A diver explores a rich coral reef

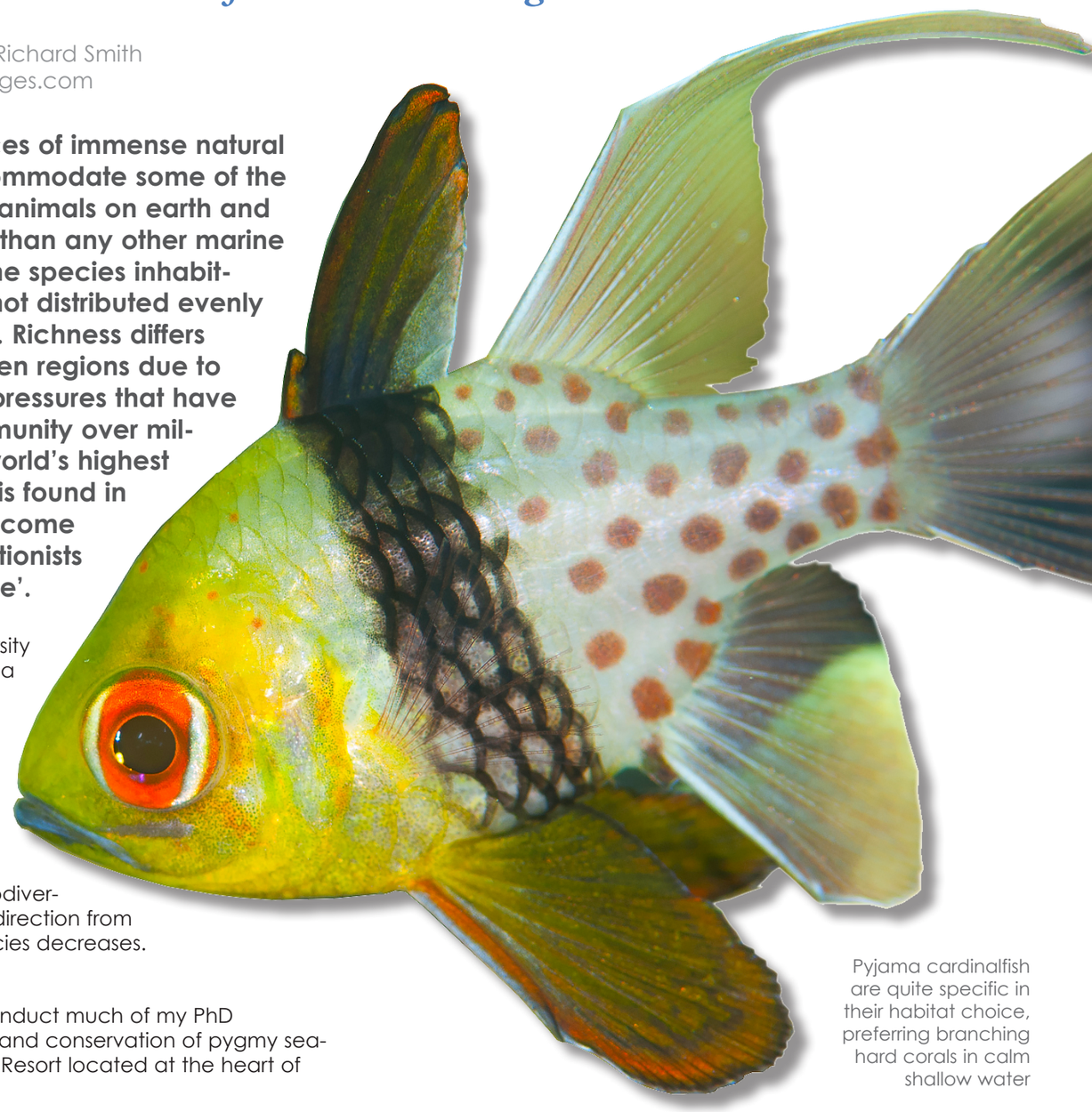
A closer look at

Biodiversity

— At the Heart of the Coral Triangle

Text and photos by Dr Richard Smith
www.OceanRealmImages.com

Coral reefs are places of immense natural diversity. They accommodate some of the highest densities of animals on earth and have more species than any other marine habitat. However, the species inhabiting coral reefs are not distributed evenly through the oceans. Richness differs dramatically between regions due to the many different pressures that have molded each community over millions of years. The world's highest marine biodiversity is found in an area that has become known by conservationists as the 'Coral Triangle'.



Pyjama cardinalfish are quite specific in their habitat choice, preferring branching hard corals in calm shallow water

This region of mega-diversity is a roughly triangular area extending from central Indonesia to Papua New Guinea and the Solomon Islands, and northwards to the Philippines. This relatively small area, on a global scale, boasts the world's richest marine biodiversity. As you travel in any direction from there the number of species decreases.

The richest reefs

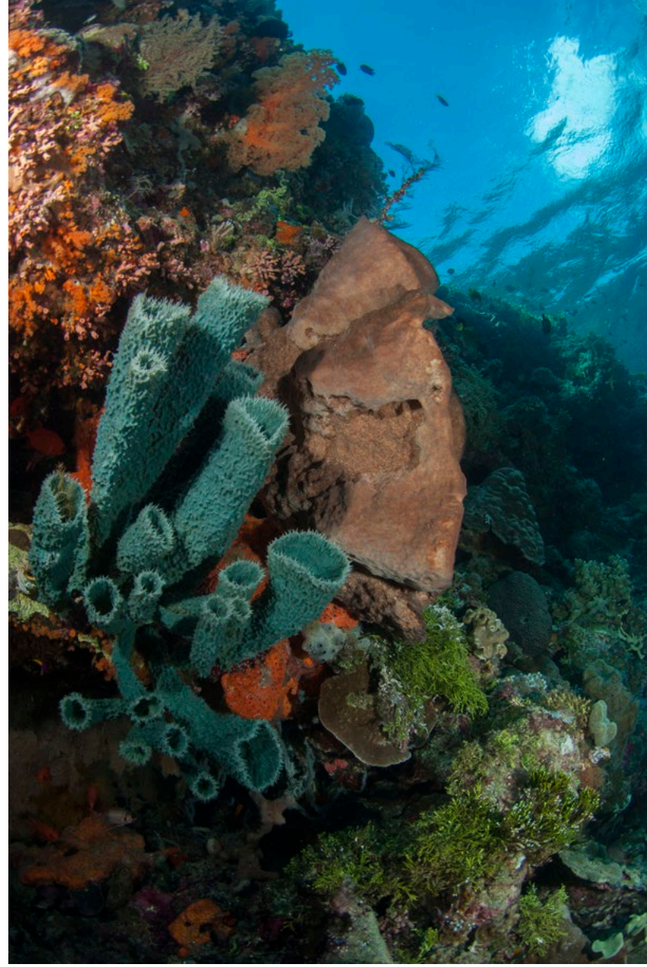
I was lucky enough to conduct much of my PhD research, on the biology and conservation of pygmy seahorses, at Wakatobi Dive Resort located at the heart of

ecology

Coral reefs are the world's most biodiverse marine ecosystem

Rough-snout ghost pipefish are rare inhabitants of muck dive sites, preferring the protected sand or rubble slopes to coral reefs

Seagrass meadows harbor a unique assemblage of marine life. Robust ghost pipefish are common in this habitat but hard to find due to their uncanny mimicry of dead seagrass fronds



A shot showing a diverse reef of sponges, halimeda algae, hard and soft corals in the Tukangbesi archipelago

the Coral Triangle. For more than six months, over a three-year period, I dived the reefs and really got chance to appreciate the amazingly high biodiversity of this region. Due to the nature of my work, I spent hundreds of hours in one specific location on the reef and as a result got to know the area like the back of my hand, and the local residents like family.

Over the years I had the opportunity to appreciate the change, or lack thereof, on the reef. Astoundingly over the three years, there was almost no perceptible change in the size of sponges, whips and soft corals in my small overhang on the Wakatobi House Reef. I was constantly amazed that, even after six months, I would still encounter something new almost daily. One day I found a tiny beige frogfish half the size of my little finger nail, the next a nudibranch I had never seen before crawling across my path and the following evening a bright orange shrimp crept from beneath a sponge. Such is the Coral Triangle, the world's most biodiverse marine habitat.

Today's diversity

Today, the two main areas of reef diversity centre on the Caribbean and Indo-West Pacific. The biodiversity in these two areas, however, is quite different: the species richness in the Indo-West Pacific vastly surpasses that of the Caribbean. The Indo-West Pacific supports at least 600 species of coral and 4,000 fish, compared to 62 and 1,400 species respectively in the Caribbean. The species count for either fish or corals in one Indonesian bay can exceed the number of species found in the entire West Atlantic. In fact, for the majority of reef organisms there are 10-30% as many species in the West Atlantic as Asia, and no reef-associated fish species are shared

Pontoh's pygmy seahorses attain a maximum length of less than 2cm

between the two bodies of water. Whilst the number of species in the Caribbean appears low, they are in fact entirely different to those of the Pacific due to millions of years of separation.

There is some debate over the explanation for such high Asiatic diversity. One theory is that the area is a hotbed for evolutionary change and species are created here, with some eventually spreading to other regions of the Pacific. Another possibility is that the ranges of many species from the Indian and Pacific Oceans overlap in the Asian archipelago, causing higher diversity where they coexist. In addition, the geology of the region has origins in many areas, each with their own fauna. The Australian and continental Asian land fragments each contribute their own unique assemblage of organisms.

Whilst the true explanation is probably a combination of these factors, the most simple and palatable reason for high diversity is the huge diversity of habitat types in the Coral Triangle. The profusion of different habitats equals a correspondingly high diversity of organisms to inhabit them: sheltered inner shore habitats have their own set of species, whilst exposed atolls have another. Beneficially, the Coral Triangle has also avoided the mass extinctions that have blighted other areas over the millennia. Instead, the Coral Triangle has been blessed with long periods of warm, stable conditions fostering the persistence of species.

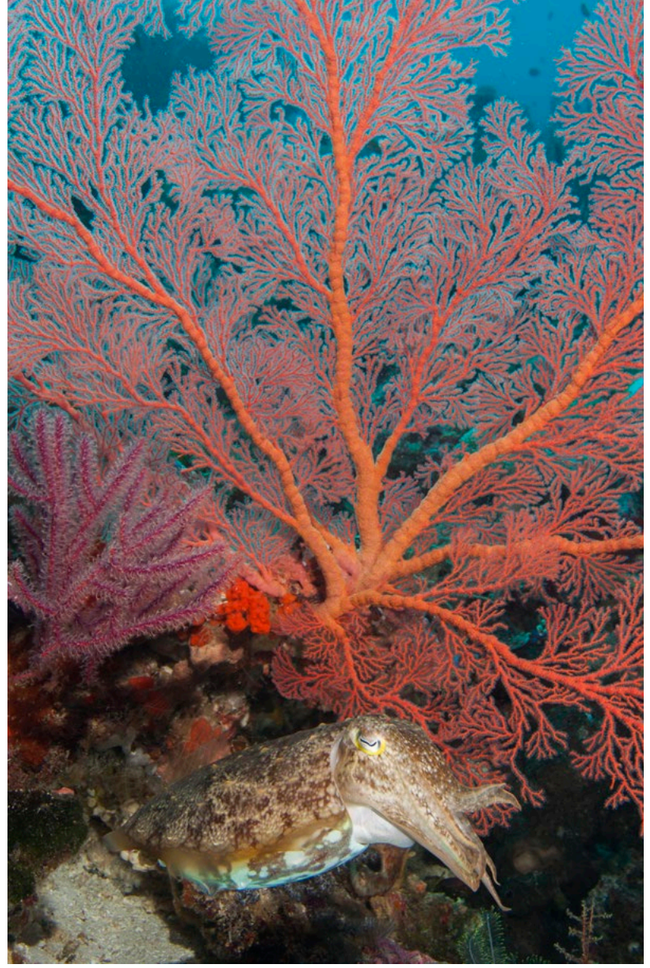
Fish doctors without borders

Last year I had the opportunity to join Wakatobi's liveaboard, Pelagian on an itinerary that ventured beyond the resort's reach and explored other islands in the chain. Whilst the resort has a profusion of different habitats including steep walls, pinnacles, ridges and bays, I had often heard about the muck dives found on Buton island, close to the Sulawesi mainland. Muck dives are interesting as they host a diverse set of species you are unlikely to see in other habitats, due to their distinct set of environmental conditions. Ghost pipefish, seahorses, frogfish and countless other oddities make this their home. It is a perfect example of the influence habitat diversity can have on overall species richness. The mangrove

A small soft coral cowrie feeding on a Dendronephthya coral

Nudibranchs reach their highest diversity in the Coral Triangle, Nembrotha lineolata

Even the infamous Crown of Thorns seastar serves a role on a healthy coral reef. Only when humans disrupt the ecosystem do they reach plague proportions



A huge cuttlefish rests next to a huge gorgonian coral

A rare crab found only on nocturnal feather stars

forests, shallow seagrass beds and even the open ocean are just a few of the other habitats that contribute their own collection of unique species to the Coral Triangle.

During our tour of the Tukangbesi archipelago, in which Wakatobi Resort lies, I also came across, for only the second time, a pair of Denise's pygmy seahorses living on a whip coral colony. Unusual associations and biological quirks such as this seem quite commonplace in the Coral Triangle. With the Coral Triangle as a production line for new species, it might be that these pygmy seahorses, or their offspring, are better adapted to life on a whip coral. In many generations time it might be that these pygmies split off to become a new, distinct species.

Endemism: riding the wave

As well as accommodating the highest number of species in the Indo-Pacific, South East Asia also has the greatest number of endemic or indigenous species (species that occur nowhere else). Certain areas of the ocean are more prone to high levels of these restricted range species: Hawaii has 86 species of endemic reef fish, the Red Sea 41, New Caledonia 43 and the Great Barrier Reef 33. The Coral Triangle vastly outshines all these areas, with over ten percent of its almost two and a half thousand species found only there.

In 2007, when I was first at Wakatobi conducting my pygmy seahorse observations, one of the guides found a tiny pipefish-like fish. It was distinct in several ways: it's miniature stature of less than 3cm in length, strange swimming method resembling a sea dragon and red wisp-like filament on the head all indicated to me this was something new. Later that year the pygmy pipehorse, Kyonemichyths rumengani, was scientifically described. Known initially only from Sulawesi in Indonesia, this tiny fish is now also recorded from Halmahera and Raja Ampat and seemingly making it another Coral Triangle endemic.

Currents play a major role in the movement of organisms around the ocean, and reef communities can become isolated from others depending on local current systems. The East Australian Current, for example, flows from tropical equatorial waters towards the much cooler waters of southern Australia and Tasmania. This effectively backs the reef organisms up against uninhabitable cold waters, isolating the organisms from other populations and fuelling their evolution into distinct species.

Certain species are especially susceptible to such conditions and form a higher than average proportion of the endemics. Those species whose juvenile forms spend long periods drifting in the ocean as miniscule larvae tend not

A small dottyback emerges from inside a protective tunicate

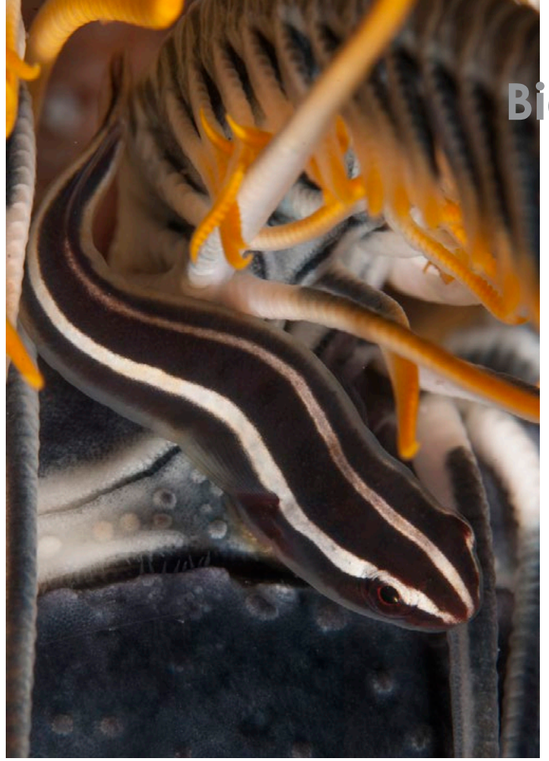
to become isolated as they are able to reach distant reefs during this period, increasing their range. Other species, such as anemonefish and dottybacks, have well-developed young that settle very quickly on the local reef. The young, therefore, do not get chance to move far from their place of birth before settling, and thus have a propensity towards endemism.

Human impact

Patterns of marine biodiversity around the globe are historically quite stable and species evolve to fill a specific role within their own community. Man's technological advances have had unexpected affects on marine organisms, as they can now reach areas that were once physically well beyond their reach. The Suez and Panama canals link bodies of water, and their inhabitants, in ways that would never meet naturally. For example, blacktip reef sharks have been found for the first time in the Mediterranean having originated in the Red Sea. Pacific nudibranchs are also arriving in the ballast water of ships in the Caribbean and Indo-Pacific Lionfish have invaded the Caribbean thanks to released aquarium subjects. These illegal aliens have the potential to severely disrupt their new home and the diversity that has evolved without them.

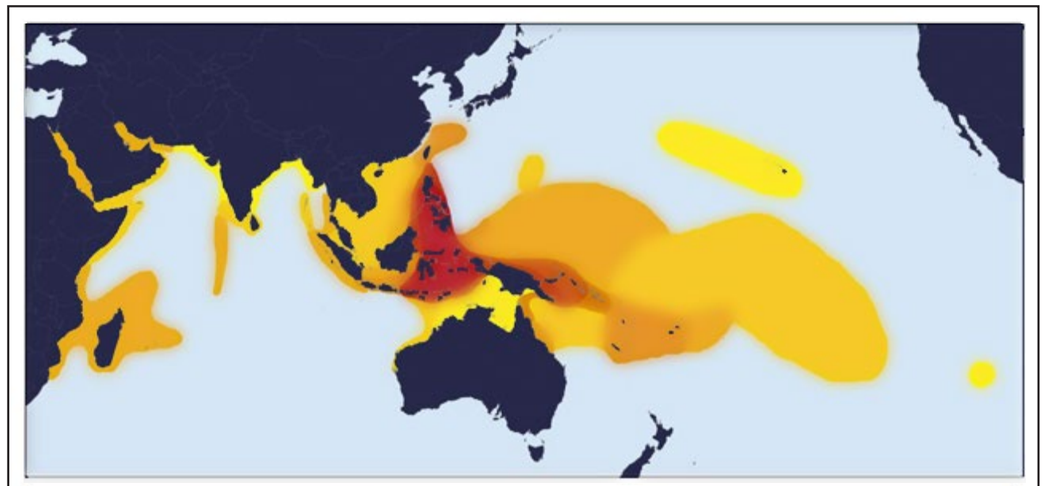
I was very pleased to see the energy that Wakatobi put into protecting their reefs. Great effort is made to educate and work with local communities to prevent destructive practices such as dynamic or cyanide fishing on local reefs. In fact, much of the revenue from guests visiting the resort goes directly into local villages in payment for a strict no-fishing policy on fifteen miles of reef surrounding the resort. The extremely remote location, extraordinarily high biodiversity and conservation efforts in the area make this a safe haven for many species that are suffering throughout the Coral Triangle.

With very limited resources available to conservation efforts, the identification of regions that contain high species diversity or many endemic organisms may help pinpoint areas of conservation priority. Scientific data indicates that the protection of South East Asian reefs will preserve the most species; however, there are also many other areas deserving of a conservation focus.



Biodiversity

Crinoid clingfish (lefft) are a small species found in small groups at the centre of feather stars. Small, cryptic species play a large role in the accumulation of the Coral Triangle's biodiversity; Scientifically described in 2007, *Kyonemichthys rumengani* (left center), is found only in the Coral Triangle



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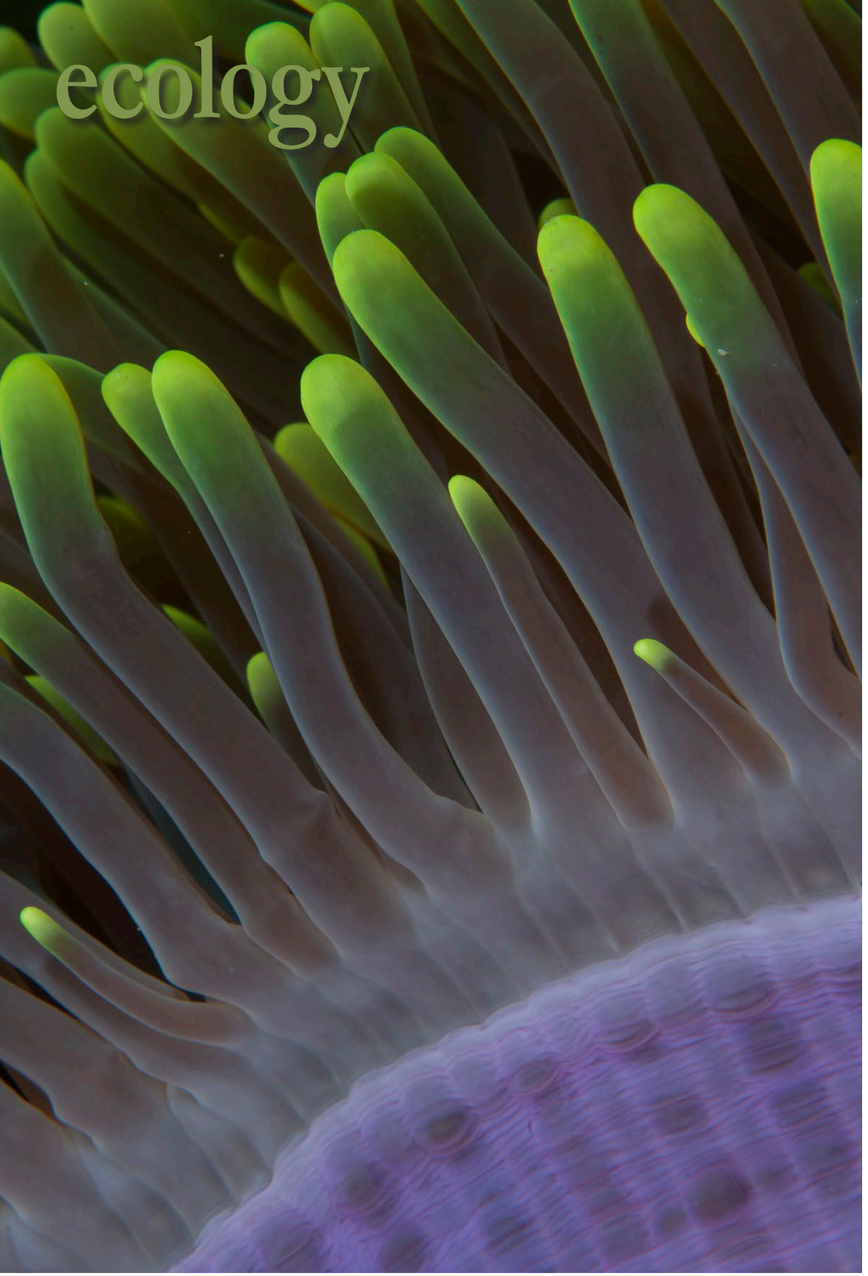
Richard Smith is a British marine biologist and photojournalist. As well as writing for many publications internationally, he leads marine life expeditions where the aim is for participants to get more from their diving and photography by learning about the marine environment: ***www.OceanRealmImages.com***



Detail of a magnificent anemone mantle

ABOUT WAKATOBI

The area commonly known as Wakatobi lies within the Tukang Besi island group, in Indonesia's Southeastern Sulawesi region. It is one of the most remote regions of Indonesia, and until recently, travel to this area required more than 24 hours from Bali by a combination of small aircraft, overland and boat travel.

The title Wakatobi is an acronym derived from the first two letters in the names of the group's four major islands: Wangi Wangi, Kaledupa, Tomia and Binongko. These islands encompass some of the planet's most productive and pristine reefs and coastal shallows.

Much of the island group lies within the Wakatobi National Park, which is the second largest in Indonesia. In 2012 this area was designated a UNESCO Marine Biosphere Reserve. In addition, a 20- kilometer section of reef is under the protection of the Wakatobi Marine Reserve, which is a private program administered through the Wakatobi Collaborative Reef Conservation Program.

This initiative was developed by the founders of Wakatobi Dive Resort to provide a proactive means of protecting the reefs and marine resources. Established in 1996, Wakatobi Dive Resort was the first operator to offer services for diving and snorkeling in this region. A portion of revenue generated from resort activity funds a lease system that pays area villagers and fishermen to honor a no-take policy on specific reef tracts. Since the program's implementation in 1998, environmentally damaging fishing practices have ceased, and the reefs have remained in near-pristine condition, with some showing marked improvement.

Rare Denise's pygmy seahorse living in association with a whip coral colony

Underwater environment

The islands of Wakatobi are typically flanked by fringing barrier reefs that drop to depths of 40 meters or more at distances of less than 100 meters from shore. There are also a number of offshore reef plateaus and sea mounds in the region that rise from the depths to create isolated areas of shallow habitat.

What sets Wakatobi apart from other venues in the region is the unmatched access divers, snorkelers and photographers have to the most promising sites, most of which begin in very shallow water. Additionally, finding many elusive, well-hidden creatures such as the pygmy seahorse, is made easier by Wakatobi's dive guides, aka dive experience managers, who are experts at locating most species in their natural environment.

The islands of Eastern Indonesia are surrounded by some of the most bio-diverse coral reefs on the planet. This region, known as the "coral triangle," is home to more than 450 varieties of hard and soft corals, 3,000-plus species of fish and several thousand more types of invertebrate animals. With literally thousands of species living in close quarters on Wakatobi's reefs and shallows, there is no one single animal that could be said to be the signature attraction for underwater identification and viewing. That said there are some that never fail to entertain or provide unique opportunities for fish watchers and photographers. A few of the interesting denizens of the reefs at Wakatobi include:

Sea turtles. Thanks in part to Wakatobi's turtle nursery program and other conservation efforts, area reefs and shallows hold extremely healthy populations of sea turtles such as the green turtle and hawksbill turtle.

Pygmy seahorses. Wakatobi provides an ideal environment for pygmy seahorses to thrive, and it was only recently that this group of tiny creatures became known to science; most significantly, four of the seven known species are regularly seen in Wakatobi, and were discovered nearby in the past decade. According to marine biologist Dr Richard Smith,

Divers investigate a rich coral reef in the Wakatobi region

An uncommon nudibranch, *Noumea crocea*, on the reefs of Wakatobi

"Anyone who has the pleasure of watching one of these animals should consider themselves privileged, because they are seeing something that few humans will ever see. And when it comes to finding pygmies, there is no better place than Wakatobi to begin the hunt." Unlike their larger cousins, the pygmy seahorses live only on coral reefs, and in many cases on a single species of gorgonian sea fans, which are found in abundance on the reefs at Wakatobi.

Cuttlefish. With eight arms growing out of their heads, and three hearts pumping blue blood through their gelatinous bodies, cuttlefish may seem like creatures from another planet, but they actually thrive in abundant numbers on the reefs of Wakatobi. In particular, the broadclub cuttlefish is a very common sighting, and groups of sometimes a half dozen can be seen hunting in pack formation, with their mantles pulsing and flashing as they send visual messages back and forth.

Humphead parrotfish. One of the larger members of the parrotfish family, the humphead can be readily identified by the crest-shaped growth on its forehead. They are seen often at Wakatobi traveling in large groups. Like other parrotfish, the humphead uses powerful incisors and pharyngea teeth to grind up coral and algae-covered rocks; the organic matter is digested while the remaining inorganic material is excreted. While this may sound destructive, it is this processed "coral poop" that washes ashore to form beaches. A school of parrotfish can add tons of soft sand to a beach each year. These fish often travel in shoals of 50 or more, and can live to be 40 years old.

Mandarinfish. Normally shy, these brightly colored members of the dragonet family loose their inhibitions as the sun goes down. At dusk, the males leave the cover of the rocky shallows they typically inhabit to perform intricate courtship displays that highlight their brilliant coloration. When a male attracts the attention of a female, they pair up belly-to-belly and begin a spiraling dance upward in the water column, releasing egg and sperm simultaneously at the apex of their ascent.

Mantis shrimp. Growing up to 30cm in length and able to deliver a smashing blow with their raptorial claws that can shatter a crustacean's shell, the mantis is one shrimp that deserves respect. The mantis are solitary borrowers, constructing elaborate tunnels into the rubble or sand strata of the sea floor. One of this animals most distinctive features are the iridescent eyes, which not only move independently to provide 360-degree binocular vision, but also see in a wider spectrum of light than any other creature in nature, including UV and polarized light.

Frogfish. There are more than 15 species of frogfish native to Wakatobi, and though they don't reveal themselves to the causal observer, divers and snorkelers who look closely may realize that what they first thought was a lump of rubble or a clump of sponge is actually a stealthy predator, lying in wait.

Crocodilefish. It is the distinctive snout and head that give the crocodile flatfish its moniker, but perhaps the most unusual feature of this ambush predator are the frilly iris lappets, which protrude over the black pupils of their eyes to break up the one remaining pattern that might alert unwary prey. Like the namesake reptile, this fish will lay motionless for long periods of time, waiting patiently for the right moment to strike out.

There are many, many other marine creatures readily found on Wakatobi's reefs. Learn more by visiting Wakatobi's blog, Wakatobi Flow, at blog.wakatobi.com. □ SOURCE: WAKATOBI MEDIA INFORMATION

What is biodiversity ... really?

Text and photos by Peter Symes

Diversity is about numbers, so the more species present in a habitat, the greater the biodiversity, right? Not quite.

Diversity in a biological context is often confused with ***richness,*** which is a simple measure that quantifies how many species are present without taking their abundance into account.

Biodiversity is a more comprehensive measure that takes into account both the number of species and their relative abundance and distribution. As such it is both a quantitative and qualitative measure consisting of two components: ***species richness*** and ***species evenness***.

To use a more familiar example, consider the barley field shown below. It is essentially a mono-culture and the patchy presence of a few wild flowers does not make it a rich and varied habitat. Including the boundary with all the many different flowers does not quite make it either because the distribution remains very uneven (there is still so much more barley than flowers).

The same notions apply to the marine environment and what we as divers would like to encounter. Say, if we want to go look for mandarin fish, pygmy seahorses, rhinopias and other photogenic or exciting species, they not only need to be present at the location to which we are headed, but they also need to be not so exceedingly few and far apart that we have little chance to find them.

Measures and maths

So how does one go about an objective measure to biodiversity? A number of mathematical indices have been formulated, which in various ways gives weight to the proportional abundance of observed species. In its simplest form, species diversity can be calculated by taking the inverse of the weighted average of species proportional abundance.

A number of indices that put emphasis on different aspects of the diversity have, over time, been proposed and put to use. The Shannon index, which is derived from information theory formulated in the late 1940s, is probably the most popular. □

A barley field (left) has low biodiversity as the presences of a few other species of flower does not significantly alter the fact that the field is a mono-culture.

Stability and resilience in ecosystems

Text by Peter Symes

The transfer of food energy from the source in plants through herbivores to carnivores is commonly referred to as the ***food chain***. The ***trophic level*** of an organism is the position it occupies in a food chain. Food chains start at trophic level 1 with primary producers such as plants such as phytoplankton, kelp or seagrasses, move to herbivores at level 2, predators at level 3 and typically finish with carnivores or apex predators at level 4 or 5. The path along the chain can form either a one-way flow or a ***food web***.

The classification of organisms by trophic levels is one of function and not of species as such, and a given species may occupy more than one trophic level i.e. when they go through stages of development. Size has a big effect on the organization of food chains; Animals on successive tropic levels tend to get larger i.e. the shark, which is the top predator, is larger than the seal which is a carnivore that largely feeds on fish and marine invertebrates.

So, in a way, it seems like foodwebs tend to organize themselves into a pyramid-like structure with few and big individuals at the top, while there are myriads of both species and individuals on the lower trophic levels forming the base.

And the question is...

Ecological communities with higher biodiversity form more complex trophic paths, but does complex mean more stable societies? And what limits the size and complexity?

Energy sets limits

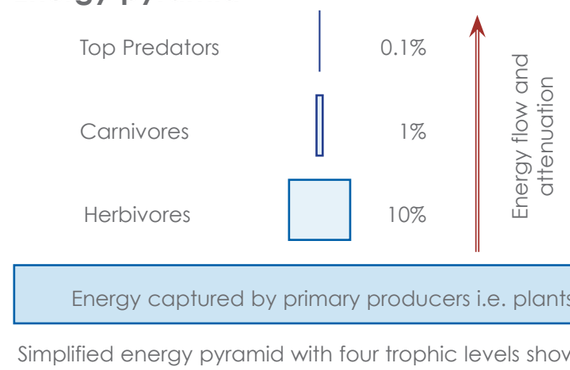
In food chains the energy moves from one trophic level to the next in what is called an ***energy pyramid.*** At the bottom of this pyramid, we have the 'primary producers', which largely are the photosynthetisers, plants and other organisms that convert the energy in sunlight to chemical energy that can later be released to fuel the organisms' activities. On the next levels, we typically subsequently have herbivores, carnivores and top predators.

The 10% limit

The efficiency with which energy or biomass is transferred from one trophic level to the next is called the ***ecological efficiency*** and is no better than about ten percent on average. In other words, consumers on each level only convert about one tenth of the chemical energy in their food to their own organic tissue. This is also known as the 'ten percent law'. Since energy drops off so quickly by passing through the levels, it follows that food chains rarely extend for more than five or six levels before energy is depleted.

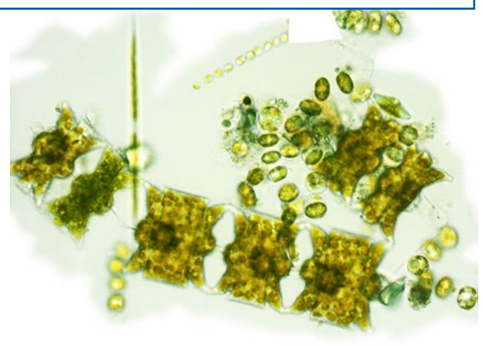
Since plants only convert about one percent of the sunlight they receive into chemical energy in the first place, of the total energy originally present in the incident sunlight that is finally embodied in a tertiary consumer, say a shark in the ocean, is about 0.001%. □

Energy pyramid



Simplified energy pyramid with four trophic levels showing the conversion and throughput of energy between levels. The energy can somewhat be correlated to biomass.

How much plankton is needed to make a shark... or two?



Stability does not follow complexity

Stability is a dynamic concept that refers to the ability of a system to bounce back from disturbances (a subject we previously treated in more detail in *X-RAY MAG* #17, p. 71, "**Why and how ecosystems change**").

For starters, the intuitive argument that increased stability follows increased community complexity in the food web was already countered in the 1970s when it was demonstrated that *complexity actually reduced stability in mathematical models.*

Where diversity does creates stability or steady state scenarios in ecosystems, it follows from the establishment of enough equilibrium and buffer mechanisms in the assemblage of interacting species, which may or may not happen through non-random mechanisms.

Stability in complex systems is not a given. In fact, some systems are inherently instable or chaotic and prone to crash, after which they will cease to exist and only the stable systems will prevail. Whether such systems are resilient to perturbations or fragile is another question.

Resilience

Resilience is a measure of the ability of the system to persist in the presence of perturbations arising from physical or chemical factors, climate or human activities such as fishing or pollution. Regulations on fisheries, for example, where outtake or harvest is limited is all about keeping the perturbations within 'sustainable limits'. Take only so much, and the resource will grow back. Take out too much, and the ecosystem may suffer a major collapse during which its overall structure and composition gets dramatically altered in a manner that is often impossible or very difficult to reverse.

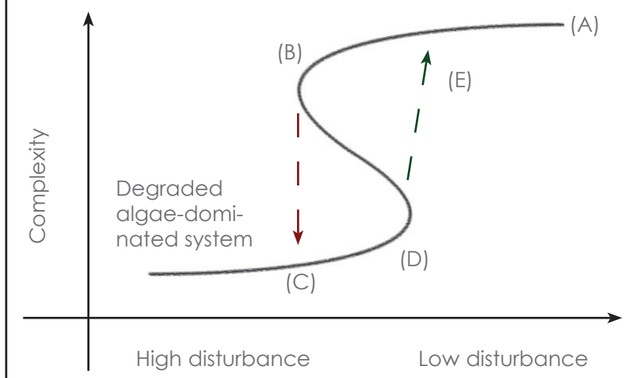
Hysteresis

In an ecological context, hysteresis refers to the existence of different stable states under the same variables or parameters.

A real-world example is helpful to illustrate the concept. Coral reef systems can dramatically shift from pristine coral-dominated systems to degraded algae-dominated systems when populations grazing on algae decline. While the shift in one direction takes one path, reversing the process will follow a different path often requiring a significant input of the driving force to facilitate the change.

In this case the disturbance or causing agent has to be reduced to a level much lower than it was when the dramatic shift occurred. □

Hysteresis and catastrophic change



When a healthy complex system such as a varied coral reef is subject to a disturbance, it will move along the gradient from (A) to a point (B) where a dramatic or catastrophic change occurs and the system collapses into one of lower complexity dropping down to point (C).

Reversing the collapse, or restoring the reef, however, takes a different path and often 'uphill' against some gradient or energy requirement. One has to, along with other restorative measures, also lower the disturbances, or cause, to at least level (D) after which it will eventually evolve back up to point (E). This curve also shows how different states can exist under the same conditions—when disturbance levels lie in the range between (B) and (D).