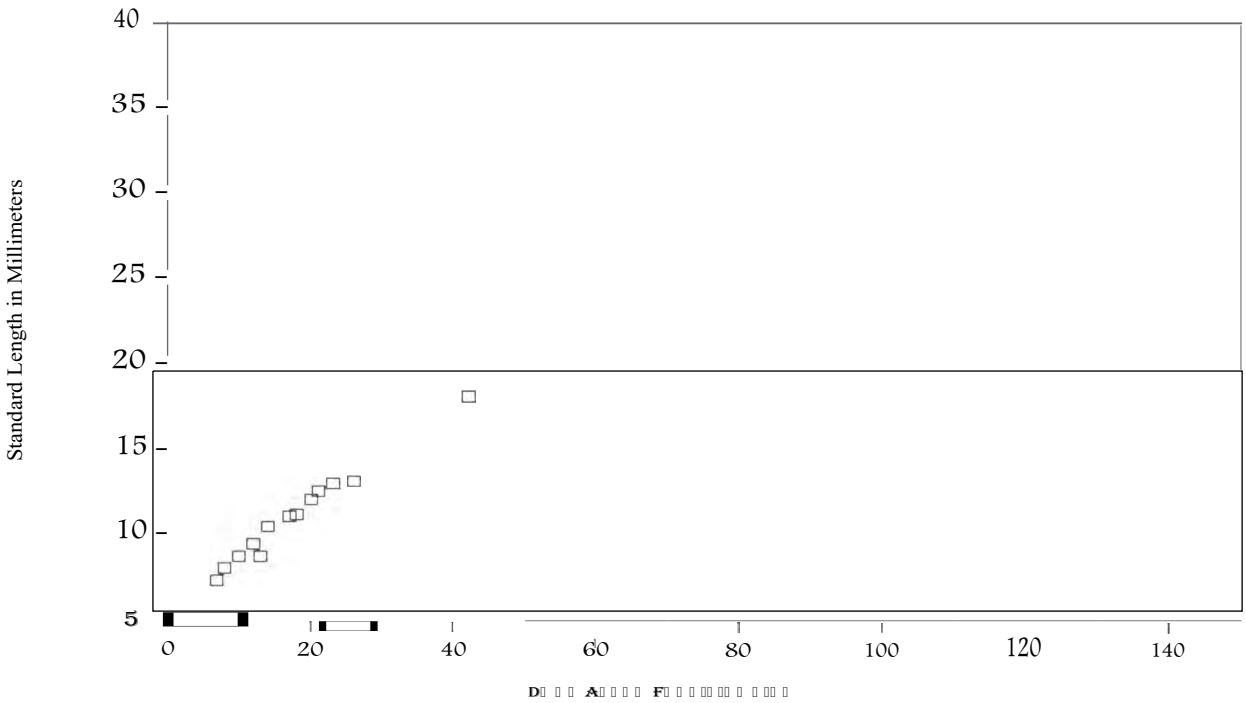


Figure C-3. Growth curve for Catostomus platyrhynchus reared by Larval Fish Laboratory (LFL) at Colorado State University. Based on specimens available for examination and measurement by Larval Fish Laboratory.