Reef-Building Corals in Timor-Leste

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Health coral community from the waters of Timor-Leste

Summary

This report describes the results of surveys of biodiversity and status of coral communities of Timor-Leste, surveyed in August 2012. This nation forms part of the Coral Triangle (CT), earth's most diverse tropical marine province. The surveys were designed to assess biodiversity and ecological condition and identify sites of conservation priority, towards improving functionality of the Nino Konis Santana National Marine Park (NKSNMP). The survey was funded by the U.S. Agency for International Development (USAID) as part of a collaborative project between Coral Triangle Support Partnership (CTSP) and the National Government, particularly the National Directorate for Fisheries and Aquaculture (Ministry for Agriculture and Fisheries) to improve marine management practices contributing to sustainable livelihoods.

A total of 39 sites (adjacent deep and shallow areas) at 20 stations (individual GPS locations) were surveyed along the NE coast inside and outside of Nino Konis Santana National Park and on Atuaro Island. Coral communities were assessed in a range of wave exposure, current and sea temperature regimes, and included most habitat types of the NE coast. Coral communities of the S coast, known to be of differing structure because of the different environmental regime, were not assessed due to weather and logistic constraints.

Species Richness

Timor-Leste hosts a diverse reef coral fauna, with a confirmed total of 367 reef-building (hermatypic) coral species. An additional 27 species were unconfirmed, requiring further taxonomic study. Three species (*Echinophyllia, Goniopora* and *Montipora* spp.) show significant morphological differences from their closest congeners, and are likely new to science, though requiring additional taxonomic study. In total, there are likely to be ca. 400 hermatypic Scleractinia present in Timor-Leste waters.

Within-station (point) richness around Timor-Leste averaged 153 species (s.d. 32 spp.), ranging from a low of 95 species at Hera W (Station 1) to a high of 214 species at Djonu East (Station 14). Other species-rich stations included Tutuala 3 Terraces (194 spp., Station 15), Loikere (193 spp., Station 4) and Belio Barrier Reef (190 spp., Station 19). These results for station and overall richness are similar to those from Bunaken National Park, higher than for Komodo and Banda Islands, and lower than Raja Ampat, Teluk Cenderwasih, Fak-Fak/Kaimana and Halmahera (all with ca. 450 spp. or more).

Community Structure

Using cluster analysis at the station level, four coral community types were identified. Each of the communities was characterized by a more-or-less distinctive suite of species and benthic attributes. Two communities occurred predominantly in NKSNMP, one of which at Jako Island and the other along the NE coast. The other two communities were most common further west and at Atuaro Island.

Coral Cover

Cover of living hard corals averaged 28 %. Dead coral cover averaged 9 % overall, such that the overall ratio of live : dead cover of hard corals was positive (3 : 1), indicative of a reef tract in moderate to good condition in terms of coral cover. Soft corals cover averaged 13 % overall. Areas of high soft coral cover occurred on rubble beds, likely created by earlier destructive fishing and/or coral predation and/or storm damage. Evidence of recent and not-so-recent blast fishing and some coral diseases were also present, the latter typically on tabular species of Acropora.

Coral Injury

The above impacts notwithstanding, corals exhibited relatively low levels of recent injury overall, other than at Lamsana Inlet, where an active crown-of-thorns seastar outbreak was occurring. There was no evidence of past or recent major coral bleaching-related mortality, as typically triggered by elevated or depressed sea temperatures.

Interregional Comparisons

Timor-Leste's coral faunal composition is typical of the larger region, with most species recorded being found elsewhere in the CT. In terms of coral composition (presence), Timor-Leste's coral fauna is most similar to those of Bali and Komodo, in the Lesser Sunda Islands. In terms of coral community structure however, Timor-Leste's coral fauna shows closest similarity to Northern Komodo, Northern Bali, Bunaken, Wakatobi and Banda Islands, suggesting that the Timor-Leste coral fauna is more under the influence of the ITF rather than the Indian Ocean.

Climate Change Resilience

There was no evidence or reports of past (1998) or recent (2010) large-scale high temperature bleaching-induced coral mortality around Timor-Leste. This is consistent with the presence of cool waters in most sites, which were typically 25-27° C at time of survey in August. This is three to four degrees cooler than many neighbouring locations, where sea surface temperatures consistently average 29-31 °C, inter-seasonal and inter-annual variability notwithstanding.

Waters to the north and south of Timor-Leste are major corridors of the Indonesia ThroughFlow (ITF), itself influenced by the cooling effects of mixing in the Banda Sea. If these cooling influences remain consistent, reliable features, Timor-Leste's oceanography may provide a cool water buffer and refuge against the increasing sea temperatures predicted from climate change over coming decades.

Conservation Priorities

Timor-Leste has shown great initiative in declaring Nino Konis Santana National Park, which, with effective management, can play a very important role in conservation and replenishment locally and regionally. NKSNMP has high quality reefs and forms an important link in the regional MPA network being developed in the Lesser Sunda marine ecoregion and the broader Coral Triangle. Reefs of high conservation value were widespread in NKSNMP and also at Atuaro Island.

Most of the high quality reefs already form part of a MPA (NKSNMP) and thus a lot of the hard work has been done in respect of achieving successful conservation outcomes, at least in the short term. Reefs at Atuaro Island are also of high conservation value for a number of different criteria. The latter area has strong potential for development into a new MPA, or even as an extension to NKSNMP.

A significant amount of work has been achieved to date in building awareness and fostering goodwill among coastal villagers and others who use marine resources. This should be continued. It is also important to increase monitoring, surveillance and enforcement capacities as far as practicable to minimize poaching; and to address, as far as practicable, the ongoing impacts. These include:

1. Destructive fishing –with evidence of recent blasting near Com (eg. Station 11)
2. Sedimentation from hinterland erosion / runoff, most notable at Lamsana Inlet (eg. Station 17) but also likely on reefs further to the west, not surveyed during the present study.

Consideration may be given to a 'User-pays' system (eg. Bunaken National Park, Raja Ampat MPA Network) whereby visitors pay a nominal fee for access. This can provide significant funds for MPA management and benefits to local communities. Given the growing importance of ocean-based toursim (diving and swimming), particular focus should be paid to developing ecologically sensitive tourism at an appropriate scale, and to maintaining healthy and attractive reef-scapes for these activities, and hence a focus on non-destructive, non-extractive activities.

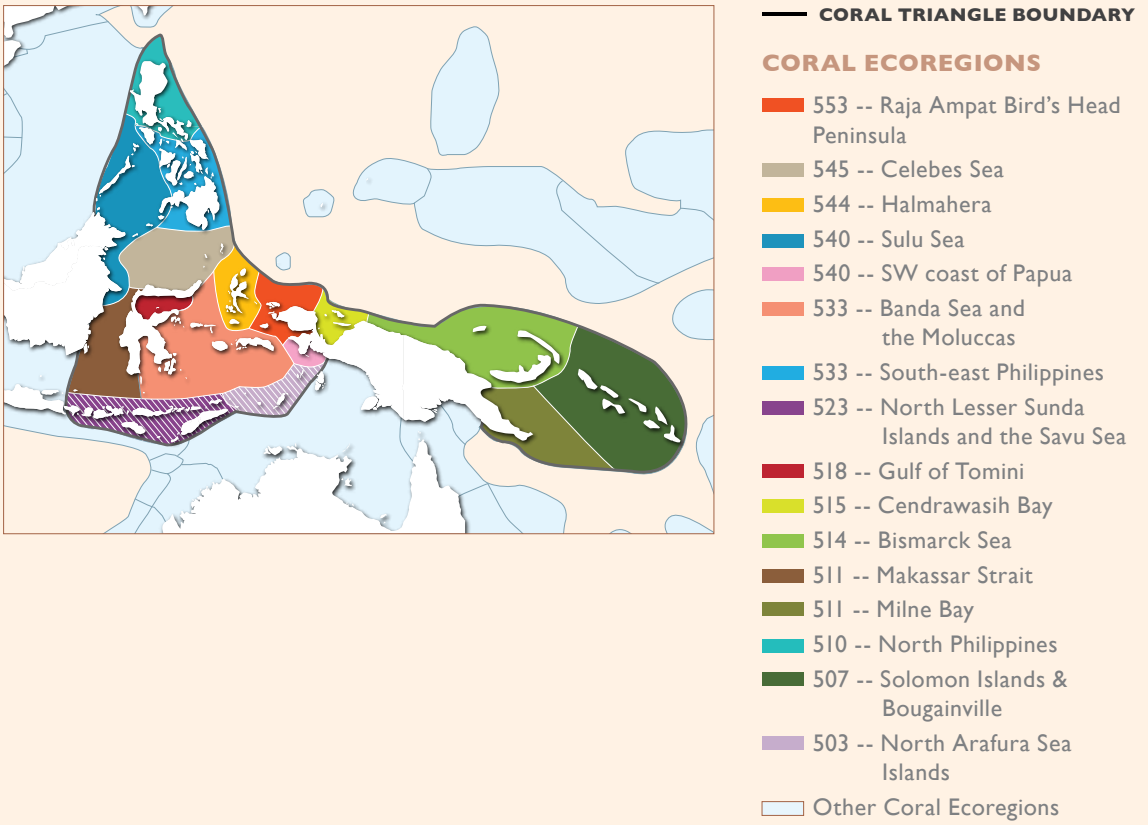
Introduction

Timor-Leste, located at latitude 8-9 S, 126 E, is situated in the Coral Triangle (CT, Fig. 1), earth's richest tropical marine realm (Allen 2007, Green and Mous 2007, Veron et al. 2009). Bordered on its south and west by the Indonesian part of Timor, Timor-Leste's coastline extends for approximately 700 km, including the islands of Ataura and Jaco and the western province of Oecussi. Offshore waters are typically deep, and form an important corridor of the Indonesian ThroughFlow (ITF), a major conduit of Pacific waters to the Indian Ocean. To the north lie Wetar Strait and the Banda Sea, which, through its influence on the ITF, plays an important role in the oceanography of Timor-Leste. To the south lies the Timor Sea.

Surrounded by deep waters channeling the ITF, Timor-Leste *"is an important migratory corridor for whales, dolphin and six threatened turtle species. Although small compared to other countries in the CT, Timor-Leste boasts rich and relatively pristine marine areas as well as economic potential in marine and coastal ecotourism."* (Esters and Erdmann 2012).

The coral ecoregion that includes Timor-Leste, namely 'North Lesser Sunda Islands and the Savu Sea', was known, prior to this study, to host at least 527 species of scleractinian reef-building corals (Veron et al. 2009). Reef coral diversity of Timor-Leste itself remained little known, although at least 124 species had previously been recorded during a 2008 survey (Ayling et al. 2009).

Figure 1. The Coral Triangle (Veron et al. 2009). Timor-Leste is located near the lower centre in the North Sunda Islands and Savu Sea Coral Ecoregion (purple colour). Crosshatching indicates that we considered the ecoregion to be data deficient.



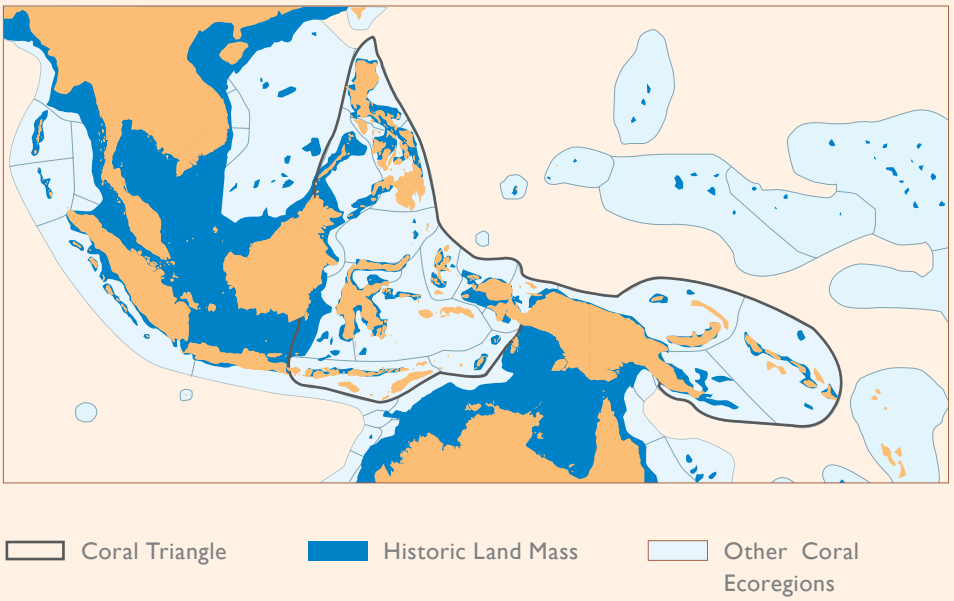
Today, areas of the larger ecoregion display a high degree of genetic distinctiveness from adjacent ecoregions for at least some reef-associated species, as exemplified by stomatopod crustaceans.

> *"Information from other taxa should reveal whether these findings apply to other Indonesian reef species, but the association of stomatopod populations with old ocean basins suggests that reef populations throughout Indonesia cannot simply be assumed to be interconnected units; … [it is important to] … also take biogeography and historical oceanography into account"* (Barber et al. 2000).

Historical oceanography, tectonics and eustacy

The island of Timor, positioned on the north-western edge of the Australian tectonic plate, drifted northward during the Miocene and Pliocene, attaining its present position relatively recently (Hall 2001, Audley-Charles 2004), and transporting a different biota to that of islands to its west. It has, over the past few million years, always been surrounded by deep waters during the episodic Pleistocene glaciations (Fig. 2). For example, bathymetry on the north coast declines steeply into a three km deep marine trench at approximately 20 km from shore (RDTL & CDU 2006; Keep et al. 2009, Boggs et al. 2009).

Figure 2. Approximate extent of exposed land (dark shading) during the major Pleistocene glaciations. Figure courtesy of Veron et al. (2009).



> *"The island of Timor is part of the Banda Arc. The Australian continental crust extends as far north as the north coast of Timor, and is thought to be uplifting Timor. … Over 40% of the country has extremely steep slopes … that are vulnerable to erosion and constantly being worn down by the monsoonal rains, with numerous rivers draining to the seas to the north and south (UNDP & RDTL, 2006)."* (Boggs et al. 2009).

Environmental Conditions and Oceanography

The major sea currents flow to the south, influenced by the ITF, which exports water from the North and central-west Pacific through Indonesia, providing a major water source for the north-east Indian Ocean and further afield (Fig. 3).

> *"Some of its waters enter the Indian Ocean through the Lombok Strait, but most flow eastward into the Banda Sea, where they cool and freshen … This modified ITF enters the Indian Ocean through the Ombai Strait and the Timor Passage …. From here, some ITF flows southward in the Leeuwin Current …, bringing heat and moisture to western Australia, but most joins the South Equatorial Current and transits across the Indian Ocean."* (Oppo and Rosenthal 2010).

There is a general north – south through-flow, but with some (mostly sub-surface) flow in the opposite direction. Perhaps paradoxically, the main areas of through-flow may be considered as both contributing to and restricting dispersal (see later). Local currents may prove as important as the influence of the ITF in connecting and isolating marine populations.

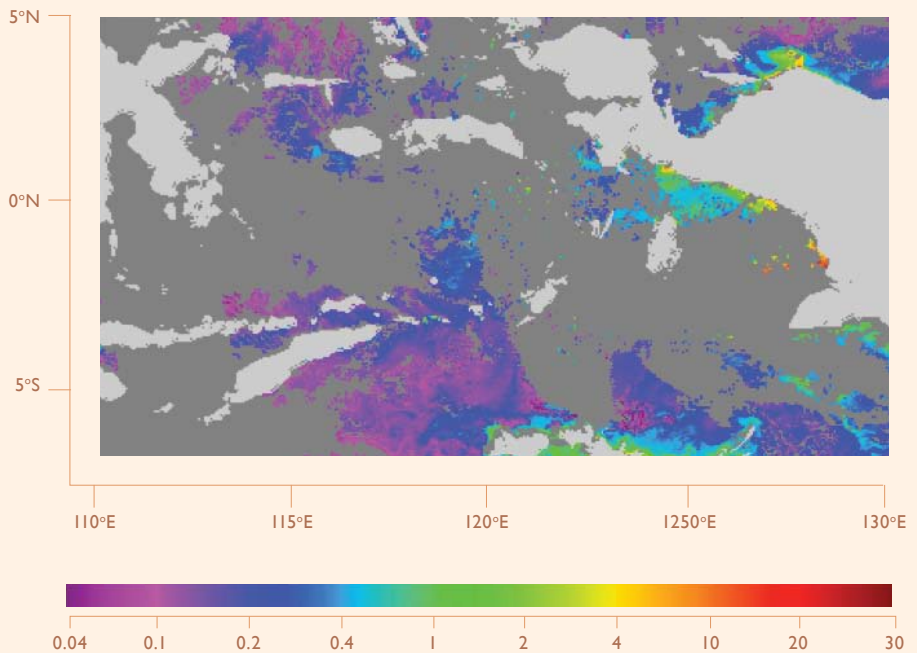
Figure 3. Main corridors of the Indonesian ThroughFlow.
Courtesy Oppo and Rosenthal 2010, Science 328 (Downloaded from www.sciencemag.org).

"[While] broad-scale oceanographic data may provide reasonable dispersal predictions…, other data may oversimplify the currents experienced by larvae that originate in near-shore environments. Eddies, stagnation zones, and local reversals of long shore currents are common in coral-reef systems, as are seasonal, tidal and weather-driven changes in current flow … These mesoscale coastal current patterns may greatly influence larval movements … and local retention … and are implicated in the formation of discrete population units … as well as in genetic structuring" (Barber et al. 2002).

Strong ocean mixing typically influences both nutrient concentrations and sea surface temperature in the broader ecoregion. Sea surface productivity, as exemplified by Chlorophyll A concentration, is patchy both spatially and temporally. In September 2012, Chlorophyll A concentration of 0.2-0.3 mg m-3 was slightly higher around Timor-Leste than waters to the south (Fig. 4), (NOAA Bloomwatch, **http://coastwatch.pfeg.noaa.gov/coastwatch/**), while Chlorophyll A levels were higher again in parts of the Banda Sea, around 0.4-0.6 mg m-3 (Fig. 3b), perhaps reflecting mixing of ITF waters there.

The southern coastlines are under the influence of long period ocean swell episodically exceeding three metres height from the Indian Ocean, generated by tropical – temperate storms, many of which are thousands of km away. By contrast, within the marginal seas to the north, waves are generally < 2 m high and generated by local weather patterns and the 'trade winds' of the monsoons, and sea conditions are often calm.

Figure 4. Chlorophyll A concentration, 13th September 2012. Downloaded from NOAA CoastWatch.



Chlorophyll-a, Aqua MODIS, NPP, 0.025 degrees, Pacific Ocean,

(mg m^ -3) 2012-09-13
Data courtesy of NASA GSFC (OBPG)

Sea-surface temperature (SST) within the Banda Sea typically varies from a low of 26.5 °C in August to a high of 29.5 °C in December and May (Gordon and Susanto 2001). Along the north coast of Timor-Leste, water temeratures ranged between 25 and 28 degrees C during the survey period of August 2012, consistent with variation in exposure to the ITF flow from the Banda Sea and localized upwelling. These temperatures are one to several degrees cooler than surrounding areas unaffected by the ITF or localized upwelling.

Inter-annual variability in air and sea temperature is caused by the influence of large-scale climate phenomena, notably the El Niño–Southern Oscillation and the Indian Ocean Dipole, and increasingly to the rapid continuing heating of earth's climate, commonly termed global warming.

Located betweem 8-10 degrees South, Timor-Leste is sufficiently close to the equator to be only occasionally affected by major tropical storms.

> *"Tropical cyclones can affect Timor-Leste between November and April, however their effect tends to be weak. In the 41-year period between 1969 and 2010, 31 tropical cyclones passed within 400 km of Dili, an average of less than one cyclone per season" (Pacific Climate Change Science Program partners 2011,* **http://www.cawcr.gov.au/projects/PCCSP/pdf/5_PCCSP_East_Timor_8pp.pdf**).

There are two distinct dry and wet seasons annually, driven by the annual movement of the inter-tropical convergence zone - the South-east and North-west monsoons. The northwest monsoon during the wet season typically extends from October-November to February-March and the southeast monsoon during the dry season from May to October, with a transition period of 1–2 months between seasons characterized by variable and lower winds. During the survey period in August 2012 however, winds at times blew from the north – north-east, generating a low northerly swell, and with episodic rain on the adjacent north coast.

> According to Boggs et al. (2009):
> *"The north coast of Timor-Leste experiences a dry tropical climate with a mean temperature above 24 °C and is influenced by the Northern Monomodal Rainfall Pattern which sees a single wet season from December to May. Annual rainfall in the north coast lowlands can be as low as <1000 mm, whereas higher altitudes might receive rainfall up to 2000 mm/year. Downpours are often extremely heavy (Barnett et al., 2003). In contrast, the southern coast is exposed to two wet seasons (Nov-Apr, May-Jul) and around 1500mm of rain annually.*
>
> *The northern and southern coast differ not only climatically, but also, with respect to coastal and nearshore environments. Topographically, the north coast is rocky and steep along most of its shoreline. The continental shelf is narrow, with coastal plains virtually non-existent or very narrow, except for around areas such as Manatuto and Dili, with numerous white sandy beaches with interspersed rocky outcrops are scattered along the coast. The north coast is characterised by karst geology and uplifted ancient coral reefs* (see Audley-Charles, 2004; Hamson, 2004; Keep, et al., 2009)."

Sea-and Reefscapes

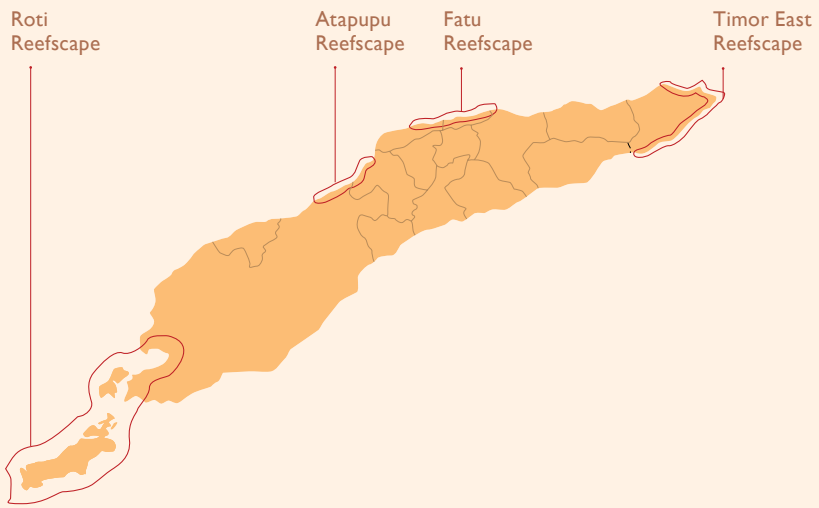
Within the Lesser Sunda ecoregion, seven smaller areas titled 'seascapes' were defined, based on the above oceanographic, geomorphological and biogeographic patterns, the most eastern of which included Timor-Leste (DeVantier et al. 2008). On its northern extent, the seascape is under the influence of the Banda Sea and the smaller, semi-enclosed Wetar Strait, and on its south extent the Timor Sea.

Around the island of Timor itself, a further reef habitat stratification identified four 'reefscapes' (DeVantier et al. 2008), three of which incorporated fringing reefs and associated seagrass and mangrove habitats of Timor-Leste (Fig. 5). Two of these were surveyed during the present study: Fatu and Timor East reefscapes, the latter coinciding with the recently designated (2007) Nino Konis Santana National Marine Park. Within NKSNMP, the south coast is more exposed to winds and swells than the more sheltered north coast.

Given this oceanographic setting, strongest biogeographic similarity is likely to occur within the north-facing (relatively sheltered) and south-facing (relatively exposed) coasts respectively. High dissimilarity is likely to occur between these two areas, with transitional areas in the semi-exposed locations. Such dissimilarity between north and south coast sites in respect of benthic composition was found during an extensive survey in 2008 (Ayling

Figure 5.

Reefscapes of Timor, Roti and adjacent small islands. From DeVantier et al. 2008 and courtesy of the Nature Conservancy.



et al. 2009). These general trends will be affected, on small scales (10s of km), by localized oceanographic and topographic features, including upwelling, and by ecological histories of particular sites. For example, coral communities at many N coast locations were impacted by population outbreaks of the predatory crown-of-thorns seastar from 2004 to at least 2008, with active outbreaks occurring at the time of the 2008 survey (Ayling et al. 2009).

Another key differentiating factor in the type and distribution of coastal marine habitats is substratum. Shallow areas of soft substrate may support seagrass beds, the adjacent coasts fringed by mangroves. Other areas are formed predominantly by kaarst, indicating earlier periods of reef growth and deposition. These porous areas may facilitate significant subterranean runoff of freshwaters during intense rainfall on the adjacent coast and hinterland, augmenting runoff carried in the episodically flowing river systems, limiting reef growth in some areas.

Dedicated habitat mapping using remote sensing (Landsat imagery and aerial photography) and ground-truthing (Boggs et al. 2009) revealed the following:

> *"The marine nearshore zone is characterised by a narrow reef flat (often < 60m wide, but up to almost 1km), dominated by seagrass in shallower water (approximately 2,200ha) and corals in deeper water and on the escarpment (approximately 2,000ha). A mixed-cover class, which included low covers of coral or seagrass and bare areas, occupied 1,250 ha. … The very limited extent of coral reef, seagrass and mangrove habitats on the north coast of Timor-Leste, impose strong limits on available marine resources and levels of harvest (particularly reef fisheries, mangroves) and in the light of increasing human resource use, underscore the urgent need for precautionary and effective conservation management.*
>
> *Importantly, the coastal mapping has revealed significant and ongoing coastal habitat loss in Timor-Leste. As such, total mangrove extent has reduced from 9,000ha in 1940, to 3,035ha in 2000 (FA0 2003) to just 1,802 ha recorded in 2008, ie. ~40% loss between 2000-2008, or disturbingly, an approximate 80% loss of total mangrove habitat since 1940. Mangrove trees are harvested for timber and fuel wood and in some instances hinterland mangroves have been removed for brackish water shrimp and/or fish ponds."* (Boggs et al. 2009).

Socio-economy

Timor-Leste restored its Independence in 2002 following decades of struggle and two years of United Nations administration. Timor-Leste's population is just over one million, approximately 60% of whom are less than 25 years old.

> *"Timor-Leste is now in the early stages of nationhood and state building. This period is a fragile time for the country which is currently relying on the international community for development assistance."* (Esters and Erdmann 2012).

The north coast of Timor-Leste is highly valued for its contribution to local livelihoods, particularly through ecotourism and fisheries (Boggs et al. 2009).

> *" … local communities rely on the sea as a source of household income and food security. … subsistence fishermen operating within the boundaries of the NKS are slowly increasing their catch efforts. Electricity has been made available and now fishermen can catch more fish, store it and sell it to buyers from different districts (Dili and Baucau). The passage from a subsistence based fisheries to market oriented fisheries coupled with population growth and … infrastructure plans for the [Nino Konis Santana Marine] National Park have potential to impact NKS fragile marine and coastal ecosystems."* (Esters and Erdmann 2012).

There is also considerable 'semi-industrial' poaching of fishes by foreign vessels, the amount of which remains unquantified. As noted by Ayling et al. (2009) following marine surveys in 2008:

> *"It is suggested that these reefs have been subjected to enough fishing pressure to reduce numbers of vulnerable target species and of commercially valuable invertebrates. However, the reefs are generally in good condition and have a number of unusual features."*

Detailed coastal habitat mapping by Boggs et al. (2009) also revealed that intensive agriculture (2,200ha) and built up areas (1730ha) were prominent features of the northern coast.

Planning for future sustainability

The Timor-Leste Government, with international and national support, is presently working towards a comprehensive long-term development strategy, including greatly improving spatial planning in both the terrestrial and marine areas. Towards these goals, the present survey of Nino Konis Santana National Marine Park (NKSNMP) was funded by the U.S. Agency for International Development (USAID) as part of a collaborative project between the Coral Triangle Support Partnership (CTSP) and the National Government.

> *"The Coral Triangle Support Partnership (CTSP) a USAID funded program has helped the Government of Timor-Leste, through its National Directorate of Fisheries and Aquaculture to conduct broad-scale habitat analysis of the marine component of the National Park. CTSP*

also co-facilitated with District level Government staff, community meetings to establish community zones and help the Government in its marine spatial planning efforts for the marine component" (Esters and Erdmann 2012).

Located in Timor-Leste's eastern area, NKSNMP comprises some 556 km2 of diverse marine habitats, extending for three nautical miles offshore, and bordering approximately 100 km of coast. NKSNMP was conceived as IUCN category V protected area (Edyvane et al. 2009, Esters and Erdmann 2012):

"Community members, fisheries staff and CTSP staff have been engaged for 2 years in identifying priority sites based on rapid biological surveys and local knowledge, these sites often referred to as community marine managed areas (cMMAs) follow the National Directorates instruction to explore the possibility of exploring cost effective management solutions with strong community participation.

To advance the cMMAs network agenda, the National Directorate for Fisheries and Aquaculture requested Conservation International to lead a team of local and international experts to survey sites in NKS National Park and provide clear recommendations on priority sites for future management, potential tourist sites and next steps for the design of the National Park. This information will be used towards the development of the NKS Marine component Management plan and to justify/socialize these plans to local government and local community stakeholders (Esters and Erdmann 2012).

Rationale and assessment objectives

The MRAP assessment, conducted during the period of 14-24 August 2012, had the following three primary objectives:

- Assess the current status (including biodiversity, coral reef condition and conservation status/resilience of hard corals and coral reef fishes) of approximately 20 sites representing the full range of oceanographic and ecological conditions found in the NKSNMP. Thorough species-level inventories of each of these groups will be compiled.
- Compile spatially-detailed data on biological features which must be taken into consideration in development of the NKSNMP Management Plan. This includes not only an analysis of any differences in reef community structure across the 20 priority sites, but also specifically identifying areas of outstanding conservation importance and/or marine tourism interest due to rare or endemic hard coral or fish assemblages, presence of reef fish spawning aggregation or cleaning sites, reef communities exposed to frequent cold-water upwelling that are resilient to global climate change, or other outstanding biological features.
- Taking the above into account, provide concrete recommendations to the Timor-Leste government on development of the MPA's management plan (including zonation plan) and on developing marine tourism in the MPA (Esters and Erdmann 2012).

In addressing these objectives, this study documents coral species composition, community structure and ecological status of the reef-building corals of Timor-Leste in August 2012. These results were compared with those of previous surveys in the "Coral Triangle" region, specifically with those from Berau, East Kalimantan (2004 TNC REA), Raja Ampat (including 2001 CI Marine RAP and 2002 TNC REA), Cenderawasih Bay (2006 CI Marine RAP), the FakFak/Kaimana Coastline (2006 CI Marine RAP) the Sangihe-Talaud region of North Sulawesi (2001 TNC REA), Bali (2008/2011 MRAP), Anambas (2012 MRAP) and Brunei (2009-2010 marine surveys) with a specific goal of quantitatively assessing ecological and taxonomic similarities in coral assemblages between Timor-Leste and neighboring regions within and adjacent to the Coral Triangle.

Based on the above information, concrete recommendations are provided to the Timor-Leste government on next steps in developing the Nino Konis Santana National Park Management Plan and fostering marine tourism development in the park. This includes identification of those reef (and other related ecosystem) areas that should be considered top priorities for inclusion in no-take or fisheries or tourism management zones within the MPA.

Methods

Rapid Ecological Assessment (REA) surveys were conducted using SCUBA at 20 reef locations (herein named 'stations', each with a specific GPS position) around Timor-Leste in August 2012 (Fig. 6, Annex 1). At all but one station (Station 22), deep and shallow areas, herein named 'sites' (designated as site #.1 and #.2 respectively) were surveyed concurrently, representing the deeper reef slope (typically > 10m depth) and the shallow slope, reef crest and flat (typically < 10m depth), for a total of 39 sites. Deep sites were surveyed first, in accordance with safe diving practice, with the surveyor swimming initially to the maximum survey depth (usually 30-40 m), then working steadily into shallower waters. In this report, the term 'station' refers to the combined results of the two sites (depths), unless otherwise specified with the specific depth designator (site #.1 and #.2 respectively).

The method was identical to that employed during biodiversity assessments in ca. 35 other regions of Indonesia and the Indo-Pacific, providing the opportunity for detailed comparisons of species diversity, composition and community structure, and of the representativeness and complementarity of different areas in terms of their coral communities. The field and analytical methods are explained in detail elsewhere (eg. DeVantier et al. 1998).

At each site, the survey swim covered an area of approx. one ha in total. Although 'semi-quantitative', this method has proven superior to more traditional quantitative methods (transects, quadrats) in terms of biodiversity assessment, allowing for the active searching for new species records at each site, rather than being restricted to a defined quadrat area or transect line. For example, the present method has regularly returned a two- to three-fold increase in coral species records in comparison with line transects conducted concurrently at the same sites (DeVantier et al. 2004).

Two types of information were recorded on water-proof data-sheets during the ca. one and a half hour SCUBA survey swims at each site: 1) An inventory of species, genera and families of sessile benthic taxa; and 2) an assessment of the percent cover of the substrate by the major benthic groups and status of various environmental parameters (after Done 1982, Sheppard and Sheppard 1991).

1. Taxanomic Inventories

A detailed inventory of sessile benthic taxa was compiled during each swim. Taxa were identified in situ to the following levels:

- Stony (hard) corals - species wherever possible (Veron and Pichon 1976, 1980, 1982, Veron, Pichon and Wijsman-Best 1977, Veron and Wallace 1984, Veron 1986, 1993, 1995, 2000, Best et al. 1989, Hoeksema 1989, Wallace and Wolstenholme 1998, Wallace 1999, Veron and Stafford-Smith 2002, Turak and DeVantier 2011), otherwise genus and growth form (e.g. Porites sp. of massive growth-form).
- Soft corals, zoanthids, corallimorpharians, anemones and some macro-algae - genus, family or broader taxonomic group (Allen and Steen 1995, Colin and Arneson 1995, Gosliner et al. 1996, Fabricius and Alderslade 2000).
- Other sessile macro-benthos, such as sponges, ascidians and most algae - usually phylum plus growth-form (Allen and Steen 1995, Colin and Arneson 1995, Gosliner et al. 1996).

At the end of each survey swim, the inventory was reviewed, and each taxon was categorized in terms of its relative abundance in the community (Table 1). These ordinal ranks are similar to those long employed in vegetation analysis (Barkman et al. 1964, van der Maarel 1979, Jongman et al. 1997).

For each coral taxon present, a visual estimate of the total amount of injury (dead surface area) present on colonies at each site was made, in increments of 0.1, where 0 = no injury and 1 = all colonies dead. The approximate proportion of colonies of each taxon in each of three size classes was also estimated. The size classes were 1 - 10 cm diameter, 11 - 50 cm diameter and > 50 cm diameter (Table 1).

Table 1. Categories of relative abundance, injury and sizes (maximum diameter) of each benthic taxon in the biological inventories.

Rank	Relative abundance	Injury	Size frequency distribution
0	absent	0 - 1 in increments of 0.1	proportion of corals in each of 3 size classes: 1) 1 - 10 cm 2) 11 - 50 cm 3) > 50 cm
1	rare		
2	uncommon		
3	common		
4	abundant		
5	dominant		

Taxonomic certainty: Despite continuing advances in identification and stabilizing of coral taxonomy (e.g. Hoeksema 1989, Veron 1986, Wallace 1999, Veron 2000, Veron and Stafford-Smith 2002), substantial taxonomic uncertainty and disagreement among different workers remains. This is particularly so with increasing use of molecular genetic techniques to examine systematic relationships (eg. Fukami et al. 2008). Results from these techniques have resulted in a major ongoing period of flux in coral taxonomy, particularly at higher taxonomic levels (eg. family). At genus and species levels however, the traditional classification scheme remains relatively stable, although different workers do provide different taxonomic classifications and synonymies for certain coral 'species' (see e.g. Hoeksema 1989, Sheppard and Sheppard 1991, Wallace 1999, Veron 2000). The analyses herein rely on our synthesis and interpretation of these revisions and with particular reliance on the species distribution maps of Veron (2000), currently being updated in the biogeographic database *Coral Geographic* (www.coralreefresearch.org).

Extensive use of digital underwater photography and a limited collection of specimens of taxonomically difficult reef-building coral species were made, in collaboration with Timor-Leste colleagues, to aid in confirmation of field identifications.

Small samples, usually < 30 cm on longest axis, were removed from taxonomically-difficult corals *in situ*, leaving the majority of the sampled colonies intact. Living tissue was removed from the specimens by bleaching with household bleach. Many of these specimens were identified, using the above reference materials, during and following the survey, and have been deposited for short-term storage at the CTSP Office, Dili.

2. Benthic cover and reef development

At completion of each survey swim, six ecological and six substratum attributes were assigned to 1 of 6 standard categories (Table 2), based on an assessment integrated over the length and depth range of the swim (after Done 1982, Miller & De'ath 1995). Because the cover estimates apply for the area and depth range over which each survey swim was conducted (eg. ca 40 – 9m depth; 8 – 1m depth respectively), these may not correspond precisely with line transect estimates made at a single depth or set of depths.

Table 2. Categories of benthic attributes

Attribute		Ranks used in calculating	
ecological	physical	% cover	Rank
Hard coral	Hard substrate	0	0
Dead standing coral	Continuous pavement	1 – 10 %	1
Soft coral	Large blocks (diam. > 1 m)	11 – 30 %	2
Coralline algae	Small blocks (diam. < 1 m)	31 – 50 %	3
Turf algae	Rubble	51 – 75 %	4
Macro-algae	Sand	76 – 100 %	5

The sites were classified into one of four categories based on the amount of biogenic reef development (after Hopley 1982, Hopley et al. 1989, Sheppard and Sheppard 1991):

1. Coral communities developed directly on non-biogenic rock, sand or rubble;
2. Incipient reefs, with some calcium carbonate accretion but no reef flat;
3. Reefs with moderate flats (< 50m wide); and
4. Reefs with extensive flats (> 50m wide).

The sites were also classified arbitrarily on the degree of exposure to wave energy, where:

1. Sheltered
2. Semi-sheltered
3. Semi-exposed
4. Exposed

The depths of the sites (maximum and minimum in m), average angle of reef slope to the horizontal (estimated visually to the nearest 10 degrees), and underwater visibility (to the nearest m) were also recorded. The presence of any unique or outstanding biological features, such as particularly large corals or unusual community composition, and evidence of impacts, were also recorded, such as:

- sedimentation
- blast fishing
- poison fishing
- anchoring
- bleaching impact
- crown-of-thorns seastars predation
- *Drupella* snails predation
- coral diseases

All data were input to EXCEL spreadsheets for storage and analysis of summary statistics.

Replenishment Index CI

The presence of high species richness, abundance and cover of reef-building corals may afford some sites greater importance than others in terms of their role as reproductive sources for local replenishment of populations. A local replenishment index, CI which rates sites based on a combination of their reef-building coral cover and individual species' rank abundance scores (DeVantier et al. 1998) was calculated for each site (depth):

$$CI = \sum A_i H_i / 100$$

where Ai = abundance rank for the ith reef-building coral taxon (as in Table 1), and Hi = rank hard coral cover category (1-5, as in Table 2), at each site. This index gives highest scores to sites that have high cover, species richness and abundance of reef-building corals. CI values for each site were averaged to produce Station totals.

Rarity Index

The presence of species that are rare in the study area may afford some sites greater importance than others in terms of the conservation of biodiversity of corals. An index, RI, to indicate the relative importance of sites based on their compliment of rare coral species was calculated for each site (after DeVantier et al. 1998):

$$RI = (\sum A_i / P_i) / 100$$

where *Ai* = abundance rank for the ith coral taxon at a given site (1-5, as in Table 2), and Pi = the proportion of all sites in which the taxon was present. This index weights species on a continuum according to their frequency in the data set, and gives highest values to sites which are least representative or most unusual faunistically (ie. with high abundance of taxa which are rare in the data set). RI values for each site were averaged to produce Station totals.

Coral Injury

Each coral species in the sites was assigned a score for its level of injury, from 0 – 1 in increments of 0.1 (from 0: no injury to any colony of that species in the site to 1: all colonies of the species were dead, see Methods above). Sites were compared for the amounts of injury to their coral communities, for the proportion of the total number of species present in each site that were injured, and the average injury to those coral species in each site.

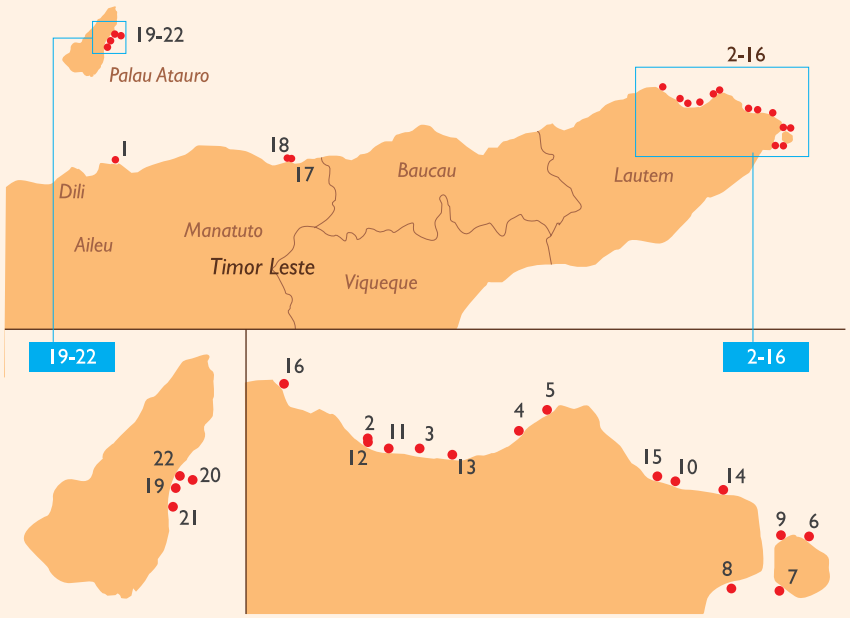
Coral community types

Site groups defined by community type were generated by hierarchical cluster analysis using abundance ranks of all corals in the individual station inventories. The analysis used Squared Euclidean Distance as the clustering algorithm and Ward's Method as the fusion strategy to generate site groups of similar community composition and abundance. Analyses were conducted on the raw (untransformed) data. The clustering results were plotted as dendrograms to illustrate the relationships among stations in terms of levels of similarity among the different community groups. Two sets of analysis were undertaken:

i. Timor-Leste
ii. Various regional analyses of adjacent regions of the CT, including Anambas Islands, Brunei, Derewan, Bali, Komodo, Wakatobi, Sangihe-Talaud, Banda Islands, Bunaken National Park, Raja Ampat, Cenderwasih Bay and Fak-Fak/Kaimana (Fig. 7).

To facilitate accurate comparison, all datasets used in the regional analysis had been recorded during various surveys undertaken by the present authors (listed in References).

Figure 6. Location of survey stations, Timor-Leste, August 2012.



For the regional comparisons, a further two sets of analyses were undertaken:

1. Using the presence of species in each location:

a. for Timor-Leste with Bali, Komodo, Banda Islands, Bunaken and Wakatobi, for a total of six locations; and

b. for Timor-Leste with the previous five regions plus 9 others - Cenderwasih Bay, Fak/Kaimana and Raja Ampat (all Birds Head Seascape, Indonesia), Sangihe-Talaud Islands (Sulawesi Sea), Derewan (Barau, East Kalimantan), El Nido (Palawan, Philippines), Brunei Darusalam and Anambas Islands, W Indonesia (latter three regions in South China Sea), for a total of 15 locations.

2. Using the species-abundance at the individual station level of analyses for Timor-Leste, with Bali, Komodo, Banda Islands, Bunaken and Wakatobi (153 stations).

Some additional temporal comparisons were made with the results of prior surveys of coral communities of Timor-Leste conducted by Ayling et al. (2009).

Figure 7.
General areas of surveys conducted in and adjacent to the Coral Triangle, including Timor-Leste (red star), Bali and Nusa Penida, Komodo, Banda Islands, Wakatobi, Derewan, Bunaken, Sangihe-Talaud, Halmahera, Raja Ampat, Teluk Cenderewasih and Fak-Fak/ Kaimana, Anambas Islands, Brunei Darusallam and El Nido, Palawan Philippines. These survey regions are each large and support diverse reef habitats. These were each surveyed as comprehensively as practicable in the limited time available (see References for details).

Results

Environmental Setting

A broad range of reef development occurred throughout the survey area, ranging from incipient reefs with some accretion to large sub-tidal and inter-tidal reefs with flats wider than 50 m (Table 3, Annex I). The coral communities were developed from low-tide level to > 60 m depth, although most coral growth occurred above 30 m depth, on slopes ranging from near horizontal (< 5o reef flats) to 70o to the horizontal (near-vertical reef walls), the latter being uncommon (Annex I). The communities were distributed over exposure regimes from sheltered to exposed, related to the degree of protection provided by coastal features. Periods of N wind generated waves to 2 m height along sections of the coast during the survey period.

Most coral communities were developed in areas of hard reefal or non-reefal substrate (mean of 78% cover) with only small areas of sand (mean 14%), and were subject to variable levels of current flow, ranging from calm to > 2 knots, the latter likely related to tidal flows and coastal marine geomorphology. There were usually negligible levels of sedimentation with silt from land-based run-off, other than at Lamsana inlet East (Station 17) on the N coast. The typically low silt levels contributed to the relatively high water clarity, which averaged 16 m, ranging from 4 m to 30 m during the survey period (Table 3).

Table 3. Summary statistics for environmental variables, Timor-Leste, August 2012.

Environmental variable	Mean (s.d.)	Ranger	Median	Mode
Reef development (rank 1-4)	3.3 (0.7)	2 - 4	4	4
Slope angle (degrees)	18 (15)	2 - 70	10	10
Exposure (rank 1 - 4)	2.4 (0.7)	1 - 4	2	2
Water Clarity (Visibility m)	16 (7)	4 - 30	15	20
Hard substrate (%)	78 (18)	30 - 100	80	80
Sand (%)	14 (16)	0 - 60	10	5
Silt (%)	2 (8)	0 - 50	0	0
Water temperature (C)	26.6 (0.7)	25 - 28	27	27

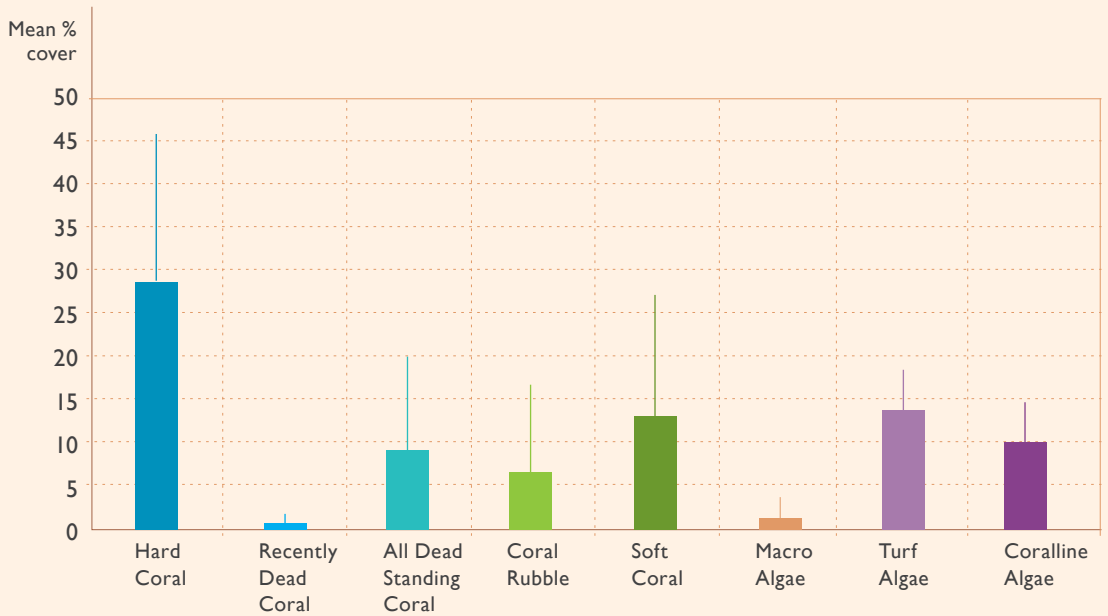
Cover of Corals and Other Sessile Benthos

Cover of living hard corals was typically moderate to high (eg. Plates 1 and 2), averaging 28 % (Fig. 8), and ranging from 5 – 70 % at individual sites. Stations with high live coral cover were widespread (Annex II). Highest cover (50 % or more) occurred at sites 6.1 and 6.2 (Jako Isl. N), 7.1 and 7.2 (Jako Isl. S) and 10.2 (Hotobumalai, Tutuala 1). Cover was dominated in some sites by large monospecific stands, notably the blue coral Heliopora coerulea at Jako Isl. N. At Jako Isl. S, by contrast, high cover was comprised of a highly diverse species mix.

Overall, rubble and dead corals contributed ca. 15 % cover, more than half of which was in the form of dead coral (9 %). Sites with relatively high cover of standing dead corals (20 % or more) were at Com (Sites 2.1, 2.2 and 3.2), Lamsana inlet East and West (Sites 17.1, 17.2 and 18.2) and Belio Lagoon S (Site 21.1) (Annex II). Previous mortality of live corals was mostly attributable to crown-of-thorns seastar and possibly *Drupella* snail predation, blast fishing, particularly around Com, and possibly coral diseases. Crown-of-thorns seastars were present at several sites, and were in outbreak numbers at Lamsana Inlet E (Site 17.2, Plate 3). As noted above, seastar outbreaks have been occurring along this coast since at least 2004 (Ayling et al. 2009), and appear to be in decline at present in all but one of the stations surveyed. Only very low levels of coral diseases were apparent, developed primarily on tabular species of *Acropora*. No evidence of recent coral bleaching was found, and no characteristic scarring indicative of previous mass bleaching during the 1998 El Nino event or other periods of elevated sea temperatures, perhaps related to Timor-Leste's oceanography (see Discussion). There was some evidence of recent blast fishing, for example at Station 11 near Com (Plate 4).

There was only low cover of recently killed corals (mean of < 1%) at most sites, and the continuing disturbances notwithstanding, the overall ratio of live : dead cover of hard corals remained positive at ca 3 : 1, indicative of a reef tract in moderate to good condition in terms of coral cover. Sites with high cover of rubble (20 % or more) included Irimasi (Sites 11.1 and 11.2), Belio Lagoon S (Site 21.1) and Belio inner Channel (Site 22.2). The ratio of live hard coral cover to dead corals plus rubble was also positive at ca 2 : 1, and is consistent with these reefs supporting ca. 40-50 % mean live hard coral cover during periods of low disturbance, as is presently the case at Jako Island and Hotobumalai, Tutuala 1 (Annex II).

Figure 8. Mean % cover (+ s.d.) of sessile benthos, Timor-Leste, August 2012.



Soft coral cover was moderate, averaging 13 % overall, and high in patches, notably on coral rubble beds. Stations with high cover (30 % or more) included Hera W, Com, Japanese Bunker and Belio Lagoon S (Sites 1.1, 1.2, 2.1, 2.2, 16.2, 21.1) (Annex II).

Plate 1.
High cover of reef-building corals, site 10.2, composed predominantly of Porites spp.

Plate 2.
High cover of reef-building corals, site 10.2, composed predominantly by branching Porites spp.

Plate 3.
Crown-of-thorns seastar feeding on Goniopora in site 17.1.

Plate 4.
Large circular 'crater' surrounded by broken coral consistent with recent blast fishing, Site 11.2 near Com.

Diversity of soft corals and related taxa was moderate to high at these, and several other, sites (see later). There was only low cover of macro-algae at most sites, averaging < 2 % overall. Only the station at Hera W had moderate MA cover (10 %, Site 1.1). Cover of turf and coralline algae was low to moderate overall, averaging 13 % and 10 % cover respectively (Fig. 8).

Species Richness

Timor-Leste hosts a rich coral fauna of 367 confirmed hermatypic scleractinian species. A further 27 species were recorded during the field surveys but remain unconfirmed at present (Annex III), such that there are likely to be some 400 hermatypic Scleractinia present, in total.

Three species may be new to science: *Echinophyllia* sp., *Goniopora* sp. and *Montipora* sp. (Plates 5-7). Each shows significant morphological variation in skeletal and / or soft tissue characters from the closest known species in their genera: *Echinophyllia costata, Goniopora fruticosa* and *Montipora Porites* respectively. Further taxonomic work is required to determine whether these are in fact new species, or rather Timorese morphs of their closest congeners.

Of the 367 confirmed species recorded (Annex III), almost all, with the possible exception of undescribed species, are shared with nearby areas of the CT (see later). The overall high degree of biogeographic similarity notwithstanding, differences exist among these areas in terms of the relative abundances of the species present. This in turn has had a differentiating effect on coral community structure (see later).

Plate 5.
Unidentified *Echinophyllia sp.*, from site 21.1.

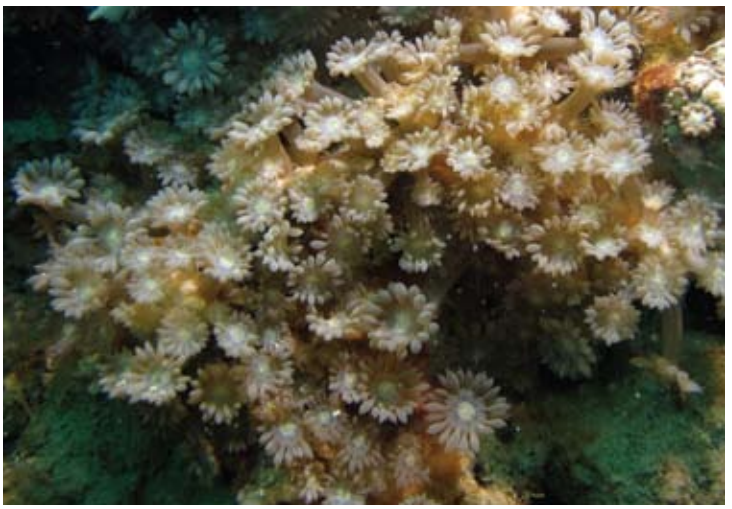


Plate 6.
Unidentified *Goniopora sp.*, from site 17.1.

Plate 7.
Unidentified *Montipora sp.*, from site 3.2.

Within-station (point) richness around Timor-Leste averaged 153 species (s.d. 32 spp.), ranging from a low of 95 species at Hera W (Station 1) to a high of 214 species at Tutuala 1 (Station 14). Other species-rich stations included Tutuala 2 (194 spp., Station 15), Umamutin (193 spp., Station 4) and Belio Patch S (190 spp., Station 19). These results for station and overall richness are similar to those from Bunaken National Park, higher than for Komodo and Banda Islands, and lower than Raja Ampat, Teluk Cenderwasih, Fak-Fak/Kaimana and Halmahera (Table 4).

Other hard corals, soft corals and other biota

In addition to the hermatypic Scleractinia, numerous other hard and soft corals were recorded, with greater or lesser taxonomic certainty (see Methods and Table 5). These included 2 species of the ahermatypic dendrophyllid *Tubastrea*, the 'blue coral' *Heliopora coerulea*, 5 species of hydroid 'fire corals' *Millepora*, the 'organ-pipe coral' *Tubibora musica* and lace corals *Stylaster* and *Distichopora* spp. (Table 5). An additional 50 genera of alcyonacean soft corals, plus zoanthids, corallimorpharians, anemones, hydroids and related sessile benthos were also recorded. Diversity and abundance of sponges was also exceptionally high (Ayling et al. 2009).

Rarity: The Rarity Index, which rated stations in respect of the occurrence of species otherwise rare in the Timor-Leste data set, revealed a broad range of RI scores (mean 5.1, range 2.3 – 8.3, Table 6), with Tutuala 1 (Station 14) being most unusual faunistically, followed closely by Tutuala 2, Belio Patch S and Umamutin (Stations 15, 19 and 4) (Table 6).

Table 4.
Comparison of diversity and other ecological characteristics of Timor-Leste with other Indo-West Pacific coral reef areas. **KO** – Komodo National Park; **BI** - Banda Isl., Banda Sea, Maluku; **BL** – Bali; **AN** – Anambas Islands; **DE** – Derewan, East Kalimantan; **W** - Wakatobi area, **S**. Sulawesi; **BN** - Bunaken National Park; **S-T** - Sangihe-Talaud Isl.; **RA** - Rajah Ampat, Papua; **TC** – Teluk Cenderawasih, Papua; **FK** – FakFak Kaimana, Papua. Data from Turak and DeVantier 2003, Turak and DeVantier in prep, Turak 2002, Turak and Shouhoko 2003, Turak et al. 2003, Turak 2006, Turak and DeVantier 2008, 2011, 2012.

Attribute		KO	BI	BL		DE	W	BN	ST	RA	TC	FK
Total number of species	367	342	301	406	339	449	396	392	445	487	469	469
Average no. of species per station	153	100	106	112	163	164	124	155	100	131	178	171
% of stations with over 1/3 rd species	100	43	61	38	100	78	41	85	8	18	79	65
Average % hard coral cover	28	32	40.3	28	35	36	32	41	21	33	27	26
Number of stations surveyed	20	21	18	48	20	36	27	20	52	51	33	34
Area covered (x1000 km2) approx.	2	2	0.4	3.7	17	20	10	0.9	23	30	27	12

Reefs of Lamsana Inlet E, one of the more sheltered locations, also scored highly, indicating locally unusal coral composition and abundance (Table 6). More than one-third of coral species (148 spp.) were locally uncommon or rare, occurring in four or less of the 20 stations. Fifty-five species were recorded from only one station, 42 species from two stations, 34 species from three stations and 17 species from four stations.

Among the rare species present were the branching dendrophylliid *Duncanopsammia axifuga* and columnar faviid *Echinopora ashmorensis*, both recorded only at Lamsana Inlet E (Site 17.2). For D. axifuga, this is the first record for the region. Conversely, some typically common coral species of the CT were very rare or possibly absent, their distributions ranges potentially disjunct at Timor-Leste. These included the acroporid *Acropora abrolhosensis*, trachyphylliid *Trachyphyllia geoffroyi* and siderastreid *Psammocora superficialis*. These species may occur in Timor-Leste waters, but were not found during the present survey. Finally, the typically uncommon acroporid *Acropora desalwii* was a relatively common component of reef slope assemblages, consistent with its type locality of the Banda Islands.

Coral Replenishment

Stations with high coral diversity, abundance and live cover were considered important for the maintenance and replenishment of populations. These were ranked using a simple coral replenishment index CI (Table 7 and see Methods). These were widespread across Timor-Leste, with highest scoring stations at Jako Island, Tutuala and Umamutin. Importantly, there was consistently strong recruitment by juvenile corals into areas denuded by previous crown-of-thorns seastar predation (Plate 8).

Table 5. Azooxanthellate scleractinian hard corals, non-scleractinian hard corals, soft corals and other biota recorded in Timor-Leste. Results are presented as the total sum of relative abundance scores and the number of stations in which each taxon occurred.

	abn	stations		abn	stations
HARD CORAL TAXA			**SOFT CORAL TAXA (CONTINUED)**		
Dendrophylliidae			• *Heteroxenia*	6	3
• *Tubastrea micrantha*	2	2	• *Xenia*	33	16
• *Tubastrea coccinae*	3	3	Briareidae		
Milleporidae			• *Briareum*	39	19
• *Millepora dichotoma*	10	7	Anthothelidae		
• *Millepora exesa*	19	13	• *Alertigorgia*	4	3
• *Millepora intricata*	9	5	• *Iciligorgia*	1	1
• *Millepora platyphylla*	19	13	• *Solenocaulon*	3	3
• *Millepora tenera*	12	7	Supergorgiidae		
Stylastraeidae			• *Subergorgia*	2	1
• *Distichopora*	5	3	• *Annella*	7	5
• *Stylaster*	8	6	Melithaeidae		
Helioporidae			• *Acabaria*	3	2
• *Heliopora coerulea*	48	19	• *Melithaea*	12	10
Tubiporidae			• *Mopsella*	3	3
• *Tubipora musica`*	35	18	Acanthogorgiidae		
SOFT CORAL TAXA			• *Acanthogorgia*	3	2
Clavulariidae			• *Muricella*	6	4
• *Carijoa*	2	1	Plexauridae		
• *Clavularia*	27	13	• *Menella*	2	1
Alcyoniidae			• *Paraplexaura*	3	2
• *Dampia*	3	2	Gorgoniidae		
• *Klyxum*	1	1	• *Pinnigorgia*	3	2
• *Lobophytum*	30	17	• *Rumphella*	11	7
• *Sarcophyton*	42	20	Ellisellidae		
• *Sinularia spp.*	48	20	• *Dichotella*	5	4
• *Sinularia flexibilis*	20	9	• *Elisella*	4	3
• *Sinularia tree*	1	1	• *Junceella*	10	6
Nephtheidae			Ifalukellidae		
• *Capnella*	28	16	• *Ifalukella*	1	1
• *Dendronephthya*	27	13	Isididae		
• *Lemnalia*	11	7	• *Isis*	36	16
• *Litophyton*	2	1	Antipathidae		
• *Nephthea*	34	17	• *Antipathes*	7	4
• *Paralemnalia*	47	18	• *Cirrhipathes*	12	10
• *Scleronephthya*	18	10	Zoanthidae		
• *Stereonepthya*	7	4	• *Palythoa*	37	19
• *Umbellulifera*	3	2	• *Zoanthus*	3	2
Nidaliidae			**Coralimorpharians**	4	3
• *Chironephthya*	5	4	**Anemones**	12	8
• *Nephthyigorgia*	1	1	Plumulariidae		
• *Siphonogorgia*	8	5	• *Aglophenia*	28	13
Xeniidae			• *Lytocarpus*	6	4
• *Anthelia*	14	8			

Table 6. Station ranking (scores) for Rarity Index RI from highest to lowest for 20 stations, Timor-Leste, August 2012.

Station name	stations	RI
Djonu East	14	8.3
3 Terraces	15	7.4
Belio Barrier Reef	19	7.2
Loikere	4	7.2
Lamsana inlet East	17	6.6
Belio - Lagoon S	21	6.0
Hilapuna	8	5.9
Djonu Twin Rocks	10	5.7
Belio - inner channel N	22	5.5
East Loikere	5	5.4
Lamsana inlet West	18	5.4
Jako Isl. SW	7	5.1
Ete Asa Lepek	11	4.4
Jako Isl. NW	6	4.1
Belio "Saddle" Patch R.	20	3.6
Hera West	1	3.3
W. Jako Isl.	9	3.2
Com Vailovaia	2	3.0
Com Koho Vari	3	2.7
Tenu, Japanese Bunker	16	2.3

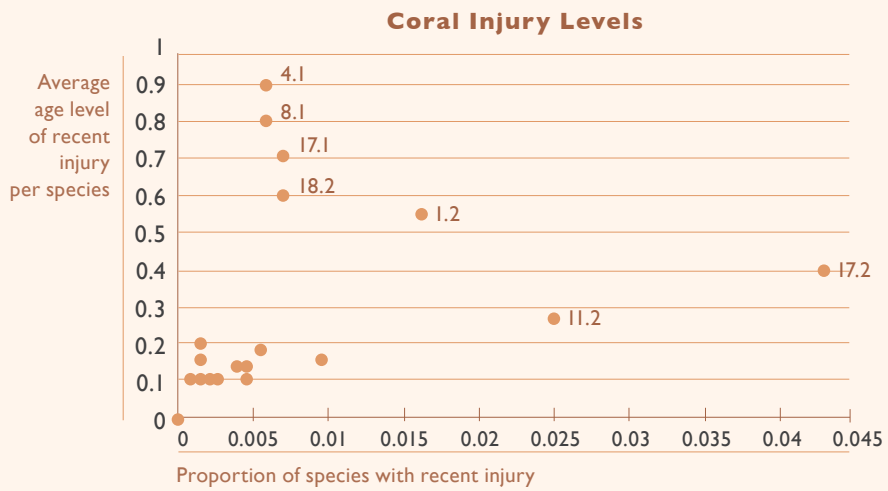
Table 7. Station ranking (scores) for Replinishment Index CI for 20 stations, Timor-Leste, August 2012.

Station name	stations	CI
Jako Isl. SW	7	7.1
Djonu East	14	6.0
Jako Isl. NW	6	5.5
Loikere	4	5.5
3 Terraces	15	5.3
Djonu Twin Rocks	10	4.9
Ete Asa Lepek	11	4.5
Hilapuna	8	4.3
Belio Barrier Reef	19	4.2
East Loikere	5	4.1
Belio - Lagoon S	21	3.6
Lamsana inlet West	18	3.4
W. Jako Isl.	9	3.0
Com Vailovaia	2	2.5
Lamsana inlet East	17	2.1
Belio - inner channel N	22	1.7
Com Koho Vari	3	1.6
Hera West	1	1.6
Belio "Saddle" Patch R.	20	1.3
Tenu, Japanese Bunker	16	0.9

Coral Injury

Corals of Timor-Leste exhibited low levels of recent injury overall, particularly in terms of the proportion of species injured of the total species present at each site. These proportions were low to very low at all sites (Fig. 9). This is consistent with the low levels of recently dead corals (< 2%, Fig. 5) and high positive ratio of live : dead coral cover. Some individual species did however exhibit high levels of recent injury at particular sites, caused mainly by predation by crown-of-thorns seastars and blast fishing, the former most notably at Stations 17 and 18, and the latter at Station 11 (Plates 3, 4).

Figure 9. Scatterplot of levels of recent injury to reef-building corals in 39 sites, Timor-Leste, August 2012. Sites with highest injury levels are named.



Litter and Pollution

There were no or very low levels of litter and pollution at most sites, consistent with the remoteness and small human populations of most areas surveyed. Lamsana Inlet (Stations 17 and 18) had higher levels of litter, including old fishing nets and lines and plastic bags (Plate 9, and see Annex II). Notably, the latter stations are outside NKSNMP and are subject to more human activity.

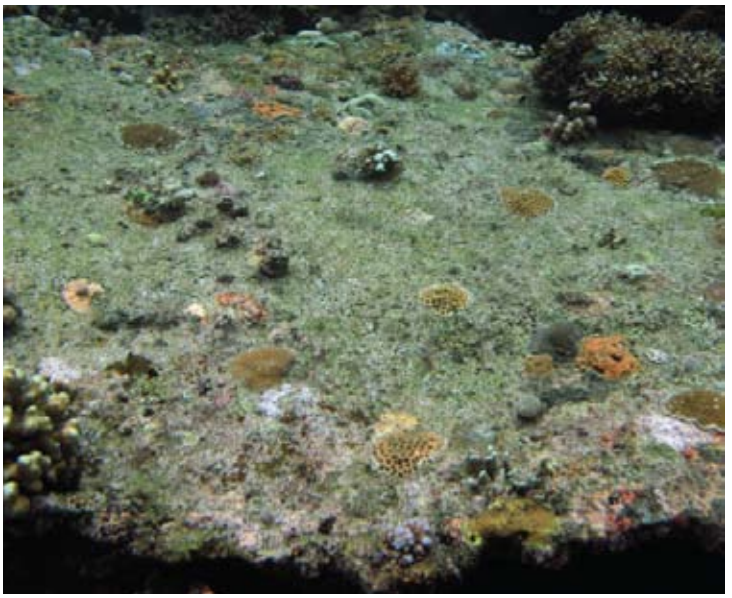


Plate 8.
Recruitment by juvenile corals to an old dead Acropora table, Site 5.2.

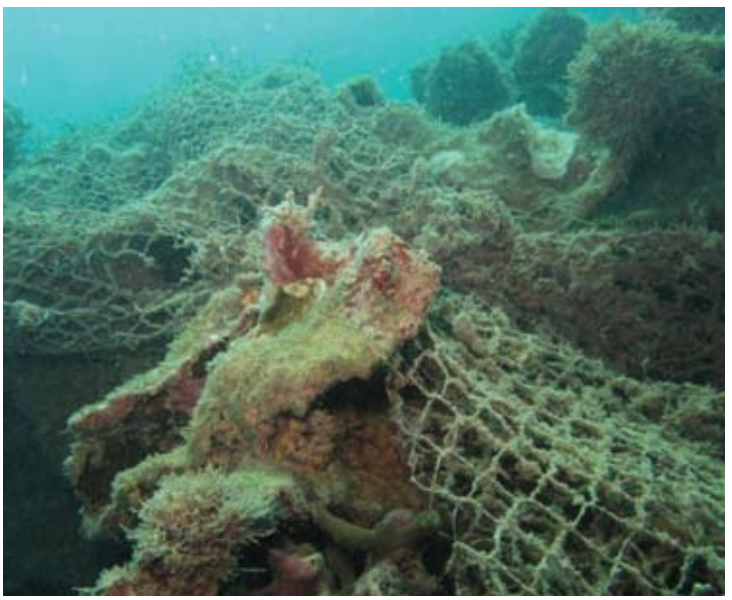
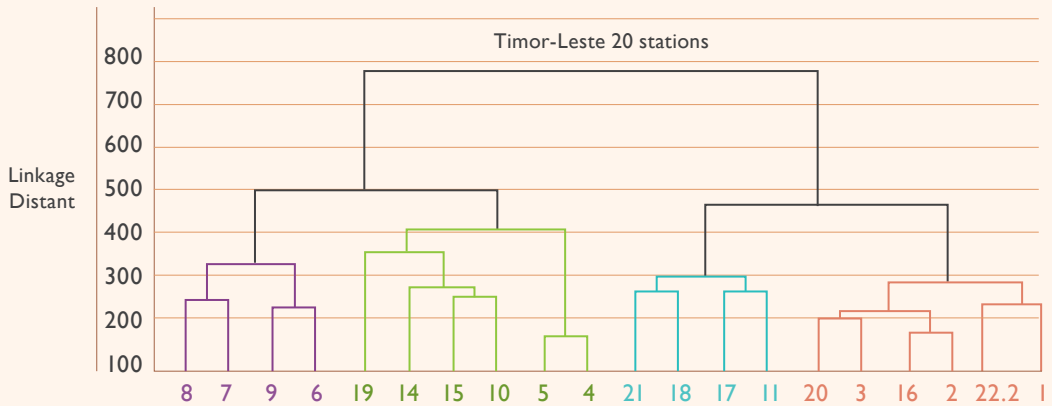


Plate 9.
Abondened fishing net caught on the reef at site 17.2.

Coral Community Structure

The cluster analysis for Timor-Leste revealed four main coral community groups (Fig. 10) at station level. Each community was characterized by a distinctive suite of species and benthic attributes (Tables 8, 9, Fig. 11), although some species were more or less ubiquitous across several community types, notably Porites spp. and various faviids. Because of their commoness, these taxa were not useful in differentiating among the different communities, although they do contribute significantly to coral cover in the region (Plates 10-17).

Figure 10. Dendrogram illustrating results of cluster analysis of coral communities, 20 stations, Timor-Leste, August 2012. Community A is represented by purple, Community B by green, Community C by blue and Community D by red. Note that Station 22 was a shallow site surveyed at only depth (22.2 on the dendrogram).



The four communities show a moderate degree of geographic separation across the survey area (Fig. 11), with two communities occurring mainly inside and two outside the NKSNP. Community A occurred predominantly on the NE coast around Jako Island, Community B along the N coast of NKSNP, and Communities C and D along the more western portion of the N coast and on Atuaro Island (Fig. 11).

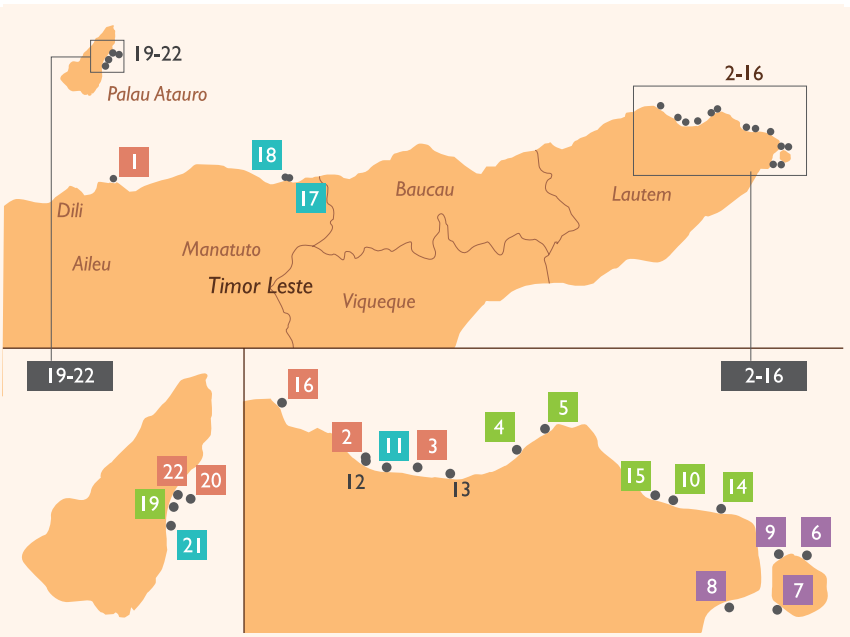


Figure 11.
Distribution of coral community types at 20 stations, Timor-Leste. Each station has one shaded 'community rectangle' indicating the identity of the community present.

- Community A
- Community B
- Community C
- Community D

Community A: *Digitate Acropora* community

Located mainly in the vicinity of Jako Island in NKSNP, this community occurred predominantly in waters of moderately good clarity (mean visibility of 16 m) along the more exposed NE tip of Timor-Leste (mean exposure of 3.3), on well-developed reefs (mean of 3.8) with relatively gentle slopes (mean of 10 degrees) (Fig. 12, Table 8). Characteristic indicator species included the digitate *Acropora digitifera* and *A. gemmifera*, the robust staghorn *Acropora abrotanoides* and massive *Montastrea annuligera* (Table 9). Community A had highest cover of living hard corals (mean 46 %) and was moderately species rich (mean of 150 reef coral spp. per station) (Plates 10, 11). Although the blue coral *Heliopora coerulea* was a predominant feature of the N coast of Jako Island, it was also a common component of Community C and hence not a strong indicator species (Table 9). As noted above, the S coast of Jako Island hosted a highly diverse coral assemblage. Reefs around Jako Island have remained in good condition over the four years since their quality was reported by Ayling et al. (2009).

Community B: Pectiniid community

This community of the N mainland coast of NKSNP clustered with Community A in the dendrogram (Fig. 10) and both occur predominantly in NKSNP. Community B had moderately high live coral cover (mean 33 %) and highest species richness (mean 191 spp.). It occurred on well developed reefs (mean of 3) with high levels of hard substrate (mean of 88 %) and steeper, deeper slopes than the other communities (mean slope angle of 25 degrees, and extending on some reefs to much deeper than 39 m). Sea conditions were semi-exposed (mean of 2.3), and water clarity was typically high (mean of 18 m) (Table 8). This community was characterized by the foliose - encrusting pectiniids *Oxypora lacera*, *Pectinia lactuca* and *Mycedium robokaki* and the tabular *Acropora granulosa* (Table 9). Various massive and branching poritids (*Porites* spp.) and mushroom fungiids (*Halomitra* and *Fungia* spp.) were also common (Plates 12, 13).

Community C: Fungiid community

This community occurred predominantly on the western part of the survey region outside NKSNP, around Com and Lamsana Inlet and also on Atuaro Island. Community C had moderately high reef coral species richness (mean of 150 spp. per station), and cover of living hard corals (mean 24 %). It had highest cover of dead corals (mean of 21 %) and rubble (mean of 13 %). It occurred on well developed reefs (mean of 3.9) in moderately sheltered waters (mean of 1.8) of good clarity (mean of 16 m) (Table 8, Fig. 12). It was characterized by a mix of mushroom fungiids, the foliose dendrophylliid *Turbinaria mesenterina* and columnar poritid *Goniopora columna* (Table 9) (Plates 14, 15). It had highest levels of silt (mean of 8 %) and litter, both mainly at Lamsana Inlet.

Community D: *Symphyllia - Diploastrea* community

This community occurred predominantly with Community C along the western part of the survey area and on Atuaro Island, outside NKSNP (Fig.11). It had lowest species richness (mean of 119 spp. per station) and lowest cover of living hard corals (mean of 14 %). It also had relatively high cover of dead corals and rubble (means of 10 % and 6 %), and highest cover of soft corals, comprised predominantly of *Sarcophyton* and *Sinularia* spp. (mean of 23 %) (Table 8). Community D was characterized by the massive mussid *Symphyllia recta* and faviid *Diploastrea heliopora* (Table 9, Plates 16, 17). The corymbose branching acroporids *Acropora cerealis* and *A. millepora* and pocilloporid 'needle corals' *Seriatopora* spp. were also common. It is likely that this community, with Community C, is widespread along the N coast of Timor-Leste.

Table 8. Summary statistics (mean values) for environmental and benthic cover variables for four coral communities, Timor-Leste, August 2012. Differentiating characteristics are in bold type.

	Coral community attributes			
	A	B	C	D
No. of stations				
Maximum depth (m)	27	**39**	31	30
Minimum depth (m)	1	1	1	3
Slope (degrees angle)	10	**25**	17	14
Hard substrate (%)	79	**88**	73	69
% cover benthos				
Hard coral	**46**	33	24	**14**
Soft coral	7	9	11	**23**
Macro algae	0	1	1	**3**
Turf algae	9	12	**21**	13
Coralline algae	9	10	11	10
Recently dead coral	1	1	2	0
All dead coral	5	3	21	10
% cover substrate				
Continuous pavement	49	**65**	51	**36**
Large blocks	19	13	11	15
Small blocks	11	10	11	19
Rubble	4	4	**13**	6
Sand	17	8	7	24
Silt	0	0	**8**	0
Environmental variables				
Exposure	3.13	2.25	1.75	2.45
Reef develop.	3.88	3.08	3.88	2.91
Visibility (m)	16	18	16	**13**
Water temp. C	26.75	26.67	26.50	26.45
Estimate of litter (1-5)	0.00	0.17	**1.75**	0.33
Mean no. of reef-building coral species	150	**191**	150	**119**

Figure 12. Mean % bottom cover of benthic attributes in four coral community types, Timor-Leste. Error bars are Standard Error (SE).

Table 9. Characteristic coral species in four coral community types identified in Timor-Leste, August 2012. Taxa used as indicators for the relevant community types are in bold.

A (4stns)		
Zooxanthellate scleractinia	abn	stns
Isopora palifera	13	4
Pocillopora verrucosa	11	4
Galaxea fascicularis	10	4
Fungia fungites	10	4
Montastraea annuligera	**10**	**4**
Porites nigrescens	10	4
Stylophora pistillata	9	4
Acropora digitifera	**9**	**4**
Favites abdita	9	4
Goniastrea pectinata	9	4
Porites vaughani	9	4
Pocillopora eydouxi	8	4
Montipora grisea	8	4
Montipora tuberculosa	8	4
Acropora abrotanoides	**8**	**4**
Acropora gemmifera	**8**	**4**
Acropora loripes	8	4
Pavona varians	8	4
Coeloseris mayeri	8	4
Fungia danai	8	4
Others		
Heliopora coerulea	**13**	**4**
Paralemnalia	13	4
Sponge massive	10	4
Sinularia spp.	9	4
CRA	**9**	**3**
Briareum	8	4
Diademnum	8	4
Palythoa	7	4
Sarcophyton	6	4
Xestospongia	6	4
Capnella	6	3
Sponge encrusting	6	3
Polycarpa	6	3
Tubipora musica	5	3
Clavularia	5	3
Nephthea	5	3
Aglophenia	5	2
Tridacna squamosa	4	4
Scleronephthya	4	2
Xenia	4	2

B (6stns)		
Species name	abn	stns
Porites vaughani	18	6
Fungia danai	16	6
Porites nigrescens	16	6
Acropora granulosa	**15**	**6**
Pocillopora verrucosa	14	6
Seriatopora caliendrum	14	6
Fungia fungites	14	6
Halomitra pileus	**14**	**6**
Oxypora lacera	**14**	**6**
Porites rus	14	6
Stylophora pistillata	13	6
Mycedium robokaki	**13**	**6**
Pectinia lactuca	**13**	**6**
Goniastrea pectinata	13	6
Echinopora lamellosa	13	6
Porites massive	13	6
Porites cylindrica	13	6
Montipora tuberculosa	12	6
Acropora loripes	12	6
Acropora subulata	12	6
Others		
Paralemnalia	16	6
Sinularia spp.	14	6
Sponge massive	14	6
Heliopora coerulea	13	6
Sarcophyton	13	6
Xenia	**13**	**6**
Briareum	**13**	**6**
Nephthea	12	6
Sponge encrusting	12	6
Tubipora musica	11	6
Lobophytum	11	6
Palythoa	11	6
CRA	11	4
Dendronephthya	10	5
Sinularia flexibilis	10	4
Millepora platyphylla	9	6
Carterospongia	9	6
Isis	9	4
Millepora exesa	8	5
Capnella	8	5

C (4stns)		
Species name	abn	stns
Fungia danai	**11**	**4**
Porites cylindrica	11	4
Porites nigrescens	11	4
Fungia fungites	**10**	**4**
Porites vaughani	10	4
Stylophora pistillata	9	4
Galaxea fascicularis	9	4
Fungia horrida	**9**	**4**
Fungia paumotensis	**9**	**4**
Ctenactis crassa	**9**	**4**
Pectinia lactuca	9	4
Turbinaria mesenterina	**9**	**4**
Porites massive	9	4
Goniopora columna	**9**	**4**
Pocillopora verrucosa	8	4
Isopora palifera	8	4
Euphyllia cristata	8	4
Pavona varians	8	4
Heliofungia actiniformis	**8**	**4**
Fungia granulosa	8	4
Others		
Heliopora coerulea	10	4
Sarcophyton	10	4
Sinularia spp.	10	4
Isis	**10**	**4**
Sponge encrusting	**9**	**4**
Tubipora musica	8	4
Briareum	8	4
Palythoa	8	4
Aglophenia	8	4
Sponge massive	**8**	**4**
Halimeda	8	4
Acanthaster planci	8	2
Carterospongia	7	4
Clavularia	7	3
Sinularia flexibilis	7	3
Paralemnalia	7	3
CRA	7	3
Peyssonnelia	7	3
Lobophytum	6	4
Capnella	6	3

D (6stns)		
Species name	abn	stns
Pocillopora verrucosa	13	6
Fungia danai	13	6
Galaxea fascicularis	12	6
Goniastrea pectinata	12	6
Porites massive	12	6
Porites cylindrica	12	6
Acropora cerealis	**11**	**5**
Seriatopora caliendrum	**10**	**6**
Montipora tuberculosa	10	6
Acropora millepora	**10**	**6**
Isopora palifera	10	6
Fungia granulosa	10	6
Mycedium elephantotus	10	6
Pectinia lactuca	10	6
Symphyllia recta	**10**	**6**
Goniastrea retiformis	10	6
Diploastrea heliopora	**10**	**6**
Seriatopora hystrix	**10**	**5**
Pavona varians	10	5
Montipora monasteriata	9	6
Others		
Sinularia spp.	**15**	**6**
Sarcophyton	**13**	**6**
Isis	13	6
Sponge massive	13	5
Heliopora coerulea	12	5
Tubipora musica	11	5
Dendronephthya	11	5
Nephthea	11	5
Paralemnalia	11	5
Xenia	11	5
Palythoa	11	5
Lobophytum	**10**	**5**
Briareum	10	5
CRA	10	4
Polycarpa	9	5
Aglophenia	9	4
Capnella	8	5
Carterospongia	8	4
Clavularia	8	3
Sponge encrusting	8	3

Plate 10.
Example of coral community A, Site 7.2, here showing one of the common corals Acropora abrotanoides.

Plate 11.
Example of coral community A, Site 9.2, here showing high cover of reef corals in shallow waters, mainly Isopora palifera and Heliopora coerulea.

Plate 12.
Example of coral community B, site 4.1, here showing one of the common corals Mycedium robokaki.

Plate 13.
Example of coral community B, site 14.2, here with Xenia, Paralemnalia and otrher soft corals.

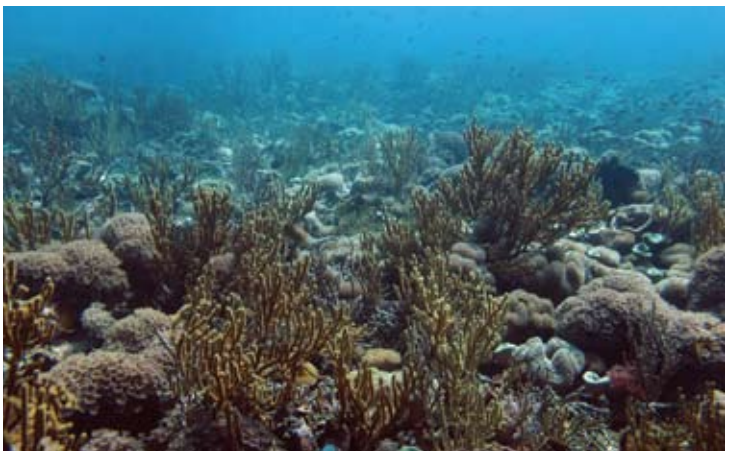


Plate 14.
Example of coral community C, site 21.2 with Isis predominant.

Plate 15.
Example of coral community C, site 21.1 with fungiids predominant.

Plate 16.
Example of coral community D, site 22.2, wit Acropora millepora, Seriatopora and othetr pocilloporids.

Plate 17.
Example of coral community D, site 2.2, with dominant Alcyonarian soft corals and Isis in the shallows.

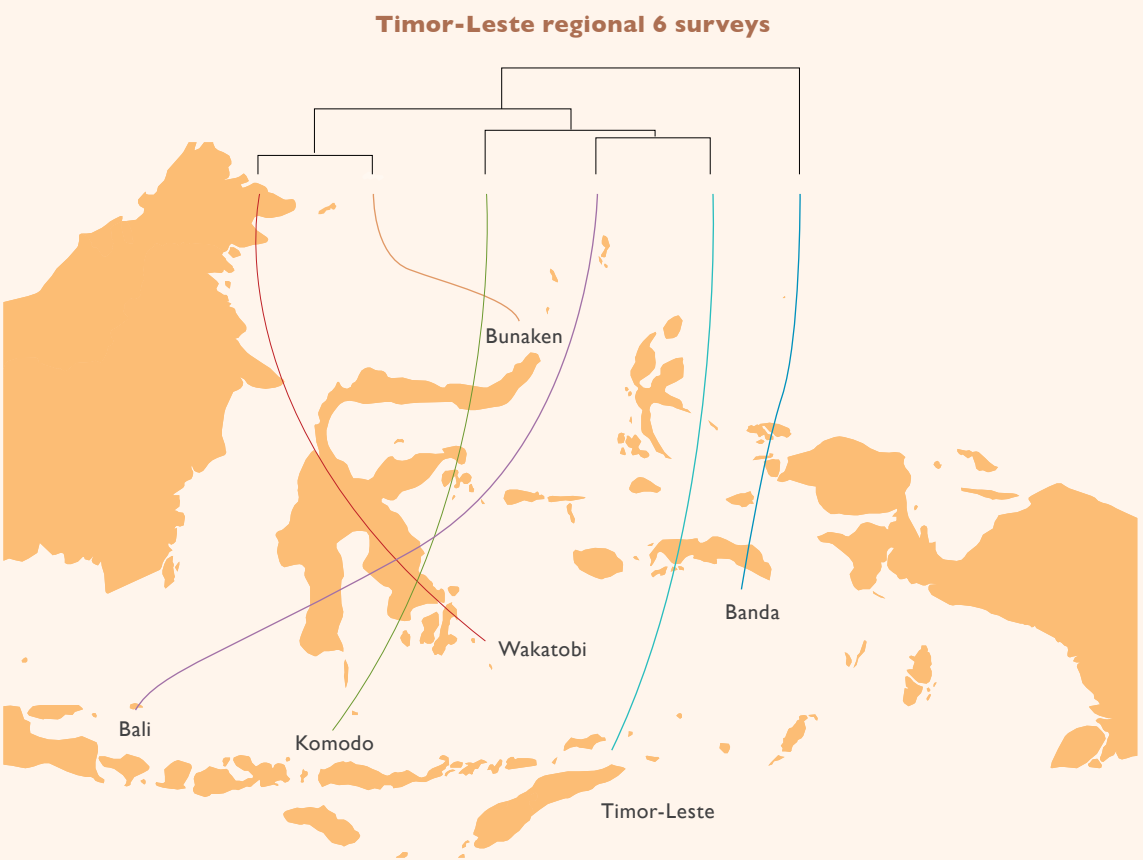
Regional Comparisons between Timor-Leste and Adjacent Locations

Timor-Leste shares almost all coral species with other areas of the CT (Annex III), with the possible exception of potentially undescribed species of *Echinophyllia, Goniopora* and *Montipora* found during the present study (Plates 5-7). Comparisons of levels of similarity in coral composition and community structure were conducted with nearby regions of the CT. For these regional comparisons, two sets of analyses were undertaken (also see Methods):

1. Using the presence of species in each location for two analyses:
   Firstly, for Timor-Leste with Bali, Komodo, Banda Islands, Bunaken and Wakatobi, for a total of six locations (Figure 13); and
   Secondly, for Timor-Leste with the previous five regions plus 9 others - Cenderwasih Bay, Fak/Kaimana and Raja Ampat (all Birds Head Seascape, Indonesia), Sangihe-Talaud Islands (Sulawesi Sea), Derewan (Barau, East Kalimantan), El Nido (Palawan, Philippines), Brunei Darusalam and Anambas Islands, W Indonesia (latter three regions in South China Sea), for a total of 15 locations (Figure 14).

2) Using the species-abundance at the individual station level for Timor-Leste, with Bali and Nusa Penida, Komodo, Banda Islands, Bunaken NP and Wakatobi (153 stations, Figure 15).

Figure 13. Dendrogram illustrating degree of similarity of Timor-Leste with five other locations in terms of reef coral species presence.



Species presence:

Corals of Timor-Leste were most similar to those of Bali and Komodo in terms of their species composition, consistent with their shared occurrence in the N Lesser Sunda Islands ecoregion. These three locations formed a larger cluster with Bunaken and Wakatobi (both Sulawesi). Banda Islands was least similar, likely reflecting the lower species richness there (Table 4, Fig. 13).

In the larger regional analysis of Timor-Leste with 14 other locations, two main clusters of locations were apparent (Fig. 14). In one main cluster, as with the previous smaller analysis (Fig. 13), Timor-Leste shared closest similarity with Bali and then with Komodo (Fig. 14). These in turn were most similar to Wakatobi and Bunaken. Anambas Islands formed a separate sub-cluster with Brunei, both locations occurring in the South China Sea, with the relatively low diversity locations of Banda Islands as the final member of the first main cluster. The second major group of locations (left of Fig. 14) included Derewan, Sangihe-Talaud, Halmahera, Raja Ampat, Fak-Fak/Kaimana and Teluk Cenderwasih and El Nido, reflecting their higher overall species richness (and habitat diversity).

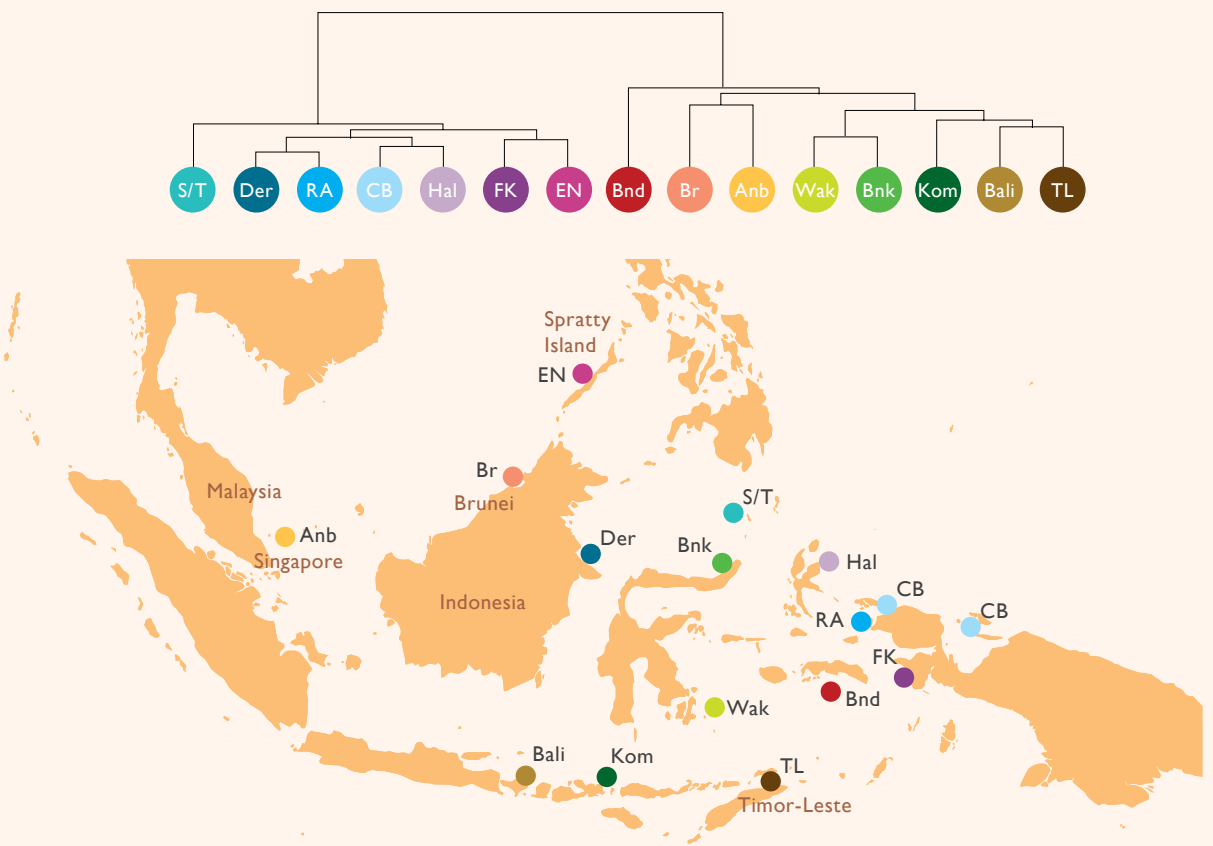


Figure 14. Dendrogram illustrating degree of similarity of Timor-Leste with 14 other locations in terms of reef coral species presence, where:

- Bali : Bali & Nusa Penida
- Kom : Komodo
- Wak : Wakatobi
- Bnk : Bunaken
- Bnd : Banda Islands
- Der : Derewan
- S/T : Sahinge-Talaud
- Hal : Halmahera
- RA : Raja Ampat
- FK : Fak-Fak/Kaimana
- CB : Teluk Cendrawasih
- EN : El Nido, Palawan, Philippines
- Anb : Anambas Islands, W Indonesia
- Br : Brunei Darusallam

Species – abundance:

The station-level analyses produced more complex patterns of similarity. In the smaller analysis of 153 stations from Timor-Leste and nearby locations (Fig. 15), Timor-Leste stations were distributed in different subsclusters and clusters (Fig. 15, left cluster), grouping most strongly with Northern Komodo, Northern Bali, Bunaken, Wakatobi and Banda Islands. South Komodo, South Bali and Nusa Penida remained distinct (Fig. 15, right cluster). This suggests that the Timor-Leste coral fauna is more under the influence of the ITF rather than the Indian Ocean.

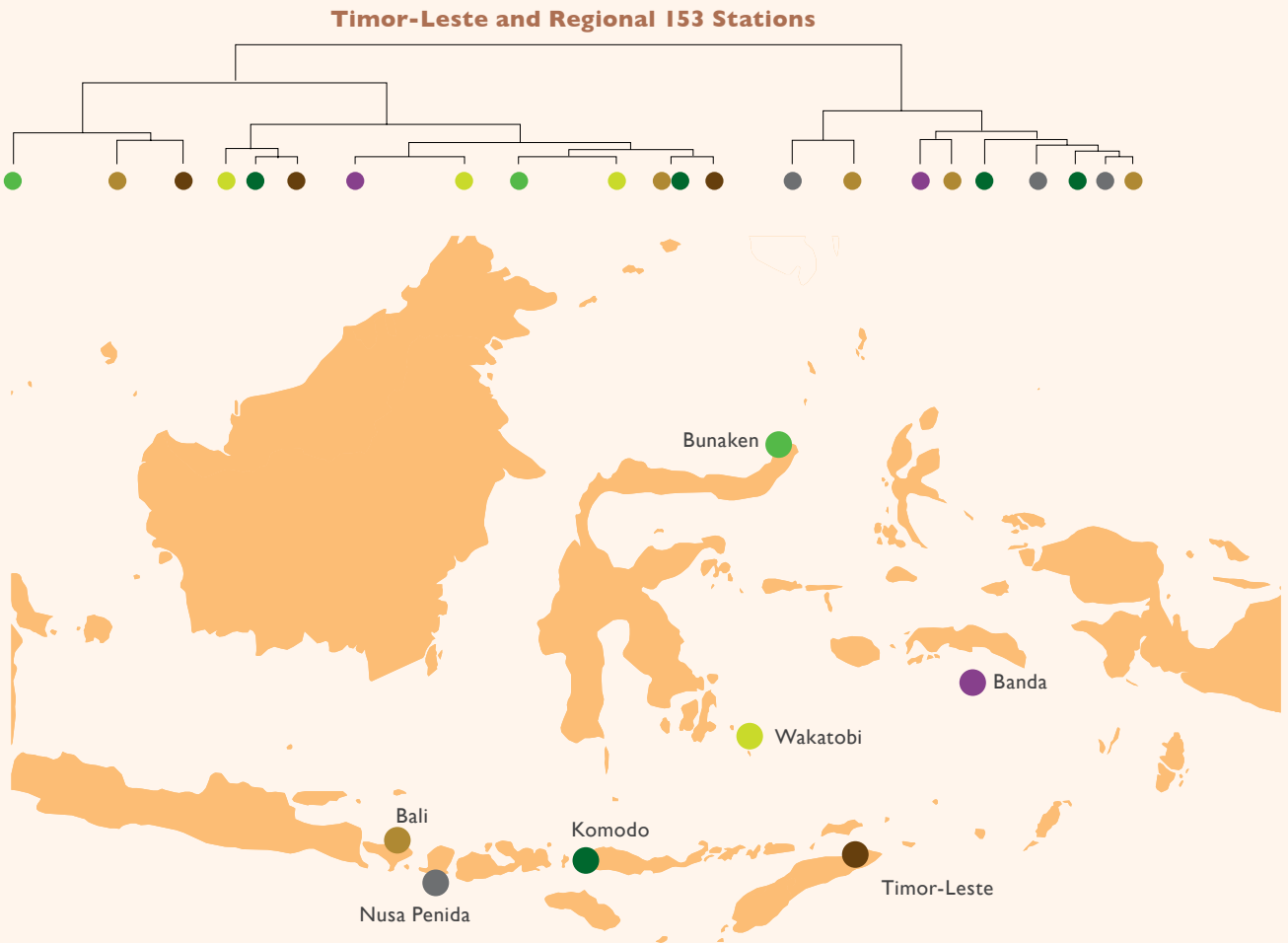


Figure 15. Dendrogram illustrating results of cluster analysis of coral communities of 153 stations across six locations: Timor-Leste, Bali and Nusa Penida, Komodo, Wakatobi, Bunaken and Banda Islands.

Discussion

Species richness and community structure

Timor-Leste's reef-building coral species richness of 367 confirmed and 27 unconfirmed species (Annex III) suggests an overall tally for reef-builing corals of ca. 400 species. This is a much higher estimate than the previous tally of 124 species (Ayling et al. 2009), relating to differences in survey methodology. The present method facilitates active searching for species within an area of approx. one ha at each station, whereas the previous method as employed by Ayling et al. (2009) is restricted to identifying only those species intercepted by line transects, effectively a much smaller survey area. All methods have advantages and diadvantages, and while the present method is far more effective at estimating total richness, the former provides quantitative estimates of abundance and cover, as opposed to our visual estimates (see later).

Timor-Leste's coral richness estimate of ca 400 species is higher than Komodo (342 spp., also in the Lesser Sunda Islands), and Banda Islands (301 spp.) and similar to Bunaken NP, Wakatobi and Bali. It is lower than Derewan or areas of the Papuan Bird Head Seascape (Table 4), reflecting the much greater habitat diversity of the latter locations.

Hence the present richness tally is consistent with Timor-Leste's location in the CT, given the relatively restricted habitat diversity and area available. And in respect of habitat area, it is important to note that the present survey was restricted to the north coast and Atuaro Island, the latter assessed only briefly.

A further ca. 130 reef coral species have distribution ranges that include the general area of the Lesser Sunda Islands (Wallace 1999, Veron 2000, Veron et al. 2009), but were not recorded around Timor-Leste during the present survey. Some of these may well be present, but were not found. Others may have localized disjunctions at Timor-Leste, possibly related to lack of suitable habitat and/or failures of dispersal and / or recruitment (see later). Although the survey was as thorough as practicable during the limited time available, rare species or those with locally limited distributions may well have been missed.

Hence the present tally should be considered a conservative estimate of total species richness. Additional survey effort around Atuaro Island and the south coast may increase the richness tally further, particularly given the differences in coral community structure between N and S coast sites identified by Ayling et al. (2009):

> *"There are distinct reef communities on the north and south facing reefs of the proposed marine park with differences in fish and benthic communities as well as in the abundance of the common invertebrates. This implies that one of the major determining factors of the reef communities in this area is exposure to the predominant SE seas throughout much of the year."*

Species composition at Timor-Leste shows closest similarity with Bali and Komodo (presence in each location, Figs. 13, 14). Although overall composition is most similar among these locations of the Lesser Sunda Islands, species abundance and community structure are not. Rather community structure is most similar to stations of Bunaken, N Sulawesi and the Banda Sea (Fig. 15). This likely reflects the different environmental conditions and habitat types of many stations in Bali and Komodo in respect of the sea temperature regime (localized cool water upwelling), current flow and attenuation in wave energy.

Coral Cover

Cover of living corals in 2012 was estimated at 28 %, an increase of approximately 10 % on a previous estimate made in late 2008 (Ayling et al. 2009), suggesting some recovery in the interim period. Caveats on this speculation include differences in survey locations, with the previous survey focused on both N and S coast sites, as opposed to the present survey's focus on N coast and Atuaro Island. Another important caveat, as noted above, is the difference in methods employed between the two surveys. Importantly, Ayling noted very high variability at the site level, a conclusion supported by the present survey, with cover of living hard corals ranging between ca. 5 and 70 %.

Ayling et al. (2009) also noted that there were few diseased coral colonies and found no evidence of coral bleaching, although predation by *Drupella* snails and crown-of-thornsd seastars had damaged corals of some S and N coast sites respectively. There were also patches of broken coral that may have resulted from explosives fishing episodes or (more likely) damage resulting from a storm.

During the present study, no evidence of coral bleaching was found, and although crown-of-thorns seastars were present at several sites, only Lamsana Inlet had a large population. There were however, large patches of broken corals that were consistent with recent blast fishing damage, most notably at Station 11 near Com (plate 4).

Climate Change Resilience

There was no evidence or reports of past (1998) or recent (2010) large-scale high temperature bleaching-induced coral mortality around Timor-Leste. This is consistent with the presence of cool waters in most sites, which were typically 25-27 degrees C at time of survey in August (Annex I). This is three to four degrees cooler than many neighbouring locations, where sea surface temperatures consistently average 29-31 degrees C, inter-seasonal and inter-annual variability notwithstanding.

It is, however, clear from the latest climate science that climate change will continue to increase in coming decades. Failures to introduce binding international agreements in respect of greenhouse gas emissions on the one hand, and the continuing expansion in fossil fuel exploration and use on the other, mean that the global trajectory for climate change is at the high end of IPCC projections. In this respect, areas that have natural features that can ameliorate these effects will become increasingly important.

As noted above, waters to the north and south of Timor-Leste are major corridors of the ITF, itself influenced by the cooling effects of mixing in the Banda Sea (Oppo and Rosenthal 2010). If these cooling influences remain consistent, reliable features, Timor-Leste's oceanography may provide a cool water buffer and refuge against the increasing sea temperatures predicted from climate change over coming decades. Additionally, consistent surface current flow along both N and S coasts of Timor-Leste may be important in dispersal and the replenishment of marine populations as far afield as NW Australia.

Conservation Priority

The potential for Timor-Leste, as indeed other locations under the influence of the ITF, to act as a climate-change refuge provides added importance and impetus for reef conservation locally and regionally.

In this important respect Timor-Leste has shown great initiative in declaring Nino Konis Santana National Park, which, with effective management, can play a very important role in conservation and replenishment locally and regionally. NKSNMP has high quality reefs and forms an important link in the regional MPA network being developed in the CT and further afield. Reefs of high conservation value were widespread in NKSNMP and also at Atuaro Island (Table 10 and Fig. 16).

Notably, most of the high quality reefs already form part of a MPA (NKSNMP) and thus a lot of the hard work has been done in respect of achieving successful conservation outcomes, at least in the short term. Reefs at Atuaro Island are also of high conservation value for a number of different criteria (Table 10). The latter area has strong potential for development of, or extension to, NKSNMP.

Table 10. Conservation values of survey stations. Replenishment Index (CI) scores from highest to lowest; Rarity Index (RI) ranked from highest (1, most unusual faunistically) to lowest. Species richness - reef-building Scleractinia; Hard coral cover is the average of the two sites at each location (except station 22). Station numbers and community types correspond with those in Figures. High scores are bolded.

Station Name	Station No.	Replenishment Index (CI)	Rarity Index (RI)	HC Cover	Species Richness	Community Type
Jako Island SW	7	**7.1**	12	**70**	161	A
Djonu East	14	**6**	**1**	32.5	**214**	B
Loikere	4	**5.5**	**4**	32.5	**193**	B
Jako Island NW	6	**5.5**	14	**52.5**	151	A
Tutuala 3 Terraces	15	**5.3**	**2**	32.5	**195**	B
Djonu Twin Rocks	10	4.9	8	**42.5**	174	B
Ete Asa Lepek	11	4.5	13	**37.5**	144	C
Hilapuna	8	4.3	7	27.5	162	A
Belio Barrier Reef	19	4.2	**3**	27.5	**190**	B
East Loikere	5	4.1	10	30	178	B
Atauro Belio Lagoon S	21	3.6	6	20	163	C
Lamsana inlet West	18	3.4	11	25	159	C
W. Jako Island	9	3	17	35	125	A
Com Vailovaia	2	2.5	18	20	122	D
Lamsana inlet East	17	2.1	**5**	12.5	133	C
Atauro Belio Harbor	22	1.7	9	10	122	D
Hera West	1	1.6	16	20	95	D
Com Koho Vari	3	1.6	19	15	121	D
Belio "Saddle" Patch R.	20	1.3	15	10	139	D
Tenu, Japanese Bunker	16	0.9	20	5	114	D

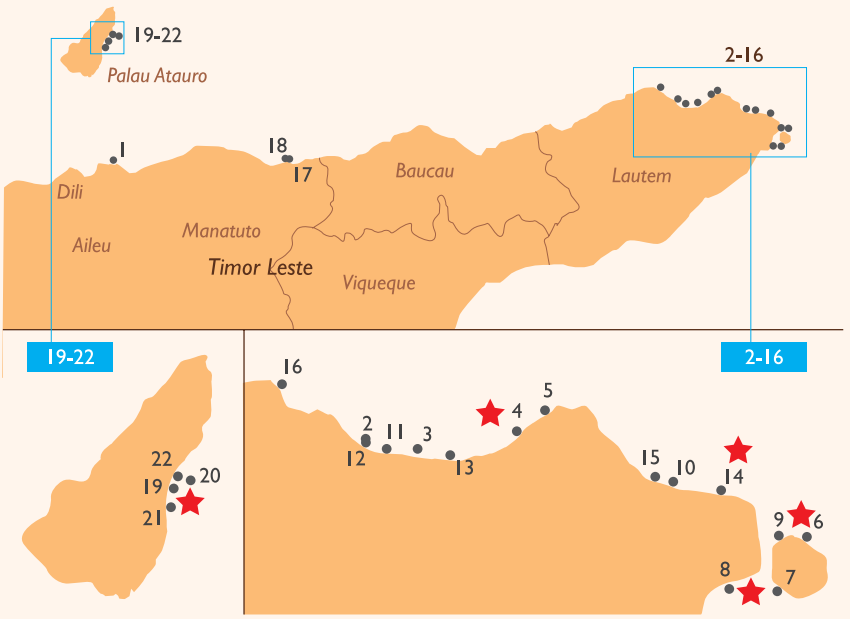


Figure 16.
Reefs of high conservation priority, indicated by red stars.