Tuvalu Marine Life

an Alofa Tuvalu Project

with the Tuvalu Fisheries Department and Funafuti, Nanumea, Nukulaelae Kaupules

Synthesis Report

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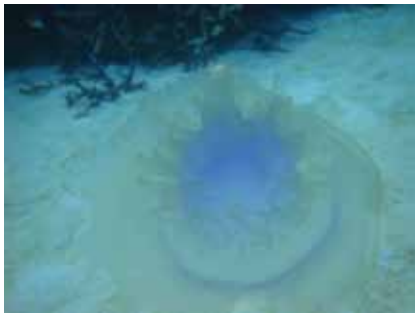
Synthesis Report

TABLE OF CONTENTS



GLOSSARY

Abiotic: Physical rather than biological; not derived from living organisms.

Anthropisation: The conversion of open spaces, landscapes, and natural environments by human actions.

Benthic: Organisms living on or in sea or lake bottoms.

Biomass: The amount of living matter in a unit area or volume of habitat.

Ciguatera: Poisoning by neurotoxins as a result of eating the flesh of a tropical marine fish that carries a toxic dinoflagellate.

Cnidarian: An aquatic invertebrate animal of the phylum Cnidaria, which includes jellyfish, corals and anemones.

Coral bleaching event: An environmentally stressful period in which the symbiotic relationship between the coral and the microscopic algae in its tissues (zooxanthellae) breaks down. When stressed, the zooxanthellae become toxic and the coral must expel them, thus losing their colour and becoming white or 'bleached'. A bleached coral no longer receives the photosynthetic product of the zooxanthellae and may die if exposed to the stressful conditions for too long. A bleaching event is one in which entire coral reefs are affected by this condition.

Coralline algae: Coralline algae are red algae in the family Corallinaceae of the order Corallinales. They are characterized by a thallus that is hard because of calcareous deposits contained within the cell.

Density: The quantity per unit volume, unit area, or unit length; the mass of a substance per unit volume.

Ecological niche: A position or role taken by a kind of organism within its community. Such a position may be occupied by different organisms in different localities, e.g., antelopes in Africa and kangaroos in Australia.

Endemic: Native or restricted to a certain country or area.

Eutrophication: A process where water bodies receive excess nutrients that stimulate excessive plant growth.

Falekaupule: The Council of Elders that functions as a local government council in Tuvalu.

Homoscedasticity *(data analysis):* The random distribution of variances around the mean.

Inner reef slope: On a coral atoll, the internal slope or wall of the reef, facing the lagoon.

Lagoon: A stretch of salt water separated from the sea by a low sandbank or coral reef.

Macroalgae: Also known as seaweed, macroscopic, multicellular, benthic marine algae.

Macroinvertebrate: An invertebrate (an animal without a backbone) that is large enough to be seen without the use of a microscope.

Mariculture: The cultivation of fish or other marine life for food.

Monospecific: Relating to or consisting of only one species.

Normality *(data analysis):* Conforming to a normal distribution, or along a regular 'bell' curve.

Overfishing: Unsustainable fishing, whereby fish are harvested faster than they can replenish their population, leading to population collapse and wide-reaching ecosystem changes.

Pinnacles: Steep-sided seamounts, or mountains rising from the seabed to just beneath the ocean's surface.

Reef flat: The top of a reef, usually the shallowest area.

Salinisation: Soils in areas where evapotranspiration exceeds precipitation, so water and dissolved salts are drawn up through the soil.

Staghorn *(coral):* Coral colonies shaped like long, tapering branches.

Terrace *(reef):* A level or flat area on a reef slope.

Transects: Lengths of measuring tape laid along the substrate.

Turf algae: An assemblage of small filamentous algae, sometimes including juvenile forms of larger species, forming a compact turf-like covering over the substratum, usually no more than 1-2cm in height.

ACRONYMS

ANOVA: Analysis of Variance
CA: Conservation Area
CITES: Convention on International Trade in Endangered Species of Wild Fauna and Flora
COTs: Crown-of-Thorns starfish (*Acanthaster planci*)
FCA: Funafuti Conservation Area
FSPI: Foundation of the Peoples of the South Pacific International
GEF: Global Environment Fund
GPS: Global Positioning System
IUCN: International Union for the Conservation of Nature
LMMA: Locally Managed Marine Area
MANOVA: Multivariate Analysis of Variance
SPC: Secretariat of the Pacific Community
SCUBA: Self-Contained Underwater Breathing Apparatus
TANGO: Tuvalu Association of Non Governmental Organizations
TML: Tuvalu Marine Life
UNDP: United Nations Development Programme
WoRMS: World Register of Marine Species

INTRODUCTION

Tuvalu is considered one of the island nations most vulnerable to sea level rise and increased storm frequency predicted under ongoing climate change[1,2]. Recent documented changes include a reduction of the islands' surface area available for cultivation, the decline of soil quality through salinization, increased erosion, greater frequency of very high tides and saltwater intrusion into freshwater lenses[3]. As the supply of land-based food becomes more uncertain, Tuvaluan reliance on coral reefs resources and surrounding ocean is increasing.

Like all Polynesian people, Tuvaluans possess an extensive traditional knowledge of marine resources and their sustainable use[4].

Despite this, increased overharvesting of marine organisms, especially by foreign fisheries, has put pressure on the marine environment. An impetus exists for the improved understanding of patterns of marine biodiversity, to assist in marine resource management through the establishment of locally managed Conservation Areas throughout the Tuvalu archipelago[5].

Documenting patterns of biodiversity allows a better understanding of the health and resilience of the coral reef communities, and this will ultimately support and inform the management of Conservation Areas.

Ecosystems with greater biodiversity tend to be more stable and productive, more resistant to human pressures, and quicker to recover from disturbances. Furthermore, they offer a richer resource to local populations that rely on coral reefs for their primary source of protein.

Previous work on Tuvaluan reef fish biodiversity resulted in a comprehensive species list, but little insight into overall patterns of species assemblages.

The *Tuvalu Marine Life* (TML) Project, an Alofa Tuvalu project, aims to support the Tuvalu Fisheries Department in gathering knowledge and implementing management of Tuvalu's marine resources.

To take into account existing knowledge, an extensive literature review listed all marine species previously identified in Tuvaluan waters[6]. This list was then updated with data gathered during the Project.

Subsequent consultation with stakeholders revealed three priorities for field surveys:

1) they should be conducted in Funafuti, Nanumea and Nukulaelae;

2) they should focus on fish (as a major component of food security);

3) biodiversity assessments of targeted marine resources within defined Conservation Areas should be conducted using low-cost and low-tech methods, with the help of trained local islanders.

Tuvalu Marine Species Richness (Update 2012)

1,526 Marine species
607 Fish
409 Macroinvertebrates
379 Cnidarians
59 Algae
41 Birds
21 Mammals
4 Sponges
4 Turtles
2 Mangroves

The Reef Fish Biodiversity Survey aims to update and expand existing reef fish species lists, and to provide additional information about abundance, species composition, biomass and distribution patterns of Tuvaluan reef fish.

The Conservation Area Survey aims to assess stocks of targeted species of macroinvertebrates and fish using simple methods, replicable by Fisheries officers and local islanders. Training will be provided in simple but robust and reliable marine resource assessment methods for use by non-scientists.

METHODS

Field surveys were conducted in May 2010 on the atolls of Nanumea, Nukulaelae and Funafuti. Different methods were used for the reef fish biodiversity surveys and the Conservation Area surveys. The reef fish biodiversity surveys were designed to yield data with which to update existing species lists and describe differences in abundance, biomass, species richness and species composition between the different atolls and the various habitats and depths surveyed on each atoll. The Conservation Area surveys were conducted to provide information on the abundance of food species and other valuable organisms inside and outside the Conservation Areas of each atoll, to provide a basis for a long-term marine resources monitoring program.

Map of Tuvalu archipelago with zoom on study atolls, including both conservation area surveys (purple star) and reef fish biodiversity survey (red dot). Top Left: Nanumea ; middle right: Nukulaelae; bottom left: Funafuti.

METHODS - REEF FISH BIODIVERSITY SURVEY

Reef fish biodiversity survey with diver towing GPS.

Diver deploying a transect tape.

Biodiversity survey over plate corals.

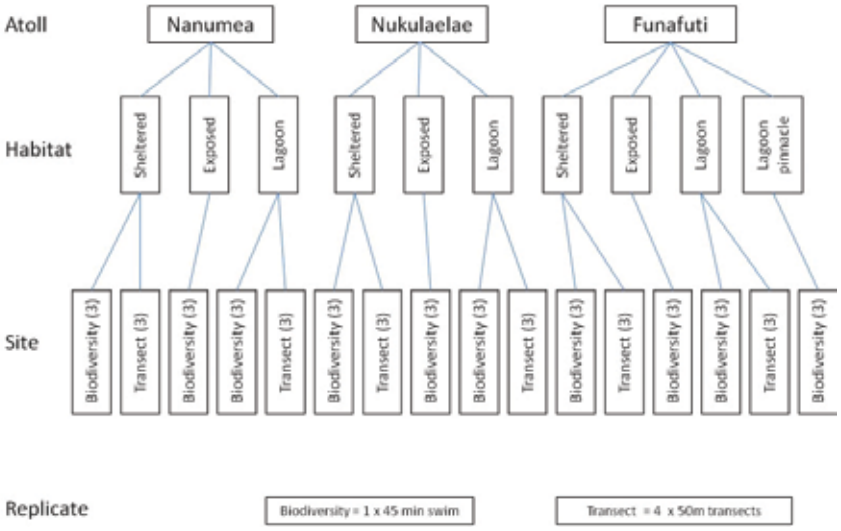
Diver conducting point intercept transect to survey the benthic community.

The Reef Fish Biodiversity Survey was conducted using two standard methods:

1) timed swims with towed GPS to record reef fish biodiversity and large predators and herbivores (referred to as "Biodiversity"), and

2) replicated underwater visual census using belt transects to determine relative abundance and species composition of the mid-slope reef fish community and the composition of the benthic community (referred to as "Transects").

Timed biodiversity swims were 45 minutes long, beginning in deeper (15-20m) and ending in shallower (3-5m) reef zones, with a towed GPS. A diver recorded all reef fish species, their relative abundance and the density and length of large predators and herbivores. The transects consisted of four 50m belts (10m wide for large, mobile species and 2m wide for small, site-attached species) per site. The first diver recorded all species of fish and the second diver recorded benthic community structure along 50 points for each transect. At least three sites were completed with each method in each of the chosen habitats.



Sampling design for the reef fish biodiversity survey.

Exposure	Nanumea	Nukulaelae	Funafuti
Exposed	3 Biodiversity	3 Biodiversity	3 Biodiversity
Sheltered	6 Biodiversity	3 Biodiversity	4 Biodiversity
	3 Transect	3 Transect	4 Transect
Lagoon	3 Biodiversity	3 Biodiversity	4 Biodiversity
	3 Transect	3 Transect	4 Transect
Lagoon Pinnacle			3 Biodiversity

Number of sites completed in exposed, sheltered, lagoon and lagoon pinnacle habitats on each surveyed atoll.

CONSERVATION AREA SURVEY - METHODS

Conservation Area Surveys were conducted with the assistance of Fisheries officers and trained local villagers. A participatory approach to marine resource data collection served a broader purpose of strengthening the local capacity to conduct such surveys and improved the understanding of the usefulness of resource management.

To ensure the long-term involvement of local people and the quality of data collected, species were selected to be representative of the exploited resource (edible fish and macroinvertebrates) and easily identified by local assessors. Training sessions were conducted on land and repeated in the lagoon.

Three sites were surveyed inside each Conservation Area, and three sites were positioned in similar habitats outside the Conservation Area, except in Funafuti, where a previously established survey design was followed (see below). At each site, targeted fish were recorded along three 50 x 10m belt transects, the sessile benthic community was surveyed using the point intercept method, and macroinvertebrate (especially *trochus*, clams and sea cucumbers) density and size was recorded in a 4m belt along the same transects.

All surveys were conducted while free-diving, except the Funafuti lagoon stations that were assessed using SCUBA.

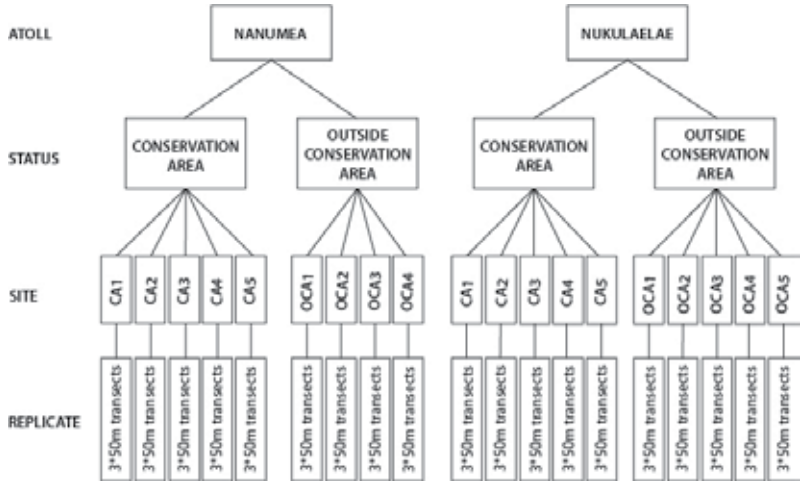
All data were represented graphically and analysed using standard statistical methods.

Selection of target species.

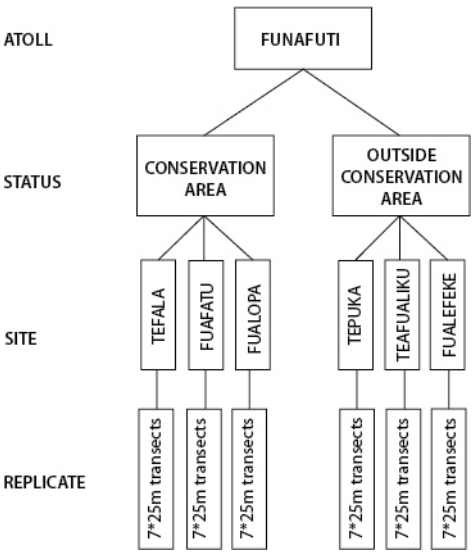
Training on land prior to field data collection.

Most of the stations were surveyed while free-diving.

Surveys of the Funafuti lagoon stations, conducted on SCUBA.



Sampling design for the outer islands' conservation areas survey.



Sampling design for FCA survey.

Macroinvertebrate target species

FS: food source; HC: handicraft; EF: ecological function; CV: commercial value; B: bait

Latin name	Common name	Nanumea name	Nukulaelae/Funafuti name	Justification
Turbo spp.	Turban shell	Alili	Alili	FS
Lambis spp.	Spider shell	Kalea	Mataga	FS, HC
Strombus luhanus	Strawberry conch	Panea	Panea	FS
Trochus niloticus	Top shell	Munikau	Munikau	FS
Cypraea spp.	Cowrie	Pule	Pule	HC
Tridacna spp.	Clam	Fasua	Fasua	FS
Pinctada margaritifera	Black lip pearl oyster	Tifa	Tifa	FS, HC, CV
Spondylus cf. varius	Thorny oyster	Hopu nifo	Sopuu	FS
Spondylus cf. variegatus	Thorny oyster	Hopu teka	Sopuu	FS
Chama imbricata	Oyster	Hopu papa	-	FS
Octopus spp.	Octopus	Feke	Feke	FS
Panulirus spp.	Lobster	Tapa tapa	Ula	FS
Conus spp.	Cone	Uga	Fakamili	HC
Holothuria atra	Lollyfish	Loli	Loli	EF
Holothuria fuscogilva, Holothuria whitmaei	White and black teatfish	Funafuna faiu	Funafuna faiu	CV
Holothuria spp., Bohadshia spp., Actinopyga spp., Thelenota spp.	Sea cucumber	Funafuna	Funafuna	EF, CV
Acanthaster planci	Crown-of-thorns starfish	Kalauna	Kalauna	EF
Drupella cornus	Coral-eating snail	Drupella	Drupella	EF
Echinometra mathaei, Diadema setosum, Echinothrix diadema, Echinostrephus acicularis	Sea urchin	Vana	Vana	EF
Arca ventricosa, Barbattia spp. and Septifer bilocularis	Ark and mussel	Kohi		FS
Cerithium nodulosum	Nodulose coral creeper		Sipo	B

Substratum categories

Nanumea / Nukulaelae		Funafuti	
BC	Branching Coral	ACB	Acropora Branching
EC	Encrusting Coral	ACD	Acropora Digitate
FC	Foliose Coral	ACS	Acropora Submassive
MC	Massive Coral	ACT	Acropora Table
TC	Table Coral	BC	Branching Coral
OC	Other Coral	EC	Encrusting Coral
SC	Soft Coral	CHL	Blue Coral
SP	Sponge	MC	Massive Coral
OL	Other Living organisms	SC	Soft Coral
MA	MacroAlgae	SP	Sponge
TA	Turf Algae	DC	Dead Coral
SG	SeaGrass	DCA	Dead Coral with Algae
DC	Dead Coral	CA	Coralline Algae
RC	Rock	HA	Halimeda
RB	Rubble	MA	MacroAlgae
SD	Sand	AA	Algae Assemblage
SI	Silt	TA	Turf Algae
		RC	Rock
		RB	Rubble
		SD	Sand
		SI	Silt

Fish target species

E: Edible, EP: Edible but Poisonous, EC: Edible and Commercially important, I: Indicative of reef health

Latin name	Common name	Nanumea name	Nukulaelae name	Funafuti name	Justification
ACANTHURIDAE	**SURGEONFISHES**				
Acanthurus achilles	Achilles tang	Maa	Kapalagi		EC
Acanthurus blochii	Ringtail surgeonfish	Ponelolo	Ponelolo	Ponelolo	EC
Acanthurus lineatus	Striped surgeon fish				EC
Acanthurus nigricans	Whitecheek surgeonfish		Kapalagi		E
Acanthurus olivaceus	Orangeband surgeonfish	Manini	Manini	Manini	E
Acanthurus triostegus	Convict tang	Pone uli	Pone uli	Pone uli	EC
Ctenochaetus striatus	Lined bristletooth		Manini lakau	Manini	EP
Naso lituratus	Orangespine unicornfish		Ume	lakau	EC
Naso unicornis	Bluespine unicornfish			Ume	EC
Naso spp.	Unicornfish			Pokapoka	EC
SCARIDAE	**PARROTFISHES**				
Bolbometopon muricatum	Bumphead parrotfish	Laea	Laea	Laea	E
Chlorurus microrhinos	Steephead parrotfish	Homo	Homo	Laea	E
Chlorurus japanensis	Japanese parrotfish		Laea	Laea	E
Scarus ghobban	Blue-barred parrotfish	Ulafi/ika hole	Ika hole	Ulafi	EC
CARANGIDAE	**TREVALLYS**				
Caranx melampygus	Bluefin trevally	Ulua	Aseu	Aseu	EC
Caranx sexfasciatus	Bigeye trevally				EC
SERRANIDAE	**GROUPERS**				
Cephalopholis argus	Peacock grouper	Loi	Loi	Loi	EP
Epinephelus fuscoguttatus	Brown-marbled grouper	Palati	Fapuku	Fapuku	EC
Epinephelus hexagonatus	Hexagon grouper	Gatalaliki			EC
Epinephelus merra	Honeycomb grouper	Gatalaliki	Gatalaliki	Gatalaliki	EC
Epinephelus spp.	Groupers	Gatala			EC
Plectropomus laevis	Blacksaddle coral grouper			Tonu	EP
CHAETODONTIDAE	**BUTTERFLYFISHES**				
Chaetodon auriga	Threadfin butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon bennetti	Eclipse butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon citrinellus	Speckled butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon ephippium	Saddled butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon lunula	Racoon butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon lunulatus	Redfin butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon ornatissimus	Ornate butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon rafflesi	Reticulated butterflyfis	Koile	Moipepe	Moipepe	I
Chaetodon reticulatus	Dotted butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon semeion	Chevroned butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon trifascialis	Latticed butterflyfish	Koile	Moipepe	Moipepe	I
Chaetodon ulietensis	Pacific double-saddle butterflyfish	Koile	Moipepe	Moipepe	I
KYPHOSIDAE	**SEA CHUBS**				
Kyphosus spp.	Sea chubs	Nanue	Nanue	Nanue	EC
LABRIDAE	**WRASSES**				
Cheilinus undulatus	Humphead wrasse		Tagafa	Tagafa	E

Latin name	Common name	Nanumea name	Nukulaelae name	Funafuti name	Justification
LETHRINIDAE	**EMPERORS**				
Lethrinus erythracanthus	Yellowfin emperor			Saputu	E
Lethrinus harak	Thumbprint emperor		Tanutanu	Tanutanu	EC
Lethrinus obsoletus	Orange-striped emperor			Tanutanu	EC
Lethrinus olivaceus	Longface emperor			Filoa	EC
Lethrinus xanthochilus	Yellowlip emperor	Filoa/Kapatiko	Kapatiko		EC
Monotaxis grandoculis	Humpnose bigeye bream	Muu	Muu	Muu	EC
LUTJANIDAE	**SNAPPERS**				
Aprion virescens	Green jobfish	Utu		Utu	EC
Lutjanus bohar	Red snapper			Fagamea	EP
Lutjanus fulvus	Blacktail snapper	Takape	Tagau	Tagau	EC
Lutjanus gibbus	Humpback snapper		Taea	Taea	EC
Lutjanus kasmira	Bluestripe snapper			Savane	EC
Lutjanus monostigma	Onespot snapper	Taiva	Taiva	Taiva	EP
HOLOCENTRIDAE	**SOLDIERFISH/ SQUIRRELFISHES**				
Myripristis spp.	Soldierfishes	Malau puku	Malau puku		EC
Sargocentron spiniferum	Sabre squirrelfish	Taa Malau	Taa Malau		E
EPHIPPIDAE	**BATFISHES**				
Platax orbicularis	Circular batfish	Laulaufou			E
BALISTIDAE	**TRIGGERFISHES**				
Pseudobalistes flavimarginatus	Yellowmargin triggerfish	Umu	Umu	Umu	E
Rhinecanthus aculeatus	Picasso triggerfish	Sumu	Sumu	Sumu	E
MUGILIDAE	**MULLETS**				
Crenimugil crenilabis	Fringelip mullet		Kanase		EC
Liza vaigensis	Diamond-scale mullet		Kafakafa		EC
MULLIDAE	**GOATFISHES**				
Mulloidichthys flavolineatus	**Yellowstripe goatfis**h			Kalo	EC
Mulloidichthys vanicolensis	Yellowfin goatfish			Vete	EC
Parupeneus barberinus	Dash-dot goatfish		Afulu	Afulu	EC
Parupeneus spp.	Goatfishes		Afulu	Afulu	EC
SIGANIDAE	**RABBITFISHES**				
Siganus argenteus	Forktail rabbitfish		Maiava	Maiava	EC
Siganus spp.	Rabbitfishes			Maiava pukupuku	EC
GERREIDAE	**MOJARRAS**				
Gerres oyena	Blacktip silver biddy			Matu	E
CARCHARHINIDAE	SHARKS				
Triaenodon obesus	Whitetip reef shark			Mago	E

REEF FISH BIODIVERSITY SURVEY - MAIN FINDINGS

This ecological survey, focused on documenting the diversity of Tuvalu's reef fish, recorded 317 species from 49 families, during 56 SCUBA dives in Nanumea, Nukulaelae and Funafuti.

Despite the short duration of the survey trip in each place, 66 species that had not previously been recorded in Tuvalu were added to the previous species list, bringing to overall total* for Tuvalu to 607 species from 73 families. The commonly calculated Coral Fish Diversity Index (CFDI) brings the estimated number of reef fish species for Tuvalu to 711.

The new records added during this survey are common reef fish species or food fish caught by fishers; their absence on previous species lists is testimony to the relatively low effort that has gone into documenting Tuvalu's marine life in the past, and to the localised distribution of some of the species.

Surveys of the other six atolls and islands of the Tuvalu archipelago are likely to reveal further previously unrecorded species. More species are also likely to be found through collections using clove oil; this may add substantial numbers of nocturnal (e.g. *Apogonidae*, *Holocentridae*) and cryptic (e.g. *Gobiidae*, *Blenniidae*) fish to the estimate. Species found deeper than 20m would require specialised SCUBA equipment or drop cameras, and pelagic species would need to be sampled by fisheries observers during open-ocean longlining or netting operations. In accordance with previous surveys[7], no endemic species were recorded.

Variability in species richness between sites, and the generally low diversity found inside the lagoons, is a common pattern and has been noted before during surveys of Funafuti lagoon[8] and other Pacific atolls[9]. The greatest number of fish species (234) was recorded in Funafuti, followed by 207 in Nanumea and 194 in Nukulaelae.

Differences in species richness were most pronounced between complex and uniform habitats, reflecting the strong relationship commonly found between the level of topographic complexity and species diversity[10].

Centropyge bispinosus, *previously unrecorded in Tuvalu.*

Overall fish density was highest on Nanumea atoll and lowest on Funafuti atoll. In contrast, fish biomass was highest in Funafuti and lowest in Nukulaelae. Areas of high biomass were localised at individual sites where large schools of benthic carnivores, predators or grazers aggregated.

Matching Nanumea's density estimate to the relatively low biomass values suggests large numbers of small fish, which was consistent with the large numbers of juveniles found in the lagoon and high abundances of small, wave-tolerant species found on the highly exposed outer slopes. Despite the low fishing pressure on Nanumea compared with the more populated atolls, larger fish were scarce, most likely due to the relatively small size of the atoll and low diversity of available habitats. This pattern seems common of highly isolated, exposed oceanic reefs with small reef areas and small or closed lagoons[11,12].

Funafuti, despite the higher fishing pressure, had relatively high biomass and low density, indicating smaller numbers of larger fish than Nanumea, probably due to the larger size of this atoll and the higher diversity of habitat types.

Higher habitat complexity usually leads to higher densities of prey species that use the reef structure for shelter, which in turn supports higher densities of larger predatory fish. Previous reports have raised concerns about signs of overfishing in Funafuti, such as lower abundances and smaller individuals, especially in accessible areas of the more populated atolls[5,8,13].

The three surveyed atolls had similar overall levels of hard coral cover (20-30%), but the study sites – especially the lagoons – varied significantly in some aspects of the benthic communities. Overall, coral cover appears similar to other atolls in the region, with Kiribati's reefs supporting an average of 30-70% live coral cover[14]. As with previous studies, it was found that macroalgal cover was higher close to inhabited areas[15]. No system exists in Tuvalu for treating wastewater, which enters the ocean and lagoon directly or through seepage of the freshwater lens. Lagoonal waters adjacent to populated areas are therefore highly likely to have elevated nutrient content.The high cover of macroalgae near Fongafale, inside Funafuti lagoon, is thought to be exacerbated by spearfishing which targets herbivorous fish[16]. This area has also been associated with high densities of the coral-eating snail *Drupella* sp., which can lead to low coral cover and high macroalgal biomass[17].

** Some species recorded in previous surveys were not recorded in the present study; these are included in the final species richness estimate.*

Fish and benthic communities were similar across the outer reefs of the three atolls, but each atoll had its own characteristic lagoon community. Atoll lagoons are well known to act as nurseries[11], and other surveys have found that lagoons contain distinct fish communities, with species that occur nowhere else[18]. Atoll size, water exchange time and lagoon size are good predictors of species composition[19]. The habitat variables that best predicted the composition of fish assemblages found in this survey were live coral, sand and coralline algae. Each of these benthic categories serves as a useful proxy for the broader habitat. For instance, high cover of live coral was generally found in relatively sheltered environments, and is likely to support fish communities that rely on live coral colonies for food and / or shelter. The cover of sand could well serve as a proxy for lagoonal area, as the lagoons were the only habitats with substantial sandy areas.

Coralline algae tended to occur in higher cover in areas more exposed to wave action, and are a good proxy for highly exposed habitats.

Certain fish species are better adapted to high wave energy environments than others[20], creating distinct fish communities in exposed habitats.

Reef community on Funafuti lagoon pinnacle.

Paracentropyge multifasciata*, from the steep wall of the Nanumea outer reef slope.*

Labropsis xanthonota *in abundant coral on the eastern side of Nukulaelae.*

FUNAFUTI

Reef fish species 234

Greatest species richness:
Outer reef near channel entrance:
99spp

Highest fish abundance:
Southern lagoon
-2,400fish/1,000m^3

Coral cover max. 46%
Coral cover mean 31%

Key observations:
High diversity of different habitat types, moderate numbers of large species, high habitat complexity and coral cover on eastern outer reef.

NANUMEA

Reef fish species 207

Greatest species richness:
Outer reef near channel entrance:
531spp

Highest fish abundance:
Southern lagoon
-7,000fish/1,000m^3

Coral cover max. 42%
Coral cover mean 22%

Key observations: Very few large fish or predators, high densities of juveniles in the lagoon.

NUKULAELAE

Reef fish species 194

Greatest species richness:
Outer reef southern end:
88spp

Highest fish abundance:
Southern lagoon
-4,400fish/1,000m^3

Coral cover max. 78%
Coral cover mean 24%

Key observations:
Very turbid lagoon with high densities of herbivores, high habitat complexity and coral cover on eastern outer reef.

FUNAFUTI CONSERVATION AREA - MAIN FINDINGS

Our findings support trends of enhanced macroinvertebrate and fish communities inside Conservation Areas (CAs), especially in Funafuti and Nukulaelae. However, none of the observed trends were statistically significant, suggesting that it may still be too early to identify definite effects of protection, especially in the outer islands. Poaching may also hamper the recovery of exploited species inside the CAs.

Clams abundance was higher within the Funafuti CA (especially at the Fuafatu and Fualopa sites) than outside. This probably reflects the positive effect of the protection of the area from collecting or fishing, despite known poaching incidents.

Despite their overall rarity, *trochus* appeared more abundant within the FCA, particularly at the Fualopa lagoon site. It must be noted that preferred *trochus* habitats on the ocean terrace were not investigated in this study. Individual sites within the FCA hosted high edible fish densities, especially in Fuafatu where the highest single density estimate was obtained.

Parrotfishes (Laea), *Monotaxis grandoculis* (Muu) and *Naso lituratus* (Manini lakau) were particularly abundant in Fuafatu. *Acanthurus triostegus* (Manini) and *Naso lituratus* (Manini lakau) were particularly abundant in Fualopa.

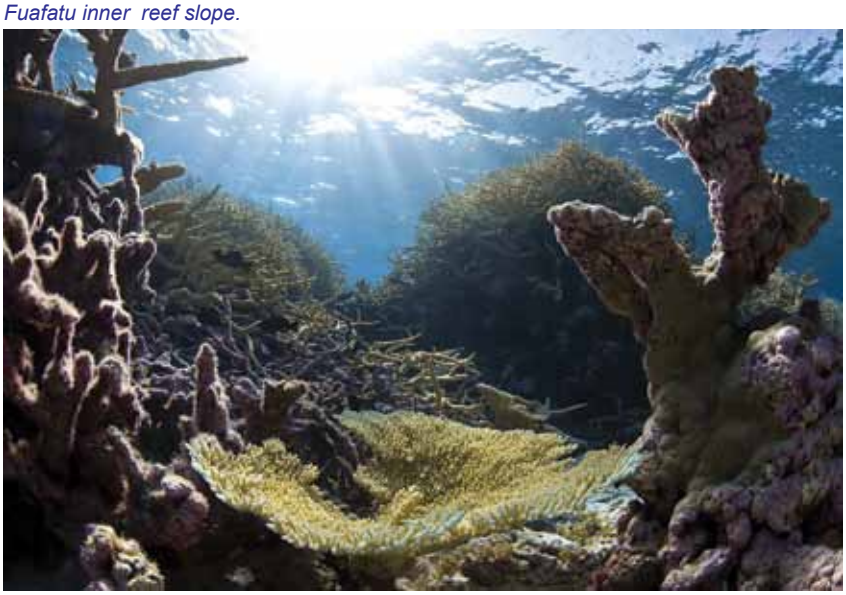
Three targeted fish species appeared to be more abundant within the FCA than outside: *Naso lituratus* (Manini lakau), *Pseudobalistes flavimarginatus* (Umu) and *Scarus ghobban* (Ulafi).

The Fuafatu inner reef slope hosted dense and healthy coral communities. The Tefala reef flat and reef slope had high crustose coralline algal cover, associated with an abundant sea urchin population, both favourable characteristics for maintaining a healthy coral reef community.

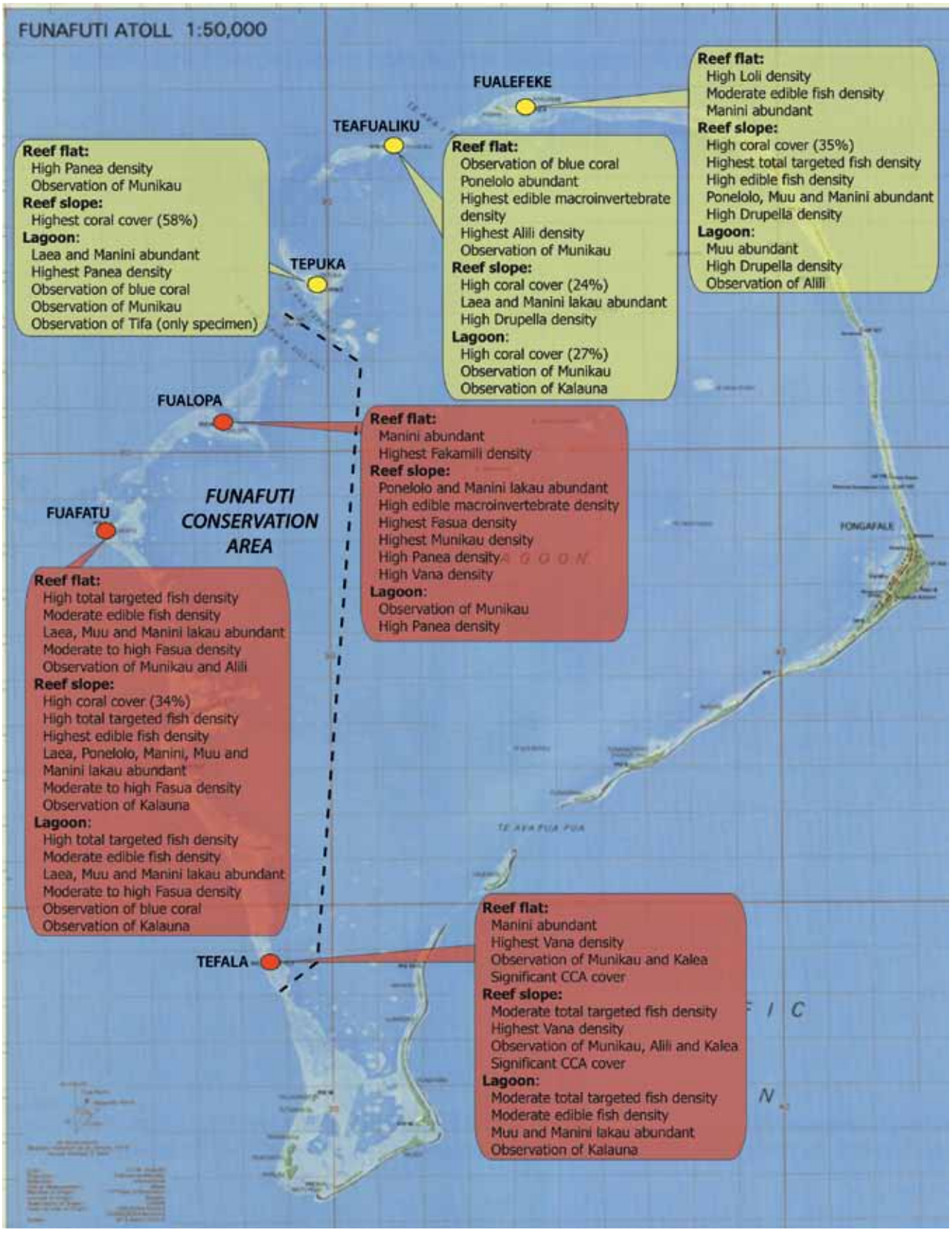
*Fasua (*Tridacna squamosa*) found within the FCA.*

*Manini lakau (*Naso lituratus*).*

Healthy coral reef on Fuafatu inner reef slope.



Points of interest at all stations investigated in Funafuti atoll.



NUKULAELAE CONSERVATION AREA - MAIN FINDINGS

Stations located within Nukulaelae Conservation Area showed:

- The highest coral cover (station CA2)

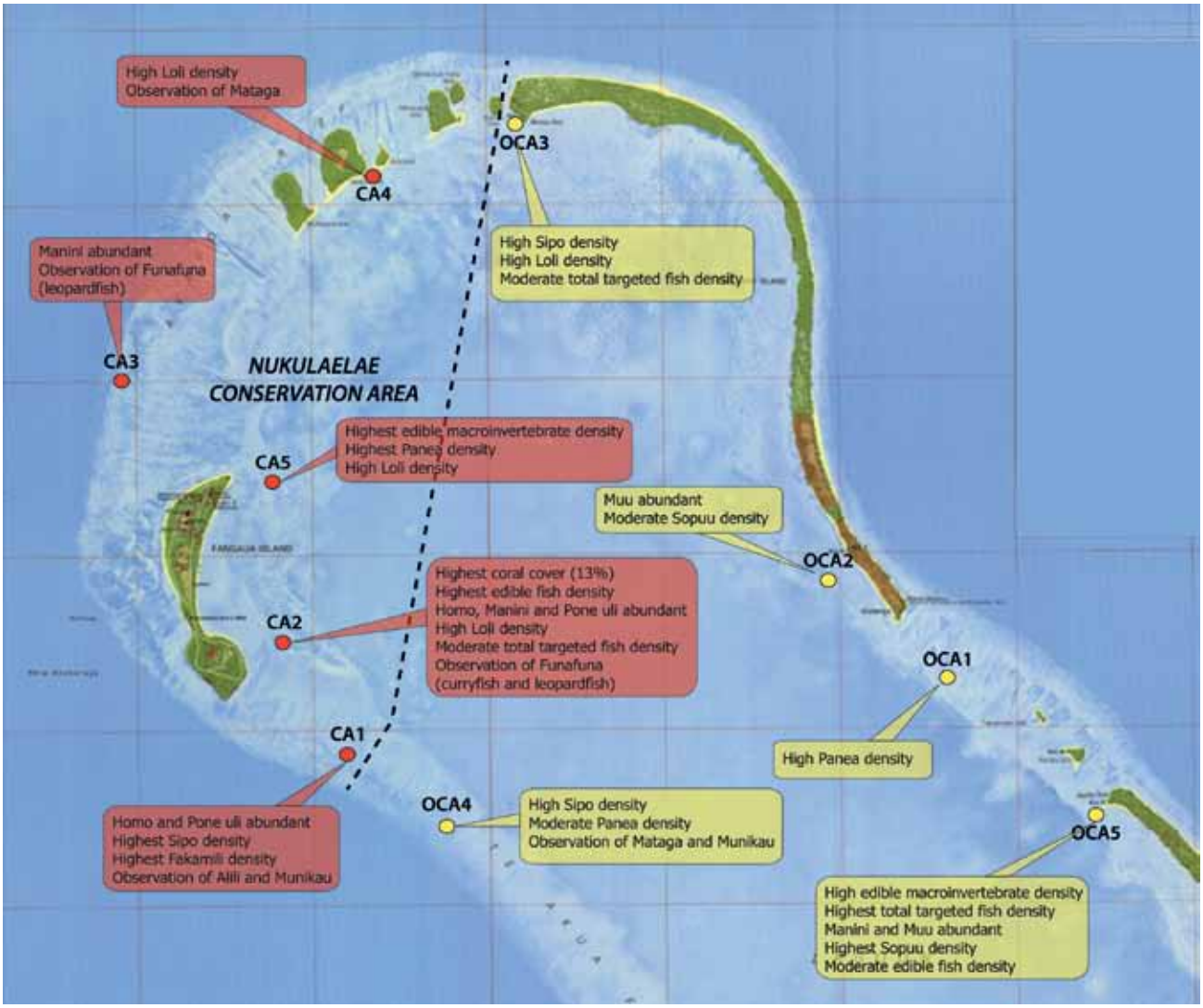
- The highest edible fish density (CA2), with particularly high abundances of *Chlorurus microrhinos* (Homo), *Acanthurus triostegus* (Manini) and *Ctenochaetus striatus* (Pone uli) (at CA1, CA2 and CA3).

- The highest densities of *Cerithium nodulosum* (Sipo, at CA1) and *Strombus luhuanus* (Panea, at CA5).
- The highest edible macroinvertebrate density (on CA5).

- The few commercially important sea cucumber species observed suring the surveys were also recorded here: leopardfish (at CA2 and CA3) and curryfish (at CA2)

- The proximity of the CA with the village where most of the people from Nukulaelae live is certainly beneficial regarding compliance with customary regulations within the CA.

Points of interest at all stations investigated in Nukulaelae atoll.



MAIN FINDINGS - NANUMEA CONSERVATION AREA

Stations located within Nanumea Conservation Area showed:

- Moderate coral cover (on CA1 and CA2)

- Abundant edible fish species *Chlorurus microrhinos* (Homo, at CA3 and CA4), *Acanthurus blochii* (Maa, at CA3 and CA5) and *Scarus ghobban* (Ulafi, at CA1).

- Four fish species targeted by fishermen appeared to be more abundant within the CA than outside: *Acanthurus blochii* (Kapalagi), *Pseudobalistes flavimarginatus* (Umu), *Epinephelus fuscoguttatus* (Fapuku) and *Monotaxis grandoculis (*Muu).

- The highest *Spondylus* densities (Hopu nifo and Hopu teka) (at CA2).

Station OCA1 located close to the American channel, appeared to be the richest station in the Nanumea lagoon, with:

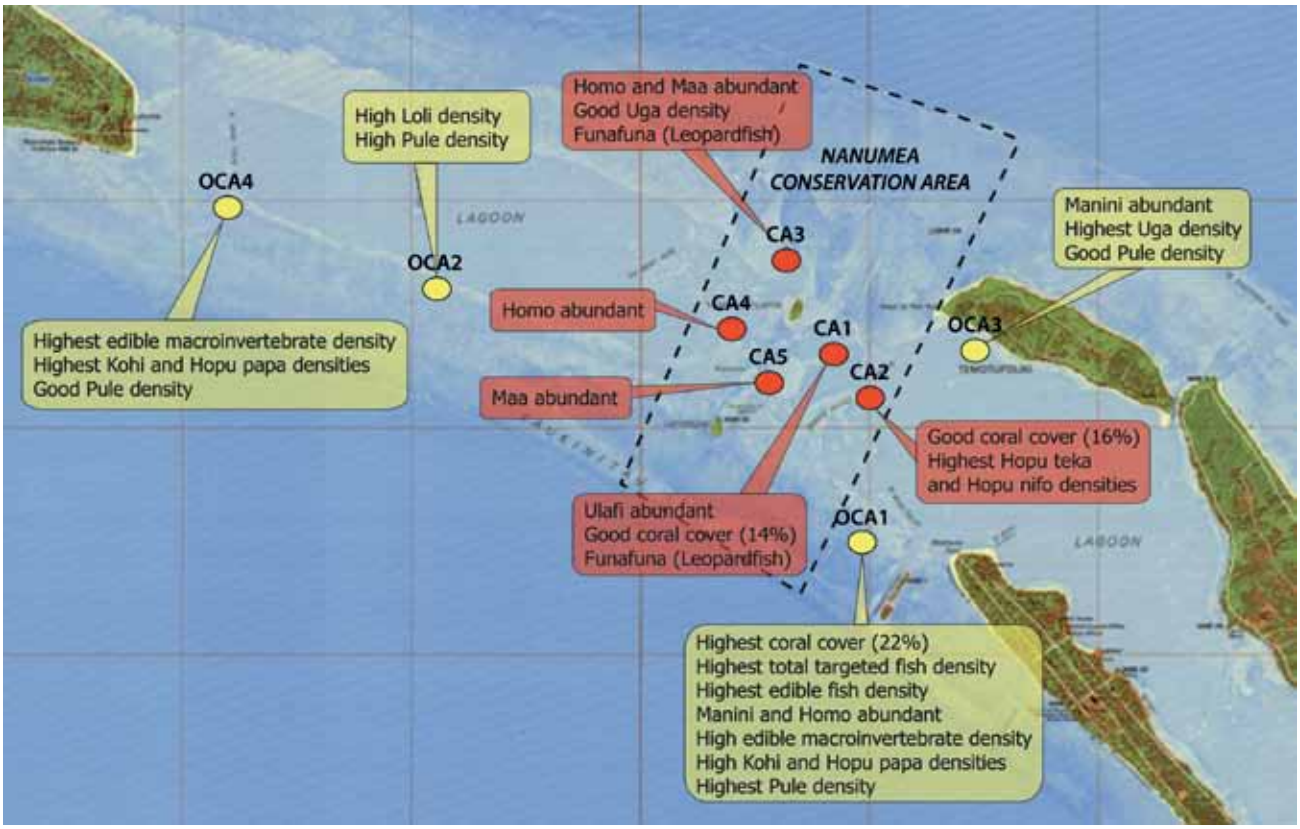
- The highest coral cover

- The highest total and edible fish densities

- The highest cowrie density.

- High edible macroinvertebrate density, especially archs (Kohi) and *Chama* sp. (Hopu papa). This station is located in the immediate proximity of the only link between the lagoon and the open ocean, and the high water movement, the exchange of nutrients and the mixing of oceanic and lagoonal species are likely to be the primary drivers of this higher level of species richness and density. It may be beneficial to initiate dialogue between local fishermen and the Tuvalu Fisheries Department about the possibility of including this station in the CA, as closing it to fishing (even partially or seasonally) may result in the effective protection of food and breeding stocks of edible fish to replenish adjacent fished areas.

Points of interest at all stations investigated in Nanumea atoll.



CONCLUSION AND GUIDANCE

The Tuvalu Marine Life Project has facilitated the addition of a substantial number of reef fish species to the existing list: a total of 317 reef fish species were recorded during this study, including **66 species that had not been listed previously for the archipelago**. These 'new species' are all common coral reef species with a broad distribution. **No endemic species were found but 79 IUCN listed species were observed.**

The total number of reef fish species for Tuvalu is currently 607, and with a greater sampling effort we may expect a total of 711 species for Tuvalu (equivalent to around two-thirds of the maximum known biodiversity, recorded in the Coral Triangle). Substantial additions of further species are likely to require alternative sampling techniques, including destructive methods such as collecting, trawling and line-fishing.

Each of the surveyed atolls hosts a unique lagoonal fish assem-blage. Reef fish communities on the two outer islands, **Nanumea and Nukulaelae, are defined by high densities of small fishes** (especially within the lagoons, where there are often large schools of planktivorous damselfish and juvenile parrotfish). **Funafuti is host to smaller densities and larger fish.** These patterns may be the result of differential fishing pressure on the three atolls, combined with environmental parameters. Unlike the two remote atolls, Funafuti lagoon is open to the ocean and offers a greater variety of habitats.

Density and biomass data reflect a relatively low fishing pressure in most surveyed areas, even though signs of overexploitation can be found around inhabited areas.
Previous reports have raised concerns about signs of overfishing in Funafuti, such as a general decline in abundance and sizes, as well as a relative increase in species that occupy lower trophic levels.

Very few sharks were observed around the three atolls surveyed. These top predators are important for maintaining ecosystem health and equilibrium, but are disap-pearing globally.

Benthic communities are indicative of healthy coral reefs, but are nevertheless subject to multiple human and natural disturbances. Some exposed sites showed signs of past storm damage, and in Funafuti, parts of the lagoon closest to densely inhabited areas showed evidence of higher concentrations of nutrients and pollutants, with turbid water and a high cover of macro-algae.

The structure of benthic com-munities appears to be a good indicator for the composition of the fish assemblage, with the best predictors being live coral, sand and coralline algae. Each of these benthic categories serves as a useful proxy for the broader habitat. High live coral cover was generally found in relatively sheltered environments, the cover of sand could well serve as a proxy for lagoonal areas, and coralline algae tended to occur in higher cover in areas more exposed to wave action. Each of these habitats tended to support a distinct group of fish species.

The CA Survey provided a first assessment of marine resources on the outer islands (Nanumea and Nukulaelae), as requested by local people. Gaining knowledge of their fish and invertebrates stocks is a key goal in the effort to manage their resources more sustainably. In Funafuti, the FCA had already been monitored several times since its implementation, but previous data were not available for comparison.

Coral cover in and around the CAs is relatively low on the surveyed atolls, and tends to increase with the degree of lagoon openness (from a mean of 6% in Nanumea to 15% in Funafuti).

There is a general dominance of branching corals of the genus Acropora. The density of edible macro-invertebrates is low in most places, except for three locations in Nanumea's lagoon where locally harvested bivalve densities ("Kohi" and "Hopu papa") were high. It was noted that clams were absent from the outer islands and very scarce in Funafuti lagoon. Most clams found in Funafuti were recorded from within the FCA. Almost no commercial species of sea cucumber were found during the survey.

Edible fish densities were low at all surveyed sites, except at two inner reef slope stations of Funafuti, in front of Fuafatu and Fualefeke. **Despite the low densities, there appears to be sufficient fish for local consumption.**

Conservation Areas were found to be similar to adjacent unprotected habitats during both surveys. Nevertheless, as Tuvalu faces a changing climate and declining resources, **no-take CAs provide the best solution to safeguarding Tuvaluan fish biodiversity and stocks of valuable food fish: lagoons may play a major role as nurseries, host a number of juveniles of locally targeted fish species and a unique fauna that should be preserved**. It may be too early after the establishment of CAs in Nanumea and Nukulaelae to detect a statistically significant effect.

We conclude by offering ideas on important marine resource management issues based on our field investigations. It is important to note that this study does not aim to advocate for particular management actions.

The following recommendations aim to take into account financial and capacity limitations and attempt to remain appropriate to the local Tuvaluan context.

Strengthen/Enforce regulations for Conservation Areas.

Enforcement is more important than monitoring, as the lack of compliance with no-take areas will severely hinder any benefits of the CA. Effective enforcement will limit poaching, especially around Funafuti. Poaching within the FCA has been noticed by the FCA officers and this survey noted common signs of poaching, such as snagged fishing lines and recently dead clam shells.

Monitoring of Conservation Areas.

Maintaining previous methodologies and collaborating with the local project's team is advised. To assist this process, a random sampling design has been chosen, leading to a high numbers of replicates within the same area and avoiding lengthy searching. It is recommended that the monitoring be conducted annually by the same team, based on the species list established during this study. It is recommended that observers attend a one-day "refresher" to revise census techniques and the identification of target species. Ideally, monitoring and training is to be conducted in collaboration with the Fisheries Department. A number of items to be used in future field surveys were left in the care of the Fisheries Department of Funafuti.

Setting up and strengthening the customary management committee on each atoll.

This management committee would ideally involve community representatives (elders, women, youth, local fishermen and commercial fishermen, including people involved in the sea cucumber industry).
Monitoring should inform adaptive management that would be updated according to changes in stocks. It would also be responsible for disseminating information within the local community. This committee may also be able to raise funds to cover the costs of resource management (fieldwork, communication, etc.), as was done in Nukulaelae, where a World Bank GEF fund was received for marine resource management).

Commercial sea cucumber stock assessment.

A dedicated sea cucumber survey will be required on each atoll where intensive commercial collection of sea cucumbers occurred in the past (such as Funafuti and Nukulaelae). We observed very low stocks of high grade sea cucumber species in the 3 lagoons studied. According to the Tuvalu Fisheries officers, sea cucumber collection was taking place primarily on the outer reef slope and moving deeper with time, systematically depleting stocks and leading to higher risks for local divers. If commercial collection was to happen again, improved management of sea cucumber stocks and diver safety protocols is highly recommended.

Clam stock assessment around Funafuti.

Along with sea cucumbers, clam stocks are very low, especially outside the FCA. As mentioned previously, poaching activities have been recorded within the FCA. One of the first management measures must be the enforcement of existing regulations. Because clams are only caught for local consumption, it might be appropriate to raise community awareness regarding the consequences of overexploitation of clams.

Trochus and turbo stock assessment.

A dedicated survey is required within the preferred habitat for these species on each atoll surveyed.
This study demonstrated a low number of these two resources. However, it is important to note that the specific habitat for these gastropods was not surveyed.

Explore options for shark conservation.

According to our field observations and discussions with local fishermen, reef shark stocks are currently very low throughout Tuvalu. A combination of mortality sources exist, both through fisheries targeting sharks and through by-catch. Awareness about the need to protect top predators for a healthy ecosystem appeared largely lacking.

Education programs could cover the importance and vulnerability of sharks, targeting a range of social groups (e.g. schoolchildren, fishermen, elders, etc.).

The imposition of catch limits and banning the finning of sharks are effective first steps towards shark conservation, but it may be necessary to extend shark management programs to include foreign fisheries operating within Tuvaluan waters. ■

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Table 2:
Patea Sela and **Esela Lopati**, CA survey, Nanumea - **Tahaoga Isako** and **Kaufiti Saloa**, Boat driver, Nanumea - **Patrick Malaki** and **Morris Melitiana**, Boat driver and CA survey, Nanumea - **Iosua Filiki** and **Monise Peni**, Boat driver, Nukulaelae - **Faiva Namoliki**, **Kinieti Pene, Losua Tepaolo**, **Mataua Lima** and **Lee Faeva Moresi**, CA survey, Nukulaelae - The Manaui crew: **Tima Talapai**, **Mauatu Tepoga**, **Kaumoe Pene**, **Kokea Toaki** - **Simon Salea**, Manaui Crew, CA survey Nanumea & Nukulaelae - **Nelly Senida**, Manaui Crew Boat driver, Nanumea & Funafuti - **Panei Togapili**, Tuvalu Fisheries, CA survey, Nukulaelae & Funafuti - **Teulu Sigalo**, Tuvalu Fisheries, CA survey, Nanumea & Funafuti - **Paeniu Lopati** and **Moeo Finauga**, Tuvalu Fisheries, CA survey, Funafuti - **Kirisi Salanoa**, The Funafuti Conservation Area, CA survey, Funafuti - **Aso Veu** and **Tennis Manu**, Boat driver, Funafuti

Table 3:
Nanumea people: T**eu Manuella**, **Filofale Taofusi**, **Tafito Miho**, **Fati Petolua**, **George Teaso** - Nanumea Kaupule members: **Eli Teuea**, **Tie Maheu**, **Isala Katalake**, **Tuivaka Paitela**, **Toai Vevea**, **Muna Tefeke** - Nukulaelae people: **Maly Tulimanu**, **Letioa Tom**, **Pua Koliano**, **Mamele Galu**, **Silika Lenese**, **Tamiloga Silo**, **Luta Lake** - Nukulaelae Kaupule members: **Ekueta Telava**, **Tom Lake**, **Petaia Mose Paeniu**, **Kelisiano Losefa**, **Faiva Tinei** - Funafuti Kaupule members: **Andrew Ionatana**, **Uluao Lauti**, **Meneua Teagai**, **Kaitu Nokisi**, **Apinelu Tili**, **Heiloa Loua**, **Suka Taupale** - TANGO: **Taukiei Kitara** - The Tuvalu Department of Environment: **Mataio Tekinene** - Tuvalu Fisheries: **Nikolasi Apinelu** and **Sam Finikaso** - NBSAP: **Eliala Fihaki** - NAPA: **Nakala Nia** - ForamSand Project: **Fumiko Matsudate** - New Zealand Department of Conservation: **Annie Wheeler** and **Dan Breen** - Radio Tuvalu - **Risasi Finikaso** and the Vaiaku Lagi Hotel team

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