Guide to Teachers' Resource Sheets on Fisheries for Vanuatu

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Vanuatu

This Teacher's Resource Kit on Fisheries for Vanuatu has been prepared by Mike King, consultant, in collaboration with staff from the Pacific Community (SPC) – Céline Barré, Aymeric Desurmont, Michel Blanc and Timothy Pickering – and with input from local education and fisheries authorities.

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The guide is part of, and should be used in conjunction with, the SPC Teachers' Resource Kit on Fisheries, the contents of which includes:

- *23 teachers' resource sheets on fisheries;*
- *29 information sheets for fishing communities;*
- *1 'Guide to information sheets on fisheries management for communities';*
- *3 leaflets: 'Community-resource management', 'Community-managed no-take areas in fisheries management', and 'Destructive fishing';*
- *3 management posters: 'Are we finding it hard to catch fish?', 'What if we lost our mangroves?', 'What if we lost our seagrass?';*
- *2 sea safety posters: 'Five minutes which can save your life before going out to sea', 'Safety checklist for small boats';*
- *1 marine debris poster: 'The most dangerous species of our coasts and lagoons';*
- *1 deepwater bottom fish poster: 'Dip botom fis blong Vanuatu';*
- *1 invertebrate poster: 'Marine invertebrates of the Pacific Islands';*
- *2 marine resource posters: 'Solwota laef blong Vanuatu' and 'Kostel wota laef blong Vanuatu'; and*
- *1 flash drive (with graphics and photographs).*

This guide includes suggestions for exercises and activities for younger and older students as well as learning outcomes and curriculum links.

It is expected that teachers will use their local knowledge and expertise to adapt, extend and add to these suggestions. The number and headings on the following pages refer to those on the teachers' resource sheets (1–23) and on the information sheets for fishing communities (1–29). The latter 29 sheets were designed for fishing communities but contain information useful to teachers and students.

All words followed by an asterisk (*) in the teachers' resource kit on fisheries are defined in the glossary at the end of this guide.

Links between fisheries and curriculum

Sheet #	Topics	Learning outcomes	Current curriculum (Year level/Subject/Topic/Subtopic/Resource)	Reviewed curriculum (Year level/Subject/Strand/Sub-strand)	Information sheet for fishing communities
1.	**Fisheries management**	Younger students identify a range of fish species caught in Vanuatu and explain the importance of fishing sustainably to ensure the availability of resources in the future.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 54/71–88	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	2, 3, 4, 5, 6, 7, 8, 9, 14, 16, 21, 24, 25
		Older students: 1. identify the need for fisheries regulations and the range of regulations applied; 2. identify the need for enforcement and compliance to ensure seafood resource availability; and 3. discuss how poor coastal zone management can affect marine ecosystems and fisheries.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The Ministry of Agriculture, pages 21–25	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
2.	**No-take areas (*tabu*)**	Younger students identify the cultural significance of *tabu* and its benefits in coastal areas in Vanuatu.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, page 81	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	
		Older students explain the role of *tabu* and, through field work, discuss the importance of conservation areas in sustaining fish stocks and enhancing ecotourism.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The Ministry of Agriculture, pages 21–25	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
3.	**Fisheries assessment**	Younger students record catches by keeping a 7-day fishing log to assess the fish stock used by their extended family and community.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 71–88	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	
		Older students explain the importance of stock assessment and monitoring to estimate fish population size by using a 7-day fishing log, fish tagging and quadrat sampling.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
4.	**Fisheries economics**	Younger students explain the importance of fisheries to the household income and the community economy.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 71–88	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	
		Older students discuss the importance of fisheries to the national economy and the value of fisheries, taking into account costs and returns.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
5.	**Fisheries and climate change**	Younger students identify the impacts of climate change on coastal fisheries.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 13–25	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	20, 25, 26, 27, 28
		Older students explain the impacts of climate change on fishery resources in Vanuatu and other Pacific Island countries and describe appropriate adaptive measures to mitigate the effects.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
6.	**Fish anatomy**	Younger students identify the external features of fish and sharks.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 54–76	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	

		Older students identify the structures and explain the functions of the external and internal parts of fish.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
7.	Marine food webs	Younger students identify the simple food webs of marine species.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 54–76	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	27, 29
		Older students explain marine food webs and the loss of energy in a food chain from plants to top-level carnivores.	**Year level:** Year 8 **Subject:** Science **Topic:** Ecosystem **Subtopic:** Interdependence **Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
8.	Oceanic species	Younger students identify oceanic fish species and distinguish them from reef species.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 54–76	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	2, 3, 4, 5, 6, 7, 8, 9, 15, 17, 18, 19, 20, 21, 23, 29
		Older students discuss morphological and behavioural adaptations of oceanic species such as fusiform shapes, counter-shading and schooling.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
9.	Deepwater snappers	Younger students identify species of poulet in Vanuatu.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 54–76	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	1
		Older students describe the fishery and its importance in Vanuatu's economy and explain regulatory measures.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
10.	Bonefish	None	-	-	
11.	Pearl oysters	Younger students recognise common molluscs as sources of protein, and seashells as material for craftwork.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 38–53	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	10, 11, 16, 22
		Older students investigate common seashell production and harvesting in Vanuatu, and examine the internal anatomy of a bivalve mollusc.	**Year level:** Year 7 **Subject:** Science **Topic:** Living things **Subtopic:** Classification	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
12.	Freshwater species	Younger students identify eels, prawns and tilapia in freshwater sources of Vanuatu.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 54–76	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	

Sheet #	Topics	Learning outcomes	Current curriculum (Year level/Subject/Topic/Subtopic/Resource)	Reviewed curriculum (Year level/Subject/Strand/Sub-strand)	Information sheet for fishing communities
12.	**Freshwater species**	Older students discuss the possible origins of freshwater species in Vanuatu.	**Year level:** Year 7 **Subject:** Science **Topic:** Living things **Subtopic:** Classification	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
13.	**Aquarium fish**	Younger students list the species exported for the aquarium trade.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 38–53	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	10
		Older students discuss the aquarium fish export industry and demonstrate knowledge of building and maintaining an aquarium.		**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
14.	**Vanuatu traditional fishing methods**	Younger students identify the range of traditional fishing methods used in Vanuatu.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 71–88	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	13
		Older students compare traditional fishing methods with those used currently.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
15.	**Modern large-scale fishing techniques**	Younger students identify the range of commercial fishing techniques used in Vanuatu.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 71–88	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	
		Older students describe a range of commercial fishing techniques used in Vanuatu and worldwide.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
16.	**Fish aggregating devices (FADs)**	Younger students describe fish aggregating devices.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 71–88	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	
		Older students discuss the use and functions of fish aggregating devices in terms of improving access to offshore fish and increasing the incomes of fishers.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
17.	**Marine aquaculture**	Younger students identify species that are currently farmed in sea water in Vanuatu, and other species that present a potential.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 38–53	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	10, 11, 12, 16
		Older students discuss the biology of farmed marine species and the methods used to farm them in Vanuatu.	**Year level:** Year 7 **Subject:** Science **Topic:** Living things **Subtopic:** Classification	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
18.	**Freshwater aquaculture**	Younger students identify species that are currently farmed in fresh water in Vanuatu, and other species that present a potential.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 54–76	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	

		Older students discuss the biology of farmed freshwater species and the methods used to farm them.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
19.	Fish spoilage	Younger students recognise fish freshness and develop an understanding of the need for personal hygiene when handling seafood.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 67–69	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	
		Older students explain the action of enzymes and bacteria in relation to food spoilage.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
20.	Fish poisoning and ciguatera	Younger students demonstrate knowledge of ciguatera and identify other marine species involved in poisoning.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 67–69	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	28
		Older students explain the sequence of events leading to fish and molluscs becoming toxic and their effects on humans.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
21.	Sea safety	Younger students demonstrate knowledge on the importance of being prepared before going out to sea in terms of safety measures and equipment.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 71–88	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	
		Older students explain marine safety measures and the use of safety equipment, including sea anchors, signalling equipment and tying important knots relating to safety and seamanship.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
22.	Job opportunities in fisheries	Younger students identify employment opportunities in the fishing industry.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 71–88	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	
		Older students explore a wide range of fisheries-related job opportunities in Vanuatu and overseas, including working requirements and conditions.	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	
23.	Financial management of a small fishing business	Younger students investigate the price of a range of seafood species that are sold in their community.	**Year level:** Year 4–6 **Subject:** Science **Topic:** Our environment **Resource:** The sea, pages 71–88	**Year level:** Year 4–6 **Subject:** Science **Strand:** Living things and the environment **Sub-strand:** Biodiversity, relationships and sustainability	
		Older students investigate the fixed and running costs in a fishing business	**Year level:** Year 10 **Subject:** Agriculture **Topic:** The development of agriculture in Vanuatu **Subtopic:** The village projects (fisheries projects)	**Year level:** Year 7–10 **Subject:** Agriculture **Strand:** Fisheries	

Suggestions for exercises and activities related to the 23 Teachers' Resource Sheets on Fisheries for Vanuatu

1. Fisheries management

At the completion of studies:

Younger students identify a range of fish species caught in Vanuatu and explain the importance of fishing sustainably to ensure the availability of resources in the future.

Older students:

1. identify the need for fisheries regulations and the range of regulations applied;
2. identify the need for enforcement and compliance to ensure seafood resource availability; and
3. discuss how poor coastal zone management can affect marine ecosystems and fisheries.

In Vanuatu, fisheries are managed by the Department of Fisheries, which is within the Ministry of Agriculture, Livestock, Forestry, Fisheries and Biosecurity (MALFFB). The Department of Fisheries often works with local communities. Vanuatu is particularly well known for its community-based management programme under which fisheries officers, environmental officers and community members work together to manage fisheries.

Teaching and learning activities for younger and older students

A. The accompanying figure shows some of the most common fish found on coral reefs in Vanuatu.

Investigate the vernacular name for each type of fish and indicate which ones are commonly caught for food in your community.

B. Request the Department of Fisheries to have an officer talk to students about fisheries management and describe the regulations that are applied to ensure the sustainability of fish stocks.

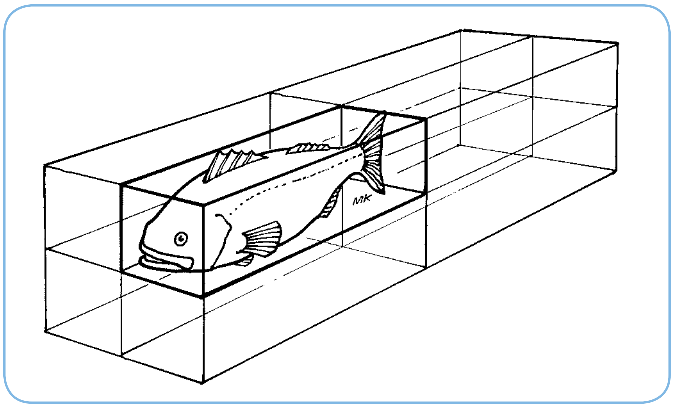
Alternatively, ask a village elder or a *Vanuatai* Resource Monitor to talk about the same subject.

For example, why is it important to have regulations on catching coconut crabs? Regulations can include leaving small individuals in the sea (size limits), setting up no fishing or tabu areas and closing some seasons to fishing.

C. Why is it important to leave some large female fish in the sea?

Most fish grow in length, width and height at the same rate (growth is said to be isometric). Egg production is related to the volume of female fish; that is, there is a cubic relationship between length and volume (and, therefore, egg production). If a mature fish doubles in length, how much does volume and, therefore, egg production increase? (For younger students: Count the 'blocks' in the accompanying figure or use eight wooden blocks to suggest what happens when a fish doubles in length, width and height).

Large female fish produce many more eggs than small fish and are, therefore, important in maintaining healthy populations. That is why we must leave some large fish in the sea.



Teaching and learning activities for older students

D. In the accompanying figure, volume (V) = length (L) cubed, or $V = L^3$.

For example, a fish 30 cm long would have a volume ($V = L^3$) of 30^3 or 27,000 cubic centimetres.

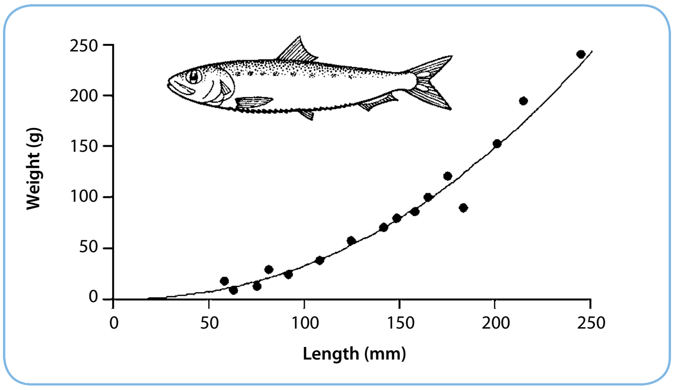
If the fish doubles in size to 60 cm, $V = 60^3$, or 216,000 cubic centimetres.

That is, the egg-carrying capacity has increased by eight times.

i. Ask students to collect a large number of one species of fish with a wide range of sizes from small to large fish (alternatively the fish can be obtained by the teacher). Each fish should be measured to the nearest 5 millimetres (mm) and weighed to the nearest 10 grams (g).

ii. Enter the data on an Excel spreadsheet and prepare a graph relating weight to length as in the example shown in the accompanying figure. Students studying statistics can extend the exercise to include the power curve equation and measures of goodness-of-fit.

The power curve equation is Weight = a $(\text{Length})^b$ where a is a constant and b should be close to 3 if the volumetric relationship holds true.



E. Sometimes there are too many people hunting too few fish. Although the rate of population increase in Vanuatu is low (2.01% estimated in 2014) the rate in many other Pacific Island countries is as high as 4% each year.

   i. Create an Excel spreadsheet using rates of 2%, 3%, 4% and 5%, to calculate when your population will be twice what it is today.

   ii. Discuss the problems for local people in catching seafood when the population is doubled.

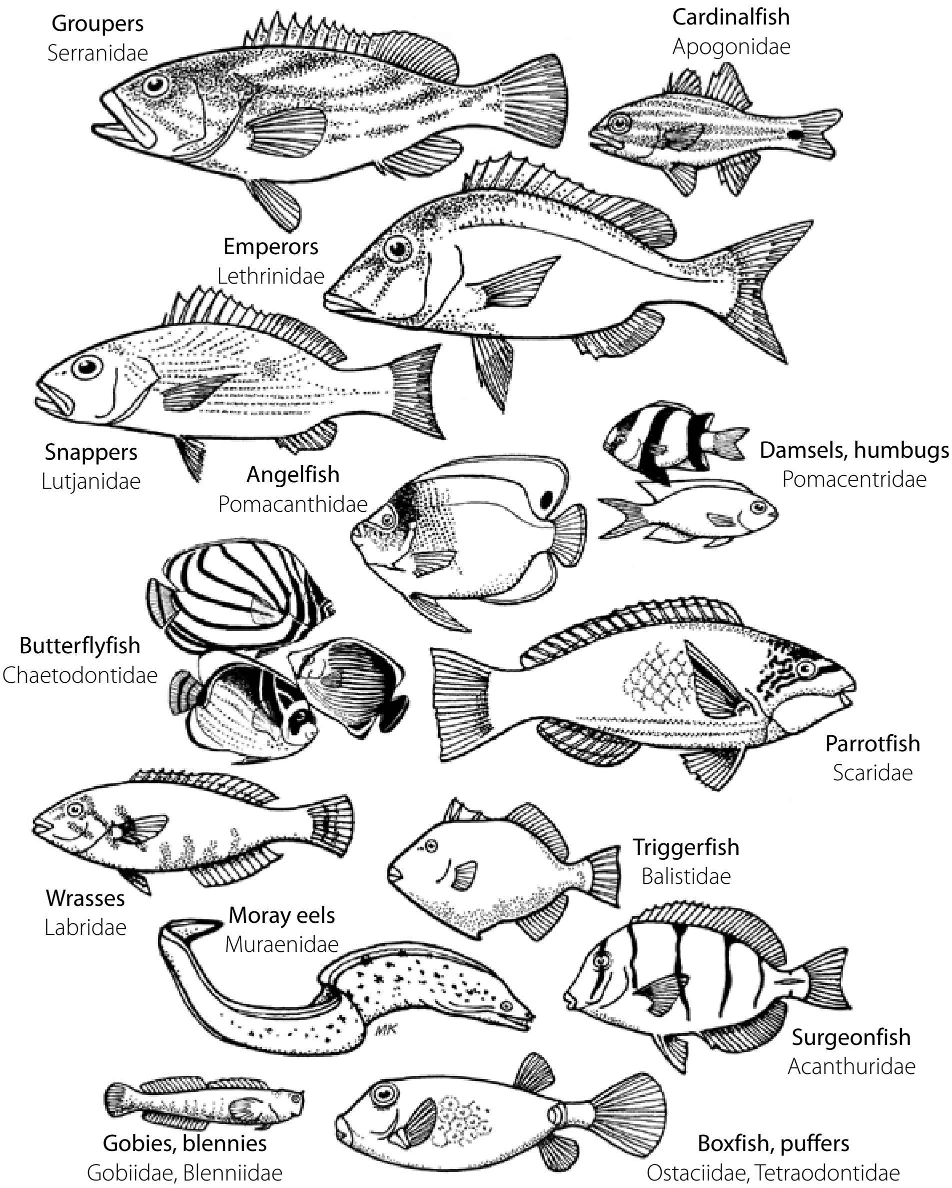
F. Besides overfishing, or catching too many fish, there are many other threats to fisheries. These include pollution*, the release of sewage, coastal development, and reclamation (refer to Information sheet for fishing communities 27: Nutrients and sediments, and 28: Harmful algal blooms).

Sea water in Port Vila harbour and the lagoons is believed to be highly polluted. The probable cause of the high pollution is the lack of sewerage systems and the poor management of many individual septic tanks*. Coastal development, including the construction of houses and hotels, may result in the siltation of coastal waters and sewage entering the sea.

Ask students to investigate the ways in which the local marine environment is being harmed.

   i. Should excessive development be controlled? Are trees left on the banks of rivers and coastlines? Is garbage disposal satisfactory? Is sewage treatment adequate?

   ii. Are large shoreline hotels required to build treatment plants for sewage?



Common fish families on a coral reef.
From: King M. 2015. Beneath the surface: Tales of a sailing marine biologist. Zeus Publications. 262 p.

2. No-take areas (*tabu*)

At the completion of studies:

Younger students identify the cultural significance of *tabu* and its benefits in coastal areas in Vanuatu.

Older students explain the role of *tabu* and, through field work, discuss the importance of conservation areas in sustaining fish stocks and enhancing ecotourism.

Vanuatu is well known for its protection of marine areas by declaring *tabu* areas in which fishing is banned or restricted. The Department of Fisheries estimates that over 200 communities have declared some type of *tabu* areas – some that are permanently closed and others that are closed at particular times of the year. These restrictions on fishing are imposed by traditional leaders to ensure that seafood resources are sustainable.

Teaching and learning activities for younger students

A. Ask a community elder to explain to students the history and benefits of *tabu* areas. How are decisions to set up a *tabu* area made? How is a *tabu* area marked? What are the punishments handed out to those who break the rules? What are the likely benefits of having an area closed to fishing?

Note: The photograph on the front of the Teachers' resource sheet 2: No-take areas (*tabu*) shows a pole and leaf that signifies a *tabu* area.

Teaching and learning activities for older students

B. Ask students to either talk to older people in their community or locate a *tabu* area in which fishing is banned. Find out the rules for the *tabu*. Ask how long the *tabu* has been in operation. Has it been successful? Do all people obey the *tabu* rules? What happens when the *tabu* area is opened?

C. Arrange for students to swim with masks and snorkels along a transect in a safe area of a lagoon (if possible and if permitted, do this within a *tabu* area). Record the numbers and types of fish seen in a band width of 5 m (two and a half metres each side of the swimmer, as in the figure on the front of the Teachers' resource sheet 3: Fisheries assessment). If possible, compare results from transects inside and outside a *tabu* area.

D. The following figure shows a hypothetical, community-managed, no-take area in a Pacific Island country. Show the figure on a screen (from flash drive supplied as part of the Teachers' Resource Kit).

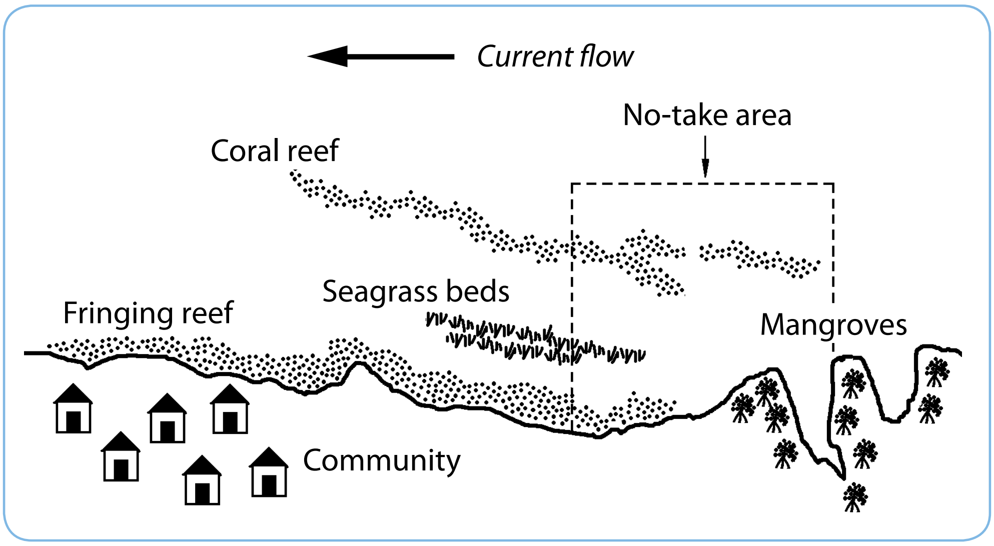
Ask students to discuss the negative and positive aspects of the positioning of the no-take area shown.

A negative point that could be raised includes:

- the community loses access to a part of its usual fishing area.

Positive points include:

- the area includes different habitats for marine life – seagrass beds, coral reef, estuary – which are important for the survival of many species; and
- larvae from the no-take area are likely to drift out into the fished areas where they can settle and grow into adults that can be caught.



3. Fisheries assessment

At the completion of studies:

Younger students record catches by keeping a seven-day fishing log to assess the fish stock in their extended family or community.

Older students explain the importance of a stock assessment and monitoring to estimate fish population size by using a seven-day fishing log, fish tagging and quadrat* sampling.

Scientists from the Department of Fisheries have completed assessments of many exploited marine species and these have been used in fisheries management. One example is the assessments of local trochus stock sizes and using these to set a quota* or catch limits for community fishers.

Teaching and learning activities for younger students

A. Ask students to identify the common Vanuatu reef fish from the figure shown earlier in this guide, and identify oceanic fish from the poster 'Dip botom fis blong Vanuatu' supplied by the Department of Fisheries.

Teaching and learning activities for younger and older students

B. Ask each student to keep a seven-day log of fish catches in their extended family. How many fish did they catch? How long did it take? An example of a student seven-day basic fishing log is shown in the table below. The log can be extended to discover the other marine species harvested from the sea.

If the exercise is done well, the information in these logs may be useful to the Department of Fisheries.

Student name ....

Time period from Saturday .... to Friday ....

Area / Fishing location ....

	Sat.	Sun.	Mon.	Tues.	Weds.	Thurs.	Fri.
No. of people fishing							
Main method of fishing							
Total hours spent fishing							
Number of (*species)							
Number of (*species)							
Number of (*species)							
Number of (*species)							
Number of (*species)							
ETC							

* Enter the name of the species of fish in the brackets above.

Teaching and learning activities for older students

C. Ask students to interview older fishers in their community or extended family. How long does it take to catch a basket or string or number of a particular fish at present? How long did it take five years ago? How long did it take 10 years ago?

Each student should record the information from the interviews. Has there been a decrease in catch rates (say catch per hour)? If so, ask the fishers why has this happened. What could go wrong with relying on the memories of people?

D. Fisheries scientists tag or mark marine animals to examine migration, death rates and population size. Discuss methods of tagging of marine species by using the figure in the Teachers' resource sheet 3: Fisheries assessment. The following activity uses beads to demonstrate how fish tagging can be used to estimate the population size of fish.

E. Spread a few thousand small white beads on a large tray (the actual number of white beads should be known to the teacher although this is not necessary). Add a smaller number, about 300, black beads to the tray – provide the actual number of black beads to the students. All the beads should be mixed up so that the black beads are randomly distributed with the white beads in the tray.

To add some interest, ask students to guess the total number of black and white beads on the tray.

The white and black beads added together represent a population of fish (N).

The black beads represent the tagged fish (T).

Divide the students into groups of two or three and give each group an empty tray. One student from each group should use a rectangular plastic container (about the size of a match box, depending on the size of the beads) to represent the fishing gear. Without looking, the student should drag the container across the tray to 'catch' a sample of the beads.

After emptying the caught beads in the group's tray, the students must count the number of black beads caught; these represent the recaptured tagged fish (R).

Count the number of white beads caught. This number added to the number of black beads represents the total catch (C).

Use the information to estimate the population or stock size (N) as demonstrated in the accompanying figure and example.

The large rectangle in the accompanying figure shows a fish stock of unknown size, into which 32 tagged fish (solid shapes) were released. At a later time, a catch of 36 fish (in the small rectangle in the lower right-hand corner) was found to include six tagged individuals. The stock size may be estimated by assuming that the ratio of tagged fish (T) in the stock (N) is equal to the ratio of recaptured tagged fish (R) in the catch (C). That is:

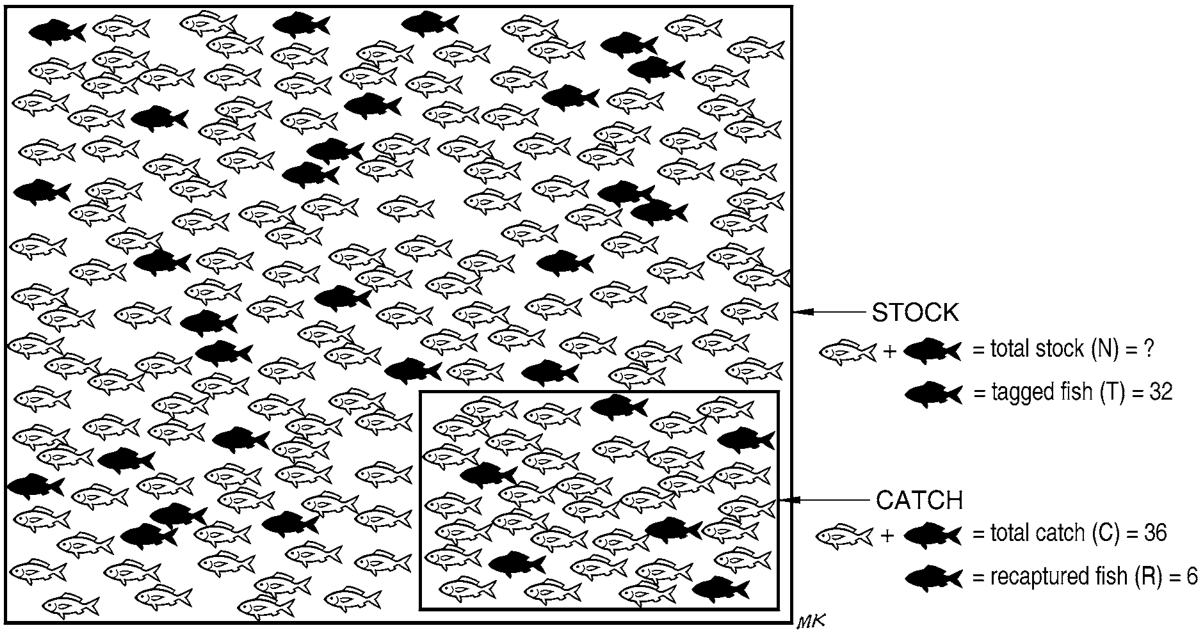
$$T/N = R/C$$

From this, an estimate of the stock size (N) may be obtained as:

$$N = TC/R$$

In this instance:

$$N = (32 \times 36)/6 = 192 \text{ fish.}$$



Older students studying statistics can make a number of replicate catches and estimate the standard error and confidence limits. The accuracy of the above method depends on several assumptions being met:

1. the tagged individuals must be distributed randomly over the population;
2. there must be no loss or gain of individuals during the experiment; and
3. the tag must not alter the chance of a fish either surviving or being caught.

Have students discuss what happens if assumption number 3 is not true. For example:

i. if an external plastic spaghetti tag (see Teachers' resource sheet 3: Fisheries assessment) resulted in tagged fish being more likely to be caught by becoming entangled in a gill net; or,

ii. if a tagged fish became stressed and would not take the bait on a fishing line as readily as untagged fish.

For the answers, think in terms of the equation N = TC/R.
In the first case, R would be larger than it should be, and N would be smaller (the population would be underestimated).
In the second case, R would be smaller than it should be, and N would be larger (the population would be overestimated).

F. The following question relates to the full page figure in which the small black squares represent sea cucumbers distributed around a sand bank. The teacher should copy the figure onto A4 sheets, one for each student or student group.

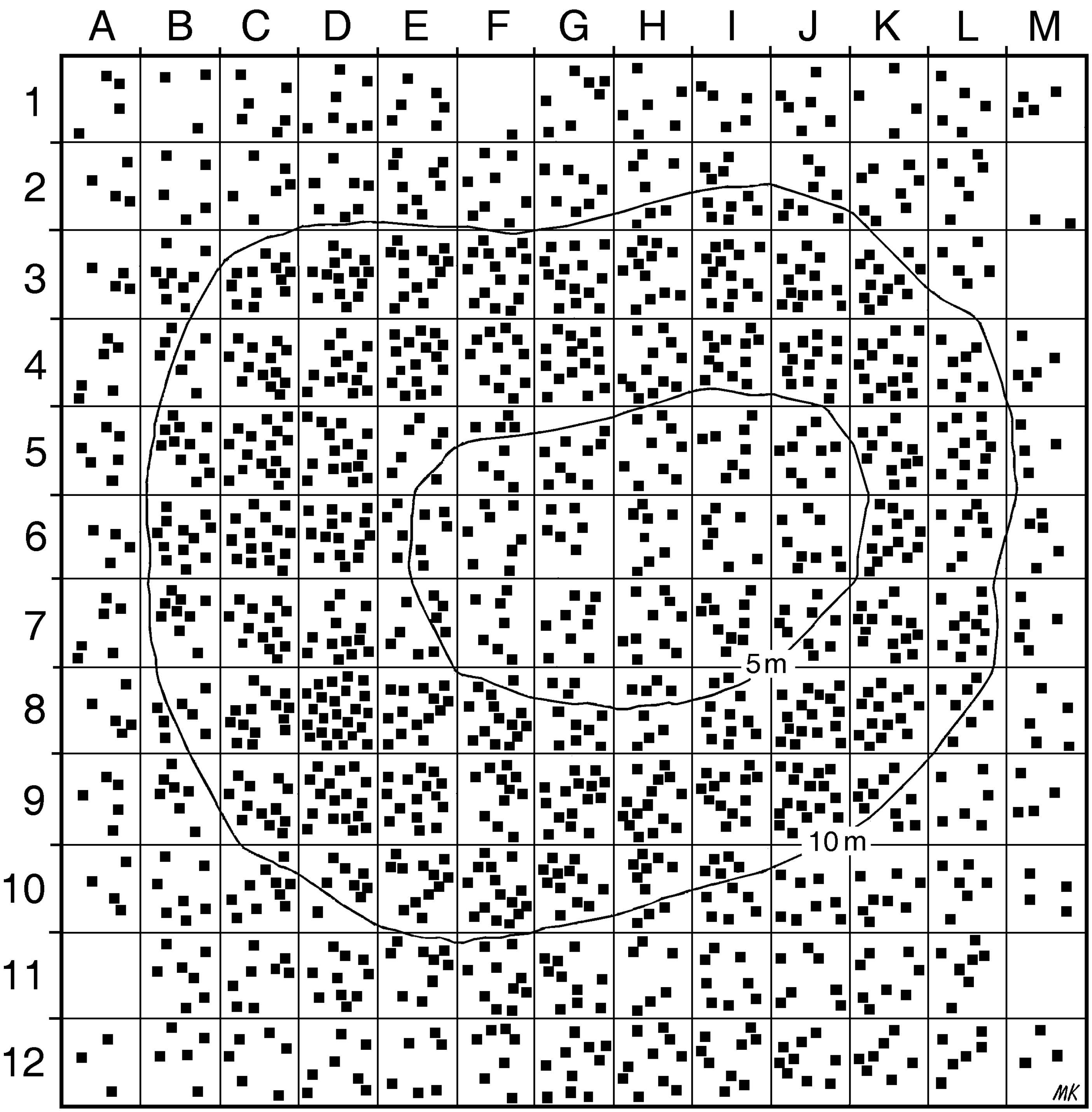
Have each student or student group randomly select six quadrats (the small squares; e.g. B2, G5, H10, K8, L1 and M9). Statistics students could use random number tables to do this. Otherwise, one student in each group should use a pencil to touch the sheet six times without looking.

Count the number of sea cucumbers (small black squares) in each of the six quadrats selected. Total the sea cucumbers from all six quadrats and divide the total number by six to estimate the mean number of sea cucumbers per quadrat.

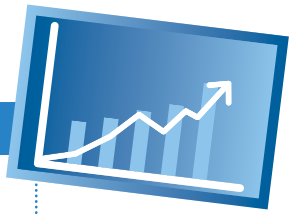
Multiply the mean number of sea cucumbers per quadrat by the total number of quadrats (156). This is an estimate of the total population size of the sea cucumbers. Why could this figure be inaccurate? If, by chance, students had randomly picked quadrats that were in water deeper than the 10 m depth contour, the population would be underestimated. Alternatively, if all six quadrats were in relatively shallow water, between 5 m and 10 m, the population would be overestimated.

As a preferred method, sample along a transect; for example, by selecting every second small square along column G. Have students discuss why this method is likely to be more accurate.

Senior students studying statistics could estimate the population size with 95% confidence limits.



The distribution of sea cucumbers (square black squares) in a total area of 15,600 m² around a sand bank. Each square grid (quadrat) is 100 m². Contours are shown at depths of 5 m and 10 m.
From King M. 2007. Fisheries biology, assessment and management. UK, Oxford: Wiley-Blackwell. 400 p.



4. Fisheries economics

At the completion of studies:

Younger students explain the importance of fisheries to the household income and the community economy.

Older students discuss the importance of fisheries to the national economy and the value of fisheries taking into account costs and returns.

Teaching and learning activities for younger students

A. Ask students to talk to elders in their community or extended family to discover the importance of local fisheries in supplying food and selling seafood for income.

Teaching and learning activities for older students

B. Ask students to examine the value of different fisheries in Vanuatu. Which fisheries are the most valuable? Ask students to identify subsistence fisheries and commercial fisheries on their island. Discuss how Vanuatu and its people benefit from these fisheries.

Jeff Muir © ISSF 2012

5. Fisheries and climate change

At the completion of studies:

Younger students will be able to identify the impacts of climate change on coastal fisheries.

Older students will be able to explain the impacts of climate change on fishery resources in Vanuatu and other Pacific Island countries, and describe appropriate adaptive measures to mitigate the effects.

Teaching and learning activities for younger and older students

A. Ask students to find out all they can about climate change on the Internet and/or from newspaper articles and books. How could climate change affect Vanuatu? Will there be more, fewer or stronger cyclones? Will the amount of rain change? Will sea level change? How will coral reefs be affected? Will fish stocks be affected?

B. Ask students to explain how the mangrove ecosystem can mitigate and adapt to the adverse effects of climate change (Information sheet for fishing communities 25: Mangroves).

Michael Sharp © SPC

6. Fish anatomy

At the completion of studies:

Younger students identify the external features of fish and sharks.

Older students identify the structures and explain the functions of the external and internal parts of fish.

Many young people, even those who have cleaned and gutted fish for their family, do not appreciate the structure and function of the different parts of a fish. These exercises are meant to increase awareness of fish, animals whose ancestors appeared on earth over 500 million years ago.

Teaching and learning activities for younger students

A. Make full-size, A4 black and white copies of the accompanying drawing of the external features of a bony fish and a shark with separated parts. Ask students to cut out the parts (along the dotted lines) and paste them onto the drawings and colour them in.

Teaching and learning activities for older students

B. Supply fresh fish of different kinds, one to each group of two or three students working together. Each group will require a dissecting kit with scissors, scalpel (or knife) and probe – the scalpel could be omitted if safety is a concern.

Ask each group of students to

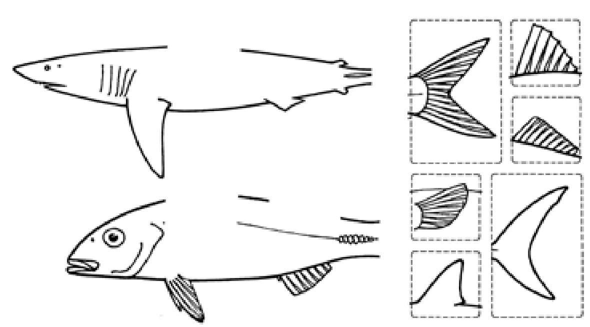
i. identify the fish;

ii. dissect each fish by carefully exposing the internal organs as shown in the figure on the Teachers' resource sheet 6: Fish anatomy; and

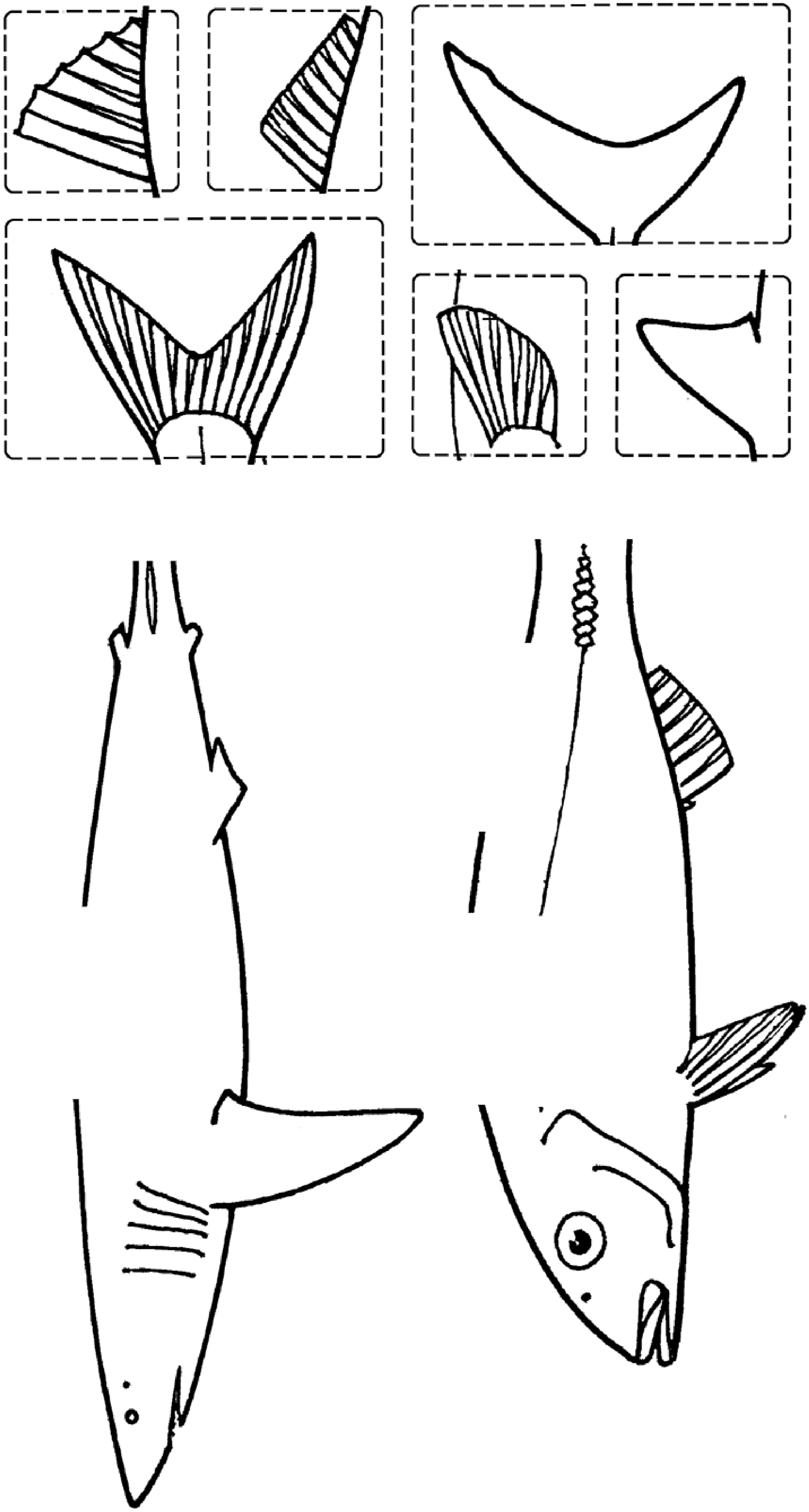
iii. make a labelled drawing (use the figures on the Teachers' resource sheet 6: Fish anatomy as a guide; show the figures on a screen using the flash drive supplied as part of the Teachers Resource Kit).

Ask students to label the important parts of the fish and give their function. Then, have students answer the following questions:

- Is the dissected fish an herbivore or a carnivore? (Have students examine the length of its intestine and the type of teeth it has.)
- How does a fish 'breathe'?
- How does a fish move through the water?



See next page for full A4 version of this figure.



7. Marine food webs

At the completion of studies:

Younger students identify the simple food webs of marine species.

Older students explain marine food webs and the loss of energy in a food chain from plants to top-level carnivores.

Most students will have some idea of the range of species in coastal areas of Vanuatu. These exercises are meant to make students aware of the connections between species; in other words, what eats what?

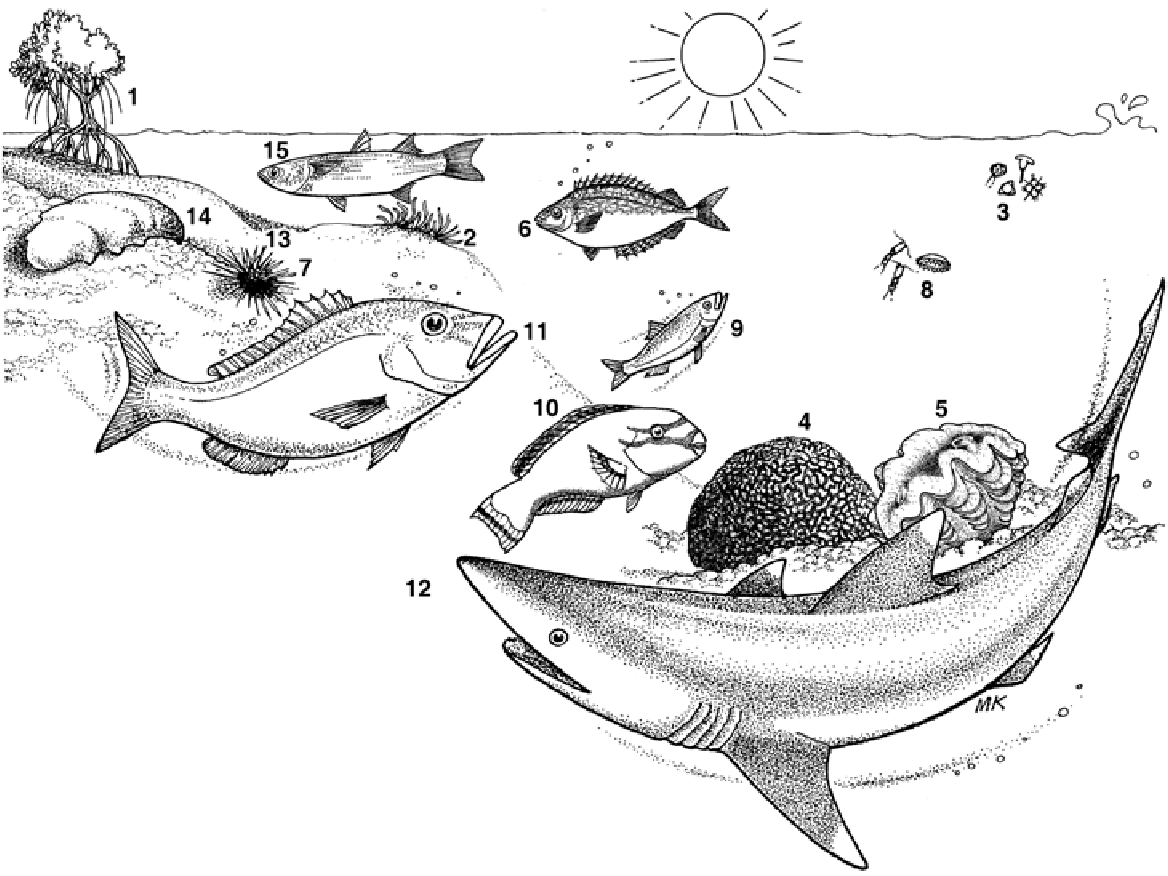
Teaching and learning activities for younger students

A. Ask students to draw common local fish and place them in a food web like the one shown in the accompanying illustration on the Teachers' resource sheet 7: Marine food webs. What does a rabbitfish eat? What does a parrotfish eat? What does an emperor eat?

Teaching and learning activities for older students

B. Discuss the energy pyramid shown in the Teachers' resource sheet 7: Marine food webs. Assuming an energy loss of 90% in each stage of the food web, estimate how much plant material it takes to ultimately produce 1 kg of snapper meat.

C. The food web shown in the accompanying figure is the same as the one on the Teachers' resource sheet 7: Marine food webs, but the connecting lines have been removed. Have students discuss primary production* (the use of sunlight, carbon dioxide and nutrients by plants) and predator-prey relationships (what eats what?). Also ask students to connect the living things (as well as detritus) to one another by drawing a line.



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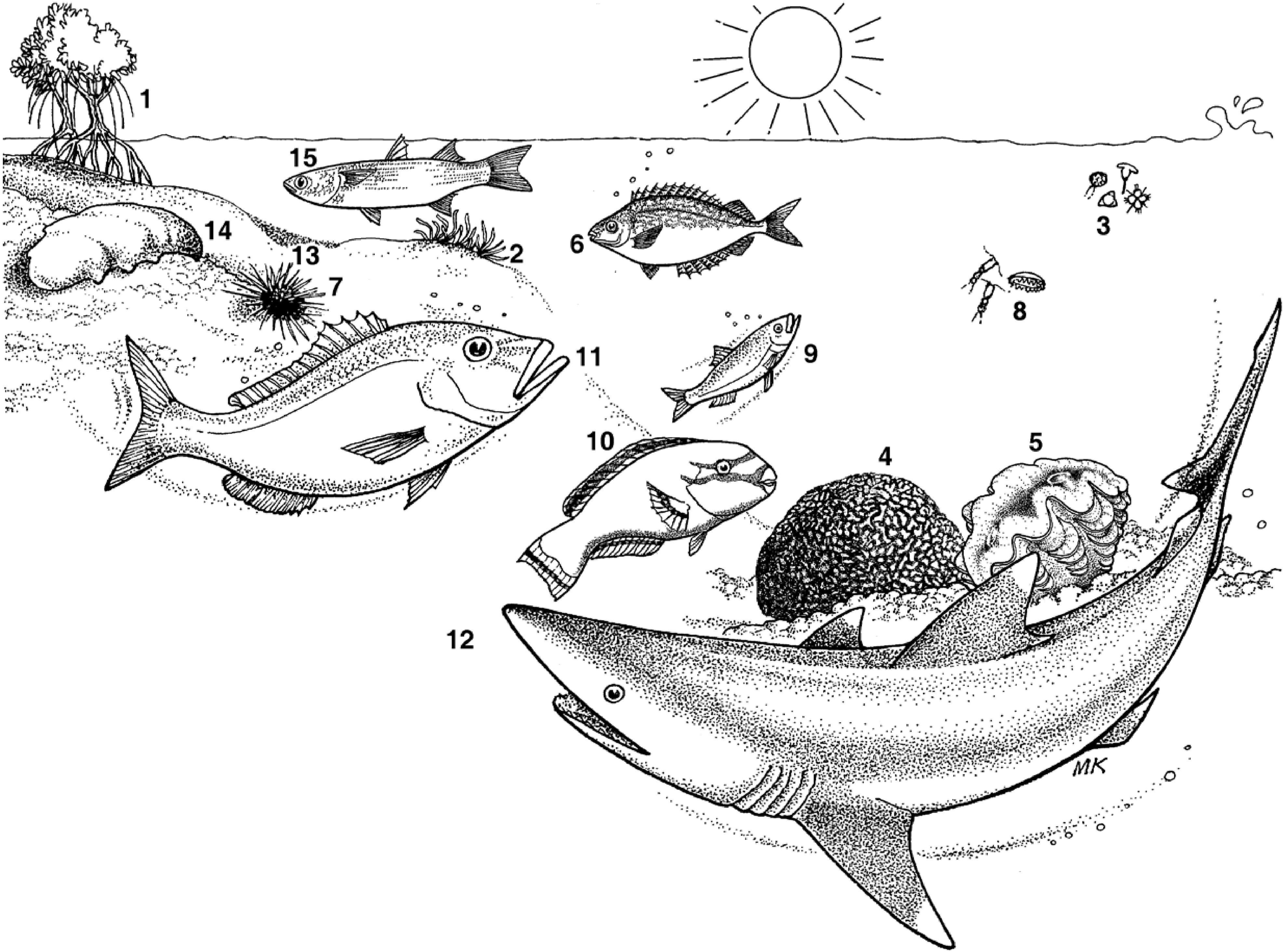
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8. Oceanic species

At the completion of studies:

Younger students identify oceanic fish species and distinguish them from reef species.

Older students discuss morphological and behavioural adaptations of oceanic species such as fusiform shapes, counter-shading and schooling.

Vanuatu shares its maritime borders with New Caledonia, Solomon Islands, and Fiji. The undisputed portion of Vanuatu's exclusive economic zone (often referred to as 'EEZ') covers 680,000 km^2 of sea. Pelagic* fish caught in Vanuatu's EEZ are for both local food and export, and include yellowfin tuna, skipjack tuna, albacore tuna, marlin, wahoo and mahi mahi.

The Department of Fisheries determines a total allowable catch* for each of the major species of tuna and issues a number of fishing licenses.

Teaching and learning activities for younger students

A. Show the accompanying figure of oceanic fish on a screen (from the flash drive supplied as part of the Teachers' Resource Kit). Ask students to identify each of the fish in Bislama (e.g. mai mai for mahi mahi, and local names if appropriate).

B. Compare the lives of open ocean fish with reef fish. Why do they look different?

Teaching and learning activities for younger and older students

C. Show the figure of the fusiform shape and the fish with counter shading on a screen (these figures are on the flash drive supplied as part of the Teachers Resource Kit).

   Ask students to:

   i. discuss the advantages of a fusiform shape. Ask what human made objects use this same shape (e.g. the hulls of outrigger canoes and the bulbous bows on large sea-going vessels).

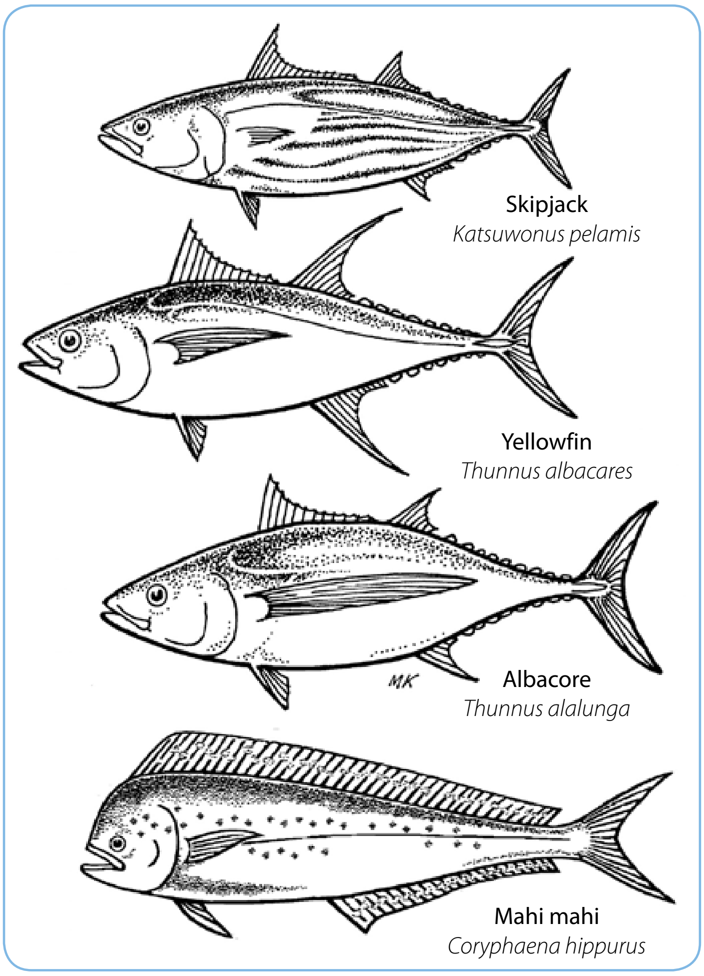
   ii. explain the purpose of counter shading in fish.

Teaching and learning activities for older students

D. What is the most noticeable difference in shape between fish that swim fast and those that live on the reef? What shape is common in oceanic fish? Why is this shape common? Why do tuna need so much food? Why does a dolphin (a mammal) have the same shape as a fish?

E. In groups, ask students to prepare a status report on a local, exploited marine species. The report should address the biology of the species, the history of the fishery, the state of the resource, current management measures and recommendations.

F. As a class exercise, conduct a brief survey of a local fish market. Make a list of all of the species offered for sale, and include their estimated weights and price per kg. Interview fish sellers to find out where each species comes from and how the availability of the marketed species varies seasonally.



9. Deepwater snappers

At the completion of studies:

Younger students identify species of *poulet* in Vanuatu.

Older students describe the fishery and its importance in Vanuatu's economy, and explain regulatory measures for *poulet*.

Teaching and learning activities for younger students

A. There is a range of deepwater species of fish or *poulet* caught in Vanuatu and these are illustrated in the 'Dip botom fis blong Vanuatu' poster.

Ask students to indicate species of *poulet* on the poster.

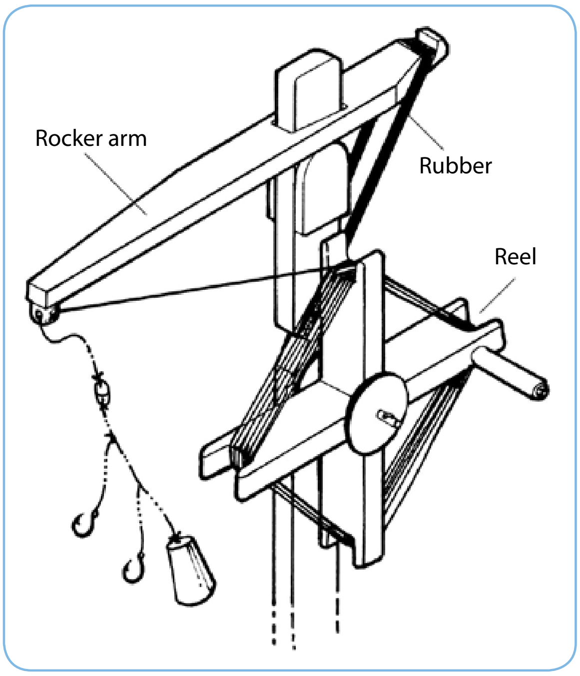
Teaching and learning activities for older students

B. Most small boats that go fishing for *poulet* are fitted with the wooden hand reel to haul in fishing lines from deep water (see accompanying figure). Ask students to visit a fishing boat and study the cleverly designed hand reel. Why is the rocker arm free to move up and down? What is the purpose of the rubber strap? (Powerful fish such as *poulet* can break a taut line unless it has some elasticity.)

C. Pressure on a fish at the surface of the sea is due to the weight of the column of air above the fish. Because water is about 800 times heavier than air, pressure increases rapidly with increasing depth. In fact, pressure increases by one atmosphere* with each 10 m of depth. Thus, at about 10 m below the surface, the water exerts twice the pressure on the fish as air does at the surface. Some deepwater *poulet* may be caught at about 200 m where the pressure is 20 times that at the surface.

Consider what would happen to the swim bladder of a fish caught at 200 m as it is hauled to the surface (see Teachers' resource sheet 6: Fish anatomy).

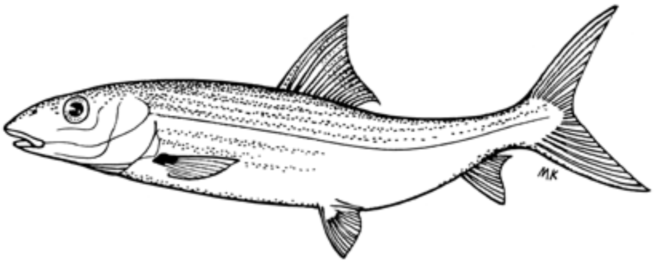
The Department of Fisheries sets rules to conserve stocks of *poulet* and ensure that they are not overfished. One regulation is that fishers cannot use a dropline with more than 10 hooks attached to it. Why would a minimum size limit and returning smaller fish to the sea be an unreasonable conservation measure?



10. Bonefish

Bonefish are found in Vanuatu but are not exploited the way they are in some other parts of the Pacific Islands region. This sheet could be used to show how sport fishing for bonefish is benefiting some island countries such as the Cook Islands.

Flyfishing* for bonefish brings foreign exchange to the Cook Islands. Sport fishers, mostly tourists, are required to have a permit and to fish only in designated areas. Fishing in spawning areas and nurseries is prohibited from three days before until three days after the new moon. A spawning area is an area where fish gather to reproduce; a nursery is an area where very young fish settle to grow and hide from predators. Most sport fishers take a photograph of their catch and release it quickly to give it the best chance of survival. Sport fishing is, therefore, an eco-friendly tourism activity.



11. Pearl oysters

At the completion of studies:

Younger students recognise that common molluscs are sources of protein*, and explain that their attractive shells are used in handicrafts.

Older students investigate common seashell production and harvesting in Vanuatu and examine the internal anatomy of a bivalve mollusc.

Pearl oysters are collected from Vanuatu's reefs for food but they are not farmed for the production of pearls as they are in some other Pacific Island countries. Many other molluscs are collected for food and the shells of some are used in handicrafts (see accompanying figure).

The green snail is sought after both for food and its valuable shell, but the green snail has has been fished to near extinction in Vanuatu. In 2005, a ban was placed on collecting green snails. The Department of Fisheries has moved adult green snails to depleted areas, and green snails are now showing signs of recovery.

Teaching and learning activities for younger students

A. Collect a quantity of molluscs, recognise the edible ones and keep the ones with a pearly layer inside the shell, such as a pen shell, trochus or pearl oyster.

   The shells should be broken up by the teacher and a small piece of broken shell (about the size of a 50 vatu piece) given to each student. Ask each student to make a small necklace pendant from their broken piece of shell. Each student will need some coarse sandpaper to shape their piece of shell. A hole could be drilled (using a nail) into the shell by the teacher so that the student can put the shell on a string to wear as a pendant.

Teaching and learning activities for older students

B. Ask students to find out how molluscs eat. Most two-shelled (bivalve) molluscs, such as the ark shell, eat by filtering out microscopic plants (phytoplankton*) from the surrounding water. Many gastropods (single-shelled sea snails) are carnivores. The helmet shell, for example, hunts and eats sea urchins.

Ben Ponia © SPC

C. Ask students to investigate how some seashells produce pearls. How are pearls formed? Why is pearl shell so glossy on the inside?

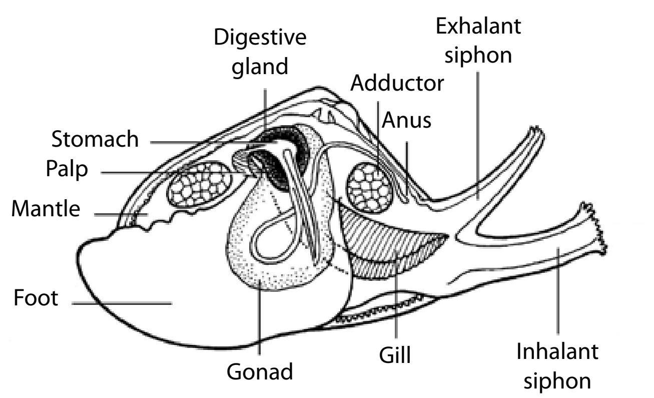
D. Obtain a number of live bivalve (two-shelled) molluscs such as ark shells or cockles (shown in the accompanying illustration). Provide one shell for each small group of two to three students. Ask each group to carefully remove one of the shells and one lobe of the mantle to expose the internal structure.

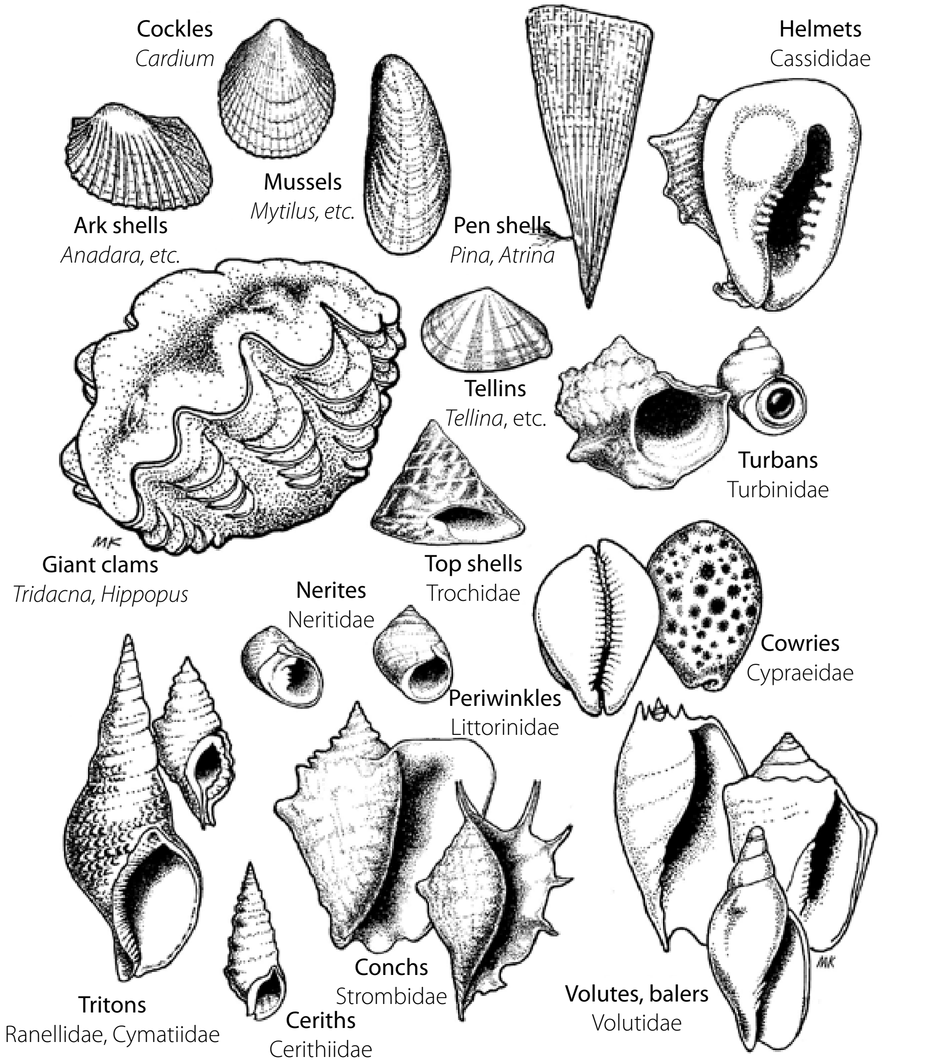
Show the figure of the internal structure of the bivalve mollusc in the accompanying figure on a screen (this figure is on the flash drive supplied as part of the Teachers' Resource Kit.)

This drawing can be used as a guide for students to identify the muscles, gills and intestine, and to make a labelled drawing.

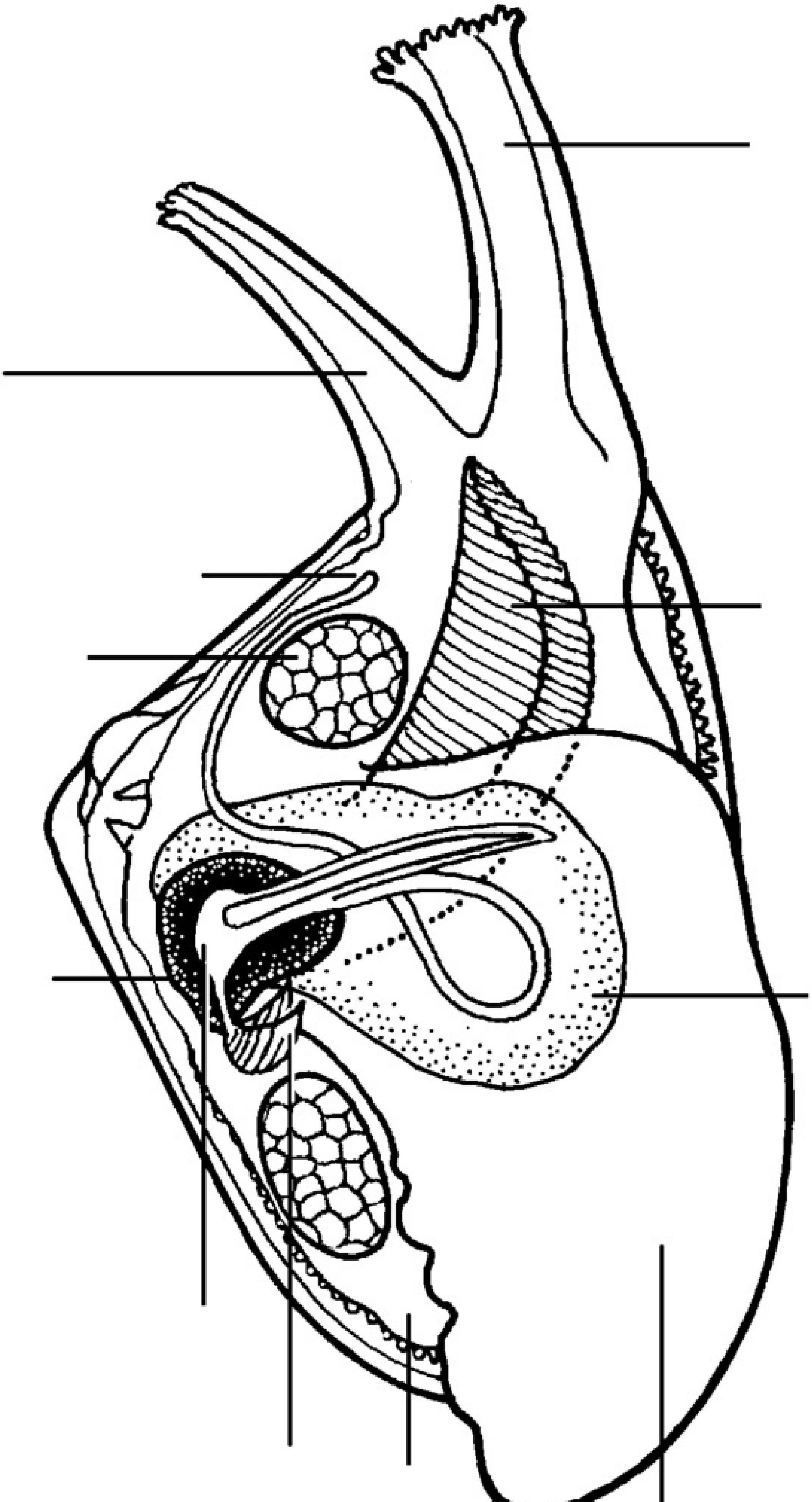
The internal structures of the pearl oyster could also be shown. The oyster and the cockle are similar except that the cockle has two adductor muscles* (the pearl oyster has only one) and it has two siphons – one to draw in water and one to expel it.

E. If dissections cannot be done, have students complete the labels on copies of the accompanying drawing of a bivalve mollusc, and discuss the functions of each structure.





Common mollusc families used for food and handicrafts in Vanuatu. *Turbo marmoratus* is the scientific name for the green snail, which is totally protected in Vanuatu.
Adapted from: King M. 2007. Fisheries biology, assessment and management. UK, Oxford: Wiley-Blackwell. 400 p.



12. Freshwater species

At the completion of studies:

Younger students identify freshwater eels, prawns and tilapia in Vanuatu.

Older students discuss possible origins of freshwater species in Vanuatu.

A small number of fish and invertebrates in Vanuatu live in fresh water. Species include some fish, eels and prawns. Eels live in both sea water and fresh water, and the freshwater fish, tilapia, has been introduced for farming.

Teaching and learning activities for younger and older students

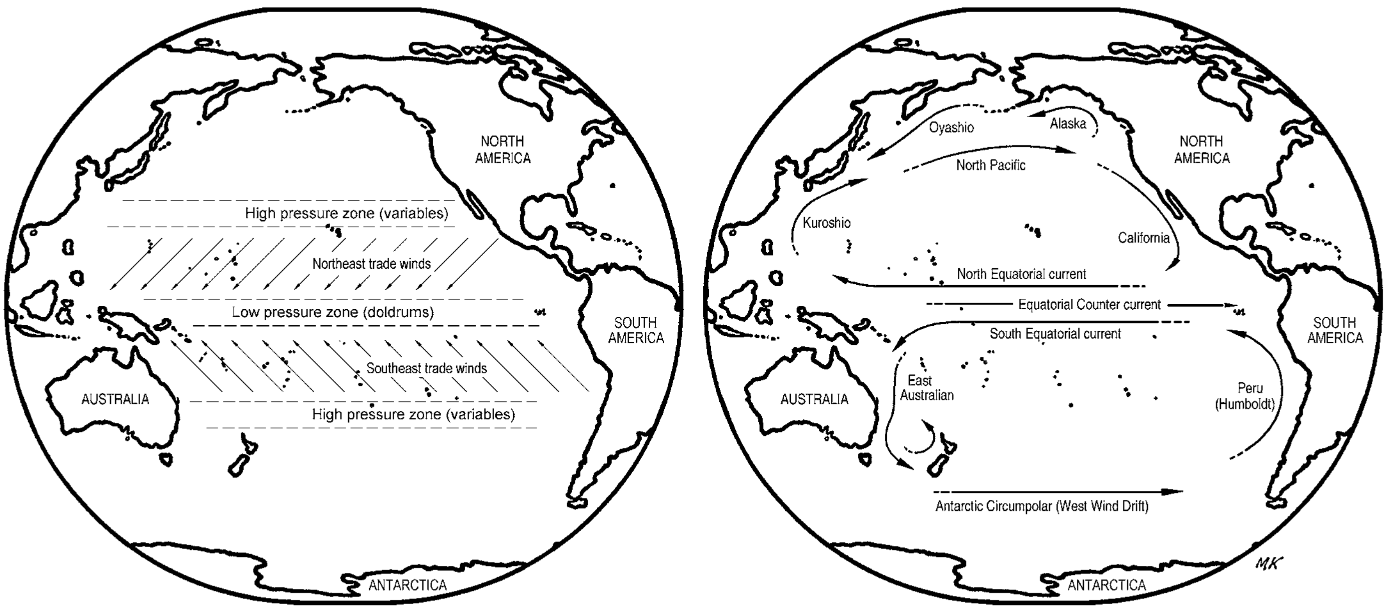
A. Ask students to talk to older people in their community or extended family about fishing for eels and shrimps. How many are caught? Have catches changed over the years?

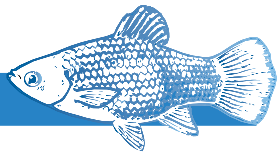
Teaching and learning activities for older students

B. The aquarium built as a student project described in page 24 could be set up as a freshwater aquarium and stocked with shrimps and small tilapia caught by students.

C. The figure below shows (left) the prevailing winds and (right) the ocean surface currents in the Pacific Ocean.

Ask students to discuss where freshwater species could have possibly come from (the origin of freshwater species in Pacific islands is not known but possibilities can be discussed).





13. Aquarium species

At the completion of studies:

Younger students list the species of fish that are exported for the aquarium trade.

Older students discuss the aquarium fish export industry and demonstrate knowledge of building and maintaining an aquarium.

Aquarium species, often called marine ornamentals, are marine fish, corals, live rock and invertebrates that are kept alive in a glass tank or aquarium. Two companies based on Efate are licensed to export small clams and small reef fish for the marine ornamental trade.

Colourful species of fish are collected from reef areas around Efate, and clams are farmed in various locations by the Department of Fisheries (see Teachers' resource sheet 17: Marine aquaculture).

Teaching and learning activities for younger and older students

A. For students in Efate, arrange for a talk from an aquarium fish exporter. Ask him or her to explain how are fish (and other species) are collected on a sustainable basis, and how aquarium fish are transported overseas. If possible, arrange a visit to an export facility or a giant clam farm.

Teaching and learning activities for older students

B. Ask students to cooperate in the building of an aquarium. Pre-cut glass, silicone glue and masking tape will be required to build the aquarium. For the filter system, a plastic pipe, plastic mesh and an air pump will be required. Details of construction are shown in the accompanying diagram.

A thin line of silicone glue must be carefully squeezed onto the edges of the glass that have to be joined. The glass can be temporarily held together with masking tape until the glue sets.

The plastic pipe and connecting pieces are fitted together without glue as shown so that the rectangular structure just fits inside the aquarium; 3–4 mm holes are drilled along the inner sides of the pipes.

The plastic mesh is placed on top of the pipes and well-washed shell grit or coarse sand is placed on the mesh screen. In the centre of the aquarium, the screen may have to be supported from below with short lengths of pipe to stop it from sagging.

The airstone must just fit inside the upright pipe. When operating, the airstone 'lifts' and oxygenates the water after it is drawn through the shell grit and sand, which acts as a filter.

A freshwater aquarium is easier to maintain than a saltwater aquarium. It can be stocked with freshwater plants, small tilapia and freshwater prawns.

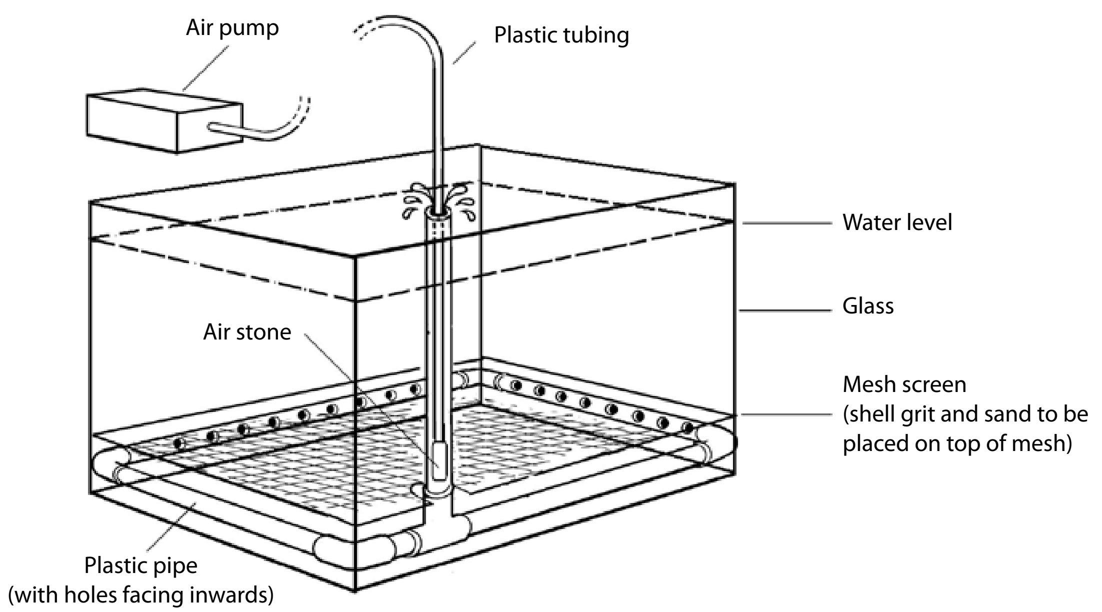
A saltwater aquarium is more difficult to maintain (the water must be changed every two to three weeks). The aquarium can be stocked with very small sea cucumbers, small crustaceans and small coral fish such as humbugs and damselfish (see illustration earlier in this guide, page 8).

C. If funds are not available for building an aquarium, show the accompanying figure of a completed aquarium (this figure is on the flash drive supplied as part of the Teachers' Resource Kit).

Ask students to describe how the aquarium works. How is the water filtered? How is the water oxygenated? If marine fish and invertebrates are kept in the aquarium, why would you need to change the seawater every few weeks?

Students should understand that the water is filtered as it is drawn down through the grit and sand, and the airstone produces very small bubbles that become dissolved in the water. In addition, students should understand that soluble wastes (such a nitrogen compounds) build up in the water and unless they are used by marine plants, will reach toxic levels.

D. An alternative to building an aquarium is for students to watch a virtual aquarium with virtual fish (several internet site are available such as www.youtube.com/watch?v=cYU_dhrmvyU)



14. Vanuatu traditional fishing methods

At the completion of studies:

Younger students identify the range of traditional fishing methods used in Vanuatu.

Older students compare traditional fishing methods with those in use today.

Teaching and learning activities for younger and older students

A. Ask students to talk to older people in their community or extended family to discuss traditional fishing. How have fishing methods changed over the years? What were the advantages and disadvantages of traditional fishing methods? This should be followed up with a classroom discussion.

A list should be made of the traditional fishing methods used by local communities (this could be done in conjunction with exercise A in Teachers' resource sheet 15: Modern large-scale fishing techniques.

B. There is a tendency to think that only modern fishing methods are responsible for overfishing and environmental damage. But some traditional fishing methods can also be damaging. Have students discuss which traditional fishing methods are damaging. What about communal fish drives or coconut leaf sweeps across a reef?

C. The fruit of the poison fish tree or *futu* (*Barringtonia asiatica*) and the roots of derris vine (*Derris* sp.), as well as dynamite, were once used to poison and stun fish. These practices have been banned because they not only kill the target fish, but also other fish, shellfish and coral in the area. Ask students to talk to older people in their community or extended family to ask about the use of these fishing methods in the past.

Futuna, the easternmost island of Vanuatu, takes its name from futu, *the local name for the fish poison tree.*

15. Modern large-scale fishing techniques

At the completion of studies:

Younger students identify the range of commercial fishing techniques used in Vanuatu.

Older students describe a range of commercial fishing techniques used in Vanuatu and worldwide.

Teaching and learning activities for younger students

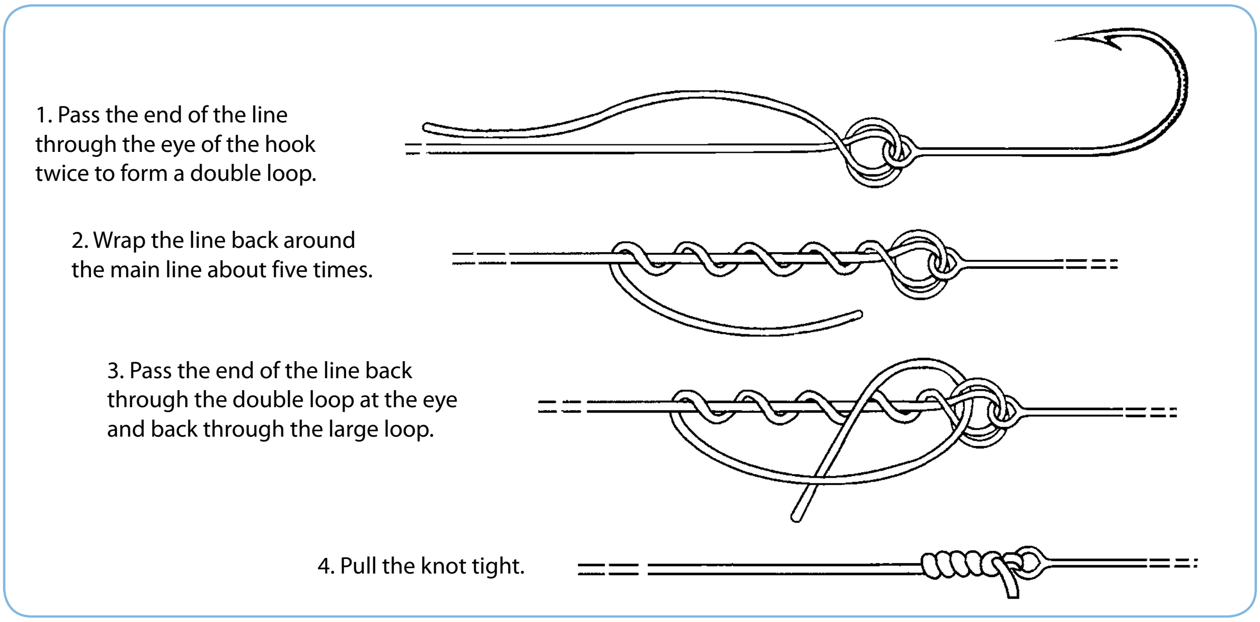
A. Ask students to talk to fishers about modern fishing techniques that they use. This exercise should be followed up with a classroom discussion. Ask students to make a list of the types of modern fishing techniques used by the local community.

Teaching and learning activities for older students

B. Have students demonstrate that they can tie the commonly used fishing knot (a blood knot) shown in the accompanying diagram.

C. If possible, arrange a visit to a local fishing boat or a gamefishing charter boat. Ask students to examine and discuss the value of the operation to the country, and the sustainability of the fish stocks targeted.

D. Ask students to discuss any impacts of modern fishing techniques on marine resources in their community.



16. Fish aggregating devices (FADs)

At the completion of studies:

Younger students describe FADs.

Older students discuss the use and functions of FADs in terms of improving access to offshore fish and increasing the incomes of fishers.

Many species of fish that inhabit the open sea are attracted to floating objects. FADs are rafts set offshore to attract oceanic fish such as tuna, wahoo and mahi mahi so that they can be more easily caught by fishers. In Vanuatu, at the end of 2014, there were 26 FADs deployed off the main islands in the provinces of Tafea, Shefa, Malampa, Penama and Sanma.

Teaching and learning activities for younger and older students

A. Build a model FAD using a raft (about 40 cm by 40 cm) made from bamboo or sticks, and attached by rope to a brick or other weight; attach short lengths of frayed rope to the underneath of the raft.

The frayed rope acts as 'aggregating' material (material that acts as a shelter for fish) as shown in the accompanying figure.

Set the model FAD (with a small flag, which makes it easier for fishermen to find) in the shallow water of a lagoon.

Have students observe the raft using a diving mask and snorkel at weekly intervals. Note any plant material and other organisms growing on the frayed rope. Are there more small fish near the model FAD than in surrounding bare areas?

Teaching and learning activities for older students

B. Ask students to suggest why pelagic fish such as tunas are attracted to FADs. Discussion possibilities include FAD:

- acting as a visual reference point in an otherwise empty ocean;
- working by attracting smaller baitfish on which larger fish feed.

Baitfish may use the FAD as a hiding place from predators or they may feed on the algae and small organisms that settle on the hanging material.

C. Ask a fisheries officer or a *Vanuatai* Resource Monitor to explain how FADs are used in Vanuatu to enhance food security and livelihoods (increased catches of pelagic fish by subsistence and commercial fishers), and to mitigate impacts of climate change (by shifting fishing pressure from reefs to offshore areas, which enables coral reefs to better cope with the negative impacts of climate change).

D. Ask students to discuss the challenges faced by the Department of Fisheries in deploying FADs in outer islands (consider the transport, cost, availability of FAD materials, and the use of a vessel large enough to set FADs). How could fishers using FADs contribute to the high cost of building, setting and maintaining them?

17. Marine aquaculture

At the completion of studies:

Younger students identify species that are currently farmed in sea water in Vanuatu and other species that could potentially be farmed.

Older students discuss the biology of farmed marine species and the methods used to farm them in Vanuatu.

Teaching and learning activities for younger and older students

A. Trochus and green snail have been produced in hatcheries in Vanuatu. Seed (very young, small molluscs) have been released on reefs where stocks had been depleted due to overfishing. Ask students to consider the problems associated with this effort. How can juvenile molluscs be protected from predators, including humans while they grow? Request a talk from a fisheries officer, *Vanuatai* Resource Monitor or farm operator.

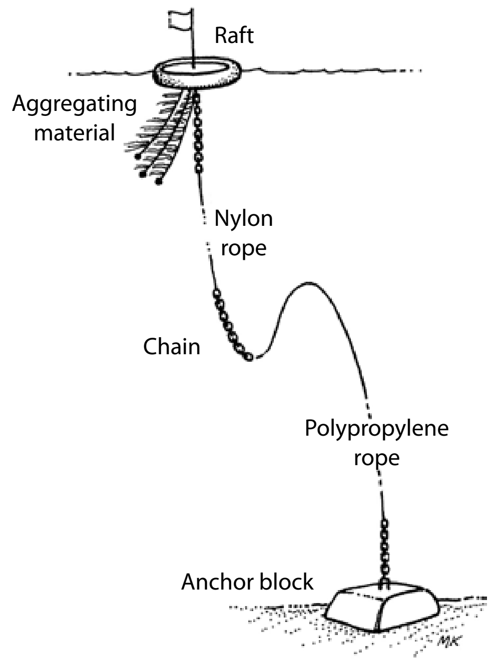
B. There are four giant clam farms in Vanuatu: one on the mainland of Efate, one at Lelepa Island, and two at Mosso Island. Both Lelepa and Mosso are offshore islands of Efate.

For students on Efate or nearby islands, arrange for a visit and a conducted tour of a giant clam farm. Ask students to draw a diagram showing the process of rearing molluscs – from adult reproduction to juvenile production to commercial size.

Teaching and learning activities for older students

C. Giant clams are hermaphrodites, which means that a single individual clam can act as both a female, which produces eggs, and as a male to produce sperm. During reproduction, how does a clam avoid fertilising its own eggs?

Refer to Information sheet for fishing communities 10: Giant clams.



18. Freshwater aquaculture

At the completion of studies:

Younger students identify species that are currently farmed in fresh water in Vanuatu and other species that could potentially be farmed.

Older students discuss the biology of farmed freshwater species and the methods used to farm them.

Teaching and learning activities for younger students

A. A new type of tilapia called GIFT (genetically improved farmed tilapia) has been produced by selectively breeding the fish so that they grow larger and live longer.

GIFT tilapia is a freshwater fish that is often farmed to provide food for communities that do not live near the coast. For students from communities that are growing tilapia, ask them to interview people involved. Are the tilapia grown in a pond or in a river? What do people feed the tilapia? Do people in the community like eating tilapia? Refer also to Teachers' resource sheet 12: Freshwater species.

Teaching and learning activities for older students

B. There is interest in farming freshwater prawns, including the native *Macrobrachium lar* and the introduced *Macrobrachium rosenbergii*. Ask students to discover the life cycle of these prawns and how this information could be used in aquaculture (unlike marine prawns, female freshwater prawns carry their eggs beneath their abdomens).

19. Fish spoilage

At the completion of studies:

Younger students recognise fish freshness and develop an understanding of the need for personal hygiene when handling seafood.

Older students explain the action of enzymes and bacteria in relation to food spoilage.

Most natural foods eventually spoil or become 'bad'. Spoilage refers to food items becoming unfit to eat. Seafood, in particular, must be handled carefully so that it does not make people sick.

Teaching and learning activities for younger students

A. Why is it necessary to wash your hands before handling food? Introduce the idea of removing contaminants and bacteria from hands before handling food.

B. Why do we keep food on ice or in a refrigerator? Explain how low temperatures slow (but do not stop) the growth of bacteria on food.

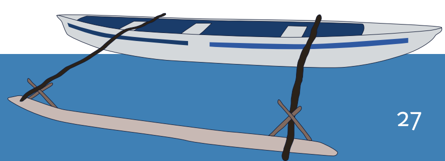
Teaching and learning activities for older students

C. Have students discuss the fact that honey is the only natural food that does not go bad. Introduce the concept of osmosis,* which causes bacteria entering honey to shrivel up and die.

D. Obtain two fresh fish of a similar type and size. Place one fresh fish in a container with ice and one in a container without ice. Ask students to observe the fish each day for several days and note changes in the smell and appearance, particularly in the eyes and gills. What makes the fish without ice begin to smell after a few days? Why would this fish be unsafe to eat?

E. Have students discuss the difference between spoilage caused by bacteria, and spoilage caused by enzymes. What are the causes and symptoms of each type of poisoning?

F. Arrange to visit a fish market or processing plant and observe how seafood is handled. Is it as good as it could be? Alternatively, ask a Fisheries Officer or *Vanuatai* Resource Monitor to give a talk on seafood handling.



20. Fish poisoning and ciguatera

At the completion of studies:

Younger students demonstrate their knowledge of ciguatera and identify other marine species that can cause poisoning.

Older students explain the sequence of events leading to fish and molluscs becoming toxic and their effects on humans.

Not all fish poisoning is caused by poor handling and bacteria. Some forms of poisoning are caused by harmful algal 'blooms'. A bloom is a dramatic increase in the numbers of very small plants (called phytoplankton*) that float in the sea. Some of these microscopic plants produce toxins that can cause people to become sick.

Interestingly, some of the toxins can become airborne because of wave action, and can cause people walking on shorelines to suffer respiratory asthma-like symptoms from inhaling the airborne droplets.

Teaching and learning activities for younger and older students

A. Ask students to identify local fish that are known to cause ciguatera poisoning.

Teaching and learning activities for older students

B. Ask students to interview members of their local community or extended family to identify species in a local area that are known to result in ciguatera poisoning. Find out how many people have suffered from ciguatera poisoning. Speak to someone who has suffered from ciguatera poisoning, and ask which fish caused it. What were the symptoms? Was any kind of medicine used to treat the symptoms?

C. Students should consider the type of conditions that cause harmful algal blooms in their local area. Could it be rain washing nutrients from the land? Could it be sewage or fertilisers entering the sea?

21. Sea safety

At the completion of studies:

Younger students demonstrate their knowledge on the importance of being prepared before going out to sea in terms of safety measures and equipment.

Older students explain marine safety measures and the use of safety equipment, including sea anchors, signalling equipment, and tying important knots relating to safety and seamanship.

The Vanuatu Maritime College based in Santo runs training programmes on fishing vessel skills and safety.

Teaching and learning activities for younger students

A.

i. Show students a copy of the checklist 'Five minutes which can save your life' on safety equipment with one item blanked out. Ask students to identify the missing item.

ii. Ask students to state the four important things to do before going out to sea.

B. Make black and white copies of the 'Small boat safety checklist' for students to colour in. Why are life jackets coloured bright yellow or orange? What is more important to carry on board the boat always: food or fresh water and why? In what circumstances can a knife be useful on board a boat?

Teaching and learning activities for older students

C. Arrange for a talk from harbour authorities or from someone who has had an accident or been rescued at sea.

D. Ask students to interview members of their local community or extended family. How many accidents at sea have occurred? What is the cost of these accidents to families and society? What safety equipment was carried? Did they carry all items shown on the checklist on safety equipment?

E. How can fishers get information on local weather and sea conditions before going to sea?

F. How does a sea anchor work and why is it useful to have it on board? (It reduces drift speed in case of engine breakdown and keeps the vessel's bow facing into the wind, which improves vessel stability.)

G. At present, in Vanuatu 80% of local fishers use small boats less than 8 m in length, which have no VHF radios. What sort of safety issues does this result in? What sort of system could be installed? How much would it cost to install this system?

H. What are the least expensive signalling devices (torch and mirror), propulsion means (sail or paddles), and floating devices (plastic container or fishing buoy)?

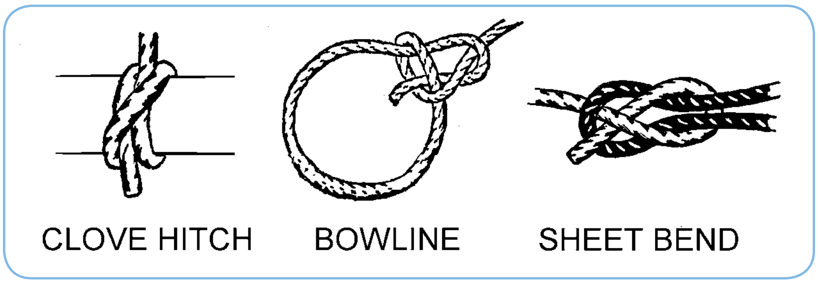
I. Ask students to discuss each of the following signalling devices:

- flares (effective at night but not during daytime; alert passing airplanes or boats; have a short lifespan so need to buy at regular intervals; are not accepted on aircraft so difficult to acquire, particularly in the outer islands);

- VHF radio (good for alerting people onshore or on board other boats; hand-held models exist; is relatively inexpensive, but requires power or AA batteries to operate; has a limited range of up to 20 nautical miles; and some areas are not equipped with VHF receiver/transmitters);
- mirror, also called heliograph (is inexpensive; is effective during daytime but requires sun to work, and does not work at night);
- torch or laser (effective at night; is inexpensive but requires batteries to operate – although manually chargeable models exist; best to have a waterproof lamp; is not useful during daytime); and
- personal locator beacon (PLB) (has unlimited range and works with satellites; is the best device to signal distress to international and local authorities; has a built-in GPS so that the user's position is known; is expensive – around 40,000 vatu; the lifespan of built-in battery varies).

J. Supply each student with two pieces of rope, each one about one metre long. Have students demonstrate that they can tie a clove hitch, bowline and sheet bend.
   - The clove hitch is commonly used to tie a rope to an object (but it can jam tight under load).
   - The bowline forms a loop that does not slip or tighten (it is used in many rescue operations and is traditionally pronounced BO-LIN).
   - The sheet bend is used to join two ropes together.

   Show the accompanying figure as a guide.



22. Job opportunities in fisheries

At the completion of studies:

Younger students identify employment opportunities in the fishing industry.

Older students explore a wide range of fisheries-related job opportunities in Vanuatu and overseas, including working requirements and conditions.

In Vanuatu, employment opportunities may include fisheries personnel such as advisers, biologists, scientists and economists in the government service (the Department of Fisheries) as well as in non-governmental organisations involved in environmental and conservation work. There may also be opportunities for working on commercial fishing boats, both in Vanuatu and overseas.

Some careers involve university study while others require practical training at institutions such as the Vanuatu Maritime College.

Teaching and learning activities for younger and older students

A. Arrange for talks by people who work in the fishing industry, such as a fisher, a fish trader, a fish seller, a fish exporter, a member of an environmental organisation, and a Fisheries Officer from the Department of Fisheries.

B. Arrange for visits to potential employment and training areas such as a tuna fishing vessel, an export factory, the Department of Fisheries, the Provincial Fisheries Office, the Vanuatu Maritime College and the University of the South Pacific.

23. Financial management of a small fishing business

At the completion of studies:

Younger students determine the price of a range of seafood species that are sold in their community.

Older students determine the fixed and running costs in a fishing business.

Teaching and learning activities for younger students

A. Ask students to prepare a list of fish that are regularly caught and what the fishers do with the fish. What quantity of the catch is eaten by the fisher (and his or her family), and what quantity of the catch is sold).

Teaching and learning activities for older students

B. Ask students to interview someone who makes a living from fishing. Find out the fisher's average catch from a fishing trip (by species, in kg), how much they sell the fish for (income, in vatu) and how many fishing trips the fisher usually completes in one year.

If possible, find out the costs of fishing: ice, bait, food, fuel, replacement of gear. Complete a spreadsheet on the costs of fishing and income from selling fish (a basic example is shown in the table below).

Fixed costs per year	
Fishing licence	Vatu______
Bank loan repayments	Vatu______
Boat regular maintenance	Vatu______
Insurance	Vatu______
Depreciation of boat and gear value	Vatu______
Total fixed costs per year	Vatu______
Running costs per fishing trip	
Crew payments	Vatu______
Fishing gear replacement	Vatu______
Fuel and food	Vatu______
Bait	Vatu______
Ice	Vatu______
Total running costs per fishing trip	Vatu______
Total annual running costs (fishing trip costs multiplied by the number of fishing trips per year)	Vatu______
Total annual costs (annual fixed costs plus annual running costs)	Vatu______
Annual income or loss (total income from fish sales minus total annual costs)	Vatu______

Suggestions for exercises and activities related to the 29 Information Sheets for Fishing Communities

Information sheets for fishing communities

The following section includes suggested student activities and questions relating to the 29 information sheets for fishing communities; these are included in the Teachers' Resource Kit on fisheries.

Information sheet 01: Groupers

A. Groupers are not shaped like fish that swim fast; for example tunas. So, how do groupers catch their food?

B. Most species of groupers start out life as females and change sex to males at age three to seven years. What are the advantages of changing sex in this way?

C. What actions could local fishers take to ensure that groupers are not overfished? Overfishing or overexploitation occurs when so many fish are caught, that there are not enough adults left in the sea to reproduce and replace the fish that have been lost or caught.

D. Ask students to talk to fishers in their local community or extended family to find out about fish catches. Where are the fish caught? Are the fish they catch as common as they were five years ago? At what time of the year do the fish have ripe gonads* (see Teachers' resource sheet 6: Fish anatomy)? Do the fishers know if fish migrate to gather in a particular place to spawn? (See Information sheet for fishing communities 24: Spawning aggregations.)

Note – C and D can be repeated for many of the species described in the following sheets.

Information sheet 02: Rabbitfish

A. Rabbitfish are herbivores* and feed on seaweeds and seagrasses. Ask students to describe how this makes them an important link in tropical marine ecosystems. Refer to Teachers' resource sheet 7: Marine food webs.

B. Ask students to discuss the reasons that rabbitfish are important in maintaining the health of corals.

Information sheet 03: Emperors

A. Emperors are easily caught because they gather in large groups to breed (in spawning aggregations). Have students discuss the dangers involved in this type of fishing (refer to Information sheet for fishing communities 24: Spawning aggregations).

B. An emperor is one of the fish shown in the food web shown in Teachers' resource sheet 7: Marine food webs. Have students discuss its position and role in the marine food web.

Information sheet 04: Parrotfish

A. Ask students to discuss the habits of parrotfish that make them particularly vulnerable to overfishing.

B. In many places, parrotfish have been overfished by people using spears and underwater torches at night to catch the fish as they sleep. Have students discuss the effect of overfishing of parrotfish on coral reef ecosystems. What actions could local fishers take to ensure that parrotfish are not overfished?

Information sheet 05: Reef snappers

A. In several Pacific Island countries, some snapper species are responsible for ciguatera fish poisoning. Ask students to talk to people in their local community or extended family to find out which fish have been responsible for ciguatera.

B. There are many different species or types of snapper. Ask students to visit markets and talk to fishers to find out how many species of snappers are caught locally. Have some species become scarce over time?

Information sheet 06: Trevallies

A. Trevallies are fast swimming fish. Ask students to compare the shape of a trevally with that of a grouper and discuss the reasons for any difference.

Information sheet 07: Mullets

A. Mullets often swim long distances along the coast before moving to offshore waters where they spawn. Ask students to consider how this behaviour has resulted in their overexploitation in several Pacific island countries.

B. Mullets are omnivores, that is, they feed on plants and small animals (invertebrates) as well as by sucking up sediments on the sea floor. Have students discuss the advantages of this type of feeding behaviour.

Information sheet 08: Surgeonfish

A. In many Pacific island coastal fisheries, surgeonfish are the most important group of fish taken for food. Ask students to survey their local community to discover the most important local food fish. How are they caught?

B. Surgeonfish can be dangerous to handle. Ask students to discuss why this is so.

C. Ask students to find out which species of surgeonfish are regarded as a delicacy or are popular in their community or on their island, and in which month of the year that such species are normally in good condition or are fat.

Information sheet 09: Sea cucumbers

A. Ask students to talk to people in their local community who have been involved in collecting sea cucumbers. What species were collected? Do fishers still collect them? If not, why not?

What are the traditional methods of preparing sea cucumbers for food?

B. Ask students to discuss the role of sea cucumbers in coral reef ecosystems. What would happen if their numbers were greatly reduced by fishing (consider their role in 'clearing' debris and organic material from the sea floor).

Bislama – The name of the language is derived from the French word for sea cucumber – bêche-de-mer.

Information sheet 10: Giant clams

A. Ask students to discuss how giant clams can 'feed' on sunlight. Discuss symbiosis.*

B. Ask students to discuss the actions that could be taken to ensure that giant clams are not overfished.

Information sheet 11: Trochus

A. Trochus have been overexploited in Vanuatu. Ask students to prepare a history of trochus exploitation, including the use of the meat for food, the use of shells, and the amount of trochus caught each year.

B. The Vanuatu Department of Fisheries has imposed minimum size limit on trochus; in other words, trochus that measure less than 90 millimetres across the base of the shell cannot be legally caught. What is the purpose of this regulation?

C. Some countries also place a maximum size limits on trochus. For example, trochus that measure more than 120 millimetres across the base cannot be legally caught. What is the purpose of this regulation? (See Teachers' resource sheet 1: Fisheries management.)

Information sheet 12: Mangrove crab

A. What sort of regulations could be imposed to protect stocks of mangrove crabs?

Information sheet 13: Spiny lobsters

A. Spiny lobsters are caught in Vanuatu but the development of a large commercial fishery may not be possible. Ask students to give reasons why.

B. Spiny lobsters usually live in crevices on reefs and move out at night to feed. Ask students to interview local people who catch lobsters. How do they catch them (what tools do they use)? Where are they caught? Are they as common as they were five years ago? At what time of the year do the females carry eggs beneath their bodies?

Information sheet 14: Coconut crab

A. Coconut crabs were once found throughout the Pacific but have disappeared from many islands. Ask students to investigate the reasons why this has happened.

B. Coconut crabs have an unusual and complex life cycle. Use the illustration in Information sheet for fishing communities 14: Coconut crab, to discuss this with students.

Information sheet 15: Octopuses

A. Ask students to interview local people who catch octopuses. How do they catch them? Where are they caught? Does the method used to catch octopuses result in damage to corals? Are octopuses as common as they were five years ago?

Information sheet 16: Green snail

A. Green snails have been harvested in Vanuatu for their meat and their pearly shells, which are sold to processing factories for making buttons, jewellery and pearl inlays. Because of severe overfishing, green snails are now protected in Vanuatu. How is the Vanuatu Department of Fisheries addressing this problem? Request a talk from a Fisheries Officer or a *Vanuatai* Resource Monitor.

Information sheet 17: Reef sharks

A. Most fish reproduce when males release sperm and females release eggs into the water. The sperm fertilises the eggs in the sea. But sharks and rays reproduce differently, by internal fertilisation. Have students list the advantages and disadvantages of internal fertilisation using the life cycle illustration.

B. Sharks are fished in large numbers for their fins, which are used in shark fin soup. Tens of millions of sharks are caught each year, and in many cases their fins are removed and the rest of the shark thrown out. Ask students to discuss why sharks, in particular, are easily overexploited? (Hint – think about a shark's method of reproduction and its position on the energy pyramid; see Teachers' resource sheet 7: Marine food webs).

Information sheet 18: Rays and skates

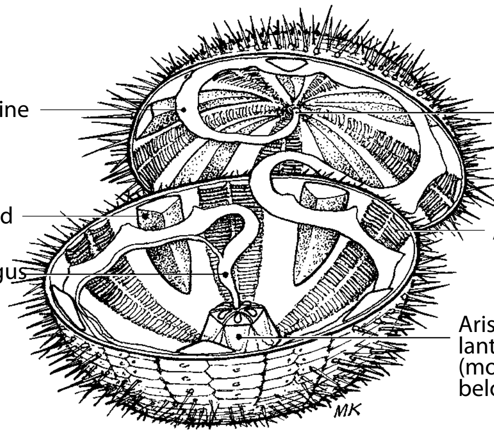
A. Rays and skates are related to sharks but feed very differently. Ask students to discuss how rays, including the related manta ray, feed. Why is the manta ray quite different from other rays?

Information sheet 19: Sea urchins

A. Obtain several sea urchins and have groups of students dissect them, using the accompanying illustration as a guide. Observe the external parts of the sea urchin, including the tube feet and spines.

Use scissors to carefully cut around the test (shell) as shown in the figure, without disturbing internal organs. The body is arranged in five parts like its sea star relatives. There are five gonads suspended on the inside of the test.

Sea urchins feed on algae and small animals using a specialised apparatus called Aristotle's lantern, which includes five calcareous plates (pyramids) that support five band-like teeth. The mouth leads into an oesophagus and intestine, which exits at the anus at the top of the sea urchin.



Information sheet 20: Crown-of-thorns

A. Examine past outbreaks of crown-of-thorns in local areas. Were these outbreaks related to factors such as the time of the year, or rainfall? Investigate how local communities dealt with such outbreaks. Were the methods used advisable?

Note: Crown-of-thorns can be used as an organic fertiliser in agriculture.

Information sheet 21: Slipper lobsters

A. Ask students to interview local fishers who catch slipper lobsters. How do they catch them? Where are they caught? Are slipper lobsters as common as they were five years ago?

B. What actions could local fishers take to ensure that slipper lobsters are not overfished?

Information sheet 22: Ark clams

A. Ask students to investigate and list the types of two-shelled molluscs (such as ark clams) that are used as food on their island or in their local community. How important is each species? How do people catch them? Where are they caught? Are they as common as they were five years ago?

Information sheet 23: Edible seaweeds

A. Have students investigate the types of seaweeds that are collected for food in Vanuatu.

B. Sea grapes (*Caulerpa racemosa*) are widespread and are harvested from reefs. Ask students to interview people who collect this seaweed. Is it as common as it was five years ago?

What actions could be taken to ensure that seaweeds are not overcollected? (In Fiji, women collecting sea grapes traditionally leave clumps of the plant in crevices to regenerate.)

Information sheet 24: Spawning aggregations

A. Many species of fish gather together to form spawning aggregations, or migrate in large groups to spawning sites. Have students interview fishers in their community or extended family to find out which fish species are known to form spawning aggregations. List the names of fish.

What time of the year does this happen for each species? Where do the fish normally aggregate? Do fishers go fishing on these spawning aggregations?

B. Catching fish as they gather in spawning aggregations is destructive because these breeding fish are responsible for producing small fish, many of which will grow and be available to be caught in future years. Ask students to discuss the ways in which aggregations of spawning fish can be managed and protected.

Information sheet 25: Mangroves

A. There are 21 species of mangroves in Vanuatu. Three common types with the different types of root systems shown on the sheet are:

- Drrong jok (*Bruguiera gymnorhiza*)
- Drrong nevis (*Rhizophora stylosa*)
- Naviv (*Avicennia marina*)

Ask students to identify these species and map their distribution in their local area.

B. Why does the number of mangrove species decrease in countries across the Pacific Ocean, from west to east? (Consider the fact that true mangroves produce seeds or propagules that drift in the sea; however, the prevailing South Equatorial Current flows from east to west.)

Information sheet 26: Seagrasses

A. Not many marine species eat seagrasses but they are important in marine ecosystems. Have students discuss the role of seagrasses. (A discussion could include the roles in providing nursery areas and the formation of detritus – particles of material that provide food for a much wider range of marine species.)

B. Organise a field trip in which older students use diving masks and snorkels to survey a shallow area of seagrass. Record the number and types of marine species living on seagrass and in seagrass beds. Students could swim along transects as described in exercise 4C in Teachers' resource sheet 2: No-take areas.

Information sheet 27: Nutrients and sediments

A. A watershed refers to an area of land over which water, dissolved material and sediments flow to rivers and the sea. This run-off often contains nutrients that cause the excessive growth of seaweeds and the appearance of harmful algal blooms (these are described in Information sheet for fishing communities 28: Harmful algal bloom). Ask students to investigate the sources of nutrients in their local area.

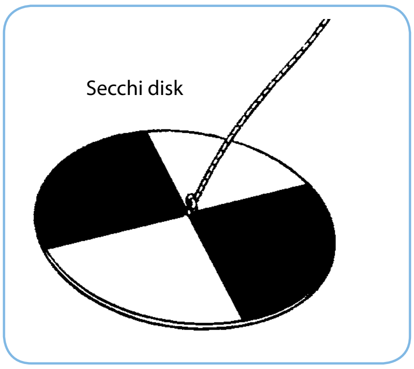
B. Ask students to examine how nutrients and sediments threaten coral reefs and fisheries.

C. Sediments can affect corals and, therefore, coral reef fisheries. The presence of sediments can be easily and inexpensively measured using a simple instrument called a Secchi disk.

A Secchi disk is a 30 cm circular disk with alternating black and white quadrants. It can be made from marine plywood 30 cm in diameter, weighted using pieces of lead (such as vehicle wheel balancing weights) so that it sinks, and painted black and white in quarter segments as shown in the illustration.

- The disk is lowered into the water by a cord marked by knots at 1-m intervals, until it is no longer visible and a first depth reading recorded.
- It is then hauled in until it becomes visible again and a second depth reading is recorded.
- The mean of these two readings measures the visibility of the water.

Have students complete a field exercise to measure the visibility of water at various coastal locations including those near the mouths of rivers. Complete the exercise before and after it rains.



D. Discuss possible sources of sediments. Ask students what can be done locally to reduce sediment run-off into the lagoon.

Information sheet 28: Harmful algal blooms

Student activities and exercises are given in Teachers' resource sheet 20: Fish poisoning and ciguatera.

Information sheet 29: Plant-eating fish

A. In many places seaweeds are replacing corals. This is usually caused when the numbers of plant-eating fish have been severely reduced by heavy fishing. Have students discuss the ways in which plant-eating fish are vital to the health and survival of coral reefs.

B. Ask students to compare the teeth of plant-eating fish with those of coral-eating or meat-eating fish.

Glossary

Adductor muscle: Muscle allowing the bivalve to close the shell tightly.

Atmosphere: A unit of measurement that refers to the force per unit area that is exerted against a surface by the weight of the air above that surface.

Bacterium (plural = bacteria): One of a large group of microscopic, single-celled organisms, most of which are crucial to life on earth and some of which can cause disease.

Billfish: A family of fish that includes marlin, sailfish and spearfish (family Istiophoridae).

Biodiversity: The variety of plant and animal life in a particular habitat.

Biomass: The total weight of living things in a population, community or trophic level.

Bioerosion: The breaking down of substrates, usually coral, by the actions of various living organisms referred to as bioeroders.

Bivalve mollusc: An aquatic mollusc that has a body enclosed within two shells that are hinged together; examples include clams, oysters, mussels and scallops.

Brackish water: A mixture of sea water and fresh water (as occurs near the mouths of rivers).

Camouflage: The colouring or shape of an animal that enables it to blend in with its background or surroundings.

Ciguatera: A kind of fish poisoning caused by eating fish that have accumulated toxins produced by certain types of very small (microscopic) plants or phytoplankton, that are found in association with coral reefs.

Commercial fishing: The production of fish primarily for sale.

Community-based fisheries management: Arrangements under which a community takes responsibility, usually with the assistance of the government or a non-governmental organisation, for managing its adjacent aquatic environment and species.

Critical habitats (or key habitats): Habitats that are crucial in the life cycle of species; for fisheries these may include nursery and spawning areas such as estuaries, mangroves, seagrass beds and reefs.

Customary marine tenure: Legal, traditional or de facto control of land, sea and resources by indigenous people.

Detritus: Particles of organic matter resulting from the breaking down of dead plants, animals and faeces.

Dinoflagellate: A small and very abundant type of marine plankton; it consists of a single cell with two whip-like threads (or flagella), which it uses to move through the water.

Ecosystem: A biological community of interacting plants and animals (including humans) and the non-living components of the environment.

Environment: The surroundings or conditions in which an animal, or plant lives.

Enzyme: A protein that is produced by a living organism and promotes a specific biochemical reaction.

Eutrophic (of a body of water): Water so rich in nutrients that it encourages a dense growth of plants, the decomposition of which uses up available oxygen and therefore kills animal life.

Evolution: The process by which different kinds of living things have developed from earlier forms, especially by natural selection*.

Exotic: Originating in a distant foreign country.

Exports: The sale of fish and seafood products to overseas markets.

Fishery: A population or stock of fish or other aquatic species that is exploited by fishers. A fishery, therefore, includes the exploited species, the fishers and the marketers as well as the ecosystems in which all aquatic species are components.

Fishing effort: The amount of fishing activity on the fishing grounds over a given period of time. Effort is often expressed for a specific gear type; for example. number of hooks set per day or number of hauls of a beach seine per day.

Flyfishing: A method of fishing or angling using a rod, reel, specialised weighted line and an almost weightless fly or 'lure' to encourage the fish to strike.

Food web: A diagram that depicts the feeding connections (what eats what?) in an ecological community.

Fungus (plural = fungi or funguses): Spore-producing organisms, including moulds, yeast and mushrooms, that feed on organic matter.

Gross domestic product (GDP): An economic measure of the productivity of an economy.

Genus: A category of living things with many similarities. For example, most giant clams belong to the genus *Tridacna* and, within this genus, the fluted giant clam is a particular species with the name *Tridacna squamosa*.

Gonads: Reproductive organs – ovaries in females and testes in males, which produce eggs and sperm, respectively.

Herbivore: Animal that feeds on plants (algae and seagrass).

Histamine poisoning: Poisoning due to histamine which is converted from histidine in fish that have naturally high levels of this amino acid; high levels of histamine are indications of a failure to chill fish immediately after capture.

International Game Fish Association (IGFA): A not-for-profit organisation committed to the conservation of game fish and the promotion of responsible, ethical angling practices through science, education, rule making and record keeping.

Indigenous: Originating or occurring naturally in a particular place; native.

Invertebrates: Animals without backbones, such as worms, molluscs and crabs.

Laminar flow: The streamlines of flow that take place without turbulence around solid objects.

Larvae: The young stages of many marine animals including corals; most larvae are small and drift in the sea before becoming adults.

Maximum legal size: A regulation that specifies the largest captured individual that may be kept after it is caught; usually justified on the grounds that larger individuals produce a greater number of eggs and are often less marketable than smaller individuals.

Minimum legal size: A regulation that specifies the smallest captured individual that may be kept after it is caught; usually justified on the grounds that growth of smaller individuals eventually produces a greater harvestable biomass and that the size of the spawning stock is increased.

Natural selection: The process by which living things that are better adapted to their environment tend to survive and produce more offspring.

Niche: The role taken by a type of living thing within its community.

No-take area: An area in which fishing is not allowed.

Nutrients: In the context of the marine environment, dissolved food material (mainly nitrates and phosphates) required by plants to produce organic matter.

Osmosis: A process in which water passes through a membrane (such as the cell wall of a bacterium) from a less concentrated solution into a more concentrated one.

Overexploitation, or overfishing, or over-collecting: A situation where so many fish are caught, that there are not enough adults left to reproduce and replace the numbers that have been lost or caught.

Pelagic: Living things that live in the upper layers of the open sea.

Photosynthesis: The process by which green plants use sunlight, carbon dioxide and nutrients (including nitrates and phosphates) to synthesise proteins, fats and carbohydrates.

Phytoplankton: Very small plants that drift in the sunlit surface layers of the sea.

Plankton: Small and microscopic organisms that drift or float in sea water; some are permanently small and some are the eggs and larval stages of larger animals.

Pollutant: Anything that degrades the environment.

Pollution (marine): The introduction by humans, either directly or indirectly, of any substance (or energy such as heat) into the sea which results in harm to the marine environment.

Predator: An animal that preys on other species.

Primary production (in fisheries economics): Activities that result in the catching or growing of fish and fish products.

Primary production (in biology): The use of sunlight, carbon dioxide and nutrients by plants to produce tissue through the process of photosynthesis.

Protein: A compound, made up of amino acids, which forms much of the structure in living things.

Quadrat: A sampling unit to assess the density of organisms.

Quota: A limit on the weight or total number of fish that may be caught from a particular stock or in a particular area.

Recreational fisher: A person who catches fish for fun and sport rather than for food or for selling.

Rigor (*Rigor mortis*): In medicine and food handling, the stiffening of the joints and muscles a few hours after death.

Rotational closures: A management system in which a fishery, or parts of a fishery, are closed to fishing on a rotational basis.

School (or shoal): A large number of fish swimming together.

Scientific name: A two-part (or binomial) name for a living thing. The first part is the genus to which the species belongs and the second part identifies the species within the genus. For example, most giant clams belong to the genus *Tridacna* and, within this genus, the fluted giant clam is a particular species with the name *Tridacna squamosa*. Note that only the first letter in the genus name is always a capital and the two-part name is written in italics.

Septic tank: An underground tank in which the organic matter in sewage is decomposed through bacterial activity.

Sewage: Waste matter, particularly human faeces and urine, conveyed in sewers, which are part of a sewerage system.

Shellfish: A general term for edible shelled molluscs (such as clams and sea snails) and crustaceans (such as crabs and shrimps).

Spawning aggregation: A grouping of a single species of reef fish that has gathered together in greater densities than normal for the specific purpose of reproducing.

Spawning: The act of releasing eggs, which in most fish, are fertilised by males releasing sperm into the sea.

Species: A distinct group of animals or plants able to breed among themselves, but unable to breed with other groups.

Subsistence fishing: The production of fish primarily for personal or household consumption.

Swim bladder: A gas-filled sac in a fish's body, used to maintain buoyancy.

Symbiosis: A relationship between two different living things that is of advantage to both.

Target species: The resource species at which a fishing operation is directed.

Total allowable catch (TAC): The total catch permitted to be taken from a fishery, usually in one year.

Toxin: A poisonous substance produced by a living thing.

Traditional fishery: A fishery that has existed in a community for many generations, in which customary patterns of exploitation and management have developed.

Transect: A straight line or band along which observations or measurements are made.

Trophic level: A feeding level containing organisms that obtain their nourishment in a similar way and from a similar source.

Wetlands: Low-lying terrestrial areas that are flooded by tides and either contain or are saturated with water; examples include salt marshes, coastal swamps and mangrove forests.

Zooplankton: Very small animals that drift in the sea, including the larvae of many marine animals.

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Teachers' Resource Sheet on

Fisheries management

What is a fishery? ***A fishery* consists of a population or stock of fish or other aquatic species* that is exploited by fishers. A fishery, therefore, includes the exploited species, the fishers and the marketers as well as the ecosystems* in which all aquatic species are components.***

An ecosystem is a biological community of interacting plants and animals (including humans) and the non-living components of the environment.*

A fishery also includes the people, in both fishing communities and government authorities, who manage the fishery.

Why manage fisheries?

All fisheries need to be managed to ensure that fish stocks are not overexploited* and continue to provide benefits to people in the future. With increasing populations and an increasing demand for seafood, a fishery will inevitably be overexploited if it is not managed.

Who manages fisheries?

Fishing communities, government agencies and fishing cooperatives can all manage fisheries. In many Pacific island countries, fishing communities are managing fisheries and are using traditional knowledge to do so. Most national governments have an agency that is responsible for fisheries management.

What are the aims of fisheries management?

The main aim of fisheries management is to ensure that fishing is sustainable. If management is successful, seafood will continue to be available both now and in the future.

Who assesses fish stocks and fisheries?

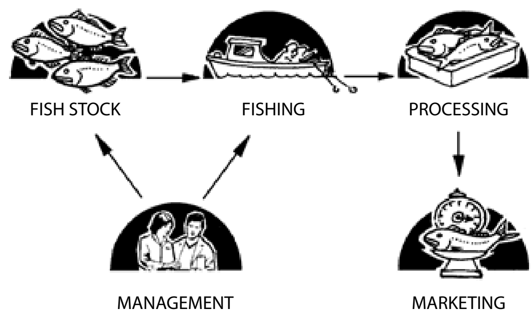
Managers rely on receiving assessments of the health of fish stocks. Sometimes this information comes from fishing communities. More technical assessments are made by scientific staff of government and regional fisheries agencies (see Teachers' Resource Sheet 3: Fisheries assessment).

What or who are we managing?

Fisheries management is mainly about managing people. It often involves preventing people from taking too many fish, using damaging fishing methods and harming the marine environment.

How can we ensure we have seafood for the future?

We have to have rules or regulations to protect our seafood species and the places in which they live. Fishing communities and national fisheries authorities impose many rules and these must be supported by all people.



Fisheries management involves controlling catches from the fish stock, restricting the amount or type of fishing and protecting marine ecosystems.

Manuel Ducrocq © Adecal

This resource sheet is one of a series produced by the Pacific Community (SPC) to assist teachers in introducing fisheries topics into school curricula.

Each sheet should be used in conjunction with the Guide to Teachers' Resource Sheets, which contains suggestions for student activities and exercises. All words marked with an asterisk (*) are defined in a glossary in this guide.

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Some general rules are:

- ***Leave small individuals in the sea.*** This allows adult fish to live long enough to breed and produce young fish, many of which will grow and be available to be caught in future years. Many fisheries authorities ban the catch of fish less than a minimum size.
- ***Leave some big fish in the sea.*** Larger individuals produce many more eggs. This is because egg carrying capacity is related to fish volume not length.
- ***Protect plant-eating fish.*** Some fish, such as parrotfish, unicorn fish and surgeonfish, eat seaweeds that would otherwise displace, compete with, or cover corals.
- ***Ban or restrict some types of fishing.*** Restrict the length of gill nets used and ban the use of small mesh nets. Limit the number of fish traps or fish fences. Ban methods such as using underwater torches and spears at night when fish are sleeping (see Community Information Sheet 29: Plant-eating fish).
- ***Ban the use of damaging fishing methods.*** People using poisons and explosives are destroying our resources and our future.
- ***Ban or reduce fishing on spawning* fish.*** Ban fishing in areas where fish are known to gather to spawn* or at times when fish are gathering to spawn. Spawning refers to the act of releasing eggs, which in most fish, are fertilised by males releasing sperm into the sea. Many fish have to gather in large numbers to reproduce successfully (see Community Information Sheet 24: Spawning aggregations)*.
- ***Protect critical habitats.**** All species need places to eat, live and grow. Some species use different habitats at different stages of their lives. These important habitats may include mangroves, seagrass beds and corals.
- ***Set up permanent reserves to protect fish and places in which they live.*** Set up an area where fishing is banned to protect areas including corals and seagrass beds. No-take areas* may allow fish catches to eventually increase in nearby areas.
- ***Protect watershed areas.*** Seek government support to reduce sediments and nutrients* running off the land into rivers and lagoons; these cause damage to many marine habitats (see Community Information Sheet 27: Nutrients and sediments).

Not all of the above measures are appropriate for all species. Individual information sheets should be consulted for the management options appropriate for specific species.

Fisheries managers recognise that we must manage not only fisheries but the areas in which fish live – this is called an ecosystem approach to fisheries management.

Teachers' Resource Sheet on

No-take areas (*tabu*)

***Why should there be areas where we can't go fishing?* We need to catch fish for food and to make a living. However, the problem is that catch rates, say the number of fish caught in one hour, is decreasing.**

***Why is this happening?* It could be that we have caught too many and there are not enough adult fish left to reproduce and replace the numbers that we catch. Or it could be that we have damaged the environment* in which the fish live or the ecosystem* of which the fish are a part.**

Fisheries authorities and fishing communities are taking steps to manage ecosystems and fishing so that stocks of fish and invertebrates* remain at a sustainable level. Fisheries can be managed in many different ways and these are discussed in Teachers' Resource Sheet 1: Fisheries management.

One of the fisheries management tools commonly used in Pacific Island countries is establishing no-take areas* in which fishing is not allowed. In the Pacific, no-take areas may also be called fish reserves, *tabu* areas or marine protected areas. The term no-take area is preferred because its meaning is clear.

What are no-take areas?

A no-take area is an area in which all fishing or harvesting of marine life is banned, ideally on a permanent basis.

© Francis Hickey

Are there other types of restricted fishing areas?

Other types of closures include an area in which particular fishing methods are banned; for example, the use of nets may be banned even though other less damaging fishing methods, such as line-fishing, are permitted. Another is an area in which the catching of a particular species* is banned; for example, the collection of sea cucumbers may be banned in an area even though the catching of other species is allowed.

In addition there are rotational closures* in which a given fishing area is divided into smaller units which are fished in rotation; for example, if there are three smaller units, fishing is banned in the first area while the other two are open to fishing. The following year, fishing is banned in the second area while the other two are open to fishing – in this example each small unit would have one unfished year to regenerate every third year.

There are also periodic closures, such as those in which fishing is banned for a short time to protect fish during spawning.*

Although these variations are important in managing particular fisheries, it is important to have some permanent no-take areas to provide long-term protection for ecosystems and the species that they support.

What are the purposes of no-take areas?

Most scientists agree that no-take areas provide the following benefits:

a. They protect habitats, plants and animals. In scientific terms, they conserve biodiversity*.

b. They enhance fisheries in nearby areas. They provide places in which fish can grow, breed and spread to other areas.

c. They protect against environmental uncertainty such as global warming. They are more likely to contain less stressed habitats, which would be more resilient to environmental changes.

d. They provide unspoilt areas for income generating ecotourism. Tourists will pay to see well-preserved areas of corals and coral reef fish (however, visitors should keep to marked tracks, or snorkelling trails, in order not to damage reef areas).

Point b) is most important to many fishers who have to obtain seafood on a daily basis to feed their families. The basic aim is to ensure that there are undisturbed habitats and a sufficient number of adult fish to produce enough young to replace the numbers caught.

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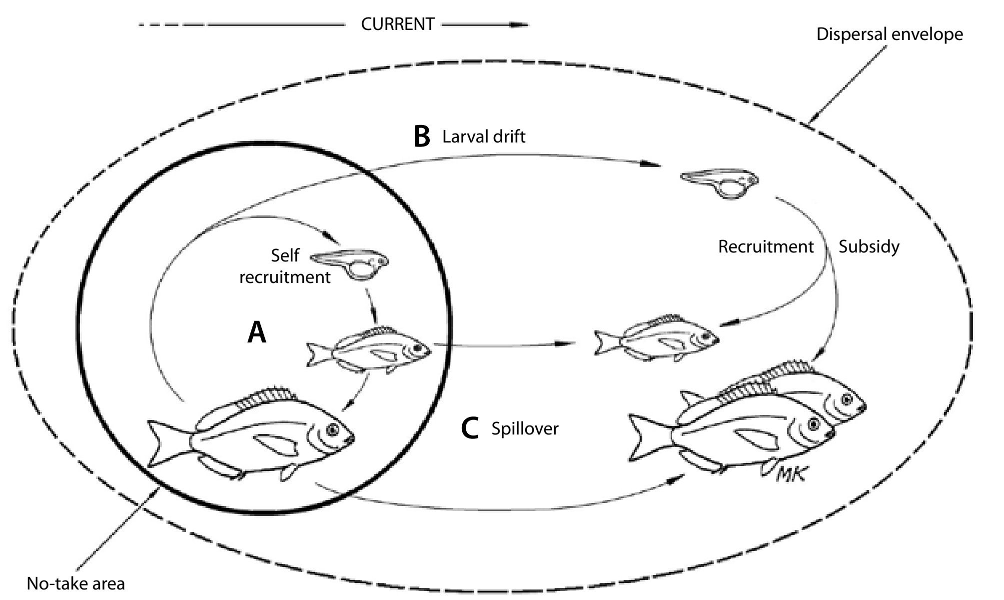
How can no-take areas increase catches?

A fishing community's expectation is that a no-take area will eventually result in improved catches outside the no-take area. In reference to the figure below, the no-take area is represented by the heavy circle.

Fish in the no-take area spawn and produce small larval stages that either A) settle and remain in the no-take area or B) drift with the currents to settle and grow outside the no-take area. Juveniles and adult fish also C) move out of the no-take area as spillover, perhaps due to crowding.

A permanent no-take area is just one way of managing a fishery* but it is an important tool in a toolbox of management controls, some of which are listed in Teachers' Resource Sheet 1: Fisheries management.

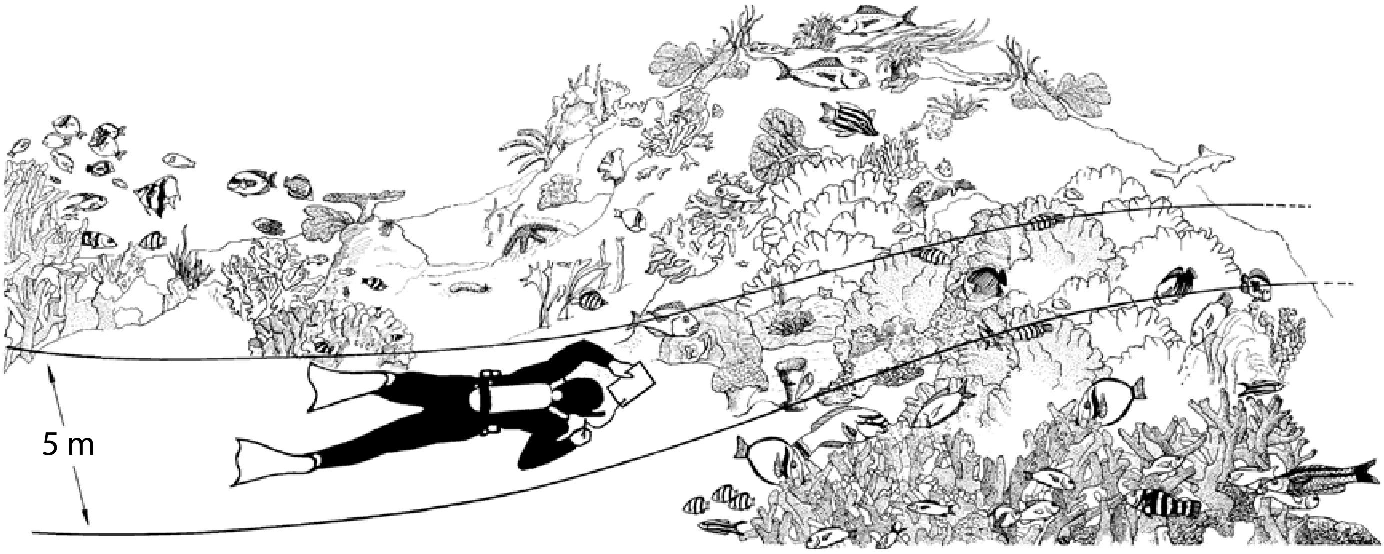


Adapted from: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

Teachers' Resource Sheet on

Fisheries assessment

To assess something is to examine its status or standing at a given time. In fisheries assessment we are gathering information on the status or health of a fish stock or fishery.* This assessment is used to provide fisheries managers with information that they can use to manage a fish stock.



A fisheries scientist swimming along a transect and counting the numbers of different species within a 5 m wide band over a coral reef.
From: King M. 2007. Fisheries biology, assessment and management. UK, Oxford: Wiley-Blackwell. 400 p.

Assessments can range from those made by fishers and fishing communities to more complex analyses made by fisheries scientists. The problem with scientific analyses is that they often require a lot of information and sometimes many years of data collection.

Examples of formal assessments are given in the accompanying guide book. One exercise is based on completing transects* to estimate the size of a population of sea cucumbers on a shallow bank (the diver in the above illustration is completing a transect across a coral reef).

One of most extensive scientific assessments in the Pacific is part of the tuna research programme completed by SPC. Part of this research depends on tagging experiments in which tuna are tagged and released in order to obtain information on their migrations and other biological parameters. An example of using tagging information to estimate the numbers of fish in a population is included in the accompanying guide book. Methods of tagging marine species* are shown in the figure at the back.

However, there are so many species in tropical waters that the individual assessment of each species is a very difficult task. Fisheries managers have to rely on less complex assessments and some of these can be made by fishing communities.

One of the most basic measures of the health or wellbeing of a fishery involves examining changes in fish sizes and catch rates. If fish sizes in catches are decreasing it may suggest that too many large adult fish are being taken from the stock.

Related facts to consider

Coastal waters in the tropics are home to many more species than those in cooler waters. The number of different species decreases with distance away from the equator. For example, big fisheries in New Zealand are based on large numbers of relatively few species whereas a Pacific Island in the tropics has fisheries based on smaller numbers of many more species.

Catch rates refer to the amount of fish caught in a given fishing time; say the number of standard strings of fish, basket of clams, or a number of lobsters caught in an hour of fishing. If catch rates have been decreasing over many years it is likely that too many fish are being taken from the stock.

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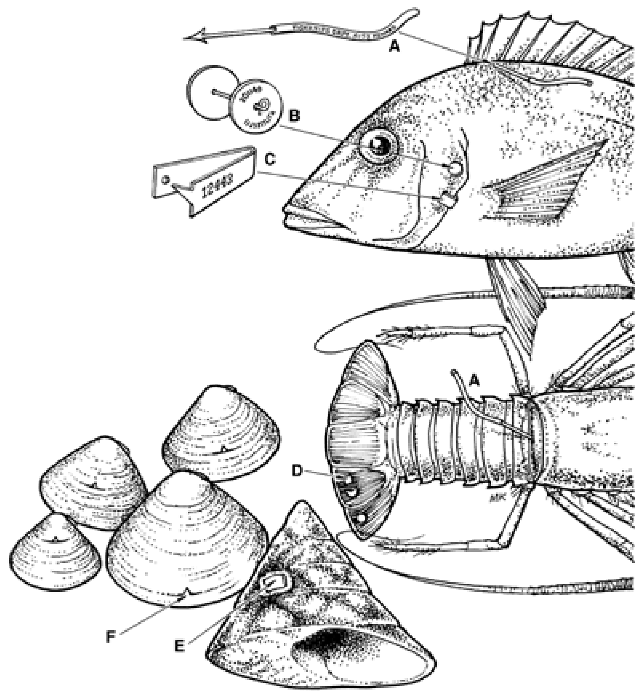
When seeking this information from fishers or in fishing communities it is often easier to ask about catch rates in terms of time taken to obtain a standard catch rather than catch per standard time. That is, for example, the time taken to catch a standard string of fish, a basket of clams, or a number of lobsters.

- If this fishing time is remaining the same, the numbers of fish are probably remaining the same. In this case, the assessment may be that the fish stock is healthy.
- If this fishing time is increasing, the numbers of fish are probably decreasing and management, if any, is not effective. In this case, different or additional management measures should be applied.

This assessment based on information from local fishers has sometimes been called 'data-less management' as it is not based on time-consuming and often expensive surveys by fisheries scientists.



Tagged, or marked, marine species. Fish are often tagged with the brightly-coloured spaghetti tag (A) shown inserted between the rays of the base of the dorsal fin. A spaghetti tag is also shown inserted into the muscle of the lobster's abdomen between the covering plates. A disk tag (B) and an opercular clip tag (C) are attached to the gill cover of the fish. The tail fan of the lobster is marked by defacement (D). The trochus has a small printed plastic tag (E) glued to its shell with quick-setting epoxy resin. The bivalve molluscs* have been marked, at some previous date, by filing a notch (F) on the shell margin. After recapture, the increase in distance from the old shell margin to the new shell margin represents growth during the period between release and recapture.
From: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

Malo Hosken © SPC

Fisheries economics

What is fisheries economics?* *Fisheries economics generally refers to the contribution that the fisheries sector makes to an economy. In economics, we typically discuss the value of fisheries products that are captured, produced or traded and what contribution the fisheries sector makes to an economy in terms of value of production, employment, exports* and government income.

Fishing and aquaculture are primary production* activities, but the fisheries sector also includes private sector processing and trading businesses and fisheries-related public sector jobs.

How do fisheries contribute to Pacific Island economies?

Fisheries contribute to the economies of the Pacific Islands:

i. by adding to the gross domestic product (GDP)* of an economy. Fishing and aquaculture add to total domestic productivity;

ii. by generating government income from the sale of fishing licences to foreign fishing companies and through taxes that are applied to traded fisheries products;

iii. by creating employment for Pacific Islanders (see Teachers' Resource Sheet 22: Job opportunities in fisheries);

iv. by creating opportunities to export, which is an important source of foreign income and contributes to GDP growth. Government income can also be generated from tax on exports.

Three major fisheries that contribute to Pacific economies

In the Pacific, the three main fisheries include:

i. the industrial tuna fishery;*

ii. small-scale fisheries; and

iii. aquaculture.

The industrial tuna fishery

The industrial tuna fishery refers to commercial fishing* vessels that capture large quantities of fish (mostly tuna) that are sold to canneries or high-value foreign markets. There are four main categories of fishing vessels operating in the industrial tuna fishery (Fig. 1).

Figure 1. Four main categories of industrial fishing vessels operating in the Pacific.

Four species* are of major commercial importance in the Pacific's industrial tuna fishery (Fig. 2).

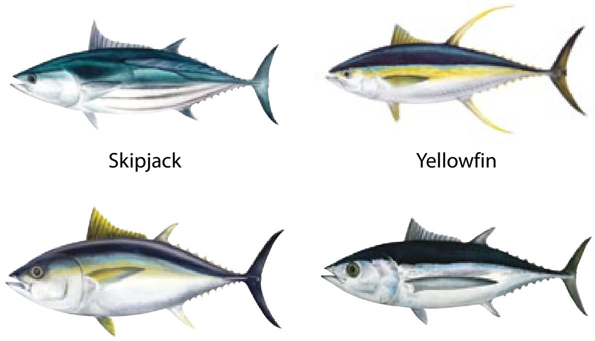


Figure 2. Four main target species* of industrial fishing vessels operating in the Pacific.

Small-scale fisheries

Small-scale fisheries can be subsistence or commercial in nature, supplying fish for local consumption and export markets. They generate income, provide food and make an important contribution to Pacific economies.

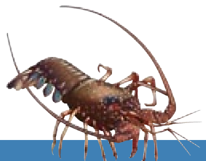
In the Pacific, the main small-scale fisheries that provide food and income to Pacific Islanders include:

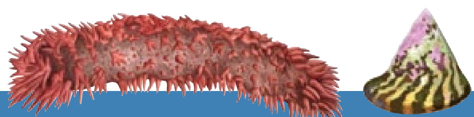
i. small-scale pelagic* fisheries capturing tuna, wahoo, mahi mahi and other pelagic fish;

ii. small-scale coastal fisheries capturing sea cucumber, trochus, reef fish, marine ornamental products and invertebrates;*

iii. demersal fisheries capturing snapper and other deepwater fish; and

iv. sport fishing tourism generating income from charter operations.





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Aquaculture

Aquaculture involves marine and freshwater production systems. Aquaculture plays an important role in food security and income generation for Pacific Islanders. Some of the important aquaculture products that are produced in the Pacific include:

Mariculture	Freshwater aquaculture
Marine shrimp	Tilapia (Nile, Mozambique, or genetically improved farmed tilapia (GIFT))
Pearl oyster	Freshwater prawn
Milkfish	Grass carp
Seaweed	
Marine ornamentals (giant clam, coral, live rock)	
Sea cucumber	

In the Pacific, in terms of income generation, the production of pearls and marine shrimp is the most valuable. In terms of economic contribution, aquaculture plays an important role in boosting domestic productivity (i.e. contributing to GDP), but also by providing foreign income from export of aquaculture products.

Colette Wabnitz © SPC

Businesses in the fisheries sector

There are many different types of businesses in the fisheries sector – some large and some small. Some businesses are involved in production (e.g. fishing vessels, aquaculture farms), some are involved in processing (e.g. tuna canneries, restaurants), while others are involved in the trade (e.g. local market sellers, exporters) of fisheries products.

Irrespective of the activity or size of a business, collectively fisheries businesses are very important to the Pacific Island economies in the sense that, as outlined above, they positively contribute to GDP, employment, exports, food security and tourism development.

Mecki Kronen © SPC

Teachers' Resource Sheet on

Fisheries and climate change

Anyone who fishes will tell you that you don't catch the same number or type of fish every time you go fishing! Catch is influenced by the bait you use, where you fish and the tide. It also depends on whether you fish during the day or at night, the prevailing weather conditions and, importantly, the time of year.

In recent years, scientists have identified another reason why the catches of some fish species* change – climate. They have recorded strong relationships between the El Niño-Southern Oscillation (ENSO) and tuna catch. When the southeast trade winds blow more strongly than usual (La Niña conditions), they push the area of warm water in the western Pacific (the Warm Pool) up against Papua New Guinea (Fig. 1). But when the trade winds are weaker than usual (El Niño conditions), the Warm Pool extends far to the east. Changes in the Warm Pool driven by the trade winds affect the catch of skipjack tuna because this valuable species is caught in greatest numbers near the eastern edge of the Warm Pool and the location of this edge can vary in by 3,000 to 4,000 km depending on the strength of an El Niño or La Niña.

The dramatic effect of ENSO on skipjack tuna demonstrates just how profound the effects of climate on fish can be. Based on these observations, there is every reason to expect that global warming, caused by higher concentrations of carbon dioxide (CO_2) and other greenhouse gases in the atmosphere, will also affect other fish species.

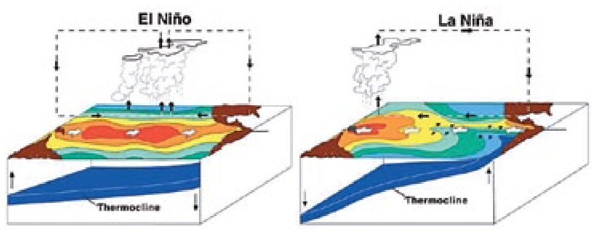

Figure 1. Effects of El Niño and La Niña conditions on the Pacific Ocean (source: SPC).

In considering this, we need to think about two different categories of fish – coastal fish and oceanic fish. Most coastal fish in the tropical Pacific are associated with coral reef habitats (Fig. 2), whereas most oceanic fish are caught offshore (Fig. 3). Most of the oceanic fish we catch are large, highly mobile species like yellowfin, bigeye, skipjack and albacore tuna, but also marlin, wahoo and mahi mahi. These species range widely across the region and are caught as they pass through the exclusive economic zones (EEZs) of Pacific Island countries and territories (the area within 200 nautical miles of the islands).

Coastal fish

The rising sea surface temperature is expected to alter the times of year when coral reef fish spawn and the food available to juvenile coral reef fish during the first few weeks or months of the planktonic (floating) phase of their lives far from shore. Survival during this phase affects how many juvenile fish are available to 'settle' back on coral reefs and replenish the fish stocks there. However, climate change is expected to have its greatest effect on coastal fish by altering the coral reefs themselves. As the ocean warms, corals will bleach more frequently – bleaching occurs when warm water stresses corals and they expel the tiny plants (zooxanthellae) within their tissues that provide them with organic compounds (food) by photosynthesis.*

The build-up of CO_2 in the atmosphere also has another negative effect on coral reefs. The CO_2 dissolves in seawater, making the ocean more acidic and reducing the calcium carbonate available to corals to build their skeletons.

The increased coral bleaching and ocean acidification, will progressively degrade coral reefs – they will lose their complex structure and provide fewer places for the fish and prey for fish, to live. Decreases in coastal fish production will follow because not all coral reef fish will be able to adapt to the loss of the shelter and food they need. By 2035, climate change is expected to reduce that catch of coastal fish by 2%–5%, increasing to 20% by 2050.

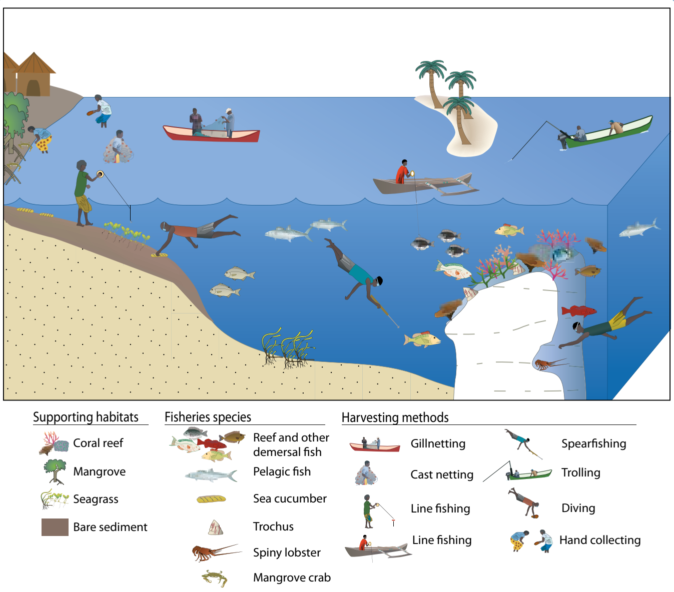

Figure 2. Range of coastal fishing activities in Pacific Islands (source: SPC).

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Oceanic fisheries

Unlike the effects of climate change on coastal fisheries, some Pacific Island countries and territories may benefit from increased catches of some important oceanic fish as the ocean warms. The reason for this is that there will be a steady increase in the overall size of the Warm Pool – it will extend further to the east under normal conditions. Over time, the distribution of tuna will be more like that observed during strong present-day El Niño conditions.

Pacific Island countries and territories further to the east are likely to receive more requests from purse-seine fishing vessels owned by distant water fishing nations (DWFNs) to fish for skipjack tuna in their EEZs because this fish could well be found in greater abundance there. Increased fishing by DWFNs will add to the revenue the government receives from fishing licence fees. Skipjack tuna could eventually be caught in higher numbers a bit further away from the equator than it does at the moment as sea surface temperature increases to be within the range preferred by this species.

Scientists are still in the process of determining the most likely effects of climate change on the other species of tuna.

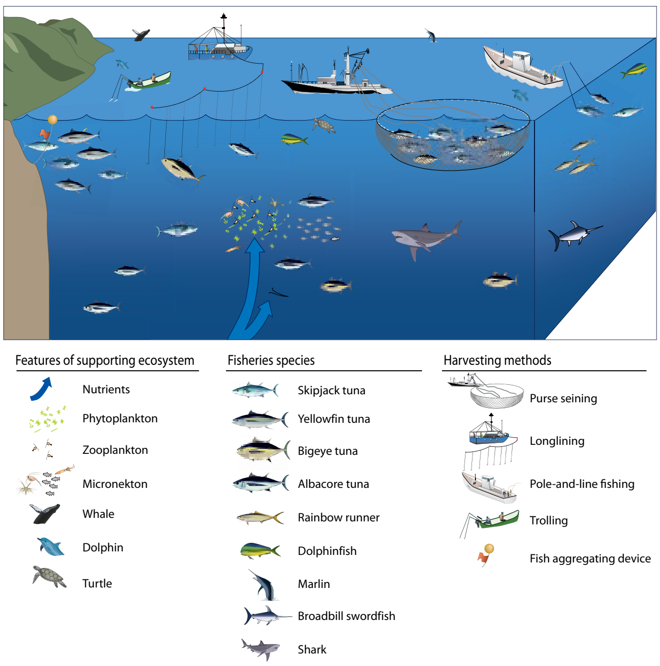
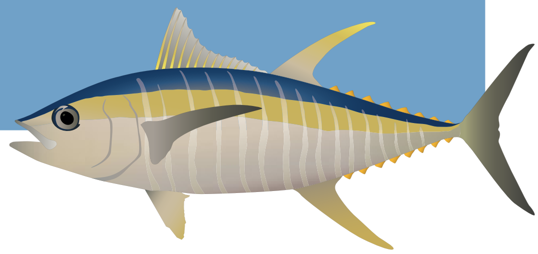


Figure 3. Range of oceanic fishing activities in Pacific Islands (source: SPC).

Interesting fact

Although the body temperature of most fish is the same as the temperature of the water in which they swim, the body temperature of tuna is warmer than the surrounding water. Tuna have a countercurrent heat exchanger that enables them to retain body heat generated as a by-product of metabolism. http://en.wikipedia.org/wiki/Countercurrent_exchange_system



Teachers' Resource Sheet on

Fish anatomy

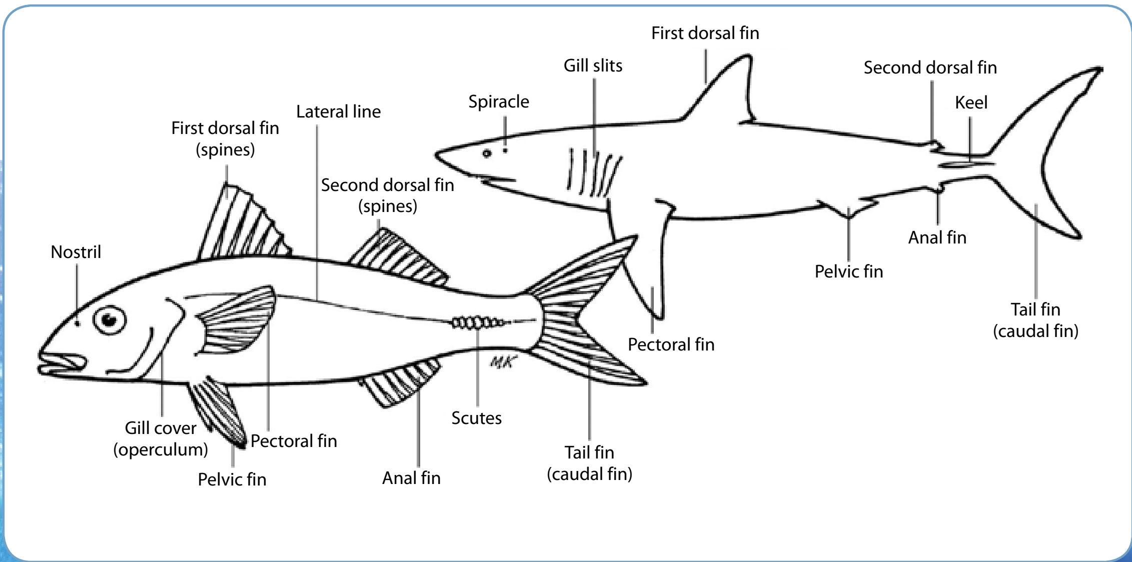
Over half of all animals with backbones (vertebrates*) are fish. There are over 25,000 different species* of fish. Some fish are adapted to eat plants and others to eat meat and they have evolved to fill all available niches* in the marine environment.* Some evolved to hunt on coral reefs and others to swim in the open sea.

External features

Fish have two sets of paired fins, the side or pectoral fins and the pelvic fins. Single fins include the dorsal or back fin, the anal fin and the caudal or tail fin.

Amazing information to think about

Fish appeared on this planet over 400 million years ago. The four limbs of all land-dwelling (terrestrial) animals with backbones that exist today are believed to have evolved from the paired fins of fish.



Jeff Muir © ISSF 2012

Internal features

How do fish stay afloat? They are heavier than water and tend to sink. The two main evolutionary lines, the cartilaginous and the bony fish, have solved the problem of staying afloat in different ways.

Sharks and rays have a light skeleton of cartilage, a firm but flexible type of tissue. They also have a large liver which is rich in the light oil, squalene and fixed pectoral fins which act as paravanes. As a shark moves forward through the water, pressure on the underside of its pectoral fins provides uplift. Thus many, but not all, species of sharks have to swim continually to stay afloat.

The other evolutionary group, bony fish or teleosts, have heavy bones of calcium, but solved the problem of remaining buoyant in a different way. Ancient fish had lungs which evolved into the air-filled swim bladder* of modern bony fish, most of which obtain oxygen through their gills. A small number of fish can gulp air at the surface.

The evolution* of the swim-bladder allowed fish to move away from speed as a way of life. Pectoral fins, no longer required for aiding flotation, could evolve to allow a greater range of movements. Present-day bony fish use pectoral fins to hover, to swerve, to swim backwards and even, in the case of flying-fish, to glide through the air. The ability to take advantage of a variety of ecological niches, to be either bottom-dwelling or pelagic,* has allowed modern bony fish to dominate the waters of the world.

The gill rakers, comb-like structures in front of the gills, sift particles of food from the water which enters the mouth and flows out through the gill slits. The digestive system includes an S-shaped stomach leading to an intestine which is often longer in herbivores than in carnivores. At the junction of the stomach and the intestine, there are often finger-like sacs, the pyloric caeca, whose function may include aiding food absorption.

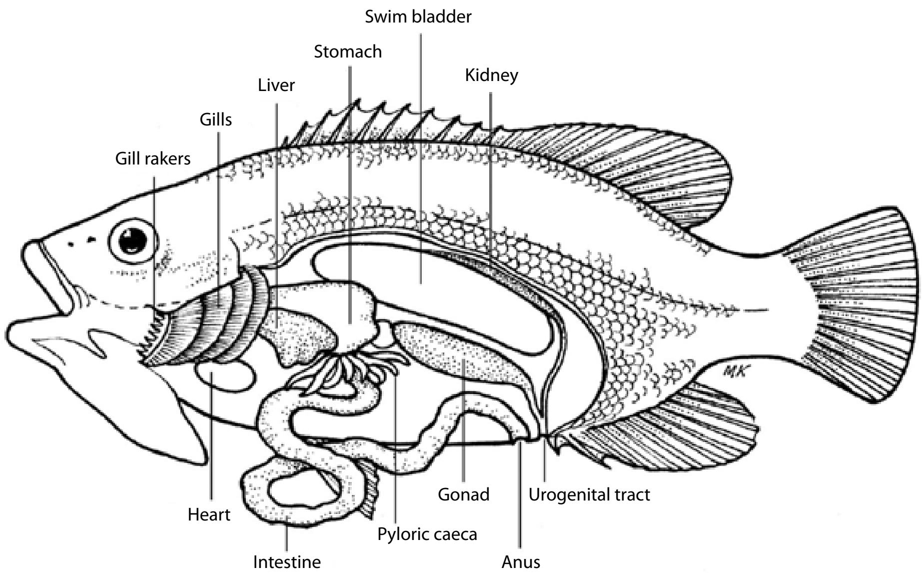
Fish have internal ears with no connection to the outside. Sound waves, travelling through the water and the head, strike dense calcium carbonate 'earstones' or otoliths which float in the fluid contained in the inner ear. The otoliths vibrate against sensory hairs in the ear. As the fish grows more layers, these are deposited on the otholiths, which enables them to be used by scientists to estimate the age of some fish.

Many fish produce sounds and this is often reflected in their common English names – drums, croakers and grunts.

And, fish have one sense that we don't have. They have a lateral line which runs down each of its sides. The lateral line is believed to be capable of detecting low-frequency vibrations in the water as well as pressure changes due to different depths.

Fish have gonads* which are usually paired. In most fish, females release eggs into the sea where they are fertilised by sperm released from males. The fertilised eggs hatch to small larvae* (often about 5 mm in length) most of which drift with ocean currents.

After a period which varies from species to species, the larvae change – benthic species settle on the sea floor. The juveniles of many fish species grow in nursery areas, including reefs, banks, bays and estuaries.



The internal organs of a bony (teleost) fish.
Adapted from: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

Did you know?

Fish eyes are spherical and have given their name to the photographer's fisheye lens used to take in a field of vision covering up to 180°. The eyes of many fish appear to be capable of distinguishing colours.

Teachers' Resource Sheet on

Marine food webs

In the sea, as on land, plant material is eaten by herbivorous animals which themselves are eaten by other, usually larger, animals. This flow of material from plants to herbivores* to carnivores* is often depicted in a diagram called a food web* that shows the feeding connections (what eats what?) in an ecological community.

What eats what?

In relation to the food web below, plants include mangroves (1), algae and seagrasses (2). Mangroves are not present in all Pacific Island countries – see Community Information Sheet 25: Mangroves.

But the most important plants in the sea are so small that most are invisible to the naked eye. These are the phytoplankton* (shown greatly magnified at point 3) that, as plants, must live in the sunlit surface layers of the sea.

Corals (4) and giant clams (5) can also use sunlight indirectly because of the plant cells, called zooxanthellae* embedded in their tissues. This relationship between two different living things that advantages both is called symbiosis.*

Larger plants in the sea are eaten by herbivorous animals such as rabbitfish (6) and sea urchins (7).

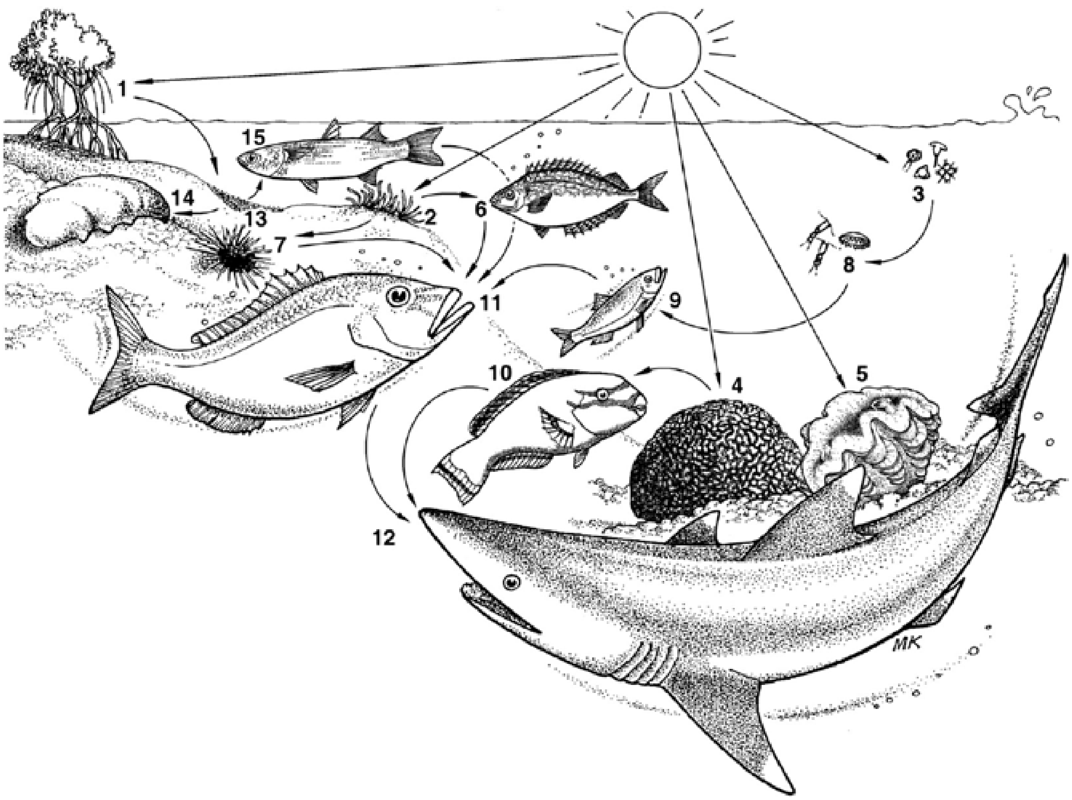
Several larger animals have evolved to take advantage of drifting phytoplankton. Bivalve molluscs,* the cockles and clams, filter out the phytoplankton. But the most important consumers of phytoplankton are the small animals, collectively called zooplankton* (magnified in 8) that drift in the sea and include the larvae* of many marine animals.

Many animals, from barnacles and corals to sardines (9) and baleen whales eat zooplankton. Also, coral polyps trap plankton in sheets of mucus or with their tentacles.

Coral grazers, such as parrotfish (10) feed on algae growing on coral.

Invertebrates* and smaller fish are preyed upon by medium-sized fish including emperors (11) which are preyed upon by large carnivores such as groupers, barracudas and sharks (12).

Bacteria* break down wastes to form detritus* (13), consumed by a wide range of animals such as the sea cucumber (14) and mullet (15).



A simplified, tropical, marine food web.
From: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

This resource sheet is one of a series produced by the Pacific Community (SPC) to assist teachers in introducing fisheries topics into school curricula.

Each sheet should be used in conjunction with the Guide to Teachers' Resource Sheets, which contains suggestions for student activities and exercises. All words marked with an asterisk (*) are defined in a glossary in this guide.

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Why are there not many sharks on a coral reef?

Organisms can be thought of as gaining nourishment at different trophic levels* and these may be depicted as the energy pyramid shown below. The first or lowest trophic level in the energy pyramid, the primary producer level, consists of marine plant material including seaweeds (algae), seagrasses and phytoplankton.

Plant material is fed upon by animals at the next trophic level (the herbivore level) which become prey species* for carnivores (the carnivore level). And, as some fish feed on other carnivores, there may be several levels of carnivores.

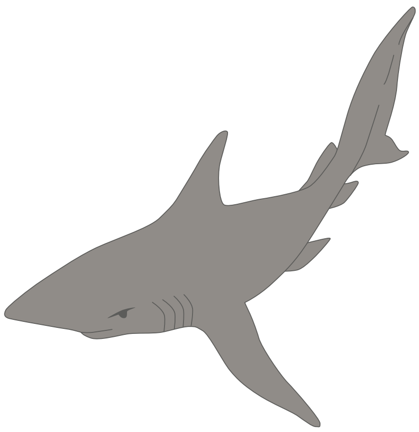
At each level most of the total weight of material or energy (the biomass*) is lost due to the use of energy for respiration, movement and reproduction. As a result, only a small proportion of the food consumed is devoted to flesh growth that may be passed on to the next trophic level. There is, therefore, a large decrease in total biomass of organisms at each succeeding trophic level.

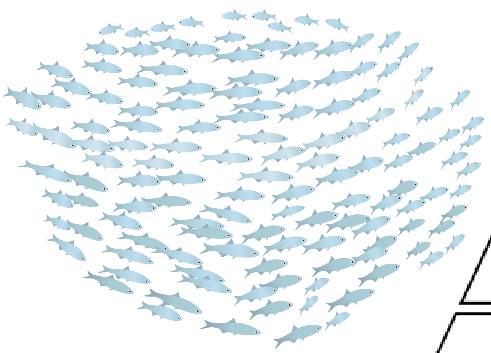
The biomass values shown to the right of the energy pyramid in the figure below arbitrarily assume a 10 per cent level of ecological efficiency – that is, the energy passed from one trophic level to the next. It therefore takes 1,000 kg of plant material to produce one kg of a higher level carnivore such as a snapper.

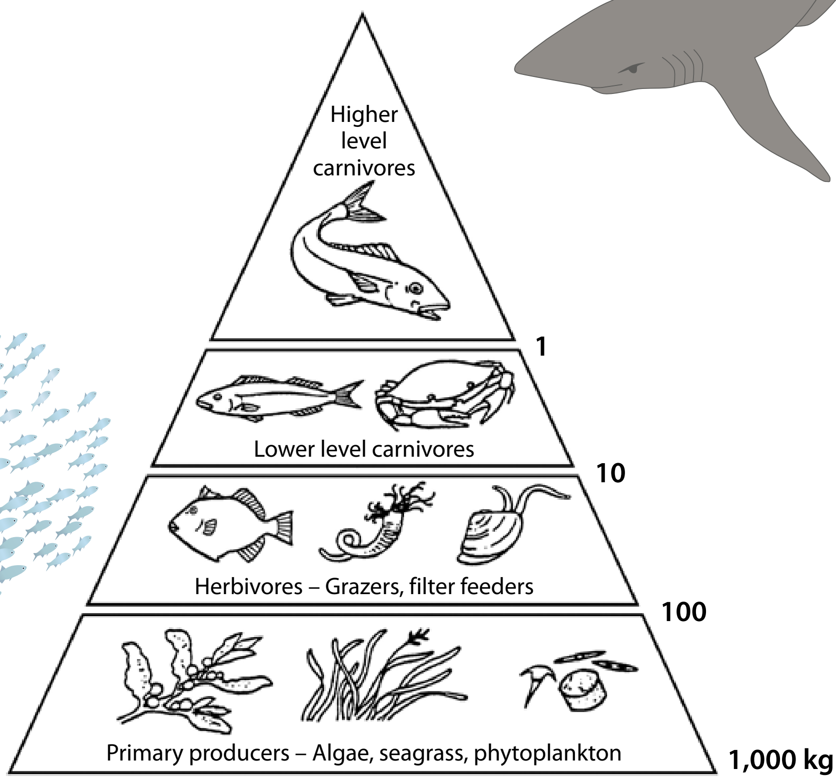
Because of this loss at each succeeding trophic level, animals at high trophic levels are unable to maintain very large populations. A top carnivore such as a large tiger shark is, perhaps thankfully, not common at all and most sharks need to swim over a huge territory to find all the food that they require.

Why we have to look after the sea and its tiny plants?

Life on earth could not exist without plants. Photosynthesis is the process by which green plants use sunlight, carbon dioxide and nutrients* (including nitrates and phosphates) to synthesise proteins,* fats and carbohydrates. Through photosynthesis, plants produce oxygen and food to support all life. Phytoplankton are responsible for half of all photosynthetic activity and produce much of the oxygen present in the Earth's atmosphere – half of the total amount of oxygen is produced by phytoplankton in the sea.*







An energy pyramid. Numbers at the right of the pyramid represent the relative biomass at each trophic level assuming an ecological efficiency of 10 per cent.
From: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

8 Oceanic species

Imagine living out on the surface of the open sea – being hunted by birds from above and by larger fish from below – and with no place to hide!

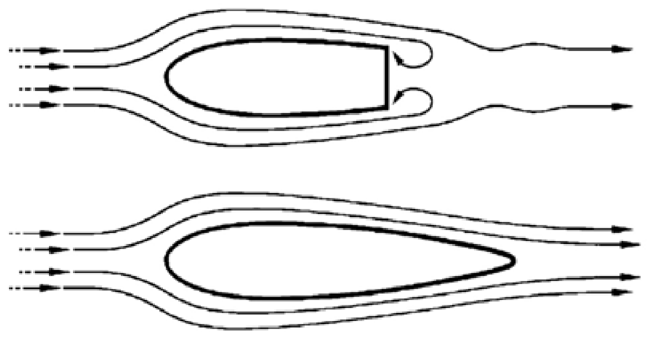
But a few species* have managed to adapt to this difficult pelagic* environment.* The best known of these are the species of tuna, which are distributed over large areas of the Pacific Ocean where they hunt smaller fish. Other oceanic species include billfish*, mahi mahi and wahoo.

Tuna are caught by local fishers often by towing (or trolling) lures behind small boats. Commercial fishing* vessels use longlines and purse seines – these fishing methods are described in Teachers' Resource Sheet 15: Modern large-scale fishing techniques. Here, we are more concerned with the amazing adaptations of fish that live in the open sea.

Pelagic fish rely on speed to catch their prey and to avoid predators*. And, as water is 'thicker' than air (in fact, 800 times more dense* than air), any part of the body that creates friction or turbulence causes a large amount of drag. Compared with travelling through the air, travelling through water is like moving through honey!

In many fast fish, the pectoral or side fins are used as brakes and rudders and fit into depressions in the body when the fish is swimming at speed. The caudal or tail fin, which provides the propulsion, may be shaped like a scythe, with both a long leading edge and a small surface area (a high aspect ratio).

But the shape of the body is most important. The best shape is one of a spindle or tear-drop, called a fusiform shape, as this offers the least resistance or drag when moving through the water. Independently, this fusiform shape has evolved in aquatic mammals such as dolphins and whales. Not so independently perhaps, marine architects have used the shape in designing boats.



Laminar flow* of water past a blunt-ended shape (top), which creates turbulence and drag and flow past a fusiform shape (bottom) which minimises drag.
From: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

Life in the fast lane

In addition to their shape, tunas have other adaptations that assist with their fast life. Unlike most other fish, tunas are warm-blooded and keep their bodies at higher temperatures than the surrounding water. A higher body temperature allows increases in muscle power and may account for a tuna's ability to swim at speeds of over 50 kilometres per hour to catch smaller fish. But another oceanic species is much faster.

Which is the fastest animal on the planet?

This is undoubtedly the peregrine falcon, a bird of prey, which can dive at over 300 kilometres per hour. The fastest land animal is the cheetah which can run to catch its prey at over 100 kilometres per hour. But in the sea, the fastest fish is the sailfish.

Bulbous bows?

Have you seen pictures of ocean-going ships below the waterline?

They often have a rounded bulb or bulge sticking out at the bow (or front) just below the waterline. The bulbous bow makes the ship's underwater profile more fusiform and allows water to flow around the hull more easily. Large ships with bulbous bows generally have a 12% to 15% better fuel efficiency than similar vessels without them.

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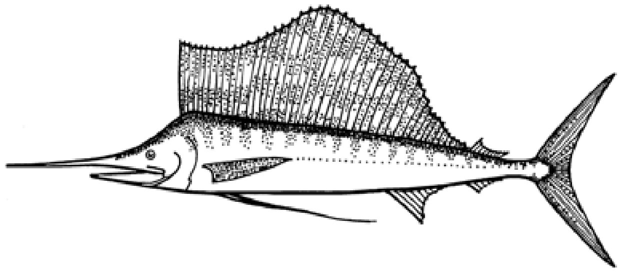
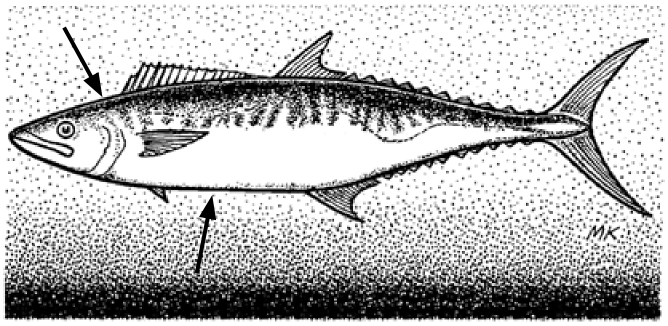




Counter-shading in a pelagic fish.
From: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

Sailfish, which can grow to reach 100 kilograms, have large, sail-like dorsal fins more than twice as high as the body is deep. They appear to hunt in groups and their tall blue dorsal fins, cutting through the surface of the sea, are used to herd prey species into a tight ball. The sailfish then move through the ball, slashing from side to side with their long bills to kill or maim the smaller fish. With a timed short-burst swimming speed of 110 kilometres per hour, the sailfish may be the fastest non-flying animal on the planet.

In the open sea, you can swim but cannot hide – or can you?

Most pelagic fish have a very subtle form of camouflage* called counter-shading to avoid predators. Fish that habitually swim near the surface often have dark backs that shade to lighter underparts. To a predator swimming below such a fish, the lighter underparts appear the same shade as the sky and the bright surface of the sea. But to a predator such as a sea bird flying above, the dark back of the fish merges in with the deep blue shades of the sea.

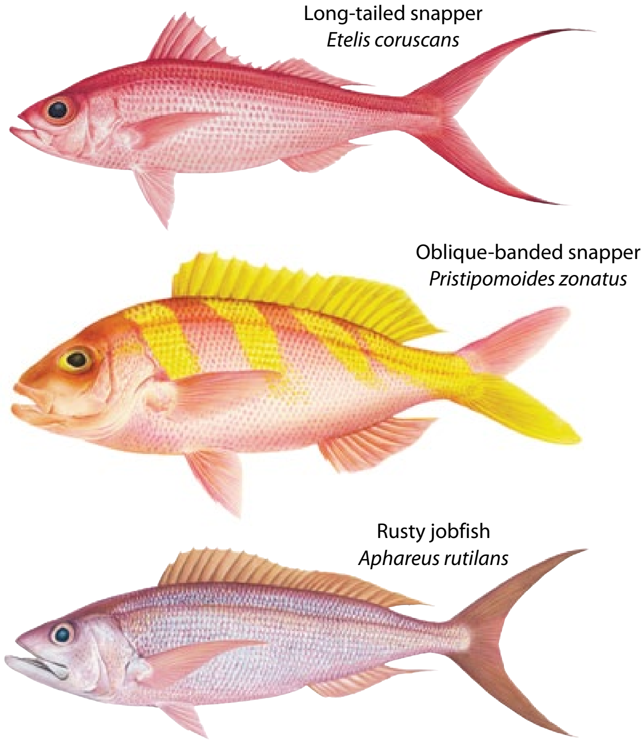
Marc Taquet © FADIO/IRD-Ifremer

Deepwater snappers

Tuna are the best known fish in surface waters beyond the coral reefs of most Pacific Island countries. But, living at the bottom of the sea in deeper water, there is another valuable group of fish. This group includes the snappers and other species that are referred to as demersal or bottom-fish – that is, they live close to the sea floor.

What are deepwater snappers?

Snappers caught in deep water are related to, but different from, snappers caught on shallow-water reefs. But all belong to the snapper (or Lutjanid) family and most have common names that include 'snapper' or 'jobfish'. Some groupers (Serranid family) and emperors (Lethrinid family) are also caught in deep water.



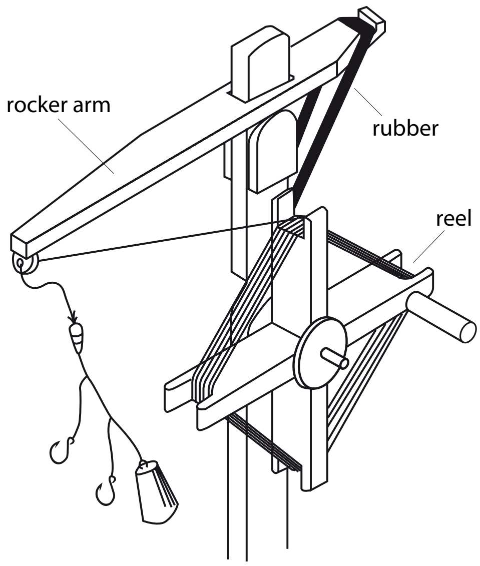
Deepwater snappers (Illustrations by Les Hata).

Where are deepwater snappers found?

Deepwater snappers are found in a depths between 100 m and 400 m around the outer reef slope of islands and seamounts.

How are deepwater snappers caught?

Fishing for deepwater snappers has been carried out commercially in the Pacific Island region for many years. In the 1970s and 1980s, the Pacific Community (SPC) assisted in developing these fisheries in many countries by training fishers to use simple, low-cost, hand-reels such as the one shown in the accompanying illustration.



A wooden hand-reel used to catch deepwater snappers.
From: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

The wooden reels used to catch deepwater fish are often made locally. Each reel consists of i) wooden bars set at right angles with notched ends to hold the fishing line, ii) a rocker arm with ends that are allowed to move up and down, and iii) a strong rubber band attached to one end of the rocker arm. Several baited hooks and a heavy lead weight are attached to the end of the line. When a snapper takes the bait and fights to free itself, the rubber allows the rocker arm to flex and move – a rigidly fixed rocker arm could allow a large, strong fish to break the line.

Fisheries for deepwater species are based in many islands including (in alphabetical order) American Samoa, Cook Islands, Federated States of Micronesia, Fiji, French Polynesia, Guam, Kiribati, Marshall Islands, Nauru, New Caledonia, Niue, Northern Marianas, Palau, Papua New Guinea, Pitcairn Islands, Samoa, Solomon Islands, Tokelau, Tonga, Tuvalu, Vanuatu and Wallis and Futuna.

Benefits of deepwater snapper fisheries

- Deepwater snappers have firm white flesh and can attract a much higher price per kilogram than most other reef fish.
- Unlike many shallow-water reef fish, deepwater snappers are free of ciguatera, a form of fish poisoning that can make people sick (see Teachers' Resource Sheet 20: Fish poisoning and ciguatera).
- Fishing beyond the reefs for deepwater species can result in a reduction in fishing pressure on inshore reefs and lagoons where catches may be decreasing due to overfishing.

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Problems with deepwater snapper fisheries

Deepwater snapper stocks are considered to be vulnerable to fishing pressure. This is because the fish live for a long time, grow slowly, and reproduce late in their lifespan. Therefore, fishing rapidly reduces the numbers of fish in the stock; this is particularly noticeable if fishing is concentrated in a small area such as around a small seamount.

Many deepwater snapper fisheries have started off with fishers making very large catches. But catch rates (say the weight of fish caught per hour fishing) declined quite quickly over time. One of the largest deepwater snapper fisheries is in Tonga, where catch rates were quite high in the 1980s with up to 40 vessels targeting deepwater snappers. But within 10 years catch rates had declined dramatically, and by the mid-1990s catches were too low to be profitable. The Tongan government moved to restrict the number of boats to allow the fish stocks to recover and, now, only 10–15 boats are licensed to fish.

Assessment of deepwater snapper fisheries

Local fisheries authorities have the task of assessing deepwater snapper fisheries in order to ensure their sustainability. But deepwater snapper fisheries are difficult to assess and SPC has been involved in assisting countries to assess the sustainability of deepwater snapper fisheries since the early 1990s.

One method has been to estimate the weight of the unfished stock (referred to by scientists as the virgin biomass) and suggest that fisheries managers restrict fishing to catch about one-third of the virgin biomass each year. This is done so that there are sufficient number of fish remaining to produce young fish and maintain the stock.

Accurate data on catch rates are needed by scientists but these are not available for most Pacific Island countries. SPC is advocating the use of measurements of the size or age of fish in the catch to suggest the level of fishing. If average fish sizes in catches are decreasing it may indicate that too many large adult fish are being taken from the stock (see Teachers' Resource Sheet 3: Fisheries assessment).

Management of deepwater snapper fisheries

Although many Pacific Island countries do not have a management plan for deepwater snappers, a plan and regulations are needed to restrict fishing to levels that are sustainable. In other words to ensure that a fish stock is not overexploited* and continues to provide benefits to people in the future (see Teachers' Resource Sheet 1: Fisheries management).

Some countries have regulations that include limiting the number and size of fishing boats, the number of hooks allowed on each fishing line, and the areas in which fishing is allowed.

i

Minimum size regulations for deepwater snappers?

A minimum size limit, in which small fish must be released back into the sea, is a common fisheries management regulation. But why would a minimum size limit be a useless conservation measure for fish caught in deep water?

Pressure on a fish at the surface of the sea is due to the weight of the column of air above it (one atmosphere of pressure). As water is about 800 times heavier than air, pressure increases rapidly with increasing depth – at about 10 m below the surface, the water exerts twice the pressure on the fish as air does at the surface. Some deepwater snapper are caught at 200 m where the pressure is 20 times that at the surface.

Consider what would happen to the swim bladder of a fish caught at 200 m as it is hauled to the surface (See Teachers' Resource Sheet 6: Fish anatomy). The swim bladder will expand rapidly as it is hauled in and burst or choke the fish.

Ashley Williams © SPC

10

Teachers' Resource Sheet on

Bonefish

What is the most valuable fish in Pacific Islands? Tuna, because of its export value? Or emperors – the most commonly caught reef fish? No, it's a fish that is full of bones and not often caught to eat.

Recreational fishers,* who regard bonefish as prized sportfish because of their fighting ability, are prepared to travel great distances to catch them. The fishers buy local food, stay in local accommodation and often pay for local guides.

And because most fishers release bonefish immediately after capture, one fish can be caught and released many times. One bonefish, therefore, has the potential to bring many thousands of dollars to a local community.

The fish

Are all bonefish the same? Evidently not – there are several different species* of bonefish but the one most commonly caught by fishers in the Pacific has the scientific name* of *Albula vulpes*. Bonefish are silver with darker fins and can reach a length of up to 90 cm. The world International Game Fish Association (IGFA)* record is 8.62 kg for a bonefish caught in South Africa in 1962; since then there have been unconfirmed reports of fish weighing more than 9 kg.

Bonefish are named for the many fine bones they contain or for their elusive habits, with names such as grey ghost. In French Polynesia they are called *o'io*, *albule* or 'sorte de mulet'.

Recreational fishers stalk bonefish as they move across shallow sandy areas hunting shrimps, small molluscs and crabs. Bonefish are caught by fly fishing* – a special method in which fishers use a rod and reel with a line and an almost weightless fly or 'lure' to encourage the fish to strike.

Although larger bonefish may swim either alone or in small groups, smaller fish often travel in large schools.* As medium-sized predators,* bonefish are an important link between invertebrates* and larger predators in marine food webs* (see Teachers' Resource Sheet 7: Marine food webs).

Bonefish are generally not preferred as food although they are eaten in some countries such as Hawaii, Kiribati, French Polynesia and the Cook Islands. However, they are highly valued by sports fishers and have the potential to be of great economic benefit to countries in which they are found.

Lifecycle

Bonefish reach sexual maturity between 3 and 4 years of age. In the Pacific, bonefish appear to spawn in deeper water over several months of the year around the time of the full moon.

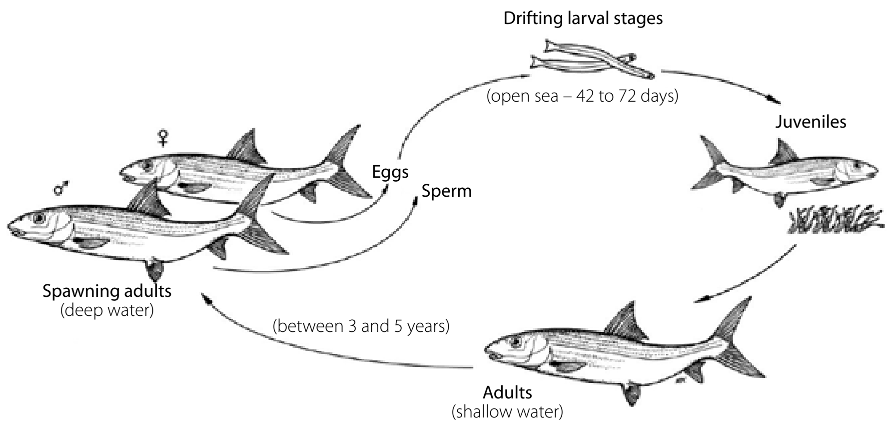
Fertilised eggs hatch into larvae* which drift in the ocean for long periods, perhaps for over two months. Many larvae do not reach areas in which to settle and many others become food for other fish. Only a small number of drifting larvae survive to settle in shallow sandy areas where they grow into juveniles that look like miniature versions of their parents.

Bonefish may live for more than 19 years but are taken by many predators including sharks and barracudas. Their main defences are their cautious behaviour and fast escape speed. For these reasons, fishers find that schools of bonefish are easily frightened or 'spooked' and the fish are difficult to catch.

Habitat

Adult bonefish are commonly found in intertidal flats, mangrove areas, river mouths and deeper adjacent waters.

A fish that breathes air? Bonefish can live in waters, such as in warm lagoons and creeks, that contain very little dissolved oxygen – they do this by swimming to the surface and gulping air into a lung-like swim bladder* (see Teachers' Resource Sheet 6: Fish anatomy).



The life-cycle of the bonefish.

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Distribution

Bonefish inhabit tropical and warm temperate waters around the world. They are fished on the east coast of North and South America and the Caribbean. They have been found in several Pacific Islands including New Caledonia, Fiji, Cook Islands, Kiribati and French Polynesia.

Management

All fisheries need to be managed to ensure that fish stocks are not overexploited* and continue to provide benefits to people in the future.

Some managers have imposed direct measures to protect bonefish stocks. In the Cook Islands fishery* in Aitutaki, for example, fishers are required to have a permit and to fish only in designated areas. Fishing in spawning* areas is prohibited from three days before until three days after the full moon.

Most sports fishers release their catch immediately after capture. This type of fishing, called 'catch and release', involves fishers returning caught fish to the water as quickly as possible. This practice is likely to protect bonefish from overexploitation.

However, management actions could include protecting important bonefish habitats* including seagrass beds in lagoons and limiting the number of local guides in a given area.

Michel Blanc © SPC

Pearl oysters

A pearl oyster is a bivalve (or two-shelled) mollusc* and is therefore related to mussels and clams. And a pearl is a pearl oyster's way of protecting itself from damage to its flesh.

If a parasite or a sharp grain of sand gets inside its shells, the oyster can cover it with layers of smooth pearl. These gleaming layers around the irritant become a blister attached to the inside of the shell or, much less commonly, a free spherical pearl that can be very valuable.

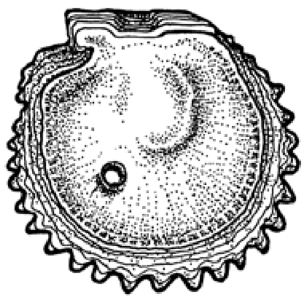
Anatomy

The pearl oyster relies on pumping seawater over its gills. The gills consist of four crescent-shaped flaps covered with fine hairs called cilia, which move water through the inside of the gaping shells. The oyster's gills, like those of a fish, are responsible for extracting oxygen that is dissolved in the water.

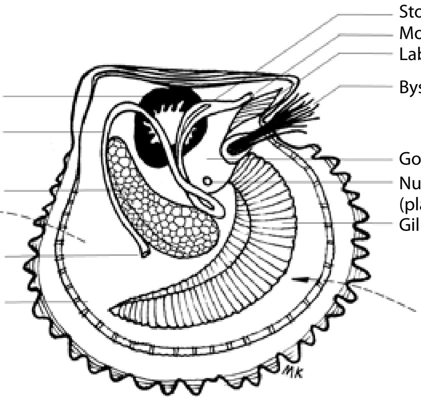
The gills also filter food – microscopic floating plants (phytoplankton)* from the water. The cilia pass the food particles to the mouth, which is hidden under two horizontal lips, the labial palps. The mouth leads into the stomach contained within a brown mass called the digestive gland. Used food passes along an intestine to pass out of an anus, conveniently placed where water currents leave the oyster.

Why is it so difficult to open the shells of a living oyster? The largest muscle in the oyster, the adductor, holds the two shells tightly shut if the oyster is exposed at low tide or threatened by a predator* – although many bivalve molluscs have two adductor muscles the pearl oyster has only one.

Oysters usually have separate sexes and the gonads* in both sexes are creamy yellow in colour. Sperm and ova develop in the gonads of males and females respectively.



The black-lipped pearl oyster, *Pinctada margaritifera*, with one of its shells removed. A pearl is lying on the oyster's mantle.



A pearl oyster with one shell, one mantle and gill lobes removed. The broken arrows show the flow of water through the shells.

An amazing living filter

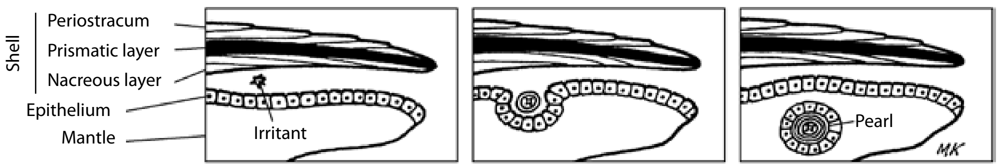
When the pearl oyster's two shells gape open it can pump up to 20 litres of water each hour removing food and gaining oxygen from the sea.

Shell and pearl formation

How does an oyster with two hard shells grow in size?

The oyster's body is covered by the mantle, a fold of tissue, edged with small tentacles. The mantle has specialised cells that produce additional shell material as the oyster grows and can encase irritants with concentric layers of mother-of-pearl or nacre.

A cross-section of a typical mollusc shell is shown in the figure at the back. The shell consists of three separate layers, an outer periostracum, a middle prismatic layer and an inner nacreous layer made up of thin layers of nacre. Iridescent colours are created by light waves reflected from the thin overlapping layers.



Pearl formation in pearl oysters. An irritant between the shell and the mantle is enveloped by the mantle which produces concentric layers around it. Very rarely, a pearl is formed around the object.
From: King M. 2007. Fisheries biology, assessment and management. UK, Oxford: Wiley-Blackwell. 400 p.

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Pearl farming

In the Pacific region, the black-lipped pearl oyster, *Pinctada margaritifera*, is grown, often on hanging ropes, to produces dark coloured pearls. After growing in the sea for about two years, each oyster has a small bead inserted in it by a skilled technician – a process called seeding.

It takes another two years for layers of nacre to be laid down around the bead and for the pearl to develop inside the oyster. Within a lifespan of 10 years, an oyster can be seeded and produce pearls several times. Many factors affect the success rate, but out of 100 oysters seeded, typically only five will produce a high quality, round pearl.

Management

Management is necessary to ensure that pearl farms continue to be productive and provide benefits to the farmers and the country.

The sites of pearl farms have to be carefully chosen to ensure that sea currents are sufficient to bring food and remove waste material from the oysters as they grow. Farms must be well spaced to avoid poor growth and the spread of oyster disease. As a healthy oyster is needed to produce a good pearl, it is in the interest of farmers as well as government authorities to maintain good environmental conditions.

Teachers' Resource Sheet on

Freshwater species

12

Although there are very few freshwater fish and invertebrates* in many Pacific Islands, several species* are important food items. Sometimes the production from freshwater fisheries is surprising – in Fiji, for example, the largest fishery* on a single species is based on the freshwater clam,* Batissa violacea *or* kai, *which women collect from rivers.

Where are freshwater species distributed?

The greatest number of freshwater fish are found in the west of the Pacific Ocean where the high islands of Melanesia, such as Papua New Guinea, Solomon Islands, Vanuatu, New Caledonia and Fiji, have many rivers and lakes suitable for freshwater species.

Where did freshwater species come from?

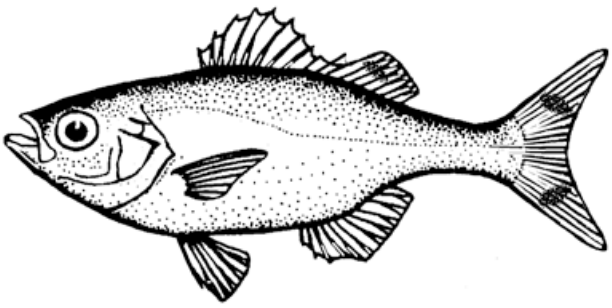
Many freshwater fish are believed to have originated from seawater species that have become adapted, perhaps over many thousands of years, for living in fresh water. A less likely possibility is that their ancestors managed to cross the sea from areas in the west. Perhaps larval stages crossed the sea in pockets of fresh water trapped in rafts of trees blown over during cyclones.

Here we discuss four widely distributed freshwater species – one fish, one prawn, an eel that spends part of its life in fresh water and one introduced species of fish.

Flagtails

Several species of fish called flagtails are found in fresh water across the Pacific. These silvery fish have dark stripes on their tails and belong to the family Kuhliidae. They are variously called *aholehole*, *sesele*, *sakelo*, *ika droka*, *mahore*, *umatari*, mountain trout and flagtail perch.

One particularly large species is the jungle perch, *Kuhlia rupestris*, which grows to 45 cm in total length and 3 kg in weight, and is an important subsistence food, particularly in the interior of the large islands.



A hotspot of biodiversity – the Coral Triangle*

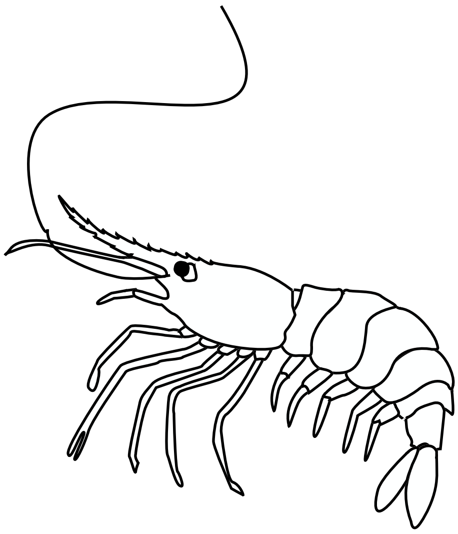
The Coral Triangle (a region comprised of the Philippines, Malaysia, Indonesia, East Timor, Papua New Guinea and Solomon Islands) contains a larger number of different species than most places in the world (it is said to have a large biodiversity).

Many species, including corals and mangroves, appear to have spread out from this area to Pacific Islands. And, because of the difficulty of larval stages reaching far away islands, the number of species decreases across the Pacific from west to east.

Freshwater prawns

Freshwater prawns (*Macrobrachium lar*) are distributed from Africa across the Pacific as far as the Marquesas. Their common names include Tahitian prawn, monkey river prawn, ghost shrimp and glass shrimp.

The prawns are collected as food and there has been some interest in farming them; however, there has been a preference for farming the giant freshwater prawn, *Macrobrachium rosenbergii*.



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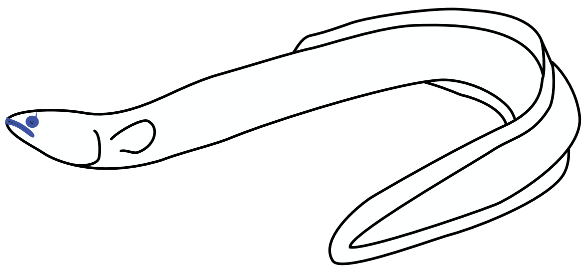
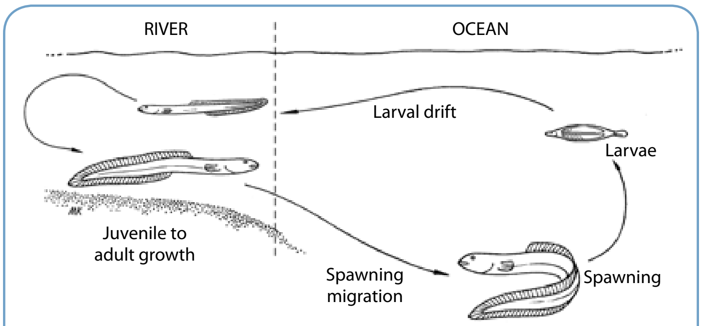
Eels

Eels belonging to the genus* *Anguilla* have a fascinating life-cycle.

The mature adults migrate from the relative safety of freshwater rivers over huge distances to breed in the deep dark sea. Here at the place where they were born, they breed and are then believed to die thousands of kilometres from the rivers where they lived for most of their lives.

The eel larvae* drift with sea currents and change into the colourless small eels known as glass eels as they reach land. After they adjust to fresh water, the eels migrate well into the upper reaches of river systems where they may gain weights of 20 kg.





Anguillid eel life cycle.
Adapted from: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

Eel confusion?

The eels described here should not be confused with moray eels of which there are many species living in sea water on coral reefs.

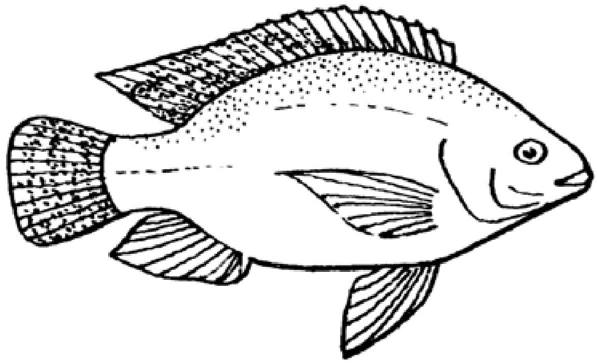
Snake-like eels?

In damp conditions, eels can move around dams and waterfalls by wriggling across land with a movement like snakes.

Tilapia

Tilapia were introduced into several Pacific Island countries from Africa beginning in the 1950s. As the species is easy to breed and eats low-cost foods, the fish was introduced for freshwater fish farming. Tilapia have been farmed in Fiji, Vanuatu, Papua New Guinea and the Cook Islands for many years.

However, the species of tilapia originally introduced to the Pacific was the slow-growing Mozambique tilapia (*Oreochromis mossambicus*) whereas 90% of the tilapia farmed globally today is Nile tilapia (*Oreochromis niloticus*).



Friend or foe?

The introduction of exotic species is not without risk. On one hand, tilapia farming can provide food for local people. On the other hand, introduced tilapia may compete and displace indigenous* freshwater fish.*

Aquarium species

13

Many people around the world love to watch colourful fish swimming in a glass tank. And the most popular are those from tropical coral reefs. Many of these fish come from the Pacific Islands.

© Haplochromis

An aquarium is a tank, usually made of glass, in which people keep aquatic species.* A freshwater aquarium is easier to stock and maintain but a marine aquarium is usually much more spectacular, particularly if it contains colourful tropical species.

Where and what species?

The export of coral reef fish, hard and soft corals, giant clams, live rock and a number of reef invertebrates* (such as sea stars, crabs and shrimps) from Pacific Island countries and territories started in the 1970s. It has since expanded to become an important source of income and employment for a number of communities in the region.

> *Live rocks?*
>
> *The rock itself is not alive but made up of the calcium carbonate skeletons of long dead corals. However, over time, this rock has been bored into by worms, sponges and bacteria* and other marine species. It is considered useful in that it is porous and has a large surface area for bacteria to colonise. The bacteria improve water quality by using nitrogen waste.*

The trade currently operates from many countries including Fiji, Papua New Guinea, Solomon Islands, Vanuatu, New Caledonia, French Polynesia, Marshall Islands, Tonga, Cook Islands, Federated States of Micronesia, Kiribati and Palau.

According to data collected by SPC, the six most commonly exported species include the following in order of decreasing importance:

- southseas devil (*Chrysiptera taupou*) from Fiji;
- whitetail *Dascyllus* (*Dascyllus aruanus*) from Fiji;
- anemone clownfish (*Amphiprion percula*) from Solomon Islands;
- bicolour angelfish (*Centropyge bicolor*) from Fiji;
- twospined angelfish (*Centropyge bispinosus*) from Fiji;
- sapphire devil (*Chrysiptera cyanea*) from Solomon Islands.

In most countries the collection of marine species for export is a relatively small operation. However, the trade provides employment, mostly in rural communities and contributes to the earning of foreign exchange.

Colette Wabnitz © SPC

The majority of aquarium fish are caught on the reef slope in depths of less than 35 metres, with occasional specimens taken at depths in excess of 50 metres. The fish are generally caught one at a time by experimented divers using scuba and either a small meshed surround net or a hand-held scoop net.

The standard method of packing live aquarium fish for air freight involves placing the fish in a plastic bag or container with clean sea water. The bag is then inflated with pure oxygen and packed in strong styrofoam containers for transport.

The use of damaging collection techniques such as those based on the use of sodium cyanide, quinaldine and rotenone (all of which are fish anaesthetics) is generally banned both by the aquarium fish collectors and governments. The capture of some fish may involve the removal of selected branches of coral. But this damage is minimal and the branches can be re-planted to grow into another colony.

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Management

Many Pacific Island countries have or are in the process of developing management plans to effectively develop, monitor and regulate the aquarium fish trade.

The industry is a non-damaging one as only a few selected species are harvested for export. And the most desirable species are small, brightly coloured fish that are generally not sought after for food by local fishers.

The aquarium keepers who buy the fish are often concerned about the possible impacts of taking large number of fish from coral reefs and may selectively source aquarium fish from well-managed operations and from countries with management plans. Some buyers are looking to stock their aquarium with fish that have been grown in aquaculture facilities.

At the moment SPC is working with industry to develop standard best practices that can be effectively and efficiently applied at the local scale by all. The standards are to achieve the following goals:

- the promotion of sustainable fishery* practices;
- the fostering of good fishing and handling practices prior to export; and
- the promotion of good packing practices at export.

Antoine Teitelbaum © SPC

Teachers' Resource Sheet on

Vanuatu traditional fishing methods

'If everyone used traditional fishing methods today, we would still have plenty of seafood' is a statement that is often made by older people. So, is this true? Like many general statements it is partly true, or perhaps even mostly true. But in the old days there were fewer people fishing. And, contrary to popular belief, some of the fishing methods used were damaging to marine species and their environment.

Traditional fishing methods used by our ancestors ranged from gleaning (or collecting by hand) on reefs for seafood to fishing offshore using sailing canoes to catch tuna and deeper water fish.

1. Gleaning

Sea snails, octopuses, crabs and other invertebrates are collected or 'gleaned', often by women, from mudflats and intertidal reefs. Sometimes sharpened sticks are used to dig these organisms out from holes and crevices on reefs. Fishers use a Y-shaped stick and light from burning coconut leaves to catch lobsters on the reef at night.

Gleaning may involve damage to corals, either directly when coral is deliberately broken to catch sheltering fish, or indirectly through the effects of people moving over the reef.

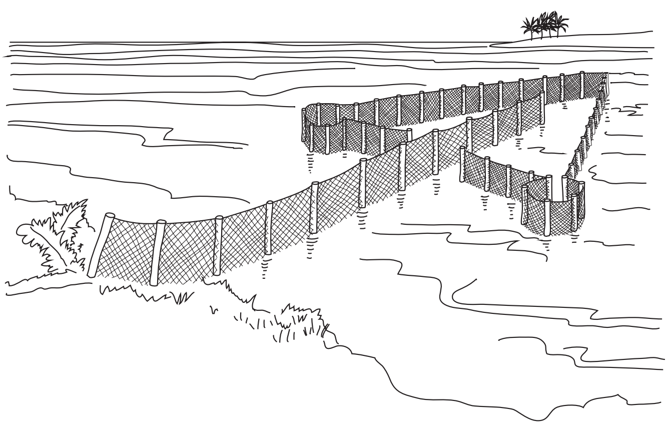
Target: Sea snails, octopuses, crabs and other invertebrates

2. Spears, bows and arrows

Men use bows and arrows or spears to catch fish from canoes or the reef edge. Sometimes coconut fronds were used to drive fish into the shallower water of a lagoon where they could be more easily speared.

Target: Various types of fish

3. Weirs, fish fences and traps



A fish fence trap built from modern steel mesh used to catch migrating coastal fish.
From: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

The simplest traditional traps are based on v-shaped or semi-circular walls of stone or coral inside which fish are stranded by the falling tide.

Fence traps are built at right-angles from shore-lines and reefs to guide migrating coastal fish such as mullet into a large retaining area. Although originally built from stone or coral blocks over many months, such traps are now made from modern materials such as wire-mesh netting in just a few days.

Target: Migrating coastal fish such as mullet

4. Fish drives

Fish drives usually involve dragging a net to either surround fish or drive them into a small area. Traditionally, the dragnet is made from coconut fronds weaved on vines and may be over 100 m long. Many men, often over 30, are needed to drag the net either in a semi-circle facing the shoreline or a full circle about 20 m in diameter.

Fish that are trapped inside the coconut frond enclosure are removed by hand or speared. Occasionally, other marine animals are caught, including turtles and dugong.

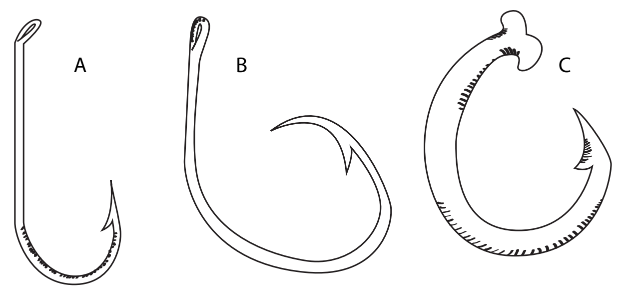
Fish drives usually involve many people moving across the reef, and this is likely to damage corals and the habitats of marine organisms.

Target: Various types of fish and occasionally other marine animals including turtles and dugong

5. Hooks and lines

Traditionally, hook-and-line gear consisted of bone or shell hooks attached to lines made of plant fibres. The line was cast into the water with either a baited hook or a lure made of shell or feathers that was pulled through the water.

Nowadays, manufactured steel J-shaped hooks are used. However, in many commercial fisheries, circular steel hooks are used and these are similar in design to the bone or shell hooks that have been used since prehistoric times. 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.



Fish hooks. A) a common J-shaped hook, B) a modern circle hook, and C) a traditional bone hook.
From: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

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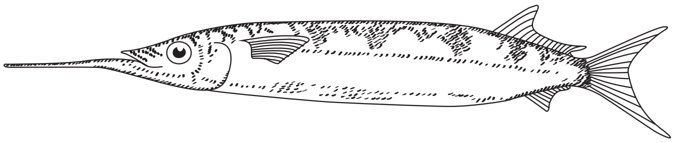
A clever way of fishing for needlefish or garfish (family Belonidae), which have mouths too small to take bone hooks, involves the use of spider webs. A rod is used to flick a lure of balled-up spider webs across the sea's surface. When a fish attacks the lure, its teeth become tangled in the spider web.

Target: Various types of fish

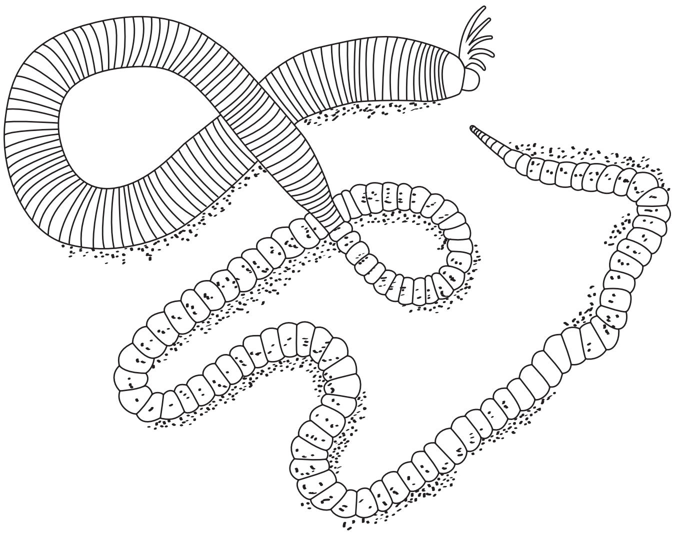


The needlefish or garfish.

5. *Palolo* fishing

The *palolo* worm, *Eunice viridis*, lives burrowed in coral, and during a short period each year, releases its reproductive tail segments, often in writhing masses that cover the sea surface. In Vanuatu, *palolo* worms are traditionally gathered from October to December by people using burning coconut torches. Some people believe that a pregnant woman holding the torch will attract more *palolo* worms. The worms are often cooked inside a length of bamboo with vegetable leaves and coconut milk.

Target: *Palolo* worms



The *palolo* worm (*Eunice viridis*).

6. Poisons

The fruit of the poison fish tree or *futu* (*Barringtonia asiatica*) and the roots of a certain vine (*Derris* sp.) are traditionally used to poison and stun fish, which then float to the surface where they can be easily collected. The use of poisons has been banned because they not only kill the target fish, but also other creatures, including corals in the area.

The plant material is pounded before being wrapped in a cloth and squeezed into rivers or tidal pools. The freshwater eel (*Anguilla*), which grows to 3 m in length, is often caught for village feasts using this method.

It has been claimed that fish could also be stunned by scraping the skin of the sea cucumber, lollyfish or *lolifis* (*Holothuria atra*), into water.

Target: Various types of fish

i *The fact that Futuna, the easternmost island of Vanuatu, takes its name from* futu, *the local name for the fish poison tree, suggests that the use of this plant poison has a long history.*

6. *Tabus*

In Vanuatu, *tabu* areas, in which the harvesting of fish and shellfish from the reef is banned or restricted, have long been part of traditional fisheries management. A *tabu* area is declared when a traditional leader places a *namele* leaf on a stick that is placed vertically into the sand.

Tabu areas may provide places where fish and other species can breed and produce young that move to nearby areas (see Teachers' Resource Sheet 2: No-take areas).

Tabus have also been imposed to protect individual species, including bans on taking trochus and turtles as well as on night spearfishing, to protect vulnerable fish such as parrotfish (see Community Information Sheet 4: Parrotfish).

i *A well-known travelling theatre group in Vanuatu, Wan Smolbag, has convinced many communities to ban or restrict the harvesting of turtles and to use other conservation measures, including* tabus.

Over time, traditional fishing methods have mostly given way to more modern ones in order to make fishing more effective and increase fish catches.

- The Hawaiian hand sling (a sharpened steel rod propelled by a rubber band) has replaced the traditional bow and arrow.
- Monofilament fishing line – with plastic lures or steel hooks – has replaced fibre lines with bone hooks.
- Monofilament gill nets have replaced traditional ones made from coconut leaves and vines, and are used for fish drives.
- Modern vessels with outboard engines have replaced sailing canoes and decreased the time and effort required for fishing.

But many modern methods and gear are too efficient, and many stocks of fish have been reduced to low levels. This makes some traditional conservation methods, such as the declaration of *tabus*, even more important to maintain stocks of seafood species.

Some traditional fishing practices have only become overly destructive as a result of increasing population sizes; in the past, the marine environment was able to sustain occasional, localised damage because the frequency of the activity was low and fewer people were involved.

Teachers' Resource Sheet on

Modern large-scale fishing techniques

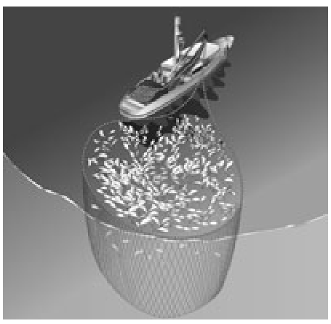
In the Pacific Islands region, large-scale, or industrial, fishing techniques are almost exclusively used to catch tuna and associated species.* The only exception is the shrimp trawl net fishery* of Papua New Guinea. The main techniques used to catch tuna are: purse seine, longline, pole-and-line and troll.

Purse seine

A school* of tuna is spotted while it feeds on schools of baitfish close to the surface. Most of the time, seabirds have also been attracted and dive to feed on the baitfish, making the spotting easier. A huge vertical net (seine) – which can measure up to 1,500–2,000 m long by 120–250 m deep – is quickly set around the school of tuna, and then closed at the bottom to form a purse in which up to 150 tonnes of tuna can be caught at one time.

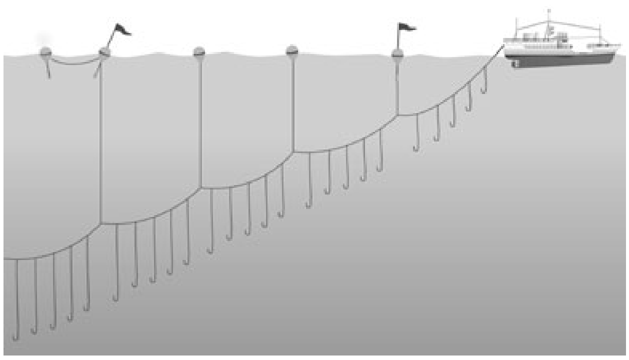
Target: Mainly skipjack and small yellowfin tuna. Most of the catch is for canning and thus ends up in tuna cans one can find in stores all over the world.

About 65% of the tuna catch in the western and central Pacific Ocean (WCPO) region is caught with purse-seine gear – about 1.5 million tonnes in 2011. Most of the purse-seine catch is taken within 5 degrees of the equator.



Longline

A long line, called the mainline, with baited hooks attached at intervals by means of branchlines, is set and allowed to drift for several hours. Large tuna longliners can set up to 3,000 hooks on one line that can measure more than 100 nautical miles. The hooks of a longline are set deep (between 80 and 400+ m), so the fishers cannot see the targeted fish. The choice of the location for a set is therefore made by experience, according to sea surface currents and temperature, season, weather, etc.



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There are two major types of longliners: (1) relatively large (>30 m) vessels that use sophisticated freezing equipment and are often based outside the Pacific Islands, and (2) smaller vessels that use ice or refrigerated sea water to preserve fish and are typically based at a port in the Pacific Islands.

Target: Large yellowfin, bigeye and albacore tunas. The prime-quality yellowfin and bigeyes are often exported chilled to overseas markets for sashimi. Most of the albacore caught by longliners end up in cans.

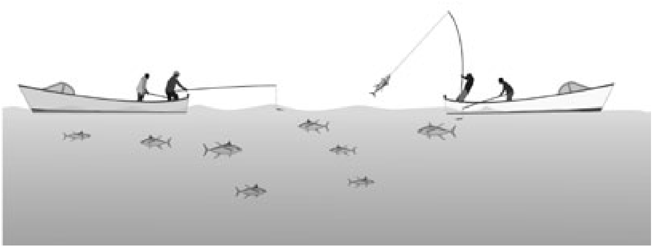
About 11% of the tuna catch in the WCPO region caught with longline gear – about 265,000 tonnes in 2011. Most of the longline catch is taken within 20 degrees of the equator.

Pole-and-line

As with purse seining, a school of tuna is spotted while it feeds on baitfish close to the surface. The pole-and-line boat is brought close to the school of tuna and left drifting while fishers throw small live bait and spray water to mimic the splashing of the school of bait. The idea is to trigger a feeding frenzy in the school of tuna. Fishers stand on the front deck and haul fish with a pole attached to a line ending with a lure and a barbless hook*.

Target: Mainly skipjack and small yellowfin tunas. Most of the catch is for canning or to make a dried product (called *katsuobushi* in Japan) sold to Asian markets.

About 12% of the tuna catch in the WCPO region is by pole-and-line gear – about 275,000 tonnes in 2011. In the 1980s, several Pacific Island countries had pole-and-line fleets, but most have stopped operating due to competition with the more productive purse-seine gear. In the Pacific now, most of the pole-and-line fishing takes place around Japan, and a few boats are still operating in Solomon Islands.



Note:

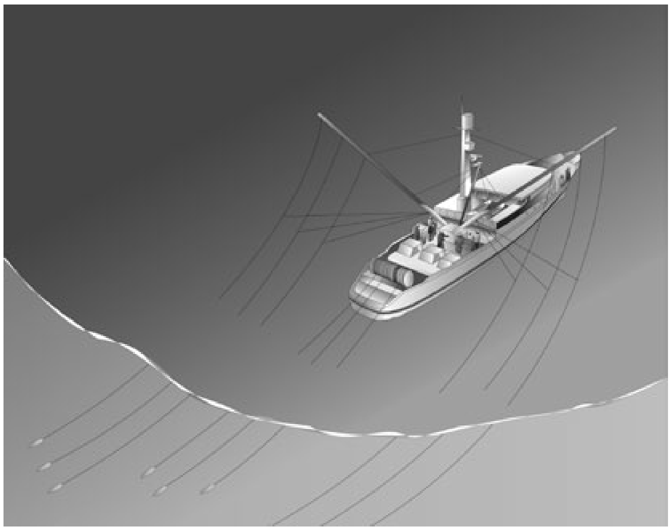
Several small-scale fishing methods and gear types are described in the 'Guide to information sheets on fisheries management for communities', including reef gleaning; spears; portable traps; barrier and fence traps; baited hooks and lines; lures for trolling; as well as cast nets, scoop nets, gill nets, seine nets and ring nets.

Troll

Several lines are trolled behind the boat with lures at the end.

Target: Large-scale tuna trolling boats target albacore for canning.

Gear types other than the three listed above are responsible for about 13% of tuna catch in the WCPO. Large-scale trolling is one of these. It is carried out in temperate waters to the south and north of the tropical Pacific Ocean (mostly south of 25°S and north of 25°N). Trolling in the south results in a catch of about 3,200 tonnes of albacore annually, which is almost exclusively sent to canneries.

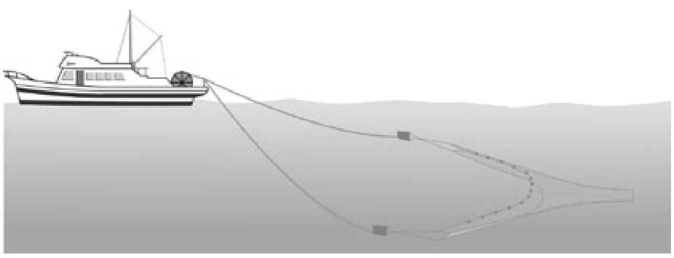


Bottom trawl

A very powerful boat drags a trawl net along the bottom of the sea. The trawling can last from a few minutes to a few hours before the trawl net is hauled and emptied on the deck of the boat where the catch is sorted. Because of its lack of selectivity*, this technique harvests a large proportion of bycatch (unwanted species which are caught and thrown back dead into the sea – for example, up to 90% of catch in the shrimp fishery can be bycatch). It is mostly used in places where the seafloor is all sand or mud. It must not be used in coral reef areas as 1) it would destroy the corals and 2) the trawl net would be damaged by the coral heads.

Target: All type of species that live close to the seafloor, such as shrimps and flatfish.

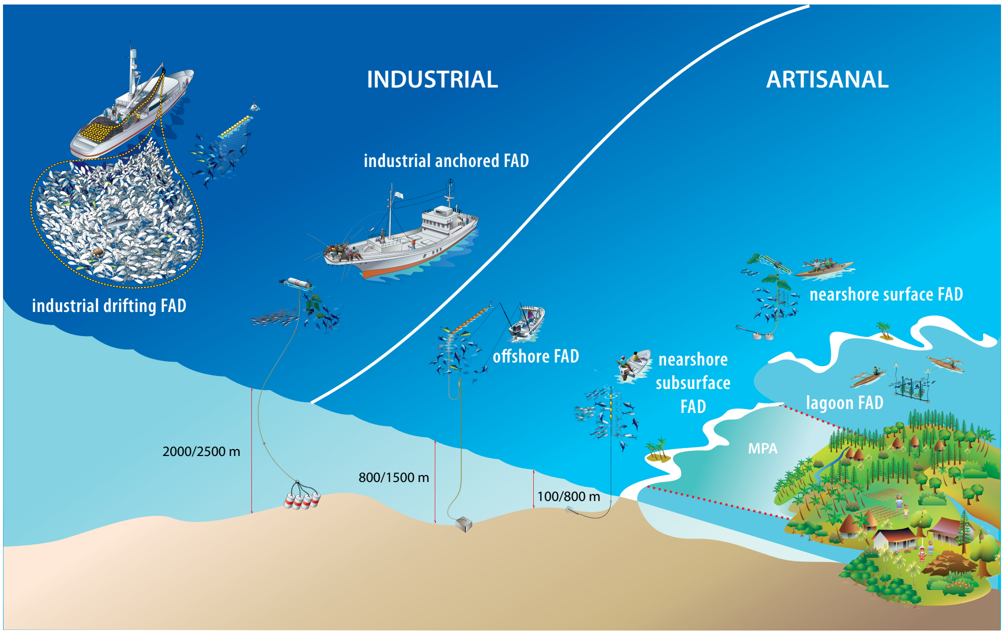
In the Pacific Islands, this technique is only used in the south of Papua New Guinea to catch shrimps.



Teachers' Resource Sheet on

Fish aggregating devices (FADs)

What are FADs? *Fish aggregating devices (FADs) are drifting or anchored buoys or rafts that attract and aggregate pelagic* fish, making them easier to find and catch. Fishers have long known that fish congregate around naturally occurring floating logs or other debris including dead whales. This aggregating phenomenon is not completely understood and there are several theories to explain it. It is believed that floating objects offer a refuge from predators* and a meeting place for schooling companions (like THE tree in the Ténéré desert, in Africa, where every caravan stops even if there is nothing other than a tree – no water, no food and not even enough shade for all members of the caravan). Another theory posits that because floating objects host a variety of small marine animals, a food chain is established around it and it becomes a feeding place for large pelagic fish. Whatever the cause, knowledge about such aggregating behaviour led to the innovative idea of anchoring something similar to a floating log to attract the fish to a place that can be easily found by fishers.*



FAD types in relation to their use and distance from shore.

Types of FADs and their use

In coastal areas, local fishers or fisheries departments moor FADs on the sea bottom in depths of 50–2,500 metres in order to encourage tunas to gather not too far offshore, where small artisanal fishing vessels can catch them. Anchored FADs improve the catch rate of people who catch fish to feed their families or sell in small amounts at local markets, as well as people who fish as a hobby. They also allow fishing effort* to be moved away from lagoons and reef areas, where resources are both limited and fragile, towards the open ocean where tuna resources are not as sensitive at such scales. The upper part of these anchored FADs can be set under the sea surface (subsurface FADs) or it can float on the surface (surface FADs). When deployed within the reach of paddled canoes, the device is called a nearshore FAD and when moored further offshore, it is called an offshore FAD and its use is limited to motorised fishing boats. Low-cost FADs can also be moored inside lagoons (lagoon FADs) where they attract small pelagic and bottom fish species.*

In the open ocean, operators of tuna purse-seiners also exploit the tendency of large pelagic fish to aggregate around floating objects. They set their large nets around FADs that have been purposely set adrift and are monitored throughout the ocean by electronic tracking beacons. One purse-seine vessel can have up to 100 drifting FADs (d-FADs) equipped in this way. These d-FADs are tools that may be considered to be 'too efficient' but getting rid of them would strike a heavy blow to the world's tuna canning industry. In fact, the volume of catches around these d-FADs (by all types of fishing combined) accounts for about 1.8 million tonnes, or 43%, of the 4.2 million tonnes for the three main tuna species worldwide. It has been suggested that purse-seine fishing around d-FADs is leading to catches of small, undersized (juvenile) tunas, unwanted bycatch such as mahi mahi and wahoo and endangered species such as sharks and sea turtles. The use of d-FADs in the Pacific needs to be regulated and monitored to avoid the overfishing of those species.

In 180 AD, the Greek poet Oppian of Corycus included, in his treatise on sea fishing 'Halieutika', a description of mahi-mahi fishing under the first recorded man-made fish aggregating devices. Those FADs were drifting devices made of bundled reeds and set adrift. Much later on, Southeast Asian countries constructed anchored FADs made of bamboo (called 'payaos'), and these are still used today in support of industrial fisheries. With assistance from SPC, Pacific Island countries and territories started to use anchored FADs in the early 1980s.

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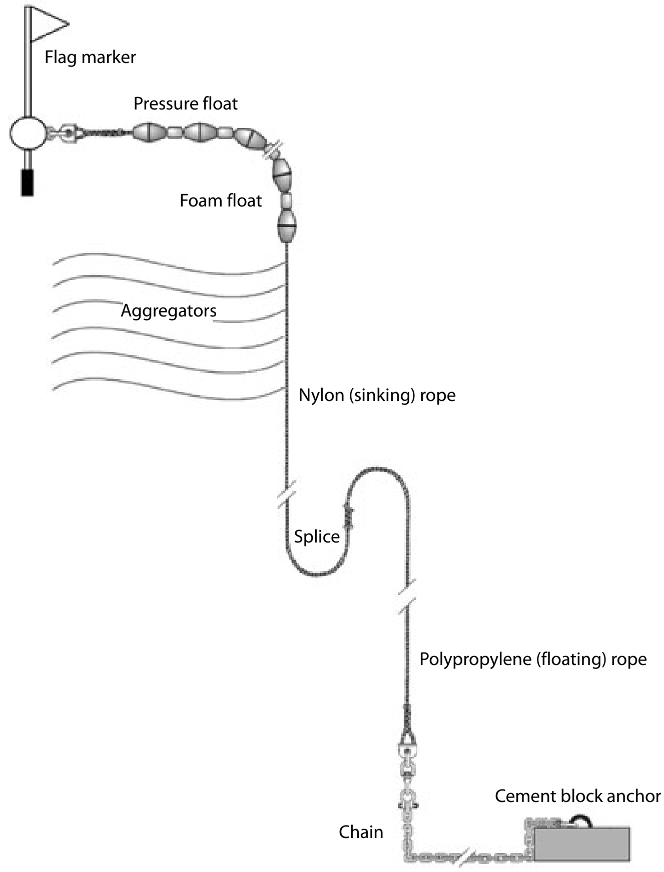
Artisanal fishers in the Pacific currently catch less than 5% of the tuna caught in the western and central Pacific Ocean and will need to harvest more in future for food security. Anchored FADs are important tools for domestic fisheries development as they can contribute to increasing the share of the tuna catch going to Pacific communities.

A FAD commonly used in the Pacific: the Indian Ocean FAD design

The FAD design illustrated here was first used at Reunion Island, in the Indian Ocean, in the early 1990s. SPC successfully introduced the design in the Pacific during the mid-1990s, with some refinements to the gear configuration. It is still widely used in the region as it is easy to deploy from relatively small boats and is cost-effective (USD 1,500 to 2,500 depending on the anchoring depth, for an average life-span of two years).

Purse-seine catch.



The Indian Ocean FAD design (main components).

Artisanal fisherman displaying a yellowfin tuna caught at a nearshore FAD off Yaren, Nauru.

A cause for concern: sabotage

One of the biggest constraints to successful FAD programmes in artisanal fisheries is vandalism, in which the upper section of a surface FAD is intentionally cut loose by fishers or other boat operators. Jealousy and ignorance are the main causes. To address this problem SPC is promoting the use of subsurface FADs.

Teachers' Resource Sheet on

Marine aquaculture in Pacific islands

What is mariculture?* *Marine aquaculture, or mariculture, is the farming of marine animals and plants in salty or brackish water.

Fresh fish, shellfish and sea cucumbers are becoming scarce on many Pacific Island reefs. These commodities are in high demand for their value as traditional foods. Many of them have commercial value, both locally and for export. Supplies from capture fisheries often cannot meet the demand for them. Mariculture can help increase the supply of these valuable commodities.

What kinds of organisms can be farmed by mariculture?

The organisms being farmed may include finfish, or invertebrates such as crustaceans, molluscs and sea cucumbers, or even sponges and seaweed.

In the Pacific islands, the main marine organisms being maricultured for commercial purposes are pearl oyster, marine shrimp and seaweed. Traditionally important food species bred by mariculture for placing in the sea and on reefs (called stocking) are giant clams, trochus, green snail and sea cucumber. Other types of organisms under development for mariculture in this region include mangrove crabs, marine finfish and bath sponges.

- Blacklip pearl oysters (*Pinctada margaritifera*) are the Pacific region's most valuable mariculture product. In French Polynesia, Cook Islands and Fiji, pearl oysters are suspended in the water on ropes and floats. The living oysters are implanted with a round pearl nucleus by a skilled technician. The nucleus sits in a pocket in the oyster's body tissue and becomes coated in the brilliant colours of mother-of-pearl (nacre) over the next two years. The harvested pearls are graded according to size and quality, and used to make valuable jewelery such as earings and necklaces.
- Marine shrimp (*Penaeus vannamei*) are farmed on land in ponds that are filled with salty water pumped from the sea, and sometimes mixed with river water. Juvenile prawns are bred and reared in special tanks in a hatchery, and grown through their planktonic (swimming) larval phases until ready to take up a benthic (crawling) existence. As adults, marine shrimp do not mind being crowded closely together. They can be stocked into ponds at quite high densities (about 25 shrimp per square metre of pond bottom). The shrimp are fed on high-protein pellet feed imported from overseas and are ready to harvest in about four or five months. Marine shrimp fetch a good price and are in high demand by restaurants, hotels and supermarkets.
- Seaweed (*Kappaphycus alvarezii*) is farmed on ropes tied to posts on sandy areas of shallow sea bottom in Kiribati, Solomon Islands, Fiji and Papua New Guinea. It is dried in the sun and baled for export to factories in China where it is used to extract carrageenan jelly for use in foods, drinks, cosmetics, lotions, and for industrial uses.
- Giant clams (*Tridacna* spp.), trochus shell (*Tectus niloticus*) and green snail (*Turbo marmoratus*) can be spawned and reared to juvenile size in tanks at a marine hatchery. Giant clams do not like being crowded together and grow too large to be kept in tanks for more than a few months. To complete their growth until ready for harvest, they need to be planted on suitable areas of coral reef. They must then be managed and protected from poaching to give them a chance to grow to a good size. The best places for releasing hatchery-reared clam juveniles into the wild are among communities who have declared marine protected areas and are managing those reefs according to a fisheries management plan.

Colette Wabnitz © SPC

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There are many other marine organisms being farmed by mariculture techniques in other parts of the world. Some of these ideas are now being tried in the Pacific. Mangrove crabs (*Scylla serrata*), tropical groupers such as the humpback grouper (*Cromileptes altivelis*), and bath sponges (*Coscinoderma matthewsi*) are just some of the other marine species that now form the basis of mariculture businesses in the Pacific.

What is needed for mariculture?

1. **Marine space** is the biggest item needed for mariculture, as a place to locate the farm. Permission is needed to use sea space for mariculture. If using ponds on land, then a supply of salty water is needed to fill the ponds. Mariculture farmers need to carry out a feasibility assessment to be sure that the space they are choosing has the correct environmental conditions for the organism they will be farming.
2. **Juvenile fish, shellfish or prawns** will need to be supplied from a hatchery for stocking into the mariculture farm. For marine shrimp the farm owners can operate their own hatchery, or they may choose to import juvenile shrimp from a healthy and disease-free hatchery in another country.
3. **Feed** is needed for animals such as finfish, shrimp and crabs. Pearl oysters will feed themselves by filtering plankton out of the surrounding sea water. Seaweeds are plants, so only need sunlight and nutrients from the water. Giant clams do not need to be fed at all, but they do need sunlight because they have a symbiotic relationship with microscopic plants that live within their tissues.
4. **Skills** are needed by the farmer to keep marine organisms alive when they are in tanks or in ponds on land. A high level of scientific skills is needed to operate hatcheries. When marine organisms are released onto reefs, a management plan must be put in place. The plan must be enforced and respected to protect these organisms until they reach a harvestable size.

Colette Wabnitz © SPC

Freshwater Aquaculture in Pacific islands

18

What is freshwater aquaculture? ***Freshwater aquaculture is the farming of fish or prawns in ponds filled with rainwater, spring water or river water.***

Fresh fish can be scarce in certain places, particularly in inland areas of high island countries such as Papua New Guinea, Solomon Islands, Vanuatu and Fiji. Fish can also be scarce at certain times of the year when the weather is too rough to go out fishing in the sea. Freshwater aquaculture is a new activity in the Pacific that is becoming a popular way to provide people with fresh fish or prawns for eating at home or for selling to earn money.

What kinds of fish or prawns can be farmed in ponds?

In the Pacific Islands region, the main freshwater fish that is being farmed is tilapia. This fish is fairly easy to breed and can eat many different kinds of food. It is mainly vegetarian, so can be given leaves of cassava or slippery cabbage to eat. Other suitable fish foods are grated coconut, copra meal, white ants, and left-over food from the kitchen. But tilapia grow fastest when fed on special fish-food pellets, which look like chicken pellets but with extra protein added. The scientific name for tilapia is *Oreochromis niloticus*. A new type of tilapia called GIFT (genetically improved farmed tilapia) has been produced by selectively breeding this fish to grow bigger and live longer.

Céline Barré © SPC

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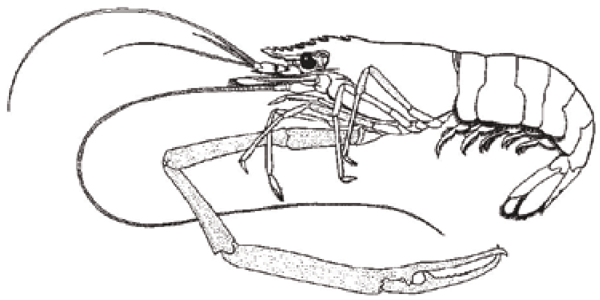
Two kinds of freshwater prawn can be farmed. The Monkey River prawn is indigenous to almost every Pacific Island with a freshwater stream and has the scientific name of *Macrobrachium lar*. The other freshwater prawn is called the Giant River prawn, which has been introduced from Southeast Asia; its scientific name is *Macrobrachium rosenbergii*.

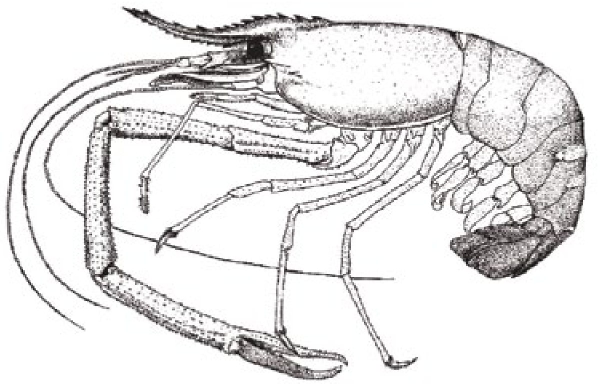
The Monkey River prawn is found in many rivers and streams of high islands with flowing water. It can be collected when it is small and fattened up in small hand-dug ponds of about 5 m x 10 m with fast running water. This type of prawn cannot be bred in a hatchery, so small prawns need to be collected from the wild. These prawns can eat plantation foods such as grated coconut, pawpaw, raw taro or cassava, but they grow fastest when fed with pellet feed made in a factory. This prawn likes to climb (like a monkey!) so a fence of black plastic must be built around the pond to stop them from escaping. This prawn is mainly being farmed in Santo where there are many small streams for catching small prawns.

The Giant River prawn looks similar to the indigenous prawn, but has blue claws. It has two advantages over the indigenous prawn: i) it can be bred in a hatchery, and ii) it does not climb out of ponds. The fisheries departments of Fiji and Vanuatu have built hatcheries to breed this prawn and supply it to small-scale farmers for selling to restaurants. The type of ponds and feeds used are similar to those used for commercial tilapia farming.

Macrobrachium lar



Macrobrachium rosenbergii



Freshwater prawns farmed in Pacific islands.
From: FAO. 1998. FAO species identification guide for fishery purposes. The living marine resources of the western central Pacific. Volume 2. Cephalopods, crustaceans, holothurians and sharks. p. 687–1396.

What is needed to farm freshwater fish or prawns?

1. **A pond** is the biggest item needed for freshwater fish or prawn farming. New farmers will need advice from local fisheries authorities who will check the site for suitability before the farmer starts to dig the pond. A water source must be available that can be piped to flow into the pond by gravity from a spring, stream or dam. The pond soil must be some sort of clay that does not leak water out underground. It takes a lot of work to dig the pond by hand with a spade. Digging with a machine digger is easier but will cost money. Once the digging of the pond is finished, fish or prawn farming only needs one or two hours of work each day. Tilapia can also be farmed in floating cages in lakes or big rivers, such as Lake Sirinumu or Lake Yonki in Papua New Guinea.
2. **Juvenile fish and prawns** need to be supplied from a hatchery for stocking into the farmer's pond. Some government fisheries authorities have hatcheries to breed both tilapia and prawns, and increasingly there will be private hatcheries producing juveniles to sell to freshwater fish or prawn farmers. Some advanced farmers can breed their own tilapia fish on their farm, after receiving extra training. But prawns need to be bred in a special hatchery.
3. **Feed** is needed if the fish or prawns are to grow well. Cheap plantation feeds can be given in the case of a small household fish pond. If the farmer wants to have several ponds and grow the fish quickly for selling, then the farmer should buy commercial fish or prawn pellet feed. The amount of feed given each day needs to be carefully managed so that the fish get enough, but not so much that feed is wasted.
4. **Skills** are needed by the farmer to keep the fish or prawns well-fed so that they grow and do not get sick or die in the pond. Fish farming is fairly simple, but it is a new activity in many Pacific Island countries so not many people know how to do it properly yet. Some training will be needed by new farmers on how to take care of their fish or prawns properly.

What happens to fish or prawns after they are harvested?

Fresh fish or prawns can be harvested gradually and eaten by the household that owns the pond and so contribute towards food security. Fresh fish is more nutritious and delicious than tinned fish.

Fish or prawns can also be sold to earn money, and contribute to livelihoods. Fish or prawns can be sold within the farmer's own community or sold to restaurants, hotels or supermarkets. Freshness is very important if prawns are being sold. Ideally, these fish and prawns should be packed in ice as soon as they are harvested, and delivered to buyers on the same day as they are harvested.

Teachers' Resource Sheet on

Fish spoilage

19

Spoilage refers to food becoming unfit to eat. Like almost any other food, seafood must be handled and stored correctly to maintain its quality and to ensure it is safe to eat.

Seafood not handled correctly goes through changes due to the action of bacteria* and enzymes* that make it taste bad and eventually become dangerous to eat. The food is then said to have 'gone off' or 'gone bad'.

Spoilage by bacteria

Bacteria are the usual cause of seafood spoiling. Surface slime, gills and the gut of a living fish contain millions of bacteria. After the fish is caught, the numbers of bacteria increase dramatically and can cause illness and food poisoning. Cooking will kill bacteria but may not degrade the toxins* that they have produced.

What is the only natural food that doesn't go bad?

Most food goes 'bad' because of the growth of bacteria and fungi, neither of which can survive in honey. Why? Honey is a very concentrated solution of sugars which draws water out of cells such as those of bacteria by osmosis* – the bacteria therefore shrivel up and die. The ancient Egyptians used honey for dressing wounds and some doctors have started using it again to kill bacteria.*

Spoilage by enzymes

Enzymes are present in all living things and are important in promoting the building of tissues as well as digesting food. After a seafood species* is caught, enzymes continue to work and start to breakdown and soften the flesh.

Histamine poisoning* is one of the common types of non-bacterial fish poisoning. Histadine occurs naturally in many fish including tuna, mahi mahi, marlin and sardines. If the fish is not chilled immediately after capture and not kept at temperatures less than 16°C, histadine is converted to histamine.

Because histamine is not destroyed by heat, even cooked fish will cause reactions that are often severe. Symptoms include allergic responses, a metallic taste, nausea, vomiting, abdominal cramps, diarrhoea, facial flushing and dizziness. Taking antihistamines (found in many hay-fever tablets) will usually give relief.

What does a properly handled fish look and smell like?

Properly handled fish have eyes that are clear and bright, scales or skin that are shiny and red gills that smell seaweed fresh. When raw, the flesh is firm and does not separate easily; when cooked, the flesh does not have a honeycombed appearance.

Stages of spoilage

After being caught, a fish quickly dies and goes through three stages, sometimes known as the three stages of *rigor*.*

Stage 1: (immediately after death) The fish feels soft to the touch. Fish just caught is very fresh and has a pleasant, seaweedy and delicate taste. The fish flesh begins to be affected by the action of its own enzymes immediately after the fish is caught.

Stage 2: (several hours after death, depending on temperature) The fish becomes stiff to the touch. The action of enzymes continues and histamines develop in some types of fish. There are no bad smells but there is some loss of flavour in the flesh.

Stage 3: (a day or more after death) The fish becomes soft to the touch again. Bacteria and enzymes are more active in this stage. The build up of bacteria causes unpleasant smells and the flesh becomes either watery or tough and dry.

The times taken for fish to go through the above stages are highly dependent on temperature. After these stages the fish becomes rapidly spoiled and is likely to cause food poisoning if eaten.

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Twice as nice on a bed of ice

After capture, a fish should be covered with a wet bag or palm leaf, or even better, kept on ice. Ideally, fish should be kept on ice from the moment they are caught. At low temperatures between -1°C and +4°C both the action of enzymes and bacteria are greatly reduced and the edible life of fish can be extended to more than a week.

Keep it clean

In addition to keeping fish on ice from the moment they are caught, cleanliness and hygiene are essential to ensure there is little build-up of harmful bacteria and other micro-organisms.

- Wash all fish baskets or containers.
- Wash hands frequently while gutting, gilling and preparing seafood.
- Wash all work surfaces and utensils used.
- Wash fish fillets in clean drinkable water before putting back on ice.

Fabrice Bouyé © SPC

Teachers' Resource Sheet on

Fish poisoning and ciguatera

Eating fish that hasn't been kept on ice can make you very sick! This is because of the build-up of enzymes* and bacteria* – see Teachers' Resource Sheet 19: Fish spoilage.

But there are other forms of fish poisoning that are not caused by poor handling and are not caused by bacteria. These include ciguatera* fish poisoning and what is broadly called shellfish* poisoning. These forms of poisoning are caused by harmful algal blooms – a dramatic increase in the numbers of very small plants (the phytoplankton)* that float in the sea.

Harmful Algal Blooms (HABs)

Populations of phytoplankton periodically go through massive increases in numbers. These increases are referred to as plankton* blooms and a few species* produce strong toxins.*

The main culprits are dinoflagellates,* small and very abundant members of the marine plankton; they consist of single cells with two whip-like threads or flagella, which they use to move through the water.

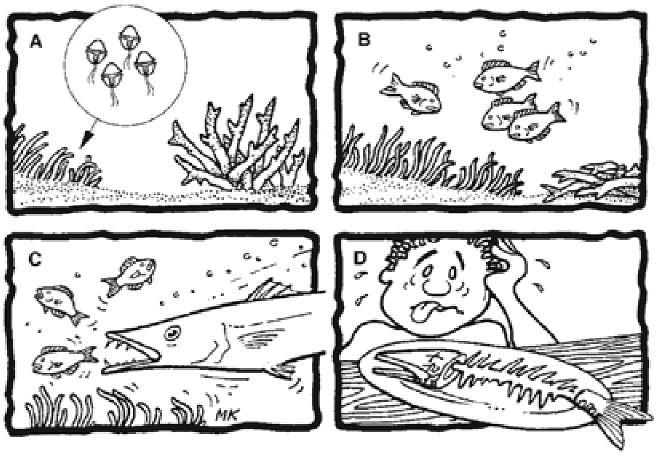
These blooms of toxic species (called Harmful Algal Blooms or HABs) are responsible for fish and shellfish poisoning in humans in many parts of the world.

Myths about recognising fish with ciguatera

One common belief is that toxic fish can be recognised by exposing a fillet of the fish to flies or ants – the flesh is regarded as poisonous if the flies avoid it. Another belief is that a toxic fish can be recognised by placing a silver coin on the flesh – if the coin turns black, the flesh is not safe to eat. Unfortunately these tests and many other widely trusted ones, do not work.

Ciguatera fish poisoning (CFP)

Ciguatera Fish Poisoning (CFP) is common across the tropical Pacific. CFP results from the consumption of fish that have accumulated toxins produced by several organisms including the bottom-living dinoflagellate, *Gambierdiscus toxicus*. The sequence of events leading to ciguatera is shown in the following figure.



A cartoon used to raise community awareness of ciguatera in Pacific Island countries. The sequence of A) to D) is described in the text. From: King M. 2007. Fisheries biology, assessment and management. UK: Wiley Blackwell. 400 p.

A The toxic dinoflagellates (shown greatly magnified in the circle) occur as a film on corals and seagrass. Their numbers increase dramatically when there are high levels of nutrients* in the sea – such as during the wet season when nutrients are washed from the land by rain and released from coral reefs damaged during cyclones. Sewage* and agricultural fertilisers entering coastal waters also add to the load of nutrients. Outbreaks of ciguatera have been associated with activities such as harbour dredging and the illegal use of explosives for fishing.

B Small grazing fish feed on the dinoflagellates and toxins build up in their flesh.

C Large predatory fish eat the smaller fish and the toxins become more concentrated in the flesh of the larger fish. By magnification up the food chain, the toxins reach dangerous levels in top carnivores such as some emperors, snappers, trevallies, barracudas, moray eels and large spanish mackerels.

D People eating these usually edible fish suffer from tingling, numbness, muscle pains and a curious reversal of temperature sensations (cold objects feel hot to touch). In extreme cases, death occurs through respiratory failure.

Unfortunately, the toxins cannot be destroyed by cooking or freezing. And in spite of widespread folklore on the subject, there is no reliable, cheap test to determine whether or not a particular fish is ciguatoxic before consumption.

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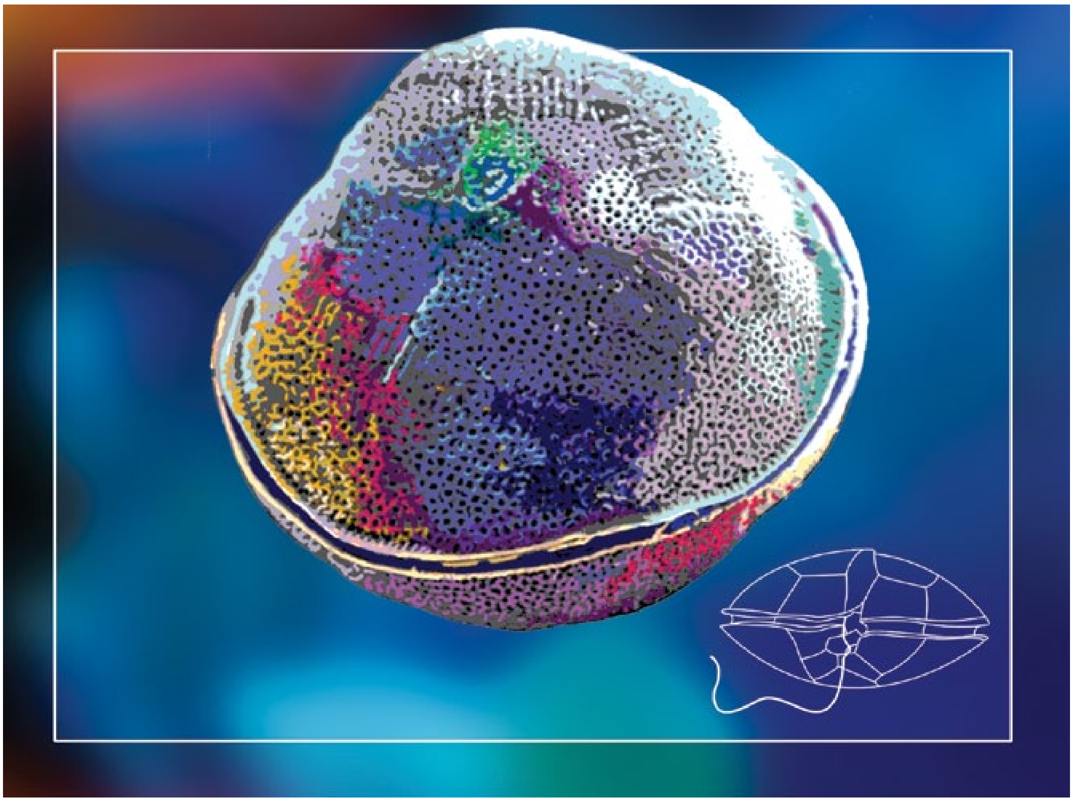
Shellfish poisoning

Other harmful algal blooms cause several conditions collectively called shellfish poisoning. The poisoning is mainly caused by eating filter-feeding shellfish (such as clams, oysters and mussels) that sieve the toxic phytoplankton from the water. Each type of poisoning is caused by different species of toxic phytoplankton and is often named after the symptoms caused.

- The condition called paralytic shellfish poisoning may cause people to stagger about and have trouble talking.
- Neurotoxic shellfish poisoning affects nerves and may cause dizziness, fever and a reduced heart rate.
- Amnesic shellfish poisoning can result in confusion and amnesia (loss of memory).
- Diarrhetic shellfish poisoning is characterised by severe diarrhoea and vomiting.

Marine toxins in the air?

Some HABs toxins can become airborne (as toxic aerosols) because of wave action and cause people swimming and even just walking on the shoreline to suffer respiratory asthma-like symptoms from inhaling the airborne droplets.



Gambierdiscus toxicus.
From: SPC/IRD Ciguatera field reference guide:
http://www.spc.int/coastfish/en/component/content/article/340-ciguatera-field-reference-guide.html

Teachers' Resource Sheet on

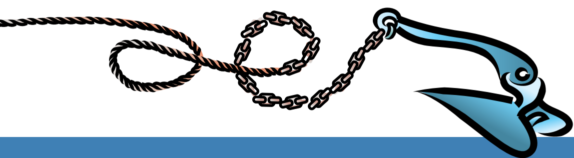
Sea safety

Fishing is considered to be the world's most dangerous occupation – estimated in 1999 by the International Labour Organization (ILO) to cause more than 24,000 deaths per year. Although Pacific Island countries have some of the highest sea accident rates in the world, most government fisheries agencies have limited involvement with safety issues. Data are insufficient to statistically demonstrate which activities are particularly risky, but there is a general perception that offshore trolling for tuna in small outboard-powered skiffs is responsible for many, if not most, of accidents at sea.

A typical trolling skiff from Tarawa in Kiribati, a country with one of highest sea accident rates in the Pacific.

What is sea safety?

Sea safety or boat safety means the ability of a vessel to return to port (or more usually the island or village) at the completion of a voyage or trip. A sea safety accident is an event that may lead to a vessel not returning to port.



The cost of small boat accidents at sea

In addition to the emotional cost experienced by families and friends as a result of accidents on small boats, regional organisations have tried to analyse the financial cost of sea safety accidents and in particular, the cost of search and rescue (SAR) operations. With 22 island states and territories covering more than 25 million square kilometres of ocean and more than 50,000 small fishing vessels working the nearshore waters of these islands, the exact number of accidents occurring each year is impossible to calculate. What is known, however, are the hourly costs of patrol boats, helicopters and planes that are deployed to undertake SAR. Based on this available information and a case study undertaken for New Caledonia, SPC has estimated that the cost of SAR operations to the region is between 5 and 8 million US dollars per annum. Whatever the exact amount, one thing is for sure, it is a cost the Pacific Islands could well do without!

The causes of sea accidents

Various studies have highlighted the importance of human errors in sea accidents. Despite the scarce data available, we know that most sea accidents in Pacific Islands are linked to mechanical breakdowns (lack of knowledge in outboard motor maintenance and trouble-shooting), losing sight of the island – particularly in atoll countries (lack of navigation skills), running out of petrol (negligence) and bad weather (unsuitable boat design and no pre-departure check of the weather forecast). Overloading of vessels and subsequent capsizing is also a common feature of Pacific Islands' small boat safety.

Overloading of a small transport vessel in Papua New Guinea.

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A world record of survival at sea?

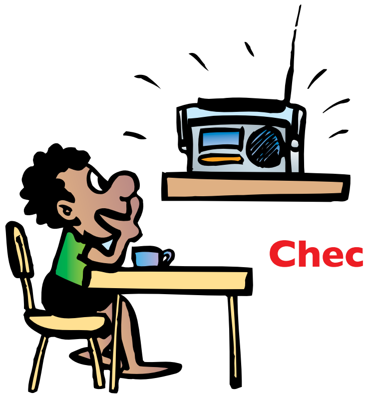
On 18 November 1991, three I-Kiribati fishers left their village on Nikunau for an ordinary fishing trip. Two of them made land again on 11 May 1992… almost six months later, in Samoa! They had survived on rain water and the sharks they could lasso while drifting. This is the longest known drift in the Pacific and possibly in the world. Those two survivors were treated as heroes upon returning home, although the cause of their sea odyssey was pure negligence: they ran out of petrol while fishing. The result was one death and thousands of dollars spent to no avail in searching for their tiny fishing vessel.

A worrisome fact

Most countries in the Pacific do not keep good records of small boat accidents at sea, making it impossible to analyse the extent of the problem and design tailor-made individual responses for countries. The collection and ongoing analysis of data on sea accident should be the first step in the establishment of any national small boat safety programme.

The importance of being prepared

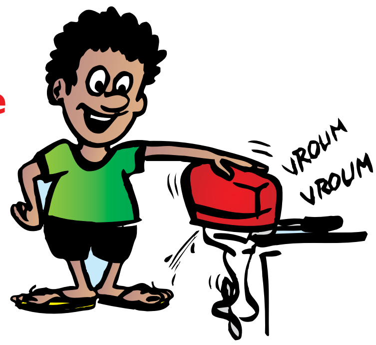
Small boat users, particularly fishers, lack a culture of sea safety. To help change that situation, SPC has released a number of small boat safety awareness materials including two checklists (included in this information package): 'Five minutes which can save your life' and a recommended list of safety equipment for small boats. Of particular importance are the things to do before going out to sea:



Check the weather forecast

Tell someone who cares where you are going and when you plan to return

Make sure your engine is working well



Make sure all safety equipment is on board

Teachers' Resource Sheet on

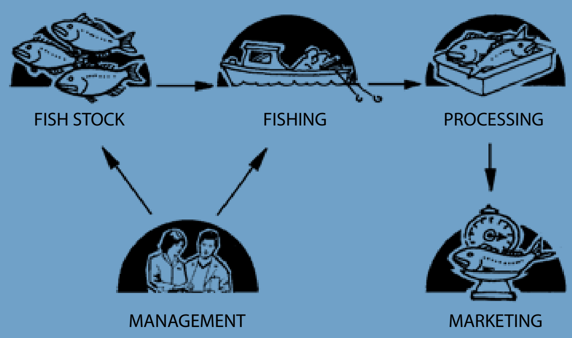
22 Job opportunities in fisheries

Want a job that is active and interesting? A job that helps to feed families and communities?

Then working in fisheries is for you.

A fishery* is not just about fish. Of course, the fish are most important but there are fishers who catch them, people who process and market the catch and fisheries managers who ensure that fish stocks remain healthy.

Fisheries work is exciting – it can involve inside and outside work depending on your preferences. Some people work at sea and some work in markets and some work on computers. But the work is always varied and interesting. The different types of jobs are discussed under the headings in the above figure.



Management

All fisheries resources need to be managed to ensure that fisheries remain sustainable – that is, they remain capable of providing food forever. Biological and economic data on the resource and the activities of fishers are collected by fisheries scientists, statisticians and economists. These professionals provide information on the status of fisheries resources and suggest policies for development and management.

Fisheries management jobs are available not only with government fisheries authorities but with non-governmental organisations (NGOs). Both of these often work with fishing communities which have much traditional knowledge of fish stocks and the environment.*

Jobs with fisheries authorities are often an exciting mixture of work in the field, the laboratory and the office and usually require university qualifications.

Fishing

Fishers are the people most directly involved in a fishery – both men and women who work on shorelines and at sea on vessels ranging from canoes to large tuna vessels. Any position of responsibility on a larger vessel requires sea-going qualifications.

In more technical fisheries, fishing gear technologists design and build fishing gear and experiment with new methods of catching fish. Some fishing operations, particularly those offshore, are dependent on boat builders providing sound fishing vessels. Trade qualifications are usually required to work with a boat builder.

Young fishers often learn their trade informally from older, more established, fishers. There are, however, training opportunities in many Pacific Island countries – skills in navigation and sea safety are also required. SPC is also involved in fishers training.

Processing

The catch landed by fishers is usually processed – which may range from the simple storage of fish on ice to the technologically more complicated procedures of freezing and canning. In some islands, many people are employed as unskilled or semi-skilled labour in tuna processors and canneries.

Seafood technologists, usually with university training in chemistry, biochemistry or bacteriology, ensure the quality of seafood and work on the development of new products. The development of value-added products, such as smoked fish, is one way of increasing the value of the catch.

Marketing

Marketing may refer to the sale of fish from a local market but, in the case of exported seafood, involves securing overseas sales and transporting the catch to foreign countries. Young people intending to work in this area may require qualifications in small business management and accounting.

This resource sheet is one of a series produced by the Pacific Community (SPC) to assist teachers in introducing fisheries topics into school curricula.

Each sheet should be used in conjunction with the Guide to Teachers' Resource Sheets, which contains suggestions for student activities and exercises. All words marked with an asterisk (*) are defined in a glossary in this guide.

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Related activities

Other marine activities include aquaculture, sports fishing and ecotourism.

Aquaculture operations, including prawn, fish and pearl farms, require biologists, technicians, engineers and divers as well as marketing and sales specialists.

Tourism-related activities include working on charter fishing vessels, acting as fishing guides and being part of recreational dive and snorkel tour operations.

Training

Fisheries careers are varied and stimulating. They often involve practical skills, such as seamanship and diving, as well as intellectual skills, such as analysing data with computers; perhaps it is this mixture of active, open-air tasks and stimulating office or laboratory work, that makes fisheries work so interesting.

Some careers involve university study while others can be pursued after intensive practical training. Fisheries and marine environmental courses are available at the University of the South Pacific in Fiji and at universities in Hawaii, New Zealand and Australia.

Whichever career in fisheries is decided upon, the student can look forward to entering a life of stimulation and adventure, working with other qualified and highly-motivated individuals surveying, developing, managing and conserving marine resources for the benefit of current and future generations of Pacific Island people.

Aymeric Desurmont © SPC

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Teachers' Resource Sheet on

Financial management of a small fishing business

What is a fishing business? ***A fishing business involves capturing fish and marine products with the primary objective of selling them to generate income. Fishing businesses in the Pacific sell many different products[1] in many different forms and in many different markets.[2] Some markets include selling direct at local fish markets; or selling to restaurants, wholesalers, retailers and processors; or to buyers in international markets (export markets).***

Types of fishing businesses

There are two general categories of fishing businesses: commercial and semi-commercial.

Commercial fishing businesses* operate to profit from the sale of fish and other marine products. These enterprises range from small, family-run businesses to large companies that employ staff to help to operate the business.

Semi-commercial fishing businesses are typically informal businesses that usually include fishing for food and income. These businesses are small and are run by a single person or household.

Products sold by a fishing business

Some of the products that are sold by fishing businesses and the form that they're sold are listed in the table below.

Typical products that are sold by small fishing businesses in the Pacific.

Product	Example	Form
Fish	Tuna, wahoo, mahi mahi, grouper, snapper, parrot fish, sardines, mackerel	Fresh (chilled), frozen, whole, filleted, gilled and gutted, cooked, canned, live
Invertebrates*	Prawns, shrimp, sea cucumber, lobster (crayfish), crabs, sponges, trochus	Fresh (chilled), frozen, whole, cooked, shelled, meat, canned
Ornamentals	Angelfish, clownfish, damsels, giant clams, corals, starfish, live rock	Usually live
Seaweed	All types of macroscopic, multicellular and benthic marine algae	Live, dried, chipped, sheets, hydrocolloids
Leisure	Game fishing, fly fishing,* spear fishing	Fishing activities that people participate in for recreation and entertainment

Management of a fishing business

Managers of a fishing business ensure that the business remains viable. A manager of a fishing business is responsible for ensuring that the product being sold meets customer expectations, for ensuring that income is generated and for managing business finances,[3] sometimes with the assistance of an accountant.

Financial management of a fishing business

Costs are usually incurred in the process of generating income. Financial management of a business largely involves ensuring that the income received is more than the costs incurred (income is greater than costs), or maximising income while minimising costs.

[1] A product is a good or service that a business sells to generate income.
[2] The market is the person or business that buys fish and marine products from the fishing business.
[3] Finances refer to the money that a business has, receives and pays.

What is income?

Income refers to the money that a fishing business receives for the sale of its goods and services.

Income per trip = Price x Quantity

For example, if a fishing business catches 10 yellowfin tuna, each weighing 10 kg, then the total catch (or quantity) is 100 kg of tuna. If the tuna are sold for $10 per kg, then the income for that fishing trip is $1,000 (i.e. $10 x 100 kg = $1,000).

Annual income is the sum of the income generated from every fishing trip undertaken over a year.

$$\textit{Total income} = \textit{Income}_1 + \textit{Income}_2 + \textit{Income}_3 + \ldots\ldots + \textit{Income}_n$$

For example, using the above income per trip of $1,000 and if we assume that we do 100 fishing trips per year and always catch the same amount of fish, we can calculate total income as $1,000 x 100 trips = $100,000). The income per trip is not always the same because the catch changes each trip, which is why we need to add income from all trips individually.

What are the costs of fishing?

As with any business, there are costs incurred when generating income. We broadly define these costs as operating costs and fixed costs.

Operating costs are incurred when going on a fishing trip and can include items such as: fuel, bait, ice, gear, crew payments (labour), rations, etc.

Fixed costs (or overheads) are incurred by the business whether or not fishing occurs. That is, fixed costs are the costs that the business has to pay regardless of the number of fishing trips that are completed. Fixed costs can include items such as fishing licence, bank loan repayments, annual vessel maintenance, insurance and depreciation. For example, the cost of a fishing licence is the same whether a business does 10 or 100 fishing trips each year – the cost is fixed.

Total cost = Total operating costs + Total fixed costs

For example, if a fishing business does 100 fishing trips each year and each fishing trip costs $500, then our total annual operating cost is $50,000 (i.e. 100 x $500 = $50,000). To operate as a fishing business, the business has to buy a fishing licence ($1,000), make loan repayments ($5,000) and pay boat maintenance ($5,000), so the total annual fixed cost is $11,000 (i.e. $1,000 + $5,000 + $5,000 = $11,000). Putting these together, we calculate our total annual cost to be $61,000 (i.e. $50,000 + $11,000 = $61,000).

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What is profit?

Profit is the money that is left over after total costs are deducted from income over a given period. **For businesses to be viable over the long-run, they must be profitable.** If a business is not profitable, then the business spends more money than it makes. Businesses need money (profit) to operate.

Profit = Total income - Total costs

For example, using the total income and total cost figures from above, we can calculate profit, as follows:

Profit and loss analysis

Total income (A)	$100,000	
Total cost (B)	$61,000	
Profit (C)	$39,000	C = A - B

In this example, profit = $39,000, which means that after total costs (operating and fixed) are deducted from total income, we have $39,000 left – this business made a profit for the year.

We can expand the above table to represent a profit and loss statement, as follows:

Detailed profit and loss statement

Total income	Price x Quantity = $10 x (100 kg per trip x 100 trips) **= $100,000**
Operating costs	Cost per trip x number of trips = $500 x 100 = $50,000
Fixed costs	Sum of all fixed costs = $1,000 + $5,000 + $5,000 = $11,000
Total costs	Operating costs + fixed costs = $50,000 + $11,000 **= $61,000**
Profit	Total income - total costs = $100,000 - $61,000 **= $39,000**

Other fields to consider in financial management

Profit is one key component of financial management. However there are many other areas of importance beyond the scope of this sheet. They surround investment expense (e.g. purchase of boat, motor, ice box), managing assets and liabilities (or creditors and debtors, such as banks and customers to whom credit is extended), cashflow, financial reporting, budgeting and decision making.

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