# Conserving top benthic predators in the Lakshadweep reefs: Identifying priority areas for grouper conservation and ecosystem functioning

## Interim Report

## Rufford Second Grant

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## Background and previous work

Coral reefs of the Lakshadweep archipelago have shown a rapid and remarkable recovery after the 1998 pan-tropical mass-bleaching catastrophe. Yet, inspite of adequate recovery of habitat structure, our previous work shows that certain reefs still support a very low diversity of top predators like groupers (even in the absence of fishing pressure). Our first Rufford project looked at patterns in distribution of a top guild of reef predators (groupers, Family Serranidae) in the Lakshadweep archipelago. This study highlights the importance of temporal habitat stability and not merely present-day habitat availability in influencing communities of long-lived groupers on reefs (paper in review).

The Lakshadweep has suffered repeated mass bleaching catastrophes in the past decade (1998, 2005, 2010). Work from another Rufford project (by Rohan Arthur), shows that reef benthic recovery and regeneration in the Lakshadweep is strongly influenced by geographic orientation and hydrodynamics. Long-term benthic data show that shallow sites on the western (monsoon exposed) aspect of atolls incurred the highest amount of coral degradation and recovery from the 1998 and 2005 mass-bleaching event, being dominated by the fast-growing and fragile *Acropora* corals (Arthur et al. 2005). As a result, these sites were structurally unstable, going through cycles of very high and very low structural complexity, during the 12 year-period sampled. In contrast, deep sites on the eastern (monsoon protected) aspect appear to have maintained their structure (in spite of coral mortality), after the 1998 mass-bleaching disturbance for over a decade. Based on depth and degree of protection from the monsoon storms, we were able to classify reefs in Lakshadweep as **low stability** (exposed shallow sites), **medium stability** (exposed deep, protected shallow sites) and **high stability** (protected deep) sites.

Our project then looked for differences in grouper communities across a gradient of present structural complexity along this habitat stability classification (exposure and depth). Our study found significant differences in grouper community structure between habitats. High stability reefs supported six times the average grouper biomass of low stability reefs. Larger bodied groupers like *Plectropomus areolatus, Plectropomus laevis, Epinephelus malabaricu*s etc. were higher in density in the high stability sites. While smaller hinds like *Cephalopholis sexmaculata, Cephalopholis urodeta, Cephalopholis leopardus* etc. were more abundant in low stability sites. More interestingly, average grouper biomass increased exponentially with present structural complexity, but only at the high stability sites, inspite of the availability of recovered structure at lower stability sites. This trend was especially pronounced for long-lived groupers (lifespan >10years). These results suggest that long-lived groupers may prefer temporally stable reefs, independent of the local availability of habitat structure. In reefs subject to repeated disturbances, structurally stable reefs

may be critical refuges for functionally important, long-lived species like the groupers.

Our previous study largely focused on describing patterns in distribution of groupers across reef stability regimes in Lakshadweep. A natural extension of this work was to study mechanisms that drive such distributional patterns in long-lived groupers and understand the ecological functioning of these natural refuge areas. **Our current Rufford project looks at behavioral plasticity or the adaptability of grouper species to fluctuating habitats by comparing observations of common and restricted grouper species, between high and low stability sites.**

Since the past two years, fishing practices in Lakshadweep are on the cusp of dramatic change. Due to the persistence of a thriving pelagic-tuna fishery in Lakshadweep since the 1970's, the island fisheries have previously been classified as low-impact on reefs. However, because of a huge dip in the off-shore tuna fishery in the past two years, the fishermen are focusing their efforts once again on near-shore coral reefs. This trend is worrying for reef predators like sharks and groupers as they are often among the first coral reef fish groups to be overexploited in reef systems, given that they are the highest priced market reef species and easiest to catch. The decline of these top predators can have major consequences for the coral reef ecosystem, triggering potential trophic cascades, with flow-on effects for reef-dependent island communities.

In the light of these changing fisheries practices it becomes essential to characterize the nascent, proliferating reef fishery as well as draw lessons and influences from historical and traditional reef management practices to guide future fisheries management in the islands. **This year's work also focuses on laying down the framework for such a socio-ecological study.**

During the course of our project, we were also able to **monitor and study an important spawning aggregation** of the square-tail grouper *(Plectropomus areolatus*). This piece of work contributes greatly to our broad project, which strives to identify and prioritize areas for conservation of top-reef predators in Lakshadweep.

This report briefly outlines the activities conducted in the past field season (December 2012- March 2013) and reports preliminary results of our work.

## Long-term monitoring survey

We surveyed a total of 18 permanent monitoring sites at three atolls: Agatti, Bitra, Kadmat and Kavaratti. At each atoll, our permanent sites have been established

along two depths (deep and shallow) and exposure (east and west) regimes. Annual monitoring data is collected from these sites on benthic structure and fish variables (species, size-classes, density and biomass density). This data adds to our permanent monitoring database which is tracking changes in the benthos and fish guilds since 1998, spanning three mass-bleaching catastrophes (1998, 2005 and 2010) in the Lakshadweep archipelago (data still to be analyzed).

## Grouper behavioral response to habitat stability- lessons of behavioral plasticity from the Peacock hind (*Cephalopholis argus)*

Habitat stability of reefs has emerged as an important factor, which influences distributions of groupers in the Lakshadweep archipelago. One of the main objectives of this study is to understand some of the mechanisms, which drive these distributional patterns of groupers. Several characteristics of stable reefs (protected deep sites) can make them suitable for supporting high biomass of predators. One of the main drivers may be difference in **prey availability** between habitats, which is often an increasing function of reef structure. Secondly the survival in low stability, dynamic habitats can be contingent upon the ability of these predators to **adapt** to fluctuating habitat resources.

Groupers are benthic associates. They rely heavily on benthic structure for predation, using ambush techniques to acquire prey. We hypothesize that the ability to persist in degraded or structurally dynamic habitats would depend upon the species' ability to modify its predation strategies to less structure dependent ones and/or have the ability to shift diet preferences as per availability. These adaptive differences between species may be critical in driving compositional differences described in our previous study.

Our aim was to explore behavioral plasticity by comparing commonly found and rare or restricted grouper species across the gradient of stability. In the course of this season however, we were only able to study the behavioral plasticity of a ubiquitous species of hind, known as the Peacock hind (*Cephalopholis argus*) between high and low stability habitats.

**Study sites and methods:**
The behavioral study was conducted in the Kadmat atoll. We used focal individual sampling on 40 *C.argus* individuals. Sampling was conducted along a gradient of habitat structure at two stability regimes (low stability sites= deep, western reefs n=20 and high stability sites=deep eastern reefs, n=20 individuals).

The peacock hind are known to be social dwellers. They are typically found in harems, with one dominant male and several smaller females. The maximum territory

size of the male can be as large as 2000$m^2$ and can encompass several smaller individual territories as large as 100$m^{2,}$ defended by smaller females. We followed individuals of a constant size (27-30cm). This size class represents individuals that are found across most habitats (i.e. deep, shallow, high and low structured sites) but importantly represent the largest size-class of individuals in the Lakshadweep archipelago, which tend to be males. Each individual was observed for a period of 30 minutes. During the sampling protocol we marked and measured core territories (defined as the area where groupers spent ~80 % of their time) and collected behavioral data for analyzing activity budgets (data analysis pending), foraging strategies and social interactions. The observational study was entirely conducted on SCUBA.

A preliminary analysis of our data shows some very obvious differences in the social and foraging behavior of *Cephalopholis argus* between low and high stability habitats. However a much more detailed analysis of the data is yet to be conducted. We report some of the most striking observations.

**1. Territory size and habitat structure.**

*C.argus* territory size appears to be inversely correlated with structural complexity (Fig 1). As the structural complexity of sites increases *C.argus* territories tend to get smaller. Conversely in low structure habitats, individual territory sizes are larger and more loosely defended.

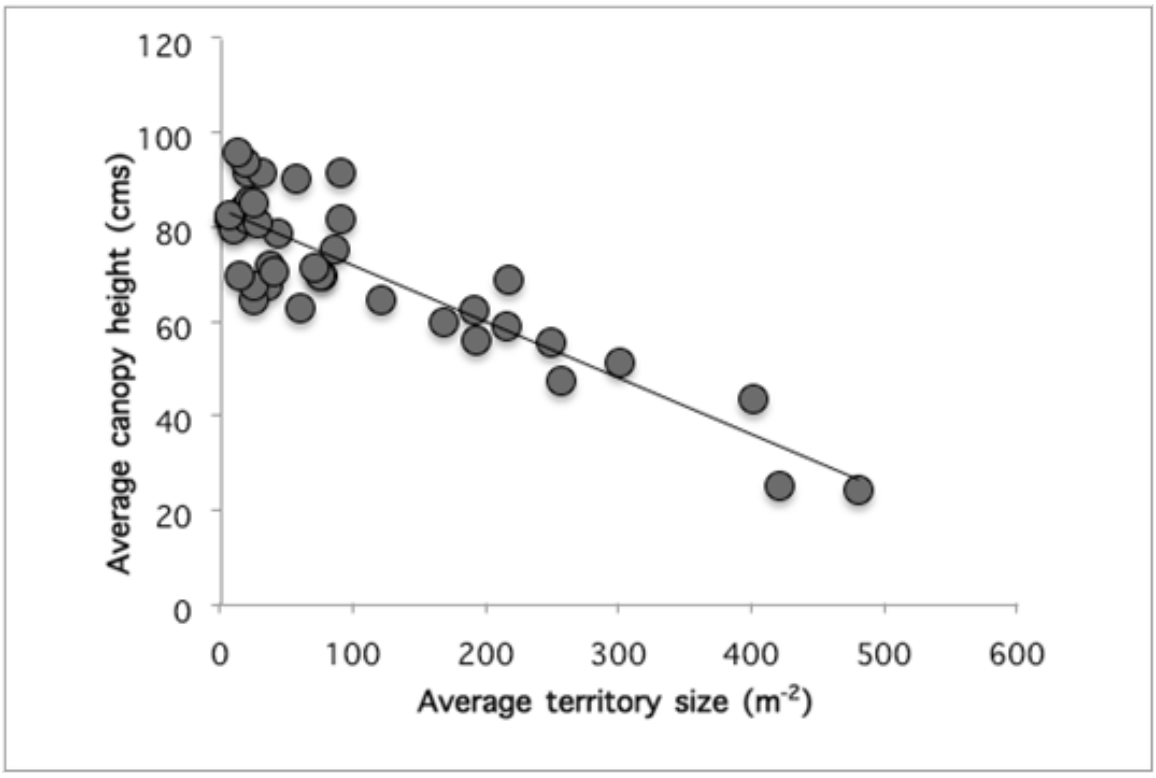


Fig 1. Average territory size as a function of structural complexity (average coral canopy height) of the territory site.

Average structural complexity (vertical coral canopy height) between high and low stability reefs appears to be comparable (data not presented here), yet *C.argus* territories on an average tend to be smaller and more compact in high stability sites.

Territory sizes may be a function of food resource availability and distribution. Higher food resource densities in high stability sites may be responsible for the formation of smaller territories. Conversely *C.argus* may need to defend larger territories in low stability habitats to overcome lower or patchier resource distributions.

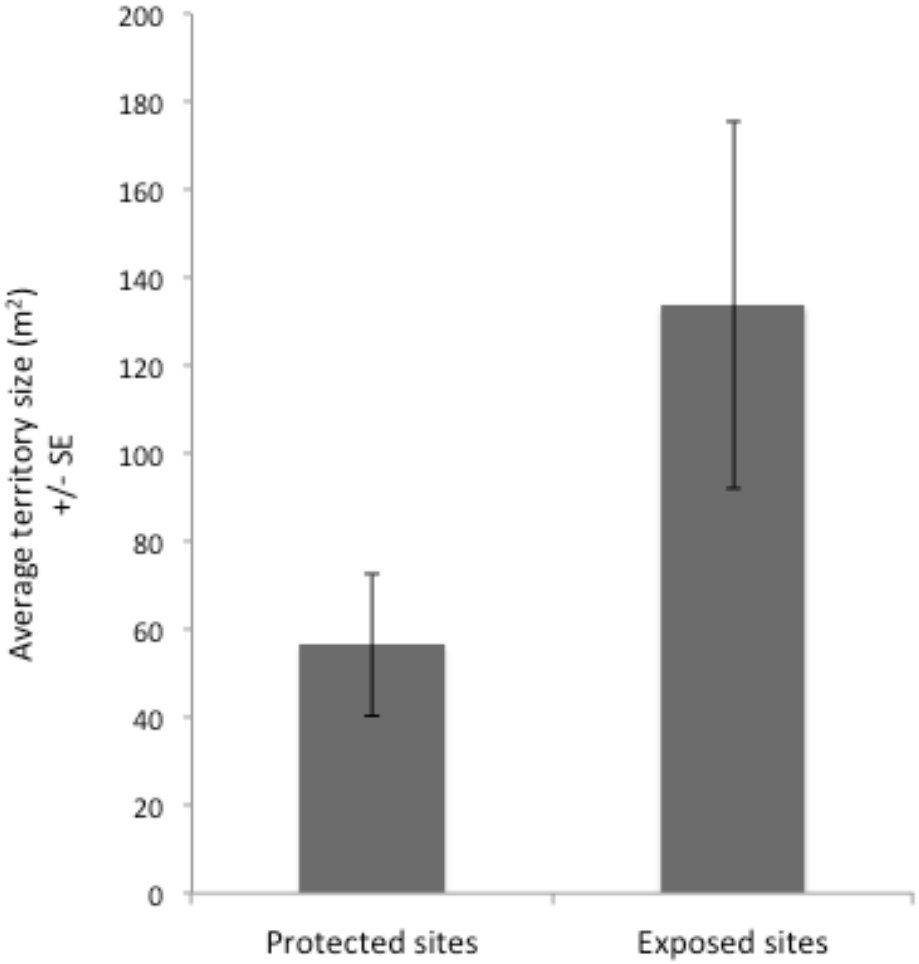


Fig 2. Difference in average core territory size (+/- SE) between high and low stability sites (n=40 individuals).

**2. Foraging strategies and prey availability**

The average density ($m^{-2}$) of prey (fish and invertebrates) was found to be higher in high stability sites. The proportional composition of fish prey (family: *apogonidae, labridae, scaridae, tripteridae, blennidae, gobiidae, pomacentridae, pempheridae, lutjanidae, clupeidae)* tended to be higher in high stability sites (Fig 3) and

invertebrate (molluscs, crustaceans, echinoderms, polychaete worms) availability is proportionally very high in low stability sites.

Two types of foraging behaviors were observed in C.argus -'probing' behavior is more of a roving strategy, where the fish swims and forages with its mouth directed towards the benthos, in a probing manner. 'Ram feeding' appears to be more of an ambush strategy where the predator makes sudden activity bursts and captures prey in the water above the benthos. Based on similar observations of foraging behaviors from other studies (Feeney et al. 2012), we assume that probing behavior is directed more towards capturing benthic invertebrates and ram feeding is associated with fish prey. We were unable to neither make direct observations of prey capture nor collect gut content samples to ascertain these behaviors at this stage. We aim to fill in these gaps in the next season. Based on this assumption, differences in foraging behaviors (ram vs. benthic probing) reflect patterns in prey availability and suggest that *C.argus* might be compensating for low fish densities in low stability sites by switching diet towards invertebrates (Fig 4).

*C.argus* is largely a piscivore and ontogenetic shifts in diet towards fish prey have been reported in this species (Meyer 2008). While invertebrates are known make up for only a small portion of its diet (<25%), our studies suggest that *C.argus* may be adapting to sub-optimal habitats by modifying its diet towards less-preferred invertebrates. At this point, we only have observations on foraging behaviors, however direct data from gut contents and stable-isotope analysis will be very useful in determining actual diet shifts in this species between sites.

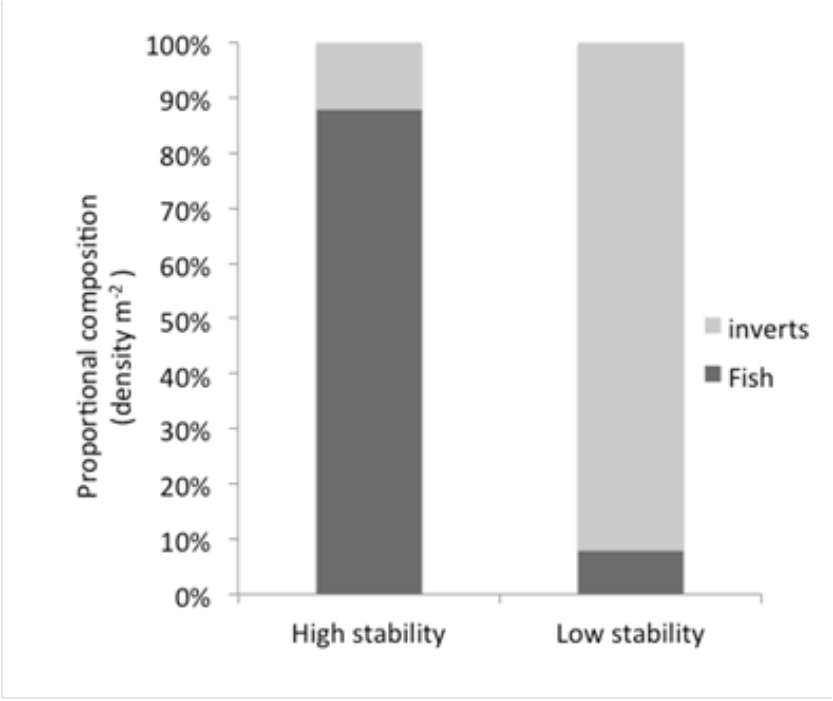


Fig 3. Proportional density of fish and invertebrate prey per $m^{-2}$ in high and low stability sites.

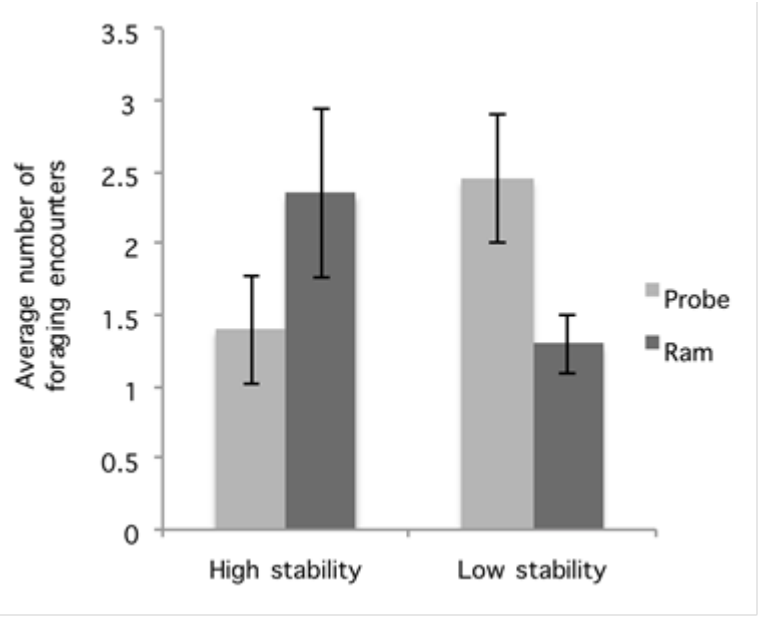


Fig 4. Number of foraging encounters (mean +/- SE) of probing (directed towards the benthos) and ram feeding (directed in the water column) type, per 30-minute sampling period each of n=40 individuals.

### 3. Group size

Average size of harems in high stability sites was found to be higher than low stability sites. Higher resource densities within territories may support a higher number of mates per individual. Similarly, it may also influence mating strategies between habitats and its effects on overall community structure.

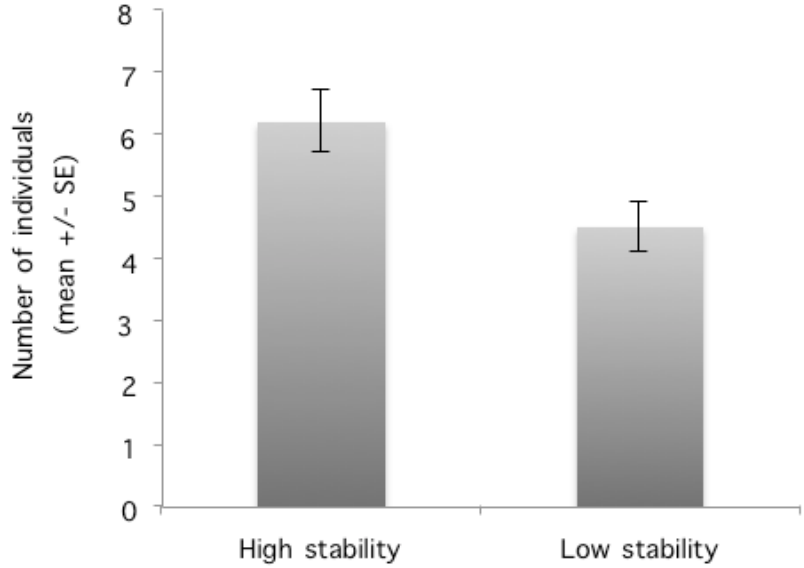


Fig 5. Social group (mean size +/- SE) within territories (presence of individuals tolerated by the territory holder).

Further work on mating behaviors, reproductive biology, genetics and stable-isotope analysis is necessary to gain a better understanding of these suggested underlying mechanisms.

## Behavioural characteristics of a 'pristine' spawning population of groupers

Our previous project has documented a spawning aggregation of the square-tail grouper (*Plectropomus areolatus*) in the archipelago. A unique feature of this aggregating population is that it is pristine and suffers from little to no targeted fishing pressure in the archipelago. The densities recorded this year (mean peak density of 181.5 fish /1000$m^{-2}$ +/- 68.9 SE) are among the highest reported across the Indo-pacific. The lack of anthropogenic pressure on this population makes it a locally and regionally important unit to study and can be used to set behavioral and population level baselines for this species.

The site was revisited this year to monitor the aggregation in terms of its stability (time, location, population density) and to undertake a detailed behavioral study of mating strategies. We used the distance sampling approach to accurately estimate densities of the aggregating population.

**Behavioral characteristics**

We studied alternative mating tactics in this aggregating population of *Plectropomus areolatus*. We used in-water, SCUBA based scan sampling and focal individual sampling to collect behavioral data, during the peak aggregation period.

One of the most exciting findings of our behavioral study is that we have documented explicit, conditional alternative male mating tactics used by males and females within this aggregating population. We find the choice of mating tactics used by male and female squaretail groupers to be conditional upon body size (age) and local mate densities.

The mating system we study is a highly complex lekking system seen in higher order vertebrates like birds and ungulates. Such a systematic study of the mating behavior of spawning groupers has rarely been undertaken, because most spawning aggregations are highly disturbed by fishing exploitation. Putting these behavioral observations in context with population genetics and dispersal work conducted in other regions sheds new light onto the population dynamics of this species and the detrimental effects of fishing on spawning populations.

**We are further focusing on understanding the evolutionary basis of alternative mating tactics in *P.areolatus* and the effect of (fishing-induced) population declines on the nature of such mating systems (manuscript in prep)**.

**Horizon scanning: threats to the spawning aggregation**

While we did not see any fishing activity directly at the spawning aggregation sites, we did observe some worrying trends and changes in reef fishing practices, which can be major threats to the aggregation in the coming years. We held an **informal group discussion with the local fishermen** of the atoll to understand the changing nature of reef fishing practices in Lakshadweep and the fisher's concerns regarding the same.

- **Encroaching mainland fisheries-**

While the Lakshadweep waters are protected and not open to mainland fishermen, they seem to have found ways around it. The local fishermen reported a rise in the number of large fishing vessels over the last two years, which are allegedly contracted by companies along the mainland coast but registered in the Lakshadweep. These vessels carry out fishing operations 2-3 times of the year. During each operation they reportedly stay for several weeks at a time in the atolls and commission local fishermen to fish certain target species of reef fishes; Nepoleon wrasses (*Cheilinus undulatus*), Red-Snappers (*Lutjanus bohar*) Paddle-tail snappers (*Lutjanus gibbus*) in particular as well as several species of Carangids, and Serranids. These operations seem to be timed during the non-monsoon months, but also coincide with the timing of this spawning aggregation.

Fish spawning aggregations are a lucrative target as it gives fishermen an opportunity to gain huge harvests with minimum efforts. Once discovered such aggregations can be easily over-exploited and completely wiped-out in a matter of years. It therefore becomes essential to set up conservation protocols for such pristine aggregations in terms of partial spatio-temporal enclosures, etc. to protect them from such inceptive, unregulated fishing.

- **Rising inter-island fishing disputes-**

Reef fishing in the Lakshadweep has largely been of subsistence type in the past. Because of its strategic importance to India, the Navy has heavily protected the Lakshadweep waters. As a result, commercial fishing never made significant headways in the Lakshadweep, as opposed to its upswing in the surrounding Indo-pacific region. Similarly, in the 1970's, the Fisheries Department introduced and heavily incentivized offshore tuna fishing in the islands after which the community has largely adopted pelagic fishing as their mainstay. This has eased off reef fishing pressures, and inadvertently protected several species of ecological and commercial importance, at least in the past decade.

One of the characteristics of the pelagic fishery is that tuna are considered an open-access resource and the fishermen follow tuna stocks indiscriminately across the archipelago, away from their natal atolls. In the recent years, dwindling tuna stocks has seen the return of reef fishing as an alternative practice. As these pelagic fishermen head out on inter-island journeys in search of tuna, they resort to fishing off other reefs often as a backup. This has led to an increase in inter-island disputes over reef fish resources. At the same time, it also exposes local fish populations and spawning aggregations to a wider audience for exploitation.

The fishermen in the discussion group identified this as a growing problem. They recognized that better equipped fishers from other atolls are exploiting their resources, while the natal fishermen of smaller, remote atolls are not able to manage or reap benefits from their own reefs. They suggested that the local people of every atoll needed to be empowered in some way to manage their own resources. They also suggested that there need to be guidelines on resource use and acquisition by non-local fishermen.

## Documenting historical reef-fishing traditions in the archipelago (informal fisher interviews)

Due to the reign of an open-access, pelagic fishery for four decades in the archipelago, knowledge of several historical reef fishing traditions and local regulatory systems appears to be slowly fading in the community. Early signs of uncontrolled and unregulated patterns in resource access and use are already visible in the archipelago. Current work from the archipelago shows that repeated natural climate-change calamities continue to steer reefs in Lakshadweep along different trajectories of degradation and recovery. Our project highlights the vulnerability of top predators to such repeated climate-change events, even in the absence of anthropogenic pressures. Taken together, the research suggests that even subsistence fishing could cross new thresholds that are being set by environmental disturbances. In the absence of governmental regulation and the attrition of traditional systems and community controls at this crucial stage of fisheries expansion, reef fishes like groupers suffer significant threats in the Lakshadweep.

The project aims to document traditional practices of reef management, which may have been locally used before the rise of the pelagic tuna fishery in the 1960's. Revisiting these traditional fishing practices, together with an information-based learning of the reef ecosystem can be an adaptive way forward in regulating the resurrected reef fisheries in these islands.

To get a sense of traditional reef fishing practices in the islands we conducted a few

informal interviews with elderly fishermen (>60 years, n=9) in Kadmat. Once we lay down a framework for an interview-based historical analysis of fisheries, on the basis these discussions, the work will be extended to other atolls (namely, Kavaratti, Agatti, Amini and Bitra), along various socio-economic gradients.

Our interviews revealed some very interesting details of historic fisheries. There was a general consensus among the elderly fishermen that fishing methods have drastically changed over the years. The differences they identified were mainly in types of gears used and in the social aspect of fishing.

1. **Fishing gears**- Reef fishing in Lakshadweep has always been of hook-and-line type. Nets were used in lagoons, but not on reefs. In the past, many different types and kinds of hooks were used to target different species of reef fish. Hooks were specifically designed to catch particular species of fish (scombrids, jacks, red snapper, emperors, grouper, sharks, barracuda etc.). One of the main advantages of such specialized gear was that it reduced by-catch, (non-preferred fish species like small larger trigger fish, puffer fish, certain groupers etc.). The general observation was that younger fishermen today seldom use such specialized gear and end up indiscriminately catching all fish species, preferred or not.

2. **Local systems of control-** While the fishermen could not identify any direct forms of control or management, they did express that a lot of weightage was given to the knowledge of the older fishermen for daily fishing activities. The younger fishermen often took advice on fishing location and times, from older fishermen, who were believed to predict catches based on astronomy, tides and wind directions. The local religious leaders (or *Imams*) were also highly regarded and consulted for daily as well as large-scale, group fishing operations. This implies that loosely defined elements of community management may have been prevalent in the past, the influence of which has greatly diminished in the recent years.

3. **Co-operative fishing**- the interviews revealed that groups of fishermen identified fishing grounds, around the atolls with unique, local names. Names, as well as the significance of such fishing grounds (with respect to fish resources) were passed down from generation to generation and shared within social groups. They interviewed fishermen identified that there was much more co-operation and facilitation between fishermen in the olden times such that information was often shared with the wider community. Benefits of fishing were thus diffused throughout the community. A striking contrast in recent years is the tendency to withhold such information within social groups and the resulting hoarding of resources by an advantaged few.

The fishing community in Lakshadweep has been largely insular in the past and the influence of the government and fisheries incentives in the recent years has been

quite vast. Before enforcing objective, external controls on the socio-ecological systems in Lakshadweep, our preliminary suggests that there may be worth in reviving and strengthening the traditional guises of resource management in the face of an expanding reef fishery**. This work is still in its very inception and we are focusing on using this preliminary data to build up a much more detailed study documenting and assessing historical reef management practices and how they can be integrated into contemporary fisheries management in the Lakshadweep archipelago.**

**References**

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Peacock hind (*Cephalopholis argus*)

Male squaretail groupers *(Plectropomus areolatus)* in a territorial battle during a spawning aggregation
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Caption- Encroaching mainland fisheries- Boats operated by companies on the mainland commissioning local fishermen to catch reef fish.

Caption- Group discussion with local fishermen regarding changing fisheries and fishing issues.