Proposal for a **SCOR Working group on the Coral Triangle**: the centre of maximum marine biodiversity

Background.

Tropical marine ecosystems are well known for their high biodiversity. Coastal ecosystems (mangroves, seagrass beds, coral reefs) and near-shore oceanic ecosystems in the tropics depend on each other for the interchange of organisms, food and nutrients. They play a role in the protection of shorelines during storms and they are important sources of income for local economies through fisheries, ecotourism and mining (Adey 2000, Cesar 2000, White *et al.* 2000, Burke *et al.* 2002, Cesar *et al.* 2003, Hoeksema 2004). However, their exploitation appears unsustainable and destructive, especially regarding coral reefs and mangroves.

Corals as main reef-builders, have increasingly endured various kinds of illnesses and plagues, such as by the coral predator Crown-of-Thorns starfish. Large reef areas have suffered from coral bleaching since 1983, which has been associated with patterns of elevated seawater temperatures. Governments, nature conservation organizations and scientists are aware that tropical marine ecosystems need to be protected to conserve global marine biodiversity.

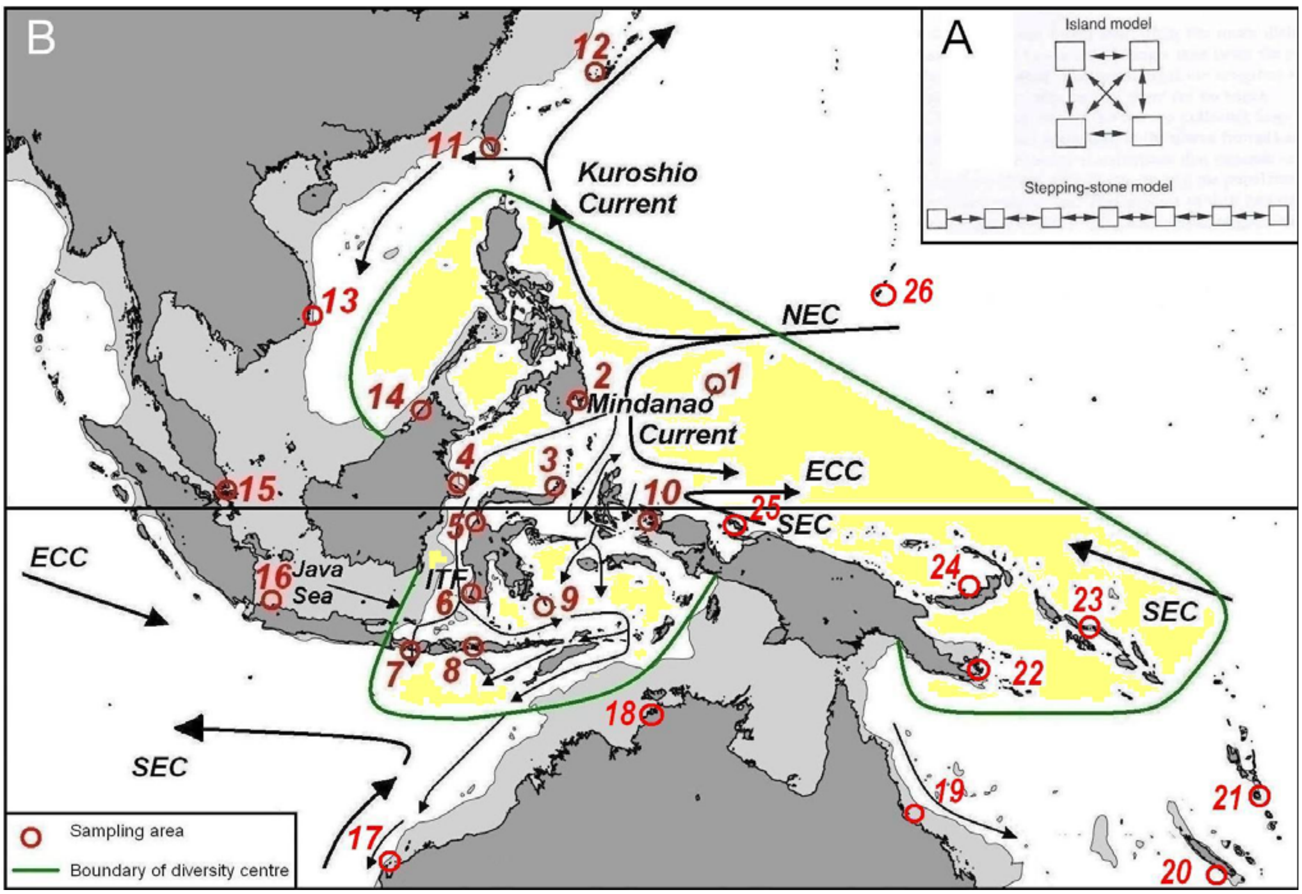

Fig. 1. The Coral Triangle: a search for patterns and processes. A. Possible mechanisms of connectivity between populations (Palumbi 2003). B. The Southeast Asian - West Pacific centre of maximum marine biodiversity with its hypothetical boundaries (Hoeksema 2007). Vanuatu may have to be included as well (Hoeksema unpublished). Oceanic currents are indicated to show most likely major pathways of gene flow. Numbers indicate suggested areas in and outside the Coral Triangle for data sampling.

Coral reefs are the world's most species-rich marine biotopes, as fringing reefs and barrier reef systems along continental shorelines and as atolls in the wide open ocean. One key to this success is formed by the complex of species interdependencies. Most reef corals and many other reef organisms harbor algal symbionts, which causes their rapid growth, lime stone accumulation and subsequent reef formation with the help of sunlight in transparent warm seawater. The corals and many other sedentary organisms, such as invertebrates and algae serve as food and hiding place to other organisms. Host-symbiont relationships appear very specific. This implies that in order to study the evolutionary history of species associations for a better understanding of species-rich ecosystems, a good knowledge of both host and symbiont species groups is required. Such studies usually require the application of molecular (DNA) techniques in order to reveal sibling species (look-alikes) and to indicate evolutionary inter-relationships (Gittenberger & Gittenberger 2005, Schiaparelli *et al*. 2005, Fransen 2007).

Coral reefs of the Indo-Pacific are richer in species and more densely populated than those of the Atlantic, particularly the coral reefs in the Southeast Asian – West Pacific (SEA-WP) region. The world's highest concentration of marine species occurs in this region. Due to its dependence on corals, it has been dubbed "The Coral Triangle". Knowledge about its species richness and about endemic and endangered species is important for the design of marine protected areas (MPAs). However, due to a lack of data from enough localities it is not yet clear where the most likely boundaries of this centre of maximum marine biodiversity are located (Licuanan & Capili, 2003, 2004, Green & Mous 2004, Hoeksema & Putra 2002, Hoeksema 2007). This delineation of the Coral Triangle has to be based on reliable species records. Such records are based on observations of sessile or demersal individuals but most marine species are also represented by a free-living phase (usually larvae) in the open water in between reefs (Paulay & Meyer 2006). The dispersal of reef organisms is largely determined by the duration of this free-living phase and by the direction and speed of currents.

Rationale: integration of taxonomic expertise and assessment methods
Knowledge on the position of the Coral Triangle would benefit from cooperation of specialists who work on different marine taxa. At present, different localities and different assessment methods are used for marine biodiversity analyses. Although diversity patterns among various groups of marine organisms appear to show much congruence, there is little data to substantiate unifying conclusions. Many marine animal species show large geographical distribution ranges that may be the result of a high dispersal capacity linked to a long-lived larval stage, while other species show very restricted ranges due to a short larval stage or its absence in the case of brooders. In the latter category, much endemism can be expected and the distribution ranges of closely related endemics may reflect their speciation pattern. Most reef-dwelling species show wide-spread (Indo-West Pacific = IWP) ranges. This indicates that they are relatively long-lived (occasionally confirmed by their fossil record) and that their present range may have been shaped during long periods of dispersal that were interrupted during low sea level stands.

In order to get a better insight in marine species richness patterns in the Southeast Asian – West Pacific region, specialists of Indo-West Pacific reef organisms should integrate their efforts. By evaluating biodiversity patterns of various reef taxa, their respective biodiversity assessments should be comparable. This does not necessarily mean that all specialists need to adopt the same methods, but for a few taxa different assessments should be used to enable calibrations. Methods that imply large taxa usually have as disadvantage that they are less reliable and nearly irreproducible due to unresolved taxonomies. This problem can eventually be solved if specimens of sampled taxa are deposited in reference collections housed by museums. This is the most time consuming method. Another reliable method is the use of presence / absence data, which is mostly applied to smaller taxa (at genus or family level) that can be assessed in a relatively short time. Because of small taxon sizes, more taxa need to be compared in order to get reliable indications of species richness patterns.

Since present species range boundaries are largely determined by gene flow, it is important to find species suitable for phylogeographic studies that indicate connectivity among populations within species ranges. Such connectivity studies support the design of potential networks of marine protected areas (MPAs), which not only conserve gene pools for areas surrounding MPAs (replenishing by spill-over) but also make MPAs themselves resilient in case organisms become extinct in one MPA and need to be replaced by larval recruits from an upstream MPA.

Scientific background

For the designation of a network of Marine Protected Areas (MPAs) and for other conservation efforts, it is important to know which areas are particularly rich in species (Ferrier 2002, Green & Mous 2004, Briggs 2004, 2005), especially in endemic species that show relatively small ranges (Myers *et al*. 2000, Allen 2002, Roberts *et al*. 2002; Hughes *et al.* 2002, Beger *et al*. 2003, Mora *et al.* 2003, Myers & Ottensmeyer, 2005).

The biodiversity assessment approaches that are used to distinguish areas fit for MPA status, usually rely on data from areas that have been selected a priori for MPA destination. They are intended for local conservation efforts and do not give complete information for biogeographic comparisons of species richness between areas. They are supposed to be rapid and just produce species lists made by individual observers through a visual census to support species richness numbers as high as possible without supporting proof (such as voucher specimens, photographs). Such records may contain synonymies, different names for the same species, which inflates the species numbers but devaluates their quality. The observers in such biotic surveys are usually generalists who are trained in the identification of species, but they may not be able to solve taxonomic problems and publish on this.

Marine biodiversity assessments for scientific biogeographical studies serve to gain knowledge on the species richness of a selected area and to collect records for the analysis of individual species ranges. Families, genera, and other species groups that have undergone taxonomic revisions are better fit for use in surveys since synonymies have been minimized. Such taxa should be used a models (key taxa, exemplars, etc.) but have as disadvantage that they may not be completely representative. The different assessment methods that need to be discussed and combined for marine biogeographic and phylogeographic studies are:

ATBI (= All Taxon Biodiversity Inventory) aims at giving an overview of as many species as possible for an area with maximum effort, including the use of many collectors and collecting methods. In theory, this method will approach the real number of species present in an area. Although common species are likely to be identified, not all species need to be identified directly since their numbers as morpho-species count (Bouchet *et al.* 2002). Material is usually deposited in a scientific reference collection for further investigation. New species are very likely to be found in the IWP.

RAP (= Rapid Assessment Program) or REA (= Rapid Ecological Assessment) aims at giving species overviews within a limited time frame of dominant key groups per area surveyed, such as reef coral species, reef fish, etc. (Werner & Allen 2000, Allen & McKenna 2001, McKenna *et al.* 2002, Allen *et al.* 2003). Since these taxa are represented by high species numbers (more than 500), no estimate of the real species number can be found in the available time limit. Records of new species remain unclear unless material has been sampled for study by a specialist. If no specimens are available, the claims remain untested. There usually also is a high risk of the occurrence synonymies in the species lists produced. The reliability of the results depends heavily on the experience of the observers.

PAR (= Presence – Absence Records) aims at giving a complete overviews of species present and absent in a surveyed area. Model taxa of 50-100 species are used (genera, families) that have been taxonomically revised. Since species presence and absence records are obtained per sample unit within a surveyed area, statistically reliable species richness estimators can be given (with error margins). The specialized observer needs to spend much time per survey area (2-4 weeks) and preferably the same observer needs to complete the surveys for each area included in the comparison. Species records are represented by voucher specimens in reference collections and/or by photographic evidence. New species are rare since the model taxon has been taxonomically revised already, which minimizes the risk of overlooked species. This method is not commonly used (Hoeksema 1993, 1997, Hoeksema & Putra 2002, McKenna, 2006, Hoeksema 2007).

LIT (= Line Intercept Transect). This method can be used to record the occurrence of species (fish, corals, etc) along 10, 20, or 50 m lines at fixed depths (e.g. 5 m). Since LITs do not cover complete reef profiles and depth gradients, no representative species lists are made for each reef site. This method is currently used by the Research Centre for Oceanography in Jakarta to compare regions within the Coral Triangle. It is therefore useful as a relative measuring method.

Phylogeography. Molecular methods using suitable genetic markers (e.g. micro-satellites) are used to map species boundaries and affinities between populations of selected reef organisms in different reef areas (Knowlton 2000, Benzie 2000, 2001, Lessios et al., 2001, 2003, Hellberg et al. 2002, Williams *et al.* 2002, Uthike & Benzie 2003). The sampling should be based on the direction of ocean currents and the position of continental shelves (Fig. 1). Results so far indicate a major genetic distinction between populations at both sides of the Sunda shelf margin, separating west and east Indonesia from each other (Barber *et al.* 2000, 2002, Lourie & Vincent 2004, Lourie *et al.* 2005, Collette 2005). The results are very useful for designing network of MPAs. In total, the design of MPA networks would benefit from knowledge on species diversity, endemism and gene flow (Ablan *et al.* 2000, Beger *et al.* 2003, Palumbi 2003, Roberts *et al.* 2006).

Terms of reference

Within the proposed four year of existence, the WG plans to achieve agreement on

- methods for coral reef biodiversity assessment or ways to combine different methods
- integration of coral reef biodiversity research and conservation
- groups of reef organisms that may act as model taxa for coral reef biodiversity assessments
- areas suitable for biodiversity assessments and DNA sampling for connectivity studies
- reef organisms that are suitable for connectivity studies within the SEA-WP region, inside and around the Coral Triangle
- genetic markers for organisms in phylogeographic connectivity studies

Organisation of three meetings in the SEA-WP region in collaboration with regional branches of nature conservation organizations working on coral reef biodiversity management and its outreach. Objectives are

- to find agreements on the issues mentioned above
- to present results on marine biodiversity and phylogeography
- to collaborate in fieldwork, to assist each other in sampling from various localities
- to assist in the organization of workshops in the SEA-WP region dealing with the identification of coral reef model taxa.

Publications of the results in a peer-reviewed volume on the Delination of the Coral Triangle using examples of various model taxa.

Time line

The meetings will be organized in conjunction with already planned symposiums and workshops. For example

2008. Coral Reef Biodiversity, Conservation and Ecotourism, a pre-meeting of the World Ocean Summit, Manado, North Sulawesi, Indonesia. In combination with reef surveys at Bunaken Marine Park and Selat Lembeh.

2009. Tun Mustapha Marine Park - Pulau Banggi Reef Survey, Sabah, Malaysia

2010. Second Asia-Pacific Coral reef Symposium, Phuket, Thailand.

The SCOR working group

Because the SEA-WP is large and specialists on IWP reef organisms are predominantly based outside this region (where most of the old reference collections and libraries are), the SCOR working group should represent many nations and specialties (taxa). Meetings on scientific results and identification workshops should preferably occur in the SEA-WP region in order to make information optimally available to local scientists, NGO's, and park managements.

Nature conservation organizations, such as TNC since 1951 (The Nature Conservancy, at http://www.nature.org/), WWF since 1961 (World Wildlife Fund, at http://www.panda.org/), and CI since 1987 (Conservation International, at http://www.conservation.org/), should link to the SCOR working group by assigning their marine biodiversity and MPA specialists to SCOR meetings as associate members in order to discuss ideas and plans regarding the Coral Triangle. TNC has established a Coral Triangle Center (http://www.coraltrianglecenter.org/) at Bali (Indonesia) in order to "generate knowledge on marine biodiversity conservation and on sustainable use of marine resources in the Coral Triangle, and to ensure that this knowledge is applied in on-site MPA management, in awareness and communication, and in policy". The results of the SCOR meetings should become available as technical information that can be applied by TNC, WWF and CI to help in the development of monitoring protocols and content for training programs according to the latest scientific insights as effective management tools for biodiversity conservation.

The WG on the Coral Triangle may be able to link up with the Census of Marine Life's (CoML), Census of Coral Reef (CReef) http://www.creefs.org/. It also plans to link with EU FP6 network of excellence, the European Distributed Institute of Taxonomy (EDIT), Work Package 7 on Taxonomy for Conservation. http://wp7.e-taxonomy.eu/. Meetings will be announced via NOAA's coral.aoml.noaa.gov e-mail list. Local scientists and marine conservation specialists (non-members) who are expected to be interested will be contacted personally.

Name	F/M	Expertise	Institute / Country
Co-chairs:			
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Dr. Michael Dawson	m	Coelenterates /connect.	University of California, Merced, USA
Dr. Philippe Bouchet	m	Molluscs	National Museum of Natural History, Paris, France
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Candidate associate members:			
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Dr. Charlie Veron	m	Stony corals	Australian Institute of Marine Science, Townsville, Australia
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Dr. Ronald Fricke	m	Reef fish	State Museum for Natural Sciences, Stuttgart, Germany
Dr. Merijn Bos	m	EDIT	State Museum for Natural Sciences, Stuttgart, Germany
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Dr. Chris Meyer	m	Molluscs	Florida Museum of Natural History, Gainesville, USA
Dr. Gustav Paulay	m	Molluscs, invertebrates	Florida Museum of Natural History, Gainesville, USA
Dr. Chris Glasby	m	Bristle worms	Northern Territory Museum, Darwin, Australia
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