Guest editorial

Coral reefs and mangroves: implications from the tsunami one year on

The countries affected by the 2004 Asian tsunami contain the most diverse and extensive coral reefs and mangroves of the Indian Ocean, and some of the richest in the world. A recent report by the UNEP World Conservation Monitoring Centre (UNEP-WCMC), the International Coral Reef Action Network (ICRAN) and IUCN emphasizes that not only are these ecosystems among the most threatened in the world, they also provide numerous essential ecosystem services (UNEP-WCMC, 2006). It is thus not surprising that reefs and mangroves received widespread attention after the tsunami, with three principal questions posed:

- Are the tsunami's impacts on reefs and mangroves a further threat to their future survival?
- Did reefs and mangroves play a role in shoreline protection and reduce structural damage and human mortality?
- How could reconstruction efforts include actions to maintain these ecosystems and reduce further threats to them?

The initial responses to these questions were inevitably based on rapid literature reviews and field surveys, and much hypothesis and opinion. More detailed studies are subsequently painting some different pictures.

Fears that there would be extensive damage proved largely unfounded. Data collated by the Global Coral Reef Monitoring Network (Wilkinson *et al*., 2006) show that the greatest damage to reefs was closest to the epicentre. Many reefs in Aceh, Indonesia and the Andaman and Nicobar Islands were affected directly by the earthquake and suffered uplift or subsidence leading to permanent exposure or drowning. Wave damage from the tsunami was, however, highly localized and patchy, comprising coral breakage and overturning of boulder corals caused by debris and the force of the wave itself, and sedimentation from run-off and the backwash. No similar collation of information on mangrove damage exists. UNEP-WCMC estimated that 35–40% of the existing mangroves in the region were within the zone of inundation by the tsunami. Field reports, however, indicated that damage was variable (30–100% in Aceh), with some areas suffering total destruction but many unaffected.

Reefs and mangroves form natural coastal barriers. Studies reviewed by UNEP-WCMC (2006) show that these barriers can absorb 70–90% of the energy of normal levels of wave action depending on their structure and form. Areas of high shoreline erosion are often correlated with offshore damage to reefs. However, tsunami waves are very different in size, structure and form from storm generated waves (Yeh *et al*., 1994), and are likely to have much greater impact in certain situations than any reefs or mangroves could withstand. Apart from one study in Sri Lanka, considered controversial by some, the UNEP-WCMC review found little evidence that the presence of reefs reduced tsunami damage on shore. Some studies even suggested that inundation was greater on coastlines with reefs than on those without, due to bathymetric factors and the way in which the tsunami can gain force as it approaches certain types of shoreline.

Mangroves certainly trapped debris, thus helping to reduce damage, and saved lives by preventing people from being pulled out to sea. Studies in Tamil Nadu, India (UNEP-WCMC, 2006), found less damage to villages behind mangroves, and modelling indicates that under some circumstances coastal vegetation could reduce flow pressure from a tsunami by as much as 90% (Hiraishi & Harada, 2003). However, it appears that elevation and distance from shore were equally important factors, and that some mangroves reported to have provided protection were located out of the main path of the wave or were otherwise inherently less susceptible to serious damage (Dahdouh-Guebas & Koedam, 2006; Danielson *et al*., 2006; Kerr *et al*., in press). Overall, distance from the epicentre, bathymetric characteristics, shoreline profile, dunes, other vegetation, and density of habitation and infrastructure were at least as, and probably more, important than reefs and mangroves in determining destruction on land.

Much initial reconstruction planning focused on construction setbacks and buffer zones, which are both standard, if often ignored practices used to reduce damage from both extreme wave events and more normal coastal erosion and deposition. Setbacks can also benefit both reefs and mangroves by reducing human impact on them. However, neither setbacks nor reefs and mangroves themselves provide guaranteed tsunami protection. The 2004 tsunami demonstrated clearly how even subtle variations in coastal characteristics can lead to enormous differences in outcome, which shows that no single setback width will suit all situations. These essential mitigation measures must be undertaken with care, and include public consultation to ensure that poor communities with limited access to land are not further disadvantaged.

The tsunami also led to proposals for restoration of reefs and mangroves, often before the extent of their damage was known. Both ecosystems are naturally resilient and can recover once a stress has been removed, but this can be slow. For mangroves, restoration programmes were already underway in many areas and have been accelerated in the tsunami affected countries. Volunteers and local labour can create large areas of new mangrove inexpensively by planting propagules and seedlings. These efforts will be of partial benefit, but research indicates that complete restoration of mangrove forests with the hydrological patterns necessary to ensure their full complement of biodiversity is uncertain (UNEP-WCMC, 2006).

The high diversity and complex growth and reproductive patterns of corals make reefs more difficult to restore. Most methods are costly and the results unpredictable. The general consensus is that restoration should be limited to small areas of reef that have high economic or scientific importance. For both reefs and mangroves the priority should be to ensure that the conditions for natural recovery are maintained or restored.

The main priority for post-tsunami recovery must continue to be the huge numbers of people still struggling to regain their livelihoods. However, the lessons learned about the ecosystems that sustain them are fundamental to recovery efforts. Reef monitoring programmes should be maintained and improved where necessary, and those for mangroves should be improved and more effectively coordinated. The rapid demonstration of surprisingly low levels of reef damage helped to free resources for more urgent priorities.

Further research is necessary to clarify the role of reefs and mangroves in shore protection and to identify the principal factors that determine the intensity of tsunami-induced damage. A rigorous analysis is also needed of whether reefs and mangroves in protected areas, or reefs that were healthier for other reasons, survived better and/or recovered faster. This research should be interdisciplinary and incorporate both broad scale and site level data in predictive modelling. Although tsunamis are rare the mechanisms involved can help to elucidate ecosystem roles and responses to more common phenomena, and in particular to the predicted consequences of climate change.

Post-tsunami reconstruction provides an opportunity to introduce and expand good coastal management practices, such as those outlined in the Cairo Principles (UNEP/GPA, 2005) and discussed in the international workshop on post-tsunami assessment and monitoring that took place in Phuket, Thailand, in February 2006. Such practices may help to mitigate the impact of future tsunamis and are essential in the face of the more certain consequences of global warming, such as sea level rise and increases in tropical storm intensity. Coral reefs and mangroves are in the front line of coastal defence – research and action are needed to secure their future.

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