2. Subsistence and artisanal fisheries in the Pacific

Fisheries

In its broadest sense, a fishery includes the marine environment, a resource or target species of seafood, and the people involved in fishing and in handling the catch. The marine environment consists of the living and non-living surroundings of a marine species – thus both corals and seawater are parts of the environment of a reef fish. A fisheries resource is a population of fish, or other marine animal, which is exploited. Some of the different types, or species, fished in Pacific Islands are described later in this chapter.

A fishing operation may be a simple one, such as the collection of shellfish on a reef, or it may be a much more complicated one, such as the catching of tuna by a large fishing vessel. Handling the catch may range from the simple storage of fish on ice to the technologically sophisticated procedure of canning. Methods of fishing and catch handling appropriate to subsistence fishing are described later in this chapter.

Fisheries are often divided into non-commercial and commercial sectors. The non-commercial or subsistence sector involves the catching of fish to eat rather than to sell. The commercial fishery may be divided into an artisanal sector, usually small-scale fishing to supply local markets and an industrial sector, involving large-scale fishing for canneries and export. This manual is concerned with subsistence fishing in coastal communities in the Pacific.

Types of coastal ecosystems

There are many different types of marine environments, or ecosystems, in tropical islands. Some islands have rivers and forests of mangroves. Many coasts have coral reefs fringing the shore while others have a sheltered lagoon between the shore and a barrier reef. Beyond the coral reefs in the open sea, there is usually no continental shelf and the sea-floor rapidly drops away to deep water. Marine animals are specially adapted to living in particular environments. A range of different environments, and some of the species present in each, are shown distributed along a profile of a tropical coastline in Figure 2.1. However, many species migrate between different environments at different stages of their life-cycle; some fish, for example, grow up as juveniles in mangrove areas before migrating out to lagoons as adults.

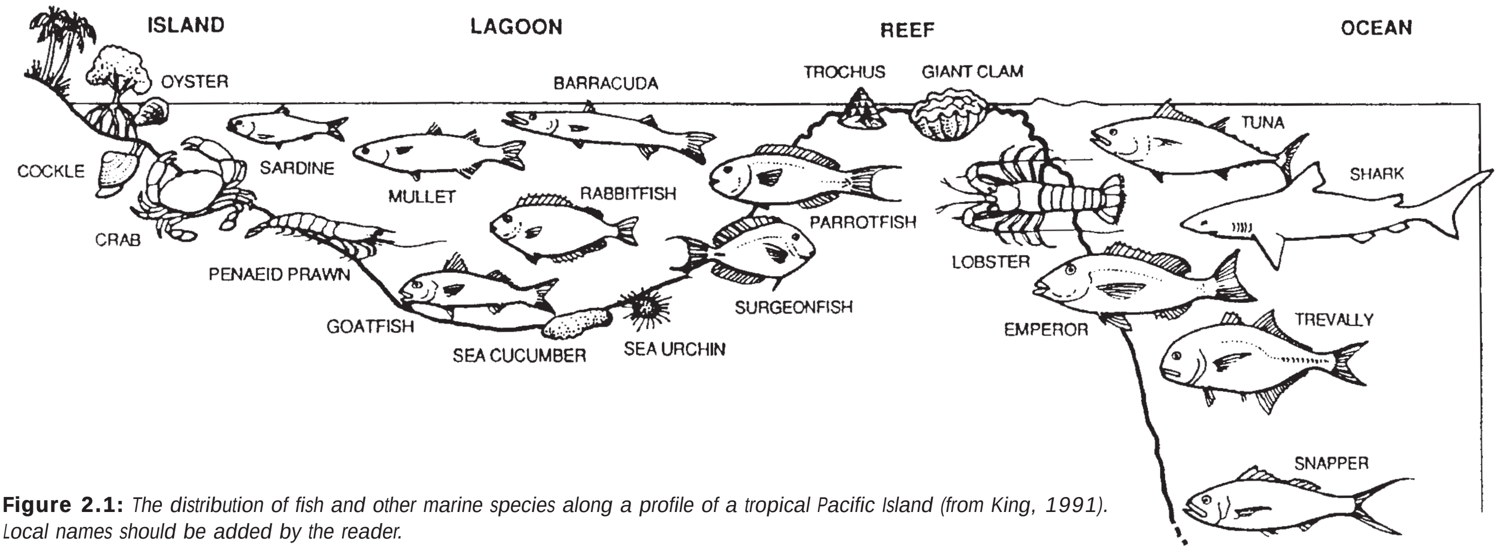

Figure 2.1: *The distribution of fish and other marine species along a profile of a tropical Pacific Island (from King, 1991). Local names should be added by the reader.*

Estuaries – brackish water and mangroves

Estuaries are places where rivers meet the sea. Here, because of the mixing of river water and sea water, the water is of low salinity, and is said to be brackish. Brackish water can also occur where there are freshwater soaks or run-off from the land. In these ecosystems, there are often forests of mangroves – trees which are specially adapted for life at the sea's edge. The common red mangrove, *Rhizophora*, is shown in Figure 2.5.

Mangroves play an important role in providing shelter and food for marine creatures. Plant material decomposes to form detritus which is used as food by crabs, prawns and many fish. The juveniles of many different species use mangroves as areas in which to grow (as nursery areas) before moving out to deeper water. Mangroves are also important in protecting and extending shore-lines.

Mangroves are often cut down during land reclamation, in which land is filled in for housing or other development. Some coastal road construction which interrupts the mixing of fresh and salt water also creates an environment unsuitable for mangroves – usually mangroves die because water on the seaward side of the road becomes too saline and water on the landward side becomes too fresh.

Beaches and seagrass

Beaches are formed by particles of material washed ashore by waves and currents, or, in some cases, particles carried from inland by rivers. In tropical regions, most beaches consist of coral which has been broken up into particles by storms, or has passed through the digestive system of coral-eating fish such as parrotfish (Figure 2.9). In each case, coral skeletons are broken down to small particles which are carried by currents and deposited inshore to form beaches.

Gently sloping beaches of sand prevent waves eroding and washing away the shore, and are, therefore, particularly important in low-lying areas. In coral atolls, beaches protect land which is often only a few metres above sea level. In some shallow sandy areas there may be extensive underwater meadows of seagrass (Figure 2.2) which provide shelter and food for many different animals. Seagrasses are similar to flowering plants on land, and unlike seaweeds (marine algae), they have root systems which are able to gain a foothold in drifting sand. Seagrass beds assist in the formation of sand bars and provide food and shelter for many marine animals.

Sand is often removed from beaches, or dredged from lagoons, to make concrete for the building industry. The mining of sand must be controlled so that there is minimal impact on the coastal environment.

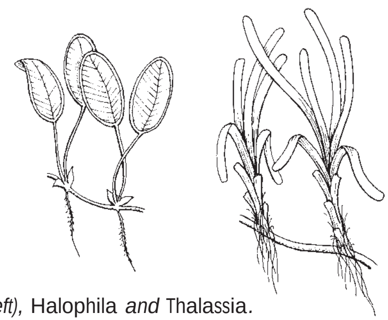

Figure 2.2: *The seagrasses (from left),* Halophila *and* Thalassia.

Coral reefs and lagoons

There are many hundreds of different types of coral. All corals are made up of small animals called polyps, which are usually less than 1 cm in diameter and live side by side in groups or colonies. A few species, such as the mushroom coral (Figure 2.3), have larger solitary polyps up to 20 cm in diameter. Many coral polyps grow together as a colony to build a shared skeleton which has a particular shape depending on the species of coral (Figure 2.3). A large number of coral colonies collectively form a coral reef, consisting of the skeletons of many millions of dead polyps. Living polyps are only found on the thin outer layer of the coral reef which continues to grow outwards and upwards with each generation.

Besides capturing food drifting in the water, coral polyps can obtain food from small plant cells (zooxanthellae) living in their tissue. Through photosynthesis, the zooxanthellae use sunlight and dissolved nutrients to produce food which is shared with the coral. Thus most corals, like plants, require sunlight and can only live in clear, shallow, sunlit waters.

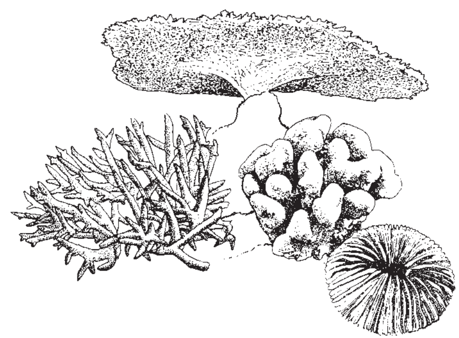

Figure 2.3: *Some common types of hard, reef building corals, including (from left) staghorn coral, table coral* (Acropora *species) and boulder coral* (Porites)*; a mushroom coral* (Fungia)*, which exists as a single, large polyp is shown on the right (from King, 1988).*

There are three basic types of coral reefs – fringing reefs, barrier reefs and atolls. One explanation of how the different types of reefs evolve is based on the concept of an oceanic island gradually sinking over many thousands of years. As long as a newly formed island in tropical waters is within reach of drifting coral larvae, it soon acquires a fringing reef of coral. As the island slowly subsides or sinks, the fringing reef around the island actively grows upwards. Eventually a lagoon will form between the sinking island and the growing coral which then becomes a barrier reef. When the island sinks beneath the sea, the barrier reef maintains its upwards growth to become a circular atoll. This sequence in reef formation is illustrated in Figure 2.4.

A coral reef is part of a complex ecosystem and includes many animals and plants which are important food items for coastal communities. In addition, coral reefs protect coastlines and villages, particularly from large ocean waves created by cyclones, and are the source of sand for beaches.

Although corals have natural predators, such as the crown-of-thorns sea star and the parrot fish (Figure 2.9), the activities of people present the greatest threat to coral reefs. Corals are collected for sale as souvenirs and coral blocks are used for building. Dredging harbours and coastal building projects often release silt into the water which blocks off sunlight or smothers coral polyps. In some areas, corals are being destroyed by destructive fishing methods (see Chapter 4).

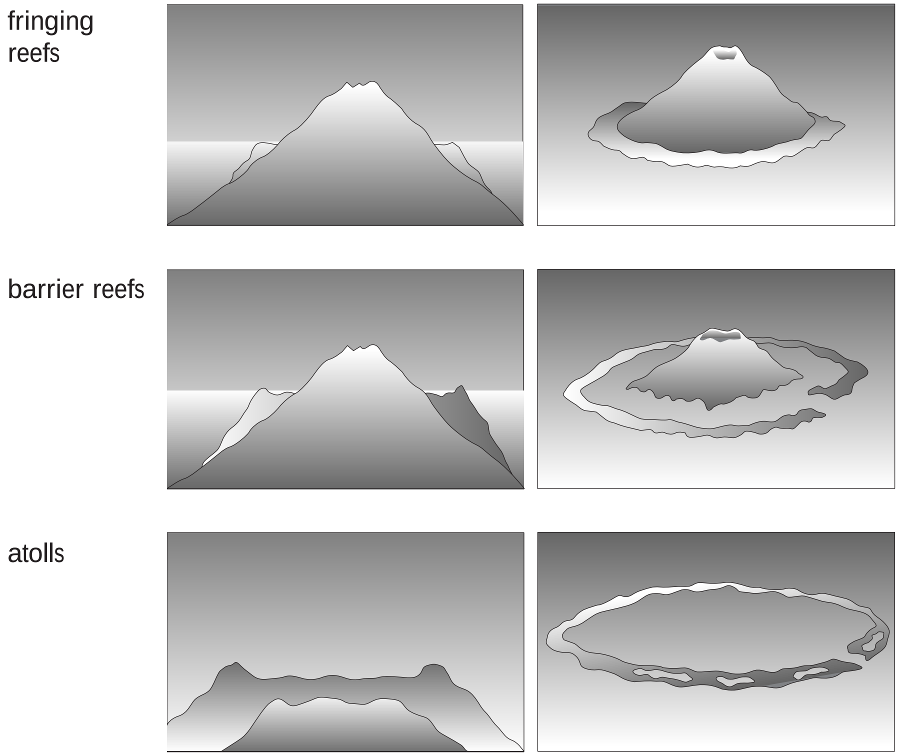

Figure 2.4: *Types of coral reefs (Adapted from Colin & Arneson, 1995).*

Outer reef slopes and the open sea

On the outer edge of coral reefs, the sea floor usually slopes down at a steep angle until the ocean floor is reached at an average depth of about three kilometres. After this the seafloor is relatively flat although it may rise to form seamounts and other island groups. In some areas the sea floor drops away to form very deep trenches (often over 10 km deep) such as the Tonga Trench and the Mariana Trench.

Many seafood species including spiny lobsters and fish such as groupers and snappers are caught on the outer slopes of reefs. But in the open ocean, there are no reefs to provide shelter or large plants to provide food, and only a few specialised types of fish, such as tuna, can live there. These oceanic fish wander over large areas of ocean hunting smaller fish which feed on small drifting animals (zooplankton). The zooplankton, in turn, feed on very small, drifting plants (phytoplankton). Phytoplankton, however, can only grow where there are nutrients, mainly dissolved nitrates and phosphates. Most surface areas of the sea contain only small quantities of nutrients to feed phytoplankton, and can, therefore, support only small numbers of fish. An exception to this is a particular area where water moves up from the deep as an upwelling, bringing with it large quantities of nutrients.

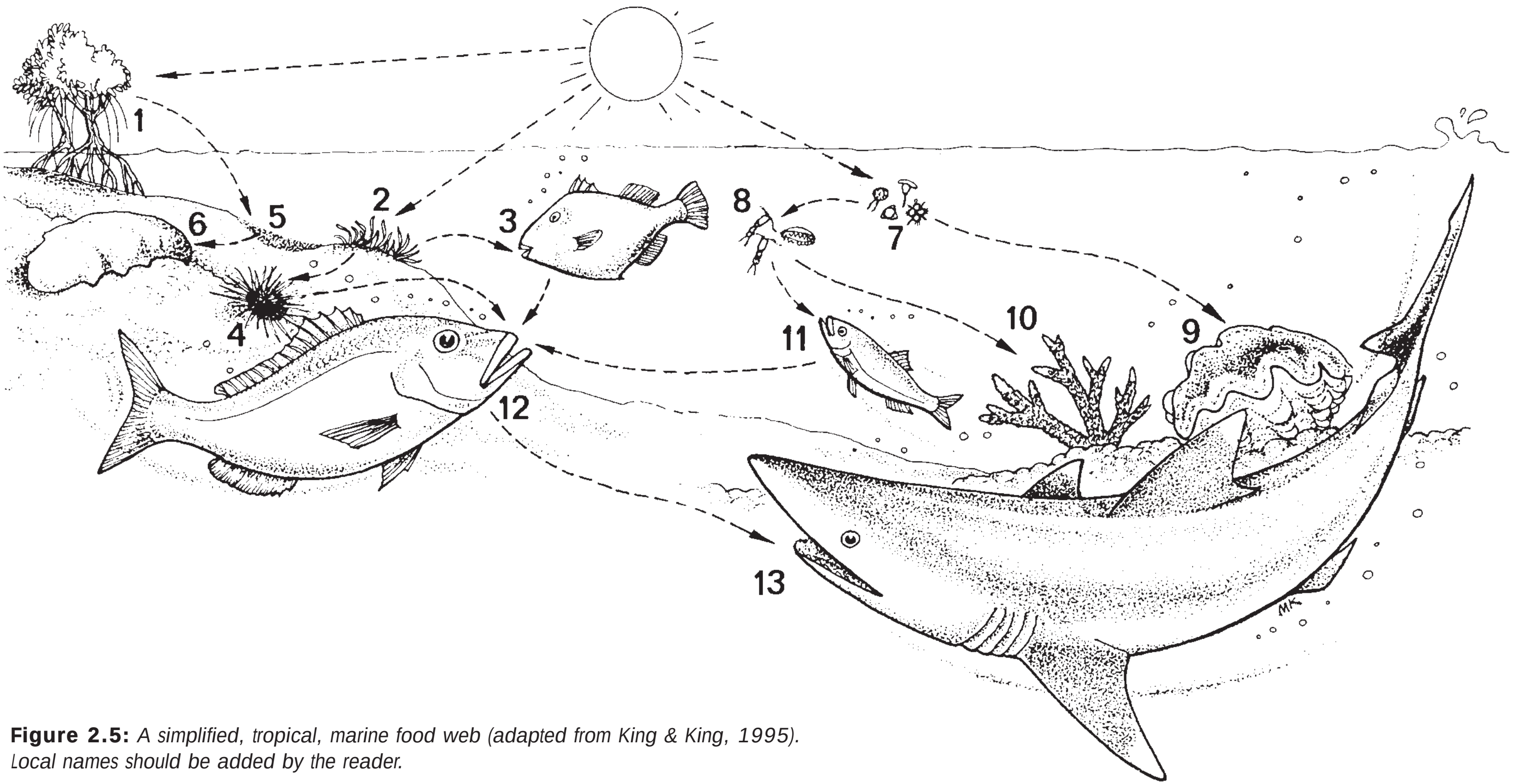

Figure 2.5: *A simplified, tropical, marine food web (adapted from King & King, 1995). Local names should be added by the reader.*

Foodwebs and relationships between ecosystems

Although ecosystems are described under separate headings in this chapter, they are not independent of each other. They are interrelated, and many species migrate between different ecosystems at different stages of their life cycles. Some fish, for example, grow up as juveniles in mangrove areas before migrating out to lagoons as adults. The larvae of other species may drift in the open sea before settling on coral reefs to grow.

Within and between the various ecosystems described in previous sections there is a flow of material and energy. Energy from the sun and dissolved nutrients are used by plants to form tissue through photosynthesis. The plant material is eaten by animals which are eaten by other, usually larger, animals. This complex flow of energy and food material is often referred to as a food web.

A simplified, tropical, marine food web is shown in Figure 2.5. Plants such as mangroves **(1)** and seagrasses **(2)** use sunlight to produce plant material from carbon dioxide and nutrients during photosynthesis. Plant material is eaten by herbivorous animals such as triggerfish **(3)** and sea urchins **(4)**. Plants and wastes from animals are broken down by bacteria to form a pool of organic material called detritus **(5)** which is consumed by a wide range of animals, including the sea cucumber **(6)**. Microscopic plants (phytoplankton – greatly magnified in **(7)** drift near the surface of the sea, and are eaten by small floating animals (zooplankton – magnified in **(8)**. Some small plant cells (zooxanthellae) live in the tissues of giant clams **(9)** and corals **(10)**. Some animals, including the giant clam, actively pump sea water through their shells to filter out phytoplankton for food. Zooplankton are consumed by small carnivores such as sardines **(11)** and corals. Fish, including emperors **(12)**, eat a wide range of smaller fish, and are themselves hunted by larger animals such as sharks **(13)**.

Each living thing is part of a food web in which material or energy accumulated at each step by plants or animals as biomass (weight of living material) is transferred as food to the next level. Hence, reducing the numbers of one marine species by overfishing or by destroying its habitat may affect many other species. Because ecosystems are connected through food webs and migration, human activities that badly affect one ecosystem may affect other types of ecosystems, even those some distance away.

Resource species

In spite of the large diversity of marine species, most exploited species of animals are contained in one of four large scientific groups – three invertebrate groups (animals without backbones) and one vertebrate group (animals with backbones). Species are included in a particular group on the basis of having similar characteristics and larval stages, as well as having what is believed to be a common ancestor, perhaps many millions of years ago.

The following sub-sections briefly describe some members of these groups – the ones that are important in fisheries of Pacific Islands. Seaweeds (marine algae) are included because of their use as food in many islands, and their importance at the base of the food webs described in the previous section. A technical review of the biology and fisheries aspects of many inshore resource species of the South Pacific is given in Wright and Hill, 1991. Details of general biology and fisheries are given in King, 1995. A review of fisheries of Pacific Islands is given in Dalzell et al., 1996.

Echinoderms – sea stars, sea cucumbers and sea urchins

Echinoderms, including sea cucumbers and sea urchins (Figure 2.5), have a covering, or external skeleton, of hard plates. In sea cucumbers, however, these plates are reduced to small spikes embedded in the thick body wall. At least seven different species of sea cucumbers are used as food in the South Pacific; some species are boiled, smoked and dried for export as beche-de-mer to Southeast Asia. Sea urchins are collected as food from shallow-water lagoons and reefs, and the star-shaped reproductive organs are regarded as delicacies in many countries of the world.

Molluscs – clams, sea snails and octopuses

Molluscs number more than 80 000 different species and include creatures as different as the giant clam and the octopus. Although most molluscs are encased in one or two shells, others have no shell at all. The three different classes of molluscs of commercial importance are the bivalves (such as clams), the gastropods (including trochus shells) and cephalopods (such as octopuses and squids).

Bivalve molluscs (clams, cockles and pipis) have two shells. Most obtain food by filtering phytoplankton from the surrounding water. Many species of bivalve molluscs (such as cockles and pipis) live under the sand, and pump seawater through two tubes, or siphons, which stick up through the sand. These are collected in village communities, particularly by women, and are an important source of seafood when the weather is too rough to fish in the open sea. The world's largest bivalves, giant clams, live in clear, shallow water on coral reefs. Giant clams have been overexploited in many islands, and some species have become locally extinct in Micronesia and Melanesia. In South-east Asia the dried muscles of giant clams are regarded as a delicacy. Pearl-oysters, which may form pearls around grains of sand or other material which irritates their soft tissues, are grown commercially in some Pacific Islands.

Most gastropods (sea snails) have a single shell for protection, although some, such as sea hares (sea slugs), have no shell. Several different species, such as the green snail, are collected from rocky shores or reefs for use as food. Gastropods have remarkable, file-like teeth, called radula. With the radula, some species scrape plant material from rocks, while other carnivorous species bore through the shells of bivalve molluscs. Trochus shells, which have pearly inner-linings, are collected and used in the manufacture of buttons. Figure 2.6 shows two trochus shells, one of which has been drilled to remove the circular pieces of shell used to make the buttons. The sea hare, which grazes on algae and is collected for food, has a shell which is reduced to an internal horny plate.

Because of their attractive shells, many different bivalves and gastropods are collected, mainly by women, for making handicrafts such as necklaces. Selling handicrafts contributes substantially to the incomes of many coastal communities.

The octopus, which is used as food in many islands, usually lives in holes on the coral reef and comes out at night to hunt. Other cephalopods include the squid, cuttlefish and nautilus. The nautilus, the shell of which is sometimes found washed up on reefs, lives in deep waters of the Indo-Pacific.

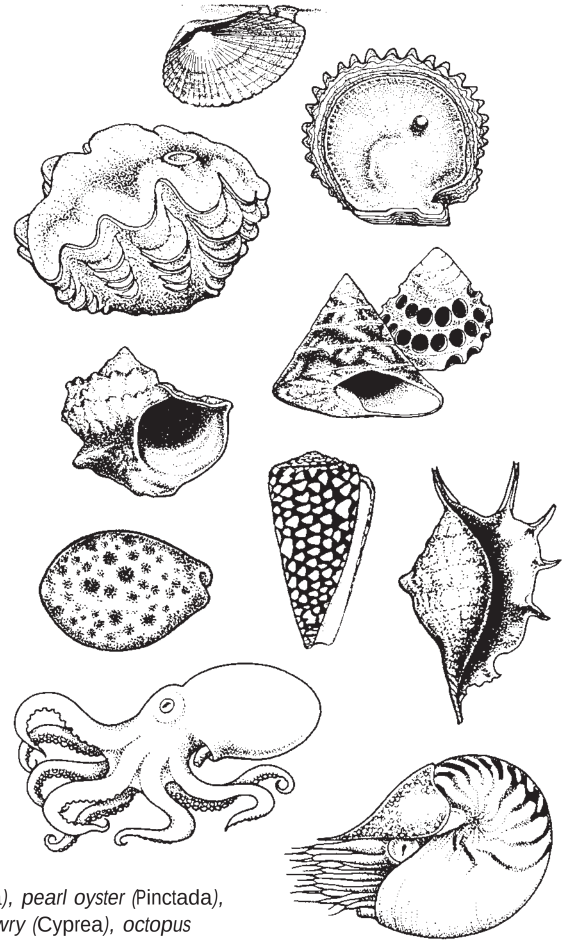

Figure 2.6: *Examples of molluscs in Pacific Islands. From the top these are the ark shell (*Anadara*), pearl oyster (*Pinctada*), giant clam (*Tridacna*), trochus (*Trochus*), green snail (*Turbo*), cone (*Conus*), spider shell (*Lambis*), cowry (*Cyprea*), octopus (*Octopus*) and chambered nautilus (*Nautilus*). Local names should be added by the reader.*

Crustaceans – lobsters, crabs and prawns

Over 30 000 marine animals including prawns, shrimps, lobsters and crabs, together with such animals as barnacles, are crustaceans. Crustaceans typically have a body covered with a hard shell (or exoskeleton) and jointed legs. In order to grow in size, the animal must cast off (or moult) its hard exoskeleton and expand before a newly-formed shell hardens.

Spiny lobsters generally live on coral reefs and outer reef slopes, and are usually caught by divers using spears. After reproduction, the female spiny lobster carries fertilised eggs underneath her abdomen or "tail". The eggs hatch to small larvae which drift with ocean currents before settling on reefs to grow to adults. Related to spiny lobsters are the slipper lobsters, which are usually speared on sandy seafloors.

One of the larger inshore species of crab is the mud crab, which spends the early part of its life-cycle in estuaries and mangrove areas. Many other smaller crabs are caught on rocky shore lines. Like lobsters, female crabs carry eggs beneath their abdomens. The mud crab, for example, carries her eggs out to sea, where they hatch into larvae which drift back to inshore areas. The coconut, or robber crab, is one of the largest of all crabs and spends most of its life on land; its large size (up to 30 cm across the shell) prevents it from living in an empty gastropod shell like other hermit crabs.

Prawns, such as tiger prawns and king prawns, are found in some western Pacific countries, and are the basis of commercial fisheries in Papua New Guinea. Most prawns require areas of brackish water for the juveniles to grow in, and are therefore not found in coral atolls or low islands with insufficient rainfall.

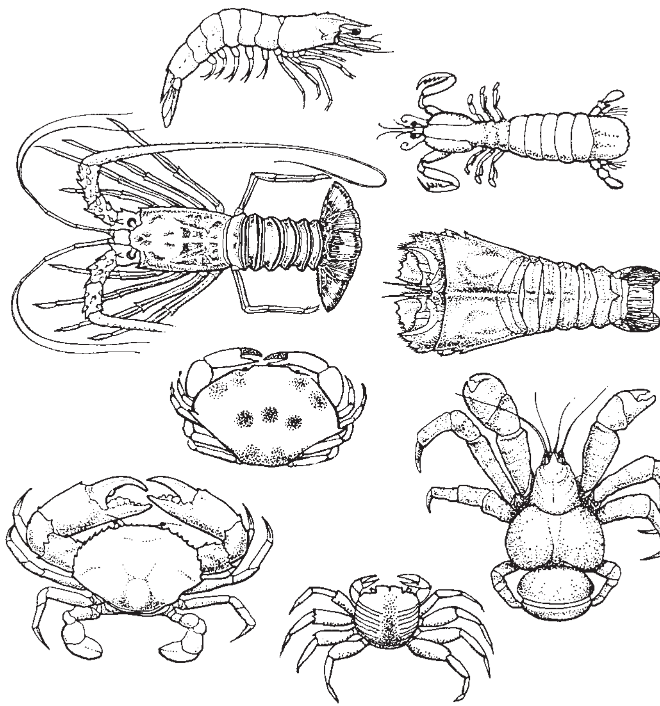

Figure 2.7: *Crustaceans of Pacific Islands. From the top, examples include the tiger prawn (*Penaeus*), mantis shrimp (*Squilla*), spiny lobster (*Panulirus*), slipper lobster (*Parribaccus*), three-spot reef crab (*Carpilius*), coconut crab (*Birgus latro*), mud crab (*Scylla*), and the shore crab (*Grapsus*). Local names of species should be added by the reader.*

Fish

Of all the groups of animals with backbones (vertebrates), fish are the most numerous. There are over 25 000 different species of fish distributed in environments from high mountain pools to the deepest parts of the ocean. In most species of fish, the female releases eggs into the sea before they are fertilised by sperm from males. The fertilised eggs hatch to small larvae which are often planktonic and drift with ocean currents. After a period which varies from species to species, the larvae change to adults which are either demersal (living near the sea floor) or pelagic (living near the sea surface).

Sheltered, inshore areas, particularly estuaries, are rich in food material and are able to support a wide variety of fish species. Some species of fish, including garfish, stay in inshore areas throughout their life-cycle. Other species use sheltered inshore waters only during part of their life-cycle, often as nursery areas in which the young grow up. Examples of common inshore fish are shown in Figure 2.8.

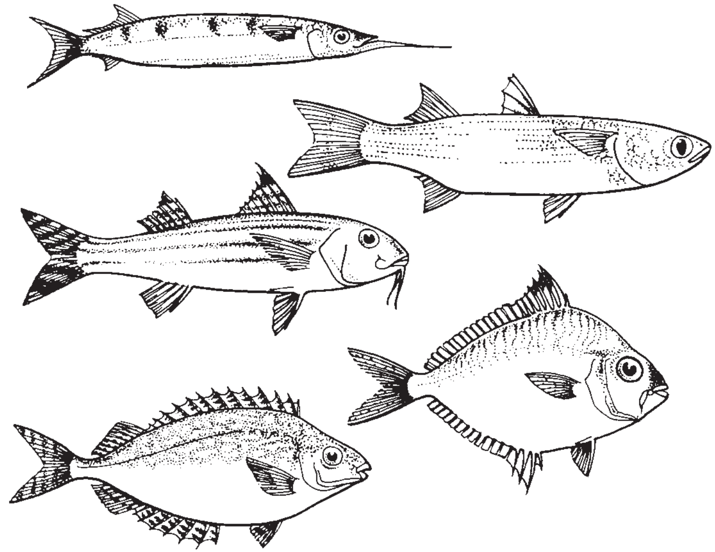

Figure 2.8: *Fish families from sheltered inshore areas of tropical Pacific Islands. From the top, examples include garfish (Hemirhamphidae), mullet (Mugilidae), goatfish (Mullidae), ponyfish (Leiognathidae), and rabbitfish (Siganidae). From King, 1995. Local names should be added by the reader.*

A coral reef ecosystem contains more species of fish than most other environments. Larger fish include the many different species of emperors, groupers and snappers. Smaller species commonly used as food include surgeonfish, parrotfish, wrasse, triggerfish and eels (Figure 2.9). Generally, coral reef fishes have adults which live within a small home range on the reef. They reproduce repeatedly over a lifespan of less than ten years to produce pelagic larvae. Many coral reef fish, particularly trevallies, groupers, and surgeonfish, produce larvae which drift far out in the ocean before returning and settling on coral reefs as adults. The species with longest larval phases, have the greatest potential for dispersal, and are widely distributed on isolated reefs across the Pacific.

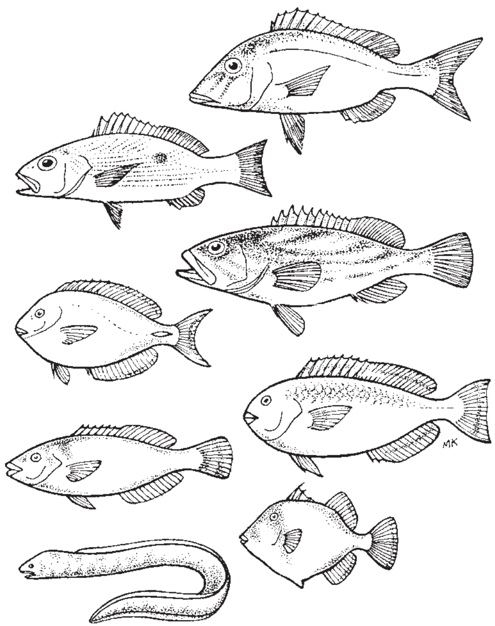

Figure 2.9: *Coral reef fish families of Pacific Islands. From the top, examples include emperor (Lethrinidae), snapper (Lutjanidae), grouper (Serranidae), surgeonfish (Acanthuridae), parrotfish (Scaridae), wrasse (Labridae), triggerfish (Balistidae) and moray eels (Muraenidae). Local names should be added by the reader.*

Beyond the coral reefs, many demersal species are caught on the shallow outer reef slopes. Deep water snappers are caught by hook and line in depths of about 200 m on the steep slopes of islands and seamounts (Figure 2.10). These large deep-water snappers are particularly valuable in tropical areas, as their distance from coral reef ecosystems means that they are unlikely to be affected by ciguatera, the toxic condition that seasonally affects some reef fish in shallower water.

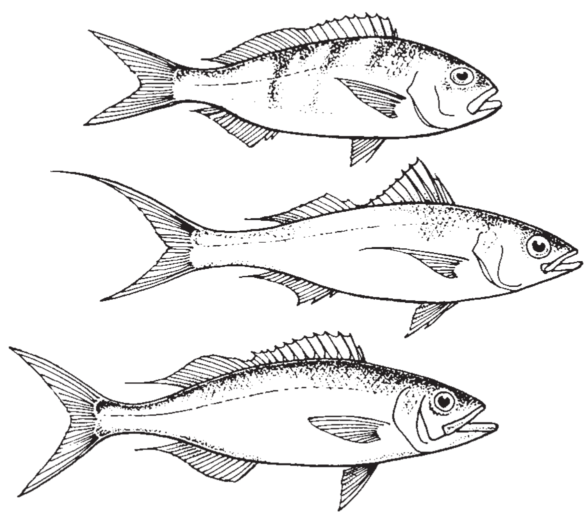

Figure 2.10: *Larger fish of the deeper outer reef slopes. From the top, examples include the oblique-banded snapper (*Pristipomoides zonatus*), the long-tailed snapper (*Etelis coruscans*), and the rusty jobfish (*Aphareus rutilans*). From King, 1995. Local names should be added by the reader.*

Inshore pelagic fish include the jacks or trevallies as well as the smaller horse-mackerels or scads, which form hunting schools on many reefs. In the western Pacific, the Indian mackerel is commonly netted in lagoons, and the Spanish mackerel is trolled off reefs. Barracudas are more widely distributed, and are voracious predators in the vicinity of coral reefs (Figure 2.11).

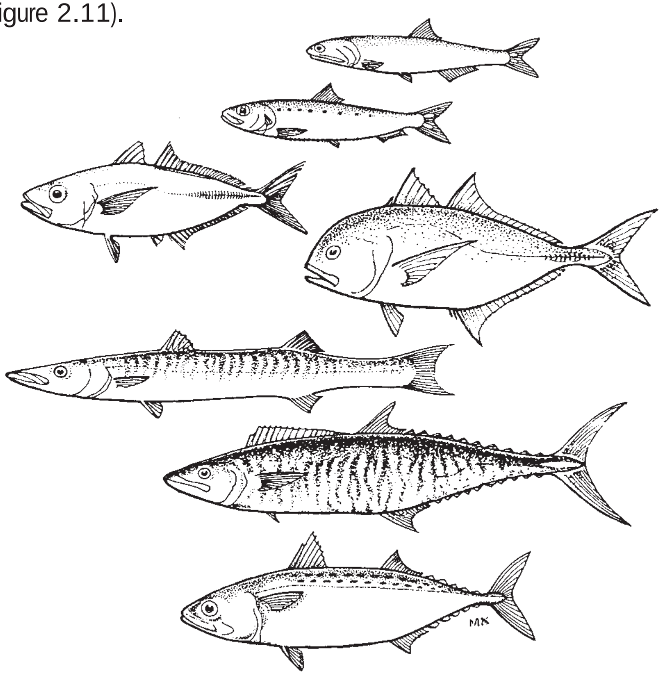

Figure 2.11: *Inshore pelagic fish in Pacific Islands include, from the top, anchovies (Engraulidae), sprats, sardines and herrings (Clupeidae), scads (*Selar, Decapterus*), trevally (*Caranx*), barracuda (*Sphyraena*), Spanish mackerel (*Scomberomorus commerson*), and Indian mackerel (*Rastrelliger kanagurta*). Local names should be added by the reader.*

Further from the coast, in the open sea, the best known pelagic fish are the dolphinfish (dorado or mahi-mahi) and several species of tuna (Figure 2.12). Tunas are fast-swimming pelagic fish related to marlins and sailfish, and are distributed over large areas of the ocean. Tuna are caught by local fishers in many Pacific Islands, often by trolling lures behind small boats. Commercial vessels use longlines and purse-seine nets to catch albacore, big-eye and yellowfin tuna. Approximately 35% of the world catch of tuna is caught in the Pacific Ocean. Some species of tuna, including albacore, move across large areas of the ocean, either to reach new feeding grounds or to reach spawning areas, whereas some species, such as skipjack tuna, may stay in one area for their whole lifespan.

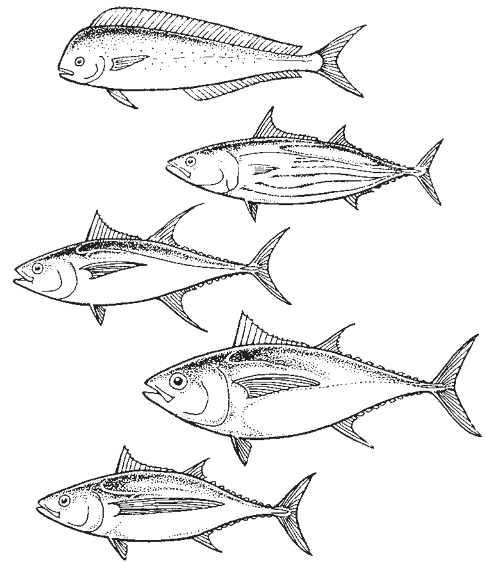

Figure 2.12: *Offshore pelagic fish of Pacific Islands include, from the top, the dorado or mahi-mahi (*Coryphaena*) and tuna such as skipjack (*Katsuwonus pelamis*), yellowfin (*Thunnus albacares*), big-eye (*Thunnus obesus*) and albacore (*Thunnus alalunga*). Local names should be added by the reader.*

Marine algae (seaweed)

Larger seaweeds are grouped, according to their dominant pigment, into either green, red or brown algae. In tropical areas, there are fewer and less striking species of marine algae than there are in cooler waters. However, algae form the basis of many tropical food webs, and, through the remarkable capacity of some species to retain calcium (become calcified), contribute to the coral reef mass. Although seaweeds are an important part of shallow-water marine ecosystems only a few species are commonly eaten in Pacific Islands.

Green algae include the common reef species *Halimeda* with its branched chains of flat segments which are often calcified and therefore greyish in appearance. Green sea grapes, *Caulerpa racemosa*, are commonly collected for food from reef tops at low tide, mostly by women. Examples of red algae include the edible seaweed *Gracilaria* and the fleshy seaweed *Eucheuma*. The latter is farmed on floating ropes before being harvested, dried and processed to extract carrageenan and agar for use as food additives.

Brown seaweeds include funnel weed, *Padina*, which grows on dead coral, and the floating brown seaweed, *Sargassum*, which is one of the largest tropical algal species. One of the few edible brown seaweeds is the spiny top, *Turbinaria*, which can be boiled and eaten.

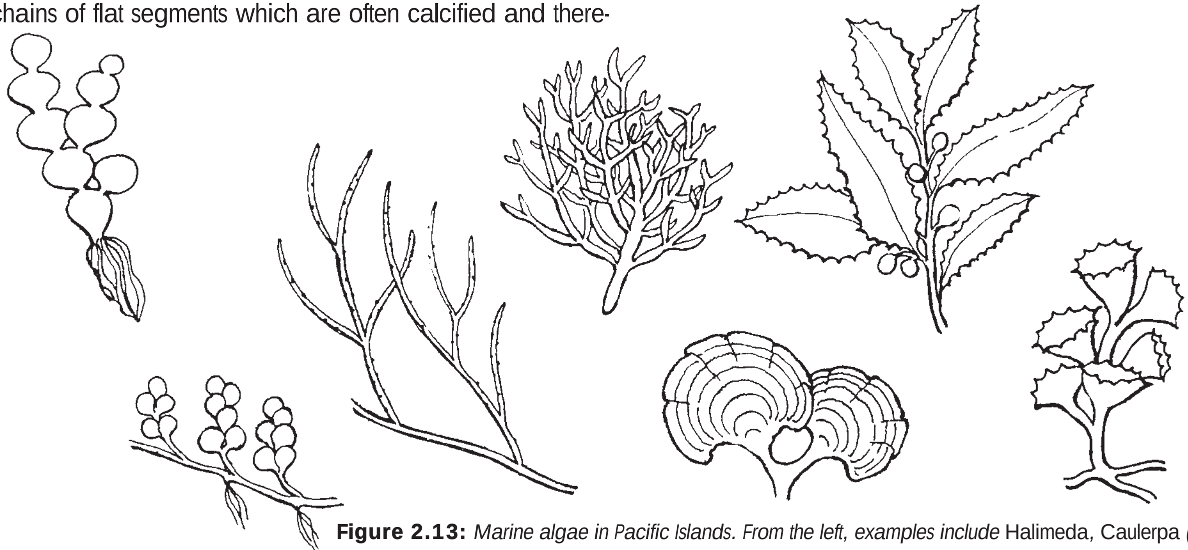

Figure 2.13: *Marine algae in Pacific Islands. From the left, examples include* Halimeda, Caulerpa *(seagrapes),* Gracilaria, Eucheuma, Padina *(funnel weed),* Sargassum, *and* Turbinaria *(spiny top). Local names should be added by the reader.*

Fishing gear and methods

Fishing gear and methods used depend on the species fished. Fishing techniques in the Pacific vary from very simple, such as the hand collection, or gleaning, of shore-line invertebrates, to complex and expensive commercial operations such as purse seining for tuna. The roles of men and women in using different fishing methods and gear is largely dictated by whether they require a boat or canoe, and whether they involve the fisher being away for extended periods. Fishing methods which can be used from the shore, on the reef or within the lagoon and close to the village are usually practised by women. For example, women are often involved in hand-line fishing from the edge of the reef, netting in the lagoon and gathering invertebrates from inshore areas. Although it is becoming more common in some areas for women to accompany men on boat trips, fishing with boats is traditionally a male activity.

A large range of fishing gear is used by commercial and artisanal fishers, and some basic types relevant to subsistence fishing in the Pacific are described in this section.

Reef gleaning

The collection of marine animals and seaweed in lagoons or on the reef flat at low tide is a common activity usually practised by women and children. A variety of species is collected in this way, including sea cucumbers, sea urchins, crabs, shellfish, seaweed, eels, small fish, worms, jellyfish and octopus. Collection can be done by hand, by digging in the sand or mud with the feet for bivalves, by overturning or breaking corals and rocks, and by using sticks and metal hooks to draw octopus, crabs or fish from holes in the reef. Although the volume of food collected by one person in this manner may be quite small, the impact on the reef and marine life can be substantial.

Traps

Traps are devices designed to encourage the entry of particular animals, which are then prevented from escaping either by particular aspects of their behaviour, or by the design of the trap itself.

Portable traps are regularly used in Micronesia and parts of French Polynesia, although in the past, cane, bamboo and mangrove wood traps were used throughout the South Pacific. Portable traps may be either baited or unbaited. The principle of baited traps is that animals, attracted to the bait, enter the trap through tapered openings from which it is difficult to escape. Baited traps or pots are used to catch various carnivorous species of crustaceans, molluscs and fish. Only two species of lobster, *Panulirus penicillatus* and *P. longipes*, will enter traps. Traditional traps made of wicker or cane and baited with sea urchins or chitons have been used to catch lobsters in Samoa, Vanuatu and Tonga, but at present, most are caught by spear or hand.

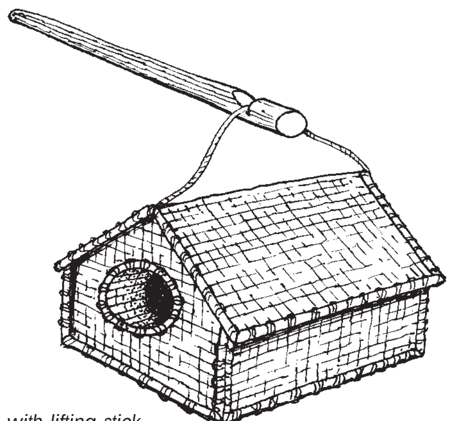

Figure 2.14: *Kiribati eel trap with lifting stick.*

Barrier and fence traps represent perhaps one of the oldest ways of communal fishing. The simplest traditional traps use the ebbing tide to strand fish in hollowed-out areas on reefs and sandbanks, and are contained by v-shaped or semi-circular walls of stone or coral. Fence traps include a wall built at right-angles from shore-lines and reefs to guide migrating coastal fish such as mullet into a large retaining area. Fish that have been feeding on the reef flat will follow the receding tide into deeper water. When they encounter the fence they will swim along it until they reach the retaining area. Fish may be either isolated in the retaining area by the retreating tide, or prevented from escaping by a complicated design or maze. Men, women and children may be involved in collecting the fish from the trap by spear, hand or net. Designs are often traditional, and vary between regions. Although originally made from stone or coral blocks, such traps are now usually made from modern materials such as wire-mesh netting (Figure 2.15). Traps may be owned by a single family or by a whole community. Their ease of construction, and their use by increasing populations, have resulted in authorities limiting the number of fence traps in some areas.

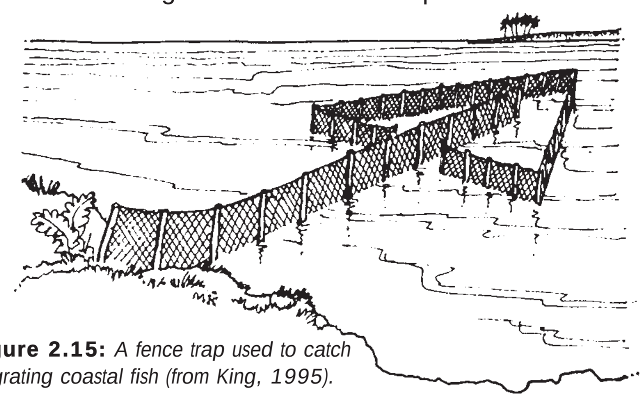

Figure 2.15: *A fence trap used to catch migrating coastal fish (from King, 1995).*

Hooks and lines

Hook and line gear is used in a wide range of configurations, the simplest being hand-held lines with one or more baited hooks. The most familiar type of manufactured steel hook is J-shaped, with the pointed part of the hook more or less parallel to the shank (Figure 2.16). In many commercial fisheries, however, the hooks are more circular in shape. Circle hooks are similar in design to the bone or shell hooks which have been used since prehistoric times in Pacific Islands. When a fish strikes a circle hook, the point rotates around the jawbone, ensuring that the fish remains caught without the fisher having to maintain pressure on the line. Steel circle hooks are now used to catch tuna, sharks and deepwater snappers.

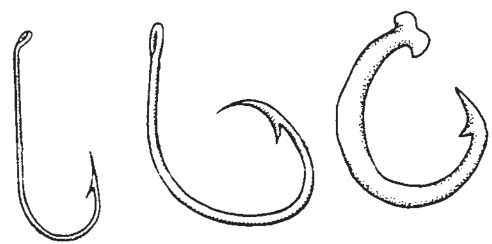

Figure 2.16: *Fish hooks, including, from left, a common J-shaped hook, a modern circle hook, and a Pacific Island traditional bone hook (from King, 1995).*

Handlining gear consists simply of one or more baited hooks attached to a line, which is weighted at the bottom in the case of demersal target species. If more than one hook is used, these are connected to the main fishing line by short side-lines or snoods. Handline fishing in shallow coastal waters is a popular subsistence and recreational fishing method and is commonly practised by women and children. When handlines (or droplines) are used to catch demersal fish in deep water, mechanical means may be used to haul in the line. Small artisanal vessels catch deepwater snappers beyond coral reefs using simple wooden hand reels to retrieve lines from depths of about 200m (Figure 2.17).

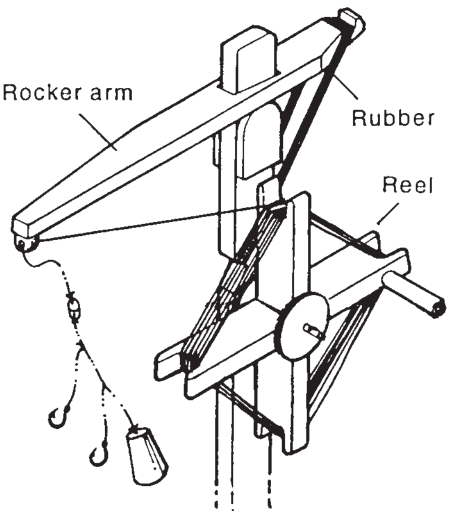

Figure 2.17: *A FAO-sponsored, Samoan hand-reel used to retrieve droplines set to catch deepwater snappers in depths of about 200m (from King, 1995).*

Longlines

A longline consists of a mainline with hooks set on short side-lines or snoods. A horizontal longline may be set near the surface for pelagic fish such as tuna (Figure 2.18), or on the sea-floor for demersal species such as sharks. A vertical longline, with hooks set from snoods along its lower section, can be set perpendicularly in the water column in areas where the sea floor is steep or rugged. Horizontal longlines set by fishermen in the Samoan tuna fishery are generally 8 to 40 km in length. This rapidly expanding commercial fishery targets albacore, yellowfin and bigeye tuna.

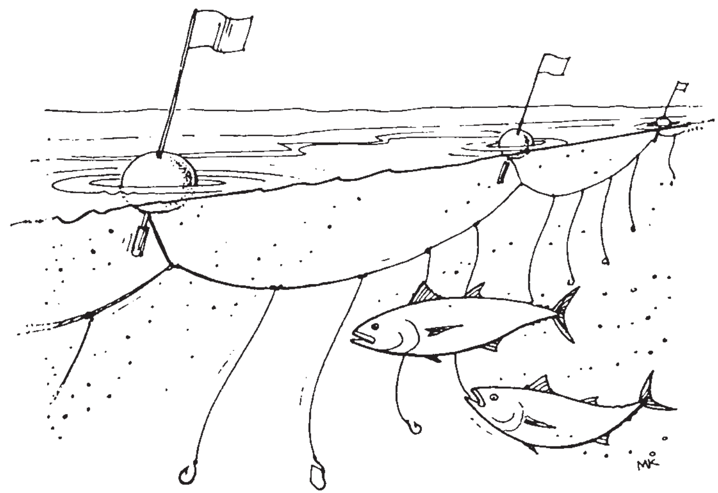

Figure 2.18: *A tuna longline (from King, 1995).*

Trolling and lures

Natural or artificial lures attached to lines may be towed (or trolled) behind boats to catch pelagic species, such as spanish mackerel, dolphinfish and tuna. In general, lures are designed to attract fish by having one or more of the following characteristics – an erratic movement when towed through the water (to resemble an injured prey), a bright or reflective surface, and fluttering appendages of feather, plastic, rubber or cloth. Instead of artificial lures, small, silver fish such as garfish and flying fish, or pieces of larger fish, may be threaded onto one or a series of hooks (Figure 2.19). Details of trolling rigs are given in Preston et al., 1987.

Tuna may be caught commercially by pole-and-lining, involving the use of barbless, unbaited wire hooks, or pearl-shell lures with a barbless hook, on short lines attached to poles. The tuna are often encouraged to strike the bright metal hooks by "chumming" the water with live baitfish to induce a feeding frenzy. Traditionally, pole-and-line fishing was an important communal fishery using live bait and mother-of-pearl lures to catch skipjack tuna. The fishery in French Polynesia is now a highly developed and competitive local industry, supplying fresh tuna to the local markets.

Squid are also caught commercially on barbless lures, or jigs (Figure 2.19) attached either to handlines, or to automatic jigging machines. The machine automatically lowers the line to a set depth, and an elliptical drum retrieves the line with a jerking or jigging movement. During night fishing, bright lights are used to attract squid into the fishing area.

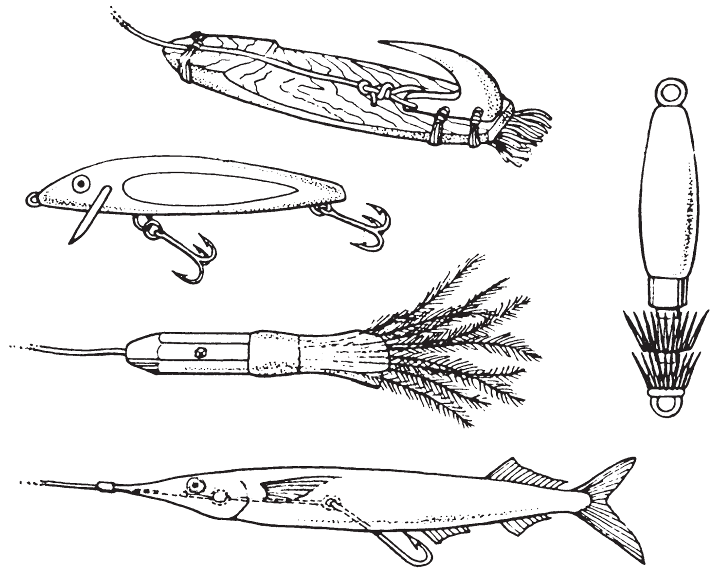

Figure 2.19: *Fish lures including (from top left down) a traditional pearl-shell lure from Kiribati, a manufactured "hard" fish lure, a manufactured "soft" fish lure, and a lure baited with a garfish. A squid jig is shown on the right (from King, 1995).*

Gill nets, tangle nets and barrier nets

Gill nets are panels of netting held vertically in the water column by a series of floats attached to their upper edge (the floatline, or corkline), and weights attached to their lower edge (the footrope, or leadline). These nets may be either anchored in shallow water, or set to drift in the open ocean. As passive gear, their catching ability relies on the movement or migration of fish through the area where the nets are set. Gill nets (Figure 2.20) are used in shallow water to catch species such as mullet and mackerel. In deeper water they may be set on the seafloor for demersal species such as sharks, or near the surface for pelagic fish such as tuna. The nets are often made from almost invisible monofilament nylon strands, which lock behind the gill covers of bony fish or the gill slits of sharks.

The main advantage of gillnets is that they are highly selective; that is they usually have a mesh size designed to catch fish of a specific size range, and very small and very large fish are not caught. The main determinant of the range of lengths of fish caught by gill nets is the hanging ratio, which is defined as the ratio of the length of the headline to the length of the stretched net. If the hanging ratio is low, say less than 0.5, the net will hang slack in the water rather than taut. In this case the net becomes less selective, as it will entangle fish as well as gill them. Some nets, referred to as tangle nets, are deliberately made this way.

Barrier nets can be set across reef passages and channels to trap fish as they try to return to deeper water on a falling tide. Often the barrier net is set in a V-shape with the point of the V lying in deeper water than the mouth of the V. As the tide falls the fish move towards the deeper water of the point. Eventually the mouth of the V is in very shallow water or on the dry reef flat and the fish are trapped in the point of the V.

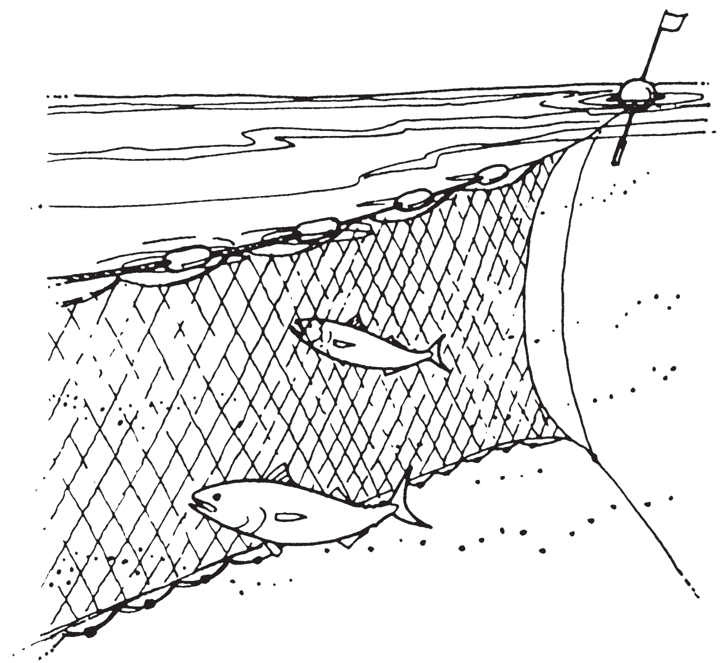

Figure 2.20: *A gill net (from King, 1995).*

Seine nets and drive-in netting

A beach seine in its simplest configuration consists of a long panel of netting which is dragged around shore-line schools of fish. The net is weighted to keep the lower side of the panel in contact with the sea-floor, and has floats to keep its upper side at the sea's surface. Some beach seines have a central panel of loose netting which forms a bunt or codend to retain fish. Ways of employing beach seines vary, although in many cases, one end of the net is anchored on the shore, and a boat is used to drag the other end seawards in a large arc and back to the shore before hauling.

Drive-in net fishing is a group activity that often involves the whole community. Nets are set in a shallow part of the water on a reef plateau or lagoon and fish are driven into the net by swimmers and scare lines. Fish may be herded with coconut leaves tied to a rope or scared by splashing the water surface with sticks and throwing rocks. The fish may then be concentrated in one part of the net for hauling, or are speared by swimmers. Fish may also be herded and scared without nets; fish are driven into an area where they can be easily speared, or they may be herded into a large trap or woven basket.

Cast nets and scoop nets

Cast nets are used in shallow water by men and women to catch schooling species such as mullet, rabbitfishes and scad. Fish are stalked in shallow water and a circular, weighted net is thrown so it spreads horizontally over the school like a parachute, entangling the fish in the net.

Flying-fish are caught in Polynesia by fishermen at night, using hand-held scoop nets and lanterns or torches. Flying-fish are located using canoes or dinghies and caught in the scoop nets while lying on the surface, dazed from the light.

Spears

Spears are used by men, women and children in a variety of ways, from both above and below the water. The spear may be used from land or a boat, or by diving beneath the water with sling-type spears and spear guns. Men and women often use torches and spears at night to catch fish at low tide. The use of modern, underwater flashlights has had a large impact on inshore marine life. Larger fish from the reef edge come in at night to sleep among the corals for protection from predators, making them an easy target for fishers with a flashlight and spear. Masks, fins, SCUBA gear, steel spears and spear guns have also increased the effectiveness of spearfishing.

Fish aggregating devices (FADs)

Many species of fish that inhabit the open sea are attracted to floating objects; some tunas, for example, congregate around drifting logs. This behaviour has been used in the deployment of fish aggregating devices (FADs), floating rafts anchored offshore to attract pelagic fish (Figure 2.21). A range of materials, including coconut logs, bamboo, and aluminium pontoons have been used in the construction of rafts. Material such as old fish nets, palm leaves, and car tyres are suspended beneath the rafts in the belief that this increases the raft's effectiveness as a habitat for fish.

The benefits of FADs are that they reduce the search time involved in a fishing trip, and therefore reduce fuel costs, as well as increase fish catches. However the costs of building and setting FADs are high, and, because of storms, wear and vandalism, their average life span is less than two years. Data on any increase in fish production where FADs have been deployed are generally not available.

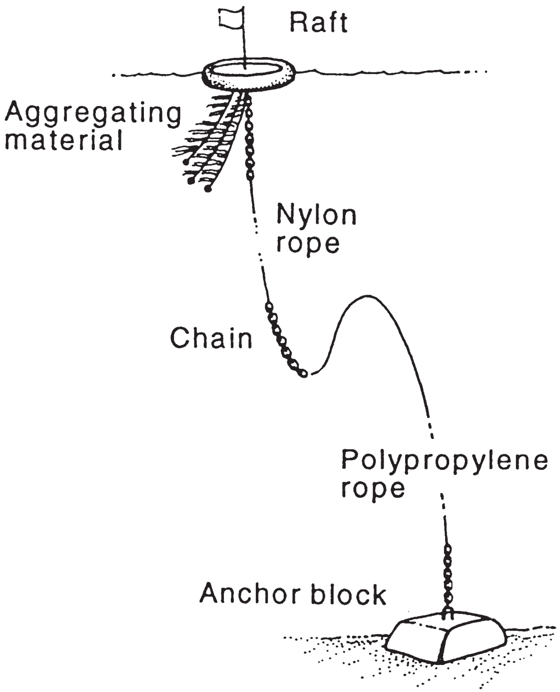

Figure 2.21: *A Fish Aggregating Device or FAD (from King, 1995).*

Processing and marketing of seafood

Processing of seafood in the Pacific ranges from simple primary processing (gilling and gutting, scaling, filleting) to secondary processing such as salting, drying or smoking of fish. Marketing may involve selling from a central market, small shops, from the side of the road or from the home.

In many parts of the Pacific men go fishing with boats and bring the fish back for the women to share or sell. Often no processing is involved from capture to sale. Women will also market their own inshore catch, and bottles of sea cucumbers, piles of shellfish and banana-leaf packages of seaweed are a common sight in many markets. Most Pacific people prefer fresh, whole fish and this is the most common way fish are sold. Small fish are often threaded onto a length of twine and sold by women or children at the side of the road. In other areas, handcarts with small ice chests may be used to sell the catch. The use of ice to keep the fish fresh before selling is still uncommon for fish intended for the local market. In many cases the quality, shelf life and subsequent value of the catch could be improved by some simple handling and storage methods.

Many markets lack facilities such as easy-to-clean display shelves, ice, cold storage facilities or, in some cases, even running water for cleaning the selling and display areas. Interest in seafood handling and processing is often high in fishing communities wanting to start or improve a small business. Many communities simply want to learn more about handling fish for family use. Many of the people catching, marketing and buying seafood are not fully aware of the effects of temperature control and hygiene in preventing poor quality or spoiled fish.

Learning new preservation techniques is of particular concern to isolated communities with limited refrigeration facilities. Workshops on seafood handling and processing, with some small business training, are good ways for government and non-government agencies to establish positive links and give technical assistance to fishing communities. However, it is important that training is directed at the right people. For example, if women are involved in fishing, processing or marketing, they must be included in any training programme. If training is given for correct seafood handling at sea, then it should be directed at boat crews and skippers, not just boat owners.

Seafood quality and handling

In most cases "quality" refers to the freshness of seafood. Quality is important for a successful seafood selling business – customers will return if they think the quality of the seafood is good. To seafood buyers, quality is important for reasons of taste (bad quality means bad taste), health (poor quality may mean loss of nutritive value and food poisoning) and value for money. Quality is also just as important to the subsistence fisher providing food for the family or community. Quality is judged on sight, touch, smell and taste. The longer a fish has been kept, the more likely it is to be of lower quality and "off" or spoiled. The way a fish has been treated after capture will also have an effect on quality and the rapidity of spoilage.

In the following discussion, the term “fish” is used to include all types of marine animals caught for food, including fish, shellfish, crabs, lobster, sea cucumbers, and eels. In all of these, quality will decrease due to incorrect handling and subsequent spoilage. Spoilage is brought about by three destructive processes:

- enzyme activity (proteins in the fish attack the flesh),
- bacterial action (bacteria feed and multiply on the flesh), and,
- oxidation (the fat or oil in the flesh becomes stale or rancid on contact with the air).

To minimise fish spoilage and maintain quality there are some simple things that should be controlled between the time the fish is caught and when it is eaten.

Quick recovery of the fish after capture reduces stress and struggling before death. This results in a slower onset of rigor mortis and minimal quality loss. Rigor mortis is when the body goes rigid sometime after death. If the onset of rigor is slow and gentle, loss of quality is minimal. If rigor commences rapidly and violently, quality loss can be severe. Muscles in the flesh contract during fast rigor, causing the flesh to fall apart, or gape. This makes the fish unattractive and difficult to cook.

Any bruises or cuts spoil appearance and reduce the amount of edible fish as well as hasten spoilage. The bacteria that cause spoilage are already present in the seafood (on the skin, in the gills and in the intestines) and will easily enter the flesh if the fish has been damaged. The boat or area where the fish is landed should be kept clean. Fish should be handled with care; for example, fish should be gaffed only in the head, and not thrown, kicked or stacked with too many on top of each other.

Bleeding the fish avoids blood clots and darkening of the flesh. Correct gutting minimises bacterial and enzymatic spoilage. The gut contains bacteria and enzymes, and correct gutting removes and isolates a large proportion of these. However, cutting and opening the usually sterile flesh, exposes it to direct bacterial attack. There is also an additional risk from contaminated knives and dirty work areas. But if working conditions are of a high standard, gutting can be beneficial. Guts should be removed completely and cleanly, unless whole fish are required for the market. Most Pacific Island countries prefer to sell fish whole. Thus, although the fish contain bacteria-laden guts and gills which can accelerate spoilage, they have not been subjected to incorrect gutting and gilling.

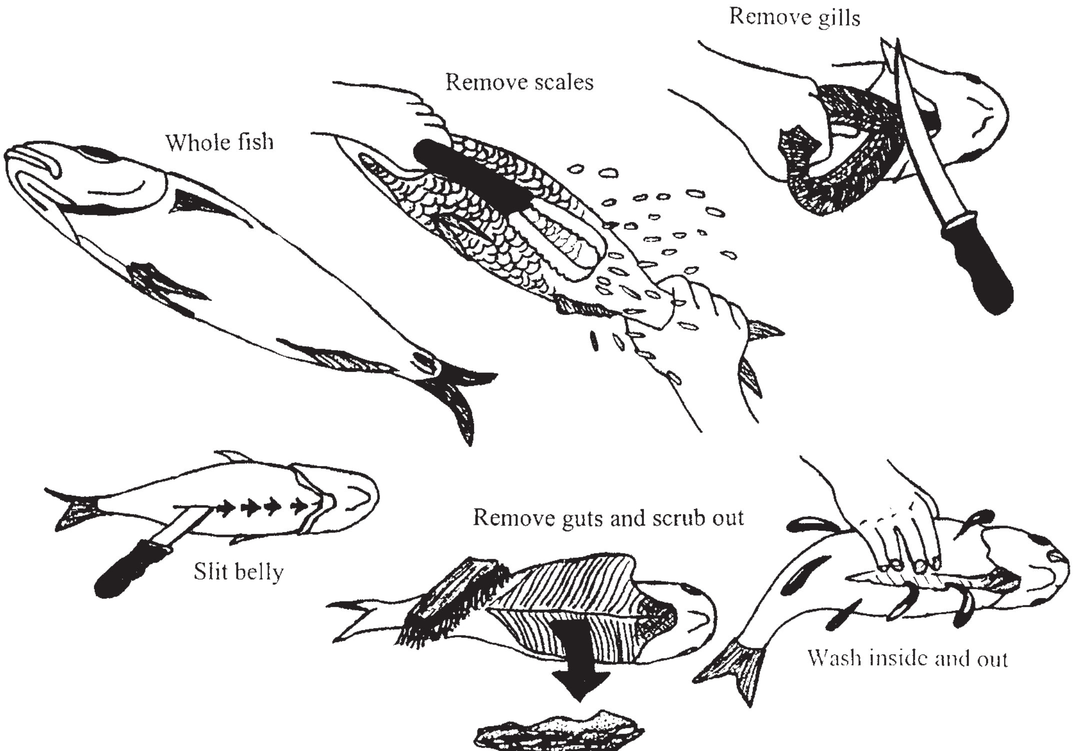

Figure 2.22: *Cleaning, gilling and gutting (SPC).*

Washing the fish or shellfish with clean water. Washing fish or shellfish with clean salt or fresh water prevents cross-contamination and lowers the rate of spoilage.

Low temperatures minimise bacterial spoilage and enzyme activity. Chilling lowers the rate of bacterial spoilage and helps achieve the slow and gentle onset of rigor. Cooling the fish as quickly as possible reduces deterioration and spoilage, reduces post-harvest losses, and produces a better quality end product. If no ice is available, all fish must be kept out of the sun and wind, and covered with a sack kept wet with seawater to keep the fish cool.

The use of ice is one of the most effective and cheapest ways to lower the temperature of fish to 0°C, the ideal temperature for storing fresh fish, especially where refrigeration and freezing facilities are not readily available. It minimises the activity of bacteria and enzymes, maintains quality and maximises shelf life (ie. the length of time a caught fish can be stored before becoming inedible). If the temperature is higher than 0° C, the shelf life is considerably reduced. For example, a fish that sits at room temperature for four hours before being chilled may already have lost four days of shelf life at 0° C.

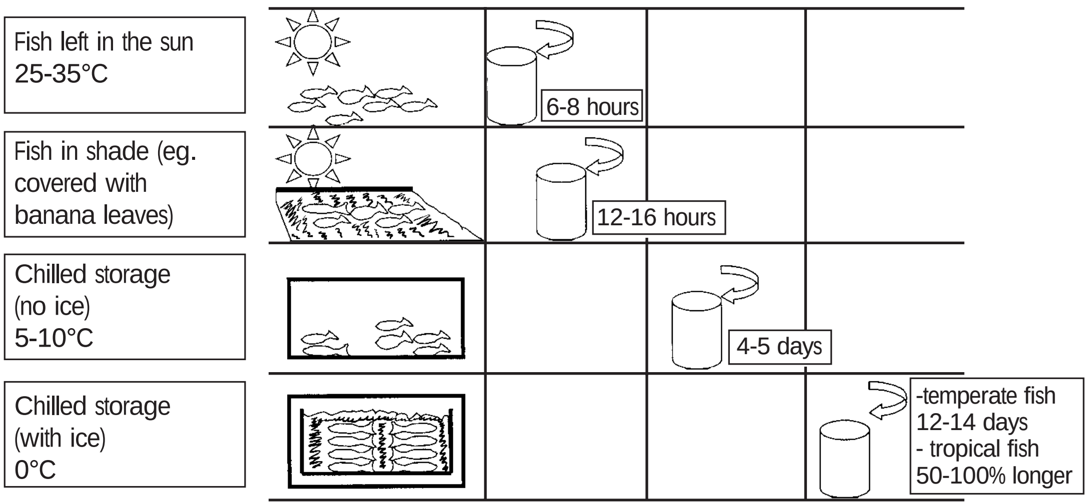

Figure 2.23: *The storage life of fresh fish (SPC).*

Ice works best if it is allowed to melt slowly and is continuously replaced when necessary. The "melt water" also improves contact of the chilling medium with the fish, keeps fish moist and removes blood and slime. The use of fish bins is the most common method of storing fish in ice by local fishers. Fish bins should have drainage holes and a smooth, hygienic and easily cleaned inner surface. *Coolers* or *eskies* (insulated boxes) are often relatively cheap and readily available.

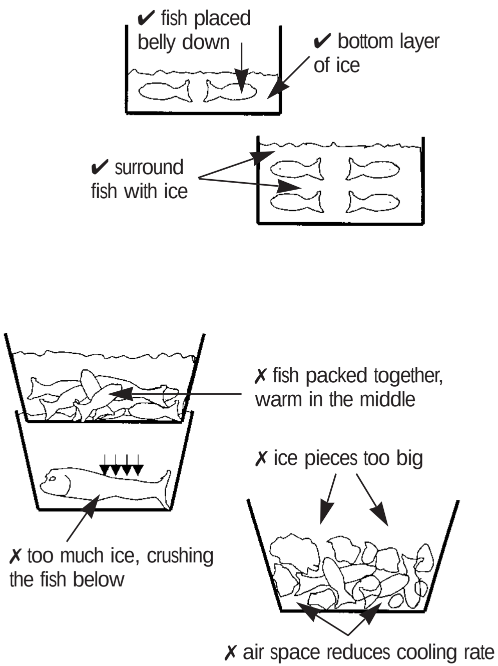

Figure 2.24: *Correct and incorrect methods of packing fish in ice (SPC).*

Hygiene. It is important that anyone handling fish works with a high level of cleanliness or "hygiene". Fishers at sea, people in the market and anyone involved in preparing and cooking fish must adopt good hygienic practices. On a personal level this includes clean hands and nails, and hair tied back. In relation to work areas and equipment, this includes a clean vessel deck, work bench, fish bins, and filleting knives.

Preservation of fish

One of the reasons fish and shellfish are processed is to preserve seafood for a longer time. Food quality and nutritional value can be maintained over a long period by preventing spoilage. Preservation, however, cannot improve a fish that is spoiled to start with.

Bacteria and enzymes survive well at ambient temperatures and in wet conditions (ambient temperature refers to the usual surrounding temperature which bacteria are accustomed to). As bacteria do not multiply well at low temperatures, chilling and freezing can be used to extend the shelf-life of fish. Also, bacteria and enzymes do not survive well in very high temperatures or in dry conditions. High temperatures will kill bacteria and destroy enzymes. Processes such as cooking, (e.g. boiling, frying, baking), hot smoking, canning, and pasteurising, extend the keeping time of food by creating conditions that destroy bacteria and enzymes.

The processes of salting and drying have been practised for centuries as an effective way to preserve meats. Salting inhibits bacterial and enzymatic spoilage due to its drying properties (dehydration) and because of the high salt concentration used in the processing.

Smoking has also been used to extend the storage life of seafood. The preservative effect of the smoking process results from the combined effects of salting, heating, smoking and drying. However, as the smoke penetrates the flesh slowly, the potential anti-bacterial effect of wood-smoke is confined to the surface of the fish. Certain parts and types of wood smoke also protect the fish against oxidation or rancidity. A smouldering fire will preserve flesh better than a hot, flaming fire due to the higher levels of smoke and anti-oxidative substances.

The keeping quality and storage life (how well the fish keeps and for how long) depends on the type of fish used, its initial quality, the actual smoking process and the use of other preservation and storage techniques after smoking. Fatty (oily) fish generally have a shorter storage life than lean (less fatty) fish. The quality of the smoked fish during and after storage is highly dependent on the quality of the fish before it is smoked. A fish that has started to spoil cannot be improved by any amount of salt or smoke. A fresh fish that is in good condition and has been handled well (kept on ice), will have a better taste and longer storage life after smoking than a fish that was of lower quality before smoking.

A simple effective smoker is easily made from an old 44-gallon drum (Figure 2.25). More complex smokers for semi-commercial and commercial operations can be built to smoke larger quantities of fish at one time.

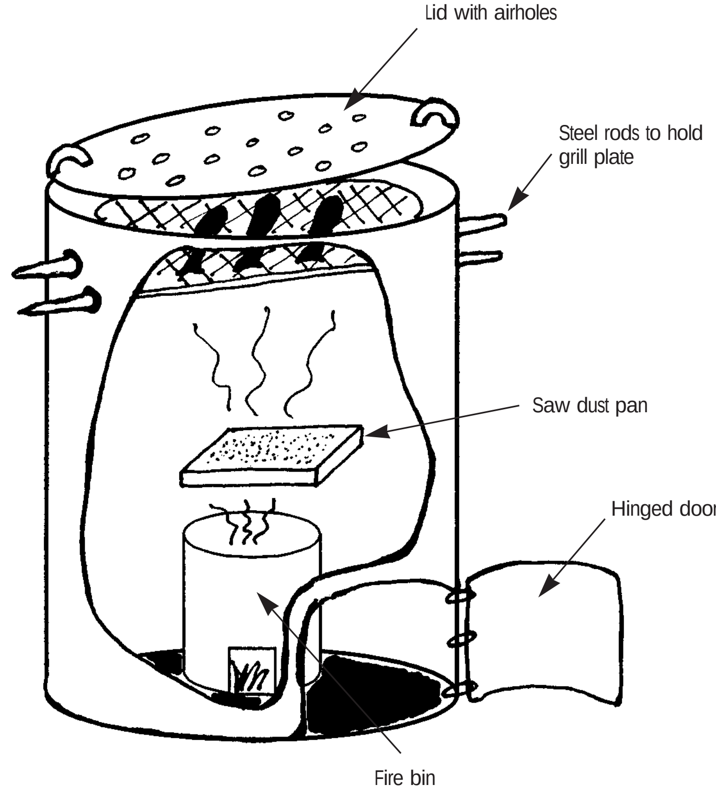

Figure 2.25: *A simple drum smoker (SPC).*

Fisheries management

A group of fish of the same type, or species, living in one area is referred to as a fish stock. A fish stock, and the forces acting on it and controlling its numbers, is shown in Figure 2.26. The number of fish is being increased by the reproduction of adult fish, which eventually results in small fish being added, or recruited, into the stock. In addition, the weight, or biomass, of the fish stock is increased by the growth of individuals – in the figure, three consecutive age groups, or different year classes, are shown. Concurrent with these increases, the stock is being reduced in numbers and biomass by natural mortality and, in exploited species, by fishing mortality as well. Fishing mortality refers to fish caught by fishers, and natural mortality refers to fish which die by other means, most commonly by predation (being eaten by another animal).

If a fish stock is unexploited or is fished at a low level, losses due to mortality are balanced, on the average, by gains through the recruitment of young fish or juveniles. The number of fish in the stock will therefore fluctuate around an average level as long as not too many fish are caught. It is for this reason that fish are referred to as a renewable resource. That is, fish can continue to be caught and used as food forever, as long as the numbers caught are replaced by more young fish being produced.

If exploitation is high, however, the number of adult fish may be reduced to a level where reproduction is unable to replace the numbers lost. In this case the numbers of fish in the stock will decrease. In severe cases of overfishing, the stock may even disappear altogether (become extinct). In Pacific Islands, many fish stocks have been overfished. Some species of giant clams are now extinct in Micronesia and one species has disappeared from Vanuatu, Fiji and Tonga since the 1970s. Stocks of mullet, which have been caught in large numbers in fence traps, are very low in some islands. The renewability of fisheries resources depends on our ability to ensure that not too many fish are caught. This implies that fisheries, and particularly the amount or types of fishing, have to be controlled or managed.

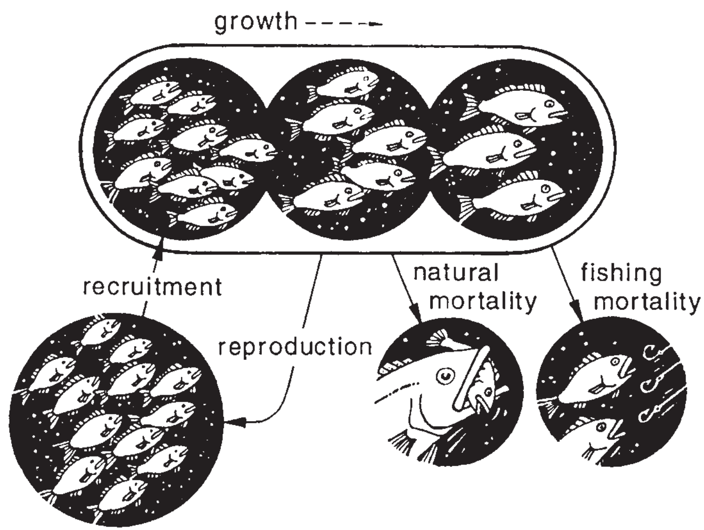

Figure 2.26: *The weight (or biomass) of an exploited fish stock (top elongate shape) is increased by reproduction which results in the recruitment of young fish (lower left circle) back into the stock. At the same time, the stock is being reduced by natural mortality and, in exploited species, by fishing mortality as well (from King, 1995).*

Fisheries scientists in various Pacific Islands, and in regional organisations such as SPC and the University of the South Pacific, are studying the basic biology and distribution of resource species. Many are attempting to determine how much of a particular species can be caught on a sustainable basis - this quantity is sometimes referred to as the Maximum Sustainable Yield (MSY).

In order to manage fisheries, that is, to ensure that fishing is done on a sustainable basis, it is usually necessary to apply one or more regulations. National governments in Pacific Islands have imposed a variety of regulations that either restrict fishing (input controls), restrict the catch (output controls) or protect the marine environment.