



Article

urn:lsid:zoobank.org:pub:7EE352D9-4FC3-49E9-A3CB-08694F4BC783

Standardized measurements, landmarks, and meristic counts for cypriniform fishes

JONATHAN W. ARMBRUSTER

Department of Biological Sciences, Auburn University, 331 Funchess, Auburn, AL 36849, USA; Telephone: (334) 844-9261, FAX: (334) 844-9234, E-mail: armbrjw@auburn.edu

Abstract

Standardized measurements and landmarks for traditional morphometrics, landmark-based (partial truss) measurements, and geometric morphometrics for Cypriniformes are described. Standardized meristic counts also are described.

Key words: Morphology, fishes

Introduction

In order to standardize as much as possible how data are taken for the All Cypriniformes Species Inventory, three morphometric schemes and one set of meristic counts are proposed. The three morphometrics are: Geometric Morphometric Landmarks (GM), Landmark-Based Morphometric Analysis (LBM), based on a partial truss configuration (Strauss & Bookstein 1982), and Traditional Morphometrics (TM), based on Hubbs & Lagler (1964). Landmarks are shared between GM and LBM, and some are shared with TM. The difference between LBM and TM is that some (e.g., Strauss & Bookstein 1982) suggest that measurements not taken between homologous landmarks (as in some TM) are not comparable across taxa. Most recent cyprinid descriptions use TM, and it is not recommended to deviate from this; however, because many cyprinids are laterally compressed, the coordinate data from GM can easily be converted to measurements, and these measurements will not have much distortion because many cypriniforms are relatively flat. Thus, the LBM method can be used on photographs, and lengths can be calculated on coordinate data using the Pythagorean theorem shown below; 1 and 2 represent the two different landmarks and c is the measurement desired.

$$a^2 + b^2 = c^2$$

$$a = \Delta x = x_1 - x_2; b = \Delta y = y_1 - y_2$$

$$c = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

It is recommended that the measurements presented herein be thought of as a minimal set of measurements for any cypriniform description, and authors may wish to add measurements and landmarks as needed. Some landmarks (e.g., barbel placement) will be valid only on those species with barbels, and only landmark numbers for the maxillary barbels are presented. Any additional measurements or landmarks should be placed at the end of the ones listed below.

Landmarks for use in Geometric Morphometrics and Landmark-Based Morphometrics

The following landmarks (Figs. 1 and 2) can be used for both geometric morphometrics and landmark-based morphometrics. Each of these landmarks represents an homologous point that can be compared across taxa. For most cypriniforms, the landmarks provided should be visible; however, it may be necessary to place a thin pin (e.g., an insect pin) to more accurately find some of the landmarks in some species.



FIGURE 1. Landmarks for use in geometric morphometrics. Photos of *Hybopsis lineapunctata*, AUM 46886, 52.7 mm SL in dorsal, lateral, and ventral views.

Dorsal View

1. Snout tip
2. Right posterior nare, posterior margin
3. Left posterior nare, posterior margin
4. Right orbit, dorsal rim, most medial point
5. Left orbit, dorsal rim, most medial point
6. Supraoccipital, posteromedial tip
7. Origin of dorsal fin

Lateral View

1. Snout tip
2. Posterior nare, posterior margin
3. Orbit, anterior margin along longest axis

4. Orbit, posterior margin along longest axis
5. Opening of mouth
6. Posterior end of jaw
7. Intersection of gill opening and ventral margin of body
8. Supraoccipital, posteromedial tip (visible as an indentation in dorsal surface)
9. Posteriormost edge of opercle
10. Origin of pectoral fin
11. Origin of dorsal fin
12. Insertion of dorsal fin
13. Origin of pelvic fin
14. Origin of anal fin
15. Insertion of anal fin
16. Origin of anterior dorsal procurrent caudal-fin ray
17. Origin of anterior ventral procurrent caudal-fin ray
18. End of vertebral column

Ventral View

1. Snout tip
2. Symphysis of lower jaw
3. Union of left and right branchiostegal membranes at isthmus
4. Left posterior edge of lip
5. Right posterior edge of lip
6. Origin of left pectoral fin
7. Insertion of left pectoral fin
8. Origin of right pectoral fin
9. Insertion of right pectoral fin
10. Left origin of left pelvic fin
11. Left insertion of left pelvic fin
12. Origin of right pelvic fin
13. Insertion of right pelvic fin
14. Vent (centered on opening)
15. Origin of anal fin
16. Origin of anterior ventral procurrent caudal-fin ray
17. OPTIONAL—placement of left maxillary barbel
18. OPTIONAL—placement of right maxillary barbel

Landmarks to be used only in LBM

- a. Tip of first dorsal-fin ray
- b. Tip of first pectoral-fin ray
- c. Tip of first pelvic ray
- d. Tip of first anal ray
- e. Posterior edge of right opercle
- f. Posterior edge of left opercle

Landmark-Based Morphometrics

The measurements in Table 1 should be considered a minimal set for Landmark-Based Morphometrics. A full morphometric truss *sensu* Strauss and Bookstein (1982) can be considered the maximum number of measurements but would likely be more work than necessary if working with calipers; however, landmark pairs can easily be converted to additional measurements on photographs.

TABLE 1. Measurements in landmark-based morphometrics. See Figure 2. Letters next to landmark numbers refer to perspective: d = dorsal view, v = ventral view, unlabeled = lateral view. Fin lengths should be calculated as in traditional morphometrics.

Landmarks	Measurement
1–18	Standard length (SL)
1–7d	Predorsal length
1–8	Snout-supraoccipital distance
1–3	Snout length
1–6	Upper-jaw length
1–9	Head length
1–10	Snout-pectoral distance
1–7	Snout-gill distance
3–4	Orbit length
4–9	Postorbital head length
7–13	Gill-pelvic distance
8–11	Supraoccipital-dorsal distance
8–13	Supraoccipital-pelvic distance
11–13	Dorsal-pelvic distance
11–12	Dorsal-fin base length
11–14	Dorsal-anal distance
12–18	Postdorsal length
14–15	Anal-fin base length
15–18	Caudal-peduncle length
16–17	Caudal-peduncle depth
2d–3d	Internarial width
4d–5d	Interorbital width
e–f	Head width
2v–4v	Mandible length
4v–5v	Gape width
6v–8v	Inter-pectoral width
10v–12v	Inter-pelvic width
14v–15v	Vent-anal distance
11–a	First dorsal ray length
10–b	First pectoral ray length
13–c	First pelvic ray length
14–d	First anal ray length

Traditional Morphometrics (Hubbs and Lagler 1964)

Most recent descriptions of cypriniforms use measurements from Hubbs and Lagler (1964; Table 2). Although this is generally sufficient, these traditional measurements are not always comparable across taxa, and the representation of the shape of the fishes is not complete.

TABLE 2. Measurements in Traditional Morphometrics. See Figure 3. Letters next to landmark numbers refer to perspective: d = dorsal view, v = ventral view, unlabeled = lateral view. Traditional morphometrics generally start at homologous landmarks but may not end at them. * Not labeled in figure. Fin-ray lengths include filaments when present.

Label	Landmarks	Measurement	Description (when necessary)
A	1–18	Standard length	
B	11–vertically below	Body depth	Body depth at origin of dorsal fin, taken as vertical from Landmark 11
C		Caudal-peduncle depth	Least depth of caudal peduncle
D	15–18	Caudal-peduncle length	
E	1–9d	Predorsal length	
F	11–12	Dorsal-fin base length	
G	14–15	Anal-fin base length	
H	11–maximum height of dorsal fin	Dorsal-fin height	From origin of dorsal fin to tip of anterior lobe (greatest height)
I	14– maximum height of anal fin	Anal-fin height	From origin of anal fin to tip of anterior lobe (greatest height)
J*	11–maximum length of dorsal fin	Depressed dorsal-fin length	From origin of dorsal fin to tip of furthest ray when fin is depressed
K*	13–maximum length of anal fin	Depressed anal-fin length	From origin of anal fin to tip of furthest ray when fin is depressed
L		Longest dorsal ray	From base of longest ray to its tip
M		Longest anal ray	From base of longest ray to its tip
N	10–maximum length of pectoral fin	Pectoral-fin length	From origin of fin to tip of longest ray
O	13–maximum length of pelvic fin	Pelvic-fin length	From origin of fin to tip of longest ray
P	1–9	Head length	Exclude gill membrane (Kottelat 1990), although included in Hubbs & Lagler (1964)
Q	8–ventromedial portion of head	Head depth	From end of supraoccipital to ventromedial point directly vertical
R	6d–7d	Head width	
S	1–3	Snout length	
T	4–9	Postorbital head length	
U		Cheek height	From ventral margin of orbit vertically to ventral margin of preopercle
V	4–posterior margin of angle of preopercle	Orbit-angle-of-preopercle distance	From posterior margin of orbit to end of angle of preopercle including spine if present
W	4d–5d	Interorbital width	
X	3–4	Orbit length	
Y	1–6	Upper-jaw length	
Z	2v–4v	Mandible length	
AA	4v–5v	Gape width	

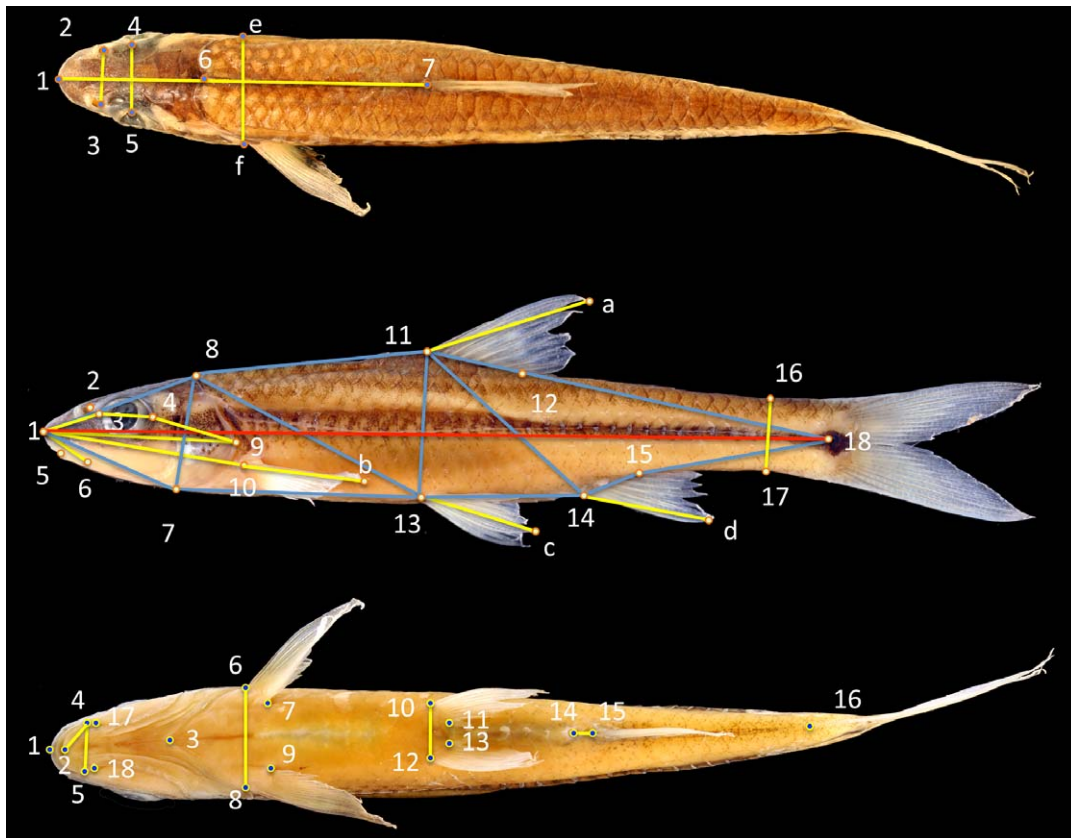


FIGURE 2. Minimal set of measurements for use in landmark-based morphometrics. Photos of *Hybopsis lineapunctata*, AUM 46886, 52.7 mm SL in dorsal, lateral, and ventral views.



FIGURE 3. Traditional morphometrics from Hubbs and Lagler (1964). Photos of *Hybopsis lineapunctata*, AUM 46886, 52.7 mm SL in dorsal, lateral, and ventral views.

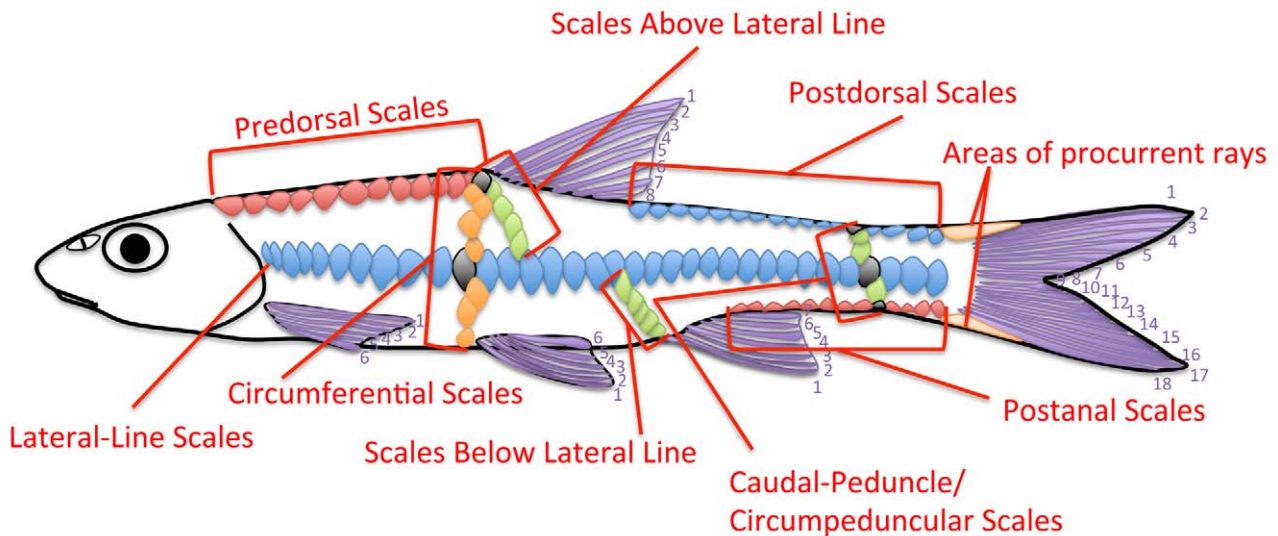


FIGURE 4. Standard meristic counts. Scales that are counted in multiple series are colored black. Drawing based on *Hybopsis lineapunctata*, AUM 46886, 52.7 mm SL, by JWA.

Meristic (Counts)

Several scale counts as well as gill raker counts and pharyngeal tooth counts are standard in cypriniform descriptions (Figs. 4–6). Counts should be made on the left side of the body for bilaterally symmetric features.

Dorsal-fin simple rays (spines)—many cypriniforms have thickened, unbranched rays anteriorly in the dorsal fin.

Dorsal-fin rays—simple rays (spines) plus branched rays. The fins of cypriniforms consist either entirely of branched rays, or of one to several simple rays or spines followed by branched rays. All fin-ray counts are in lowercase roman numerals for the simple rays or spines and Arabic numerals for branched rays (ii, 8). The posterior two rays of the dorsal fin are branches of the same ray that unite internally; they should be counted as one. The last branch is sometimes counted as a half-ray; e.g., the count for a dorsal fin with two simple rays and eight branched rays might be given as ii, 8½, or as number of branched rays 8 with the last ray united internally); however, reporting the count as ‘ii, 8’ is recommended.

Anal-fin rays—simple rays plus branched rays. Count broken into simple rays and branched rays as in the dorsal fin. As for the dorsal fin, count the last ray as one even if its branches are separated to the fin base; that is, if the branches of the ray look as if they will join just below the surface, they probably do and are counted as one ray.

Principal caudal-fin rays—all rays excluding procurrent rays. Count includes unbranched rays that form the dorsal and ventral borders of the caudal fin and all other rays between them, which usually are branched. Occasionally this count is broken into number of rays supported by the upper and lower hypurals separated by a + sign; e.g., the count might be given as 16 or as 8 upper + 8 lower).

Pectoral-fin rays—simple rays plus branched rays. Count broken into simple rays and branched rays as in the count for the dorsal fin.

Pelvic-fin rays—simple rays plus branched rays. Count broken into simple rays and branched rays as in the dorsal fin.

Lateral-line scales—scales bearing the lateral-line canal from the head to the end of the vertebral column (end of the hypural plate). If the lateral line is not complete, continue the count along a row of scales from the last pored scale. This count is sometimes referred to as the lateral-scale count.

Pored lateral-line scales—scales with lateral-line pores. If the lateral line is complete, this count will duplicate the count for the lateral-line scales.

Pored scales on the caudal fin—in some species, the lateral line continues past the end of the vertebral column and onto the caudal fin.

Scales above the lateral line—scales counted in a diagonal from the origin of dorsal fin posteroventrally to the lateral line (does not include lateral-line scale). Dorsalmost scale is often counted as half a scale, but the recommendation is to count it as one.

Scales below lateral line—scales counted from the anterior insertion of the anal fin anterodorsally to the lateral line (does not include lateral-line scale). Ventralmost scale is often counted as half a scale, but the recommendation is to count it as one.

Predorsal scales—scales in row between the supraoccipital and the origin of the dorsal fin. These often are difficult to see. If the scales cannot be counted in medial row, count the adjacent row on the left side.

Postanal scales—scales in the ventral scale row from the insertion of the anal fin to the end of the vertebral column (be careful not to count the ventral procurrent rays as some look like scales).

Caudal-peduncle scales—scales from the ventromedial to posteromedial lines at narrowest portion of caudal peduncle. Count at an angle from anterodorsal to posteroventral.

Circumpeduncular scales—as above, but continued around other side in an anterodorsal to posteroventral direction.

Circumferential scales—scales encircling the body immediately anterior to the dorsal fin.

Pharyngeal tooth count—use sharp forceps to remove the pharyngeal arch by slicing through the cleft just posterior to the gills and gently remove the arch. Traditionally, both pharyngeal arches have been removed, but it is suggested that one be left in the fish for future reference. There are one to three rows of teeth on each arch. If only one row is present, state number of teeth. If two or more rows are present, give count as a formula ('2–4' means two teeth in the outer row and four teeth in the inner row (Fig. 5); left and right sides are not necessarily symmetric). This is destructive sampling, so limit the number of specimens counted and obtain permission from curators of institutions owning the specimens prior to dissection.

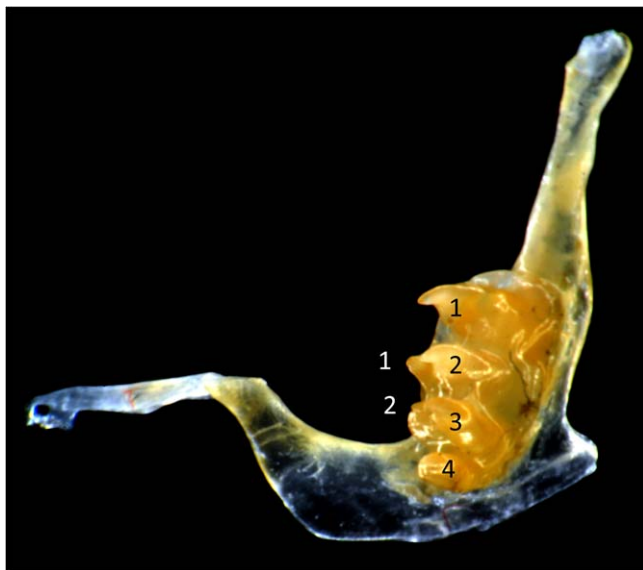


FIGURE 5. Pharyngeal jaw from *Luxilus chrysocephalus*.

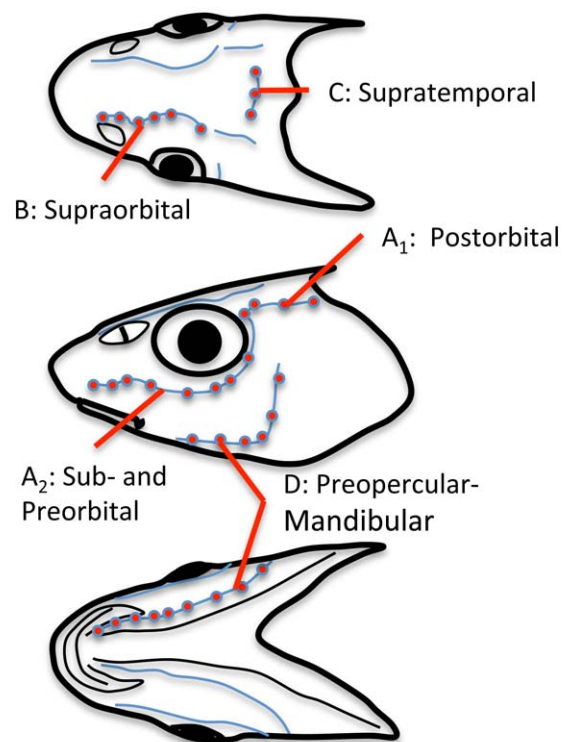


FIGURE 6. Cephalic lateral line system. The four sections are as follows: (A) infraorbital canal (divided into A_1 —postorbital pores and A_2 —preorbital and suborbital pores), (B) supraorbital canal, (C) supratemporal canal, and (D) preoperculo-mandibular canal. Drawings based on *Hybopsis lineapunctata*, AUM 46886, 52.7 mm SL, by JWA.

Gill rakers—the bony or cartilaginous projections on the anteromesial margin of the first gill arch. It may be informative to split the count between the upper and lower limbs. To view the teeth, remove the gill arch or fold back the opercle. This may be destructive sampling, so limit the number of specimens counted, and obtain permission from curators prior to dissecting the specimen.

Gill rakers on upper limb—the number of rakers on the dorsal section of the gill arch.

Gill rakers on lower limb—the number of rakers on the ventral section of the gill arch.

Vertebrae—vertebrae from the head (include a count of five for the Weberian Complex) to, but not including, the hypural.

Trunk vertebrae—vertebrae from head (include 5 for the Weberian Complex) to, but not including, the first vertebra with a hemal arch.

Caudal vertebrae—vertebrae with hemal arches (does not include hypural).

Cephalic lateralis system—a series of canals with associated pores. Pores are counted in four sections with the first (the infraorbital canal) broken into two subdivisions (Fig. 6, see also Kottelat 1990). The canals are colored blue in Fig. 6 where optimal views to count the pores are presented. For preoperculomandibular pores, both ventral and lateral views must be seen to count all of the pores.

Acknowledgements

Thanks to L. M. Page, R. L. Mayden, the participants of the All Cypriniformes Species Inventory International Conference in Chiang Mai, Thailand, and members of the Armbruster lab for suggestions on the characters presented here. Thanks to S. Ferdous for answering questions about geometric morphometrics. This paper was supported by the U.S. National Science Foundation “All Cypriniformes Species Inventory” Grant (DEB-1023403).

References

- Hubbs, C.L. & Lagler, K.F. (1964) *Fishes of the Great Lakes Region*. University of Michigan Press, Ann Arbor, MI, USA, 213 pp.
- Kottelat, M. (1990) *Indochinese Nemacheilines, A Revision of Nemacheiline Loaches (Pisces: Cypriniformes) of Thailand, Burma, Laos, Cambodia and Southern Viet Nam*. Verlag Friedrich Pfeil, Munchen, Germany, 262 pp.
- Strauss, R.E. & Bookstein, F.L. (1982) The truss: body form reconstruction in morphometrics. *Systematic Zoology*, 31,113–135.