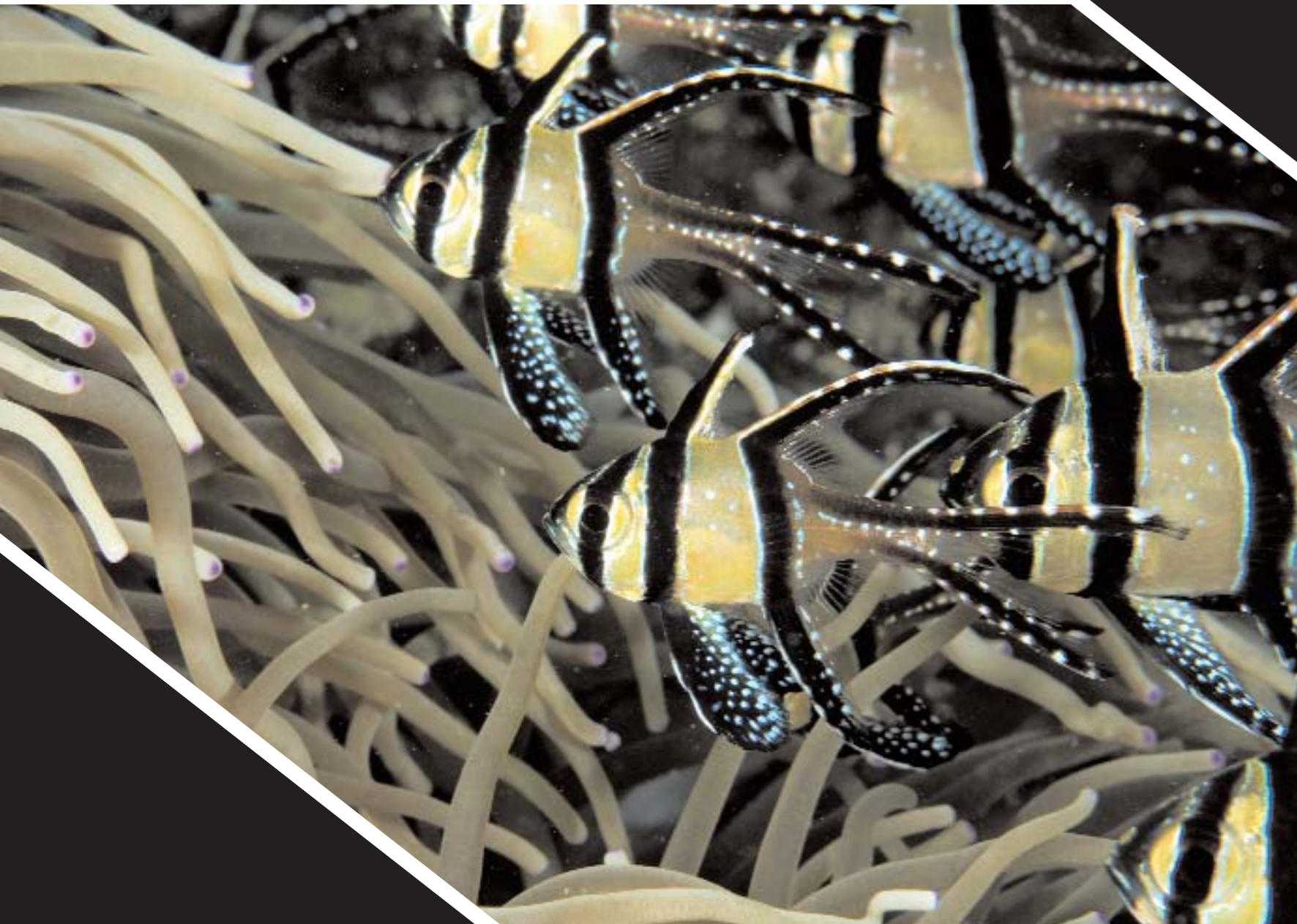


✦ CORAL REEFS HAVE IMMENSE BIODIVERSITY. THEY ACCOMMODATE SOME OF THE HIGHEST DENSITIES OF ANIMALS ON EARTH AND HAVE MORE SPECIES THAN ANY OTHER MARINE HABITAT. BUT REEF ORGANISMS AREN'T DISTRIBUTED EVENLY – SPECIES DIVERSITY DIFFERS DRAMATICALLY BETWEEN REGIONS DUE TO THE MANY DIFFERENT PRESSURES THAT HAVE CHANGED THE OCEANS OVER MILLIONS OF YEARS.

: RICHARD SMITH richard@oceanrealmimages.com

PATTERNS OF DIVERSITY



Banggai cardinalfish may displace other species when they are introduced into areas outside of their natural range. Lembah Straits, Indonesia.

Today's two main regions of reef diversity centre on the Caribbean and Indo-Pacific. The number of fish and coral species is highest around the many islands of South East Asia, specifically Indonesia, the Philippines and Papua New Guinea. This highly diverse area supports 600 species of coral and 4,000 fish compared to 62 and 1,400 species respectively in the Caribbean. In fact, for the majority of reef organisms there are 10-30% as many species in the West Atlantic as Asia and no fish species are shared between the two oceans. While the number of species in the Caribbean appears low, they are entirely different species compared to those of the Pacific.

Hundreds of millions of years ago one large land mass named Pangaea consisted of an amalgamation of today's continents. During the Cretaceous period, 144-65 million years ago, North and South America began to drift away from Europe and Africa thanks to the movement of the earth's crust. At this time the Americas weren't joined by the land bridge that today includes Panama, Costa Rica and Mexico – a huge tropical sea spanned much of the globe's circumference from Asia round to Europe with abundant coral reef habitat. As the land bridge between the two American continents began to form, water currents were disrupted, isolating fish populations in today's Atlantic and Pacific Oceans. A land bridge finally joined the landmasses approximately 3.5 million years ago.

Immediately after the formation of the Caribbean Sea, the fish species present mirrored those found in the eastern Pacific. Soon after the breakup of the two water bodies, communities on the Caribbean side began to encounter very different environmental conditions. The area available for coral growth in the Caribbean is relatively small due to great rivers such as the Mississippi and Amazon bringing large amounts of sediment into the ocean. This sediment blocks sufficient light from reaching corals and prevents their growth at the northern and southern extremes of the Caribbean. Here reef communities were further moulded by ice ages that reduced the water temperature and killed off many of the organisms that require balmy tropical waters.

The Caribbean's distinct environmental pressures helped shape the organisms into an entirely different community. Natural selection, or survival of the fittest, weeds out the species and individuals poorly suited to a given environment and helps those with traits that improve their survival. Over millions of years these pressures have gradually created Caribbean reefs that share no species identical to those in the Pacific, for example the hamlets that only occur in the Caribbean. Species that split from a common ancestor into two or more species are known as 'sister' species. An example of this are the small Pacific reef groupers that closely resemble Caribbean hinds. Both species are in fact groupers, although Caribbean species have altered slightly over time.

Species diversity is considerably higher within insular South East Asia than the Caribbean. The species count for fish or corals in one Indonesian bay can easily exceed the number of species found in the entire West Atlantic. The region contains an extraordinarily large area of shallow coral reef habitat, which appears to be imperative for high species diversity. Historically, the Pacific has been more climatically stable than the Atlantic and large reef area has provided many refuges for organisms if conditions became unfavourable. The broad north-south range of reef habitat also enabled organisms' ranges to shift as temperatures have risen and fallen.

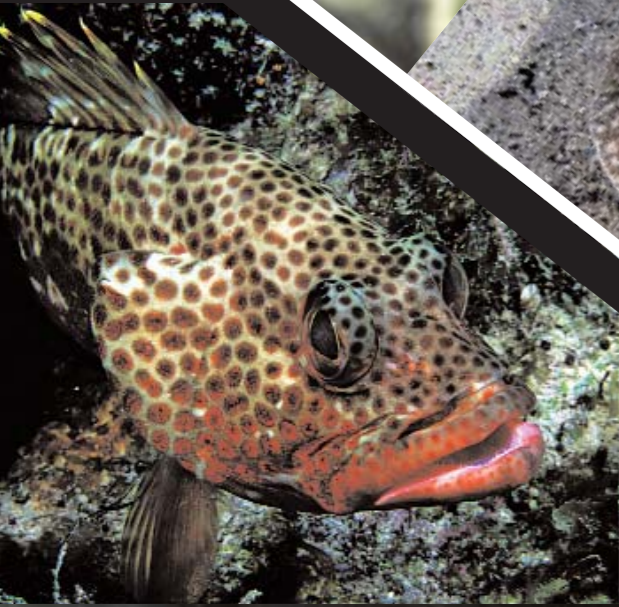
There's some debate over the explanation for such high diversity in the Asian region. One is that this is a hotbed for evolutionary change and species are created here, subsequently spreading to other regions of the Pacific. Another possibility is that the ranges of many species from the Indian or Pacific Oceans overlap in Asia causing high diversity. The former of these two possibilities appears most likely as genetic analysis of one group, the parrotfishes, shows Asia to be their original geographical home from where they spread outwards to a global distribution.

As well as having the highest number of species in the Indo-Pacific, South East Asia also has the greatest number of



Left to right

- Pyjama cardinalfish are closely related to banggai cardinalfish although have a much broader geographic range. Solomon Islands.
- The Red Sea torpedo ray is found only there, having evolved in isolation due to the frequent segregation of the sea from the Indian Ocean. Egyptian Red Sea.
- Lacy scorpionfish (*Rhinopias aphanes*), an unusual species that is found only in Southern Papua New Guinea and the Coral Sea. Milne Bay, Papua New Guinea.
- This rarely seen lionfish is known from a few locations in Indonesia and the Philippines. Species such as this add to the high diversity of this area. Alor, Indonesia.



Hinds are small Caribbean groupers, very closely related to those of the Pacific, which they significantly resemble. Turks and Caicos Islands.

Some species are very rare and may mistakenly be considered endemic, but in fact inhabit a wider range than is known. The Picturesque dragonet, a close relative of the mandarin fish, is found at very few locations in Indonesia and the Philippines. Bali, Indonesia.

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. The Red Sea has 41 species of endemic fish such as the masked butterflyfish and Red Sea anemonefish, New Caledonia has 43 including the three stripe butterflyfish and half band angelfish, the Great Barrier Reef has 33 such as the Great Barrier Reef anemonefish and Madagascar has 31 including the Reunion angelfish. The 'coral triangle' of Indonesia, New Guinea and the Philippines on the other hand outshines these areas with 90 species of fish that inhabit only these reefs. Torpedo rays from the Red Sea and Komodo are illustrated here; both have small known ranges restricted to one of these areas.

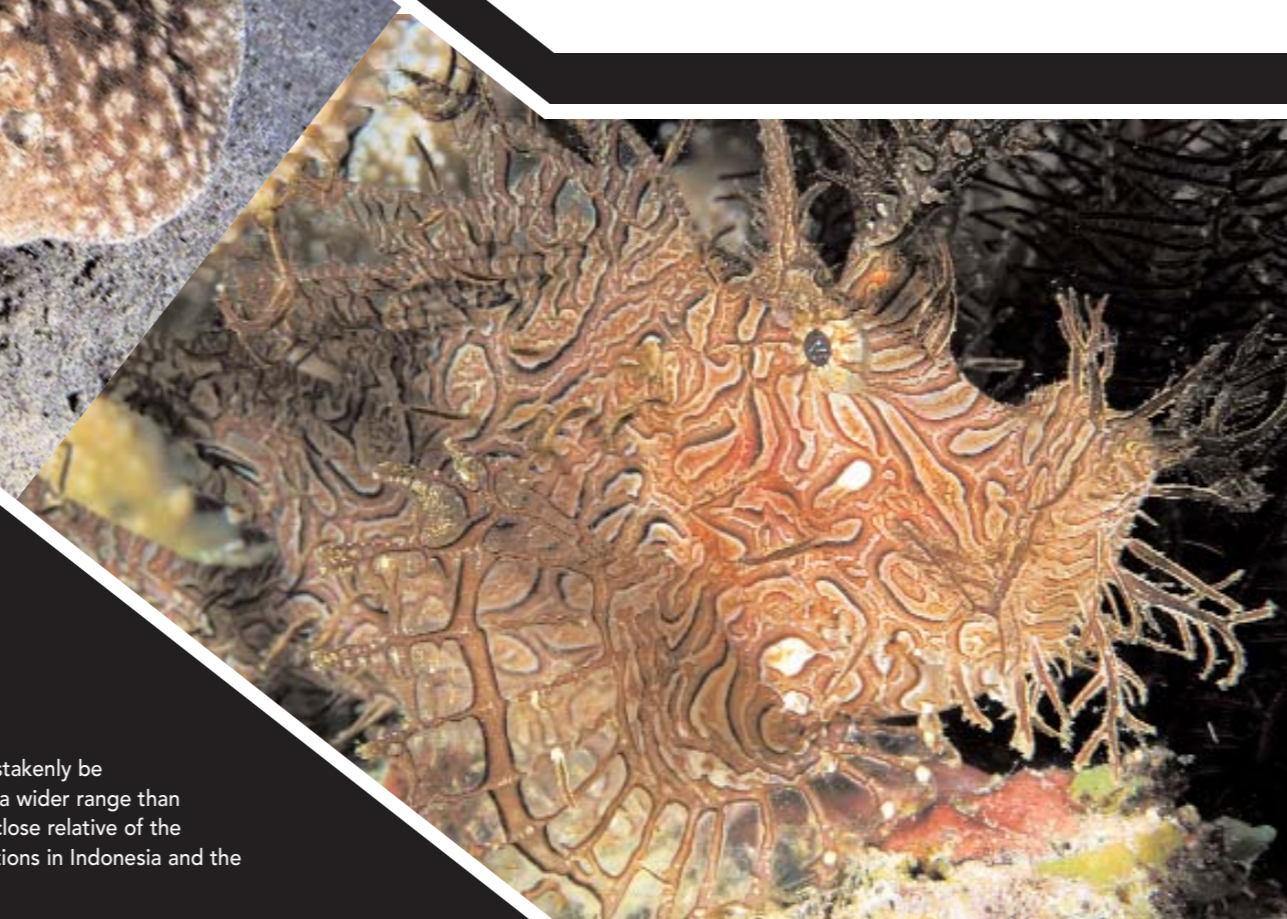
Currents play a major role in the movement of organisms within the ocean and reef communities can become isolated from others depending on local current systems. The East Australian Current moves from tropical equatorial waters to much cooler waters toward the Antarctic. This effectively backs the reef

organisms up against inhabitable cold waters, isolating the organisms from other populations and fuelling their differentiation in to 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 to become isolated, as they are able to reach distant reefs in this time. Epaulette sharks, a small carpet shark, have several regionally endemic species, the taxonomy of these is currently under revision. Milne Bay and Raja Ampat species, at opposite ends of New Guinea, have recently been identified.

Two cardinalfish species illustrate this point well. Pyjama cardinalfish, like all cardinalfishes, are mouthbrooding, meaning that eggs and young are protected in the mouth of their parent until they are ready to be released. The pyjama cardinalfish hatches its young and quickly releases them into the water to spend an extended period drifting before

finding a site to settle. The banggai cardinalfish on the other hand keeps its young within the mouth until they have grown to a relatively advanced stage of development and they settle almost immediately onto the reef. The young do not get a chance to move far from their place of birth before settling and thus do not mix on a global scale as other species do. As a result, pyjama cardinalfish can be found in many locations across the Indo-Pacific, whereas the banggai cardinalfish is naturally only known from a tiny group of islands in Indonesia.

HUMAN IMPACT: Global patterns of species diversity are naturally in a continuous state of flux as organisms colonise new areas and exploit new opportunities. Man's technological advances have had unexpected affects on reef organisms as they can now reach areas that once were well beyond their reach. The Suez and Panama Canals link bodies of water and their inhabitants, in ways that would never happen naturally and could cause dramatic disruptions as species meet for the first time. Blacktip





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1 A rare torpedo ray only commonly known from a small area in southern Indonesia. Komodo, Indonesia.

2 The Raja Ampat epaulette shark is another member of this species complex. It is known to 'walk' along the substrate feeding on small crustaceans. Raja Ampat, Indonesia.

3 The masked butterflyfish is commonly seen in pairs on reefs in the Red Sea where it is indigenous. Egyptian Red Sea.

4 Lacy scorpionfish (*Rhinopias aphanes*), an unusual species that mimics crinoids and is found only in Southern Papua New Guinea and the Coral Sea. Milne Bay, Papua New Guinea.

5 Pacific groupers are very similar to the Caribbean hinds. They have diverged since the Central American land bridge isolated the two populations. Great Barrier Reef, Australia.



◀ Milne Bay epaulette shark. One of a number of epaulette species found throughout Indonesia, Papua Nw Guinea and Australia. Milne Bay, Papua New Guinea.

reef sharks are for the first time arriving in the Mediterranean from the Red Sea, Pacific nudibranchs are arriving in the ballast water of ships in the Caribbean and Asian lionfish live in the northern Caribbean thanks to released aquarium subjects. The banggai cardinalfish has also become resident in north-west Bali and Lembeh straits in northern Sulawesi thanks to accidental or intentional release. These illegal aliens have the potential to severely disrupt their new home and the diversity that has evolved in isolation.

CONCLUSION: With very limited resources available to conservation efforts, the identification of regions containing high species diversity or many endemic organisms may help pinpoint areas for conservation priority. Whilst scientific data indicates that protection of South East Asian reefs will preserve the most species per unit area, there continues to be little conservation impetus there. Due to evolutionary processes several areas with higher than average species diversity have arisen that should receive specific conservation attention.

JARGON BUSTER

- **Evolution** – Gradual change through time from an earlier form to a new species
- **Natural Selection** – Organisms best adapted to their environment will have the highest survival and reproduction chances - survival of the fittest
- **Endemic** – A species restricted to a certain region
- **Species Diversity** – Number of species in an area or community

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