

Evaluating the status of Cambodia's coral reefs through baseline surveys and scientific monitoring

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ប្រទេសកម្ពុជាសម្បូរទៅដោយផ្កាថ្មប៉ប្រះទឹកជាច្រើនទ្រង់ទ្រាយ ប៉ុន្តែស្ថានភាពទូទៅរបស់ផ្កាថ្មទាំងនេះត្រូវបានស្រាវជ្រាវនិងរក្សាទុកជាងកសាងតិចតួចណាស់។ អង្គការអភិរក្សផ្កាថ្ម Coral Cay Conservation រួមគ្នាជាមួយក្រសួងកសិកម្ម រុក្ខា និងនេសាទនៃប្រទេសកម្ពុជា បានដឹកនាំការស្រាវជ្រាវពីផ្កាថ្មប៉ប្រះទឹកពីខែកុម្ភៈ ឆ្នាំ២០១០ ដល់ខែកុម្ភៈ ឆ្នាំ២០១១ នៅជុំវិញកោះរុង កោះកូន និងកោះរុងស្ទឹងម ខេត្តព្រះសីហនុ។ ទិន្នន័យត្រូវបានប្រមូលរួមមានសមាសភាពនិងប្រភេទផ្សេងៗនៃត្រីនិងសត្វរស់នៅបាតសមុទ្ររាក់ៗក៏ដូចជាទិន្នន័យពីសារធាតុលាងជម្រះនិងជម្ងឺផ្កាថ្មដែរ។ ការស្រាវជ្រាវរបស់យើងបានរកឃើញថាផលប៉ះពាល់បង្កឡើងដោយមនុស្សមានកំរិតទាប ដូច្នេះហើយកំណើនល្បាប់មានកំរិតខ្ពស់។ ផ្កាថ្មរឹងនៅរស់មានប្រហែល២៥% ជាមួយនឹងតំបន់ផ្កាថ្មប៉ប្រះទឹកល្អបំផុតរហូតដល់៤០%។ គឺមានទំរង់ផុលនៃជីវិតផ្កាថ្មច្រើនលើសលុប និងមិនសូវមានទំរង់ស្លឹកនិងបែកមែកទេ។ អំបូរត្រីសំខាន់ៗបានបង្ហាញនូវសញ្ញានៃការថយចុះ ទោះបីកន្លែងខ្លះនៅមានប្រភេទត្រីដែលបង្ហាញថានៅមានធនធានត្រីក៏ដោយ។ ឈ្លឹងសមុទ្រនិងសត្វឥតឆ្អឹងកងបាតសមុទ្ររាក់ៗដូចជាបង្កងប៉ាក ត្រូវបានប្រមូលផលជាពាណិជ្ជកម្មកម្រនឹងជួបប្រទះណាស់ ដែលបង្ហាញថាមានការប្រមូលផលហួសកំរិត។ នៅកោះរុង មានការអភិវឌ្ឍយ៉ាងសំខាន់ ដែលអាចបង្កជាសម្ពាធទៅលើប្រព័ន្ធផ្កាថ្មប៉ប្រះទឹកនៅតំបន់នោះទៅអនាគត។ អនុសាសន៍នៃការគ្រប់គ្រងរួមមានការអនុវត្តតំបន់ការពារសមុទ្រពហុប្រយោជន៍ ដែលរួមបញ្ចូលនូវតំបន់មិនធ្វើអាជីវកម្មមួយចំនួន អាចអោយផ្កាថ្មនិងធនធានត្រីនៅទីនោះកើតឡើងវិញបាន។ ផែនការគ្រប់គ្រងមានប្រសិទ្ធភាព ត្រូវតែបង្កើតឡើងជាចាំបាច់សំរាប់ការកសាងសមត្ថភាពរដ្ឋអំណាចមូលដ្ឋាននិងរដ្ឋាភិបាល ដើម្បីបន្ថយការអាស្រ័យលើចំណេះដឹង ជំនាញរបស់បរទេស និងបង្កើតមុខរបរផ្សេងៗក្រៅពីការនេសាទសំរាប់ជីវភាពរស់នៅក្នុងមូលដ្ឋានសំដៅទៅរកទេសចរណ៍មាននិរន្តរភាព។

Abstract

Cambodia is rich in fringing coral reefs, but the general status of these reefs is poorly researched and documented. Coral Cay Conservation, in association with Cambodia's Ministry of Agriculture, Forestry and Fisheries, conducted research on coral reefs from February 2010 to February 2011 around the islands of Koh Rong, Koh Kon and Koh Rong Samloem, Phreah Sihanouk Province. Data collected included benthic and fish diversity and composition as well as coral disease and bleaching data. Our research found that anthropogenic impacts were low although there were high levels of siltation. Live hard coral cover was around 25% with the best coral reef sites having up to 40% coral cover. There was a dominance of massive coral life forms and a lack of foliose and branching lifeforms. Key fish families showed signs of depletion although some sites still had representative species, indicating that recovery of fish stocks is possible. Commercially harvested holothurians and benthic invertebrates, such as lobsters, were rarely encountered, indicating over-harvesting. The island of Koh Rong is due to undergo significant development, which will likely put further pressure on the area's reef systems. Management recommendations include the implementation of a multiple-use marine protected area that incorporates several no-take areas to allow local reefs and their associated fish stocks to recover. An effective

management plan must also address the need to build local and governmental capacity to lower the dependency on foreign expertise, and diversify local livelihoods away from fishing and towards sustainable tourism.

Keywords

Coral Cay Conservation, Coral Reefs, Ecosystem Management, Koh Rong.

Introduction

The coastline of Cambodia stretches along the Gulf of Thailand and includes 64 islets that support rich diversity of marine species (ICEM, 2003). Most coral reefs in Cambodia are fringing reefs, located along islands with a rocky substrate, which provide shelter for many fish, invertebrates and other species that thrive in coral reefs and related ecosystems (ICEM, 2003; Burke *et al.*, 2002; Kim *et al.*, 2004). In addition to their biological significance, coral reefs have a high socioeconomic value and provide ecosystem services such as supporting fisheries, improving tourism development and providing coastal protection (Kim *et al.*, 2004). In Cambodia, most people living in coastal areas earn their livelihood through the use of natural resources provided by nearshore waters, and reefs are therefore an important asset to the wellbeing of the nation (Yeang, 2009; World Bank, 2007).

Cambodia is rich in fringing coral reefs, but the general status of these reefs is poorly researched and documented. Most reef systems are considered to be under high potential threat, with impacts including overfishing, pollution, coastal development (increased sedimentation), reef destruction (destructive fishing methods, coral extraction), coral bleaching and coral disease (Wilkinson & Souter, 2008). Therefore, there is an urgent need to collect accurate data on these natural resources to assess the biological and socio-economic importance of coral reef ecosystems in the country (Chou *et al.*, 2003; Wilkinson & Souter, 2008). Koh Rong island has been designated for extensive, tourism-related coastal development (see www.kohrong.com.kh). Anthropogenic impacts on coral reefs are predicted to increase, placing pressure on the marine species they support. The effects of intensified coastal development cannot be assessed accurately if there is little knowledge and information detailing the current status and health of reef ecosystems. In Cambodia, existing knowledge about local reef habitats has been limited, and this can be detrimental to the application of several management approaches in conserving coral reefs, including the implementation of marine protected areas (Chong, 2005).

To conduct scientific baseline assessments of Koh Rong and Koh Rong Samloem's coastal resources, Coral Cay Conservation (CCC), a U.K.-based NGO, was invited

by the Fisheries Administration (FiA) of the Ministry of Agriculture, Forestry and Fisheries (MAFF), to establish a research project in 2010 following an initial pilot project in the same area. The main objective of this project is to collect detailed scientific baseline data to develop a higher level of scientific knowledge of the reefs of Cambodia and help to establish an effective management tool for multiple use zoning schemes around these islands. In addition, the project gathered scientific survey data from the mass coral bleaching event which affected the Gulf of Thailand between May and October 2010.

Methods

The survey area was around the islands of Koh Rong, Koh Kon and Koh Rong Samloem, Phreah Sihanouk Province (Fig. 1). The data collection methodology followed the survey protocol 'Reef Check', which was designed to be used by volunteer recreational divers who are trained, qualified and led by marine scientists in the field (Hodgson *et al.*, 2006). Reef Check is based on the identification of indicator organisms on coral reefs to quantify the abundance, diversity and composition of selected fish, invertebrate and benthic groups (Hodgson *et al.*, 2006). The Reef Check methodology is widely accepted and applied in several aspects of coral reef research (Hughes *et al.*, 2010; Bruno & Selig, 2007). A total of 37 survey sites were set up around the islands of Koh Rong, Koh Kon and Koh Rong Samloem where data was collected throughout the course of the research project by trained volunteers.

Data were recorded along a 100 metre (m) transect parallel to the shore at two different depth bands: 2-6 m ("shallow") and 6-12 m ("deep"). Volunteers worked in two pairs and covered a total transect length of 95 m (four replicates of 20 m length, separated by 5 m gaps) (Fig. 2). Four types of data were recorded: *site description* (e.g. geographical coordinates, water temperature, turbidity and other observational data), *diversity and abundance* of target fishes and invertebrates, *substrate cover and composition* and the *prevalence of coral bleaching and diseases*.

Fish and invertebrates were recorded within belt transects (four replicates per depth band, each 20 m x 5 m; fish counted up to 5 m above the sea floor), with the

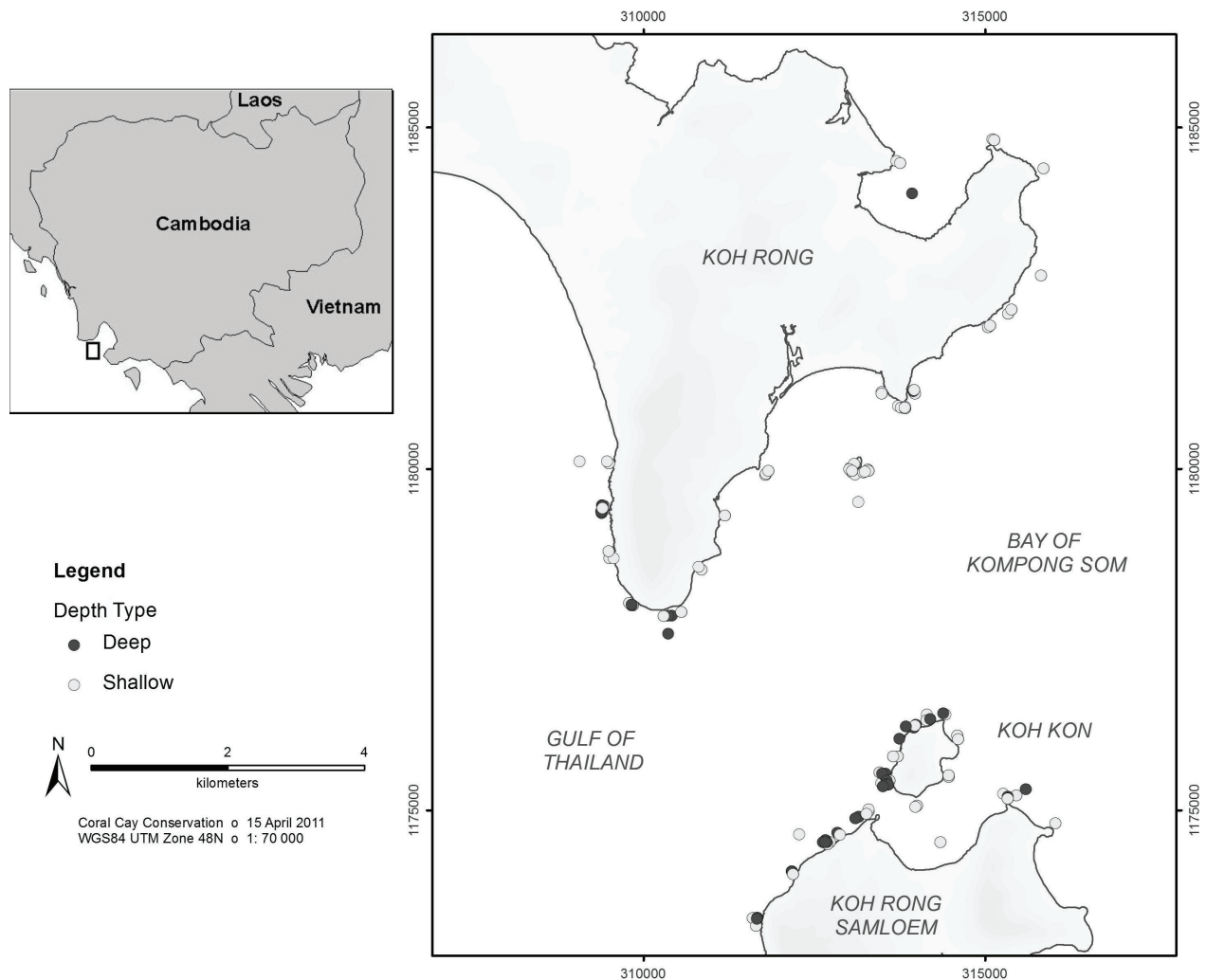


Fig. 1 Locations of survey sites around the islands of Koh Rong, Koh Kon and Koh Rong Samloem. Inset: Map of the Kingdom of Cambodia with the survey area outlined.

number of individuals counted within four imaginary 'boxes' along four 20-m replicates. Substrate composition was assessed along a line transect (four replicates per depth band, each 20 m long) and benthic data were recorded every 50 cm using point intercept samples. Along the point intercept transect, divers also counted the number of recently killed, bleached and diseased coral colonies as a percentage of coral cover. Where possible, the coral disease was identified to black band,

white band, brown band or pink *Porites* disease. Damage was recorded on a categorical scale from 0 to 3 (0 = none, 1 = low, 2 = medium, 3 = high). Impact on the site from garbage was recorded and separated into general and fishing nets/ traps. Coral damage types were divided into 'boat/ anchor', 'dynamite' and 'other'.

In addition to the standard Reef Check indicator species, several other locally dominant indicator species were selected (Hodgson *et al.*, 2006). Hard coral colonies

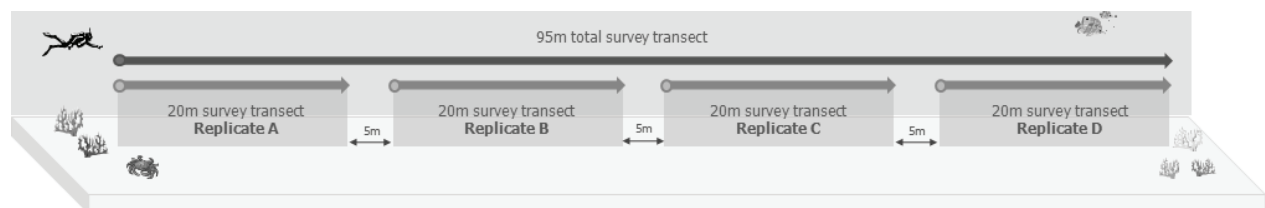


Fig. 2 Transect layout for coral reef surveys.

were categorised into 11 growth lifeforms and identified to either species (14) or genus (11, including *Heliopora*, *Tubipora* and *Millepora*) level, or grouped into distinct morphological categories of closely related species (6). A total of 52 selected fish families and species, recognized as being good indicators of fishing pressure, aquarium collection and reef health, were included as target species. The body length of species of Serranidae and Scaridae were estimated to the nearest 10 cm. Thirty-three target motile benthic invertebrates were selected using similar criteria.

Thirty-seven coral reef sites were surveyed over 126 survey dives between February 2010 and February 2011. The field data was entered into a Microsoft Excel database. ArcGIS (ESRI software) was used to facilitate data analysis and display survey results on Geographic Information System (GIS) maps. The Shannon-Wiener diversity index was used in order to calculate coral diversity and it was generated in PRIMER-5 software (Plymouth Routines in Multivariate Ecological Research).

Results

Anthropogenic impacts observed were generally low. Although the impact of garbage varied between sites, observed coral damage was consistently low at all survey sites (< 0.5 impact severity measured). Some sites had a clear indication of fishery-related impacts such as anchor damage and fishing nets. Siltation levels changed dramatically throughout the survey period with the onset of heavy rainfall and all reef sites suffered from elevated sediment levels. High levels of siltation of over 20% cover were found around both of the main islands. High siltation levels of up to 28% were found on the south-western point of Koh Rong.

The dominant benthic substrates observed at all survey sites were rock, sand and live hard coral (Fig. 3). The highest frequency of live hard coral cover (~40%) was found around the north-western side of Koh Kon and the northern side of Koh Rong Samloem (Fig. 6). Mean hard coral cover was 25% for all sites. The level of nutrient indicator algae was generally below 1% for all sites (Fig. 3). Cover of soft corals and other animals such as hydroids, anemones, gorgonians and ascidians combined were below 6% at all survey sites. Coral diversity across all sites was generally low, with branching and foliose corals rarely encountered and massive colonies such as *Porites* sp. and *Diploastrea heliopora*, apparent at all sites. Massive *Porites* colonies were the most dominant coral species, comprising over 50% of coral cover (Fig. 4).

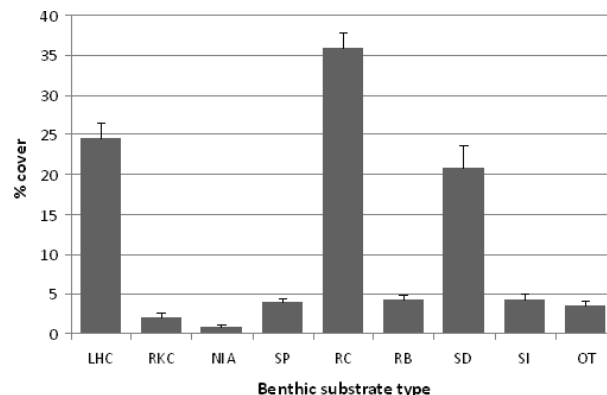


Fig. 3 Benthic composition of main substrate categories around Koh Rong and Koh Rong Samloem. Error bars indicate standard error. LHC = Live Hard Coral, RKC = Recently Killed Coral, NIA = Nutrient Indicator Algae, SP = Sponge, RC = Rock, RB = Rubble, SD = Sand, SI = Silt, OT = Other substrates.

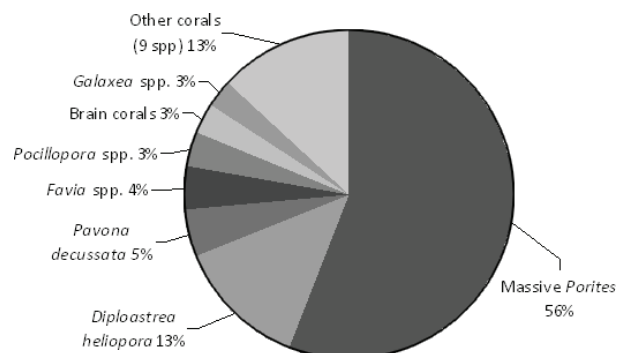


Fig. 4 Coral composition as a percentage of all target coral species and groups encountered on surveys.

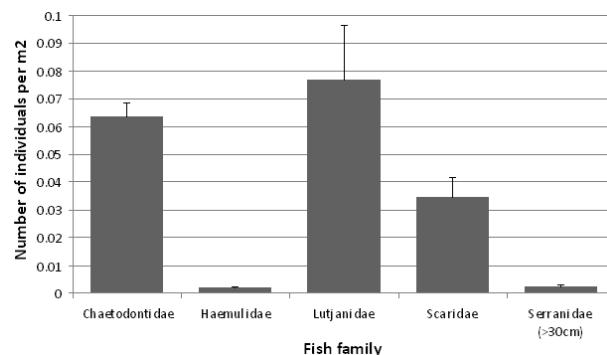


Fig. 5 Abundance of key fish families. Error bars indicate standard error.

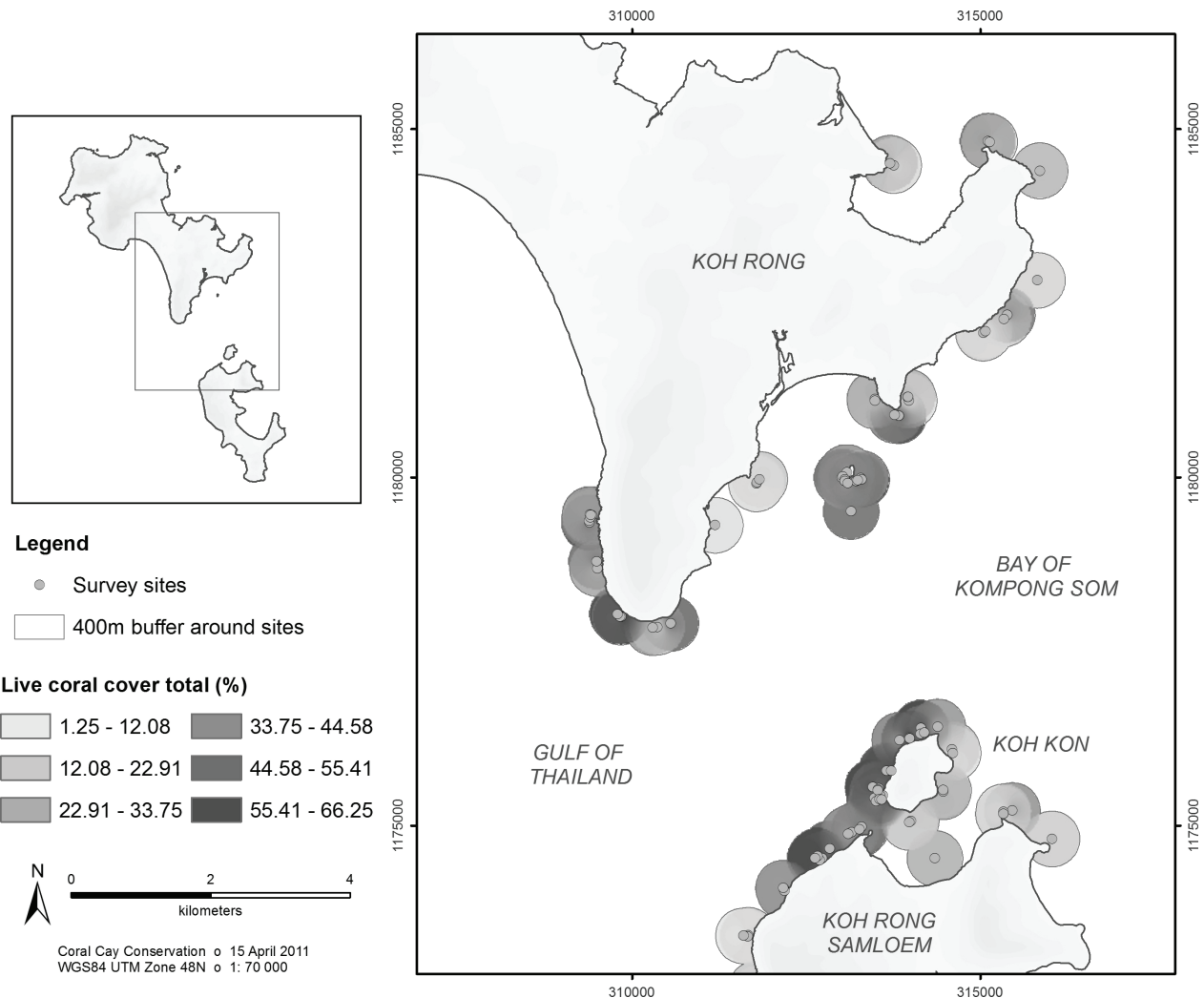


Fig. 6 Map of live hard coral cover around the islands of Koh Rong, Koh Kon and Koh Rong Samloem. The level of shading of the coloured buffer around each survey site indicates the live coral cover as a percentage of the total coral cover.

Butterflyfish (Chaetodontidae) densities varied between surveyed sites, with higher densities in areas where the coral cover was high. Mean butterflyfish density was 0.06 individuals per m^2 (ind./ m^2 , Fig. 5). Parrotfish (Scaridae) density also varied between sites, but was generally low (0.035 ind./ m^2). Snapper (Lutjanidae) numbers (0.07 ind./ m^2) were higher than those of other key commercial fish families including groupers (Serranidae, 0.002 ind./ m^2) and sweetlips (Haemulidae, 0.002 ind./ m^2).

After combining all commercially important fish families and mapping their total densities on GIS maps, we found relatively high densities of 1.2-1.6 ind./ m^2 around Koh Kon and some more sheltered sites around Koh Rong and Koh Rong Samloem (Fig. 7). Comparisons with similar studies of the same area in 2003 and 2009 indicate

there has been a decrease in the density of groupers and snappers, although there are only limited data to support this.

Diadema (longspine) sea urchins were found on most surveys around the islands. Sites around Koh Rong Samloem had particularly high densities, reaching nearly 2.4 ind./ m^2 . The density of giant clams *Tridacna* spp. ranged from 0 to 1.35 ind./ m^2 , with high variation between reef sites (Fig. 8). Sea cucumbers (Holothuria) and lobsters (Palinuridae) were not observed on over 90% of surveys (<0.0005 ind./ m^2 for all survey sites). Similarly, the density of crown-of-thorns starfish *Acanthaster planci* was below 0.00017 ind./ m^2 .

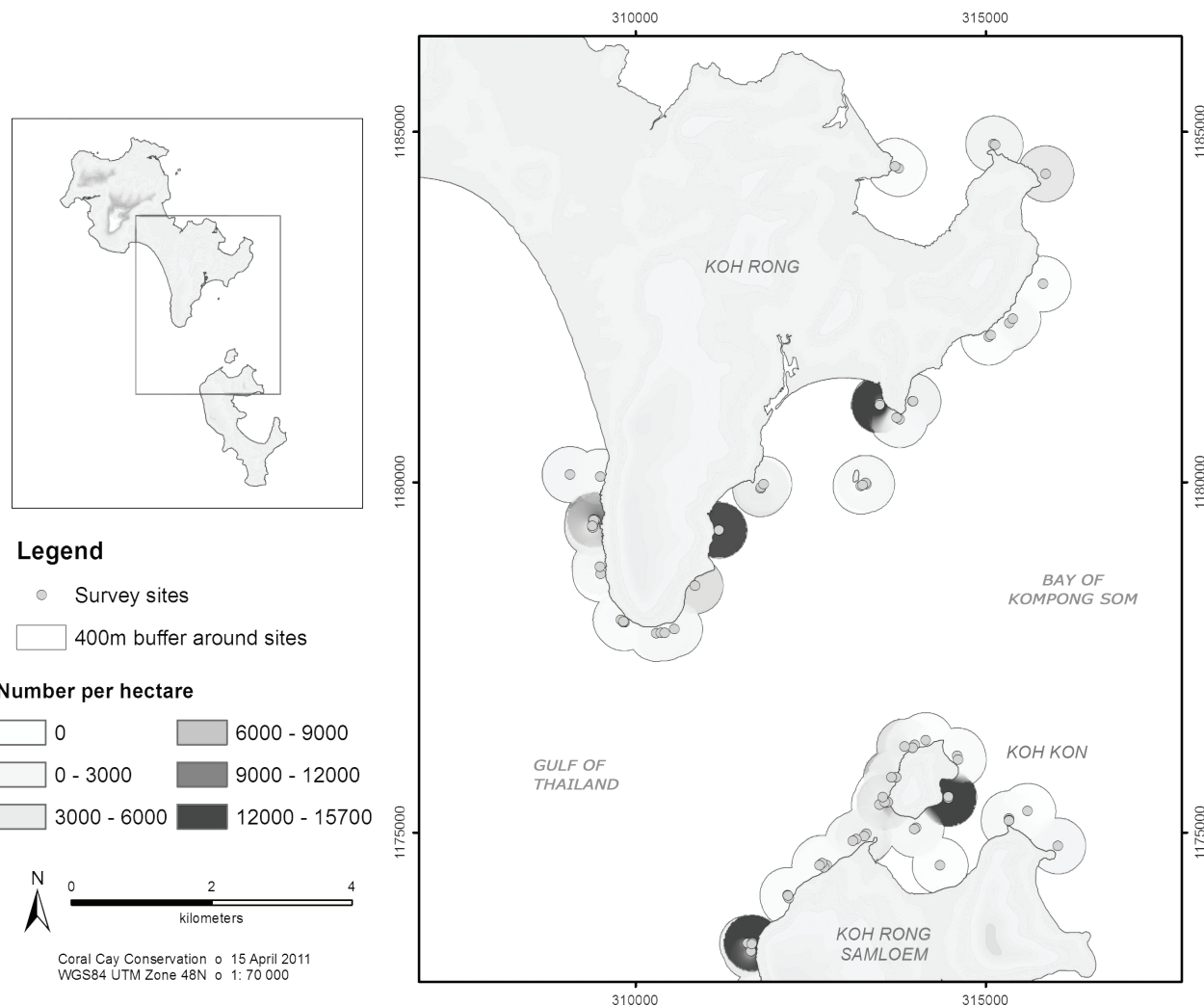


Fig. 7 Map of commercial fish density around the islands of Koh Rong, Koh Kon and Koh Rong Samloem. The level of shading of the coloured buffer around each survey site indicates the number of commercially important fish individuals per hectare. Families include Serranidae, Scaridae, Lutjanidae, Haemulidae Sphyraena and Carangidae.

Discussion

The surveys conducted as part of this programme provided a highly detailed baseline assessment of the status of the areas coral reefs preceding the mass-bleaching event of the second half of 2010. Although some sites still had relatively high coral cover (~40%), the dominance of massive coral species such as *Porites* and *D. heliopoara* and lack of foliose and branching coral lifeforms may be attributed to previous coral degradation, likely a result of high and prolonged sedimentation levels from land runoff, harvesting of corals for the curio trade and regional impacts such as storms. Dead coral, rock and rubble cover was around 40%: 10% higher than the percentage recorded in 2009 at similar sites (van Bochove *et al.*, 2009). Ongoing monitoring will determine the extent of degradation caused by the mass-bleaching event.

Groupers and snappers were rarely seen on most surveys, indicating high fishing pressure on the islands' fringing reefs. However, relatively high numbers of commercial fish families were found around Koh Kon and around some sheltered sites around Koh Rong. Therefore, there is hope that with large (>20 ha) no-take zones at the best reef sites, fish populations may start to increase. These no-take areas should be set up around the best reef sites where fish stock recovery can have the best chance of succeeding. Areas should include Koh Kon and sites around Koh Rong and Koh Rong Samloem, highlighted to contain relatively high coral cover and high densities of commercial fish. These areas will also provide a source of coral larvae to areas that are severely degraded.

There are strong indications that the condition of coral reefs around the islands is still deteriorating, however.

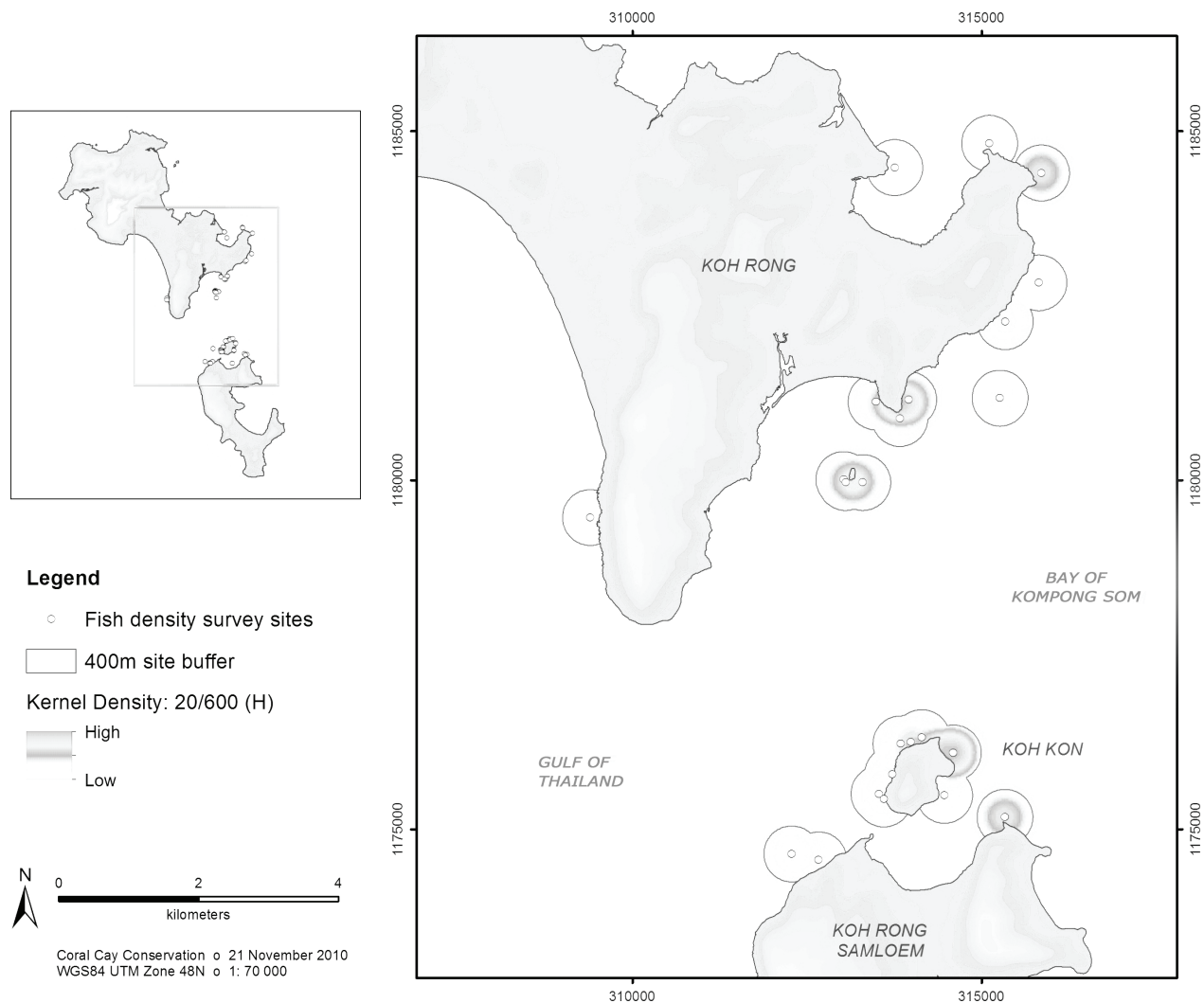


Fig. 8 Map of the abundance of giant clams *Tridacna* spp. around the islands of Koh Rong, Koh Kon and Koh Rong Samloem. The darkness of the coloured buffer around each survey site indicates the density of giant clams.

Comparisons with previous research in the area in 2003 (Chou *et al.*, 2003) and 2009 (van Bochove *et al.*, 2009) indicate that commercially valuable fish species are decreasing in number. However, the lack of extensive and accurate data make it impossible to quantify and assess temporal changes over the past decade. The baseline data now available will be invaluable for ongoing monitoring of the same reefs to assess post-bleaching degradation and subsequent recovery. The baseline information can furthermore be used to assess the impact of management initiatives for the area. The FiA is currently working with stakeholders and local NGOs, including CCC, to develop a multiple-use marine protected area that includes no-take and limited fishing zones. This marine protected area is planned to be established in 2012.

This work has highlighted local and regional stress factors that threaten the health of coral reefs around Koh

Rong, Koh Kon and Koh Rong Samloem. Local factors such as overfishing, sedimentation and pollution continue to threaten the reef systems and it is likely they are restricting the recovery of these systems from the 2010 bleaching event. Therefore, it is essential that every effort is made to minimise these impacts through appropriate mitigation measures that promote coastal management and marine conservation. Management recommendations include the implementation of a multiple zone marine reserve around the island of Koh Rong. This is particularly important in light of the significant tourism development that is set to take place on the island over the coming years. It is likely that this will increase anthropogenic impact levels to the already stressed reef systems around the islands.

What is of particular concern is the high amount of siltation that was observed during the rainy season.

Much of this siltation is a result of runoff from the mainland and a holistic and regional management should be considered to effectively address this issue.

The implementation of the marine protected area should also be complemented by education and capacity-building programmes for the local community to ensure that conservation efforts are effective. The development of alternative livelihoods in tourism will help relieve local dependence on dwindling fish stocks and help diversify livelihood dependency away from marine resource extraction. Capacity development schemes in the area should be further expanded to provide conservation awareness and improve the technical expertise of government employees and community officials to support the establishment of a marine protected area, thereby reducing dependency on foreign NGOs for coastal monitoring and management. CCC is providing ongoing capacity building and educational activities in addition to scientific survey work to support the conservation of the areas marine resources. Support from local officials, the private sector and the community is crucial for the effective sustainable management of this area in the face of significant coastal development.

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