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Recovery from the Indian Ocean Tsunami - Guidance for Ecosystem Rehabilitation incorporating livelihoods concerns

1. The Indian Ocean tsunami and ecosystem rehabilitation

The 26 December 2004 tsunami caused the deaths of large numbers of people and was responsible for damage to livelihoods and ecosystems across large areas of coastal regions in south and south-east Asia and eastern Africa. The event affected coastal ecosystems and, as a result, will severely affect the livelihoods of people living in these areas, both immediately and in the long-term. A great deal of evidence (from literature on previous natural disasters) demonstrates that the poor are particularly vulnerable to natural disasters such as severe storms, floods, landslides, fires and earthquakes because they often live in unsafe locations. It is also important to remember that the poor have less reserves to enable any quick recovery and that some legal and institutional arrangements with respect to property rights may even act as serious constraints to regaining some measure of livelihood security.

The initial response of the local and international communities in the aftermath has been to deal with urgent humanitarian concerns - ensuring adequate shelter, food, water supplies, health and security of the survivors. The next stage will be to re-establish the communities and help them to rebuild and develop sustainable livelihoods. Many of these communities relied heavily on natural resources (marine and terrestrial). The sustainability of livelihoods in such cases can be enhanced by the rehabilitation of these resources and ecosystems. Attention to restoring the ecosystems that provide the life support systems for these people will benefit both communities and biodiversity for the future.

Box 1. Why restore ecosystems as an integral part of tsunami recovery plans?

1. The sustainability of livelihoods, both in the short and longer term, in areas affected by the tsunami will depend on the restoration/rehabilitation of ecosystems.

2. Restoring habitats across coastal landscapes will improve the capacity of both ecosystems and human economic and social systems to withstand future disasters.

As policy makers make decisions about the reconstruction process, it is vital that two key principles be followed as plans and programmes are developed: 1) participation of all stakeholders; and 2) application of adaptive management principles.

Box 2: Key principles for implementing successful ecosystem rehabilitation

1. Ensure that all relevant stakeholders will be involved and given the opportunity to make informed decisions.

2. Apply an adaptive management approach for planning and implementing both ecosystem rehabilitation and livelihood reconstruction, because complexity and uncertainty makes it impossible to accurately predict outcomes.

2. The impact of the tsunami

Beyond the immediate and overwhelming impact of loss of life (now estimated to approach 200,000), the impacts of the Indian Ocean tsunami are extensive from both environmental and long term livelihood perspectives.

Environmental Impacts

As more details are accumulating about the impacts of the tsunami and the factors which enhanced or mitigated damage, considerable variation has been observed in the extent to which environmental damage has occurred and also considerable variation in the magnitude of the impact on human communities in different places.

The reasons for the variation in environmental impacts are complex. Observations, and evidence from other tsunamis or severe storm events, indicate that differences in environmental impacts have been caused by differences in

- coastal geomorphology (off-shore and on-shore)
- the presence or absence of off-shore coral reefs
- the width of the mangrove belt
- the maturity of the mangroves
- whether the mangrove is on a small island, large island or mainland coastline
- location of human settlements

Considerable evidence from multiple locations in Malaysia, India, Thailand, Bangladesh, Myanmar and Indonesia demonstrates that areas with mangroves and vegetated coastal dunes suffered less damage and lower death rate. However, the way mangroves influenced the impacts of the tsunami depended on many other variables.

Livelihood Impacts

Some economists have suggested that macro-economic impacts have been relatively minor except in the fisheries and tourism sectors. However, the effects at the national and local level on livelihoods of many people have been massive, especially for people involved in small-scale economic activities. These people have short term needs for food, shelter and clean water – all part of the life support systems dependent on healthy ecosystems.

It is too early to have detailed pictures from each country, let alone from particular areas within each country. Very important local differences are apparent and indicate what types of livelihood systems have been affected. For example, it appears that impacts in India were especially on coastal fisheries and agriculture. In Sri Lanka, fisheries (an estimated 80-95% of the fleet was lost in some affected regions), tourism and small-scale retail trade were most affected. The coastal infrastructure is destroyed in large parts. Lowland arable fields and home gardens were also heavily affected.

Information on some of the first post-tsunami assessments on the impact on marine ecosystems and their related livelihoods are available at www.cordio.org. IUCN is also gathering information on other assessments in the region and this will be available on the IUCN website (www.iucn.org/tsunami).

3. Planning the recovery process

Gathering Information

Any planning for ecosystem and livelihood rehabilitation will depend on knowledge about the extent and type of damage that has occurred and considerable knowledge about the specific context of each site,

including both cultural and environmental concerns. Surveys of ecological and social impacts are providing information upon which a shared vision can be developed within the affected communities.

More specific information at site levels is also being collected to complement these larger scale investigations. Information useful for planning includes:

1) environmental impact surveys to identify

- The location, extent and type of damage that has occurred and may still be occurring – including physical (coral reef damage, hydrological/erosion, etc.), chemical (salinisation, contamination of ground water) and biological (including species introductions and changes in breeding grounds)
- The characteristics of the coastline and coastal ecosystems compared to the extent and type of damage
- The likelihood and estimated time needed for ecosystems to recover and an analysis of the opportunities for accelerating such recovery.

2) social and economic impact assessments to identify:

- How and the extent to which different types of livelihoods have been affected taking into account:
  - Gender and other equity differences
  - Differences between relatively wealthy and poor people/communities
  - Direct and indirect, short and longer term impacts e.g. Loss of assets (human capital, financial capital, physical capital and natural capital); impact on power relationships (social differences such as gender, access to resources, relationships with public authorities, rule of law) and changes to vulnerability (e.g. are people even more vulnerable now and what will be the mid to long term changes in vulnerability if natural resources are not rehabilitated effectively?)

A preliminary typology of some of the livelihood types most affected by the tsunami is included in Table 1.

Methodologies for rapid assessment of mangrove/terrestrial ecosystems are available from a number of sources including:

- CRI/ISRS 2005. Tsunami Damage to Coral Reefs: Guidelines for Rapid Assessment and Monitoring. GCRMN/CORDIO/IUCN/Reefbase/ ReefCheck/AIMS. January 2005. Seychelles.http://www.iucn.org/tsunami/temp/index.htm
- Kelly, C. 2003. Guidelines for Rapid Environmental Impact Assessment in Disasters, Benfield Hazard Research Centre, University College London and CARE International *Version 4.2,* December 2003 http://www.benfieldhrc.org/SiteRoot/disaster_studies/rea/rea_guidelines.pdf
- OECS 2003. Technical Manual For Post-Disaster Rapid Environmental Assessment Volume 1 & 2, OECS - Environment & Sustainable Development Unit, Organization of Eastern Caribbean Countries http://www.oecs.org/esdu/
- UN-ECLAC 2003. Handbook for Estimating the Socio-Economic and Environmental Effects of Disasters, United Nations Economic Commission for Latin America and the Caribbean, 2003 http://www.proventionconsortium.org/toolkit.htm
- Wetlands International 2005. Assessment field protocol for rapid wetland and coastal assessment – a guide for staff http://www.wetlands.org/Tsunami/Tsunamidata.htm

Methodologies for a broader environmental impact assessment are available from a number of sources, including:

- Biswas AK and SBC Agarwal (eds.) 1992. Environmental Impact Assessment for Developing Countries. Oxford; Butterworth Heinman.
- Lohani BN. 1997. Environmental Impact Assessment for developing countries in Asia. Asian Development Bank. Manila.
- Barrow, C. J. 2000. Social Impact Assessment: An Introduction. London: Arnold. ISBN: 0-340742186

- International Association for Impact analysis - http://www.iaia.org/Non_Members/Pubs_Ref_Material/pubs_ref_material_index.htm

However, planning for recovery of the affected communities cannot wait until all the information is available. Already decisions are being taken and activities implemented to rebuild livelihoods for people. Nevertheless, experience from previous natural disasters has demonstrated that human livelihoods can be made much more sustainable if consideration is given at an early stage to restoring or rehabilitating the natural resources in the affected areas. Timely consideration of restoring biodiversity will also minimise the loss of future natural-resource-based livelihood options. For example, by applying environmentally sound approaches to sourcing of roundwood for re-construction the reconstruction effort can avoid unnecessarily depleting local resources in the immediate aftermath of the disaster.

In the case of the Andaman Sea tsunami, coastal habitats and biodiversity are important because they can:

- protect hydrological cycles, surface water and groundwater supplies
- protect coastlines from erosion and off-shore reefs from sedimentation
- sustain fishing industries
- provide resources such as timber and non-timber forest products for direct consumption and sale
- attract and sustain tourism.
- physically protect settlements and farming areas from storms and other natural hazards in the future.

Some planning tools are already available for use including “Forest Management – A Handbook promoting sound practices in refugee-related situations”, a joint UNHCR/IUCN publication. In addition, a list of experts from the region affected by the tsunami is available (see Appendix 1).

In the case of the Andaman Sea tsunami, numerous assessments are already underway. Overviews of completed assessments are being compiled by various organisations including UNEP and IUCN.

Stakeholder participation

Any rehabilitation/recovery planning exercise will necessarily raise a large number of crucial social and equity issues. The best people to ask about these issues, the ways they have been affected and their immediate needs are the people actually affected. Therefore it is critical to establish early on who the stakeholders are and how they can be involved in the decision-making process as informed participants. Guidance on ensuring stakeholder participation, and in particular participation of women, is available from:

- Biodiversity in development - http://www.wcmc.org.uk/biodev/index2.html
- Diversity makes the difference - http://www.generoyambiente.org/ES/publicaciones_uicn/biodiversity/modulebiodiversity.htm
- In Search of the lost gender: gender equity in Protected Areas - http://www.generoyambiente.org/ES/publicaciones_uicn/moduloapi/moduloapi.htm

Among many issues, some of the questions this stakeholder group will need to answer include:

- How can previous land holders be compensated or provided with viable alternatives if land use patterns change?
- How to deal with the needs of people who may not have had legal rights to the lands they were using before the tsunami?
- How should zoning to restrict building and transport infrastructure be best implemented when it involves relocation of people?
- If relocation occurs, what land is available?

- How should cases be dealt with where land ownership records have been lost and tenure cannot be demonstrated?
- What issues of traditional access rights to natural resources will need resolution?

Adaptive Management

All rehabilitation programs will be based on explicit or implicit assumptions about how an ecosystem functions and how a human community will interact with that ecosystem. Rehabilitation after a disaster can be planned, but events will not necessarily develop in the manner expected. Incomplete knowledge or understanding and the unpredictability of many ecological and social processes means an adaptive management approach will be necessary.

Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. The key to any adaptive management program is having a good monitoring program. This should act as an early warning system that tells the manager or community when adverse changes or trends are beginning to develop or, conversely, when management is so successful that interventions can be accelerated. However, it is important to note that the consequences of change may appear gradually in ecological systems. Once alerted, managers can decide how to modify current management programs.

Different circumstances will require different approaches to establishing a monitoring program. However they should:

- Focus on key processes (e.g. rates of plant growth in new reforestation areas, erosion rates, coral growth, sedimentation rates, groundwater salinity, run-off rates, sea temperature development, fish stocks etc. or changes in general properties such as the “health” of ecosystem in buffer areas);
- Be simple to use (so minimising the need for skilled technical experts);
- Be cost effective (so many observation or monitoring points can be established);
- Identify triggers for action (so data are not being collected for their own sake but can be used to identify when action must be taken and management practices changed).

Some possible attributes to use in ecological and social monitoring are shown in Table 3. These are not meant to be prescriptive or comprehensive, but to suggest the types of attributes that might be used.

Adaptive management and monitoring are dependent on an organisation to carry out the monitoring and another to act on the information gathered. These may be local community-based organisations, non-governmental organisations, or part of the government sector (or a mixture of both). Monitoring programmes, if not already in place, should be established on the understanding that they may have to last at least several years.

Preparing Plans

Plans for re-construction will ideally need to incorporate social, economic and environmental considerations. Policy makers considering options will be looking for cost effective answers to issues of immediate concern and they will be faced with trade-offs among choices. When options are selected, every effort should be made to ensure that the trade-offs are equitably distributed among all stakeholders and that the balance between ecosystem and human livelihood needs are balanced.

Box 3. Rehabilitation vs. Restoration

Rehabilitation –Most of the key ecological processes and functions are re-established and some but not all of the former biodiversity is recovered.

Restoration - All of the key ecological processes and functions are re-established and all of the original biodiversity is re-established.

In addition to consideration of the trade-offs, policy makers should question some assumptions that may be inherent in the planning process, namely:

i) Don't assume that you are planning to re-create what was there before

An important principle is to ensure that planning needs to be done in a way that ensures all those affected will have the means to re-establish their livelihoods. In areas affected by the tsunami, coastal zone planning should also lead to a reduction in peoples' vulnerability to future natural disasters.

Prior to the tsunami, land use activities in some coastal areas were not sustainable and some may have increased the vulnerability of communities to natural disasters. A good example is the extensive clearing of mangroves to establish aquaculture industries such as prawn and shrimp farms. These developments removed natural buffers, increased risks to local communities and may have threatened the long-term viability of marine fisheries by destroying spawning and breeding areas of natural fish and crustacean populations.

In some cases, this situation has occurred because many coastal land practices were established *ad hoc*, were incremental and occurred without long term planning. The final landscape and land use pattern in many regions have evolved as a result of numerous unconnected small decisions. In other situations, land use practices occurred illegally despite well-developed regulations and plans.

Because of this, it may not be appropriate to simply recreate what was there before. Instead, new land use plans should be developed that take account of both environmental conditions (soils, topography, terrestrial, coastal and marine habitats, previous disturbance or degradation etc.) and the need for communities and habitats to be made less vulnerable to natural hazards.

This planning process will require:

- Strengthening of protection by existing natural ecosystems in coastal regions (e.g. existing natural mangrove areas)
- Identifying areas to be rehabilitated. These might include strips of land on the seaward side of agricultural areas or areas previously used for aquaculture or tourism.
- Strengthened capacity of communities to develop and enforce these new land use plans.
- Identify dangerous areas where building and residence should be restricted. (This may involve developing new regulations, or simply enforcing existing regulations.)

ii) Don't assume that you need to rehabilitate all areas affected by the tsunami

It will not be necessary to rehabilitate all areas degraded by the tsunami. For example, some areas will be needed for infrastructure (e.g. for roads or housing) and others may recover relatively quickly without human intervention (e.g. sand dune communities).

On the other hand, intervention of some kind may be needed to hasten the recovery process (e.g. mangroves). These may be areas degraded by the tsunami or areas used for purposes such as prawn farms but which are now needed to act as buffer zones or to sustain livelihoods. A summary of some of the ecosystems likely to need rehabilitation is shown in Table 2.

Active intervention to rehabilitate these ecosystems will have several benefits, including:

- Fostering spatial and biological heterogeneity
- Improving ecological resilience by re-establishing key ecological processes upon which agricultural and natural communities depend (e.g. hydrological cycles, nutrient cycles and flows)
- Buffering communities and habitats from damage caused by natural hazards
- Creating new and potentially sustainable resources (e.g. new mangroves forest are likely to act as fish and crustacean nurseries and thus improve the supply of a number of marine resources)

hence, improving economic resilience by adding to the diversity of economic resources available to these coastal communities

The creation of sustainable resources may also require the development of new management structures. Who controls these and manages them? Who has access to the resources they generate? Historically it seems that community-based or collaborative approaches have a greater success than centralised approaches. In the case of mangrove management, this is particularly clear from cases in Asia.

BOX 4: Undertaking reforestation to protect coastal areas and restore livelihoods

Most of the reforestation undertaken during the rehabilitation program will probably involve either mangrove reforestation on marine flats or tree planting with species such as *Casuarina equisetifolia* on coastal areas or dunes immediately above the tidal zone.

Mangrove forests are relatively simple communities compared with other tropical forests and the forest at any one site is usually dominated by a small number of species. However, restoring mangrove forests is not necessarily a simple process. A simple plantation-style reforestation program using just one species across the whole site will rarely succeed.

Variations in salinity and tidal movement mean that the tidal zone in which mangroves grow is made up of a series of distinctly different habitats each of which favours particular mangrove species. Successful reforestation on even relatively undisturbed habitats requires careful species-site matching. Where highly disturbed sites are being reforested (e.g. because they were previously used for aquaculture) it will probably be necessary to develop appropriate drainage lines to recreate the specific hydrological conditions required by particular species of mangrove. Natural recolonisation (mangroves and other marine organisms) will occur over time if intact forests are nearby but the rate at which this occurs will depend on local circumstances. Consideration should therefore be given to methodologies that also accelerate the rate at which marine resources become available to local communities.

Away from the tidal zone, reforestation of coastal areas in south and south-east Asia has commonly used *Casuarina* because these are tolerant of winds, salt and relatively unstable soils. This is a more straight-forward process than mangrove reforestation.

There is little information available to indicate how extensive any reforestation effort must be to provide protection (that is, how broad should any belt of mangroves or *Casuarinas* be). In principle, more extensive reforestation will be needed in areas where waves are able to penetrate further into the coastal zone because of the flat topography. Information on this issue may emerge from current post-tsunami surveys. Nor is there information on how large a tree must be to offer protection although it seems that trees with many low branches are more effective at dissipating wave energy than those without. It is likely that most young forests will provide little protection until they are more than several meters tall. Again, post-tsunami surveys may be able to provide information on this.

For assistance and guidance on planning for re-forestation, IUCN provides a list of experts from the region in Appendix I.

Reference:

Field, C. 1996. Restoration of mangrove ecosystems International Tropical Timbers Organisation, Yokohama.Box 5 contains some ideas about the potential for reforestation to rehabilitate ecosystems and assist livelihoods.

Tsugil et al. 1995, *Pure and Applied Geophysics* 144: 481-524

Box 5: What are the attributes of a resilient community or coastal zone?

To facilitate planning processes and to help set long term targets, it is useful to consider the attributes of a disaster-resilient community. Some possibilities are listed below.

(a) Disaster resilient communities are:

- Those with diverse economic bases. That is, they are not dependent on just one activity.
- Have strong community self- management systems, including management zoning to regulate future development and resource development.
- Have infrastructure that provides for alternatives; e.g. multiple access roads; various water supply systems; health systems located in safe areas

(b) Disaster resilient coastal zones are those where:

- There are areas of natural vegetation deliberately maintained under effective management plans. Mangrove forests and forests on dunes may play an especially important protective role.
- Areas of high risk have been identified and incorporated into land use plans. E.g. these may be coastal areas without fringing coral reefs and with shallow water off-shore and gentle on-shore topography.
- Buffer zones have been re-established in areas of high risk where natural vegetation has been cleared.
- There are effective management structures for sustainable resource use (e.g. Local community, government agencies).

References:

Gunderson L. and C.S. Holling (eds.) 2002. Panarchy: understanding transformations in human and natural ecosystems. Island Press, Washington.

Berkes, F. Colding, J. and C. Folke. 2003. Navigating social-ecological systems: building resilience for complexity and change. Cambridge University Press.

5. Establish priorities for action

In the immediate post–tsunami period the priorities for rehabilitation will be relatively clear (providing food and housing, providing clean water, sanitation and medical services etc.). Priorities for rehabilitation after this time will be more site-specific because of the large variation in human and ecological circumstances across the region.

Housing and health will continue to be priorities, of course, but there will also be the need to re-establish livelihoods and livelihood systems. At the same time many of these livelihoods will require key ecological processes and functions to be restored if they are to be sustainable. This is particularly true of livelihoods dependent on natural resources such as fishing and agriculture, but also relevant to other livelihoods as they too require ecosystem services such as fresh water. Because rehabilitation of biodiversity may take some time it should be initiated at a relatively early stage

Issues needing to be addressed and prioritised are:

- To what extent were previous resource (land and marine) use activities sustainable? Are there ways these activities might be made more sustainable?
- What parts of the landscape/coastal zone/marine area need to be rehabilitated?
- To what extent should previous patterns of use be recreated? Should the opportunity be taken to revise these patterns?

- If changes are needed can some rapid form of land use planning be carried out with affected communities to identify areas that should be rehabilitated?
- Do local communities already have the capacity to undertake the rehabilitation action or must outside expertise be brought in to assist?

When prioritising action, two other considerations that should be used include:

a. Affirmative action for the needs of the "poor"

One of the key concerns of post-tsunami reconstruction will be to ensure that victims are provided with opportunities to develop livelihood systems. This is particularly important in the case of the poor and more generally in the case of people who have depended on small-scale industry, small business, services, and small-scale agriculture and fishing. These people, even when not normally regarded as poor, are at serious risk of falling into poverty where they do not have the resources to reinvest in necessary equipment and assets. Restoration of livelihoods needs to be focused on these people and this will often require positive discrimination in their favour.

Some examples of situations where special attention might be desirable are:

- In cases where suitable land is in short supply, consideration needs to be given to placing priority on the needs of the poor rather than on commercial interests. Despite the best of intentions on the part of planners, powerful commercial interests (such as tourism enterprises) may tend to get favourable consideration in obtaining suitable sites at the cost of the poor and/or landless. Exemptions from zoning regulations are often more likely in cases of commercial interest than they are for the poor.
- To the extent that re-establishing livelihoods requires provision of loans or grants, it will almost certainly be necessary to bypass requirements for collateral and legal title as prerequisites. Many poorer people have built up their productive assets over long periods and could not meet such requirements in order to replace assets in the short term. Further, many people will have lost documents supporting title over assets such as boats and other equipment.

b. Avoid further damage

In the haste to alleviate the worst after effects of the tsunami, damage may be caused to relatively undamaged natural ecosystems. For example

- Restoring infrastructure such as roads, bridges and living areas can cause further damage to remaining habitats.
- Clearing debris can have negative effects as in cases where debris is dumped in mangrove forests, wetlands or the sea.
- Increased pressure on nearby intact forests and reefs for building materials and timber can deplete already vulnerable ecosystems
- The needs to restore natural resource supplies can lead to use of invasive alien species with dramatic and long lasting effect (see Box 6 at end of document)

Just as reconstruction efforts may cause further damage to ecosystems, attempts to rehabilitate the environment or to enforce safer settlement patterns may themselves have negative effects on livelihoods. For example, people with previous marginal livelihoods may be further disadvantaged if they are relocated away from the coast.

Safety regulations may be a two-edged sword for the poor. On the one hand people may be protected from future natural disasters, but this may occur at the expense of existing (however unsatisfactory and unsustainable) livelihoods.

A Final Note - Cautions for planners

The impact of the tsunami has been highly variable depending on a wide array of factors. Similarly the response must be similarly varied.

There are two things that must be avoided:

"One size fits all solutions"

There is no single solution that will be appropriate in every circumstance. While vegetative barriers may work to reduce the impacts of tsunamis in some cases, in others there are almost certainly geomorphologic circumstances that negate this effect. And just because mangroves may have worked in some cases, doesn't mean that massive mangrove plantation projects are the solution everywhere. There may be inappropriate soil conditions or other technical and social factors that make mangrove plantations inappropriate.

"Gut reactions"

Rapid, often unconsidered, responses may seem commonsense, but they don't always work and can raise further problems. For example, it may sound like common sense to enforce restrictions on building too near the beach, but strict enforcement of this may leave poor people without any alternatives. Or it may seem sensible to ban all harvesting from mangroves to allow them to regenerate, but such restrictions may again seriously affect the livelihoods of the poor.

These pitfalls can be avoided by ensuring that relevant stakeholders are involved in the planning and implementation process from the beginning and that any plans are flexible enough to deal with unexpected consequences.

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Box 6 - Invasive species and ecosystem rehabilitation

Potentially invasive species, be they “alien” or not, have a chance to invade after an event when ecosystem boundaries collapse, seawater and freshwater mix and areas become “degraded”. The recent tsunami event created just such a situation.

Many freshwater species that are actual or potential invasives are kept isolated in their habitats near coasts by the presence of seawater. Examples would be water hyacinth and other invasive water plants in the freshwater end of estuaries and in freshwater wetlands near the coast. After tsunami events these plants or their propagules can easily be swept back into previously uninfested freshwaters or slightly saline areas and remain alive to infest new areas. Any rehabilitation of such freshwater ecosystems should ensure that potentially invasive species are eliminated from reviving habitats before they establish to the stage of invasion – and monitoring for the presence should continue for a reasonable length of time.

The same processes can occur for submerged (wild) invasive species such as finfish, crustaceans and molluscs which can move to new habitats via the sea during tsunami events.

Another problem is the escape of (often alien) species that are present in aquaculture and/or mariculture – especially finfish, crustaceans such as shrimp and crabs and table molluscs such as oysters and scallops, etc. This applies to cage culture in the open sea or in estuaries as well as to open mariculture and aquaculture in ponds. In the case of marine species (especially alien and/or genetically modified species) in cage culture it is obvious that the tsunami events may result in their release into the open sea or estuary and so make invasion possible. Similarly, alien species in ponds (such as tambaks) could be washed inland and then out to sea again releasing potentially invasive species (and their diseases) into the local faunal assemblages.

There are several popular species of freshwater cichlid fish, often alien and sometimes genetically modified, which are used in aquaculture but which are capable of survival in brackish water or saline conditions. If these are released into the surges of the tsunami they are capable of not only surviving marine conditions but of spreading far along a coast and then entering other brackish or freshwaters distant from their origin. Examples would be the tilapias such as *Oreochromis niloticus* and *O. mossambicus* (originally of African origin) which may have been genetically modified or hybridized for fish production. There are records of these species establishing in new freshwater systems and being responsible for the extinction of local fish species, local invertebrates and even local aquatic plants as they are omnivorous and fast breeders.

Managing escaped and possibly invasive species that are submerged (fish, invertebrates) is extremely difficult in both freshwater and marine environments. One approach would be to list the species that are being cultured in a given area – in both cage and open systems - and develop a list of potential invasive species. These could be searched for in any habitat to be restored or rehabilitated to ensure that escaped exotics with invasive potential are not knowingly encouraged within the restoration process.

Degraded or disturbed areas are classic places for the establishment of alien species which may have the potential for invasiveness. This applies as much to plants (terrestrial and aquatic, which will initially be seen as “weeds”) as it does to animals – such as rats, exotic birds, feral fish and aquatic invertebrates. Waste lands, destroyed fields, polluted and salinised freshwaters, former housing areas, rubbish dumps and even piles of useful materials and food stores can become habitats for invasive species which may prejudice easy rehabilitation of habitats. Constant vigilance during all stages of assessment and restoration is needed to ensure that such degraded or disturbed areas do not provide foci for the spread of invasive species which could compromise the restoration process.

TABLE 1: Indicative typology of the types of livelihood systems affected, the ways they are affected and possible things to focus on in planning responses

Note: This typology is intended to be a first cut to indicate some of the variety and complexity of livelihood impacts and issues. Each type and sub-type can be further disaggregated. Specific impact assessments will identify additional issues and different combinations of elements and each case must be addressed on its merits.

Livelihood system	**Impact**	**Possible response/ comment** **[All responses situation dependent]**
Fisheries	Marketing and transport infrastructure damaged	Support re-establishment of middlemen and transport businesses and storage facilities
	Damage to fish stocks	In some case mangrove rehabilitation (or, on a smaller scale, artificial reefs) might help, but there will be no easy or quick solutions
Sub-type: Coastal fishing (small boats)	Boats destroyed Boat engines lost Boat houses lost	Establish supply of timber for boats (depending on local availability could be supplied locally or imported)
		Provide construction timber and tools
		Train people in boat construction and re-establish construction facilities and businesses [Even if unaffected by tsunami, boat construction facilities would be geared to much lower capacity than required to replace whole fleets]#
		Provide loans and/or grants
Sub-type: Beach fishing	Nets and other equipment destroyed	Similar responses as for boat construction in terms of supplying materials, equipment, facilities and training
Small retail and service businesses	Loss of buildings and equipment	Provide loans and/or grants
	Inadequate capital	Provide loans and/ or grants
	Lack of skilled personnel (due to deaths or increased demand)	Recruit and train personnel
Sub-type: Tourist related small businesses such as beach restaurants, beach equipment	Loss of facilities, stock, equipment	Provide loans and/or grants

hire (canoes etc), rides, beach vendors (drinks, snacks, services)*		
Agriculture	Loss of equipment	Provide replacement equipment or capital for purchase of replacement equipment
	Damage to land (salinity, erosion etc)	Technical support, earthworks as appropriate
	Damage to irrigation canals, wells	Equipment and capital for repair
	Loss of crops	Financial assistance
	Loss of seed stock	Provision of new supplies of seed stock in time for next planting period
	Loss of livestock	Provide replacement breeding stock

Even in cases where construction facilities for equipment and infrastructure have previously existed locally, these facilities may be operating at drastically reduced capacity after the tsunami at a time when the immediate need far outweighs normal capacity anyhow. (This applies not only to construction of boats, production of equipment such as nets, but also to services such as earthworks etc for agriculture.) Questions of availability of skilled staff and resources will be crucial.

* This is an important category. Many economic and livelihood niches exist in tourism outside the formal sector.

Table 2: Coastal ecosystems possibly affected by the tsunami and the extent to which intervention might be needed to accelerate rehabilitation following any damage they may have sustained. The susceptibility of these ecosystems to damage from natural hazards such as tsunamis is based on reports in the literature and the actual extent of damage in any particular case will necessarily depend on location and circumstances.

Ecosystem and communities	**Possible impact of tsunami**	**Need for Rehabilitation**
Mangroves	Depends on magnitude of disturbance but scientific literature suggest natural recovery usually occurs relatively quickly if damage is not severe; young plantations are likely to be severely damaged	High priority if damage is severe; damage to mangroves can impact on fisheries. Requires reforestation, monitoring and evaluation, and surveillance against illegal uses to some extent.
Freshwater swamps and wetlands	Sedimentation and changes to drainage patterns; changes to salinity levels; contamination by chemical pollutants or sewage.	In most cases system will probably recover natural functions over time. However, requires monitoring.
Estuaries and *Nipa* palm swamps	Sedimentation and damage to surrounding coastal vegetation	In most cases system will probably recover natural functions over time. However, requires monitoring.
Frontal dunes	May reconfigure shape	Can stabilize if necessary using species such as *Casuarinas* or *Spinnifex*
Coastal forests	Probably small depending on topography	Low priority; systems will probably recover natural functions over time.
Coastal plantation (e.g. coconuts)	Extent of damage depends on coastal topography and magnitude of waves; often able to withstand moderate waves.	Depends on economic significance of plantations.
Sea grass meadows	Can be badly damaged by sediment and debris, and affected by increased run-off	Removal of debris. Difficult to treat and will probably recover unaided over time; severe damage can affect populations of fish (Juvenile and spawning habitats) and dugong.
Coral reefs	Coral can be physically damaged and/or broken; also covered with debris and sediment; increased risk for marine invasions; scientific evidence is that recovery can occur naturally although composition and structure may change and the recovery rate is generally slow and highly variable depending on circumstances.	Remove debris from shallow areas where reef is accessible, with help of large volunteer networks (e.g. local nature groups, Reef Check, dive operators, local communities, others). Start rehabilitation in areas most important for tourism. Foster and strengthen monitoring.
Prawn/Shrimp	Potential to be severely damaged:	May need to replace some of these by

farms and other aquaculture	sedimentation and salinisation; mechanical destruction; displacement of exotic invasive species from ponds; eventually contamination through decaying caged organisms and increased sewage run-off	natural vegetation, especially along coastal strip. Decision on which to re-establish (modify if necessary, with increased ecological measures), which to replace and respective livelihoods-based alternatives will depend on planning. See also Box 2.
Agricultural ecosystems	Potential to be severely damaged by erosion, sedimentation and salinisation.	May need to replace some of these by natural vegetation, especially along coastal strip. Decision on which to re-establish and which to replace will depend on planning. See also Box 2

Table 3: Suggested attributes that might useful for monitoring for adaptive management in areas that have been rehabilitated (the actual attributes will depend on local circumstances).

Biophysical	**Social and economic**
Growth rates of trees	Changes in population density in areas that have been rehabilitated
Areas covered by reforestation	Community management systems in place for new resources
Evidence of increased erosion	Illegal harvesting of firewood from reforested areas
Evidence of natural colonization of mangrove species in rehabilitated forests	Resources being gathered from rehabilitated areas
Evidence of coral bleaching or natural coral recovery, of changes in coral distribution and natural (re-)colonization.	Changes in fish catches (i.e., average catch per day of fishing effort; catch composition; etc.)
Evidence of pollution (land run-off, debris, etc.), sedimentation or mechanical damage to marine ecosystems.	Illegal harvesting of fish, shrimp, crabs from reforested mangrove areas or possibly new areas for protection
Evidences of changes in sea temperature and hydrological/oceanographic parameters.	Evidence of connections between more impacted land areas and coastal/offshore resource uses
Evidence of species that may be newly introduced, e.g. through changes in water conditions.	Evidence of newly introduced species, e.g. transmitted with aid donations such as fishing gear. Displacement of exotics grown in aquaculture ponds.

APPENDIX 1:REGIONAL TECHNICAL EXPERTISE ON COASTAL PROTECTION AND REHABILITATION

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