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A Journey through Lakshadweep Atolls
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*A Journey through Lakshadweep Atolls*

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ICAR

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CMFRI

Indian Council of
Agricultural Research
Central Marine Fisheries
Research Institute

**Lagoon *Ecos*** *A Journey through Lakshadweep Atolls*

ISBN 978-93-82263-80-7

Published by
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Front cover photo: The sea Goldie

Back cover: A Lakshadweep atoll





# Foreword

India, celebrated as one of the world's seventeen mega-diverse nations, holds within its expanse an extraordinary wealth of biological treasures, none more enchanting than the lagoons and reefs of the Lakshadweep archipelago. These delicate coral atolls, scattered like jewelled rings across the Lakshadweep Sea, stand as living testaments to nature's patience and precision. Their beauty is beyond words, a sight that fills the heart with wonder. Yet, they are as fragile as they are beautiful, caught in the delicate balance between ecological endurance and human intervention.

Lagoon Ecos offers a visual and narrative journey into the vibrant, interwoven ecosystems of these atolls. The images featured in this volume were captured over several years of field study by the authors, years marked by tide-bound explorations, underwater observation, and countless moments of awe in the presence of living reefs. Each photograph tells a story: of coral colonies forming the foundation of marine life, of lagoons nurturing communities of fish and invertebrates, and of the rhythmic pulse that sustains these delicate habitats.

This chronicle is a stark reflection of our times. The accelerating pace of anthropocentric development, fueled by expanding coastal activity, pollution, and climate shifts, is casting an ever-deepening shadow over the Lakshadweep reefs. Coral bleaching events, declining fish populations, and the erosion of traditional island livelihoods are not just issues; they are urgent reminders that our progress often comes at a profound ecological cost. The book invites readers not only to witness the breathtaking beauty of the Lakshadweep reefs but also to recognize and act upon humanity's shared responsibility to protect and restore them.

I congratulate the authors on this remarkable visual achievement. This book is more than a collection of photographs; it is a visual meditation on the most exquisite and vulnerable ecosystem of our planet. Through the lens of Lagoon Ecos, may we rediscover reverence for the natural world and reaffirm our role as stewards, not exploiters, of the life that thrives within these fragile, luminous waters.

# Preface

For millennia, we have measured human achievement by its architecture: the stone walls of ancient cities, the intricate defensive structures, and the monumental edifices that underpin our societies. But look beneath the waves, and you find a civilization built without human hands, a complex, defensive society defined by its intricate, living structure: the coral reef.

This is the lens through which we must view the Lakshadweep archipelago. Scattered across the vast, deep blue of the Lakshadweep Sea, these islands are not continental fragments, but the exposed rooftops of massive, underwater metropolises. Each atoll is a perfect, ancient city, constructed entirely from the skeletal remains of billions of coral polyps, the ultimate biological engineers. At the very heart of this coral civilization lies the Lagoon. This central body of protected, shallow water is the communal square, the agricultural ground, and the teeming central district. It is the perfect embodiment of the term Ecos - the Greek root meaning "house," "dwelling," or "home."

The geographic isolation of Lakshadweep, hundreds of kilometers from the nearest mainland shore, has ensured the unique character of this Lagoon Ecos. The deep ocean currents act as a constant cleansing stream, maintaining a purity that allows this complex society to thrive. We invite you to join us on the perimeter of this remarkable community, a world where every wall, every pillar, and every crevice is a testament to cooperation and survival.

The true marvel of the Lagoon Ecos is the Bloom, the sheer, audacious volume of life it supports. The soft, sunlit environment nurtures a bewildering array of species: iridescent schools of damsels; secretive moray eels peering from ancient coral heads; and the massive, yet tranquil, sea cucumbers grazing silently across the seafloor. This productivity is the ultimate testimony to the success of the atoll system.

We have captured the rules of this Ecos in action. Our lens has tracked the essential rituals of the reef: the cooperative cleaning stations where larger fish queue for tiny cleaners; the camouflaged scorpionfish ready to ambush and the intricate, working reciprocity that sustains the Ecos. From the mesmerizing ballet of the megafauna patrolling the outer edge, to the careful construction of sand castles by the shrimp-and-goby teams, every photograph tells a story of adaptation, survival, and symbiosis. But our documentation is also a reflection on fragility. Coral ecosystems, though ancient, are intensely sensitive. The concept of the Ecos, the home, implies vulnerability. When the external environment shifts, the inhabitants of the house feel the change immediately. Global threats like ocean acidification and rising sea temperatures impose an immense stress on the delicate coral polyps, the very foundation upon which these islands are built.

Through these images, we hope to establish a visual connection between the reader and the life sustained within this blue dwelling. May this book serve not just as a visual catalogue of beauty, but as an intimate record of a unique and precious habitat. For within the clear, calm waters of the Lakshadweep Lagoons lies an ecosystem, a magnificent Ecos - that deserves our careful and constant watch.



# Contents



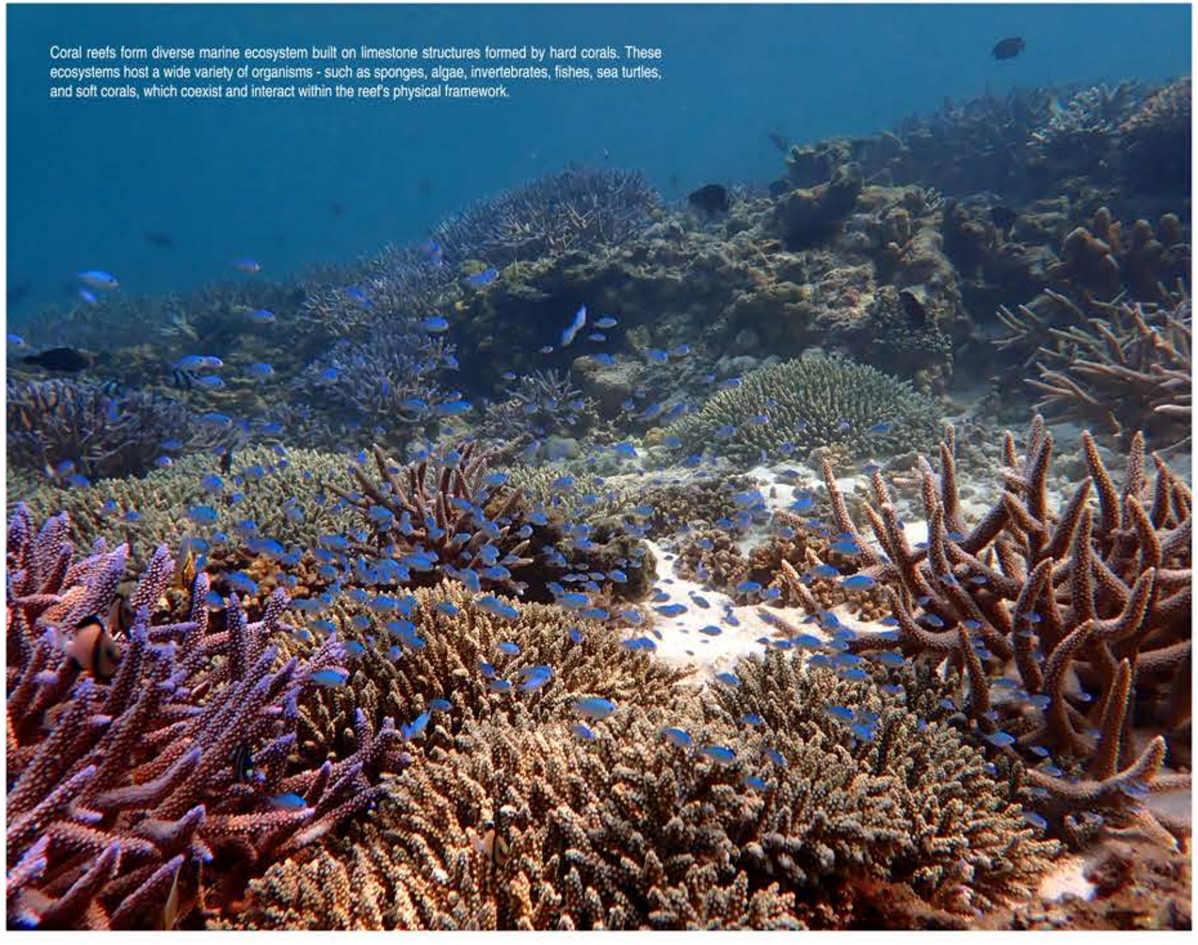
# THE CORAL SEASCAPE

Of the various ecosystems on our planet, coral reefs are undoubtedly the most artistic, showcasing a masterful interplay of structure, function, and beauty. Their intricate formations reveal the skillful balance of countless organisms working together, while their vibrant colours, shapes, and textures tell stories of innovation, adaptation, and imagination. In this harmony of complexity and creativity, coral reefs stand as living masterpieces, inspiring awe and reminding us of nature's unparalleled artistry.

At least three structurally different forms, such as the branching, foliose and boulder types, of corals together built this healthy patch in Kavaratti atoll

Certain reef sites are homogenous in its structural make up like these areas where the *Porites* sp. and the *Acropora* sp. (below) are dominant

A dom-shaped colony of *Pocillopora* sp.



Coral reefs form diverse marine ecosystem built on limestone structures formed by hard corals. These ecosystems host a wide variety of organisms - such as sponges, algae, invertebrates, fishes, sea turtles, and soft corals, which coexist and interact within the reef's physical framework.

Barred thicklip *Hemigymnus fasciatus*, Peacock hind (*Cephalopholis argus*) and Oval butterflyfish *Chaetodon lunulatus* in a dense *Acropora* patch

Every reef type, whether it is an atoll, a barrier or a fringing type, had a simple foundational history to say. They all might start from a few delicate polyp predecessors, possibly of a single species! settled on a hard substratum located on the suitable abiotic conditions. From this seemingly simple beginning, through continuous growth and the accumulation of skeletal material, the complex and biodiverse ecosystems of coral reefs arise over vast timescales. Within such a reef, spatial partitions will occur due to the dominance of a particular coral species as can be seen in these images. More elaborate and complex coral structures usually tend to attract more mobile species by providing specific niches.

Acroporid corals, showcases a remarkable array of growth morphologies. These variations are influenced by various environmental factors like light, water movement, sedimentation, temperature, and depth.



Branching *Acropora* corals provide a structurally complex habitat offering shelter, food, and nursery areas for several fish species like this school of *Chromis viridis*

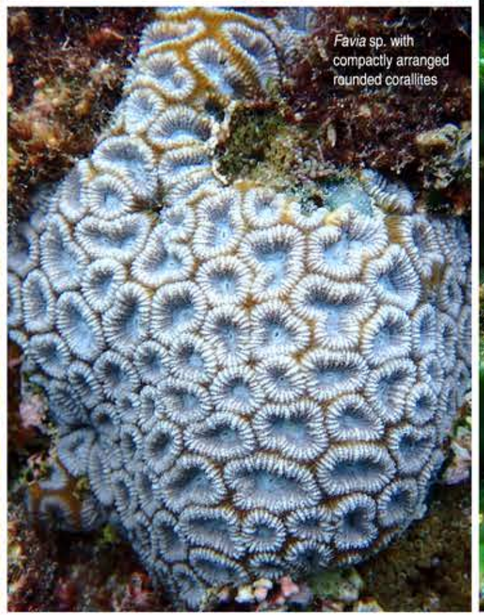
# THE CORAL INTRICACY

Corals display a remarkable diversity of architectural beauty. Coral shape is largely governed by simple growth rules that control how neighbouring polyps divide as the colony grows. These growth patterns are influenced and sometimes modified by the surrounding environment. Many coral species show different forms in deep water compared to shallow habitats. Corals also adjust their shape in response to water movement, usually growing toward the direction of currents.

Moon Coral *Diploastrea heliopora* showing plocoid coralites



*Gardineroseris* sp. with irregular polygonal calyces



*Favia* sp. with compactly arranged rounded corallites

*Fungia* corals are solitary, free-living corals with a distinctive circular, disc-like shape and radiating septa

# CLAIMING SPACE IN REEFS

Due to the abundance of marine life, reefs are limited in space. This scarcity creates intense competition among various organisms for resources such as sunlight, food, and territory. Thus, various species have evolved morphological adaptations to utilize all the available spaces in the reefs. Varying morphological adaptations in different species provided each with a means of occupying unclaimed sites. For example, prickly sea urchins occupy crevices and holes in the coral skeletons. Giant clams, which require sunlight, position themselves on large coral boulders. Likewise, Christmas tree worms can be found in large numbers on the entire surface of large boulders of *Porites* sp. Many species of small and large fish also settle in their permanent hideouts among the coral skeletons' elusive and intricate tunnelways, like the large morays and small squirrel fishes, as well as cryptic blennies.

Sea urchins exhibit burrowing behavior, carving out depressions or crevices within the reef substrate to secure space and protection from predators. These primarily nocturnal animals emerge from their hiding places at night to feed.

Slate pencil urchin *Heterocentrotus mamillatus* is known for burrowing into dead coral and seeking shelter beneath rocks

The burrowing urchin *Echinometra mathaei*

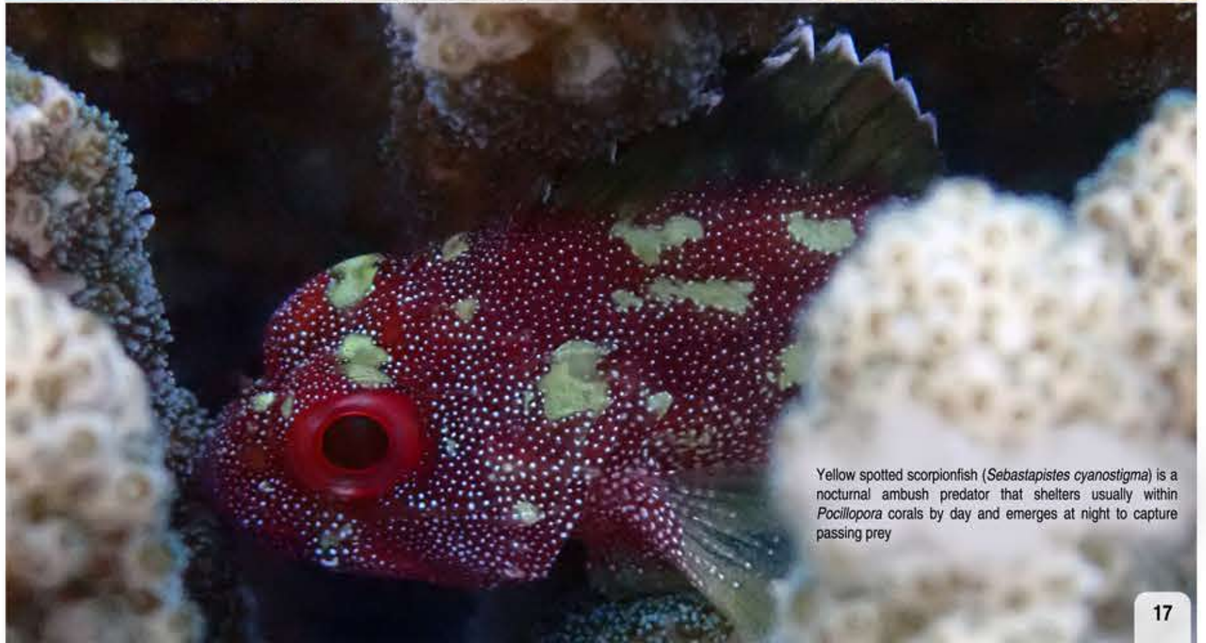


Small giant clams (*Tridacna maxima*) like this are brilliantly coloured and elegant reef inhabitants. Their large, hard bivalve shells are firmly cemented to coral rock, while the fleshy, photosynthetic mantle spreads upward like petals in bloom.

*Spirobranchus* spp., commonly known as Christmas tree worms, are widespread across Indo-Pacific reefs and occur in numerous colour morphs. These tube-dwelling annelid fanworms can instantly retract into their protective tubes, startling nearby animals with their sudden disappearance.

A fangblenny (*Petroscirtes* sp.) hiding in a coral burrow

A Gaint moray (*Gymnothorax javanicus*) emerges from its coral den



Yellow spotted scorpionfish (*Sebastapistes cyanostigma*) is a nocturnal ambush predator that shelters usually within *Pocillopora* corals by day and emerges at night to capture passing prey

## SOFT AND SPONGY

Amidst the hard foundation of the reef lies the velvety and porous framework of soft corals and sponges. These organisms enhance structural complexity while performing vital functional roles within the reef ecosystem. Unlike their stony counterparts, their skeletons comprise calcite spicules embedded in an organic matrix. Sponges, in particular, play indispensable roles in regulating microbial communities and recycling nutrients, thereby sustaining reef health.

Soft corals of the genus *Dendronephthya* known for their tree-like morphology

A sea fan (gorgonian) sways gracefully against a vibrant reef wall as a school of fusiliers glides past in the background.



Soft corals of the genus *Sarcophyton* occur in large lobed forms

Sponges in the reefs play prominent roles as filter feeders, binders as well as bioeroders

Encrusting sponge *Clathria* sp.

# SENTINELS OF THE REEF

Although coral reefs cover less than 1% of the world's ocean surface, they provide habitat for approximately 25% of all marine fish species. These fish play essential roles in coral reef ecosystems by functioning as grazers, predators, and prey, helping to maintain the reef's health and stability. Reef fish possess diverse adaptations such as camouflage, specialized feeding strategies, and distinctive body structures, allowing them to thrive in the coral reef environment.

The emperor angelfish *Pomacanthus imperator* under the ledge of coral



A vibrant group of threadfin butterflyfish (*Chaetodon auriga*) foraging around a table coral

A pair of Scrawled butterflyfish (*Chaetodon meyeri*)

Lemonpeel angelfish (*Centropyge lavissima*)

Most reef fish have distinct body shapes compared to pelagic species, which are typically built for speed with torpedo-like bodies to minimize friction. In contrast, reef fish navigate complex and confined coral reef environments, where agility is more critical than speed. Consequently, they have evolved body structures that facilitate quick directional changes and rapid darting movements, allowing them to evade predators and forage along coral surfaces by weaving through reef crevices.

Butterflyfish and angelfish, for example, have laterally compressed, deep-bodied shapes rather than elongated forms. Their pectoral and pelvic fins are specially adapted to enhance manoeuvrability, working in coordination with their streamlined shape to navigate the intricate reef landscape efficiently.

A school of Redtail butterflyfish (*Chaetodon collare*)

Moray eels (*Gymnothorax* spp.) are apex predetors of the reefs. They are usually nocturnal and hunts fish, crabs and octopus among other reef animals.



Parrotfish maintain a complex and dynamic relationship with coral reefs. They are essential reef cleaners by grazing constantly on algae, thus preventing algal overgrowth. They act as bioeroders, producing sand and ensure nutrient recycling.

This Peacock Rockcod (*Cephalopholis argus*) is a mid-level ambush predator in the coral reefs

Damselfishes such as (*Stegastes* spp.) maintain algal turfs within their small, fiercely defended reef territories. They actively weed out less palatable algae and protect their 'farms' from grazers such as parrotfish and surgeonfish.

The Holocentrids like these tailspot squirrelfish, are prominent nocturnal predators in the reefs and their diet consists of mainly small invertebrates. They are generally social and can be seen hiding in coral crevices and caves during the day.

Many reef fishes are poisonous. The stonefish, considered one of the most venomous fishes in the world, has an exceptional ability to blend seamlessly with surrounding rocks, making it nearly invisible to predators and unsuspecting prey.

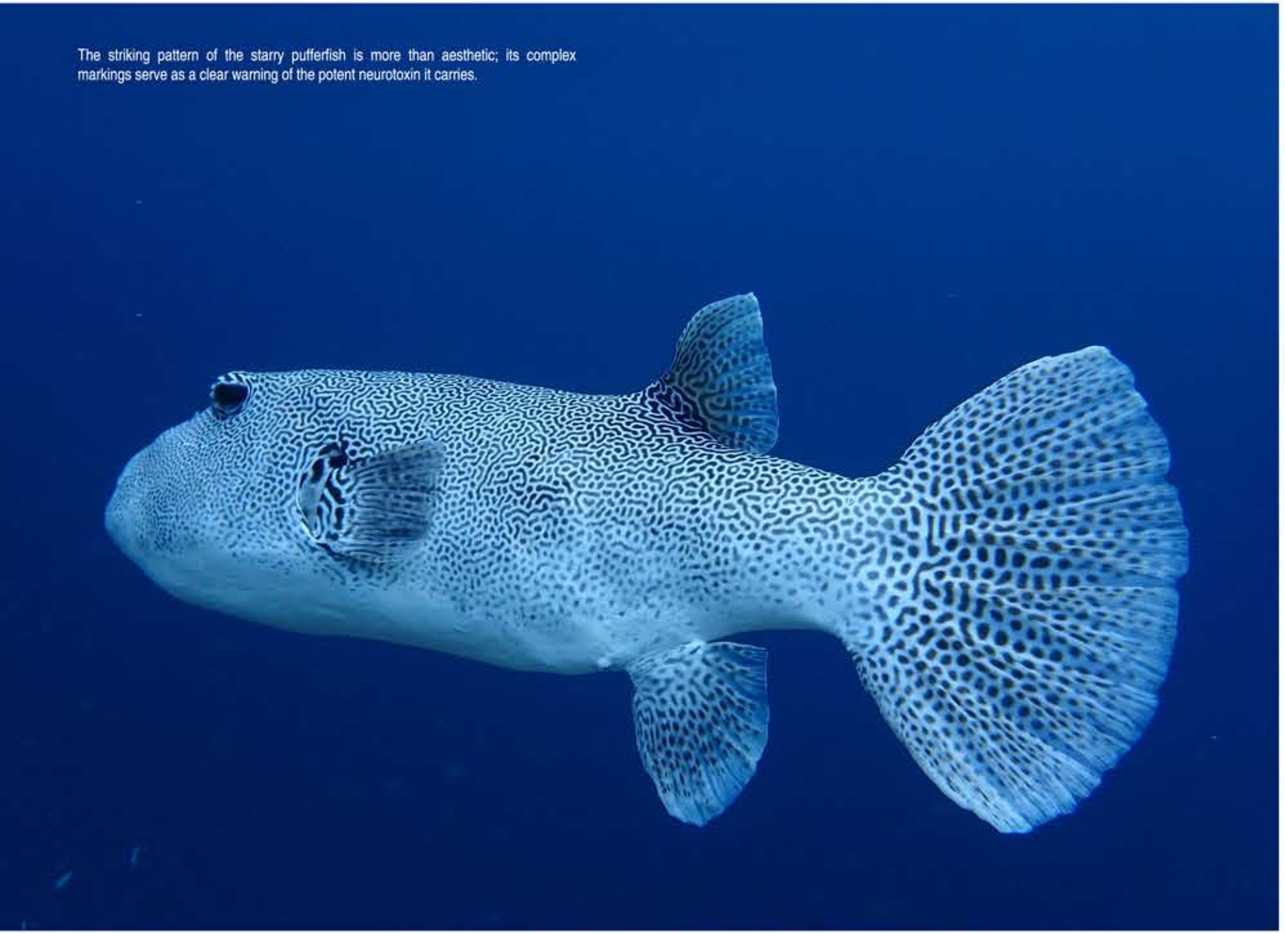
Spot-fin porcupinefish (*Diodon hystrix*) is a solitary species, with scales modified into sharp spines. They can inflate by swallowing water to deter predators.

Clearfin lionfish (*Pterois radiata*)

Lionfishes are both captivating and intimidating, bearing venomous spines and displaying some of the most vibrant coloration among fishes.

Starry pufferfish (*Arothron stellatus*) on the sandy reef floor

The striking pattern of the starry pufferfish is more than aesthetic; its complex markings serve as a clear warning of the potent neurotoxin it carries.



*Gobiodon citrinus*, commonly known as the poison goby, is a coral-associated reef species, predominantly in close association with branching Acroporids. This species secretes a mucus layer that contains toxic compounds, serving as a chemical defense mechanism.

Dog-faced puffer (*Arothron nigropunctatus*) is an attractive solitary species. They possess the potent neurotoxin tetrodotoxin as a defense against predators.

A school of goldspot seabream (*Gnathodentex aureolineatus*) foraging on bottom dwelling invertebrates

Many reef fish species have evolved specialized feeding techniques, featuring advanced mouth structures, jaws, and teeth adapted to their primary food sources within coral ecosystems. Additionally, many species alter their diets as they mature, which is unsurprising given the vast diversity of prey available in coral reef environments.

This Arc eye Hawkfish (*Paracirrhites arcatus*) an ambush predator perches atop corals, propped up on its strong pectoral fins, ready to snatch passing prey.

Yellow Longnose Butterflyfish (*Forcipiger flavissimus*) uses its elongated snout to reach small crustaceans, worms, and other tiny prey hidden among coral branches and within narrow reef crevices

Reticulate pipefish (*Corythoichthys conspicillatus*) foraging among algae. A close relative of seahorses, it possesses a tubular snout, a toothless mouth, and in males, a brooding pouch where the eggs are incubated.



Coral reef fish exhibit a remarkable diversity of vibrant and often unusual colour patterns, in contrast to many other fish species that are typically counter-shaded with silvery tones. These colour patterns serve multiple functions. In some cases, they provide camouflage, allowing fish to blend into their surroundings. During reproduction, distinctive coloration aids in species recognition. Additionally, some fish use bold, contrasting colours as a warning signal to predators, indicating the presence of venomous spines or toxic tissues.

A longfin rockcod (*Epinephelus quoyanus*) is a small, solitary grouper commonly found in shallow Indo-Pacific reefs. This species, along with other serranids, forms one of the major predatory fish groups within reef ecosystems.

Blue-lined surgeon (*Acanthurus lineatus*) is a major herbivore on coral reefs, which usually move in groups.



Speckled sandperch (*Parapercis hexophtalma*) is best adapted to sandy reef areas with scattered rubbles that perfectly match it's coloration.

A golden striped soapfish (*Grammistes sexlineatus*) taking refuge in a coral crevice.

Leopard blenny (*Exallias brevis*) perfectly blending with the reef floor



Oneline cardinalfish (*Pristiapogon exostigma*) seeking shelter among coral crevices in a reef habitat

This Orange-lined trigger (*Balistaspus undulatus*) found a hideout enough to lock its trigger spines to escape from an approaching predator

Lawnmower blennies (*Salarias fasciatus*) are masters of camouflage, displaying a mottled pattern of bands, stripes, and spots in shades of brown, green, and cream, helping them blend effortlessly into their reef surroundings

# THE HIDDEN HALF

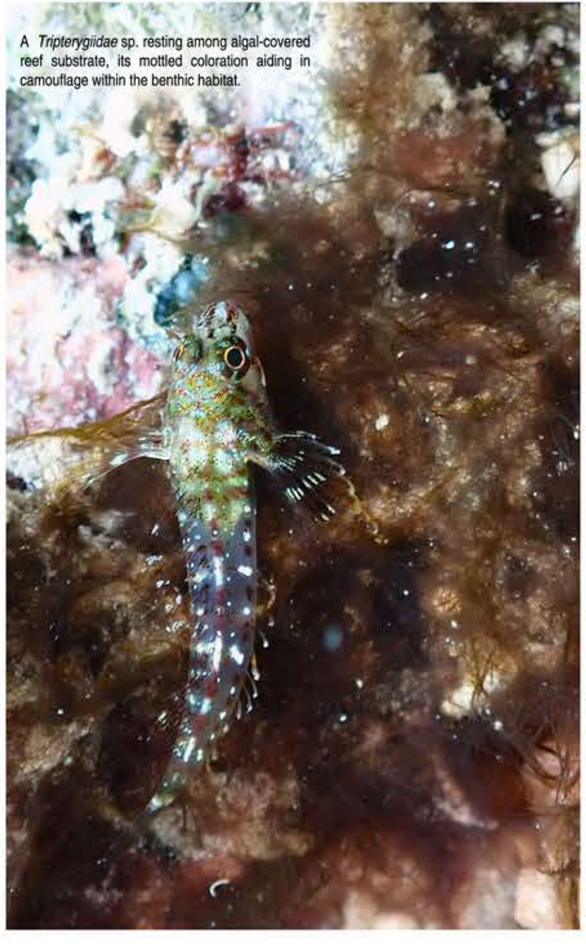
Cryptobenthic fishes are small, bottom-dwelling species typically less than 5 cm in length. They are visually and/or behaviourally cryptic and maintain a close association with the benthic substrate. This group, which includes gobies, blennies, and cardinalfishes, represents one of the most diverse yet often overlooked components of coral reef ecosystems. Despite their diminutive size and secretive behaviour, cryptobenthic fishes play a crucial ecological role in reef functioning. Their rapid life cycles and high turnover rates make them an essential component of coral reef food webs.



Yaeyama blenny (*Ecsenius yaeyamaensis*) perched on a coral rock, blending seamlessly with its reef habitat while surveying its surroundings.

This diminutive Eviota Goby exhibits spectacular cryptic coloration

Tropical striped triplefin (*Helcogramma striata*) is normally found perched on coral or other hard surfaces where it watches for drifting food



A *Tripterygiidae* sp. resting among algal-covered reef substrate, its mottled coloration aiding in camouflage within the benthic habitat.

Eviota mikiae perched on a coral-encrusted substrate, its translucent body and fine stripes providing excellent camouflage within the reef microhabitat.

Bicolour blenny (*Ecsenius bicolor*) lives in crevices on coral reefs and found in three distinct colour forms. The two-coloured form is bright orange posteriorly. The second form is dark brown (top left) all over, and the third form has a more complex pattern with a black and a white stripe along the body. All three forms have a curved pinkish marking behind the eye.

# EARLY LIFE AMIDST THE REEF

Coral reefs serve as essential refuges and nurseries for juvenile fishes, offering abundant shelter, food, and protection from predators. The complex structure of corals with their crevices, branches, and overhangs provides ideal hiding spaces where young fishes can grow and develop with reduced risk.

A blackfinned anemonefish (*Amphiprion nigripes*) tending its eggs

A dense school of juvenile fish utilizing a coral reef crevice for shelter and defense against predators

# THE GREAT CORAL REEF HIDE-AND-SEEK

Reefs are sites of incessant interaction, where food webs are immensely intricate due to the participation of diverse groups of interplaying organisms. As "eating and being eaten" is the universal norm here, animals resort to stealth as a means to deceive prey or predators. Thus, they evolve complex physiological and ecological mechanisms to blend in with the reef's physical settings. Physiologically, they can change skin color and patterns through the use of pigments, involving complex biochemical processes and hormonal regulation. Ecologically, they can adapt their coloration to match their specific environment.

Fishes of various families especially the Synancieds (Stonefishes) are adept in background matching and thereby ensuring an extended survival



Stonefishes usually hide in plain sight within the degraded reef patches. They seem to be imperturbable towards approaching humans as they often hold their fins even when we breach an expected escape distance.

A juvenile Cigar Wrasse (*Cheilio inermis*) utilizes the linear shape and coloration of the surrounding seagrass blades for flawless camouflage

A minute Triplefin blenny rests perfectly camouflaged among the turf algal bed

A small Gracile lizardfish (*Saurida gracilis*) rests motionless among algae-covered rocks, its mottled body blending perfectly with the surrounding reef floor

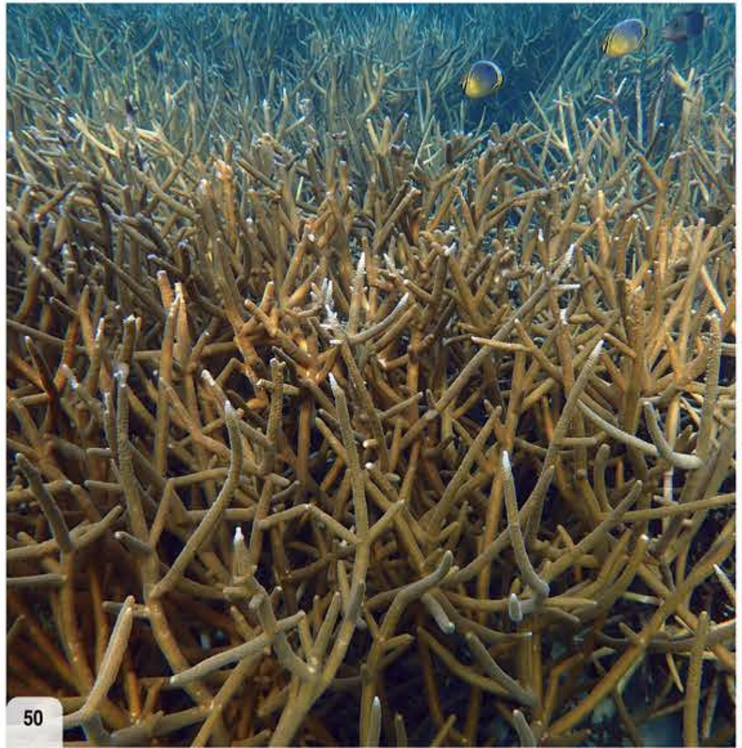


Octopuses present another brilliant case of disguise in reef settings. Together with their ability of rapid flight through water and the instant swapping of colours, like flashing colour lights in a moving object, they evade as well as embarrass predators.

A camouflaged stingray partially buried in sandy substrate, seamlessly blending with the seabed as it rests and avoids detection.

# MUTUALISM: THE ART OF REEF PARTNERSHIPS

A reef exists through countless biological agreements, and the strength of these partnerships supports the very survival of the ecosystem. Fundamentally, a reef is a mutualistic system; without the enduring coral polyps-zooxanthellae partnership, reefs would cease to exist. This fundamental interaction that build a reef is reflected in many reef partnerships such as cleaner fishes and their clients, clownfishes and sea anemones, cooperative hunting between groupers and giant moray eels as well as the defensive partnership between gobies and pistol shrimps.



Climate change is the biggest threat to coral reefs, and is making marine heatwaves hotter, longer and more frequent. When ocean temperatures remain elevated for extended periods, corals become stressed and expel the symbiotic, zooxanthellae, that live within their tissues. These algae provide corals with essential nutrients and energy through photosynthesis, supporting their growth and reproduction. When environmental conditions such as temperature, light, or nutrient levels fluctuate, corals become stressed and expel the symbiotic algae within their tissues, resulting in a complete loss of color known as coral bleaching. While some corals can survive temporarily by other means of feeding, most eventually starve without zooxanthellae. Recovery is possible if conditions improve, but full reef restoration can take a decade or longer.

A bleaching episode at Agatti Island, Lakshadweep

The anemone-clownfish symbiosis, one of the most celebrated partnerships in nature, still surprise researchers by the mechanisms that facilitate the clownfishes in avoiding anemone stings, the secrets behind the obligate partnership between the spinecheek clown and the bubble tip anemone as well as the factors that limit mutualism in just ten out of the thousand species of anemones.

*Amphiprion nigripes* peeks its surrounding



Tiny, vibrant coral crabs reside among the branches of Pocilloporids forming a mutually beneficial symbiotic bond in which the coral provides the crabs protection, while the crabs help maintain the colony by removing debris and sediment

Goby watching over as the shrimp brings out sand from their hole. The shrimp constructs and maintains a shared burrow while the fish provides protection from predators.

A giant moray eel pauses as a cleaner wrasse tents to it

# REEF MIMICS: MASTERS OF DISGUISE

Mimicry on coral reefs is a fascinating survival strategy that has evolved in various marine species. Many have developed a superficial resemblance to species with which they share no close taxonomic relationship.

Sea slug *Phyllidia varicose*

Juvenile of sea cucumber *Pearsonothuria graeffei*

Juveniles of *Pearsonothuria graeffei* have vibrant coloration, typically white and blue or black, with several large, yellow, thorn-like projections. This striking appearance closely mimics the sea slug *Phyllidia varicosa*, whose bright colors serve as a warning to predators about its toxicity. As sea cucumbers grow, their appearance gradually changes, rendering the mimicry less effective.



*Plagiotremus phenax* (Above) mimics the color pattern of sympatric members of another fangblenny species, *Meiacanthus smithi* (Below). The noxious mimic benefits to some extent by resembling a non-aggressive species, allowing it to approach its victims unnoticed a strategy known as aggressive mimicry. An even greater advantage arises from the venomous fangs of Meiacanthus blennies, which likely deter predators and defensive responses from the victims of Plagiotremus. Therefore, the *Plagiotremus-Meiacanthus* mimicry is also an example of Batesian mimicry.

Bluestriped fangblenny (*Plagiotremus rhinorhynchos*)
a specialised mimic of juvenile bluestreak cleaner wrasse

Juvenile bluestreak cleaner wrasse

Indian Mimic goatfish (*Mulloidichthys ayliffe*) often found in mixed schools searching for food over coral and rocky reefs, mimicking the Bluestripe snapper (*Lutjanus kasmira*) with which they take shelter during the day



Indian Mimic goatfish schooling together with Bluestripe snapper

Myrichthys colubrinus, commonly known as the banded snake, mimics a venomous sea snake

# JEWELS OF THE SEA

Nudibranchs, often referred to as "sea slugs," are among the ocean's most colorful and captivating creatures. The name nudibranch means 'bare' or 'naked gill'. These soft-bodied molluscs come in an astonishing variety of shapes and patterns, resembling living jewels gliding across the seafloor. Unlike most molluscs, nudibranchs shed their shells after their larval stage and rely on chemical defences instead. Many species absorb toxins from their prey, such as sponges, and use them for protection.

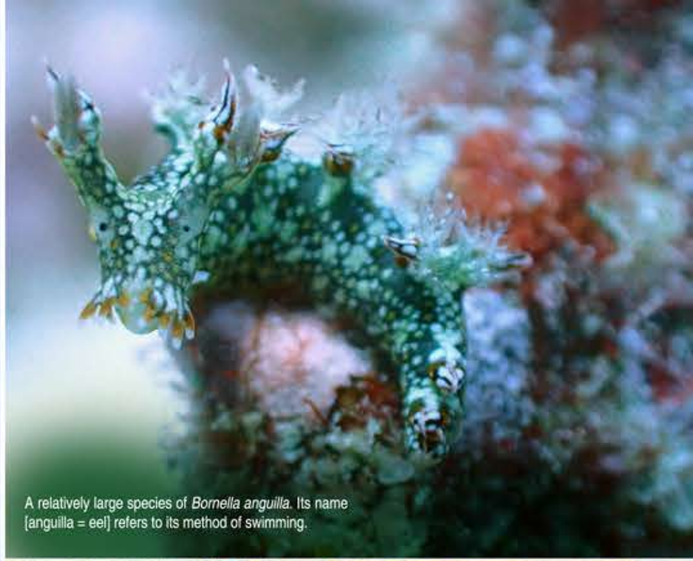
*Glossodoris* cf *cincta*



*Robastra gracilis* is a relatively small nudibranch found in the Indo-Pacific Ocean

*Glossodoris atromarginata*

Solar powered sea slug *Elysia* sp. feeds on a patch of macroalgae, extracting live chloroplast cells that accumulate within its own tissue



A relatively large species of *Bornella anguilla*. Its name [anguilla = eel] refers to its method of swimming.

A pair of bubble snails *Haminoea cymbalum*

## CLAWS BENEATH THE CORAL

Shrimps, crabs, and lobsters, though often small or hidden, play vital roles in maintaining the reef's delicate balance. They occupy interstitial spaces within the reef structure, contribute to nutrient cycling, bioerosion, and the maintenance of benthic community dynamics.

A vividly coloured peacock mantis shrimp (*Odontodactylus scyllarusrests*) among coral rubble, its striking exoskeleton and powerful raptorial claws revealing the beauty and strength hidden within the reef's crevices



A convex reef crab *Carpilius* sp.

Banded coral shrimp (*Stenopus hispidus*) It is a cleaner shrimp that signals passing fish by gently waving its long white antennae

A white spotted hermit crab (*Dardanus megistos*) tucked within its borrowed shell

## THE STARS OF THE REEF

Starfish, often referred to as sea stars, are not closely related to fish at all. Unlike fish, which possess bilateral symmetry with distinct left and right sides, sea stars exhibit radial symmetry. Their bodies are organized around a central disk, from which their arms extend outward. Sea stars have existed long before dinosaurs walked the Earth, but predicting how much longer they will thrive is challenging. They are highly sensitive to marine pollution, making them valuable indicators of a marine ecosystem's health. However, their habitats have suffered significant damage in recent years due to the growing frequency of natural disasters, rising ocean temperatures caused by global climate change, and the discharge of wastewater into the sea.

*Linckia laevigata*, a slender-armed seastar found in crevices on shallow reefs and under rocks on the reef flat

Cushion star (*Culcita novaeguineae*) foraging at the reef edge

Granular Sea Star (*Chorisater granulatus*) showcases its plump arms as it rests on the reef

Some sea stars can be surprisingly ruthless. In addition to preying on shells, they can devour entire coral colonies. A prime example is the Crown-of-Thorns Sea star (*Acanthaster planci*)



Feather stars are fascinating marine invertebrates known for their delicate, feathery arms that sway gracefully in ocean currents. These ancient echinoderms thrive in diverse marine environments, from shallow coral reefs to deep-sea floors. To secure the most advantageous position, they climb tall structures using tiny feet called cirri and extend their tentacles in elegant, fountain-like sprays.

Red feather star (*Himerometra robustipinna*)

# THE ROOMBAS OF THE OCEAN

Sea cucumbers are the most prominent detritivores in a coral reef. They are commonly found in the back-reef sandy areas. They digest organic matter within the sediments they ingest, helping to cleanse the seafloor and enhance overall coral reef health. Sea cucumbers have been heavily exploited for their meat and other products, leading to significant population declines and functional extirpation in some regions.

*Pearsonothuria graeffei* is a scavenger and roams around the coral reef substrate with its feeding tentacles

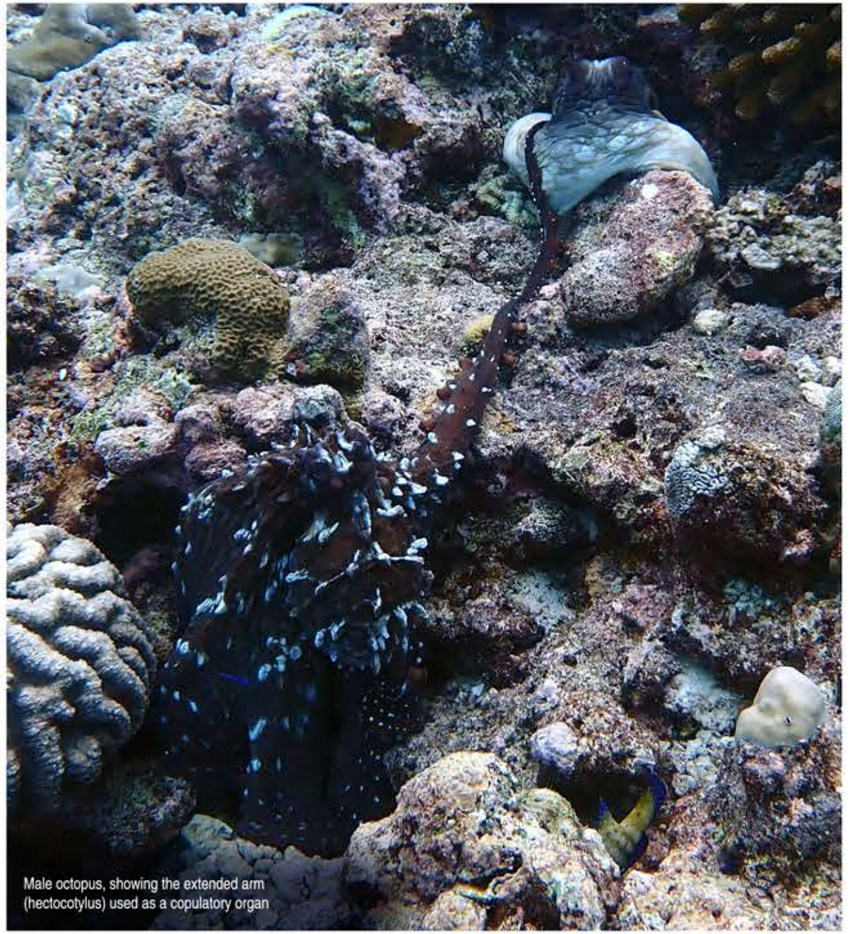
Pineapple sea cucumber (*Thelenota ananas*) has a unique star-shaped, spotted teats covering the entire body

*Stichopus chloronotus* or the greenfish foraging in an algal patch at Kavaratti atoll

During spawning, sea cucumbers adopt a "cobra-like" posture, raising their front end higher than the rear, as depicted below. The larvae drift in the water column for several weeks before settling on the ocean floor, where they take several years to mature to their full size.

# MINDS BENEATH THE REEF

Belonging to the family of cephalopods, the octopus stands out not only for its unique appearance but also for its extraordinary cognitive and physical abilities. Often hidden within crevices or blending seamlessly with the coral, these soft-bodied creatures are masters of deception, strategy, and curiosity. Equipped with a highly developed nervous system and capable of problem-solving, learning, and even play, octopuses represent one of the most remarkable examples of intelligence in the marine world.



Male octopus, showing the extended arm (hectocotylus) used as a copulatory organ

# GUARDIANS OF CORALS

Green and hawksbill sea turtles depend on seagrass beds as a main food source. By grazing on seagrass, they prevent overgrowth that could shade underlying coral reefs and help control algal accumulation. In the process, turtles ingest algae that might otherwise settle on corals and impede their growth. Their digestion produces nutrient-rich waste, and when deposited near reefs, it provides essential nutrients like nitrogen and phosphorus to support the reef ecosystem. Sea turtles unintentionally support coral reproduction by dispersing coral larvae. When they consume coral polyps, the undigested larvae are expelled in their faeces, enabling corals to colonize new areas. This process is important for the growth and genetic diversity of coral reef populations.

A hawksbill turtle roaming around the forereef slope



Green turtles are relatively common in shallow lagoons, yet they face persistent threats from ghost nets and vessel mooring ropes.

# NOCTURNAL LIFE IN THE REEFS

At night, herbivores like this parrotfish retreat to shelter, making way for nocturnal carnivores, some of which possess unique adaptations that allow them to hunt effectively in total darkness.

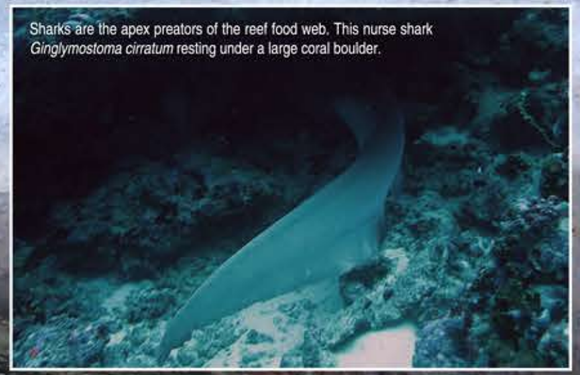
A sleeping parrotfish encases itself in a self-produced mucous bubble, which helps conceal its scent from nocturnal predators such as sharks and eels



At night, most coral polyps expose their tentacles. A colony of *Goniopora* sp. coral has come to life by stretching its tentacles to catch prey

A feather star spreads its delicate arms to capture zooplankton. These crinoids often gather in small clusters and return to their preferred spots each night, clinging with gripping appendages known as cirri.

A bignose unicorn fish *Naso vlamingii* resting under the safety of a coral cave



Sharks are the apex preators of the reef food web. This nurse shark *Ginglymostoma cirratum* resting under a large coral boulder.

A green sea turtle searching for a peaceful spot in the coral reef at night

# BATTLEGROUND BENEATH THE WAVES

Coral reefs are vibrant ecosystems where space is a highly contested resource among sessile organisms like corals, sponges, and algae. These organisms compete for substrate through overgrowth, shading, allelopathy, and physical aggression.

*Atriolum robustum* is a colonial tunicate growing over massive *Porites* sp. potentially impacting the coral's health and growth



A dynamic underwater scene shows intense competition for space between coral, sea anemones and ascidians on a reef. The vibrant contrast highlights the struggle for dominance in this complex marine ecosystem.

Different coral species also compete for space; here, massive *Porites* and encrusting *Pavona* are actively competing.

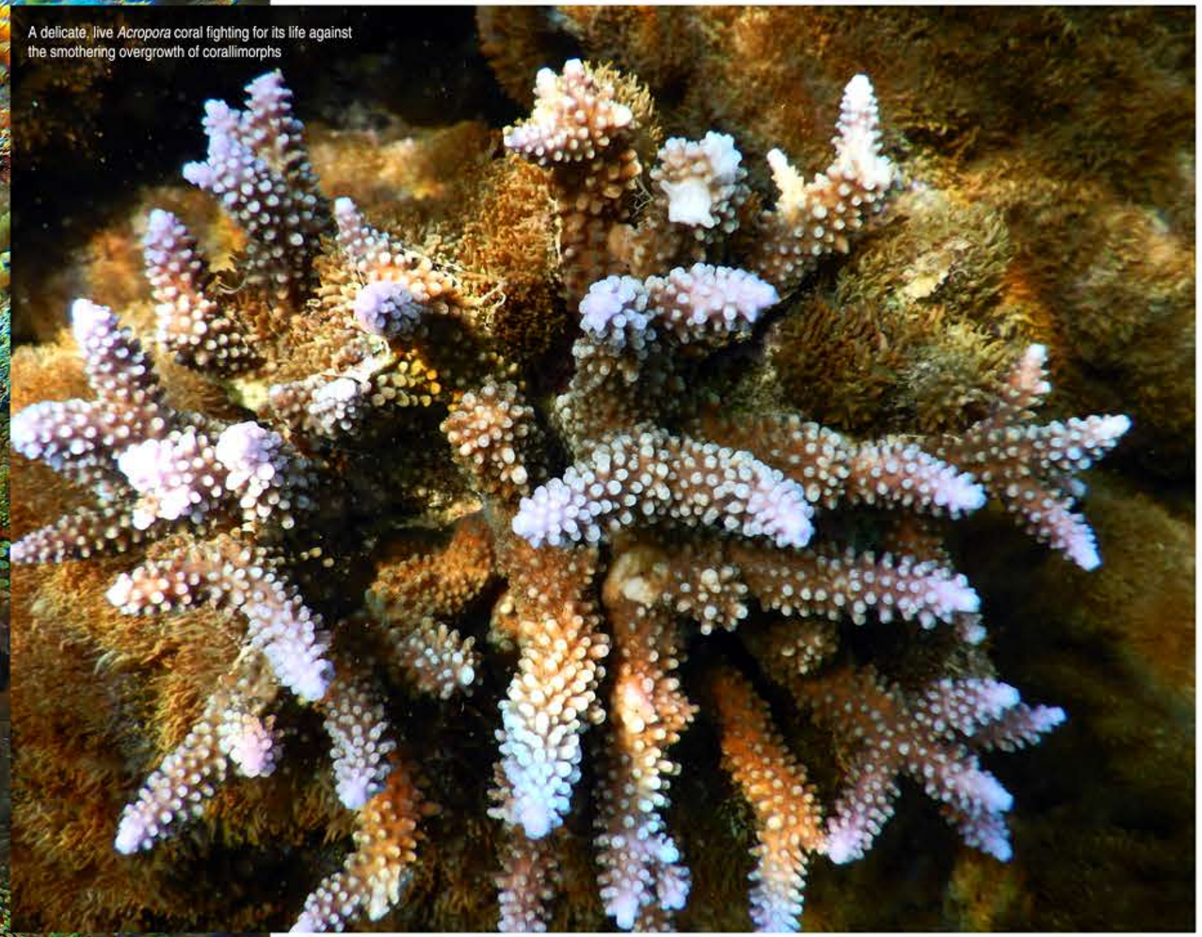
Zoanthids can be aggressive competitors with corals on coral reefs, potentially inhibiting coral growth

Macroalgae often dominate the reef following a major disturbance that had initially damaged the corals. Sometimes, these facilitations by climatic factors lead to a phase shift, where macroalgae can outcompete corals and will become the dominant inhabitants on the reef.

# LIFE AND DEATH STRUGGLES

As space is among the key limiting factors on reefs, intense and relentless competition arises among organisms at various levels. An atoll reef structure, primarily formed by the accreted calcium carbonate from coral polyps, became the venue for fierce competition among multitudes of marine animals. Even the foundational organisms, corals, must compete with other cnidarians like sea anemones and corallimorphs, as well as various macroalgae, for space to grow and prosper. These competitions might not be even, with those possessing superior survival strategies emerging victorious while others may be forced to retreat temporarily.

Sea anemones can experience explosive growth, dominating the entire reefal substratum and leading to the death of corals and the degradation of their skeletal framework. This rapid expansion, often facilitated by changes in the physico-chemical conditions of the water, can result in the demise of all other sessile invertebrates.



A delicate, live *Acropora* coral fighting for its life against the smothering overgrowth of corallimorphs

Stressors are all around a reef enough to threaten its existence. Thermal stress is among the primary dangers that can wipe out a healthy coral ecosystem. The bleaching events due to a temperature rise could be irrevocable if the stressors continue to act and the destruction can be hastened by macroalgal growth.



Amidst the ghostly remains of bleached coral, a resilient sea anemone clings to life

# THE ATOLL AVIARY

Atolls offer varying habitats such as lagoon, reef flats, motus, and open ocean surroundings for birds to thrive. Many atolls of the Indo-Pacific, including a few in Lakshadweep are prime hatcheries of seabirds. Such atolls may be vegetated or barren, and various bird species are adapted to breed in such specific topography. Besides such breeding species, atolls receive migratory birds from the temperate, subpolar and polar terrains and oceans. They prey upon the shoreline benthic organisms and the lagoon fishes. Intertidal pools, exposed and worn-out coral outcrops as well as coral rubbles washed ashore offer varying microhabitats for species to forage.

Ruddy Turnstones are known to efficiently harvest the hidden prey by turning the rubbles on the shoreline. Groups of this wintering species are ubiquitous in the supralittoral and intertidal zones of Lakshadweep atolls.

Breeding pair of Brown Noddies at the Pitti islet

Two species of crested terns viz, Lesser crested and Great crested frequent the waters of Lakshadweep. These elegant oceanic terns are among the important pelagic feeders in these areas.

This Tibetan Sand Plover migrates to the islands in winter months after traversing Indian subcontinent from their central Asian breeding grounds.

Pacific Golden Plover is charismatic in appearance with its gold-spangled plumage. This species, known for its impressive long-distance migration, traverses the Pacific to reach its tropical wintering grounds.

Gray Plover (*Pluvialis squatarola*) usually solitary, which forages in intertidal pools and along sandy beaches, feeding on molluscs, polychaetes, and crustaceans.

Black-tailed Godwit (*Limosa limosa*) is a long-distance migrant and a winter visitor to India, usually flocking in large numbers in inland wetlands. This vagrant individual foraging at Lakshadweep is probably having a special diet than its main land companions.

Sanderling *Calidris alba* is a small, energetic species renowned for its distinctive behavior of running back and forth along sandy beaches, chasing the receding waves as it forages.

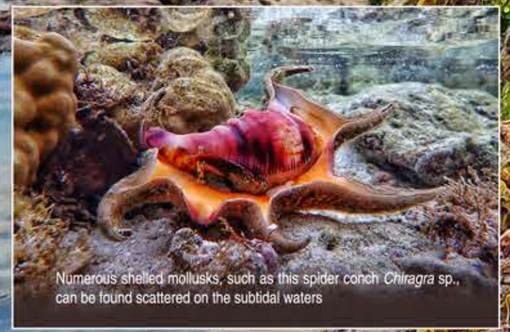
# THE TRANSIENT BORDER

*Eriphia sebana* is a common inhabitant on the intertidal habitats foraging on algae, thereby controlling the algal overgrowth

Shorelines are dynamic environments where diverse marine species have adapted to changing conditions. Atoll reef shorelines are composed of coral sand and weathered coral skeletons, constantly influenced by tidal cycles. Lagoon shores serve as intermittent feeding grounds for various species such as crabs, mollusks, and shorebirds. Tidal pools on rocky shorelines provide temporary habitats for small fish, sea cucumbers, gastropods and even large fishes like eels and rays. These areas support the growth of seaweeds and seagrasses as well, often thriving on degraded coral patches and sandy bottoms.

Coastal crab species like *Eriphia* sp. and *Ocypode* sp. are frequently found in coral rubble and sandy beaches. Numerous hermit crabs, which inhabit empty gastropod shells and scavenge on washed-up marine animals, provide valuable ecosystem services.

Ubiquitous Horned Ghost crab *Ocypode ceratophthalmus* in its foraging zone



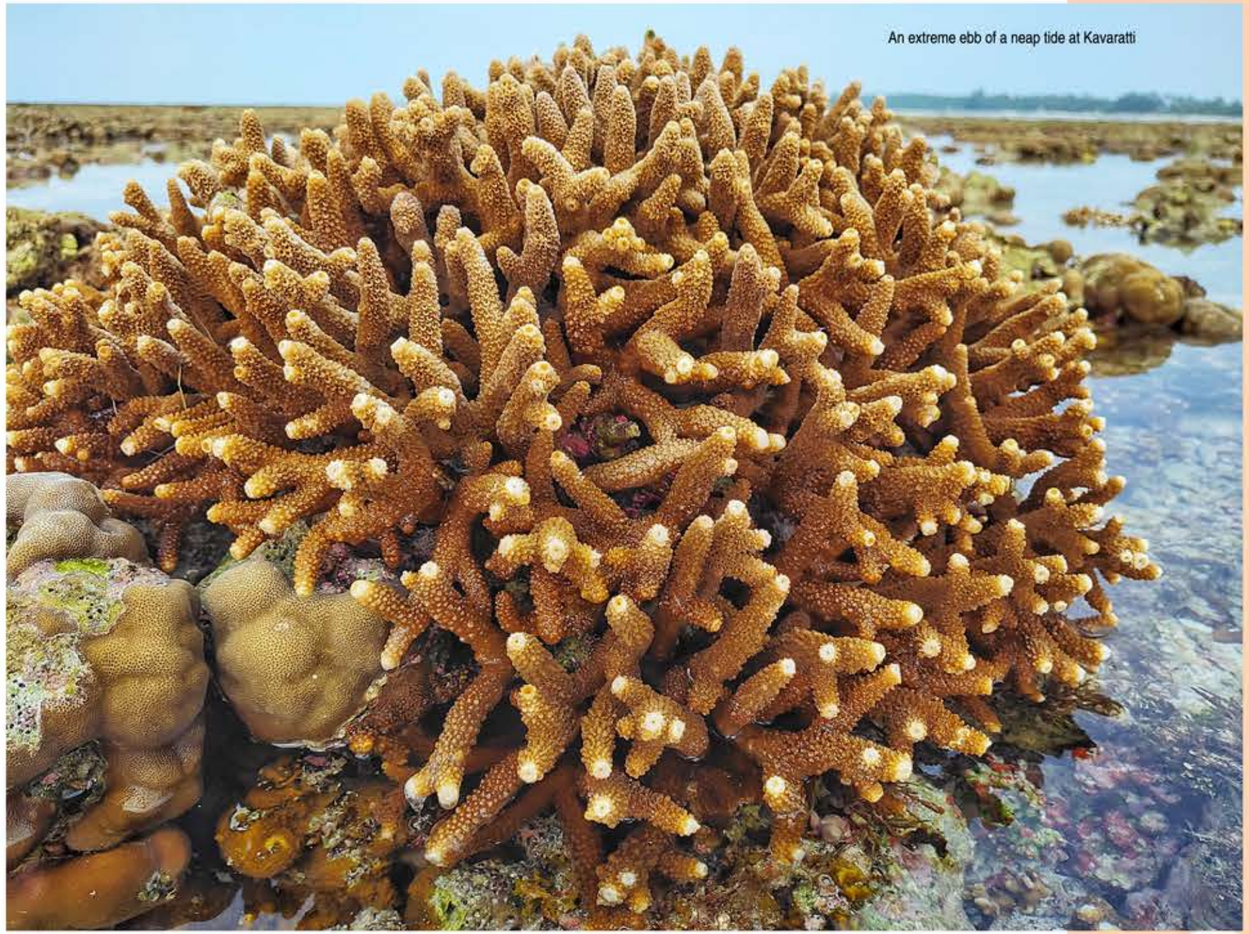
Numerous shelled mollusks, such as this spider conch *Chiragra* sp., can be found scattered on the subtidal waters

Mottled Lightfoot Crab *Grapsus albolineatus* commonly found on rocks and coral reefs in the inter tidal zone

The exposed reef flat at low tide, illustrating the algal-dominated transient border between the marine and terrestrial environments

During extreme neap tides, when water levels recede to their lowest, the flushing of lagoon waters exposes intertidal coral communities, subjecting them to significant physiological stress. Massive coral structures, while possessing greater thermal inertia, face temporary cessation of water flow, limiting gas exchange and nutrient acquisition. Encrusting coral forms, tightly adhered to the substrate, minimize surface area exposed but still undergo osmotic stress and potential bleaching under prolonged exposure.





An extreme ebb of a neap tide at Kavaratti

Branching coral morphologies, with their high surface area to volume ratio, experience increased desiccation and potential photoinhibition due to direct solar radiation

# THE MEGAFAUNAL PATROL

Reefs evolved on seamounts are nourished by the dynamic interplay of currents, upwelling and the resultant increased productivity. Seamounts force the currents upwards, bringing nutrient rich cooler water from below, fuelling the establishment of highly productive zones around atoll reefs. These zones become hotspots of biodiversity, attracting a wide range of marine life, including migrating megafauna and resident species like spinner dolphins, which frequently patrol these areas.

Observations across the western oceanic province of India reveal that blue whales utilize Lakshadweep Sea as a crucial foraging ground, especially during the monsoon season when productivity surges. The Lakshadweep archipelago, experiencing exceptionally high levels of biological activity, becomes a hotspot for these magnificent creatures.



Orcas, also known as killer whales are the largest dolphins. These highly social animals live in groups called pods and can be seen in oceanic and coastal waters. Hunting cooperatively, their prey base is diverse and includes fishes, squids, dolphins, and even large sharks.

A pair of spotted dolphins

A pair of striped dolphins

A pod of Risso's dolphins

A short-finned pilot whale

Dolphins are among the most intelligent marine animals, and many species such as spinner *Stenella longirostris*, Risso's *Grampus griseus*, spotted *Stenella attenuata*, and bottlenose *Tursiops truncatus* are often drawn to the rich biodiversity and abundant food resources found within coral reef ecosystems.

A pod of Spinner dolphins

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**Acknowledgements:** The authors are grateful to Dr. Grinson George, Director ICAR-CMFRI, and Dr. A. Gopalakrishnan, former Director ICAR-CMFRI, for their support, encouragement, and guidance in the successful completion of this work. We are deeply grateful to the Lakshadweep Administration and the Krishi Vigyan Kendra (KVK), Kavaratti, for the valuable assistance extended during the field surveys. We greatfully acknowledge the financial support provided by Coral Resilience Project (MBD/CRL/31), funded by ICAR-CMFRI and the National Innovation in Climate Resilient Agriculture programme (NICRA-1009459), and the Marine Mammal Stock Assessment in India (MMSAI-1014351) project, financed by the Pradhan Mantri Matsya Sampada Yojana (PMSSY). The support rendered by LAK SCUBA, Kavaratti, in diving is much appreciated.


ISBN 978-93-82263-80-7