## 1. INTRODUCTION

This catalogue includes taxonomic references to all the known species of the family Sillaginidae. At present, 3 genera, 3 subgenera and 31 species are recognised (Fig. 1). The taxonomy of this family is approaching stability with perhaps only a few undescribed species remaining (McKay, 1985; 1989). The family is widespread throughout the Indian Ocean and the western Pacific Ocean. All species are inshore fishes with a few species found in deeper water to about 180 m. They are commonly taken by net and hook-and-line in shallow sandy bays and frequently enter estuaries. All sillaginids are of small to moderate size and their flesh is very white, tender, and of exceedingly delicate flavour, making them esteemed table fish throughout their range. Steamed whiting fillets are ideal as food for invalids and infants because they contain very little oil and are easily digested.

The family is well represented in Australian waters and supports valuable commercial fisheries in many countries (Table 1). Their importance as food fish is perhaps underestimated because in many areas they are taken by small-scale fishermen using seine net and hook-and-line in large quantities and do not necessarily enter records of commercial catches. In Australia the "whitings" are among the most common beach and estuarine fishes caught by recreational fishermen who, although hoping to land large sport or food fish, instead are often rewarded for their efforts by a bag of sillago.

Sillaginids are easily identified as a family due to their similarity of shape and general uniformity of coloration. They have an elongate body, a long conical snout, a long soft dorsal and anal fin, and the lower part of the preopercle is horizontal. This external morphological similarity however, has led

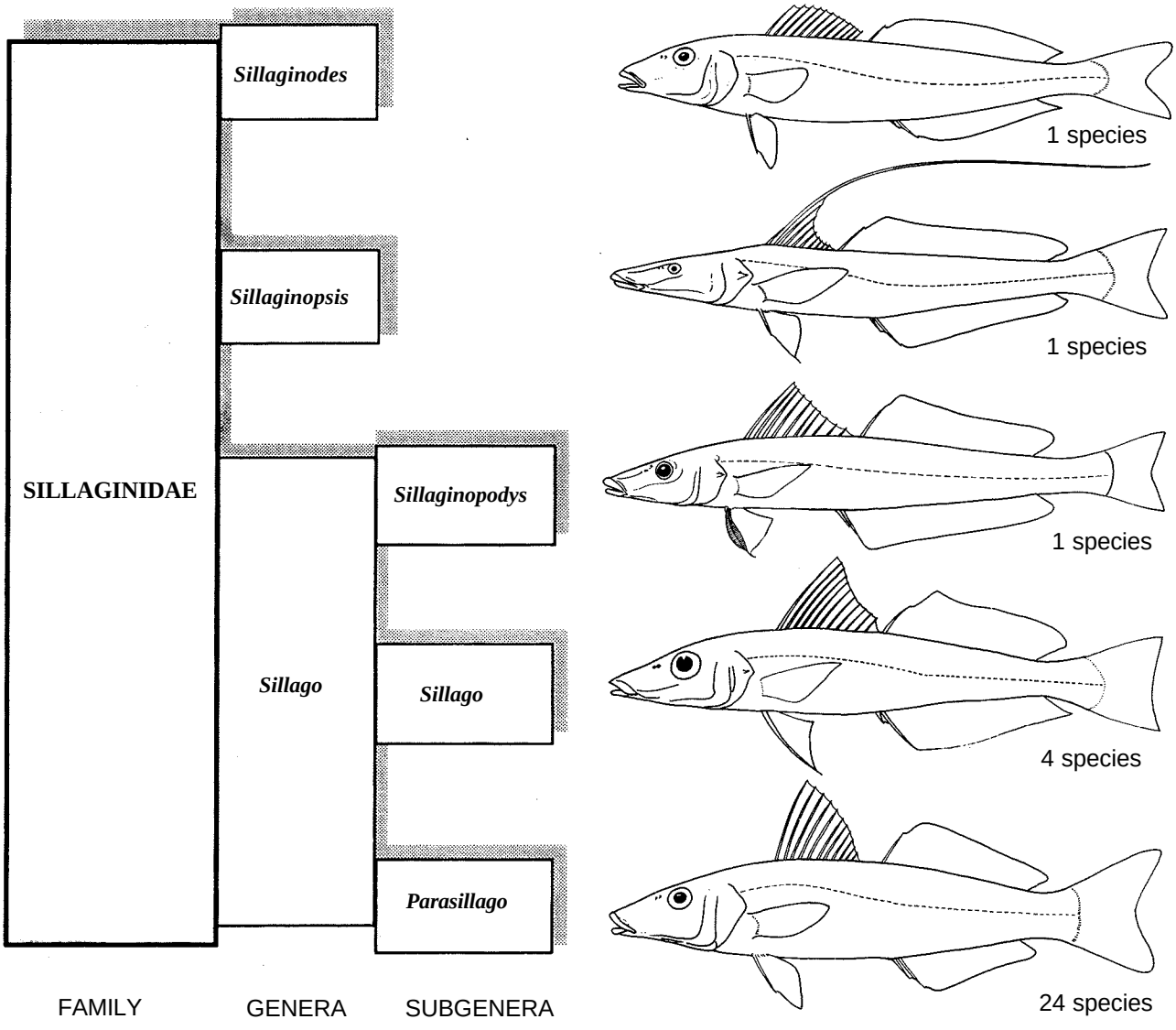


**Fig. 1 Classification of the family Sillaginidae**

**Table 1**
**Sillaginid catches in world flsheries in metric tons (F = FAO estimates)**

| COUNTRY | FAO Area | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 |
| Pakistan | 51 | 486 | 624 | 228 | 312 | 350 | 310 | 290 | 280 |
| W. Australia | 57 | 1 991 | 1 965 | 2 071 F | 2 918F | 3 725F | 3 909F | 3 267F | 4 156F |
| Malaysia | 57 | 573 | 448 | 353 | 386 | 386F | 386F | 390F | 390F |
| Thailand | 57 | 247 | 293 | 884 | 1 006 | 846 | 1 048 | 1000F | 960F |
| Korea | 61 | 998 | 289 | 160 | 709 | 103 | 160 | 141F | 140F |
| N.E. Australia | 71 | 1 | - | - | - | - | - | - | - |
| Malaysia | 71 | 448 | 566 | 474 | 440 | 440F | 440F | 440F | 440F |
| Philippines | 71 | 10 091 | 8 354 | 9 600 | 9 866 | 12 178 | 9 729 | 10 326 | 10 478 |
| Singapore | 71 | 84 | 106 | 107 | 116 | 95 | 137 | 107 | 128 |
| Thailand | 71 | 1 386 | 2205 | 3 063 | 3 123 | 3 373 | 3 678 | 4 000 | 3 820F |
| S.E. Australia | 81 | 1 265 | 911 | 960F | 1 353F | 1 727F | 1 812F | 1 514F | 1 926F |
| Species total | | 17 570 | 15 761 | 17 900F | 20 229F | 23 223F | 21 609F | 21 475F | 22 718F |

Source: FAO Fisheries Statistics, 1992.

to much confusion in their specific identification and many true species have been concealed in the synonymy of wide ranging species. For example, the separate identities of the three trumpeter sillaginids *Sillago maculata, S. aeolus* and *S. burrus* were only recognised in 1985 and are elevated to full species in this work. Similarly, the specific identities in the *Sillago bassensis - S. flindersi* complex in southern Australia was only determined by the discovery of coexisting populations of both species and the application of electrophoresis of muscle and liver enzymes (Dixon et al., 1987) following their separation on the basis of vertebral counts and small differences in coloration by McKay (1985). In the fish market it is not uncommon to find mixed consignments of two or more species although experienced fishermen are seldom confused.

It is often difficult to obtain accurate catch statistics for some species of sillaginids because of proximity of similar species and ecological differences in coloration of the same species. The species of sillaginids trawled in slightly deeper waters offshore are frequently different from those species taken in nearby inshore areas by beach seine or castnet. In contrast to shallow coastal marine populations of the same species, estuarine populations may be darker in coloration with black edging to the caudal fin, snout, and sides of the body. These problems are further discussed in section 1.4.

The biology of many species is unknown and in general, sillaginids are poorly researched. Only the commercially important species have been investigated, and then, very inadequately. In recent years this family has been recognised as a superior candidate for aquaculture in estuarine areas.

The literature on sillaginids is not extensive. An effort has been made to include most of the pertinent literature on the family. References to the parasites of sillaginids are generally omitted.

### 1.1 Habitat and Biology

Sillaginids are bottom feeding, schooling, carnivorous, coastal fishes, inhabiting open sandflats, muddy substrates, and nearshore along beaches subject to moderately strong wave action. Some species enter estuaries and even penetrate fresh water for considerable periods, despite the absence of renal corpuscles in the kidney (Nadkarni, 1963). Shallow water of a few centimetres may be inhabited by juvenile sillaginids, especially in the vicinity of mangroves or seagrass beds, and other species are trawled to depths exceeding 180 m.

The sharp snout of sillaginids facilitates burrowing in the sand in search of worms, crustaceans, and small molluscs. In muddy substrates sillago drive the snout deep into the bottom to feed on worms. The feeding grounds may be identified in shallow water due to the conical depressions left in the surface. *Sillago analis* has been observed to plough up the substrate in search of prey. Food items commonly reported for sillaginids are benthic and epibenthic organisms, principally polychaete worms, small shrimps, amphipods, small crabs, fish and filamentous algae.

These fishes are capable of burrowing completely into the sand to escape predators or to dodge the seine net. Fishermen sometimes walk behind the hauled seine to feel with their bare feet for sillaginids buried under the sand after the leadline of the net has passed; for this reason they are frequently called sandborers.

The greatly expanded sensory system of the lower part of the head and the swollen sides of the snout are apparently employed in the location of prey below the substrate. This highly developed sensory canal system, particularly the lachrymal and the ventrally directed subpreopercular canals may receive vibrations from prey organisms in the sand. The filamentous tip of the first pelvic-fin ray which many species maintain in contact with the substrate, is an additional potential sensory receptor. In *Sillago chondropus,* this filament has been modified to form a sled-like runner. The curious tubular extension from the lower part of the swimbladder to the ventral wall of the abdomen may also function as a receptor for sound or vibration, conveying stimuli to the swimbladder in the manner of an external ear. The complex swimbladder undoubtedly receives sound and transmits this to the auditory capsules in a number of species having anterior extensions from the swimbladder to the skull. The function of the lateral extensions and the post abdominal extensions of the swimbladder in some *Sillago* species has not been determined. This family does not have sonific (drumming) muscles associated with the swimbladder and therefore this organ is unlikely to produce sound as in the related family Sciaenidae.

According to Leis and Trnski (1989) the eggs of sillaginids are small (0.6 to 0.8 mm), spherical and pelagic. The larvae can be distinguished by a myomere count of 33 to 39, an elongate body, a gas bladder that is not visible during daylight, a gut that is initially straight and coils during flexion, very reduced head spination, dorsal and anal fin with similar numbers of rays, and the pigmentation pattern (Fig. 2).

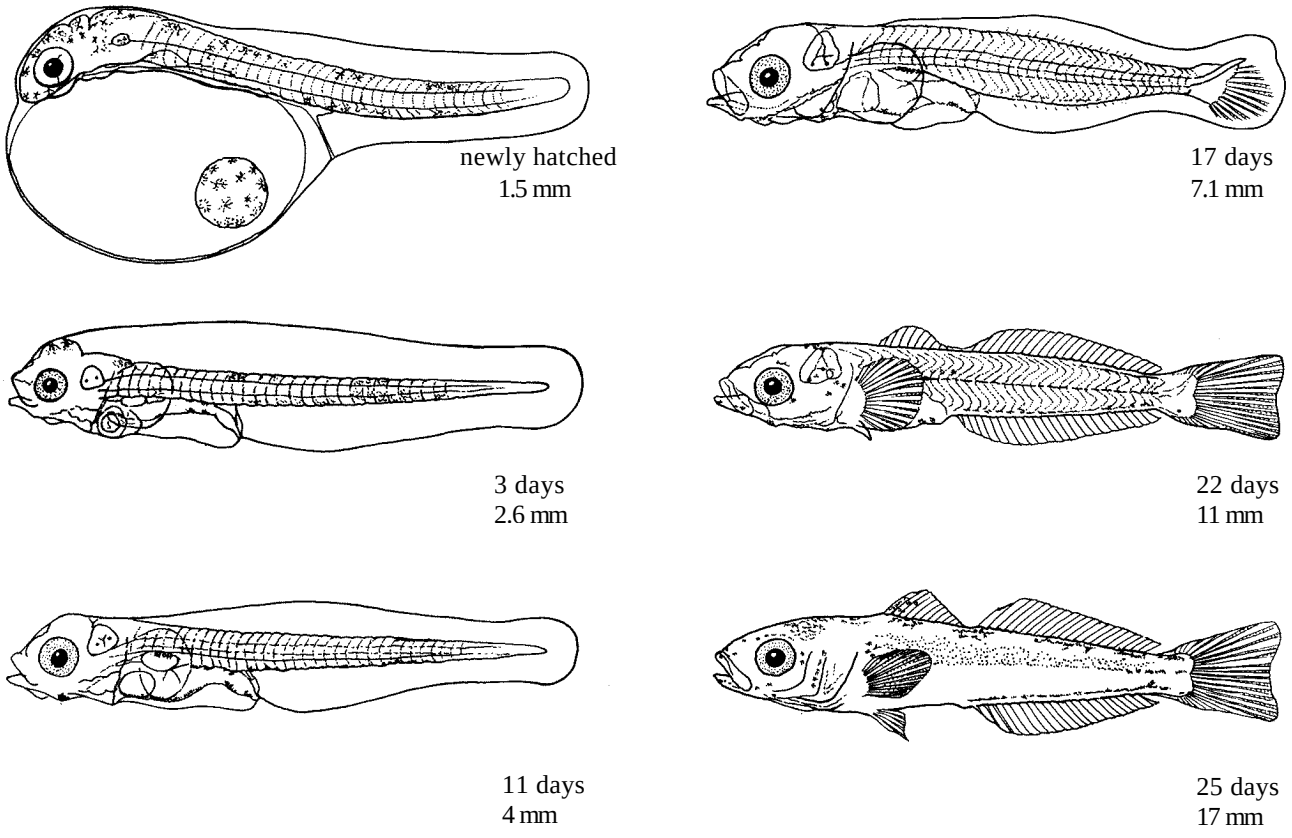


**Fig. 2 Larval development *of Sillago japonica* (after Oozeki et al., 1992)**

### 1.2 Fisheries

Small but locally important fisheries exist throughout the range of the family. Sillagos are benthic fishes and are fished on the bottom. The fishes generally inhabit inshore coastal waters and are mostly taken by beach seines. In deeper water, trawlers take considerable quantities using beam trawl and otter trawl nets. As all species consume a variety of food items, many sillaginids are taken by line baited with worm, shrimp, and fish. Some of the most popular baits are soldier-crabs *(Mictyris),* worms and yabbies *(Callianassa).* Some species are taken by line in the surf zone and in remarkably shallow water over sandflats and in the sandy channels of estuaries. Some marine species, such as *Sillago sihama,* enter fresh water (Günther, 1861: 221) and may remain in the estuary for considerable periods.

Large schools of sillago are observed feeding in shallow water early in the morning and late afternoon, usually working against the tide. In the middle of the day they may move into deeper water and are not as readily taken by line. Experienced fishermen take care not to make undue noise on the beach or in the boat as the fish are regarded as sensitive to noise and in some small estuaries are disturbed by outboard motors to the extent that schools may avoid entering such areas. The fish are also sensitive to movement, especially shadows; castnet fishermen employ the tactic of paddling into the sun toward a school and drifting slowly upon it before casting the net. Estuarine castnet fishermen frequently work in pairs or trios, all casting at the same time or one after another in quick succession.

Sillaginids are sought after by recreational fishermen who take considerable quantities in Australian waters. Pollock (1980) estimated the annual catch by net fishermen in southeast Queensland during the 1980-81 season at 240 t. He estimated that recreational anglers caught 25 t of *Sillago ciliata* at nearby Bribie Island in the same season. Catches by angling club members at the latter location has decreased due to heavy fishing pressure, but the recreational catch in Moreton Bay shows no change in abundance (Pollock and Williams, 1983). Catches from commercial fisheries are reported from 7 countries (Table 1). During the period 1983 to 1990 overall catch was relatively stable with moderate increases reported in Australia and Thailand.

Sillaginids are important in estuarine aquaculture in India, Japan and Taiwan (China). Their potential for aquaculture in Australia has been recognised and research is under way on *Sillago ciliata* and *Sillaginodes punctata.*

### 1.3 Systematics and Zoogeography

The Sillaginidae are related to the family Percidae, but their sister group is yet to be determined as this family possesses a number of primitive characters. The shared derived characters (synapomorphies) of the Sillaginidae are the swimbladder duct to the ventral abdominal wall, the haemal funnel, the lower part of the preopercle is bent inward, and the highly cavernous skull. The otolith morphology is characteristic of the family. See McKay (1985) for further information regarding the systematic affinities of the Sillaginidae.

The most plesiomorphic genera of the family are the monotypic *Sillaginodes* and *Sillaginopsis* which lack the duct from the ventral surface of the swimbladder. The genus *Sillaginodes* is perhaps the most plesiomorphic, whereas *Sillaginopsis* and to a lesser extent *Sillago (Sillaginopodys) chondropus* are specialized bottom resting species that have the swimbladder reduced or even absent.

All are inshore species frequenting the sandy or silty substrates of the continental shelves of the Indo-Pacific region. The oceanic islands of the Pacific, including Fiji, Tonga and Samoa lack sillaginids. The family is found in New Caledonia and to Santa Cruz Island, but not southward to New Zealand where they are represented as fossils in Eocene and Lower Miocene deposits (Schwarzhans, 1984, otoliths only).

The origin of the Sillaginidae was probably in the Tethys Seaway during the Lower Eocene. During the Upper Eocene a shallow sea-way broke through south of Tasmania and this family colonized southern Australia. During the Miocene many Indo-Pacific sillaginids had become endemics (Schwarzhans, 1984). Fossil otoliths are known from Germany and France from the Upper Oligocene to the Lower Miocene. The family became extinct in New Zealand, probably during the Middle Miocene.

### 1.4 Problems of Identification

The identity of the species in this family has been considerably confused in the literature. The main reason for this problem is the great similarity in shape and coloration among the species. Many species are of uniform colour or external morphology. The juvenile coloration of *Sillago ciliata* and *S. analis* resemble the juveniles and adults of *S. maculata* in having a series of dark blotches and bars on the body. This juvenile coloration persists until the fish reach 10 cm, but in some specimens of *S. analis* it may still be discernible at 20 cm, or appear briefly on capture. The characteristic black spot at the

base of the pectoral fin in *S. ciliata* and *S. maculata* may not appear until a standard length of about 5 cm is attained. Juvenile *S. maculata* can be distinguished from those of *S. ciliata* in having clearly defined dark round blotches anteriorly. A key to the juveniles of *S. maculata, S. ciliata* and *S. analis* is provided by Weng (1983). Another source of confusion is the possession of a very similar colour pattern by quite distinct species. This led to the inclusion of *S. burrus* and *S. aeolus* in the synonymy of *S. maculata* and confusion between *S. bassensis* and *S. flindersi.*

The resolution of such species groups was possible only when the shape of the swimbladder and the division of the vertebrae into abdominal, modified (haemal arch) and caudal components was taken into account (McKay, 1985). The field identification of sillago remains difficult. Where vertebrae counts are required it is possible to place fresh or frozen sillaginids into cold water and bring the fish to a gentle boil and then cool quickly with cold water and deflesh carefully. The vertebral column can be kept intact (with a little practice) and air dried for storage or preserved in alcohol. The shape of the swimbladder can be studied in fresh specimens, but is more readily dissected after fixation in formalin or exposure to undiluted alcohol for several days. Specimens are dissected by a cut down the ventral surface from the isthmus to a few millimetres before the vent, thence circumventing the anus and urogenital aperture and cutting along the base of the anal fin to the vertebral column to expose the full length of the swimbladder; the gills and viscera are removed and the thin peritoneum covering the swimbladder is pulled away with blunt forceps. Care should be taken not to damage any anterior or lateral appendages nor break the tubular process arising from the ventral surface of the swimbladder to the abdominal wall near the urogenital aperture. This tubular, blind, duct-like process is not connected to the gut (Fig. 3).

In addition to the key to the genus *Sillago,* which should be used for all specimens where locality of capture is unknown or doubtful (market material), area keys are provided to facilitate identification. **The area keys may contain species not yet recorded from the area.** All identifications made from the illustrated keys should be confirmed by consulting the diagnoses in the species accounts. Full descriptions of all species can be obtained by consulting the references cited in the literature provided for each species. Unfortunately, most of the earlier publications containing accounts of the family Sillaginidae are unreliable. In many instances the type specimens were not examined and valid species were incorrectly placed into synonymy based on inadequate descriptions. Misidentifications abound in the literature due to the neglect of useful internal characters.

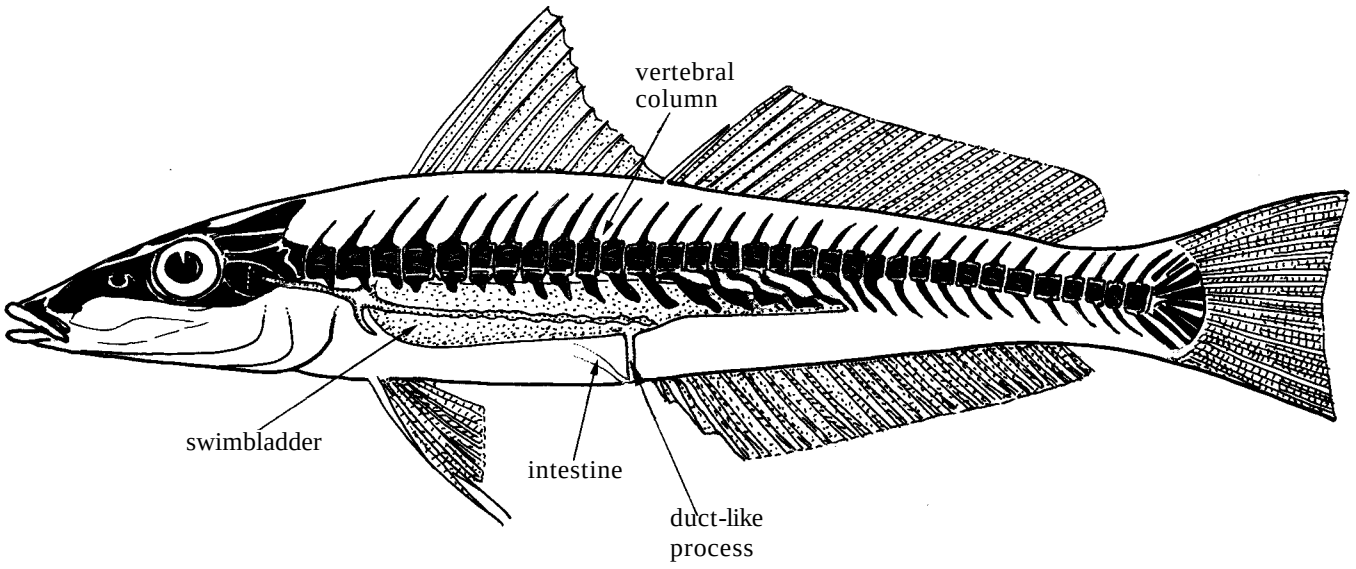


**Fig. 3 Swimbladder in relation to the vertebral column**

### 1.5 Illustrated Glossary of Technical Terms, Measurements and Counts

A typical sillago is shown in Fig. 4. Note that the snout and head measurements are taken from the tip of the snout and not the upper lip which is frequently depressed or sometimes protracted in alcohol preserved specimens.

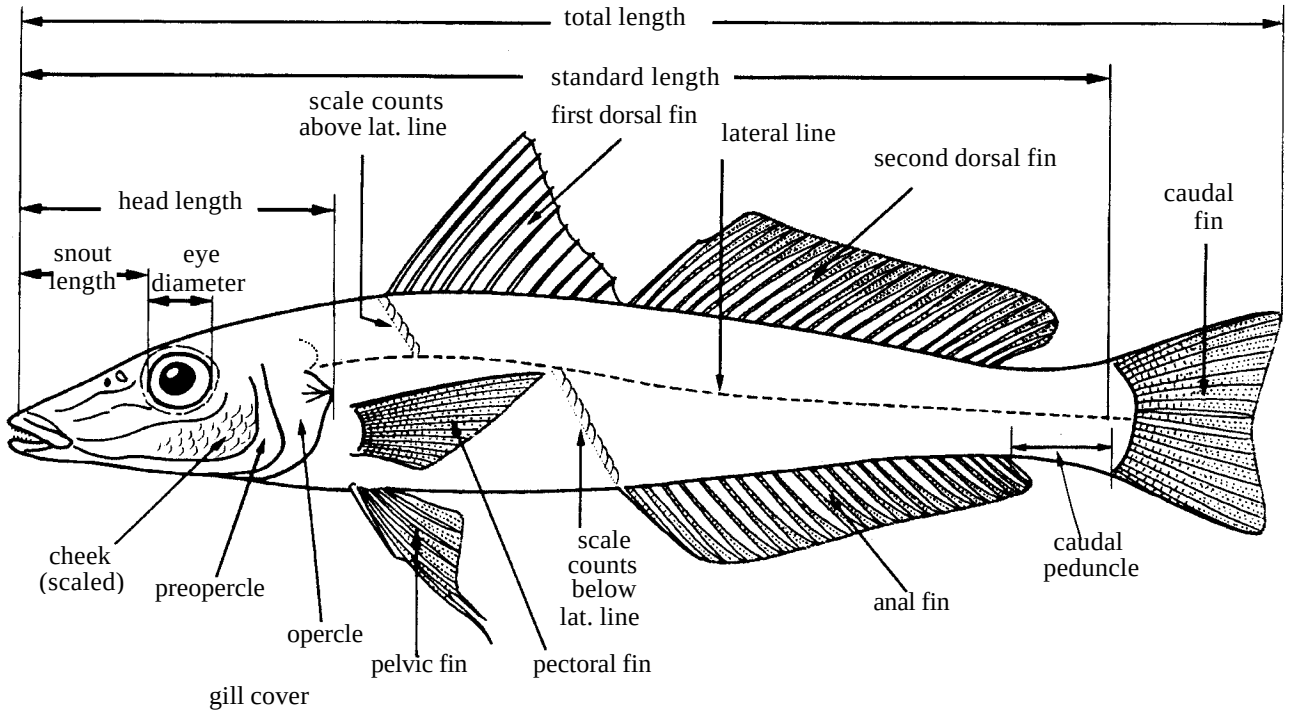


**Fig. 4 External morphology and measurements**

**Anterior** - The front portion; the opposite of posterior.

**Anus** - External opening of the intestine, situated on the ventral midline of the body (Fig. 4). Also known as vent.

**Bar** - An elongate colour marking with vertical orientation, the sides of which are usually more or less straight.

**Blotch** - A pigmentation, irregular in shape.

**Caudal peduncle** - The narrow end of the body between the posterior basal end of the anal-fin base and to the base of the caudal fin (Fig. 4).

**Cheek, cheek scales** - The area between the lower part of the eye and the lower limb of the preopercle. The scale rows may consist of ctenoid, cycloid, or both kinds of scales, frequently the cycloid scales are above and anterior to the ctenoid scales if both are present (Fig. 4).

**Ctenoid scales** - Scales with small spiny projections at the posterior end (Fig. 5a).

**Cycloid scales** - Scales without spiny projections at the posterior end (Fig. 5b).

**Dorsal** - Toward the back or upper part of the body.

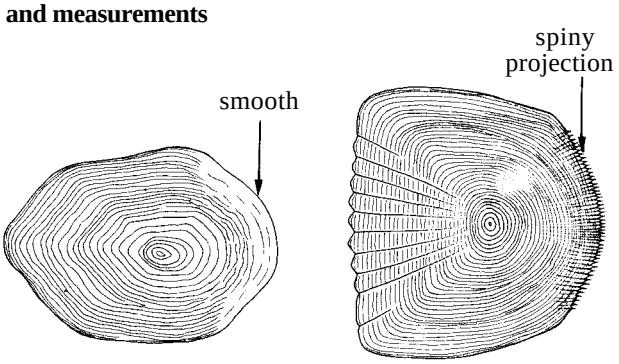


**Fig. 5 Scales**

**Dorsal fin** - A median fin along the back. Sillaginidae have two dorsal fins; the first is supported by spinous rays while the second has one spinous anteriorly and soft rays posteriorly (Fig. 4).

**Eye diameter** - The diameter between the fleshy margins of the orbit (Fig. 4).

**Gill arch** - The J-shaped structure under the gill cover that bears the gill filaments and normally the gill rakers.

**Head length** - The distance from the most distant end of the opercle to the snout and not the upper lip which is frequently depressed or sometimes protracted in alcohol preserved specimens (Fig. 4).

**Hyaline** - Transparent.

**Lateral line** - A series of pored or tubed scales forming a raised line along the side of the body (Fig. 4). The **lateral-line scales** are counted from the most anterior pored scale near the upper end of the operculum to the base of the caudal fin which is detected by the crease which results from folding the fin forward. There are often one or more tubed scales that continue onto the caudal fin, posterior to the base of the caudal fin; these are not included in the count of lateral-line scales.

**Medial** - Toward the middle or median plane of the body; opposite of lateral line.

**Opercle** - The large bone forming the upper posterior part of the **gill cover** (Fig. 4).

**Orbit** - The bony border surrounding the eye. Measurements or distances which involve the orbit do not include the fleshy rim of the orbit. It is sometimes necessary to slightly squeeze the rim of the orbit to exclude this fleshy portion.

**Pectoral fin** - The fin on each side of the body immediately behind the gill opening (Fig. 4).

**Pelvic fin** - One of a pair of juxtaposed fins ventrally on the body below the pectoral fins (Fig. 4).

**Posterior** - The rear or hind portion; the opposite of anterior.

**Preopercle** - Bone on the cheek in front of the opercle and forming the front part of the **gill cover** (Fig. 4).

**Rays** - The rigid structures that support the fin; **soft rays** are segmented, and flexible; **spinous rays** are stiff, unsegmented, and support the anterior portion of the anal and dorsal fins. The number of spines are designated by roman numerals (I, II, III, IV, V ...) and the number of soft rays are designated by arabic numerals (1, 2, 3, 4, 5 ...). In the Sillaginidae, the last dorsal- and anal-fin pterygiophore supports two rays that are counted as a single element in this work. The anal spines are invariably two in number, the first is often quite small.

**Scales above and below lateral line -** A transverse series of scale rows; scales below lateral line are counted from the origin of the anal fin in an oblique row to the lateral-line scale, but not including the lateral-line row; scales above the lateral line are counted from the origin of the dorsal fin in an oblique row to the lateral-line scale, but not including the lateral-line row (Fig. 4).

**Snout length** - The distance from the anterior "fleshy" margin of the eye to the snout (Fig. 4) and not to the upper lip which is frequently depressed or sometimes protracted in alcohol preserved specimen.

**Spot** - A small, rounded regular pigmentation.

**Stripe** - An elongate colour marking with a horizontal or length-wise orientation, the sides of which are more or less straight.

**Standard length** - The straight line distance from the tip of the snout to a vertical line passing through the base of the caudal fin (taken to be the point of flexure of the caudal fin) (Fig. 4).

**Swimbladder** - A gas filled sac in the dorsal part of the body cavity. In Sillaginidae the swimbladder is important in classifying many forms and the swimbladder may be absent, poorly developed, or highly complex with various extensions (Figs 3, 6).

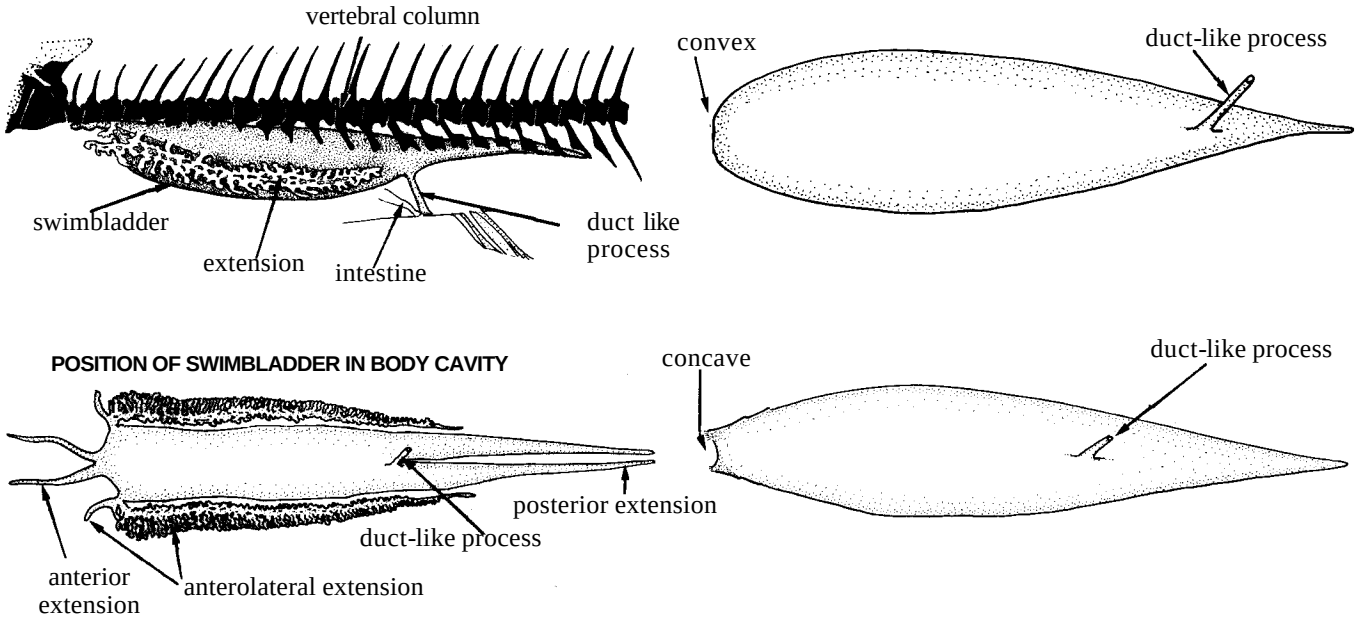


**Fig. 6 Swimbladders**

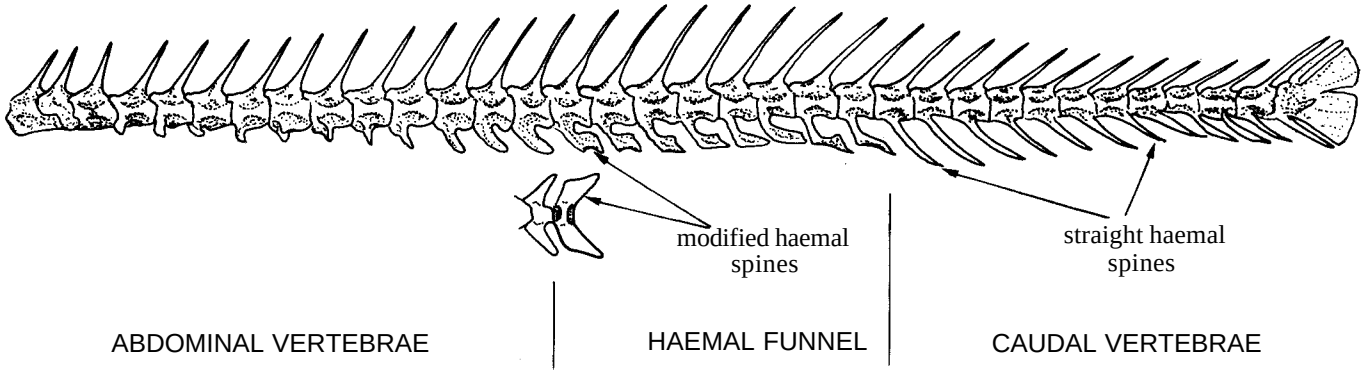


**Fig. 7 Axial skeleton of *Sillago***

**Ventral** - Toward the lower part of the body; the opposite of dorsal.

**Vertebrae** - The axial skeleton is divided into 3 sections; the **abdominal vertebrae** are counted from the base of the skull to the first haemal arch (the arch that appears as a canal under the circular centrum and is formed above the fused proximal ends of the haemal spines of caudal vertebrae); the **modified vertebrae** overlay the swimbladder (**haemal funnel** or **haemal vertebrae**); the **caudal vertebrae** bear a **haemal spine** (the spines that extend ventrally from the centrum of a caudal vertebrae) ventral to the vertebral centrum (urostylar vertebrae included) (Fig. 7).

### 1.6 Plan of the Systematic Catalogue

A family description is given, followed by a key to genera. The species accounts are arranged alphabetically by genera and species. Each genus is introduced with its type reference and synonyms. The information pertaining to each species is arranged in the order listed below:

**(1)** **Scientific Name:** The reference for the original description and type locality is given.

**(2)** **Synonyms:** All invalid names, combinations and misidentifications that have been applied are referenced. References are provided here since the bibliography of this family is not extensive.

**(3)** **FAO Names:** The FAO English name is considered the standard to be used for fishery purposes. This should avoid confusion which can be caused due to the existence of multiple names for the same species or the same name for several species. The FAO name is not intended to supplant the use of local names but rather, to serve as a worldwide reference.

**(4)** **Diagnostic Features:** Distinctive characters of the species are given as an aid for identification, accompanied by useful diagrams. These diagnoses should be consulted to confirm species identified using the illustrated keys.

**(5)** **Geographical Distribution:** The general geographic range is given in the text and illustrated on a map. The map shading includes known areas of occurrence and intermediate areas between locality records where a species is expected to be found.

**(6)** **Habitat and Biology:** Information on habitat, behaviour, food, feeding habits and reproduction is given.

**(7)** **Size:** The maximum known total length or standard length is given.

**(8)** **Interest to Fisheries:** General information on the extent, type of fishery and utilization is given. Detailed fisheries data are unavailable for many species as species are rarely separated in fishery statistics.

**(9)** **Local Names:** These are given where published names are available. Often, a single local name is applied to several species.

**(10)** **Literature:** Recent references containing illustrations that supplement those contained in this catalogue are given. The most important references containing full bibliographies and descriptions are provided. It is stated if an incorrect name is given in the reference. Where incorrect scientific names are commonly applied a more comprehensive bibliography is given.

**(11)** **Remarks:** Useful information that is not covered in the previous paragraphs is included here.