# 3. Taxonomy and field techniques for identification and available regional guides

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## 3.1 SHARKS, RAYS AND CHIMAERIDS: WHAT ARE THEY AND HOW ARE THEY CLASSIFIED?

### 3.1.1 General classification

Sharks, rays and chimaerids comprise the class Chondrichthyes, which are separated from the other major class of living fishes, the Osteichthyes (comprising about 95% of the modern fish fauna) in having a skeleton made entirely of cartilage (the Osteichthyes have a bony skeleton). All chondrichthyans also have small tooth-like denticles on their skin and internal fertilization by male claspers (modified pelvic fins). About 57% of them give birth to live young, the remainder lay large eggs contained in a horny capsule.

The chondrichthyans are divided into elasmobranchs, the sharks, skates and rays, and holocephalans or chimaeras. The elasmobranchs have 5-7 gill openings on each side of the head, a body largely covered by dermal denticles and teeth that are continuously replaced and embedded in the gums. Chimaeras have a single gill opening, a largely naked skin and teeth that are fused into plates that grow with the animal. They have a large head, large pectoral fins, two dorsal fins (the first preceded by a long spine), a weak caudal fin that may have a long terminal filament and they may have an anal fin that is barely separated from the caudal fin. Adult male chimaerids have extra claspers on their head and in front of the pelvic fins. Currently, there is no uniform agreement on the higher classification of the chondrichthyans, and there are many alternate schemes. This chapter follows Compagno (1999a, b) and McEachran, Dunn and Miyaka (1996), although with some differences, in separating the elasmobranchs into two superorders of sharks (selachei), the Squalomorphii and Galeomorphii that together contain the eight orders of living sharks, and one superorder of batoids (Rajomorphii) with six living orders. Sharks are mostly fusiform in shape (a few are ray-like), have one or two dorsal fins, (sometimes with a spine at their origin), usually have an anal fin, and most have a well-developed caudal fin. Rays are derived from sharks and have become dorso-ventrally flattened, mostly for life on the seafloor (although a few are shark-like in shape). Rays have their gills on the underside of the head and their enlarged pectoral fins are joined to the head in front of the gill slits. They have one or two dorsal fins (occasionally none) without fin-spines, no anal fin and a thin, often whip-like, tail.

### 3.1.2 Diversity

Compagno (2001) lists 60 families within the living orders of chondrichthyans. There are nearly 500 species of living sharks, over 600 species of batoids and 50 species of chimaeras, with new species constantly being described.

Chondrichthyan fishes exhibit great diversity inhabiting most of the seas on earth (although only a few species live in cold polar waters) from the intertidal zone to the deep abyss and a few also inhabit freshwater lakes and rivers and hypersaline habitats. Diversity is greatest in shallow, tropical regions, particularly in the Indo-Australian area. In the northwest Australian region, which has about 178 species, some 23% of known species are ubiquitous, about 15% are endemic and the remainder have more regional distributions (Last and Seret, 1999). Endemism is almost entirely of demersal species, and in the tropical eastern Indonesian-Australian region it is most pronounced on the continental slope, except in north west Australia where more than 60% of the endemics are demersal shelf species (Last and Seret, 1999). The distributional status of a number of problematic taxonomic genera such as *Squalus, Centrophorus, Mustelus* and *Himantura*, as well as several deep-water groups, may change when thorough systematic studies are carried out on a regional or global basis. Chondrichthyans vary greatly in maximum size with sharks ranging from 20-1200 cm total length, rays from 25-880 cm long and up to 670 cm disc width and chimaerids from 50-200 cm long. Sharks vary in shape from the "typical" carcharhinids to the bizarre hammerheads and threshers. Some sharks are ray-like and some rays are shark-like in shape. They vary in colour from drab browns and greys to the highly ornate patterning of some of the wobbegongs and stingrays. Most are predators, but there is a diversity of feeding mechanisms from giant planktivores to the semi-parasitic cookie-cutter sharks.

## 3.2 MORPHOLOGICAL GLOSSARY

***anal fin:*** the unpaired fin on the underside of the body behind the anus in sharks (Figures 3.1, 3.3)
***anterior:*** the front or head end (Figure 3.1)
***barbel:*** a slender, fleshy, tentacle-like sensory structure on the underside of the snout of some sharks (Figure 3.1)
***caudal:*** pertaining to the tail region
***caudal fin:*** the tail fin (Figures 3.1, 3.2, 3.3)

FIGURE 3.1
**Terminology for a generalized shark**

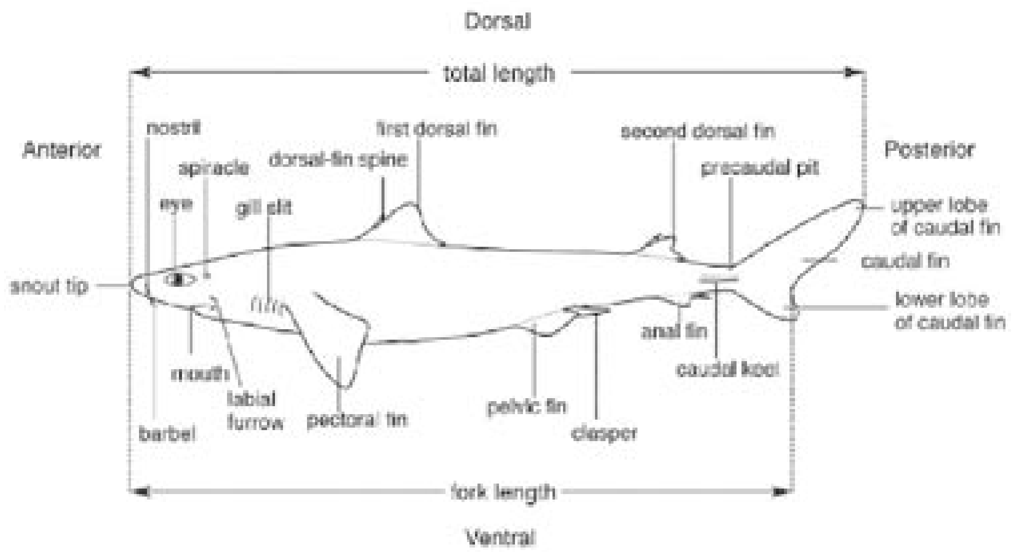


FIGURE 3.2
**Terminology for a generalized ray**

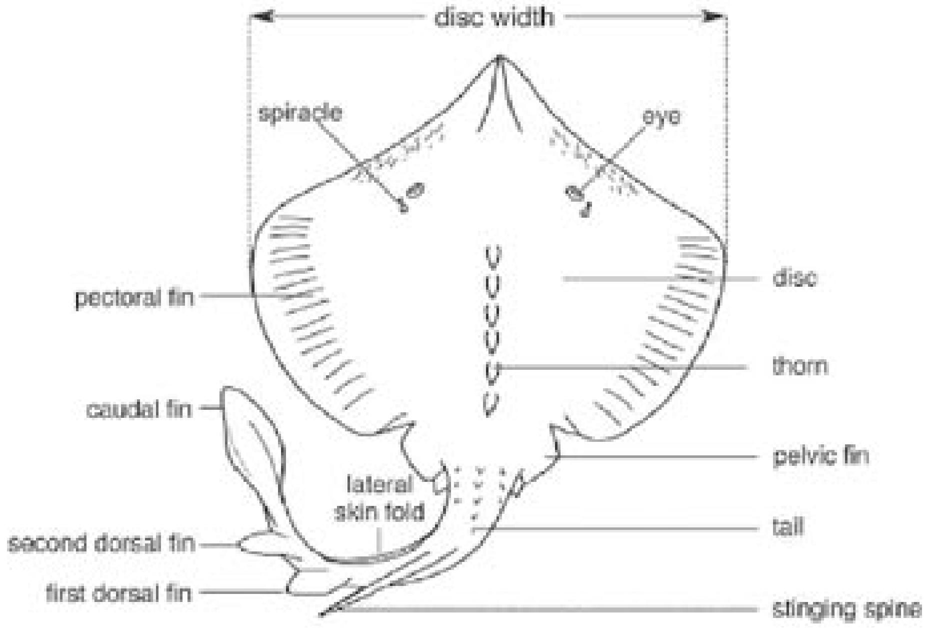
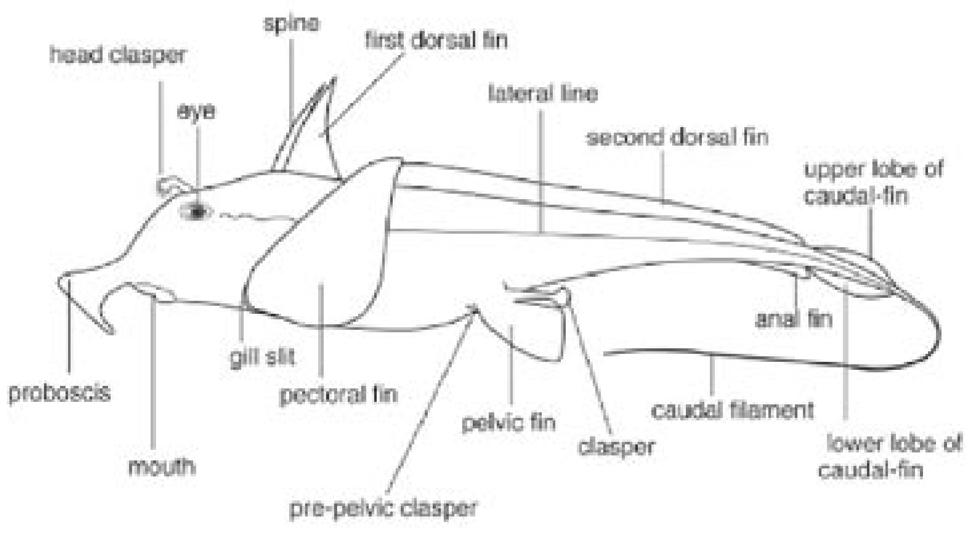



FIGURE 3.3
**Terminology for a generalized chimaera**




***caudal keel:*** a longitudinal, fleshy ridge along the side of the caudal peduncle (Figure 3.1)
***caudal peduncle:*** the posterior part of the body supporting the caudal fin (from the insertions of the second dorsal and anal fins to the anterior of the caudal fin)
***chondrocranium:*** the cartilaginous skeleton enclosing the brain and inner ear
***clasper:*** paired cylindrical extensions of the pelvic fins of males used in mating (Figure 3.1, 3.2, 3.3)
***cusp:*** a projection (point) on a tooth; many teeth have just one large cusp but some have additional side cusps

***dermal denticles:*** the tooth-like scales of sharks, rays and chimaeras
***diplospondylous:*** elasmobranchs have two types of vertebrae; diplospondylous vertebrae extend posteriorly from the back of the body cavity, and have two centra per myotome. In most shark species, the transition from monospondylous to shorter diplospondylous vertebrae begins above the pelvic fins
***disc:*** the combined head, trunk and enlarged pectoral fins of some sharks and rays with dorsoventrally flattened bodies (Figure 3.2)
***dorsal:*** the upper surface of the body or head (Figure 3.1)
***dorsal fin:*** the unpaired fin or fins along the upper surface of the back (Figures 3.1, 3.2, 3.3)
***endemic:*** confined to a localised area (e.g. a species endemic to southern Australia is not found anywhere else)
***fork length:*** *missing*
***fusiform:*** shaped like a spindle or cigar; tapered at both ends
***gill slit:*** a long, narrow gill opening in sharks and rays (Figures 3.1, 3.2, 3.3)
***head length:*** distance from the tip of the snout to the most posterior gill slit
***insertion:*** (of a fish's fin) the most posterior point of a fin base
***interdorsal ridge:*** ridge running along the mid-dorsal surface between the dorsal fins
***keel:*** a fleshy or bony ridge (Figure 3.1)
***labial furrows:*** the fold behind the corners of the mouth which provide slack in the skin for protrusion of the jaws (Figure 3.1)
***lateral:*** refers to the sides
***lunate:*** crescent shaped; refers to the caudal fin when the upper and lower lobes are about the same size
***meristic:*** pertaining to serially repeated structures such as vertebrae, teeth and other structures that can be counted like spiral valve turns
***monospondylous:*** elasmobranchs have two types of vertebrae; monospondylous vertebrae extend posteriorly from the chondrocranium, and have one centrum per myotome. In most shark species, the transition from longer monospondylous to shorter diplospondylous vertebrae begins above the pelvic fins
***morphometric:*** a character based on measurement. In fish, measurements are taken as a straight line, not around the curve of the body
***nasal flaps:*** skin flaps extending from the nostrils
***nictitating eyelid:*** an eyelid which can be pulled up or down (varies between families) over the whole eye (Figure 3.4)
***nostril:*** external opening of the nasal organs, usually pore-like in fishes (Figure 3.1)
***origin:*** of a fish's fin, the most anterior point of a fin base
***pectoral fins:*** paired fins just behind or just below the gill opening of sharks and chimaeras (Figure 3.1, 3.3), part of the disc in rays (Figure 3.2)
***pelvic fins:*** paired fins on the underside of the body (at the posterior of the body cavity) of sharks and chimaeras (Figure 3.1, 3.3), and near the tail in rays (Figure 3.2)
***posterior:*** the hind or tail end (Figure 3.1)
***precaudal pit:*** a notch on the dorsal or ventral surface of the caudal peduncle just in front of the caudal fin of some sharks (Figure 3.1)
***proboscis:*** elongated, flexible extension of the snout (Figure 3.3)
***rostrum:*** a rigid projection of the snout
***skin fold:*** an area where skin is bent over upon itself, forming a fleshy ridge (Figure 3.2)
***snout:*** the part of the head in front of the eyes of fishes (Figures 3.1, 3.2)

FIGURE 3.4
**Shark eye showing lower eyelid.**

***spiracle:*** a respiratory opening behind the eye in sharks and rays (Figures 3.1, 3.2)
***spiral valve:*** section of the intestine arranged with tight spiral turns, or broad turns like a scroll of paper, to increase the surface area for absorbtion
***stinging spine:*** the large, serrated, sword-like bony structure on the tail of some rays (Figure 3.2)
***symphysials:*** small teeth at the center of the jaws that are noticeably different in size and shape from the adjacent laterals
***terminal filament:*** filamentous section at the end of the caudal fin in some chimaerids (Figure 3.3)
***thorn:*** a sharp, tooth-like structure on the skin of a skate or ray (Figure 3.2)
***tooth row:*** the line of functional and replacement teeth derived from a single germinal area that is usually at approximately right angles to the jaw cartilage.
***tooth plate:*** fused (often beak-like) teeth of chimaerids
***tooth series:*** the line of teeth parallel to the jaw axis, all of them in different rows
***total length:*** longest length of a fish, measured as a straight line from the snout tip to the tip of the upper caudal fin (excluding the terminal filament of chimaerids) (Figure 3.1)
***vent:*** anus/urogenital opening
***ventral:*** refers to the lower surface or underside of the body (or head) (Figure 3.1)

## 3.3 CHARACTERS USED FOR IDENTIFICATION

### 3.3.1 Field identification

When in the field, whether it is at sea or sampling fish markets, there is some basic equipment that should be carried for identifying sharks and rays. This should comprise a camera, notebook, forms, vernier calipers, tape measure, calculator, sharp knife and selected identification sheets from regional guides. A digital camera can be particularly useful as can be a tape recorder. All these items can easily be carried in a backpack. Where possible, it is easiest to operate in pairs, this means someone can keep clean hands for taking notes, photographs, etc. For any regional identification study it is important, where possible, to build up both a photographic and specimen collection (see later sections). The collection of material will vary on the individual situation. Trips onboard research or commercial fishing vessels offer the best chance for getting fresh material. Local fish markets also provide excellent opportunities for good quality material and in undeveloped countries with poor data collection systems can also provide information on the fishing methods and gear being employed (particularly where vessels land directly to the market). It is important to set up a protocol (particularly in tropical locations where specimens dry out and deteriorate rapidly) for photographing, measuring and retaining specimens in a quick and efficient manner. Identification forms, tailored for the individual, should be designed to make the recording of measurements and meristics easier.

Characters used for identification vary with the group, but generally colour and markings, fin positions and shape, presence of an anal fin, number of gill slits, possession of dorsal fin spines, proportional body measurements, vertebral counts, tooth shape and counts are important in the sharks. In batoids, tooth characters are less useful while disc and tail shape, colour and markings, position of the dorsal fins, structure of the mouth and nostril region, and distribution and shape of dermal thorns and denticles are important. In the chimaerids, colour, head shape, fin position and shape, relative heights of the dorsal fin and spine, tooth plate structure and presence of an anal fin are important diagnostic characters. Some characters vary between the sexes, and so it is important to record the sex of the individual. Males can be distinguished by their claspers, paired cylindrical extensions of the pelvic fins used in mating. In mature individuals the claspers are elongated and rigid. Immature males have short soft claspers which are sometimes overlooked.

Colour varies with life stage and many species (particularly triakids, carcharhinids and sphyrnids), which have a metallic bronzy sheen in life, become a drab grey after death. Photographs are particularly important in documenting colour, fin positions and body proportions. Proportional body measurements are expressed as percentages of total length (TL) in sharks, most batoids and chimaerids (although the long caudal filament is excluded) and disc width in rays. Total length is measured as a straight line (not over the body curve) from the tip of the snout to the tip of the upper caudal fin lobe (Figure 3.1). Total length can vary depending on how the upper caudal lobe is positioned; usually it is pulled back parallel to the body axis in species with a weak lower caudal lobe. In sharks with more equally lobed caudal fins, the upper lobe is pulled back while still maintaining a 'normal' tail position. Other length measurements frequently used for sharks are fork length, tip of the snout to the fork in the tail (Figure 3.1) and precaudal length, tip of the snout to the origin of the upper caudal fin. Total length is used for most rays, but in the dasyatids, gymnurids, myliobatids, rhinopterids and mobulids disc width, the maximum width across the body (Figure 3.2), is measured as the tail is often damaged. Fin and body measurements should follow schemes proposed by Compagno (2001) and should include both longitudinal (parallel to the body axis) and point to point measurements. Measurements on most small species can be made with a combination of vernier calipers, a measuring board and possibly a standard 40 cm ruler. For large species, a combination of vernier calipers, large spring calipers, a 1 m wooden or steel rule and tape measure or folding measuring board can be used. Usually it is only necessary to make a few measurements to check diagnostic characters, but for unusual or possibly new species a full set of measurements should be taken (Compagno, 1984). Pre-designed forms should be used for recording information. Waterproof paper, although expensive, can be useful.

Vertebral counts can be made easily in the field, even on relatively large specimens, with the aid of a large, sharp, wide-bladed butchers knife. Protocol for precaudal (mono and diplosondylous) and caudal counts should follow Compagno (1984) and Garrick (1982). Precaudal counts are taken to the anterior edge of the precaudal pit. To make a count the tail should first be severed at the precaudal pit. The precaudal count can then be made by placing the specimen on its side and, starting at the tail, filleting it by running the knife along the vertebral column continuing forward right into (or through) the chondrocranium. Usually only minimal scraping of flesh from the column is required before counting is possible. Counts should not include the half vertebra fused to the back of the chondrocranium. When making the caudal count it is important not to damage the delicate terminal vertebrae. It is best to run the knife about half way along the column from the cut end, and then firmly grasp the flap of cut skin and flesh and strip off the remainder by pulling on it. In small specimens, the count may have to be completed in the laboratory using a microscope. Tooth counts and tooth shape are most important in the carcharhinids. Counts should follow the protocol in Garrick (1982) essentially being expressed as the number of laterals (left and right side) and symphysials in the upper jaw over those in the lower jaw:
*For example:* 13-1-13 over 12-1-12 for *Carcharhinus leucas*

Teeth counts for carcharhinds can usually be made in situ, sometimes slitting the mouth corners can help in accessing the extreme lateral teeth. Where there is any uncertainty, jaws can be removed, cleaned and examined in the laboratory. It is a good idea to compile a reference collection of jaws (see Section 5). In the carcharhinids the shape of the upper laterals can be diagnostic, although differences between species are often subtle. Garrick (1982) and the series of papers by Bass, D'Aubrey and Kistnasamy (1973–1976) on South African sharks provide excellent drawings and photographs of carcharhinid teeth. Compagno (1984, 2001) includes useful drawings of teeth for most species for which they are diagnostic.

### 3.3.2 Laboratory identification

Some characters and techniques are more practically carried out in the laboratory. Where it is possible to retain and transport specimens for measuring, electronic calipers linked to a pre-designed spreadsheet can greatly facilitate time-consuming proportional measurements. Where specimens need to be retained for a collection vertebral counts can be made by X-ray. Pins can be used to mark the position of the precaudal pit. Exposure rates and film will vary depending on the type of machine available. Tooth counts on newly-born carcharhinids, or species with many tooth rows such as the scyliorhinids (mainly required for new species descriptions), are best carried out in the laboratory using a microscope. If several duplicate specimens are available it is easiest to remove and dry the jaws before counting (although some distortion of tooth rows can occur). If specimens must be retained intact, removal of all mucous, blotting dry, the use of water-soluble dyes and pins as reference marks can aid examination under the microscope. Spiral valve counts (number of turns or flaps in the intestine, which is immediately posterior to the stomach) can be useful in some groups. This is most easily carried out by removing it from the specimen, opening lengthways with scissors, washing out all the contents and mucous, and then counting (this can also be done in the field). In some cases, description of characters such as dermal denticles, clasper structure and occasionally chondrocranium structure may be required. Preparation techniques for these are described in Compagno (1988).

## 3.4 TAKING PHOTOGRAPHS

The left side of sharks and chimaerids should be photographed; dorsal and ventral views of batoids should be taken. A shot of the underside of the head back to the level of the pectoral-fin origins should be taken for sharks and for some families a dorsal view; more detailed shots of teeth, fin markings, mouth regions etc., can be taken as necessary. Specimens should be washed clean and layed out on a plain matte white background so that their fin origins and inner margins are clearly visible. For ventral shots, where white is a common skin colour, a darker matte background may be required. Thick plastic material is relatively easy to carry and clean in the field. Plasticine, small stones, pieces of paper, wood, etc., can be used to prop-up the fins or stabilise the head. Bright sunlight can cause problems with reflection and shadows and a shady area is preferable. With very large specimens, fitting them into the field of view can be a challenge and may call for innovative solutions such as climbing onto the roof of a truck or taking shots from a balcony or ladder. Always include a scale, preferably a coloured rule. It is a good idea to also include a label with the species name or a field code, this can be cropped out later if necessary. Maintain a register of all photographs taken. Where available, digital cameras are an advantage as results can be checked immediately. It is helpful to compile a photographic collection to accompany a regional collection of specimens.

## 3.5 SPECIMEN COLLECTION, PRESERVATION AND CATALOGUING

Any serious attempt to document regional chondrichthyan faunas should involve compiling and maintaining a reference collection of specimens. Specimens should be collected as fresh as possible, washed, photographed, measured, labeled and fixed in 10% formalin made up with seawater (40-44% concentrated formaldehyde = 4% formalin). All specimens over about 15 cm TL should be injected in the body cavity with concentrated formalin using a large-gauge hypodermic needle. Waterproof paper labels recording the species identification along with a field number written in pencil (entered in a register with date, collection location, identifier, length and sex of the specimen) should be attached to the specimen. (Plastic waterproof paper, such as Phase 3, tends to split but can be used if encased in a self-sealing plastic bag; I use Nalgene polypaper, which doesn't tear.) Labels are best attached through the upper caudal-fin lobe of sharks, close to the caudal fin of chimaerids and towards the margin of the "wings" of batoids using plastic T tags fired from a tagging gun (type used by clothing companies such as Monarch 3020 from Canada). Specimens should be fixed in containers that allow them sufficient space to prevent them being bent or distorted. For smaller specimens, 30 litre polythene drums with large diameter screw-on (or snap on) lids are ideal; for larger sharks fiberglass or polyethylene tanks (approximate dimensions 1.5 m long, 0.5 m wide and 0.8 m deep) with sealing lids are required (these may have to be specially manufactured). After fixation in formalin for four weeks, specimens should preferably be transferred to 70% ethanol after first washing in water. A layer of muslin covering the specimens in the tank will help to prevent those at the top from drying out. Fluid levels should be monitored periodically, every month if tanks are stored outside in tropical areas. For large specimens, it may not be possible to retain the whole animal in which case the head, and possibly fins of sharks should be kept. For large rays, the wings can be removed. Jaw collections can be valuable, particularly for carcharhinids. Jaws should be cut out of the shark and all flesh removed by paring away the muscle and skin with a sharp knife or scalpel. When clean, the jaw should be held open (two pieces of wood across the jaws work well) and dried in the shade as if placed straight into the sun they may distort.

### 3.6 DISSECTION

Dissections for vertebral and spiral valve counts, and preparation of jaws have been described in previous sections. More complicated dissections and preparations such as those for clasper elements and chondrocrania are described by Compagno (1988).

### 3.7 FAMILY KEY

The illustrated family key provided here is taken from Daley *et al.* (2002). There are some minor differences between the systematic scheme followed in the key and that in Section 3.8 which follows Compagno (1999b) and McEachran, Dunn and Miyaka (1996). In particular, the Squalidae have been separated into several families (Section 3.8) that have not been recognized as such in many of the regional guides cited herein and used for identification by fisheries workers.

### KEY TO FAMILIES

**Step 1:** Five to seven gill openings on each side of head (Figures 3.5, 3.6), last two openings sometimes very close together and appearing as one. Go to Step 2
One external gill opening on each side of head (Figure 3.7). Go to Step 3
**Step 2:** Snout saw-like, flattened and armed with lateral teeth (Figures 3.8, 3.9). Go to Step 3
Snout not saw-like, no lateral teeth. Go to Step 4

FIGURE 3.5
**Head of shark**

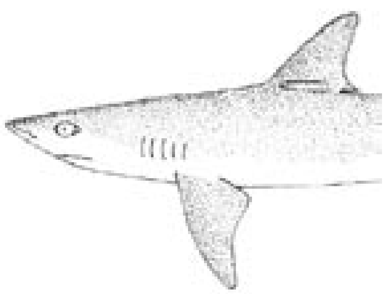


FIGURE 3.6
**Undersurface of head**

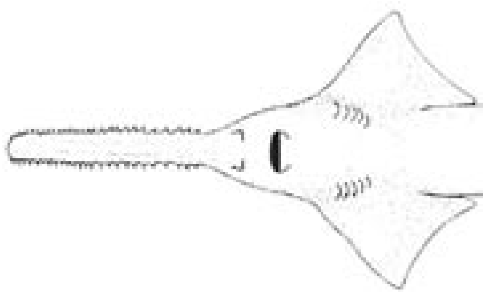


FIGURE 3.7
**Head of chimaera**

**Step 3:** Gill slits on undersurface of head (Figure 3.6); no barbels on snout; sawfishes (Pristidae) (Figure 3.8)

**Step 4:** Body dorso-ventrally flattened, ray-like (Figure 3.10); eyes on top of head, except in devilrays (Figure 3.33), eagle rays (Figure 3.35) and cownose rays (Figure 3.34). Go to Step 5

Body more or less streamlined, shark-like (Figure 3.11); eyes on sides of head (Figure 3.11). Go to Step 19

FIGURE 3.8

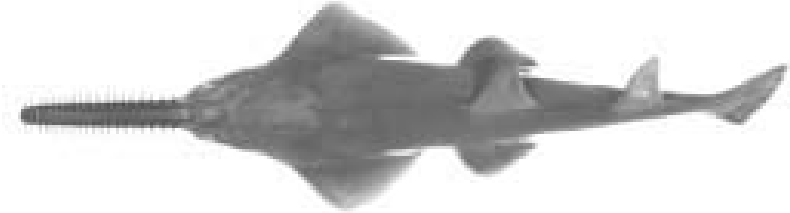
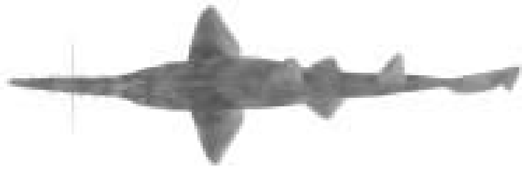


FIGURE 3.9
**Gill slits on sides of head; barbels present on snout sawsharks (Pristiophoridae)**



**Step 5:** Gill openings partly on sides of head (Figure 3.12); pectoral fins clearly detached from head (front part of fin extending forward of fin origin) (Figure 3.12); angel sharks (Squatinidae) Figure 3.13

Gill openings entirely on undersurface of head (Figure 3.14); pectoral fins wholly or partly joined to head (Figure 3.14). Go to Step 6

FIGURE 3.10

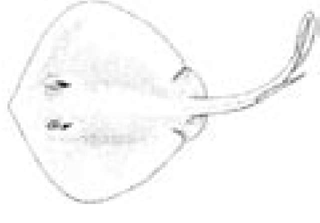


FIGURE 3.11

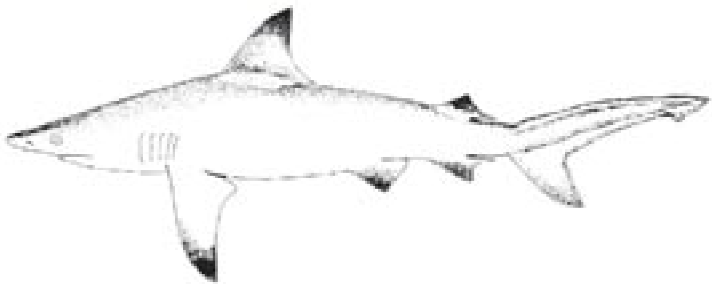


FIGURE 3.12
**Undersurface of head**

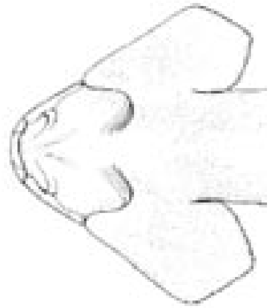
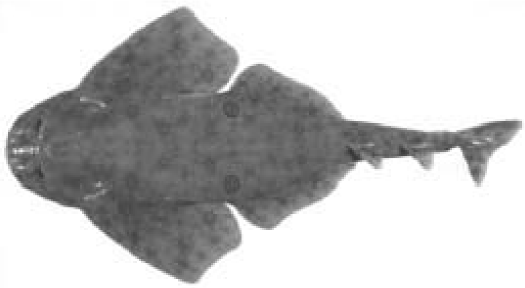


FIGURE 3.13



**Step 6:** Two distinct dorsal fins (Figure 3.15); first dorsal fin originating closer to insertion of pelvic fins than to tip of tail (Figure 3.15). Go to Step 7
Dorsal fins 0–2; origin of first dorsal fin closer to tail tip than to insertion of pelvic fins when two fins are present (Figure 3.14). Go to Step 11

FIGURE 3.14
**Undersurface**

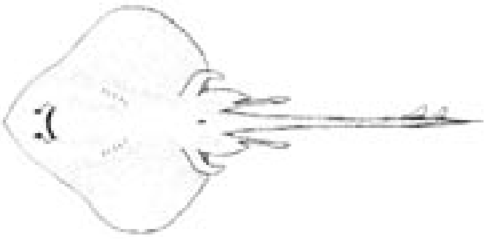
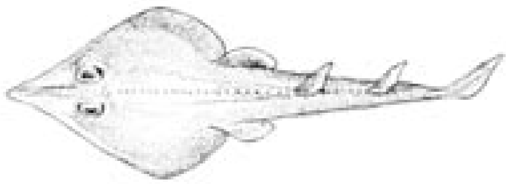


FIGURE 3.15



**Step 7:** Disc large relative to tail, its maximum width more than twice tail length behind pelvic-fin tips (Figure 3.17); dorsal fins close together (Figure 3.18). Go to Step 8
Disc smaller relative to tail, its maximum width about equal to or less than tail length behind pelvic-fin tips (Figure 3.16); dorsal fins widely separated (Figure 3.15). Go to Step 9
**Step 8:** Caudal fin much larger than dorsal fins, about the same size as pelvic fins; torpedo rays (Torpedinidae) (Figure 3.17)
Caudal fin barely larger than dorsal fins, much shorter than pelvic fins; coffin rays (Hypnidae) (Figure 3.18)

FIGURE 3.16

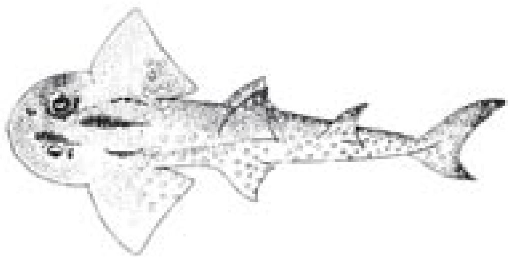


FIGURE 3.17

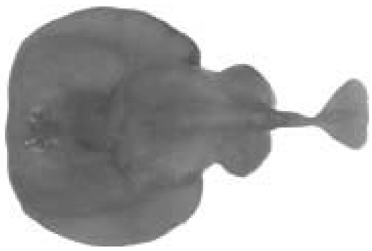
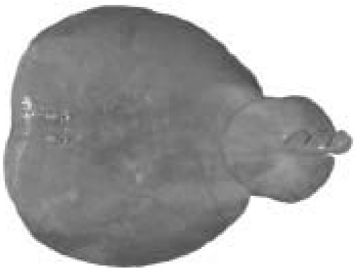


FIGURE 3.18

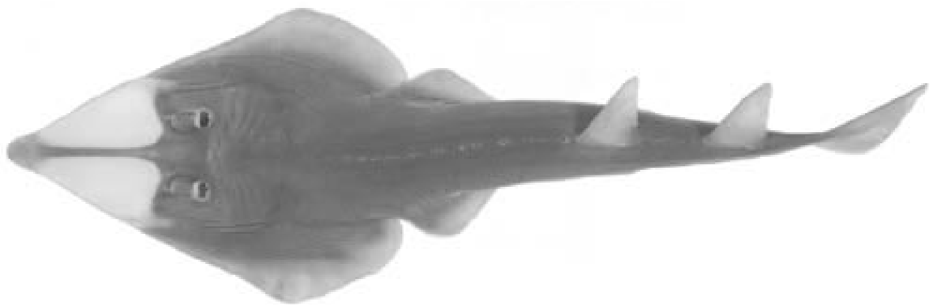


**Step 9:** Caudal fin with a well-developed, angular lower lobe; pectoral and pelvic fins not overlapping; sharkfin guitarfishes (Rhynchobatidae) (Figure 3.19)
Lower lobe of caudal fin not well defined; pectoral and pelvic fins touching or over lapping (Figure 3.20). Go to Step 10

FIGURE 3.19

**Step 10:** Snout wedge-shaped, forming a sharp angle at tip or snout broadly rounded; thorns or fine denticles present on body or tail (surface rough); no electric organs; shovel nose rays (Rhinobatidae) (Figure 3.20)
Snout broadly rounded; body surface entirely smooth; electric organs present; numbfishes (Narcinidae) (Figure 3.21)
**Step 11:** Pelvic fin divided into two distinct lobes; no enlarged stinging spine on tail (Figure 3.22). Go to Step 12
Pelvic fin with one lobe (Figure 3.23); 1–2 enlarged, serrated stinging spines usually present on tail (deep scar visible when spine absent) (Figure 19). **Go to Step 13**

FIGURE 3.20



**Step 12:** Thorns or fine denticles (rough to touch) present on at least part of dorsal surface; snout in front of eyes less than 8 times eye diameter; tail slender but not thread-like; skates (Rajidae, in part) (Figure 3.24)
Entire dorsal surface smooth (except for outer disc thorns of male); snout in front of eyes more than 8 times eye diameter; tail very short, thin and thread-like (Figure 3.25); leg skates (Rajidae, in part)

FIGURE 3.21

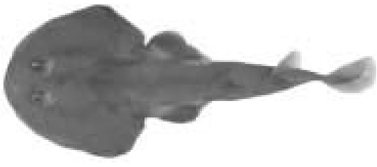


FIGURE 3.22
**Undersurface**

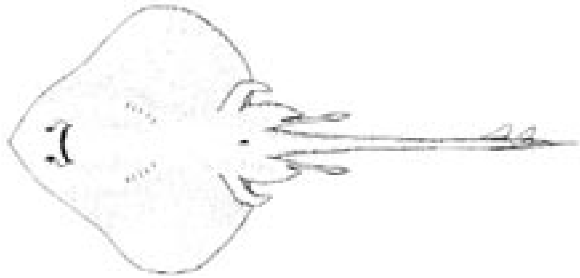


FIGURE 3.23
**Undersurface**

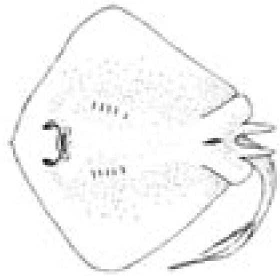


FIGURE 3.24

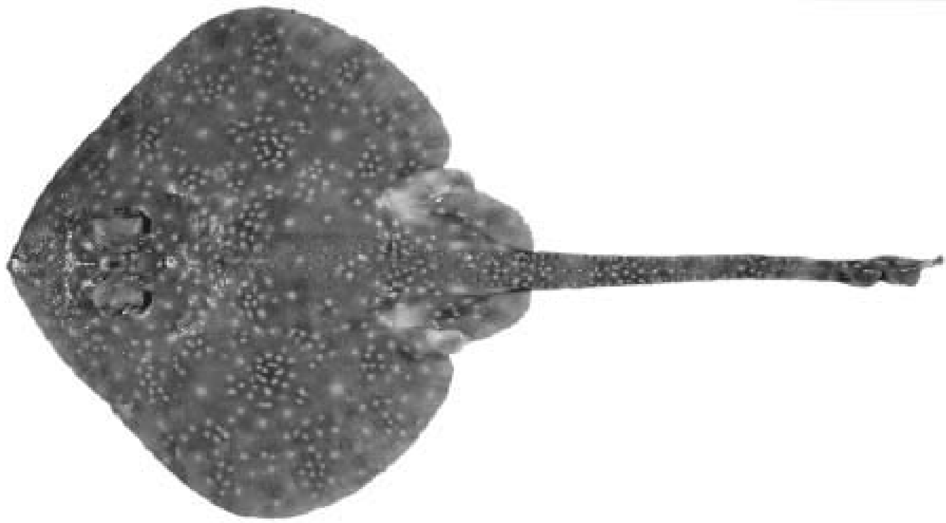
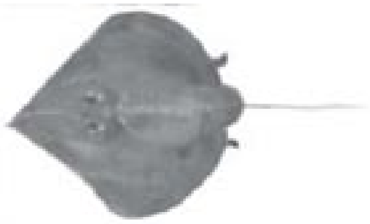


FIGURE 3.25



**Step 13:** Six pairs of gill slits (Figure 3.26); sixgill stingrays (Hexatrygonidae) (Figure 3.27)
Five pairs of gill slits (Figure 3.23). Go to Step 14
**Step 14:** Anterior part of head not extended beyond disc; eyes located on top of head and well inward from disc edge (Figure 3.28). Go to Step 15
Anterior part of head extended beyond disc; eyes located on side of head (Figure 3.29).Go to Step 17
**Step 15:** Disc very broad, width more than 1.5 times length; tail extremely short and threadlike; butterfly rays (Gymnuridae) (Figure 3.30)
Disc width less than 1.5 times length (Figure 3.31); tail moderately (Figure 3.32) to very long (Figure 3.31). Go to Step 16
**Step 16:** No caudal fin; central disc and dorsal surface of tail normally with some thorns or small rounded projections; stingrays (Dasyatidae) (Figure 3.31)
Caudal fin present; no thorns or small rounded projections on disc or tail (completely smooth); stingarees (Urolophidae) (Figure 3.32)
**Step 17:** A long, paddle-like flap projecting forward from each side of head; teeth minute, in many rows, more than 10 rows in each jaw; devilrays (Mobulidae) (Figure 3.33)

FIGURE 3.26
**Undersurface**

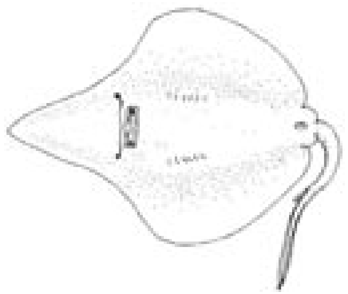


FIGURE 3.27

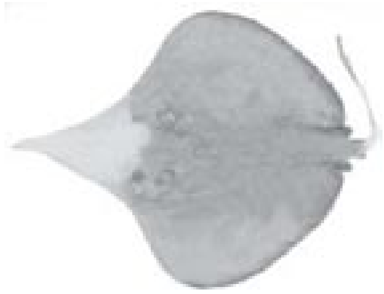


FIGURE 3.28

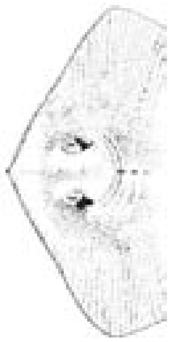


FIGURE 3.29

FIGURE 3.30

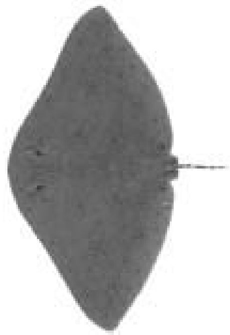


FIGURE 3.31

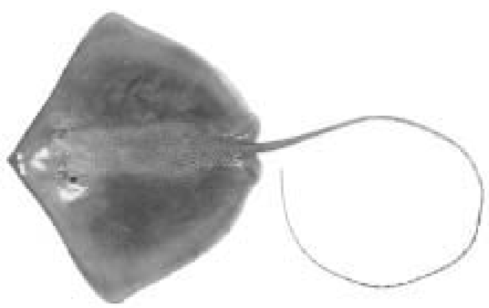
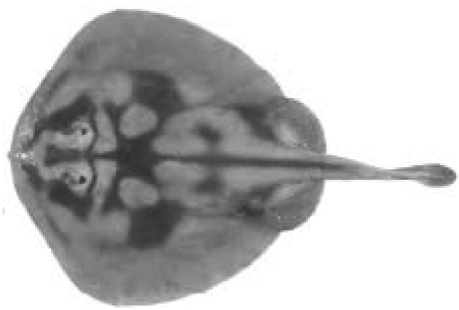


FIGURE 3.32



No long, paddle-like flap projecting forward from each side of head, instead with a single, fleshy, lobe (Figure 3.35) or pair of broadly rounded lobes forming the snout (Figure 3.34); teeth large, plate-like, less than 10 rows in each jaw. Go to Step 18
**Step 18:** Undersurface of snout uniformly rounded; floor of mouth with small fleshy projections; eagle rays (Myliobatidae) (Figure 3.35)
Undersurface of snout with two lobes separated by a deep central notch; floor of mouth without small fleshy projections; cownose rays (Rhinopteridae) (Figure 3.34)
**Step 19:** A single dorsal fin; 6–7 pairs of gill openings (Figure 3.36). Go to Step 20
Two dorsal fins; 5 pairs of gill openings (Figure 3.37). Go to Step 21
**Step 20:** Mouth at tip of snout (Figure 3.40); first gill openings connected around throat (Figure 3.38); no notch on underside of upper caudal-fin lobe (Figure 3.40); frilled sharks (Chlamydoselachidae) (Figure 3.40)
Mouth on undersurface of head (Figure 3.41); first gill openings not connected around throat (Figure 3.39); notch on underside of upper caudal-fin lobe (Figure 3.41); sixgill and sevengill sharks (Hexanchidae)

FIGURE 3.33

FIGURE 3.34

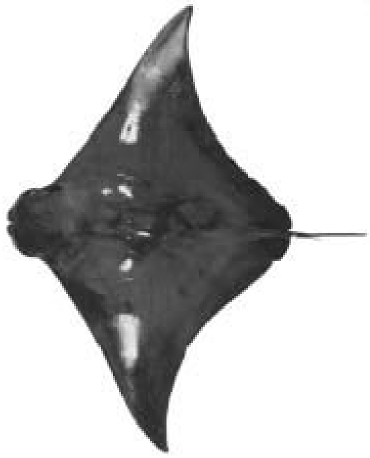
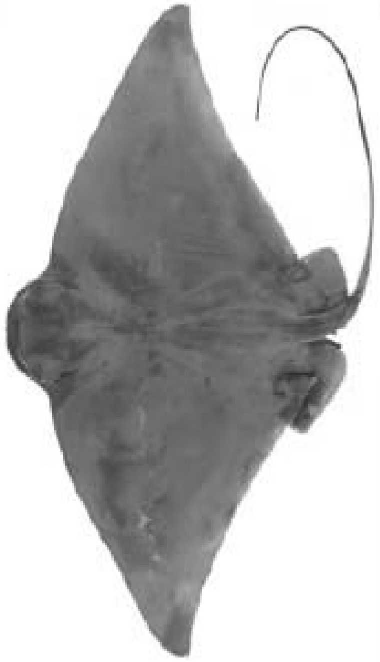


FIGURE 3.35



**Step 21:** Anal fin absent (Figures 3.42-3.44). Go to Step 22
Anal fin present (Figure 3.45), sometimes small (Figure 3.46). Go to Step 24
**Step 22:** First dorsal fin originating behind pelvic-fin origins; dorsal fins located near caudal fin and almost touching each other; denticles extremely large. bramble sharks (Echinorhinidae) (Figure 3.42)
First dorsal fin originating in advance of pelvic fins (Figure 3.44, not pictured); dorsal fins well separated and located well forward of caudal fin (Figure 3.43); denticles not greatly enlarged. Go to Step 23
**Step 23:** Trunk laterally compressed, almost triangular in cross-section; fins tall, height of first dorsal fin more than or about equal to head length; prickly dogfishes (Oxynotidae) (Figure 3.43). Trunk rounded or oval in cross-section; fins much lower, height of first dorsal fin much less than head length; dogfishes (family Squalidae) (Figure 3.44, not pictured)
**Step 24:** Head hammer-shaped; eyes located on outer edge of head hammerhead sharks (Sphyrnidae) (Figure 3.45). Head not hammer-shaped. Go to Step 25
**Step 25:** Length of caudal fin equal to or more than half total length; body not spotted or banded; thresher sharks (Alopiidae) (Figure 3.46)
Caudal fin much less than half total length (Figure 3.47) (caudal fin also long in *Stegostoma* but body spotted and/or banded, see Figure 3.56). Go to Step 26

FIGURE 3.36

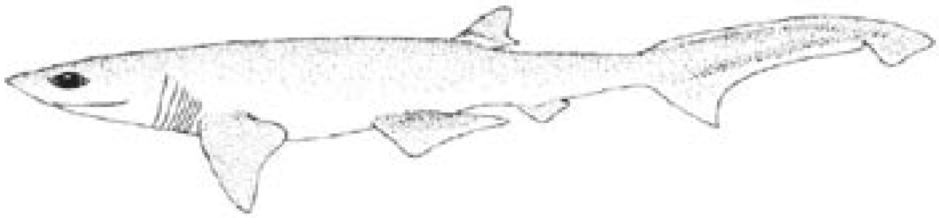


FIGURE 3.37

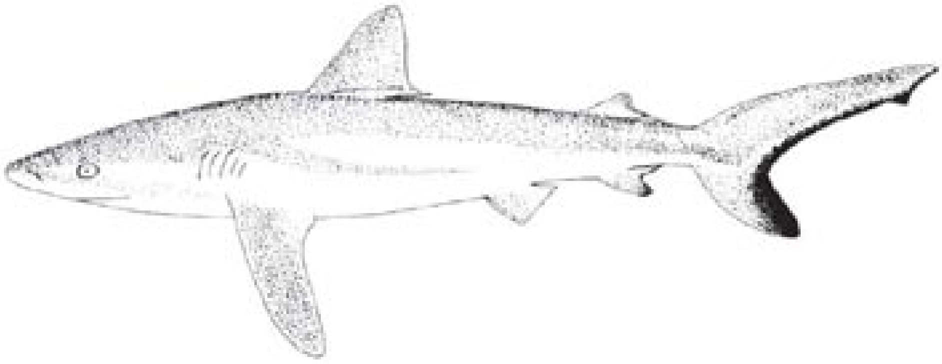


FIGURE 3.38

FIGURE 3.39
**Undersurface of head**

FIGURE 3.40

FIGURE 3.41

FIGURE 3.42

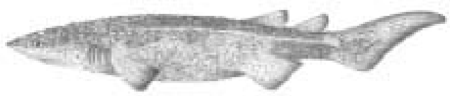


FIGURE 3.43

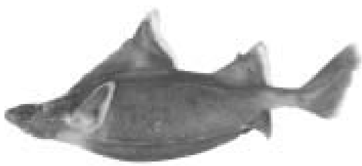
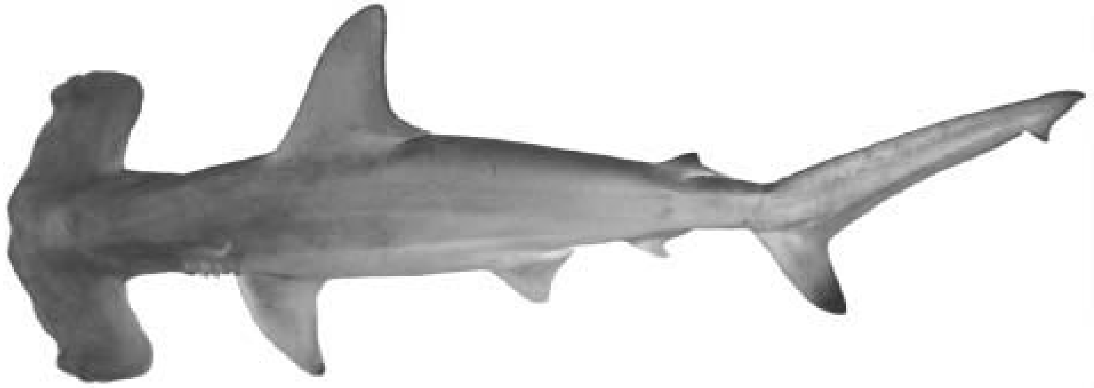


FIGURE 3.45



**Step 26:** Dorsal-fin spines present; horn sharks (Heterodontidae) (Figure 3.47). Dorsal-fin spines absent. Go to Step 27

**Step 27:** Snout extending above mouth as long, flattened, blade-like shelf (Figure 3.48); nostrils close to mouth (Figure 3.49); goblin sharks (Mitsukurinidae) (Figure 3.48)
Snout not as above (extended slightly in some catsharks, family Scyliorhinidae, Figure 3.75), but nostrils well forward of mouth). Go to Step 28

**Step 28:** Whole mouth forward of front edge of eye (Figure 3.50). Go to Step 29
Mouth partly beneath or behind front edge of eye (Figure 3.51). Go to Step 35

FIGURE 3.46

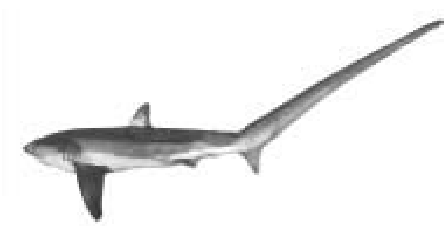


FIGURE 3.47

FIGURE 3.48

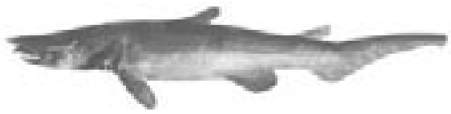
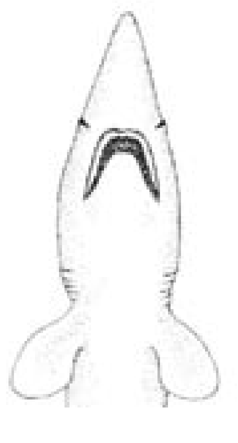


FIGURE 3.49
**Undersurface of head**



**Step 29:** Mouth at snout tip and very broad; caudal fin forked, upper and lower lobes tall; no notch on underside of upper caudal-fin lobe; whale sharks (Rhincodontidae) (Figure 3.52)
Mouth smaller, not right at snout tip; upper and lower lobes of caudal fin low; a notch on underside of upper caudal-fin lobe (Figure 3.53). Go to Step 30
**Step 30:** No fleshy lobe or groove on outer edge of nostril (Figure 3.54). Go to Step 31
Fleshy lobe and groove present on outer edge of nostril (Figure 3.55). Go to Step 32
**Step 31:** Caudal fin very long, almost as long as body; ridges present on side of body; zebra sharks (Stegostomatidae) (Figure 3.56)
Caudal fin shorter, much less than half length of body; no ridges on side of body; nurse sharks (Ginglymostomatidae) (Figure 3.57)
**Step 32:** Origin of anal fin forward of origin of second dorsal fin; anal fin more than its base length from caudal fin; collared carpet sharks (Parascylliidae) (Figure 3.58)
Origin of anal fin well behind origin of second dorsal fin; anal fin next to caudal fin (Figure 3.59) and sometimes barely distinguishable from it (Figure 3.63). Go to Step 33
**Step 33:** Body strongly flattened (top to bottom) anteriorly; skin flaps present along side of head behind nostrils (Figure 3.60); enlarged canine teeth at tip of both jaws; wobbegongs (Orectolobidae) (Figure 3.62)

FIGURE 3.50

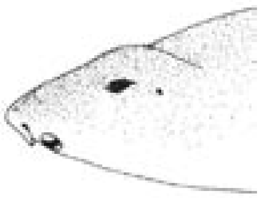


FIGURE 3.51

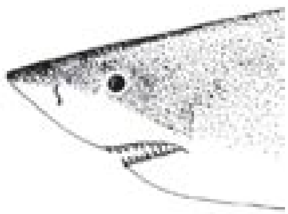


FIGURE 3.52

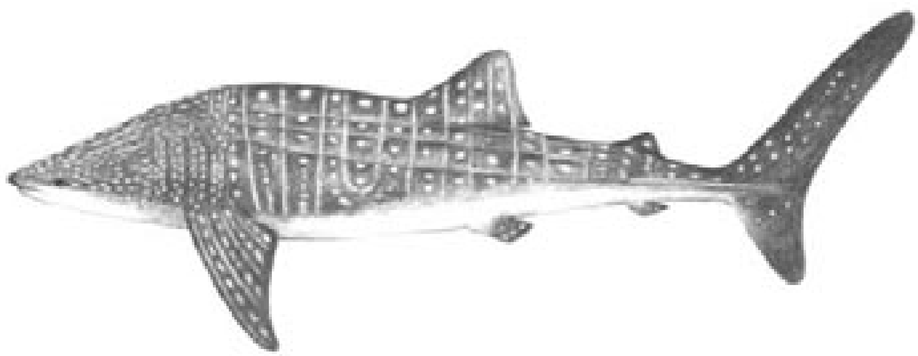


FIGURE 3.53

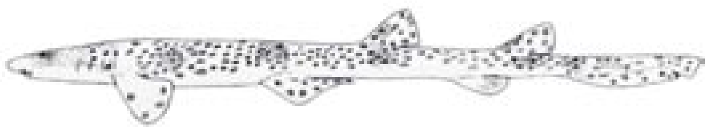


FIGURE 3.54
**Undersurface of head**

FIGURE 3.55
**Undersurface of head**

Body more or less cylindrical anteriorly; no skin flaps along side of head behind nostrils (Figure 3.61); teeth small, those at tip of jaws not distinctly larger than those next to them. Go to Step 34

**Step 34:** Tail long, distance from anus to lower caudal-fin origin greater than distance from snout to anus; insertion of second dorsal fin well in front of anal-fin origin; longtail carpet sharks (Hemiscylliidae) (Figure 3.63)

Tail shorter, distance from anus to lower caudal-fin origin less than distance from snout to anus; insertion of second dorsal fin over or slightly behind origin of anal fin; blind sharks (Brachaeluridae) (Figure 3.64)

**Step 35:** Caudal-fin lobes almost the same size, upper lobe less than 1.5 times longer than lower lobe (Figure 3.65). Go to Step 36

Caudal-fin lobes of unequal length, upper lobe more than 1.5 times longer than lower lobe (Figure 3.66). Go to Step 37

FIGURE 3.56

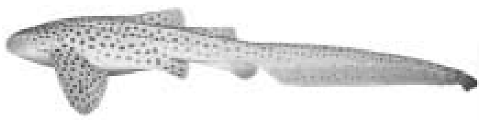


FIGURE 3.57

FIGURE 3.58

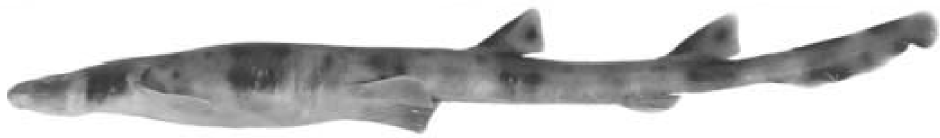


FIGURE 3.59
**Tail**

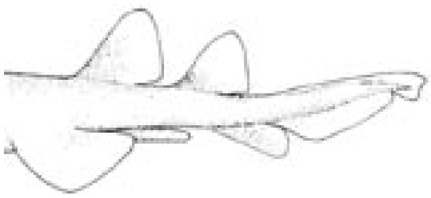
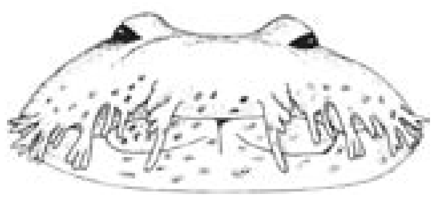


FIGURE 3.60
**Front view of head**



**Step 36:** Gill openings very long, extending on to both dorsal and ventral surfaces (Figure 3.67); first gill openings almost continuous on throat; more than 150 rows of small hook-like teeth in both jaws (Figure 3.69); basking sharks (Cetorhinidae) (Figure 3.67)

Gill openings shorter, confined to sides (Figure 3.68); first gill openings widely separated on throat; less than 40 rows of sharp blade-like teeth in

FIGURE 3.61
**Front view of head**

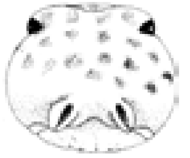


FIGURE 3.62

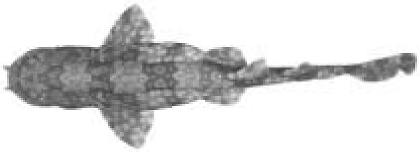


FIGURE 3.63

FIGURE 3.64

FIGURE 3.65
**Caudal fin**

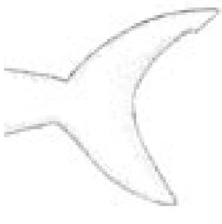


FIGURE 3.66
**Caudal fin**

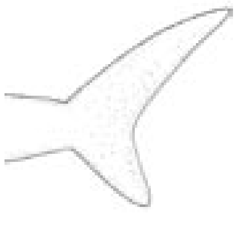


FIGURE 3.67

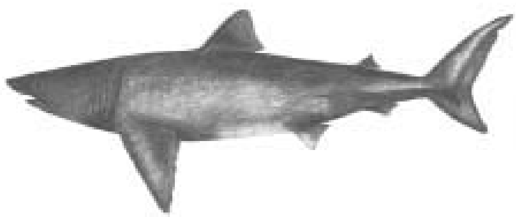
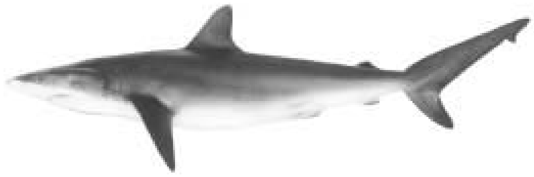


FIGURE 3.68



each jaw (Figure 3.70); mackerel sharks (Lamnidae) (Figure 3.68)

**Step 37:** Mouth huge and at tip of snout, lower jaw extending to snout tip; very large sharks.. megamouth sharks (Megachasmidae) (Figure 3.71, not featured)

Mouth located on undersurface of head, distance from snout to mouth distinctly longer than eye diameter (Figure 3.72). Go to Step 38

FIGURE 3.69

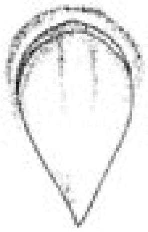
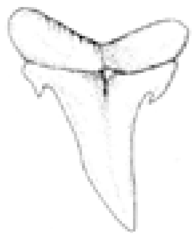
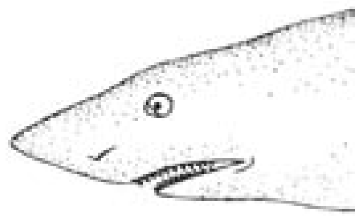


FIGURE 3.70
**Teeth of upper jaw**



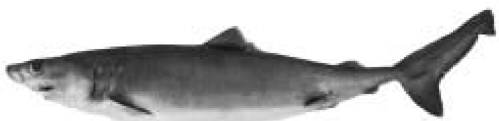
**Step 38:** Eyes very large, more than half greatest height of snout; gill openings extending onto dorsal surface of head; caudal keels present; crocodile sharks (Pseudocarchariidae) (Figure 3.73)

FIGURE 3.72
**Head**



Eyes smaller, less than half greatest height of snout; gill openings not extending onto dorsal surface of head (Figure 3.74); caudal keels absent in most species. Go to Step 39

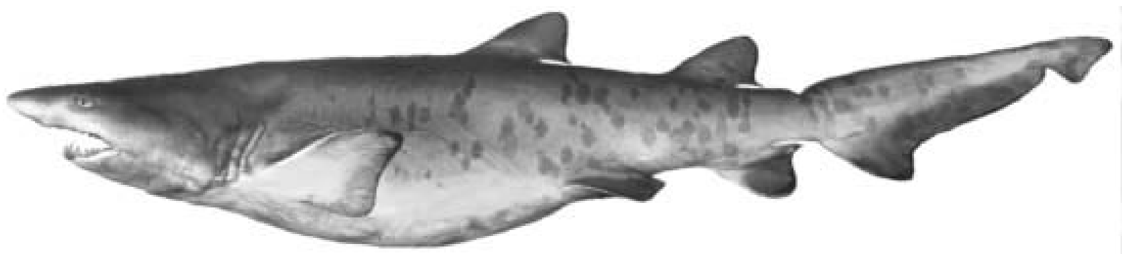
FIGURE 3.73



**Step 39:** Eyelid fixed, not capable of closing over eye.. grey nurse sharks (Odontaspididae) (Figure 3.74)

Eyelid capable of closing over eye (nictitating). Go to Step 40

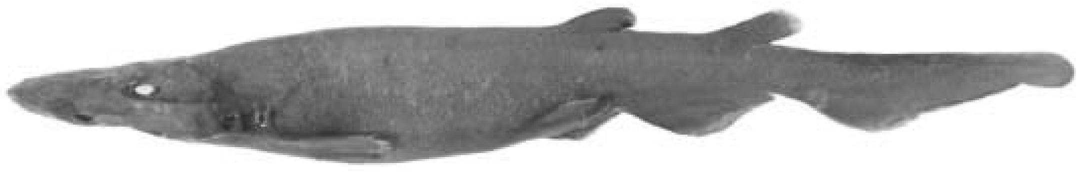
FIGURE 3.74



**Step 40:** First dorsal-fin origin well behind pelvic-fin origin; catsharks (Scyliorhinidae) (Figure 3.75)

First dorsal-fin origin well in front of pelvic-fin origin (Figure 3.76). Go to Step 41

FIGURE 3.75



**Step 41:** No precaudal pit; leading edge of upper lobe of caudal fin smooth (Figure 3.77); hound sharks (Triakidae) (Figure 3.76)

Precau dal pit present; leading edge of upper lobe of caudal fin usually rippled (Figure 3.78). Go to Step 42

**Step 42:** Posterior edge of second dorsal fin deeply concave; spiracles present; weasel sharks (Hemigaleidae) (Figure 3.79)

Posterior edge of second dorsal fin not deeply concave; spiracles mostly absent; whaler sharks (Carcharhinidae) (Figure 3.80)

**Step 43:** Snout long and flexible with a hoe-shaped tip; caudal fin arched upward; elephant fishes (Callorhinchidae) (Figure 3.81)

Snout straight, bluntly rounded or pointed; caudal-fin axis straight (Figures 3.82, 3.83). Go to Step 44

**Step 44:** Snout relatively short, tip bluntly rounded; shortnose chimaeras (Chimaeridae) (Figure 3.82)

FIGURE 3.76

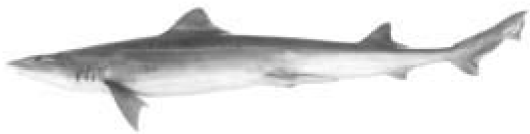


FIGURE 3.77
**Caudal fin**

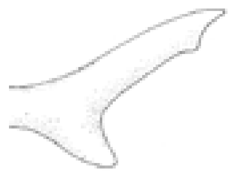


FIGURE 3.78
**Caudal fin**

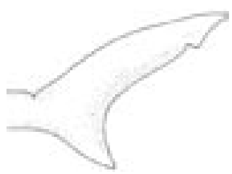


FIGURE 3.79

FIGURE 3.80

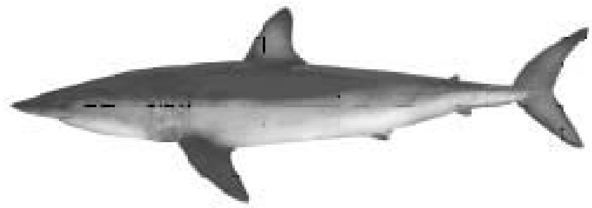
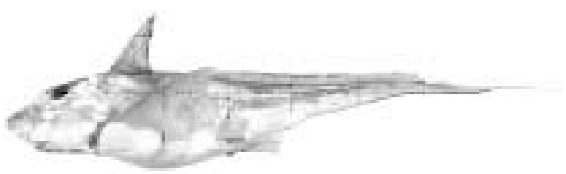


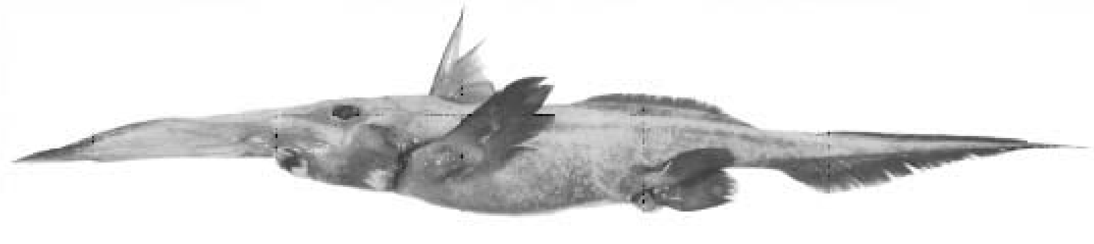
FIGURE 3.81

FIGURE 3.82



Snout very long, tip pointed; spookfishes (Rhinochimaeridae) (Figure 3.83)

FIGURE 3.83



## 3.8 ORDERS AND FAMILIES

### 3.8.1 Order Hexanchiformes (frilled, sixgill and sevengill sharks)

These sharks are easily identified by the combination of six or seven pairs of gill slits on each side, a single dorsal fin and an anal fin. The order contains two families. The Chlamydoselachidae (frilled sharks) includes one living species, which has an elongate, eel-like body, six pairs of gill slits and a reptilian-like head with terminal mouth and long tricuspid teeth. The family Hexanchidae (sixgill and sevengill sharks) have a fusiform body, ventral mouth with comb-like lower teeth and six or seven pairs of gill slits. The family contains four medium to large (1.4-4.8 m) sharks that mainly live near the bottom in deepwater in temperate and tropical regions (one species inhabits shallow bays and estuaries).

### 3.8.2 Order Squaliformes (dogfish sharks)

Squaliform sharks are identified by the combination of a fusiform body, short snout (not sawlike), five gill slits, no anal fin and usually spines in front of the dorsal fins (minute or absent in a few species). There are seven (Compagno, 1999b) living families; the Echinorhinidae, Squalidae, Centrophoridae, Etmopteridae, Somniosidae, Oxynotidae and Dalatiidae. The echinorhinids (bramble sharks) contain two relatively rare species (2.6-4 m) of deepwater, bottom -iving, temperate and tropical sharks, which have two small, posterior-placed, spineless dorsal fins (origin of the first is behind the pelvic-fin origins) that are close together, and enlarged, thorny denticles on the body. There are four species of small (mostly < 1 m) oxynotids (prickly dogfishes) that live near the bottom in deepwater of temperate and tropical regions. These bizarre shaped sharks have a hump-backed body almost triangular in cross section, ridges between the pectoral and pelvic fins, two high, sail-like dorsal fins with spines, and very rough skin. The squalids (dogfishes) contain 2 genera (*Cirrhigaleus* and *Squalus*) and about 12 mostly small (< 1.2 m) species. Squalids have two relatively low dorsal fins usually preceded by spines, the origin of the first fins anterior to the pelvic-fin origins. The centrophorids (gulper sharks) comprise about 14 species within two genera of small- to medium-sized (up to 1.6 m) sharks, the etmopterids (lantern sharks) contain five genera and about 38 small (mostly < 1 m) species and the dalatiids (kitefin sharks) contain seven genera and about 10 mostly very small (with the exception of *Dalatias* which attains about 1.8 m in length) species. The somniosids (sleeper sharks) comprise four genera and about 16 species and include *Somniosus* spp. some of which attain about 7 m in length and are among the largest sharks. The genera *Centrophorus, Etmopterus* and *Squalus* contain many species that are difficult to identify, with many new forms being reported as new areas are sampled. Snout length, dorsal fin shape, colour markings (particularly of juveniles), denticle patterns, spine thickness and height of the spine relative to the dorsal fin are important characters. Revision on a global (or at least large regional) scale is required to fully resolve their taxonomy at the species level.

### 3.8.3 Order Pristiophoriformes (sawsharks)

This order contains one living family, the Pristiophoridae (sawsharks), which is comprised of two genera and about seven relatively small (< 1.5 m) species. Sawsharks are unmistakable among the sharks because of their blade-like snout armed with rostral teeth (resembling a saw); they also have barbels on the underside of the saw, sub-cylindrical to slightly flattened (but not ray-like) bodies, two dorsal fins without spines, five or six pairs of gill slits and no anal fin. Sawsharks should not be confused with the batoid family Pristidae (sawfish) that have the pectoral fins joined to the head in front of the ventrally placed gill slits, no barbels on the saw, and which grow much larger (up to 7 m).

### 3.8.4 Order Squantiniformes (angel sharks)

Squatiniform sharks are easily identified by the combination of no anal fin and a dorso-ventrally flattened, ray-like body with broad pectoral fins and a terminal mouth. However, unlike batoids the gill slits are on the sides of the head and the pectoral fins join the head behind the gill slits (although they project forward of them as a lobe). The order contains the single living family Squatinidae (angel sharks) that is comprised of about 14 globally distributed species.

### 3.8.5 Order Heterodontiformes (bullhead or horn sharks)

Heterodontiform sharks are identified by the combination of an anal fin and two dorsal fins preceded by spines. The order contains a single living family the Heterodontidae (bullhead or horn sharks), comprising eight species of warm temperate and tropical, medium-sized (up to 1.6 m) sharks from the Pacific and western Indian Ocean. Other distinctive characters are a large, blunt head with a prominent ridge above each eye, a small, nearly terminal mouth, rough skin and molar-like rear teeth.

### 3.8.6 Order Orectolobiformes (carpet sharks)

Orectolobiform sharks are identified by the combination of an anal fin, two dorsal fins without spines, five gill slits on each side of the head and a mouth that is well in front of the eyes. They comprise a diverse group of mainly Indo-Pacific, benthic sharks including the small, shallow-water epaulette shark found on coral reefs, the flattened and ornately coloured wobbegongs and the giant, planktivorous whale shark. The order contains seven living families, the Parascyllidae (collared carpet sharks), Brachaeluridae (blind sharks), Orectolobidae (wobbegongs), Hemiscyllidae (longtail carpet sharks), Stegostomatidae (zebra sharks), Ginglymostomatidae (nurse sharks) and Rhincodontidae (whale sharks).

The Rhincodontidae contains a single, huge (reaching 12 m), circum-tropical, plankton feeding species that has a very wide, almost terminal mouth, minute teeth, long gill slits with internal filter screens, longitudinal ridges on the body, a semi-lunate caudal fin (except in very small juveniles) and a colour pattern of light spots and stripes on a dark background. The Stegostomatidae also contains a single distinctive species that has a long, blade-like upper caudal lobe (about as long as the rest of the shark), rough skin with a colour pattern of dark spots on a yellow background (juveniles with yellow stripes on a dark background), small mouth connected to the nostrils by grooves, barbels, longitudinal ridges on the body and two dorsal fins close together. The Ginglymostomatidae contains three species of medium to large sharks that have small mouths connected to the nostrils by grooves (but no lobes or grooves on the outer margin of the nostrils), barbels, two relatively large, posteriorly placed dorsal fins and a caudal fin with a weak ventral lobe. The orectolobids are distinctive, dorso-ventrally flattened (in front of the dorsal fins) sharks with skin flaps along the sides of the head, enlarged canine teeth and ornate colour patterns. There are three genera and seven recognized species. However, the group is more complex and requires more detailed faxonomix work with several probable new species taken recently in the Indo-Pacific region. The remaining three families contain small, often superficially similar species that can also be confused with some of the catsharks (family Scyliorhinidae). However, in the catsharks the mouth is located partly beneath the eyes. In the parascyllids (two genera, seven species), the anal-fin origin is in advance of the second dorsal-fin origin and the anal fin is separated from the caudal fin by a distance greater than the anal base length. The anal and caudal fins are almost touching in the brachaelurids (one genus, two species) and hemiscyllids (two genera, 12 or 13 species) and the anal-fin origin is well behind the second dorsal-fin origin. The brachaelurids have a short tail (distance from vent to lower caudal-fin origin less than distance from snout to vent) while the hemiscyllids have a long tail (distance from vent to lower caudal-fin origin greater than distance from snout to vent).

### 3.8.7 Order Lamniformes (mackerel sharks)

This order of mainly large (1.1-6 m) sharks is comprised of five families and can be identified from the following combination of characters; an anal fin, two spineless dorsal fins, a mouth located partly beneath the eyes, relatively large teeth, no barbels or grooves connecting the nostrils and mouth, and no nictitating membrane over the eyes.

Of the six families, the Alopiidae (thresher sharks) are unmistakable having an enormously elongated, scythe-like upper caudal-fin lobe that is equal in length to the rest of the body (the zebra shark also has a long upper caudal lobe, but has barbels, and grooves connecting the nostrils and mouth). There is one genus, and three species of thresher sharks. The Cetorhinidae (basking sharks), contains a single living species of huge (up to 10 m) plankton feeders. Basking sharks have a stout, fusiform body, conical snout (elongate and proboscis-like in juveniles < 4 m), huge gill slits that almost encircle the head (with internal filter screens), caudal keels and a lunate caudal fin. Basking sharks are grey-brown above and paler ventrally and superficially resemble large white sharks (family Lamnidae), but have minute teeth.

The family Odontaspididae (sand tiger sharks) contains two genera and three species of large, stout-bodied sharks with conical snouts, long awl-like teeth with lateral cusplets, two large dorsal fins, a large anal fin, and an asymmetric caudal fin with a short ventral lobe. The families Pseudocarchariidae (crocodile sharks), Megachasmidae (megamouth sharks) and Mitsukurinidae (goblin sharks) each contain a single living species of readily identifiable sharks. The goblin shark (attaining 3.8 m) has a bizarre head with an elongated snout forming a flat, blade-like rostrum, and very protrusile jaws. The filter-feeding megamouth (attaining 5 m) has a bulbous, blubbery whalelike head and a very wide, terminal mouth. The crocodile shark is smaller (up to 1.1 m), has a fusiform body, conical snout, very large eyes, long gill slits, a low first dorsal fin, asymmetric caudal fin, and is dark brown above and paler ventrally.

The family Lamnidae (mackerel sharks) consists of three genera and five species of highprofile sharks, the white, mako and porbeagle, which are of considerable fisheries importance. These large (3-6 m) species have conical snouts, fusiform, spindle-shaped bodies, awl-shaped or triangular teeth, minute second dorsal and anal fins, caudal keels, and lunate caudal fins. The shape of the teeth, body colouration and number of caudal keels are important for identification at the species level.

### 3.8.8 Order Carcharhiniformes (ground sharks)

This diverse order of sharks contains many commercially important species within its eight families. They can be identified by the following combination of characters; an anal fin, two spineless dorsal fins, a mouth located partly beneath the eyes, five gill slits, relatively large teeth, no barbels or grooves connecting the nostrils and mouth and a nictitating membrane over the eyes. The families Leptochariidae (barbeled houndsharks) and Pseudotriakidae (false catsharks) each contain a single living species and, together with the Proscylliidae (finback catsharks) comprising four genera and seven species, are relatively obscure groups. The Scyliorhinidae (catsharks) is by far the largest family of sharks with 15 genera and more than 110 mostly small, bottom-living species. The Carcharhinidae (requiem sharks) comprise 12 genera and about 50 species of small to large 'typical-looking' sharks. The Triakidae (houndsharks) are also relatively speciose with nine genera and about 40 species, while the Hemigaleidae (weasel sharks) have four genera and five species. The Sphyrnidae (hammerheads) have two genera and nine species.

The Sphyrnidae are easily recognized by their bizarre, hammer-shaped heads. Variations in head size and shape are important for species identification. The Pseudotriakidae are also distinctive with a long, low first dorsal fin and over 200 rows of teeth in each jaw. The Scyliorhinidae are best separated from the other families by the position of their first dorsal-fin base, which is opposite or behind the pelvic-fin base. The Hemigaleidae and Carcharhinidae have precaudal pits and an undulating or rippled dorsal margin to the upper caudal fin, while the other families have no precaudal pits and a smooth dorsal caudal margin. These two families are difficult to tell apart and while hemigaleids have a small spiracle, usually absent in carcharhinids, reliable diagnosis mainly relies on the structure of the intestinal valve. The carcharhinids have a scroll-type valve and the hemigalids a spiral one. The Proscylliidae have labial furrows that are short (confined to mouth corners) or absent, and comb-like posterior teeth. Triakids and leptochariids have much longer labial furrows and posterior teeth that are not comb-like. In the leptochariids, the upper labial furrows are long (length more than half the mouth width) and there are barbels on the nasal flaps. The traikids have no nasal barbels (except in *Furgaleus*) and the upper labial furrows are shorter (length less than half the mouth width).

The genus *Carcharhinus* (Carcharhinidae) contains about 30 species that are difficult to identify for those not experienced with the group. Important characters are fin shape and positions, colour markings on the fins, the presence of an interdorsal ridge, tooth and vertebral counts and the shape of the upper teeth in the middle of the jaw. Species in the genus *Mustelus* (Triakidae) are also notoriously difficult to identify with partial overlap of many of the morphological, morphometric and meristic characters used to separate them. An increasing number of 'regional forms' have been discovered recently.

### 3.8.9 Order Torpediniformes (electric rays)

The four families Torpedinidae (torpedo rays), Hypnidae (coffin rays), Narcinidae (numbfishes) and Narkidae (sleeper rays) are small to medium sized (0.15-1.8 m) rays with large, oval, rounded or shovel-shaped discs, naked skin without denticles, short stout tails with usually two (occasionally one or none) dorsal fins and a broad caudal fin. The thick pectoral disc has two kidney-shaped electric organs on its ventral surface. In the numbfishes (four genera and at least 17 species), the tail length from behind the pelvic-fin tips is about equal to, or a little longer than, the maximum disc width while in the other three families the disc is wider than the tail length. The coffin rays comprise one species endemic to Australia and have a pear-shaped disc, pelvic fins joined together to form a smaller second disc and a short tail that extends slightly beyond the pelvic fins. The caudal fin is about the same size as each of the two dorsal fins and much smaller than the pelvic fins. In the torpedo rays (one genus, at least 15 species) the caudal fin is much larger than either of the two dorsal fins and about the same size as the pelvic fins. The sleeper rays (four genera, nine species) have a large round pectoral disc and a strong tail with only a single or no dorsal fin.

### 3.8.10 Order Pristiformes (sawfishes)

The family Pristidae (sawfishes) consists of two genera and about six species of mostly large (up to 7 m) tropical marine and freshwater species. These are unmistakable batoids with the snout highly modified into a “saw” bearing large lateral rostral teeth. Unlike the superficially similar sawsharks (family Pristiophoridae), sawfish have their gill slits situated ventrally (rather than laterally) on the head, have no barbels on the saw and their relatively small pectoral fins join the head in front of the gill slits. The number of rostral teeth, shape of the caudal fin and position of the first dorsal fin relative to the pelvic fins are important characters for identification at the species level.

### 3.8.11 Order Rhiniformes (sharkrays)

McEachran, Dunn and Miyaka (1996) consider this order to comprise one family (Rhinidae) containing a single species of large ray (*Rhina ancylostoma*) attaining a length of at least 2.7 m. It has a broadly rounded head distinctly demarcated from its pectoral fins, falcate shark-like fins, almost lunate caudal fin and horny ridges on its back bearing thorns and spines. Other authors have placed *Rhina* together with *Rhynchobatus* in the Rhinidae (Compagno 1999b) or in the Rhynchobatidae (Last and Stevens, 1994).

### 3.8.12 Order Rhynchobatiformes (wedgefishes or sharkfin guitarfishes)

The single family Rhynchobatidae (sharkfin guitarfishes) contains mainly inshore rays with a flattened body, a mostly wedge-shaped or oval disc and a broad, shark-like tail with two large dorsal fins and a large caudal fin. In the shovelnose rays (*Rhinobatos* spp.), the first dorsal-fin origin is behind the pelvic fin, the caudal fin has a weak ventral lobe and a well-developed dorsal lobe with a straight posterior margin. Species diversity is highest in the Indo-West Pacific region with four genera and about 40 species, but more are likely to be discovered as these rays are not well known in many areas. The sharkfin guitarfishes have the first dorsal-fin origin in front of the pelvic-fin insertions, both caudal lobes are well developed and the posterior margin of the dorsal lobe is concave. There are two genera and more than five species, which mostly occur in the Indo-West Pacific; however, the taxonomy of the genus *Rhynchobatus* requires more study.

### 3.8.13 Order Rajiformes (skates)

The taxonomy of the skates is complex with two subfamilies, some 26 genera and around 200 species. These bottom living rays have enlarged pectoral fins forming a disc that varies in shape from nearly circular to rhomboidal. Their pelvic fins are deeply notched forming two lobes, and they have a fairly narrow tail with two (rarely one or none) small dorsal fins near the tiny caudal fin. Most species have enlarged thorns around the eyes, along the dorsal midline or on other parts of the body. The shape of the disc and snout, the presence and shape of the cartilage supporting the snout, relative lengths of the pelvic-fin lobes and the pattern of thorns are important identification characters at the species level. The genus *Anacanthobatus* (leg skates) consists of about 18 species that have their pelvic fins separated into a mobile leg-like front lobe and normally have smooth skin.

### 3.8.14 Order Myliobatiformes (stingrays)

This is a complex grouping which McEachran, Dunn and Miyaka (1996) consider contains three suborders (Platyrhinoidei, Zanobatoidei and Myliobatoidei) and two superfamilies (Hexatrygonoidea and Dasyatoidea). In the interests of simplicity this account differs slightly from this classification. The families Urolophidae (stingarees), Hexatrygonidae (sixgill stingrays), Dasyatidae (stingrays), Gymnuridae (butterfly rays), Myliobatidae (eagle rays), Rhinopteridae (cownose rays) and Mobulidae (devilrays) usually have one or more stinging spines on the dorsal surface of the tail, a large pectoral disc and a stout to very slender tail with a caudal fin and single dorsal fin variably present or absent. The hexatrygonids are unique among the batoids in having six pairs of gill slits; there is a single genus and about seven species most of which are known only from a single specimen. More work is required to resolve the validity of these species. The gymnurids (two genera and at least 12 species) have a wide (width more than 1.5 times its length), butterfly-shaped disc and a short filamentous tail. Mobulids are the largest of all rays (attaining at least 7 m width). The two genera and about 10 species are easily recognized by their wide, angular, wing-like discs, prominent fleshy lobes projecting forward like scoops on each side of the head, terminal (or nearly so) mouth with minute teeth (they are plankton feeders) and filamentous tails. Myliobatids (four genera and about 22 species) and rhinopterids (one genus and about 10 species) also have wing-like disc shapes and filamentous tails, but a single bulbous fleshy lobe extends around the snout in myliobatids; in rhinopterids this is indented to give it a distinctive bilobed forehead.

Dasyatids have a circular to rhomboidal disc with a whip-like tail that usually has stinging spines but lacks dorsal, anal or caudal fins. However, they may have membranous skin folds on the dorsal and or ventral midlines of the tail; the central disc and dorsal tail surface usually has thorns or tubercles. Dasyatids are represented by at least five genera and more than 60 species that occur in marine and freshwater habitats; their often large size (some species > 2 m disc width) makes them difficult to study and more taxonomic work is required on the group. Disc and snout shape, colour patterns (which may change subtly with size), the presence of membranous skin folds on the tail, and the pattern of denticles on the disc and tail are important species identification characters.

Urolophids resemble dasyatids in body shape, but have shorter tails with a well developed caudal fin and usually no thorns or tubercles on the disc or tail; There are three genera and about 40 species. Disc and tail shape, structure of the nostrils, presence of a dorsal fin and colour pattern are important for identifying species. However, some species are difficult to identify on external characters alone. The family Platyrhinidae (thornback rays) comprise two genera and two species of inshore batoids that have round or heart-shaped discs, long, stout, shark-like tails, two large dorsal fins (situated anteriorly on the tail), no stinging spines, and large thorns on the disc and tail. Compagno (1999b) placed the family Platyrhinidae within the order Rhinobatiformes.

### 3.8.15 Order Chimaeriformes (chimaeras)

Diagnostic features of the chimaeras were given in Section 1. The order contains three families, the Callorhinchidae (elephant fishes), Chimaeridae (shortnose chimaeras) and Rhinochimaeridae (longnose chimaeras). There is one genus and three species of silvery coloured elephantfishes that are easily recognized by their long snouts terminating in a flexible hoe-shaped structure, relatively shortbased second dorsal fin, large anal fin and well-developed caudal fin that has no caudal filament and is arched upwards from the body axis. Shortnosed chimaeras (two genera and at least 22 species) have a relatively short snout with a bluntly rounded tip and a caudal-fin axis that is straight. Most species occur in deepwater and are dark brown to purply-black in colour;

the systematics of the group needs more attention with several new forms reported recently. Longnose chimaeras (three genera, at least seven species) also have a straight caudal-fin axis, but they have a very long snout with a pointed tip; they range in colour from pinkish-white to black.

### 3.9 ACKNOWLEDGEMENTS

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