Beautiful Oceans
Science Diver & Science Snorkeler program

CORAL REEF

ARCHITECTURE & ORGANISMS

CARIBBEAN

BEAUTIFUL OCEANS

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We are indebted to numerous individuals who contributed advice, knowledge, time and effort in making this course what it is today: a fun, scientifically validated, high quality publication that helps SCUBA divers and snorkelers to better understand and enjoy their coral reef experience, while supporting and protecting this invaluable ecosystem..

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FOREWORD

Welcome to Beautiful Oceans, home of the finest coral reef science courses for SCUBA divers and snorkelers.

Our exciting courses, which take place online and are designed to be applied in-class and in-water, provide divers and snorkelers with a unique and comprehensive understanding of the coral reef ecosystem. Whether you apply this knowledge by yourself or under the supervision of a Science Diver Instructor or Science Snorkel Guide, we are very confident that you will experience coral reefs like never before.

Beautiful Oceans Coral Reef Science Courses were born from a passion for diving and snorkeling, a desire to share knowledge and a will to preserve coral reef ecosystems.

At Beautiful Oceans we understand and value the strong bonds that connect living organisms and their environment. We have a responsibility to safeguard the cycles, processes and systems on which the web of life has relied for millions of years. Only by recognizing this interconnectedness, can we respect all forms of life and the environment within which they live.

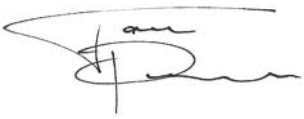
By enrolling in this course, you demonstrate more than a desire for knowledge; Beautiful Oceans Science Divers and Science Snorkelers make a statement about environmental awareness. With each course you take, Beautiful Oceans invests in the environment. We provide financial support for conservation projects, including scientific assessments, marine protected areas and local education programs.

"In the end, we will conserve only what we love, we will love only what we understand, we will understand only what we are taught."
(Senegalese environmentalist Baba Dieum,1965)

As Science Divers and Science Snorkelers you demonstrate your devotion to the natural world and its diverse and interconnected life, while taking an important step toward preventing further degradation of a unique and magnificent ecosystem—the coral reef.

For this, we would like to thank you,

Stephan Becker
President CEO



Ian Popple
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INTRODUCTION

The Earth—our blue planet

The Beautiful Oceans experience takes you on a journey through the world's oceans—a vast world that covers nearly three-quarters of our planet's surface to an average depth of 4 km (2.5 miles).

Approximately 97 percent of the water on Earth is contained within the three oceans—Atlantic, Pacific and Indian. These oceans are home to millions of organisms, amounting to over 90 percent of the world's living biomass. All life evolved from this environment, and to this day, all life owes its continued existence to it.

The oceans maintain Earth's habitable temperature by trapping heat from the sun and distributing it around the globe via their network of currents—a circulation that takes centuries to complete. Fresh water evaporates from the surface of the oceans and falls on the land as life-giving rain, quenching the thirst of both plants and animals alike. Microscopic organisms, called phytoplankton, drift in the surface waters, adding oxygen to our atmosphere in the same way as plants do on land. This vital process allows every one of us to breathe. Without the oceans, life on Earth would simply cease to exist.

Countless people around the world are drawn to the ocean, and many of the more adventurous among us are drawn to explore what lies beneath. Recreational SCUBA diving and snorkeling have provided the means for us to explore the underwater realm, and each year millions take this opportunity to discover coral reefs—one of the most beautiful and unique ecosystems in the world.

Coral reefs—the rainforest of the ocean

Coral reefs are often referred to as the rainforests of the sea because the number of organisms they support is comparable to that of terrestrial rainforests. The number of different species that depend on coral reefs is estimated in the tens of thousands, including approximately 4,000 species of fish, and around 700 species of coral; incredibly this represents nearly 25 percent of all known marine life, yet coral reefs make up less than 1 percent of the world's oceans.

So many organisms packed into such a small space makes for exciting diving and snorkeling, as anyone who has explored a coral reef is quick to share. The sheer number of organisms encountered on a healthy coral reef produce a kaleidoscope of colours and shapes that literally take the breath away.

Tragically, however, coral reefs are under threat from a barrage of environmentally unsound practices, such as overfishing, unregulated

coastal development and pollution resulting in global warming. In the past decade, 25 percent of the world's coral reefs have been destroyed—an area greater than the size of Greece.

Unless we change our irresponsible behaviour, the first generation of divers and snorkelers to discover this unique world may, tragically, be the last. Understanding coral reefs is the first step toward protecting and conserving this precious ecosystem.

Marine biology and ecology—the science of ocean life

Marine biology is the study of sea life; marine ecology involves study of the relationships between these organisms and their environment. Both scientific disciplines intersect several other related fields including chemistry, physics and geology.

The thought of completing a scientific course may strike fear in the heart of many, but those who know Beautiful Oceans understand there is nothing to fear. With this Beautiful Oceans course, you will discover how incredibly simple and truly fascinating marine science can be.

Here are some important tips that will help you get the most from your Beautiful Oceans experience:

Beautiful Oceans uses both common and scientific names

Scientific names are both useful and fun to learn. The scientific name of an organism remains the same, whereas common names can vary from country to country. All scientific names consist of two words: a genus name with a capitalized first letter and a species name; both are written in italics.

In short, a species is a group of organisms that can reproduce, resulting in fertile offspring. Blue tangs represent an individual species, as do ocean surgeonfish, for example. A genus represents a group of similar species, which do not reproduce together. Blue tangs and ocean surgeonfish are in the same genus, but represent different species.

Scientific names are usually of Latin or Greek origin. Where possible, the route of each scientific name is explained: Gr. denotes Greek origin; L. denotes Latin origin; NL donates New Latin origin. We also provide a pronunciation key.

Technical terms are defined in the glossary

Technical terms are written in bold blue text and link to the respective entry in the glossary. In the Beautiful Oceans course pack, the glossary is located at the back of each booklet. For web-based courses at the Beautiful Oceans eAcademy, simply click on these words for a full explanation. Scientific terms are also automatically linked to the glossary when you communicate within a Beautiful Oceans eAcademy student forum. As you save your thread, each technical term becomes a link, allowing other students to better understand your contribution, questions and advice.

Beautiful Oceans courses contain additional information

Beautiful Oceans courses include additional information in the form of **Did you know?**, **Science box**, **Science Diver & Snorkeler tip**, **Science Diver & Snorkeler best practices**, and **Quick quiz**, which complete your learning experience. Did you know? boxes provide 'wow' facts that are sure to amaze. The **Science box** contains interesting overviews of the latest research breakthroughs or additional scientific information related to a particular section of the course. **Science Diver & Snorkeler tips** provide interesting advice and observations for your discovery dive or snorkel tour. **Science Diver & Snorkeler best practices** provide advice to help you become an environmentally responsible 'eco-diver' or 'eco-snorkeler'. The **Quick quiz** contains "food for thought", allowing you to test your knowledge at the end of each section.

Course links help you find information that interests you

Beautiful Oceans offers courses on all aspects of coral reef biology and ecology. Subject matter that falls outside the realm of the particular course you are taking may be explained in more detail in another Beautiful Oceans course.

Practical application through diving and snorkeling

Our courses are designed with the recreational diver and snorkeler in mind. At Beautiful Oceans we believe that applying the knowledge learnt in our courses will vastly improve your learning experience. After the successful completion of the in-class component of your course, you will receive your official Beautiful Oceans Certification Card. Be sure to inquire about discovery dives and snorkel tours at your Beautiful Oceans Science Dive Center.

LEARNING OBJECTIVES

Course objectives:

This course will familiarize you with the six zones of a typical fringing coral reef and some of the organisms found in each zone. You will discover a simple system to recognize specific coral reef zones, and you will understand why some species are more abundant in some areas than others. You will discover some of the most common behaviours observed in coral reef organisms. You will understand why scientific names of coral reef species are important, and discover an easy way to help you learn these names. This course will also introduce you to the process by which fringing reefs, barrier reefs and atolls are formed.

Course key words:

Coral reef zonation, zone indicator, wave action, depth, biodiversity, water mixing, photosynthesis, sunlight, ghost crab, turf algae, threespot, surgeonfish, blue tang, southern stingray, finger coral, redlip blenny, encrusting coralline algae, spur and groove, Acropora, elkhorn coral, staghorn coral, growth form, blackbar soldierfish, squirrelfish, sea urchin, graysby, grouper, sponge, boulder star coral, growth form, abundance, fringing reef, barrier reef, atoll.

This course will answer the following questions:

- What is a fringing reef?
- What are the different zones of a fringing reef?
- Which coral reef organisms are typically found in which zone of a coral reef?
- What are some of the behaviours of these organisms?
- Why is it important to know the scientific names of coral reef organisms?

- How can I have fun learning the scientific names of coral reef organisms?
- What are the different types of coral reefs and how are fringing reefs, barrier reefs and atolls formed?

Course benefits:

- Understanding fringing reef zonation allows divers and snorkelers to get the most from each and every discovery dive or snorkel tour. If you are interested in locating a specific species, or family of organisms, knowledge of each zone will give you better chance of finding your own, personal 'creature of interest'.
- Knowing how to identify coral reef zones allows you to better communicate with other divers and snorkelers, your Divemaster or Instructor; this is particularly useful when you wish to describe what you saw and where you saw it.
- Knowing which coral reef organism can be found in which zones of the coral reef helps you better orient your dive or snorkel tour.
- Learning the behaviour of typical coral reef organisms allows you to better understand what you see underwater.
- Learning the scientific names of coral reef organisms will help you identify, describe and discuss them. This course makes it easy and fun to learn the scientific names of all organisms encountered.
- Understanding fringing reef zonation allows you to add more detail to your dive or snorkel logbook, allowing you to associate a species, or family of organisms, with a particular zone on the reef. This may also prove useful when returning to previous dive or snorkel sites for further exploration.
- Understanding that atolls were formally barrier reefs and fringing reefs, allows divers to recognize the similarity between the zones found on these different reef types.

By the end of this course:

- You will be able to distinguish between the six different zones of a typical fringing reef.
- You will also be able to identify and scientifically name some of the organisms that typify each zone.
- You will know why certain species are more abundant in some coral reef zones compared to others.
- You will understand some behaviours of typical coral reef organisms.
- You will know the difference between a fringing reef, barrier reef and atoll and will understand how they are formed.

CONTENTS

Coral Reef Architecture & Organisms

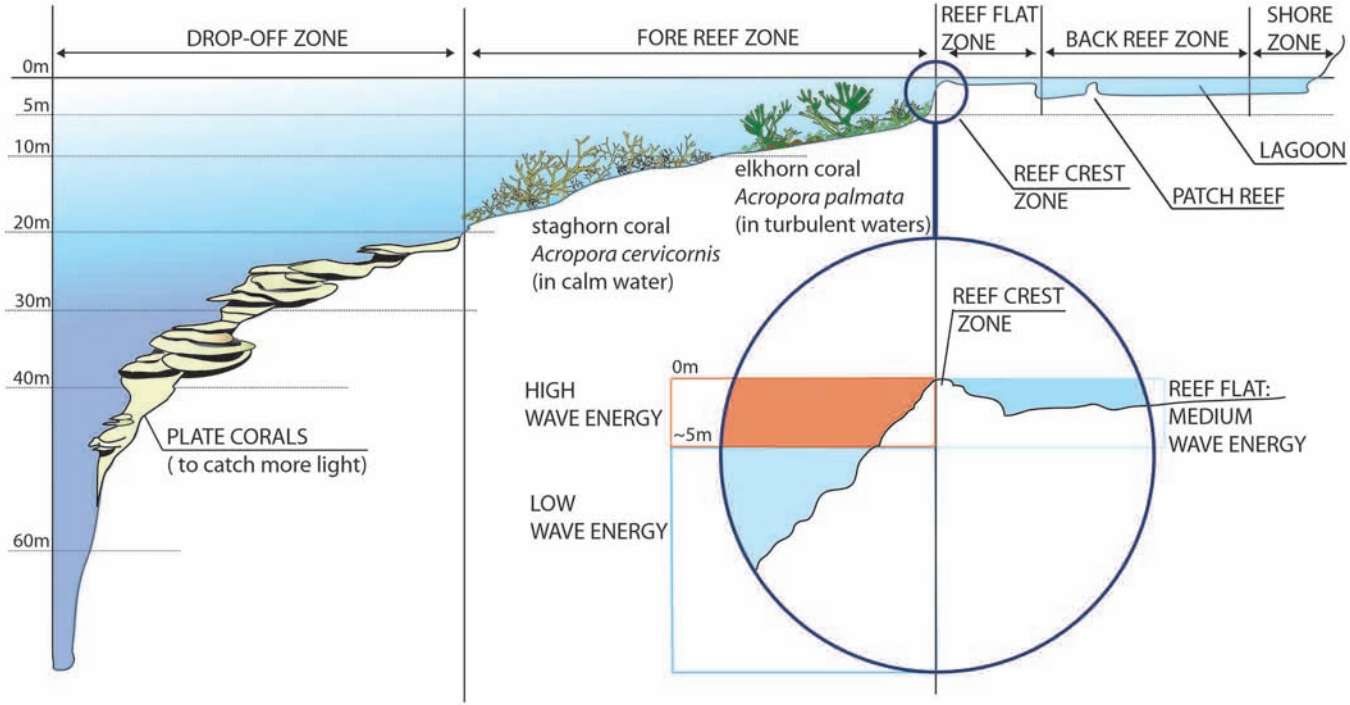

Figure 1.1: Zonation of a typical fringing coral reef (illustration by David Devaux)

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1. **Fringing reef**—a reef that forms along the shore

Fringing reefs hug the shorelines of many tropical countries—hence the name 'fringing'—making them the most readily accessible reefs to SCUBA divers and snorkelers. Fringing reefs can be broadly divided into six zones, defined by various parameters, such as **wave action**, **depth**, **biodiversity** and **water mixing**, which in turn influence the **organisms** that live there.

Divers and snorkelers entering the water from the beach first encounter the **shore zone**—a relatively featureless zone compared to other parts of the reef. As we will see later, however, this zone is far from lifeless. The second zone from the beach is generally the **back reef zone**—a shallow **lagoon** area containing numerous **patch reefs**. The back reef rises to a plateau called the **reef flat zone**, which culminates in the reef crest—the shallowest part of the reef. The **reef crest zone** marks both the end of the reef flat zone and the beginning of the **fore reef zone**, which may contain distinctive **spur and groove** features. The fore reef zone gradually increases in **depth**, and is followed by the **drop-off zone**—the most seaward **fringing reef zone**.

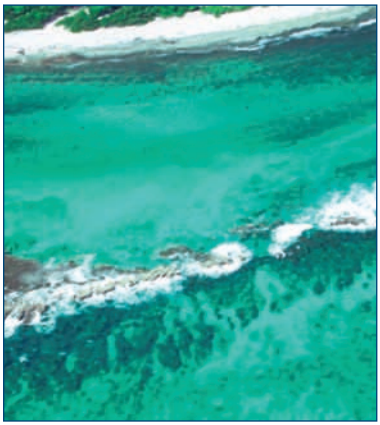

Figure 1.2: Caribbean fringing reef from above. Note the waves breaking on the reef crest in the center of the picture.

Although figure 1.1: Zonation of a typical fringing coral reef shows clear distinctions between **fringing reef zones**, most reefs are rarely this straightforward. It is important to note that fringing reef zones are often indistinct, tending to blend into each other rather than having clearly defined boundaries; some reefs may even lack several of the described zones entirely. As such, it is difficult to describe a coral reef **zonation** pattern that works for all reefs. Recognizing the zones described in this chapter underwater may sound challenging, but there are numerous techniques that can help Science Divers and Science Snorkelers with this task.

Quick Quiz

1. How many zones does a typical fringing coral reef contain?
2. Can you name the zones of a typical fringing reef?
3. Where is the fore reef zone situated?

Answers: 1. Six zones; **2.** From shore to the open ocean: shore zone, back reef zone, reef flat zone, reef crest zone, fore reef zone, drop-off zone; **3.** Between the reef crest zone and the drop-off zone.

Coral Reef Zone Indicators

To help us understand why life on the **coral** reef varies from one zone to the next we need to understand how each of these zones differs in terms of their environment. In the following section, each **coral reef zone** is analyzed in relation to four easily verifiable indicators: **wave action**, **depth**, **biodiversity** and **water mixing**. Our comparisons between the different **fringing reef zones** are relative to each other. This means, for example, 'low biodiversity' in the **shore zone** is low relative to other zones, such as the **back reef** of the same reef. This does not mean that biodiversity is high in all back reefs; it simply means that, generally speaking, back reef zones contain higher biodiversity than shore zones.

Each zone is also described in terms of the **organisms** that might be found there. We highlight at least one example organism for each reef zone. These organisms are by no means found exclusively in the zone we describe; they are simply organisms that may be common in this location. To emphasize this we have included a graph for each coral reef zone that describes how all indicator organisms may vary in relation to each other.

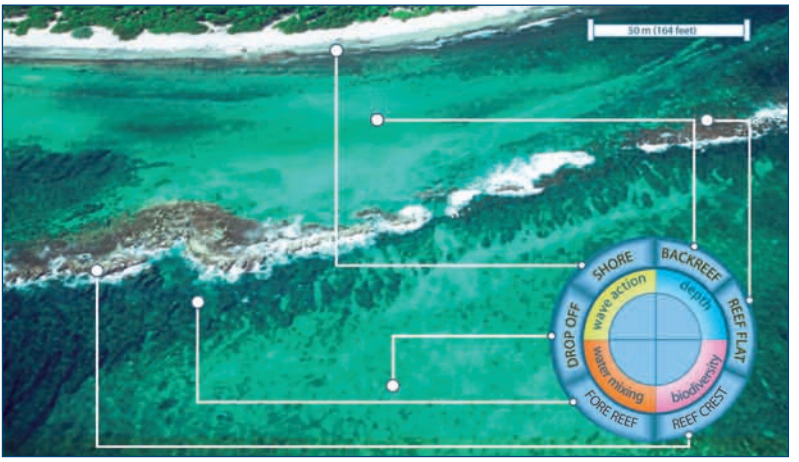

Figure 1.3: Six coral reef zones and four indicators describing each zone (illustration by David Devaux)

Coral Reef Zone Indicator: **Depth**

Depth is one of the most important factors determining the amount of **sunlight** that reaches bottom-dwelling **organisms** like **corals**. **Reef building corals** possess microscopic **algae** in their body tissue, called **zooxanthellae**. These algae need light to **photosynthesize**—the process by which they gain energy from sunlight—which is why reef building corals are found only in the shallow, sunlit waters of the tropics. The zooxanthellae provide this energy to the **coral polyps**, and in return, the coral polyps provide safe and comfortable accommodation for the zooxanthellae. The energy provided by the zooxanthellae is vitally important to the coral polyps—without it coral reefs as we know them would simply cease to exist. The relationship between corals and their zooxanthellae is a form of **symbiosis** known as **mutualism**—a close and intimate relationship in which both partners benefit.

As you know, the deeper you dive the darker it gets; this is because sunlight is absorbed and reflected by particles in the water. Specific parts (colours) of the **light spectrum** are also filtered-out at specific depths—the deeper you dive the more colours are lost. As you have probably experienced, red is the first colour to go, which is the reason everything appears blue underwater. This is a particularly important consideration for underwater photographers. In figure 1.4, notice the generally blue appearance of the coral reef in deeper water, except where the photographer's flashlight illuminates the two sponge colonies in the foreground, revealing their true red color.

Figure 1.4: Underwater photographer preparing to capture an image of sponges in the lower drop-off zone (photo by NOAA)

Science Box

Red and **orange** are the first colours to go. During your Discovery Dive or Snorkel Tour, observe how the orange bubbles of the **Beautiful Oceans** logo on your dive slate progressively change shade the deeper you hold your dive slate in the water.

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Coral Reef Zone Indicator: **Wave action**

Wave action can represent as much of a risk for **corals** as for SCUBA divers and snorkelers. The incessant pounding of waves on the **reef crest** can make life hard for coral reef **organisms**. Many corals cannot survive here, and those that do often adopt a smaller, more flattened shape to deflect the energy of the waves.

Figure 1.5: Waves breaking over the reef crest.

Coral Reef Zone Indicator: **Water mixing**

Water mixing provides reef **organisms**, such as **corals**, with the perfect balance of food, oxygen and **nutrients**, and helps stabilize temperature and **salinity**—the salt content—of their environment. You may be surprised to learn that the salinity of water in landlocked **lagoons** is often higher than in the open ocean. As the sun beats down on the lagoon, water evaporates leaving the salt behind, thus gradually increasing the salinity of the lagoon. Most marine organisms are incapable of dealing with significant changes in salinity.

Figure 1.6: High water mixing occurring on a reef crest and blue spotted cornetfish *Fistularia tabacaria*

Coral Reef Zone Indicator: **Biodiversity**

Biodiversity is a term used to describe a broad spectrum of biological variation. The most basic measure of biodiversity is **species richness**, which provides information on the number of different **species**, but does not take into consideration that some species are more abundant than others. Biodiversity is actually a more complex term that can involve many different biological classifications.

Biodiversity varies in each **fringing reef zone** and is affected by all of the previously mentioned reef indicators—**depth**, **wave action**, and **water mixing.** Factors affecting biodiversity are not limited to just those indicators however. Biodiversity can also be affected by disease, **predation** and **pollution**, to mention but a few.

Corals support many **organisms** by providing food and shelter; so high coral diversity often results in high total **biodiversity**, which includes **fishes**, **lobsters**, **crabs**, **snails**, **urchins** and countless other organisms. One of the reasons this is so important is that a pristine and diverse **ecosystem** is better able to withstand disruptions, such as **pollution** (**anthropogenic**) and hurricanes (natural).

In order to better understand the **fringing coral reef**, let us now 'dive in' to each zone individually.

Figure 1.7: Healthy coral reefs have high biodiversity

Quick Quiz

1. What is the purpose of coral reef zone indicators?
2. Can you name four indicators that can be used to differentiate between fringing reef zones?
3. What is meant by the term salinity?
4. What effect does water mixing have on the temperature and salinity of water?
5. What factor or factors influence biodiversity in the different fringing reef zones?

Answers: 1. To help Divers and Snorkelers recognize and understand the difference between coral reef zones; **2.** Depth, wave action, water mixing, biodiversity; **3.** Salt content of water; **4.** It helps stabilize (equalize) temperature and salinity; **5.** Water mixing, depth (i.e. light) and wave action all influence biodiversity (note: factors affecting biodiversity may not be limited to just these factors).

The Shore Zone

The **shore zone** is the first reef area encountered upon leaving the beach; it constitutes part of the beach and the first few meters of water, usually not deeper than half a meter (<2ft) (See figure 1.1: Zonation of a typical fringing coral reef). Remember, there are no clear boundaries between zones—the shore zone gradually becomes the **back reef zone** as you swim away from the beach.

The **shore zone** represents a tough area for most reef creatures to carve-out their existence. **Sediment** and fresh water may enter this zone from streams and **mangrove ecosystems**. Sediment can quickly turn crystal-clear water cloudy, blocking sunlight from reaching **corals**. Sediment can also smother the fragile **coral polyps** as it sinks to the seabed. Freshwater can affect both the temperature and **salinity** of the shore zone, which can influence the survival of corals and other reef **organisms**.

Figure 1.8: A snorkeler exploring the shore zone of a fringing reef

Shore Zone indicators

The shallow **depth** of the **shore zone**, combined with **tides** and the gentle swash and backwash of waves, can result in partial expose of the shore zone to the elements. **Organisms** that live in this zone may also be vulnerable to **predators** largely absent in the other reef zones, such as shore birds, land crabs and even mongooses.

Water mixing is relatively low near the shore, largely because this zone is cut-off from the open ocean by the **reef flat** and **reef crest**. This location has advantages however, such as being relatively protected from **wave action**. Unfortunately, it often takes only the feeblest of waves to disturb sandy beach **sediments**, which can quickly reduce visibility. This represents a real challenge for **coral polyps**, which may become smothered by the sediment and struggle to obtain the necessary light for **photosynthesis**. For these and other reasons, coral diversity is generally low in the **shore zone**, which limits the overall **biodiversity** of this zone.

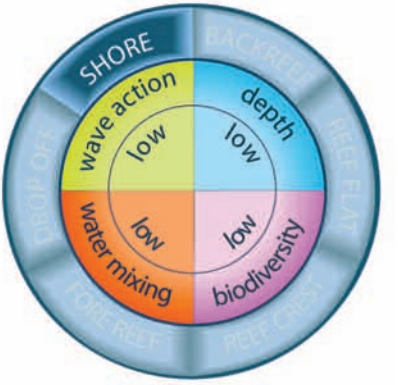

Figure 1.9: Shore zone indicators (illustration by David Devaux)

Science Box

The zone closest to the beach is often referred to as the intertidal zone by scientists. Intertidal literally means 'zone between the high and low **tide**', which in the Caribbean, because of the particularly small tides, represents only a fraction of the **shore zone**.

Quick Quiz

1. What effect do shallow depth and tides have on the shore zone?
2. Why is water mixing relatively low in the shore zone?
3. What effect do even small waves have on beach sediments in the shore zone?
4. Why is biodiversity generally low in the shore zone compared to other zones?

Answers: 1. Shallow depths and tides often result in partial exposure of the shore zone to the elements; **2.** Water mixing is low because this zone is relatively isolated from the open ocean; **3.** Even small waves may stir up sandy beach sediments, which smother coral polyps and may reduce light availability for photosynthesizing coral; **4.** Biodiversity is low because the waves and tides may exposure parts of this zone to the elements, and beach sediments may be stirred up by waves and smother coral polyps. Biodiversity is higher in areas where coral is abundant. Additionally, terrestrial predators may feed on organisms in this zone.

Typical organisms of the Shore Zone

The exposure created by **wave action** and the changing **tide** produces tough conditions for survival in the **shore zone**. The **organisms** that live here possess special adaptations that help them overcome the challenges that life in this zone brings. The shore zone sounds like a pretty desolate place, but for divers and snorkelers curious enough to wallow around in the shallow waters, a number of interesting organisms can be found. We have selected typical representatives of the shore zone from three different organism groups—**crabs**, **fishes** and **algae**.

Typical organisms of the Shore Zone—crabs

Example family: Crabs—Ocypodidae [meaning 'swift footed family'—from (**Gr.**) *ocy*=swift + (Gr.) *podo*=foot + (**NL.**) *idae*=suffix denoting a **family** of animals] pronounced: ossi-pode-i-day. The Ocypodidae family contains many **species** of 'stalk-eye' crabs. They are known as semi-terrestrial, which means they live on land, but are comfortable in the water, and are particularly common in the **mangrove ecosystem**.

Example species: Ghost crab—*Ocypode quadrata* [meaning 'the swift footed square one'—from (**Gr.**) *quadrato*=square, probably in reference to the square shape of the **carapace** (shell)] pronounced: ossi-pode kwod-rata. Worldwide there are approximately 20 different **species** that share the common name ghost **crab**.

Description: Yellowish-white (sandy); **carapace** width can reach over 5cm (2 inches).

Behaviour: Ghost **crabs** are often seen running frantically up and down beaches in their search for food. Ghost crabs are **omnivorous**, which means they eat both plants and animals, but in real terms this means they eat almost anything, including turtle eggs, insects, vegetation, garbage washed up by the sea and even other crabs.

Figure 1.10: Ghost crab—*Ocypode quadrata* (photo by Martin Harvey, Cousine Island)

Ghost **crabs** feed mostly at night when temperatures best suit their frantic pace of life. As most people tend not to be **nocturnal**, the best time to see them is at dawn or dusk; however some individuals may remain active during the day. You may also notice their burrows in the sandy beach. Although ghost crabs are mostly found on the beach, they must regularly enter the water to wet their **gills** in order to breathe.

Ghost **crabs** produce three sounds: a rapping of their claws on the beach surface, a rasping produced by rubbing their legs together, and a bubbling sound made through their **gill** openings. When you are on the beach, listen for the various sounds of the ghost crab.

Quick Quiz

1. What is the common name of a group of animals whose scientific name translates as 'swift-footed'?
2. What is the best time of day to observe ghost crabs?
3. What is meant by the term omnivorous?
4. Why must ghost crabs enter the water from time to time?

Answers: 1. Ghost crab; **2.** Dawn and dusk; **3.** Organisms that eat both plants and animals; **4.** To wet their gills in order to breathe.

Typical organisms of the Shore Zone—Damselfishes

Example family: Damselfishes—Pomacentridae [meaning 'family with operculum spike'—from (**Gr.**) *poma*=lid, cover, **operculum** + (Gr.) *kentron*=sting, spike + (**NL.**) *idae*=suffix denoting a **family** of animals] pronounced: pom-a-centri-day. The Pomacentridae family is particularly common on **coral** reefs—over 300 **species** worldwide. Members of the Pomacentridae family are often small fish that aggressively defend a **territory**.

Example species: Threespot damselfish—*Stegastes planifrons* [meaning 'one with flat forehead who defends territory'—from (**Gr.**) *steg*= cover, contain, **territory** + (Gr.) *astes*=one who, agent + (**Lat.**) *plani*=flat, level + (Lat.) *frons*= forehead] pronounced: steg-ast-es plan-i-frons.

Figure 1.11: Threespot damselfish—*Stegastes planifrons* (juvenile) (photo by Robert M. Fenner)

Figure 1.12: Threespot damselfish—*Stegastes planifrons* (adult) (photo by Robert M. Fenner)