II

# Fish measurements

# II 1 Measuring equipment

Equipment for measuring the size of parts of a fish body varies depending on the size of the fish, and each type of equipment has a distinct precision. For measuring huge fish such as sharks, a tape measure is used, whereas fish larger than 30 cm are usually measured using a straightedge (wooden ruler) in millimeters. If the size is <30 cm, a vernier caliper is used to accurately measure the size down to the first decimal point (in tenths of millimeters). Vernier calipers include dial calipers and digital calipers, the latter of which have a variety of types, including ones to which recording equipment can be attached. Every caliper can read down to the second decimal point. However, precision to the first decimal point is sufficient for the measurement of organisms. In the case of a microscopic size such as the case of larvae and juveniles, a micrometer is used. However, because the measurements use projection (see the column) in most cases, it is inevitable that the measurement angle of each part becomes a little inaccurate.

## Division reading and principle of vernier calipers

You need to carefully understand the method and principle of vernier calipers because an error in the reading of divisions of a vernier caliper frequently used in measurement of fish bodies can lead to a serious mistake.

## The ways to divide scales on vernier calipers

Normally, a vernier has n divisions that are equal to n−1 divisions on the main scale. Depending on the precision, there are two forms for the divisions, as shown in the table below.

| The minimum division on the main scale (mm) | The way to divide the vernier | The minimum read value (mm) |
|---|---|---|
| (1) 1 | 19 mm are equally divided by 20 (Fig. 1)<br>39 mm are equally divided by 20 | 1/20=0.05 |
| (2) 0.5 | 12 mm are equally divided by 25<br>24.5 mm are equally divided by 25<br>49 mm are equally divided by 50 | 1/50=0.02 |

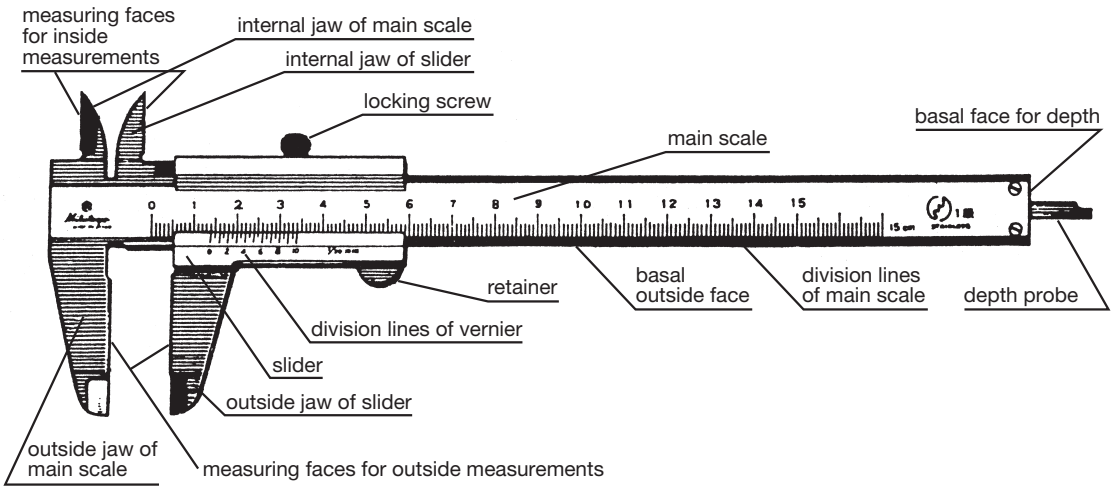


**Fig. 1** Legends of vernier caliper.

## How to read divisions on vernier calipers

(1) Principle: In the case of Figure 2, because the division line 0 on the vernier is over 7 on the main scale and the 4th division line coincides with a division line (regardless of the position) on the main scale, the size is as follows:

$$7 + (0.05 \times 4) = 7 \text{ mm} + 0.2 \text{ mm} = 7.2 \text{ mm}$$

Convenient method: Add (the division line on the vernier coinciding with a division line on the main scale) × 0.1 to the division line on the main scale over which the division line 0 on the vernier lies. That is, read it as follows:

$$7 + (2 \times 0.1) = 7 \text{ mm} + 0.2 \text{ mm} = 7.2 \text{ mm}$$


**Fig. 2**

(2) Principle: In the case of Figure 3, because the division line 0 on the vernier is over 4.5 on the main scale and the 11th division line coincides with a division line (regardless of the position) on the main scale, the size is as follows:

$$4.5 + (0.02 \times 11) = 4.72 \text{ mm}$$

Convenient method: Add (the division line on the vernier coinciding with a division line on the main scale) × 0.1 to the division line on the main scale over which the division line 0 on the vernier lies. That is, read it as follows:

$$4.5 + (2.2 \times 0.1) = 4.72 \text{ mm}$$

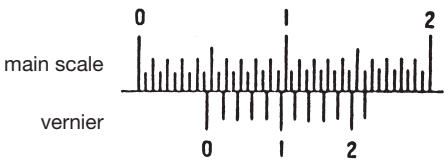


**Fig. 3**

II 2

# How to measure Chondrichthyes; sharks

Measurements of Chondrichthyes are generally done on projection on lateral axis. These customs are different from those on Teleostei, done on point-to-point lengths.

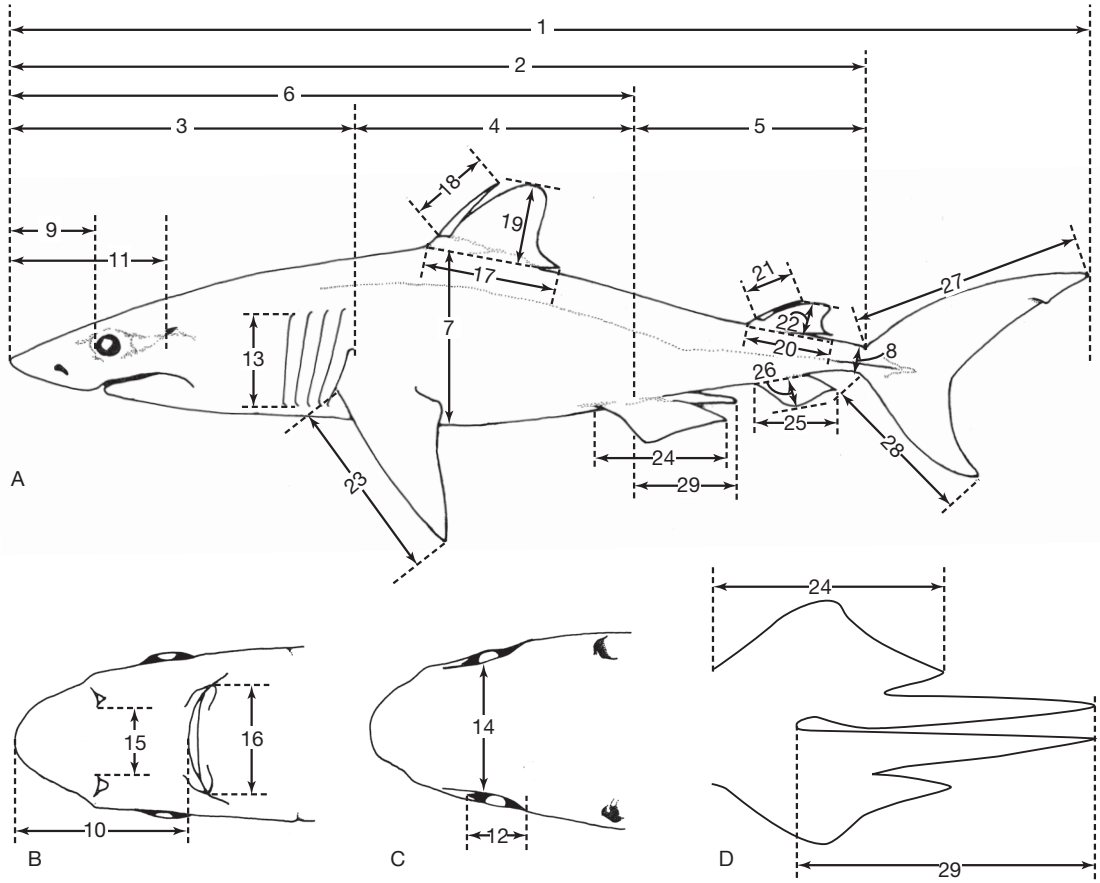


**Fig. 1** Common measurements on sharks.
A, lateral view; B, ventral view of head; C, dorsal view of head; D, ventral view of pelvic fin.
See text for numbers on the figures. Drawn by Yumi Kawai.

1. **Total Length; TL**

   Length from anterior-most point of body to posterior-most point of caudal fin. Anterior most point has both cases on upper and lower jaws. Generally this length has taken to the endpoint of upper lobe of caudal fin with normal position, but sometimes taken with most end point by pulling anterior direction. In some species the end of upper lobe is not be able to detect, and precaudal lengs as below is used instead of total length.

2. **Precaudal Length; PCL**

   Length from anterior-most point of body to origin of upper lobe of caudal fin, or if present, to deepest point of precaudal pit, incision between caudal peduncle and upper lobe of caudal fin.

3. **Head Length; HL**

   Length from anterior most of body to posterior most point of last gill slit.

4. **Trunk Length**

   Length from anterior-most point of body to midpoint of insertion of vent (cloaca).

5. **Tail Length**

   Length from midpoint of insertion of vent to origin of upper lobe of caudal fin, or if present, to deepest point of precaudal pit.

6. **Snout-vent Length**

   Length from anterior-most point of body to midpoint of insertion of vent.

7. **Body Depth; BD**

   Depth on deeper most part of body, without fin parts.

8. **Depth of Caudal Peduncle.**

   Depth of lower most part of caudal peduncle. Generally measured on origin of caudal fin.

9. **Preorbital Length**

   Length between anterior-most points of body and orbit.

10. **Preoral Length**

    Length between anterior-most points of body and mouth.

11. **Prespiacular Length**

    Length between anterior-most points of body and spiracle (if exists).

12. **Orbit Diameter**

    Horizontal diameter of orbit.

13. **First Gill Slit Length**

    Length between upper and lower-most points of first gill slit.

14. **Interorbital Width.**

    Shorter-most width between right and left orbits, from dorsal view.

15. **Internarial width**

    Shorter-most width between right and left nasal pores, from ventral view.

16. **Mouth Width**

    Width between right and left ends of mouth.

17. **First Dorsal-fin Length**

    Length between origin and posterior most point of first dorsal-fin.

18. **First dorsal-fin Spine Length**

    Length of exposed part of first dorsal-fin spine from proximal origin to tip. Record in cases of broken and/or worn down.

19. **First Dorsal-fin Hight.**

    From base to distal most point of first dorsal-fin.

20. **Second Dorsal-fin Hight.**

    From base to distal most point of second dorsal-fin.

**21. Second Dorsal-fin Spine Length**

Length of exposed part of second dorsal-fin spine from proximal origin to tip. Record in cases of broken and/or worn down.

**22. Second Dorsal-fin Hight**

From base to distal most point of first dorsal-fin.

**23. Pectoral-fin Length**

From base to tip of pectoral-fin.

**24. Pelvic-fin Length**

From anterior origin to posterior tip of pelvic-fin.

**25. Anal-fin Length**

From anterior origin to posterior tip of anal-fin.

**26. Anal-fin Hight**

From base to higher-most point of anal-fin.

**27. Dorsal caudal-fin length**

From origin to posterior most point of upper lobe of caudal.

**28. Preventral caudal-fin Length**

From origin to posterior most point of lower lobe of caudal-fin.

**29. Clasper Length**

From anterior most point of insertion of vent (cloaca) to tip of clasper.

II 3

# How to measure Chondrichthyes; skates and rays

Measurements of Chondrichthyes are generally done on projection on lateral axis. These customs are different from those on Teleostei, done on point-to-point lengths.

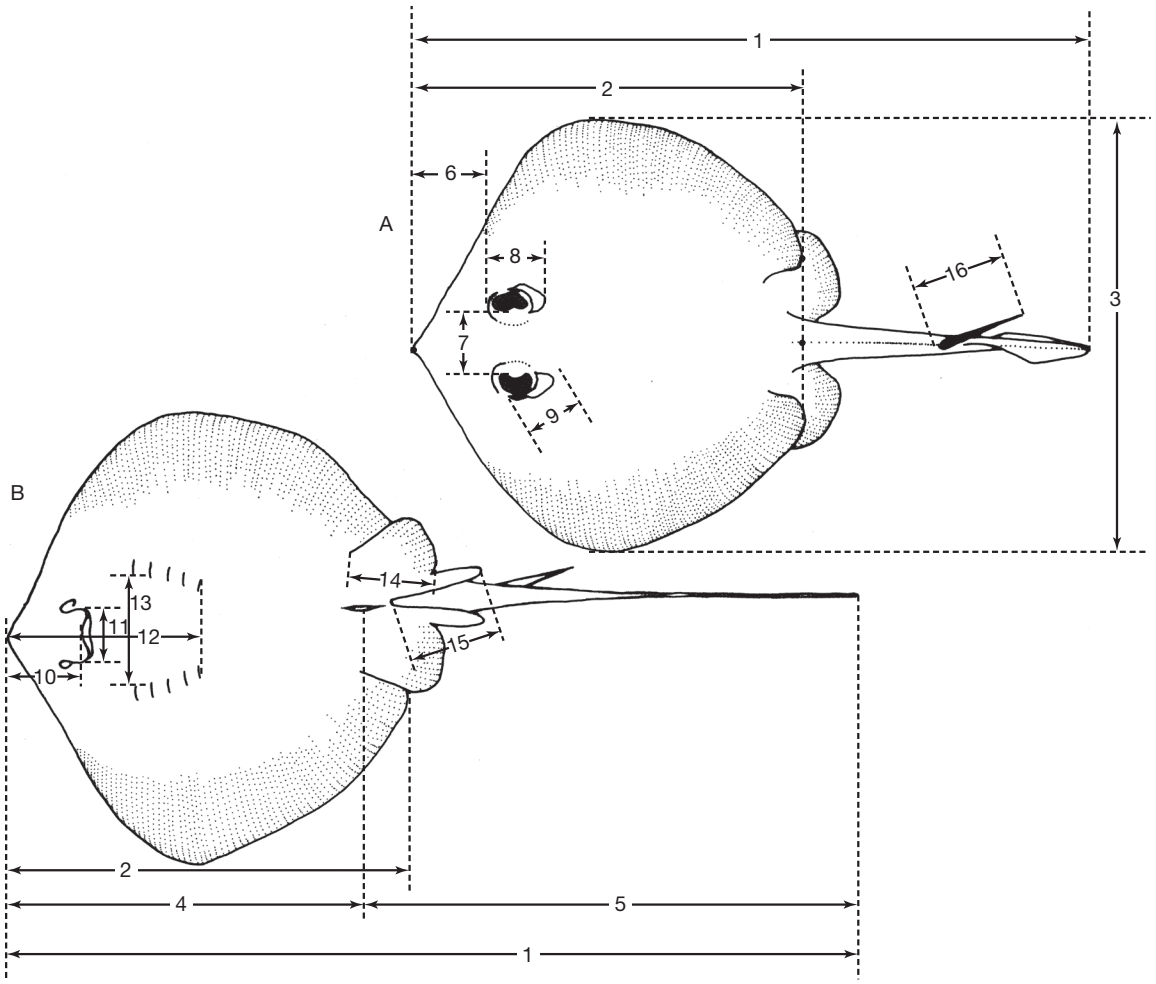


**Fig. 1** Common measurements on rays and skates.
A, dorsal view of Sepia Stingray *Urolophus aurantiacus*; B, ventral view of Wip Stingray *Dasyatis akajei*.
See text for numbers on the figures. Drawn by Yumi Kawai.

1. **Total Length; TL**

   Length from anterior most part of body to posterior end of caudal-fin or tail. Rays of the Superfamily Dasyatoidea generally do not have caudal-fin, but with tail like a wip. Remind that such tale sometimes lost their tips.
2. **Disc Length; DL**

   Length from anterior-most point of body to posterior end of pectoral-fin. Posterior end of pectoral fin is decided by point of left or right side of fin, or intersection of line between both end of pectoral fin and body medial axis.
3. **Disc Width; DW**

   Distance between distal ends of both pectoral fin.
4. **Snout-vent Length**

   Length from anterior-most point of body to midpoint of insertion of vent.
5. **Tail Length**

   Length from midpoint of insertion of vent to posterior most of caudal-fin or tail.
6. **Preorbital Length**

   Length between anterior-most points of body and orbit.
7. **Interorbital Width.**

   Shorter-most width between right and left orbits.
8. **Orbit Diameter**

   Horizontal diameter of orbit (soft part) as sharks or teleosts.
9. **Spiracle Length**

   Length between anterior and posterior most points of spiracle.
10. **Preoral Length**

    Length between anterior-most points of body and mouth.
11. **Mouth Width**

    Width between right and left ends of mouth.
12. **Snout-last gill slit length (= Head Length; HL)**

    Anterior most point to intersection of lines between both end of right and left last gill slit and body medial axis.
13. **Inter-first Gill Slit Width**

    Distance between right and left first gill slits,
14. **Pelvic-fin Length**

    Length from anterior origin to posterior tip of pelvic-fin. In some rajid skates, pelvic-fin has anterior and posterior lobes, and should be measure both of them.
15. **Clasper Length**

    Length from anterior most points of insertion of vent (cloaca) to tip of clasper.
16. **Caudal Spine Length**

    Length of exposed part of caudal spine from proximal origin to tip. Record in cases of broken and/or worn down.

# II 4 How to measure Teleostei

Teleostei have many bones, many of which can be outlined from the body surface. Fins are constituted of many foldable bony fin rays. The body surface is covered by bony scales in general. Because many of these structures become traits for counting and measurement, Teleostei have many more measurement parameters, particularly counting parameters, than do Chondrichthyes.

**Measurement method**: As opposed to measurements of Chondrichthyes, which generally use projection, in measurements of Teleostei, the distance between two points is measured by directly applying a vernier caliper to both ends of the measurement site, as shown in the figure below. Therefore, the axis of measurements is independent of the body axis, and oblique measurements are frequently used. However, this is only the method for making measurements; therefore, it is understood that sketching uses projection.

To compare measurement values between species or individuals, it is typical to calculate and examine the ratio or percentage of body parts to the standard length or the head length. In addition, the percentage of one body part to another body part, for example, the eye diameter to the upper jaw length, is also a valid examination parameter. When a graph is prepared with the vertical axis representing such a ratio or percentage of the length of a body part and the horizontal axis representing the body length, the plots are distributed horizontally if the species shows no change during growth, whereas an inclined distribution means that the rate changes with growth. If any difference is seen in the distribution range of the plots in a comparison of graphs of the same parameter between fish species, it is a valid taxonomic character, and the less the overlap is, the higher the validity is estimated.

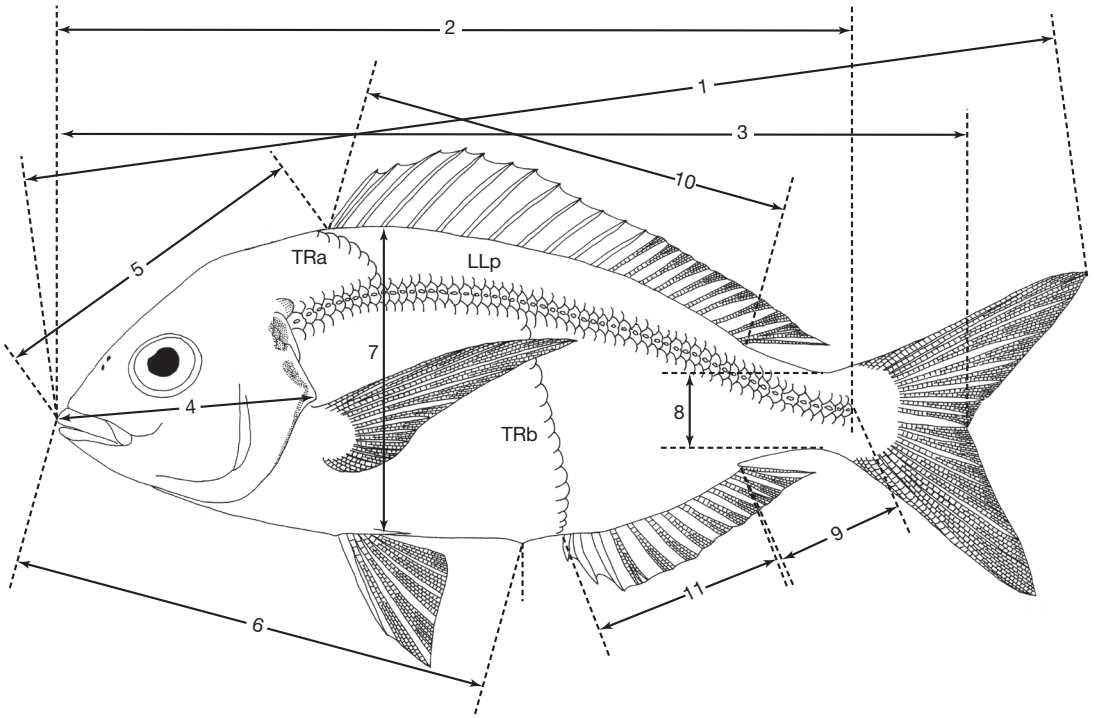


**Fig. 1** Common counts and measurements on teleosts.
See text for numbers on the figures.

1. **Total length (TL)**

This is the length from the most anterior terminus of a body to the most posterior terminus of the caudal fin. The anterior terminus may be on either the upper or lower jaw as long as it is the most anterior. For the posterior terminus of the measurement, use the most posterior terminus of either the upper or lower lobe of the caudal fin, including a thread-like extension. The official definition prescribes to measure it by compressing the caudal fin if it is a fresh fish, the caudal fin of which can be opened and closed. However, in the case of a specimen with fixed fins or of caudal fins that cannot be opened and closed, like those of fish in Scombridae, use the posterior terminus of the caudal fin extended in the normal form. Although this is a measurement valued in market and fisheries science, it is not valued very much in ichthyology because the posterior terminus of caudal fins is damaged in many cases.

2. **Standard length (SL) or body length (BL)**

This is the length from the snout tip to the terminus of the vertebral column (posterior margin of the caudal skeleton) (see Figure 4 in III-7). Because the most anterior terminus of the head varies depending on the fish species, it is not necessarily consistent with the snout tip. Even if the lower jaw protrudes more than the upper jaw (superior mouth), as in Scorpaeniformes, Serranidae, and Hemiramphidae, the lower jaw should not be included. When the edges of both jaws are at the same position (terminal mouth) or the upper jaw is at the most anterior terminus (subterminal mouth) as in Carangidae and Sparidae, measure from the most anterior terminus of the upper lip. If the mouth is located on the ventral surface (inferior mouth) as in Engraulidae and Polynemidae, measure from the snout tip located superior to the upper lip. Because the terminus of the vertebral column, the posterior terminus of the measurement, is also the base of the caudal fin, use the folding line made by bending the caudal fin hard as the terminus of the measurement. This is the parameter valued most in ichthyology as the measurement representing the size of fish.

3. **Fork length (FL)**

This is the length from the snout tip to the point where the posterior margin of the upper and lower lobes of the caudal fin meet. This is used for the measurement of fish with a crescent or fork type of caudal fin. The start point of measurement is the same as that of the standard length in 2. The posterior terminus is the most concave part at the center of the posterior margin of the caudal fin. This is regarded as an important measurement parameter as an alternative for the standard length in fish in Carangidae and Scombridae in which joint parts of the caudal fin are so rigid that it is difficult to bend the fin.

4. **Head length (HL)**

This is the length from the snout tip to the most posterior margin of the branchiostegal

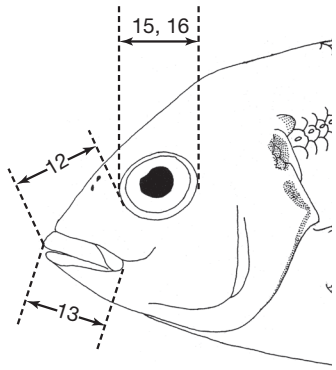


Fig. 2


Fig. 3

membrane. In some cases, the measurement terminus is the posterior terminus of the skeleton constituting the operculum. However, because it is difficult to ascertain in many cases, measure this length by including the membranous part.

5. **Predorsal length (PDL)**

   This is the length from the snout tip to the start point of the dorsal fin or the first dorsal fin.

6. **Preanal length (PAL)**

   This is the length from the snout tip to the center of the anus. Alternatively, there is also a method that measures the length to the start point of the anal fin.

7. **Body depth (BD) or body height (BH)**

   This is the height at the highest part of the body. Measure this by excluding the fleshy part and scales belonging to fins, and additionally note the measurement point by the ray number of the dorsal fin, etc. Because the position of the highest part varies among individuals, or depending on the physiological condition even in the same individual, the measurement site is often prescribed, such as the start point of the first dorsal fin and the position of the median spine of the dorsal fin.

8. **Depth of caudal peduncle**

   This is the minimum height of the caudal peduncle (from the posterior terminus of the anal fin base to the caudal fin base).

9. **Length of caudal peduncle**

   This is the length from the posterior terminus of the anal fin base to the center of the caudal fin base.

10. **Basal length of dorsal fin**

    This is the length from the start point of the dorsal fin (anterior terminus of the base of the first ray) to the posterior terminus of the base (posterior terminus of the base of the last ray). The fin membrane part following this should not be included. If the dorsal fin is separated into two or three parts, measure the size of each of them.

11. **Basal length of anal fin**

    This is the length from the start point of the anal fin to the posterior terminus of the base. The notes for this length are the same as above.

12. **Snout length**

    This is the length from the snout tip to the anterior margin of the orbit.

13. **Maxillary length or length of upper jaw**

    This is the length from the most anterior point of the upper lip (premaxillary) to the posterior terminus of the maxillary. Note that this is not the length of only the maxillary.

14. **Interorbital width**

    This is the minimum width of the bony part between the orbits when viewed dorsally. The minimum width including the fleshy part is measured in some cases.

15. **Orbit diameter (OD) ≒ eye diameter**

    This is the maximum diameter of the fleshy orbit, measured horizontally where possible. The bony orbit diameter is measured by applying a vernier caliper hard in some cases. The orbit refers to a groove in which an eyeball is located.

16. **Eye diameter (ED)**

    This is the maximum horizontal diameter of the eyeball across the cornea. This is equal to the fleshy orbit diameter in many fish.

17. **Length of fin ray**

    Normally, the maximum ray length of each fin is measured. However, a ray is specified using an ordinal number in some cases. However, in the case of the caudal fin, the soft ray at the median is usually measured.

In the case of spines, a thread-like part attaching to the edge and a part extending like a soft ray should not be included. In the case of soft rays, measure the length to the tip including these extensions. Enter the number of the ray which was measured in ( ).

## Counting method:

1. **Number of fins**

   If the dorsal fin (D) and the anal fin (A) among the vertical fins are divided longitudinally, count them as the first dorsal (anal) fin, the second dorsal (anal) fin, etc.

2. **Number of fin rays**

   The number of rays constituting each fin is the most basic and important countable trait for the identification of the species. At the time of the counting, you need to have sufficient knowledge of the basic structure.

   There are two kinds of Teleostei fin rays formed by any type of bony material, the non-paired spine at the median of the fin (Figure 4A) and the left-to-right paired soft rays (Figure 4B and C). Moreover, another difference between the types is that the soft rays have many transverse segments whereas spines lack them. In addition, when the soft rays are observed from the side, branched soft rays (Figure 4B) originating from a base and ramifying to several branches in the middle, and unbranched soft rays (Figure 4C) that have no branching to the tip (Figure 4C) are found. To distinguish such ray types on small specimens, you need to observe them under a stereomicroscope with transmission light. Even in the case of a large specimen, it is better to observe them with a transmission light using a fluorescent lamp or sunlight. In the case of even larger specimens, the fins of which are covered by a thick fin membrane and/or have many black pigments making ray identification difficult unless modified, compress them hard with your finger pad, or if this does not work, somewhat peel off the fin membrane.

   When counting fin rays, their bases are supposed to be counted. However, the counting of branched soft rays requires particular care. An important rule is that the last two soft rays adjacent at the base should be regarded as a branched soft ray in the dorsal and anal fins. This is based on the fact that such apparently two soft rays are supported by only one bone (pterygiophore). Do not add the number of the rudimentary ray located at the start of the dorsal fin and top and bottom

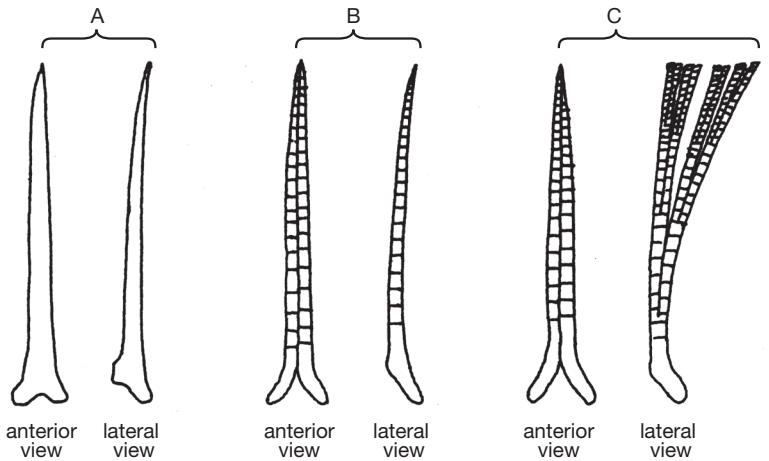


**Fig. 4** Skeletal fin rays of teleosts.
A, spine; B, unbranched soft ray; C, branched soft rays.

of the caudal fin base to the number of rays. In the caudal fin (see III-7-5 and Figure 4 in III-7), only the number of all branched rays is described separately in the upper and lower lobes in some cases, and in other cases, soft rays of both the upper and lower lobes reaching nearly the posterior terminus are counted and mentioned as the number of principal rays separately in the upper and lower lobes. Generally, the number of principal rays is equal to the number of branched soft rays plus an unbranched soft ray in the upper and lower lobes.

The counting of rays of paired fins uses fins on the left side except in the case of damage and the like. Because the starting part of the pectoral fin ($P_1$) has a rudimentary ray and/or an unbranched ray in some cases, not only the number but also the difference in the condition is important in some cases. Regarding pelvic fins (pelvic fin; $P_2$), because a spine is close to the first soft ray in some cases, you must count it by separating them using a needle, etc.

The number of rays counted according to the criteria above is represented as follows:

Represent spines by capital Roman numerals (I, II, …V, … X, see p. 40), unbranched soft rays or rudimentary rays by lower case Roman numerals (i, ii, … v, …), and branched soft rays by Arabic numerals (1, 2, 3, …). In addition, represent the intervals between multiple fins separated in a vertical fin by a hyphen (-), and the border between spines and soft rays in a fin by a comma (,). The ordinal number of a fin and the number of spines or soft rays of a fin are expressed by the following fin formulas.

a) If a vertical fin composed of only soft rays is clearly separated:

D. 13-18-16; A. 21-27 (Figure 5A-example of Pacific cod *Gadus macrocephalus*)

b) If the dorsal fin is completely or nearly completely separated, and any vertical fin composed of both spines and soft rays is included:

D. XIII-1, 11; A. III, 7; P2. I, 5 (Figure 5B-example of Korean rockfish *Sebastes schlegeli*)

**3. Number of scales in the lateral line (LL)**

All scales arranged on the lateral line should be counted. However, if any scales are on the caudal fin, exclude them.

**4. Number of pored scales in the lateral line (LLp)**

Count all pored scales by excluding the poreless scales among the scales arranged on the lateral line. Exclude scales on the caudal fin.

**5. Scales in a longitudinal series**

In cases of lateral line not exit, running far from mid sagittal line, or breaking, scales in a longitudinal series, excluding on caudal fin, are counted, from pectoral girdle to the end of vertebrae.

**6. Number of transverse scales; TR**

**a) Scales above lateral line; TRa**: vertical number of scales on a line from base of dorsal fin to lateral line. Lateral line scale is not included. In some cases this count starts from medial spine of dorsal fin etc. with special definition.


**Fig. 5** Skematic figures of teleosts.
A, Pacific Cod *Gadus macrocephalus*. B, Korean Rockfish *Sebastes schlegelii*.

b) **Scales below lateral line; TRb**: vertical number of scales on a line from base of anal fin to lateral line. Lateral line scale is not included.

Lateral line scales and transverse scales are expressed by scale formula as below.

Scales: 7+70+11

This formula means TRa is 7, LL is 70, and TRb is 11.

**7. Predorsal scales**

Count of scales on mid dorsal line from anterior most of dorsal fin base to front.

**8. Number of gill rakers; GR, see Figure 1 in III-2.**

Gill rakers are aligned in two lows, and the outer low is longer. Generally the count is taken from the outer side row of 1st gill arch, but sometimes count only on lower limb of arch with remarks.

Counts on upper limb and lower limb are joint by "+" and generally the raker on the joint is counted on lower raker as 8+12. However sometimes counted and expressed as 8+1+11 as for "Figure 2 in III-2".

Rakers on upper limb have basal structure for fordable to ventral angle, and those of lower limb have such to dorsal angle. Also the raker on the angle is fordable to both angles.

**9. Number of branchiostegals; Br**

Number of limb-like bones under head, appearing when mouth closing.

**10. Number of pyloric caeca**

Count number of all tips, except in cases of branching.

**correspondence of Arabian and Roman Numbers**

| Arabian Numbers | Roman Numbers | Arabian Numbers | Roman Numbers |
|---|---|---|---|
| 1 | I | 21 | XXI |
| 2 | II | 22 | XXII |
| 3 | III | ··· | ··· |
| 4 | IV | 28 | XXVIII |
| 5 | V | 29 | XXIX |
| 6 | VI | 30 | XXX |
| 7 | VII | 40 | XL |
| 8 | VIII | 50 | L |
| 9 | IX | 60 | LX |
| 10 | X | 70 | LXX |
| 11 | XI | 80 | LXXX |
| 12 | XII | 90 | XC |
| 13 | XIII | 98 | IIC |
| 14 | XIV | 99 | XCIX |
| 15 | XV | 100 | C |
| 16 | XVI | 101 | CI |
| 17 | XVII | 126 | CXXVI |
| 18 | XVIII | 200 | CC |
| 19 | XIX | 300 | CCC |
| 20 | XX | 400 | CD |
| | | 500 | D |