Studies on Reef Connectivity Within the Context of the Transmap Project

*M.H. SCHLEYER[1], A.H.H. MACDONALD[1], D.E. STARZAK[1], B.Q. MANN[1], J.P. PAULA[2], I. SILVA[2], A. COSTA[3], A. MACIA[4] & D. ABREU[4]

[1]Oceanographic Research Institute, P.O. Box 10712, Marine Parade, 4056 Durban, South Africa
[2]Fundação Universidade de Lisboa, Campo Grande, 1749-016 Lisboa, Portugal
[3]WWF-Mozambique, P.O. Box 4560, Maputo, Mozambique
[4]Universidade Eduardo Mondlane, P.O. Box 257, Maputo, Mozambique
*Tel: +27-31-3288222 Fax: +27-31-3288188 E-mail: schleyer@ori.org.za

INTRODUCTION

Increased research has been focused in recent decades on the sustainability of marine resource use in East Africa. Resources shared by neighbouring countries have, in particular, become a subject of concern. With this in mind, marine scientists successfully submitted a proposal to gather scientific information needed for the creation of an effective trans-boundary network of marine protected areas (MPAs) in the East African region. This EU-funded project, known as Transmap, is being conducted by an international consortium in the trans-boundary regions of Tanzania, Mozambique and South Africa. The study area thus covers Mnazi Bay and the Rovuma estuary in Tanzania, the Quirimbas group of coral islands and the Machangulo Peninsula and Inhaca Island in Mozambique, and the Greater St Lucia Wetland Park in South Africa. While coastal and marine habitats straddling the borders of these countries are the subject of attention, it is expected that principles emanating from the research will find application elsewhere in the western Indian Ocean (WIO). Five European and five African institutions are involved, each contributing their expertise to the collective goal of generating scientific knowledge to underpin transfrontier MPAs.

The project's overall goal is to establish the type, size and location of reserves needed to maintain ecological function in the trans-frontier coastal environment while creating opportunities for sustainable resource-use and associated socio-economic development. This will be achieved through integration and modelling of a range of strategic issues, including biophysical, socio-economic and governance parameters. All the information is being compiled in a Global Information System (GIS) which will provide the basis for future MPA decision-support and zonation.

An understanding of biotic connectivity within and between the different coastal habitats is clearly needed to meet the project goals and is being approached in a number of ways. Coral reefs have received particular attention in East Africa over the last decade in view of the severe consequences of the 1998 El Niño Southern Oscillation and associated coral bleaching. Reef connectivity is thus being determined through appropriate genetic studies of a number of corals. Mark-recapture techniques are

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being used to establish fish movement amongst inshore angling fish as well as selected species on reefs subjected to and closed to fishing. Connectivity between other habitats, viz. rocky and sandy shores, mangroves and seagrass beds, is being assessed through measurement of morphometric variations between populations of selected species, the differences being confirmed in genetic studies to exclude those due to environmental adaptation. Trophic linkages within and between these environments is being determined through stable isotope studies. An overview of these approaches is presented here with an outline of the direction that the results are taking.

Morphometric Measurements: Fundação Universidade de Lisboa

Landmarks have been photographed and measured in the Crustacea *Uca annulipes* and *Perisesarma guttatum* as well as the Mollusca *Cerithidea decollata*, *Littoraria glabrata*, *L. scabra* and *Nerita plicata* to determine differences in their geometric morphology. Clear regional differences have emerged in the morphometry of a number of the study organisms. Their validity as indicators of connectivity rather than different expressions of the same genotype is being confirmed through genetic studies. Genetic primers have been optimized for *Uca annulipes*, *Perisesarma guttatum*, and *Nerita plicata*. The development of specific primers has proven necessary for *Littoraria glabrata*, *L. scabra* and *Cerithidea decollata*; these are being tested.

Genetic Connectivity Studies: Oceanographic Research Institute

Early molecular studies at a smaller scale revealed panmixia in a *pocilloporid* coral (Ridgway et al., 2001) found within the Transmap region. Species with differing life-strategies were thus chosen for the Transmap study, *Platygyra daedalea* being a relatively long-lived, broadcast-spawning coral, *Acropora austera* an extremely fast-growing broadcaster with a high population turnover, and *Pocillopora damicornis* a relatively fast-growing coral with known mixed

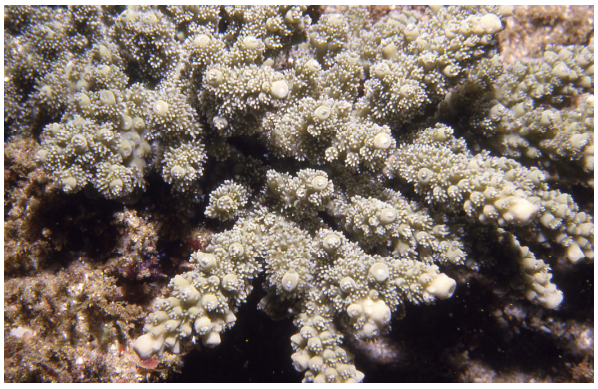

Figure 1. A close-up of *Acropora austera*, a widely-distributed Indo-Pacific coral under genetic study in the Transmap Project.

reproductive strategies (Ward, 1992). The slow-growing octocoral, *Sarcophyton glaucum*, was also included in the sampling regime. Samples of these corals were collected at representative localities throughout the Transmap region as well as outlier material from the Chagos Archipelago.

DNA has been extracted from the samples for analysis of both the host and zooxanthellar genome. PCR amplification of most of the scleractinian extracts has been completed, using the ITS1-5.8S-ITS2 intron region and a single-copy nuclear marker in the host DNA of *Platygyra daedalea*, and intron markers developed at the Centre for Marine Studies (CMS) at the University of Queensland to amplify a genetically informative region in the *Acropora austera* genome. In both cases, amplified host material was sequenced for further comparison and, where necessary, cloned. Single-copy nuclear markers and the ITS region are being investigated for *Pocillopora damicornis*. ITS haplotypes have been used to establish sub-cladal differences between zooxanthellae sampled from representative colonies of all the species examined in the study.

The results of the animal genome studies completed thus far have revealed relatively little genetic variation in the Transmap region, indicating that they manifest relatively high gene flow. Panmixia has been found and is probably attributable to the

current systems in the Mozambican Channel that result in a net southward movement in surface water masses. Thus, the large populations of reef corals in the equatorial parts of Transmap probably provide propagules to reefs in the southern part of the study area at a reasonably constant rate. Sub-cladal differences were found in the symbiotic zooxanthellae, however, and these infer a certain level of heterogeneity and concomitant resilience within the coral population attributable to this diversity.

Stable Isotope Studies: Universidade Eduardo Mondlane

The connectivity of coastal habitats in terms of trophic relationships is being assessed in stable isotope studies of three economically-important penaeid shrimps (*Metapenaeus monoceros*, *Penaeus japonicus* and *Metapenaeus stebbingii*). This is being undertaken in the southern Transmap area in Mozambique. Sample collection was undertaken in the northern (Sangala Bay) and southern (Saco da Inhaca) bays of Inhaca Island in 2006. Penaeid shrimps and their possible sources of carbon (mangrove leaves, sea grasses, epiphytic algae, polychaetes, plankton, benthic micro-algae and sediment) were collected in the main habitats (mangroves, sand flats, mud flats and seagrass beds) in the two bays.

The samples were prepared for stable isotope analysis in the Ecology Laboratory of the Department of Biological Science at UEM and 13C and 15N analyses were undertaken in the Analytical Chemistry Laboratory of the Free University of Brussels (Vrije Universiteit Brussel) in Brussels, Belgium. Interpretation of the analyses is incomplete but the results for the three prawn species are separating out quite clearly, suggesting that differential food-sourcing will emerge. The results are currently being compared with those of the different food sources.

Fish Migration Studies: WWF Mozambique & Oceanographic Research Institute

No-take zones were created in the recently promulgated Quirimbas National Park in northern Mozambique, their need arising because of heavy resource use within this MPA. Fish catches are being monitored in two of these no-take zones as well as the adjacent harvested areas at the islands of Ibo and Matemo. Fish movements were determined using tag-recapture techniques, focusing primarily on *Scarus ghobban*, this species being the most important component of artisanal catches in the Quirimbas National Park. Results of the latter are being used in the Transmap connectivity study.

In total, 195 *Scarus ghobban* with a fork length (FL) ranging between 23 and 44 cm were tagged and 84 were recaptured between September 2005 and September 2006. Of these, a total of 181 were tagged and 68 were recaptured within the Matemo and Ibo no-take zones. Recaptures indicated that the distance travelled by tagged fish was generally less than 500 m, revealing that their range is very limited.

Two different approaches were used to analyse regional fish migrations at the Oceanographic Research Institute (ORI) and have provided illuminating results. In the first, relevant data were extracted from a long-term fish tag-recapture programme that has been running at ORI since 1984. The database was interrogated concerning all fish found and tagged within the Transmap region and these data were analysed concerning individual fish migration. In the second approach, a case-specific study in the southern Transmap region, designed to gain information on fish movement at a finer scale (100 m), was subjected to similar analysis.

The long-term tag-recapture programme, known as the ORI-WWF SA Fish Tagging Project, yielded a list of 41 species, comprising some 70 000 tagged fish, for which a minimum of ten recaptures had been recorded. Of these 41 species, 17 can be considered resident or semi-resident fish that are vulnerable to exploitation as they are easy to target, the balance

being more resilient as they are nomadic or migratory. Data for these were analysed for a parameter termed travel range length (TLR), this being the radius within which 95% of the recaptures are recorded (Griffiths & Wilke, 2002). Experimentation has shown that, provided certain conditions are met, protection of three times the TLR provides the optimum no-take zone size for such species (Griffiths & Wilke, 2002). The minimum size of marine protected areas (MPAs) to protect such species can thus be calculated and, in this case, ranged between 3.6 and 91.2 km.

In the finer-scale study, 2965 fish were tagged at Cape Vidal in the Greater St Lucia Wetland Park between 2001 and 2006. Of these, 304 have been recaptured. Data for resident, reef-associated species were subjected to the analysis described above and yielded valuable results. The bulk of reef-associated recaptures (169) were speckled snappers, *Lutjanus rivulatus*, which have shown a high degree of site fidelity and residency. The majority of recaptures (83%) were caught within 200 m of the original position of capture and only ten fish (6%) moved more than 2 km. Interestingly, of these ten fish, all were recaptured more than 5 km away from where they were originally tagged and one fish was recaptured 63 km from where it was originally tagged.

As has been found with many other species of reef fish, this suggests that there is a component of the population more disposed towards a nomadic lifestyle. Clearly such a life history strategy enables a better spread of genetic variability throughout the population. Simultaneously, it also ensures movement of some adult and sub-adult fish out of no-take protected areas, thus improving the yield in adjacent fished areas.

TLR analysis of the above reef fish data yielded minimum sizes of MPAs to protect these species between 1.9 and 63.5 km, results in many ways comparable with those derived from the ORI-WWF SA Fish Tagging Project. The results for speckled snapper, the species for which the greatest number of recaptures were obtained, are believed to provide the most realistic estimate of reserve size needed to adequately protect resident inshore reef fish species, i.e. approximately 20 km of coastline with suitable habitat. The question of connectivity and how far no-take reserves should be spaced apart is more difficult to answer. The fact that most reef fish have pelagic eggs and larvae which are assumed to be widely dispersed by ocean currents further complicates the question of connectivity. However, recent studies have shown that there is a high degree of natal homing in larvae of reef fish species, which suggests that no-take MPAs need to be a lot closer together than previously assumed to ensure their conservation. Biodiversity conservation targets set at the World Summit for Sustainable Development (2002) and World Parks Congress (2003) require that approximately 20% of marine habitats should be protected within MPAs. The provisional no-take MPA size for the protection of inshore reef fish species in the subsequent Transmap modelling process (see below) would thus be 20 km, probably with an absolute maximum spacing of 100 km between the MPAs. Closer spacing will be recommended to ensure protection of less migratory species such as the yellowbelly rockcod and grey grunter.

Figure 2. A tagged spectacled snapper, *Lutjanus rivulatus*, the species for which the most recaptures have been recorded in a mark-recapture programme in the Greater St Lucia Wetland Park.

Modelling Connectivity

The above provides an overview of Transmap research on habitat connectivity within the WIO that will be of interest to the CORDIO community. Implications of

the results with regard to habitat connectivity are to be modelled individually and combined with biophysical, socio-economic, institutional and governance parameters in Marxan/Spexan models. The fish movement work is most advanced at this stage but haplotype networks and food web connectivity will, for example, soon be incorporated respectively from the genetic and stable isotope studies. The final product will be complete in mid-2008.

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