Natural Geography In Shore Areas Procedure Manual

DIWPA/IBOY - Marine Coastal Habitats in the Western Pacific
Latitudinal Biodiversity in Coastal Macrophyte Communities

Written by

Yoshihisa Shirayama (Seto Marine Biological Laboratory, Kyoto University)
Ashley A. Rowden (Marine Biodiversity Group, National Institute of Water & Atmospheric Research (NIWA))
Hiroshi Kawai (Research Center for Inland Seas, Kobe University)
Hiroshi Mukai (Northern Biosphere Field Science Center, Hokkaido University)
Allan J.K. Millar (The Royal Botanical Garden Sydney)
Jeong Ha Kim (Department of Biological Science, Sungkyunkwan University)
Yoon Sik Oh (Department of Biology, Gyungsang National University)
Zaidi Che Cob (School of Environmental and Natural Resource Science, National University of Malaysia)
Asmida Ismail (School of Environmental & Natural Resource Sciences, Universiti Kebangsaan Malaysia)
Susetiono (Research Centre for Oceanology, Indonesian Institute of Sciences (LIPI))
Husni Askab (Research Centre for Oceanology, Indonesian Institute of Sciences (LIPI))
Hong ZHOU (Swire Institute of Marine Science, Department of Ecology & Biodiversity, University of Hong Kong)
Xiaorong TANG (College of Marine Life, Ocean University of Qingdao)
Dennis P. Gordon (Marine Biodiversity Group, National Institute of Water & Atmospheric Research (NIWA))

1. <u>Introduction</u>

As defined by the United Nations Environment Programme, the coastal region extends from upper tidal limits out across the continental shelf, slope, and rise (see Global Biodiversity Assessment, UNEP 1995). This definition includes rocky shores, sandy beaches, kelp forests, sub tidal benthos, and the water column over the shelf, slope, and rise. Coastal systems are generally considered to encompass the Exclusive Economic Zones of nations, a strip approximately 200 nautical miles wide.

The importance of coastal ecosystems to humanity is vital as most of the world's people live within 80 km of the coast. Coastal ecosystems provide food and other resources, transportation, waste disposal, recreation, and inspiration. Some kelp forests, inter tidal shores, and estuaries are among the most productive ecosystems in the world, and coastal fisheries are the richest in the world, with more than 75% of the world's catch coming from coastal waters. Coastal ecosystems are also among those most heavily affected by humans, and threats to biodiversity are multiple and serious; they may also be synergistic. The effects of over-exploitation and pollution are increasingly obvious and serious (e.g. depletion or loss of food species, viral and bacterial diseases of marine organisms, contamination of food organisms, toxic-algal blooms), but the full consequences of alien species introductions, habitat modification or destruction, changes in UV-B radiation, and climate change have yet to be documented. Human pressure on the marine environment has never been so intense.

1.1 <u>Importance of habitats</u>

Article 7 of the Convention on Biological Diversity calls for the identification and monitoring of biodiversity, i.e. of ecosystems and habitats, species and communities, genomes and genes. In marine, as in terrestrial and freshwater ecosystems, it is well recognized that the biotic and physical attributes of habitats have a major influence on the diversity, distribution, and survival of organisms. Changes in the nature of marine habitats can cause rapid changes in biodiversity composition, including species of commercial interest. For example, sea grass beds in estuarine and open-coast environments influence local species diversity including fish species whose juveniles use such beds as nursery areas. In the tropics, scleractinian and soft corals structure habitats three-dimensionally, locally increasing biodiversity by providing spatial niches for a wide range of invertebrates, vertebrates, and algae, in turn influencing food-web structure and increasing the complexity of biological interactions. In shallow temperate waters, large seaweeds, bryozoans, hydroids, and tubeworms play a similar role, and in deeper water, as on seamounts, tree-like black corals, gorgonians, scleractinians, and stylasterid hydrocorals are important. Alterations to natural habitats may be caused by natural processes or human activities. The latter may be direct (e.g. input of terrestrial sediments from forest clearance, pollutants, mariculture, benthic trawling, dumping of offal from fish-factory ships, introduction of alien species including disease organisms) or indirect (e.g. climate change). Changes in population abundance or density, or removal of species (especially keystone, trophically important, or habitat-structuring species), can initiate a cascade of effects that may fundamentally alter biodiversity. Destructive fishing techniques seriously affect marine communities structured by slow-growing coralline and tree-like organisms on rocky bottoms, but very few impact and monitoring studies have been carried out in such critically important subtidal habitats

1.2 Importance of monitoring

Inventory and monitoring of biodiversity are crucial for identifying or clarifying the pressures that impact on ecosystems, the rates at which those pressures are operating, present and likely states of those ecosystems, and the actions or responses needed to mitigate or stop negative pressures. The pressure-state-response model is among the more helpful models being used to guide the process of asking the right questions and formulating monitoring programmes.

Monitoring generally requires repeated sampling over time. Effective monitoring requires that sampling is replicated to detect variations over short to long time periods, and at more than one location. This means that sampling design is a very important part of devising a monitoring strategy. Studies of distribution and abundance generally sampling through time to detect patterns that could potentially change over short time-scales of days (state of tide, fluctuations in light, temperature, and atmospheric pressure), seasons, years, and decades. Sampling frequency must therefore coincide with whatever variable is being measured. For example, if one is sampling every month, additional sampling should be done within months to demonstrate that variation within a day, between days, and between weeks is less than the variation one is finding among months, seasons, and years; and ideally this procedure should be done at more than one location.

1.3 Baseline studies

Baseline studies refer to data that are collected to define the present state of a habitat, population, or biodiversity in general, in relation to physical parameters and anticipated impacts. Before conducting a baseline study it is important to ask some initial questions. What is being measured? What changes could be anticipated and why? What spatial and temporal scales are appropriate?

One-off baseline studies are generally of limited value if they are not replicated in time and space. They have very little predictive power.

Baseline data usually include:

1. The presence and/or abundance of species or other units;
2. Other dependent data (e.g. size and distribution of rock pools, boulders, caves, canopy species, and other features of habitats affecting marine occurrences).
3. Appropriate influential abiotic variables (see below).
4. Human variables.

As the goals and scales of inventorying and monitoring programmes may change with time the baseline data collected should be sufficiently robust to accommodate such changes. Provided the data represent a robust sample of the system under study, baseline data can calibrate methods of Rapid Biodiversity Assessment (see below).

2. Goals for Monitoring Coastal Ecosystems

For the purposes of IBOY, we suggest monitoring three codependent gradients in the coastal zone throughout the DIWPA region to a depth of 10 m (15 and 20 m are optional). These are latitudinal and related gradients or clines; gradients induced by human impacts; and temporal gradients (long-term monitoring).

2.1 Latitudinal and related gradients

Gradients of distribution of organisms have been identified in the sea. The details of some of these gradients are still being clarified, however, as they are not all necessarily straightforward. For example, in the northern hemisphere there is a said to be a latitudinal increase in the numbers of species from the Arctic to the tropics. This is not the case in the southern hemisphere, however, where some of the highest diversities for soft-sediment biota have been found at 38 ° S off the Victorian coast of Australia, and Antarctica has high diversities for many taxa.

It is also still not clear how diversity changes in soft sediments from the continental shelf into the deep sea, as there are relatively few data for many groups of organisms and the deep sea is badly under-sampled. One of the best-known diversity patterns is that of regional-scale decreases in coral genera from the Malaysian archipelago eastwards across the Pacific Ocean and westwards across the Indian Ocean, with the lowest diversity in the Caribbean. Similar patterns have been found for mangroves and gastropod snails. On a smaller scale, some South Pacific islands have an E–W rainfall gradient that may be expected to have local effects in lagoonal and littoral environments.

Inventory and monitoring of biodiversity in the coastal environment (as defined above) are necessary to clarify the details of such gradients and how they may shift as a consequence of natural and anthropogenic perturbations.

2.2 Long-term monitoring

DIWPA monitoring sites have the potential to become Long-Term Ecological Research (LTER) sites

3. Site Selection

3.1 Regional level

Within the DIWPA region, from the Russian sub-Arctic through the tropics to New Zealand's sub Antarctic islands, there is a huge range of coastal marine ecosystems and habitats. As a preliminary to selecting biodiversity monitoring sites in the DIWPA region, those countries that have not yet devised coastal classification schemes would benefit from doing so. Various schemes have been devised, including one for the marine realm globally. That is a hierarchical scheme that begins "coarse-grained" (zoogeographic realm): then proceeds through "medium-grained" (the finest level possible at a regional scale) to "fine-grained" (national and provincial scale), at which point it becomes a genetic classification, subdividing coastal environments, offshore environments, pelagic environments, coast-associated habitats, living reefs, and critical habitats into finer categories (see appendix). Use of a consistent classification scheme, like that above, throughout the DIWPA region would more easily allow selection and subsequent monitoring of comparable sites (e.g. shallow sub tidal kelp beds in Japan with those in New Zealand; hermatypic coral reefs in the northern Ryukyu Islands with those in the southern Great Barrier Reef).

In reality, coastal ecosystems represent the margins of larger ecosystems, varying considerably depending on atmospheric, oceanographic, geological, and historical factors. Accordingly, forty nine Large Marine Ecosystems have been delineated globally, representing regions of ocean space from deltas and estuaries to the seaward boundaries of continental shelves and coastal current systems. They are regions characterised by distinct bathymetry, hydrography, productivity, and tropically linked populations. Those in the

DIWPA region comprise: West Bering Sea, Sea of Okhotsk, Oyashio Current, Sea of Japan, Kuroshio Current, Yellow Sea, East China Sea, South China Sea, Sulu-Celebes Seas, Indonesian Seas, Northern Australian Shelf, Great Barrier Reef, New Zealand Shelf, and Insular Pacific.

A similar concept is that of the Global 200, the world's most outstanding ecoregions (233 identified) organized biogeographically by habitat type within terrestrial, freshwater, and marine realms (Olson & Dinerstein 1998). Of these, 18 are located within the DIWPA region. Ideally, it would be desirable to locate biodiversity monitoring sites in each of the Large Marine Ecosystems / Global 200 Ecoregions in the overall DIWPA region. As Brunckhorst and Bridgewater (1994) have pointed out, bioregions should be the ultimate management units for sustainable societies, affecting consequent planning and management purposes, in which ecologically sustainable use becomes the management paradigm.

More practically, in order to compare biodiversity on a global scale, in the IBOY study at least three study sites are required in each 20° bin along the proposed latitudinal transect between 50°N and 50°S.

3.2 Local selection criteria

A two-tiered approach to biodiversity monitoring is recommended, utilizing core and satellite sites. Intensive baseline studies and monitoring will be carried out at core sites using all standard methodologies; at satellite sites, only some methodologies need be employed or data collected. Core and satellite sites may be selected on the basis of the following criteria.

A. Infrastructure. Long-term monitoring (over years to decades) is most easily accomplished in proximity to a research facility (e.g. a marine laboratory) where there is also likely to be accommodation and ongoing research programmes. Automatic 24-h monitoring of physical data is possible when remote instrumentation is connected directly to a computer in a laboratory. [See section 5 on methodology.] A major benefit of locating monitoring sites near a research facility is that routine measurements of biodiversity and physical variables can often be carried out relatively cheaply using student labor or other on-site/near-site human resources. It also means that a commitment to long-term monitoring is more easily achievable. Marine station networks may facilitate planning and coordination of research effort.

B. Baseline information. For a variety of historical, geographic, resource, and other reasons, some areas of coastline are better known biologically and physically than others. The existence of historical data allows closer comparisons between former and current states, and may help in the process of site selection when potential monitoring sites are otherwise closely similar. In addition such information would be useful for future compilation of biological information.

C. Reasonably natural environment (pristiness according to MARS definition). A goal of the regional monitoring programme is within-region comparisons of biodiversity and biotic change. For this reason, it is desirable that monitoring should be carried out in areas that are as natural as possible. It would be advantageous to locate monitoring programmes within marine protected areas (MPAs), for example. There are a variety of marine reserves and usages throughout the DIWPA region, ranging from controlled exploitation of certain species (usually line-fishing of reef fish) to completely no-take. The latter type of MPA is not common but could be ideal for monitoring activities provided other criteria are satisfied.

D. Long-term stability of the site. It needs to be ascertained if a proposed monitoring site is likely to remain the same during the monitoring period. Thus it may be necessary to determine if coastal development or modification of an adjacent catchment is intended. It is important to eliminate human-caused variables as far as possible.

E. Accessibility. Sites that are more natural in biological character, i.e. containing ecosystems or habitats that are unmodified or scarcely modified by human activities, are frequently the most remote and difficult of access. Some coasts are also subject to greater wave exposure and are less able to be regularly sampled. Deeper-water habitats are expensive to sample and monitor, and successful occupation of the same station for extended periods or over the long term is dependent on sea-surface state.

F. Biological character. Pre-selection criteria can include known biodiversity values; is the candidate site biodiversity-rich, is it representative of a wider biotic ecosystem or realm, is there a significant number of rare species, etc.? It is also important that the target habitats i.e. 'homogenous' macroalgae-hard and/or sea grass-soft substratum habitats with a shoreline extent of 20-200m should be available in the site.

3.3 Application of selection criteria

Potential biodiversity monitoring sites can be rated according to each criterion (excellent, reasonable, poor, no data) and ranked according to their scores.

3.4 Potential availability of no-fishing/no-take areas for stability of long-term monitoring

It is mentioned under 3.3, above, that monitoring is could effectively be carried out in protected areas. Ideally, these should be completely no-take marine reserves in which no kind of extraction of organisms takes place. Such reserves are unfortunately rare anywhere in the world but should be established as a matter of principle. In the event, in most maritime countries there are already many areas of seafloor that are declared no-fishing and/or no-entry areas for sectoral reasons — because of their restricted nature these areas constitute de facto reserves (e.g. military areas and cultural sites). All of these constitute areas where potential undisturbed monitoring could take place under appropriate circumstances.

3.5 Marine BioRap — Identifying biodiversity priority areas

Marine BioRap is a methodology and set of analytical tools developed in Australia for identifying and assessing, in less than 18 months, priority areas of marine biodiversity. It is a decision support tool that can help planning and decision-making by identifying priority areas from local to ocean-basin scales. BioRap also uses biodiversity itself (or surrogates of biodiversity) to identify priority areas, while taking into consideration other factors, and precedes using iterative approaches. BioRap is an approach that can be used in selecting from among candidate monitoring sites when there are number of similar sites to choose from.

4. Sampling Protocol

4.1 Sampling strategy

At each study site a stratified random sampling strategy will be employed, with strata representing vertical heights above and below low water datum. That is for each study habitat, five random replicate samples are to be taken at high, mid and low intertidal positions and 1, 5 and 10m subtidal water depths (15 and 20m depth strata are optional). The most expedient randomization procedure should be adopted. The sampling programme at each study site should take place at least once a year, during the period of expected highest diversity, and commence by the end of 2002.

4.2 Sampling methodology

The sampling methodology hereafter described is a minimal requirement to be done at each site for IBOY activity. Ideally, there are a lot of factors to be measured or subjects to be studied. All these are described later as a recommendation.

At each random replicate sample location both non-destructive and destructive sampling will be undertaken according to the following protocol: -

In-situ observation (non-destructive)

A photographic image record (digital or film) should be made immediately prior to sampling. If conditions do not permit such a photographic record to be made (e.g. poor visibility) then a hand-drawn map should be constructed as an alternative. All macrophytes and conspicuous macrofauna (>2cm length) within a quadrat sample will be identified in-situ, and either counted or an estimate

of % cover made using a standard technique. For macroalgae-hard substrate habitats a 1x1m quadrat will be utilized, whilst for seagrass-soft substrate habitats a 50x50cm quadrat will be sampled. Counts will be made of solitary fauna, erect colonial organisms and seagrass plants. Percent cover estimates (using a standard technique) will be made for canopy and understorey macroalgae, and encrusting colonial organisms.

Direct removal (destructive)

A photographic image record (digital or film) should be made immediately prior to sampling. All macrophytes and fauna within a quadrat or core sample will be carefully and completely removed. For macroalgae-hard substrate habitats a 25x25cm quadrat will be sampled, whilst for seagrass-soft substrate habitats a 15cm diameter cylindrical core (to 10cm substrate depth) will be utilized. Both quadrat and core shall have a 63 cm mesh bag attached, into which macrophytes and fauna should be collected without significant loss of material. Hand scrapers will be used in macroalgae-hard substrate habitats in order to facilitate removal of attached organisms.

In the first year of sampling, the 25x25cm quadrat utilized for directly sampling the macroalgae-hard substrate shall form a sub-sample (always the same position within the larger sample) of a 50x50cm quadrat, from which only macroalgae shall be completely removed. This latter sample is taken in order to ensure sufficient algal reference material to support the in-situ observation.

The surface and bottom seawater temperature should be measured at each sample location. In addition, the substratum should be visually classified according to the standard Wentworth convention for the description of sediments.

Resulting samples should be sieved on nested meshes of 1mm and 63 microns. Macrophytes remaining on the 1mm sieve should be carefully washed (and if necessary scraped) over the mesh to remove associated macrofauna. Both the floral and faunal component of the 1mm sample are to be retained, but should be stored separately. The material retained on the 63 μm sieve will largely comprise of meiofauna. All three portions of the sample should be separately fixed and preserved using 5% neutralized* seawater formalin (2% formaldehyde).
*concentrated formalin (=35% formaldehyde) saturated with borax (sodium hexaborate)

4.4 <u>Recommendations</u>
The above protocol constitutes the minimum standardized sampling requirement for the proposed biodiversity determination, comparison and monitoring study. The following recommendations represent actions which are considered useful optional additions to the programme: (1) Sampling to take place more than once a year, e.g. during potentially separate periods of highest diversity for macrophytes and associated fauna. (2) Sampling of additional habitats that occur at study site, e.g. mangrove, coral reef, unvegetated sediment. (3) Creation of a macrophyte and macrofauna reference collection for the study site (4) Taking of additional samples for future molecular studies (fixed and preserved in 100% ethanol). (5) Compilation of a site species inventory from existing information. (6) Construction of site history, e.g. adjacent terrestrial land ‘use’, potential anthropogenic impacts.

5. Subjects To be Studied and Monitored
A regional approach to monitoring coastal biodiversity invites the question, What aspects of biodiversity may be monitored that can be compared throughout the region? Four subjects are recommended here for study and monitoring at core sites
(a) species inventory of selected taxonomic groups
(b) abiotic and biotic parameters
(c) habitat mapping
(d) all-biota taxonomic inventory.

The minimal requirements for sampling mentioned above will provide samples that fulfill most subjects mentioned below. However, it is not possible to carry out all subjects listed below, for each participating sampling site due to lack of funds, facilities and human resources. Strategies to overcome these problems will be discussed later.

5.1 <u>Species inventory of selected taxonomic groups</u>
Major taxa to be studied may be selected by a variety of criteria including representation throughout the DIWPA region, ease of identification by non-experts, commonness, ecological role (keystone species, habitat-structuring, trophic importance), use as an environmental indicator, etc. Selected species from the following groups are recommended:
(a) macroalgae
(b) seagrasses
(c) mollusks
(d) decapod crustaceans
(e) echinoderms
(f) fish
(g) cnidarian corals.

Depending on locality and geographic area, optional taxa can include selected species of:
(a) sponges
(b) other macro-invertebrates (large bryozoans, hydroids, ascidians)
(c) marine reptiles
(d) sea birds
(e) marine mammals.

5.2 Abiotic and biotic parameters

Easily measurable physical and biological parameters influencing or associated with coastal biodiversity include the following:
(a) temperature
(b) salinity
(c) water chemistry (C, H, N, O, nutrients, etc.)
(d) pH
(e) suspended sediments
(f) currents
(g) light
(h) chlorophyll a.

Although the sampling protocol requested to measure only temperature, it is recommended that the parameters listed above will be measured at the sea surface down to 20 m depth. To ensure data quality and to facilitate regional comparisons, continuous observation by multiple-sensor data-loggers is most desirable. Standardized methodology may be possible by mass production of sensing apparatus

5.3 Habitat and biodiversity mapping

As mentioned in the sampling section, it is necessary to find a homogeneous macroalgae-hard and/or seagrass soft substratum habitat in each site. Information obtained from habitat mapping will provide data necessary for selecting sampling place at each site.
Mapping can be a two-tiered exercise. At one level, entire coastlines can be mapped biologically, based on a variety of data sources, though it is not mandatory for each participating site. If such maps already exist, as they do for parts of some DIWPA countries, again they can facilitate the selection of biodiversity monitoring sites. At a finer level, detailed maps may exist for some marine protected areas, and should be carried out in areas selected for monitoring. If maps of coastlines do not already exist, then the production of habitat maps at monitoring sites can contribute to the downstream production of larger-scale coastal maps.
Coastal-zone maps may already exist for mangroves and coral reefs at a variety of scales. Maps can also depict the distribution of macroalgae, subtidal biogenic structures (e.g. bryozoan mounds, tubeworm reefs, sponge beds), shellfish beds, seagrasses, seabird and turtle nesting sites, and hauling grounds for pinnipeds. Use of GIS can overlay and correlate associated sediment, hydrographic, and other data obtained from on-site and remote (aerial and satellite photography, sonograph) measurements

5.4 Species inventory and sampling

Coddington et al. (1991) have provided strategies for species inventories. These include —

- Use proven collecting methods for different taxonomic groups in order to standardize techniques with previous and future workers.
- Keep the number of collecting methods for each group to the minimum necessary, but maximize the independence among methods.
- Use general protocols that work in plot-based or plotless sampling.
- Keep the sampling unit general, simple, and comparable: time spent sampling is perhaps the best unit of measure. Sample unit should be small enough to permit among-sample comparisons.
- Large samples should be reassembled from smaller replicate samples.
- Data collected should permit variation to be estimated and analyzed, especially with respect to site, season, sampling method, etc.
- Samples of species and individuals per species should be sufficient to construct species abundance distributions that can be used to estimate species diversity.

Since quantitative sampling tends to under-record rare taxa, sampling should aim to reliably reproduce the population characteristics as distinct from sampling-error effects.

- Voucher specimens of each species must be conserved to ensure taxonomic consistency and accuracy of identification.

More detailed information can be found in Global Biodiversity Assessment (Heywood 1995: p. 478).

The sampling protocol described in section 4 was designed to fulfill all these criteria.

5.5 All-biota taxonomic inventory

Where appropriate, some core monitoring sites throughout the region in similar habitats should be chosen for all-biota taxonomic inventory (ABTI). These could be considered as core sites for long-term monitoring beyond the immediate scope of the IBOY project.

Impediments to an ABTI include the availability of systematic expertise in the short and long term and funds for capacity building. It is recommended that, where possible, the same taxonomic experts be available for shared comparative inventory across the DIWPA region. The availability of expertise will determine whether an inventory of target taxa will be intensive or whether some form of rapid assessment will be used. The latter approach can be effective if it allows for repeatability in the discrimination of recognizable but unnamed taxa (so-called RTUs).

6. Strategies for future activities

6.1 Sampling kit

To ensure the highest degree of standardization practicably possible it is desirable to seek central funding for the provision of sieves and digital camera equipment (part of minimal sampling kit).

6.2 Future activities

In the near future, it is proposed that a database containing contact addresses/emails of the study participants and the details of all selected study sites will be constructed. Study site details (e.g. precise latitude/longitude, habitat characteristics etc) have been solicited by questionnaire. Information pertaining to the study - its aim, sampling protocol, map of study sites, list of participants etc - will be posted on a soon to be developed DIWPA webpage (with support from CoML). It is essential that all study participants communicate their sampling schedule directly by means of the group email list and via the webpage.

In order to analyze the initial results of the study (data for macrophytes and conspicuous macrofauna), a workshop will be organized for all participants at the end of 2002 or the beginning of 2003. Currently there is no precise agreement as to the mechanism by which the samples of fauna (macrofauna and meiofauna) not examined in-situ will be identified, and the results compiled and analyzed. However, one possibility is to assemble a team of 'itinerant' post-doctoral researchers who can be collectively responsible for ensuring that the biodiversity assessment of each study site is completed.

It is envisaged that collaboration will be established and maintained with related projects within programmes such as BIOMARE.

7. BIBLIOGRAPHY

Brunckhorst, D.J.; Bridgewater, P.B. 1994: A novel approach to identify and select core reserve areas, and to apply UNESCO Biosphere Reserve principles to the coastal marine realm. Pp. 12–17 in Brunckhorst, D.J. (ed.) Marine protected areas and biosphere reserves: ‘Towards a new paradigm’. Australian Nature Conservation Agency, Canberra. vi + 98 p.

Kingsford, M.; Battershill, C. 1998: Studying temperate marine environments □ A handbook for ecologists. Canterbury University Press, Christchurch. 335 p.

Jeffrey, S.W.; Mantoura, R.F.C.; Wright, S.W. 1997: Phytoplankton pigments in oceanography: guidelines to modern methods. Monographs on Oceanographic Methodology 10: 1–661.

NOAA, 1997: Remote sensing for coastal resource managers: An overview. U.S. Department of Commerce, Washington, D.C. 77 p.

Olson, D.M.; Dinerstein, E. 1998: The Global 200: A representation approach to conserving the Earth’s most biological valuable ecoregions. Conservation Biology 12: 502–515.

Ormond, R.F.G.; Gage, J.D.; Angel, M.V. (eds) 1997: Marine biodiversity □ patterns and processes. Cambridge University Press, Cambridge.

Phillips, R.C.; McRoy, C.P. (Eds) 1990: Seagrass research methods. Monographs on Oceanographic Methodology 9:

Ray, G.C. 1977: A preliminary classification of coastal and marine environments. Pp. 123–137 in Tamura, T. et al. (ed. comm.) Collected abstracts and papers on the International Conference on Marine Parks and Reserves, Tokyo, Japan, 12–14 May 1975. Bulletin of the Marine Park Research Stations 1: 1–328.

Ray, G.C. 1988: Ecological diversity in coastal zones and oceans. Pp. 36–50 in Wilson, E.O.; Peter, F.M. (eds) Biodiversity. National Academy Press, Washington, D.C.

Sherman, K.; Alexander, L.M. (eds) 1986: Variability and management of Large Marine Ecosystems. AAAS Selected Symposium 99. Westview Press, Boulder.

Sherman, K.; Alexander, L.M.; Gold, B.D. (eds) 1990: Large Marine Ecosystems: Patterns, processes and yields. AAAS Press, Washington, D.C.

Snedaker, S.C.; Snedaker, J.G. 1984: The mangrove ecosystem : research methods. Monographs on Oceanographic Methodology 8: 1–251.

Sournia, A. (Ed.) 1978: Phytoplankton manual. Monographs on Oceanographic Methodology 6: xvi, 1–337.

Stoddart, D.R.; Johannes, R.E. 1978: Coral reefs : research methods. Monographs on Oceanographic Methodology 5: 1–581.

Tranter, D.J.; Fraser, J.H. (Eds) 1968: Zooplankton sampling. Monographs on Oceanographic Methodology 2: 1–174.

UNESCO 1984: Comparing coral reef survey methods. UNESCO Reports on Marine Science 21: 1–170.

Von Alt, C.; DeLuca, S.M.; Glenn, J.F.; Grassle, J.F.; Haidvogel, D.B. 1997: LEO-15: monitoring and managing coastal resources. Sea Technology 38: 10–16.

Ward, T.J.; Kenchington, R.A.; Faith, D.P.; Margules, C.R. 1998: Marine BioRap guidelines: Rapid assessment of marine biological diversity. CSIRO, Perth. 52 p.

8. Appendices

8.1 Global 200 marine ecoregions occurring within the DIWPA region

Marine ecoregions:
Large deltas, mangroves, and estuaries:
Indomalayan :
185. Mekong River Delta mangroves □Vietnam, Cambodia
187. Sundaland and eastern Indonesian archipelago mangroves □Indonesia

Australasian :
189. New Guinea mangroves □Papua New Guinea, Indonesia

Coral reef and associated marine ecosystems:

Western Pacific Ocean :
201. Isthmus of Kra marine ecosystems □Thailand, Malaysia
202. Nansei Shoto marine ecosystems□Japan
203. Sulu Sea□Philippines, Malaysia
204. Sulawesi Sea□Philippines, Indonesia, Malaysia
205. Banda-Flores Seas marine ecosystems□Indonesia
206. Northern New Guinea and Coral Sea marine ecosystems □ Papua New Guinea, Indonesia, Solomon Islands
207. Micronesian marine ecosystems □ Palau, Federated States of Micronesia

Southern Pacific Ocean :
209. South Pacific marine ecosystems □ Vanuatu, Fiji, New Caledonia, Samoa, Tonga, Tuvalu
210. Great Barrier Reef □ Australia
212. Lord Howe Island and Norfolk Island marine ecosystems □ Australia

Coastal marine ecosystems

Western Pacific Ocean :
222. Yellow Sea and East China Sea □ China, North Korea, South Korea, Japan

Southern Pacific Ocean :
228. South temperate Australian marine ecosystems □ Australia

Polar and subpolar marine ecosystems Antarctic seas :
230. New Zealand marine ecosystems □ New Zealand

Arctic Ocean and seas :
231. Bering and Beaufort Seas □ Russia, USA, Canada
232. Sea of Okhotsk and northern Sea of Japan □ Russia, Japan

END