Asia-Pacific
Economic Cooperation

Best Practices Methodology for assessing changing conditions of Large Marine Ecosystems in the Asia-Pacific Economic Cooperation region

Final Report

Marine Resources Conservation Working Group

February 2011

Asia – Pacific Economic Cooperation
(APEC)

Best Practices Methodology for assessing changing conditions of Large Marine Ecosystems in the Asia-Pacific Economic Cooperation region

Final Report

14 February 2011

Korea Ocean Research and Development Institute (KORDI)
National Oceanic and Atmospheric Administration (NOAA), USA
Ministry of Land, Transport and Maritime Affairs (MLTM), Republic of Korea
UNDP/GEF YSLME Project
Asia Pacific Economic Cooperation (APEC) Secretariat

This report may be cited as: Best Practices Methodology for Assessing Changing Conditions of the LMEs in the Asia-Pacific Economic Cooperation Region 2011. APEC Secretariat, Singapore.

APEC Project No. MRC 01/2009

Prepared for
APEC Secretariat
35 Heng Mui Keng Terrace Singapore 119616
Tel: (65) 6891 9600 Fax: (65) 6891 9690
Email: info@apec.org Website: www.apec.org

APEC#211-MR-01.2

TABLE OF CONTENTS

1. THE APEC REGION

The Asia Pacific Economic Cooperation (APEC) Region comprises 21 Member Economies which account for 41% of the world’s population, 55% of the world’s GDP and 49% of world trade. The marine goods and services of the APEC Region contribute substantially to the annual GDP of the Member states. Marine resources of the 27 Large Marine Ecosystems in the APEC region (**Figure 1**) are in a downward economic spiral from overfishing, pollution, habitat degradation, nutrient over-enrichment, climate warming and loss of biodiversity. In recognition of the need to reverse the downward trend, the APEC Marine Resource Conservation Working Group organized its first scientific workshop on the assessment and management of APEC Large Marine Ecosystems (LMEs) in Qingdao, China in 2007. Co-chaired by the People’s Republic of China and the United States, the workshop began the process of describing the Large Marine Ecosystems of the Asia-Pacific Region. The 21 economies, represented by the LMEs are: Australia, Brunei Darussalam, Canada, Chile, People's Republic of China, Hong Kong (China), Indonesia, Japan, Republic of Korea, Malaysia, Mexico, New Zealand, Papua New Guinea, Peru, Philippines, Russia, Singapore, Chinese Taipei, Thailand, United States, and Viet Nam. These economies make a major annual contribution to the global economy of $12.6 trillion in marine ecosystem goods and services (Costanza, d'Arge et al. 1997), including fisheries, transport, mining, energy production and tourism activities.

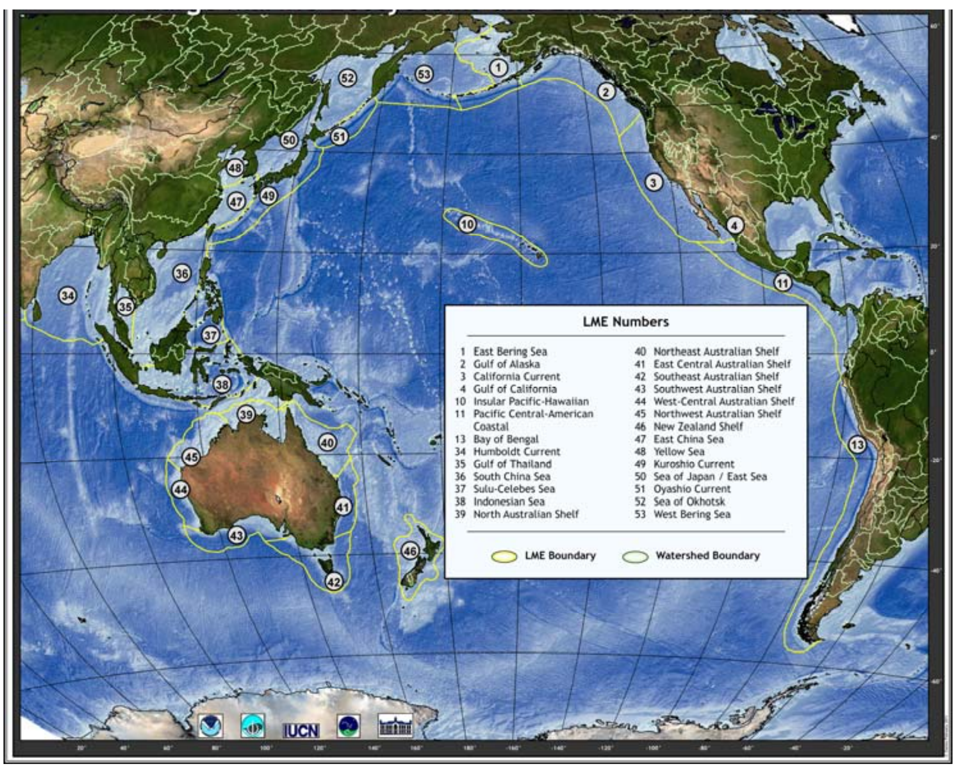


Figure 1. Map of the APEC Region: 27 Large Marine Ecosystems and Linked Watersheds. Phase 1 of the APEC LME Project produced this LME map. Included are the Bay of Bengal LME and all LMEs adjacent to Australia.

The APEC LME Project developed science-based criteria to be used in identifying suites of indicators to monitor and assess change in LMEs. Phase 2 of the APEC LME Project continued the assessment of LME goods and services in the 27 LMEs of the APEC Region, with a particular focus on the economic benefits of a sustainable marine resource base, and on the legal and administrative support needed for ecosystem-based management practices.

2. THE LARGE MARINE ECOSYSTEM ASSESSMENT AND MANAGEMENT APPROACH

The LMEs are natural regions of coastal ocean space encompassing waters from river basins and estuaries to the seaward boundaries of continental shelves and the seaward margins of coastal currents and water masses. They are relatively large regions characterized by distinct bathymetry, hydrography, productivity, and trophically-dependent populations (Sherman 1994; Duda and Sherman 2002). The LME approach to the assessment and management of ocean goods and services is broad and place-based, focused on clearly delineated ecosystem units. It is within the boundaries of the World's 64 Large Marine Ecosystems (**Figure 2**) that 80% of mean annual marine fisheries yields is produced, overfishing is most severe, marine pollution is most concentrated, and eutrophication and anoxia are causing dead zones.

Figure 2. Map of the 64 Large Marine Ecosystems of the world and their linked watersheds (Sherman, Celone et al. 2004).

3. THE FIVE-MODULE LME METHODOLOGY

The LME approach combines the application of five modular suites of indicators into an adaptive system for ecosystem-based management. The five module LME approach has developed indicators of (i) productivity, (ii) fish and fisheries, (iii) pollution and ecosystem health, (iv) socioeconomics, and (v) governance to assess ecosystem-wide changes (**Figure 3**).

The five-module indicator approach to assessment and management of LMEs has proven useful in ecosystem-based projects in the USA and elsewhere in the world. The suites of LME indicators are used to measure the changing states and condition of LMEs, in support of adaptive management actions. The effort to better understand climate variability, to improve the long-term sustainability of marine goods and services, and to move in the direction of ecosystem-based ocean management applies to all 64 LMEs and linked watersheds. For example, climate warming of 1° in the North Sea LME can result in a reduction in primary productivity leading to a decline in fisheries biomass yields (Sherman, Belkin et al. 2009).

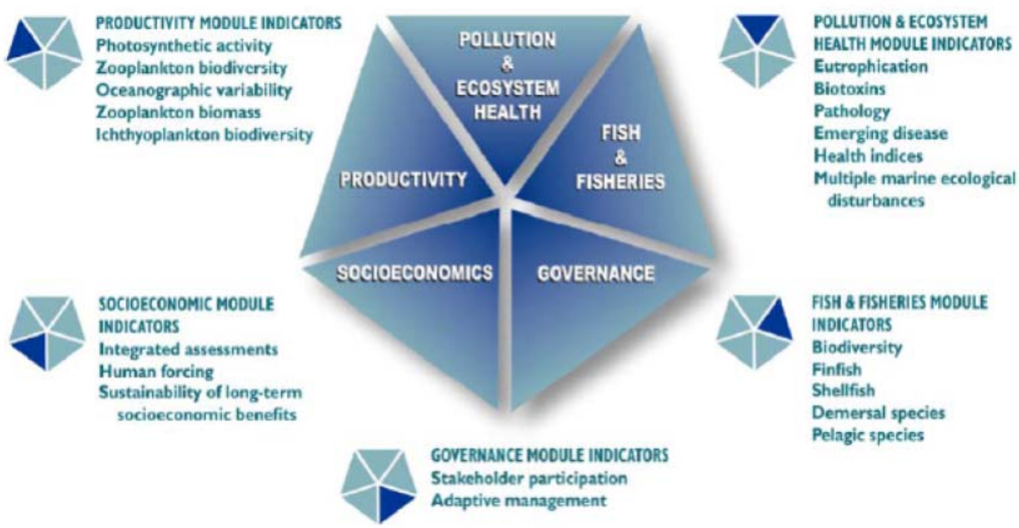


Figure 3. The five LME modules and examples of ecosystem indicators (Sherman 2005).

Taken together, the 5 modules provide indicators and metrics used to determine the changing states of LMEs and support actions for the recovery, sustainability, and management of marine ecosystem goods and services. The approach is part of an emerging effort to relate the scale of place-based ecosystem research and assessment to an improved ecosystem-based management of ocean resources within the natural boundaries of LMEs. Fourteen LME volumes have been published since 1986 (Sherman and Adams 2010). The 2008 UNEP LME Report provides synopses of ecological conditions for each of the world's 64 LMEs, based on the five module assessment framework of (i) productivity, (ii) fish and fisheries, (iii) pollution and ecosystem health, (iv) socioeconomics, and (v) governance. The publications lists and LME briefs are available at the LME website at: www.lme.noaa.gov.

Since 1995, the Global Environment Facility (GEF) has provided substantial funding, presently at a level of over $3.1 billion, to support country-driven projects for introducing multi-sectoral ecosystem-based assessment and management practices for the recovery and sustainability of LME goods and services located around the margins of the oceans.

4. BEST PRACTICES METHODOLOGY: INDICATORS OF CHANGING CONDITIONS OF LARGE MARINE ECOSYSTEMS OF THE APEC REGION, APPLICATIONS OF THE FIVE-MODULE LME

4.1 The Productivity Module

Primary productivity supporting marine populations in LMEs is higher than in the open ocean (**Figure 4).** At present, 110 developing countries are engaged in the preparation and implementation of 17 GEF-LME projects.

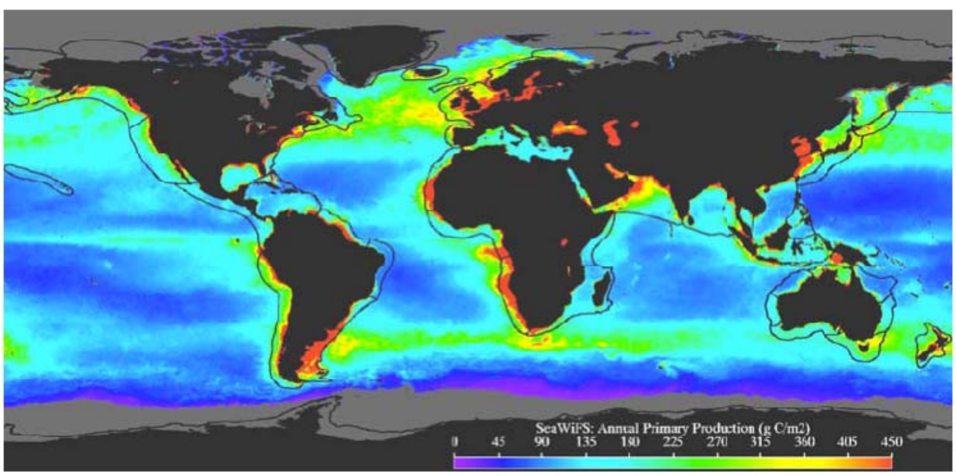


Figure 4. The Productivity Module measures the carrying capacity of an LME for supporting fish resources; and serves as a useful indicator of the growing problem of coastal eutrophication. Global map of average primary productivity and the boundaries of the 64 LMEs. The annual productivity estimates are based on SeaWiFS satellite data collected between September 1998 and August 1999, and the model developed by (Behrenfeld and Falkowski 1997). The color-enhanced image provided by Rutgers University depicts primary productivity from a high of 450 gCm^{-2} $year^{-1}$ in red to less than 45 gCm^{-2} $year^{-1}$ in purple.

Productivity indicators measure the carrying capacity of an ecosystem for supporting living marine resources (Pauly and Christensen 1995; Christensen, Walters et al. 2009). It has been reported that the maximum global level of primary productivity for supporting the average annual world fish catch has been reached, and that further large-scale, unmanaged increases in fisheries yields from marine ecosystems are likely to be at trophic levels below fish in the marine food web (Beddington 1995). The ecosystem parameters measured and used as indicators of changing conditions in the productivity module are zooplankton biodiversity and species composition, zooplankton biomass, water-column structure, photosynthetically active radiation, transparency, chlorophyll-a, nitrate, and primary production. Properly calibrated satellite data and undulating instrumented towed bodies can provide information on ecosystem conditions including physical state (i.e., surface temperature), nutrient characteristics, primary productivity, and phytoplankton species composition (Aiken, Pollard et al. 1999; Berman and Sherman 2001).

The UNEP LME Report (Sherman and Hempel 2008) contains information on the productivity of each of the world's 64 LMEs, including the 27 LMEs of the APEC Region. Available productivity Indicators of changing ecosystem states at the LME scale include primary productivity and chlorophyll trends (1998-2006), LME fronts of temperature gradients, and Sea Surface Temperatures (SST) profiles and anomalies (1957-2006 and 1982-2006).

4.1.1 Chlorophyll *a* and primary productivity, APEC region Mean annual trends (1998 – 2006) in chlorophyll *a* (mg/m^3) and primary productivity in grams of carbon per square meter per year ($gC/m^2/yr$) have been published for each of the 64 LMEs (Sherman and Hempel 2008). For example, **Figure 5** shows primary productivity indicators for the Bay of Bengal LME (Sherman and Hempel 2008). Primary productivity estimates have been derived from satellite data archived at NOAA's Northeast Fisheries Science Center, Narragansett Laboratory. These estimates originate from ocean color sensors carried by satellites including the Coastal Zone Color Scanner (CZCS) Sea-viewing Wide Field-of-view Sensor (SeaWiFS), and Moderate Resolution Imaging Spectroradiometer (MODIS-Aqua and MODISTerra). A large archive of *in situ* near surface chlorophyll data, and satellite sea surface temperature (SST) measurements made by Advanced Very High Resolution Radiometer (AVHRR) flown on NOAA satellites was used to quantify spatial and seasonal variability of near-surface chlorophyll and SSTs in all LMEs (Sherman and Hempel 2008). The data allow the classification of LMEs into 3 categories: Class I, high productivity (>300 gCm^{-2} $year^{-1}$), Class II, moderate productivity (150-300 $gCm^{-2}year^{-1}$), and Class III, low productivity (<150 gCm^{-2} $year^{-1}$). Productivity Information for all 27 LMEs of the APEC Region is available at: www.lme.noaa.gov/.

Plankton can be measured over decadal time scales by continuous plankton recorder (CPR) systems as deployed for the past 75 years by the Sir Alistair Hardy Foundation for Ocean Science (SAHFOS) from commercial vessels of opportunity (SAHFOS 2008). CPRs can be fitted with sensors for temperature and salinity, to provide additional information on ecosystem conditions.

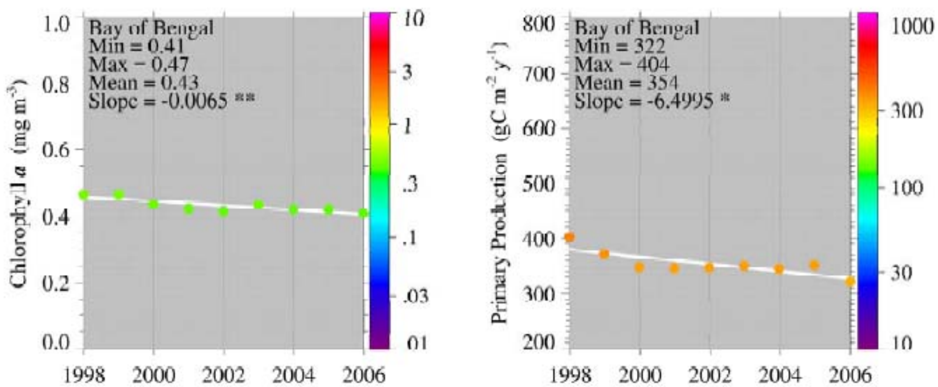


Figure 5. Chlorophyll (left) and Primary productivity (right) trends (1998-2006): Bay of Bengal (Sherman and Hempel 2008, p.239).

Within the water column in temperate waters, significant concentrations of chlorophyll can be found at subsurface depths not detectable by satellite-borne color sensors. A method for overcoming this gap is chlorophyll data collection and subsequent primary productivity estimation using the output of an undulating vehicle with the capacity to carry sensors for chlorophyll and other oceanographic measurements. A prototype undulating system has been developed for deployment in LME projects. The system is an undulating towed sampling platform developed to obtain biological and physical measurements through profiling of the upper 70 m of the water column of LMEs. The system measures a suite of biological, chemical and physical parameters with a focus on primary productivity and plankton. The Mariner Shuttle (Berman and Sherman 2001), an advanced plankton recorder, provides the means for *in situ* monitoring and calibrating satellite-derived oceanographic data (**Figure 6**).

Figure 6. The Mariner Shuttle Mk II, Instrumentation: CTD; Plankton Sampler; Fast Repetition Rate Fluorometer with a PAR sensor to study photosynthesis and primary productivity; fluorometer to measure both chlorophyll and turbidity; nitrate sensor dissolved oxygen sensor. The system is towed at up to 8 kts and can adjust the flight pattern match the bottom depth.

Southeast Asia, 4 LMEs -- the South China Sea, Sulu-Celebes Sea, Indonesian Sea, and Gulf of Thailand -- are undergoing ecological disturbances from overfishing, loss of coastal habitats (e.g. seagrasses, mangroves, coral reefs) and biodiversity, nutrient over-enrichment, increasing pollution and vulnerability to climate change. In recognition of the need to introduce ecosystem-based assessment and management actions, countries in the region have requested and been granted financial assistance from the Global Environment Facility and World Bank for implementing the five module LME approach for the recovery and sustainability of depleted fish stocks, the mitigation of nutrient over-enrichment, the conservation of biodiversity and adaptation to climate change. Trends in chlorophyll and primary productivity from 1998-2006 for the four LMEs are shown in **Figures 7 through 10**.

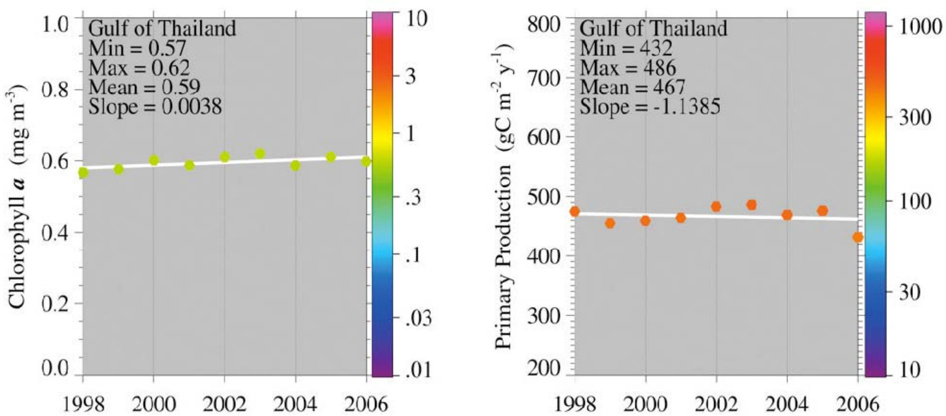


Figure 7. Trends in chlorophyll-*a* (left) and primary productivity (right), 1998-2006 for the Gulf of Thailand. Values are color coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde, NOAA, NMFS, Narragansett Laboratory.

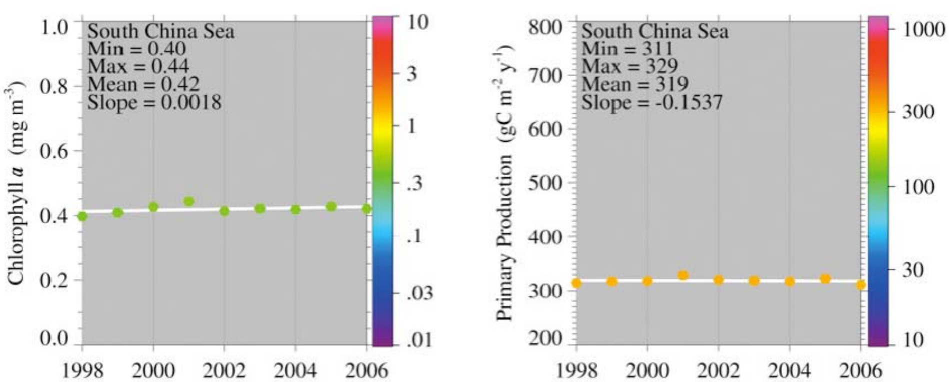


Figure 8. Trends in chlorophyll-*a* (left) and primary productivity (right), 1998-2006 for the South China Sea LME. Values are color coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde, NOAA, NMFS, Narragansett Laboratory.

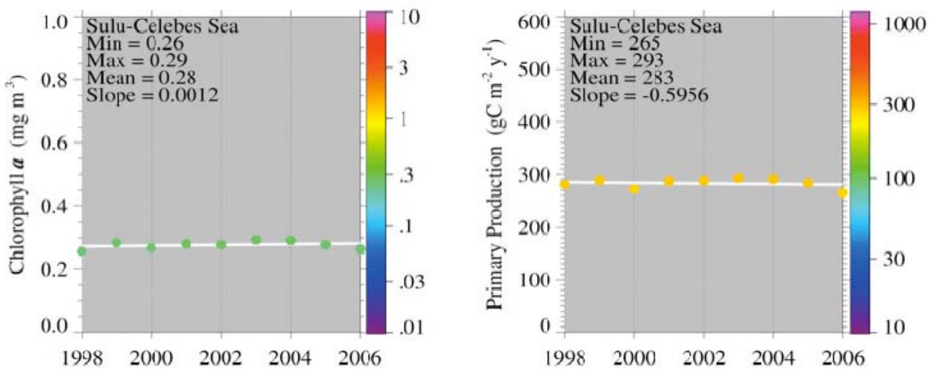


Figure 9. Trends in chlorophyll-*a* (left) and primary productivity (right) 1998-2006 for the Sulu-Celebes Sea LME. Values are color coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde, NOAA, NMFS, Narragansett Laboratory.

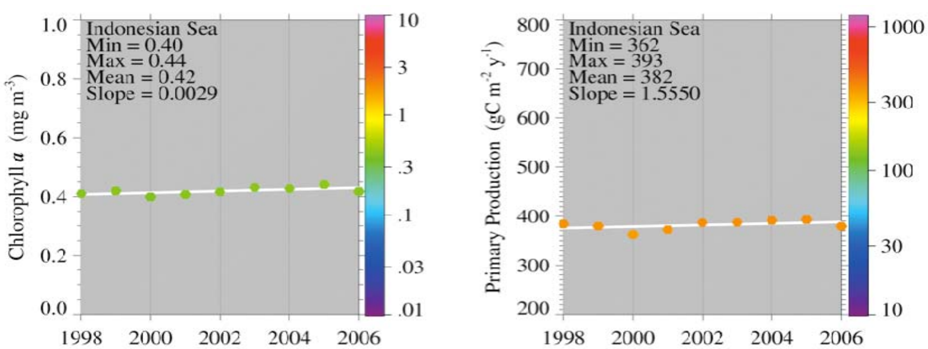


Figure 10. Trends in chlorophyll-*a* (left) and primary productivity (right) 1998-2006 for the Indonesian Sea LMEs. Values are color coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde, NOAA, NMFS, Narragansett Laboratory.

4.1.2 Oceanographic fronts, APEC region An oceanographic front is a relatively narrow zone of enhanced horizontal gradients of physical, chemical and biological properties (e.g. temperature, salinity, nutrients). Oceanic fronts affect productivity; therefore front mapping is an important aspect of LME characterization. They are important for climate change monitoring and prediction, the fishing industry, pollution control, waste disposal and hazards mitigation, marine transportation, marine mining, including the oil and gas industry, submarine navigation and integrated coastal management. Maps of LME oceanographic fronts for each of the 64 LMEs are presented in (Sherman and Hempel 2008).

The first global remote sensing survey of fronts in LMEs was based on a unique frontal data archive assembled at the University of Rhode Island. Thermal fronts were automatically derived by front detection algorithm (Cayula and Cornillon 1992; 1995; 1996) from 12 years of twice-daily global 9-km resolution SST data to produce synoptic (instant) frontal maps and compute long-term monthly

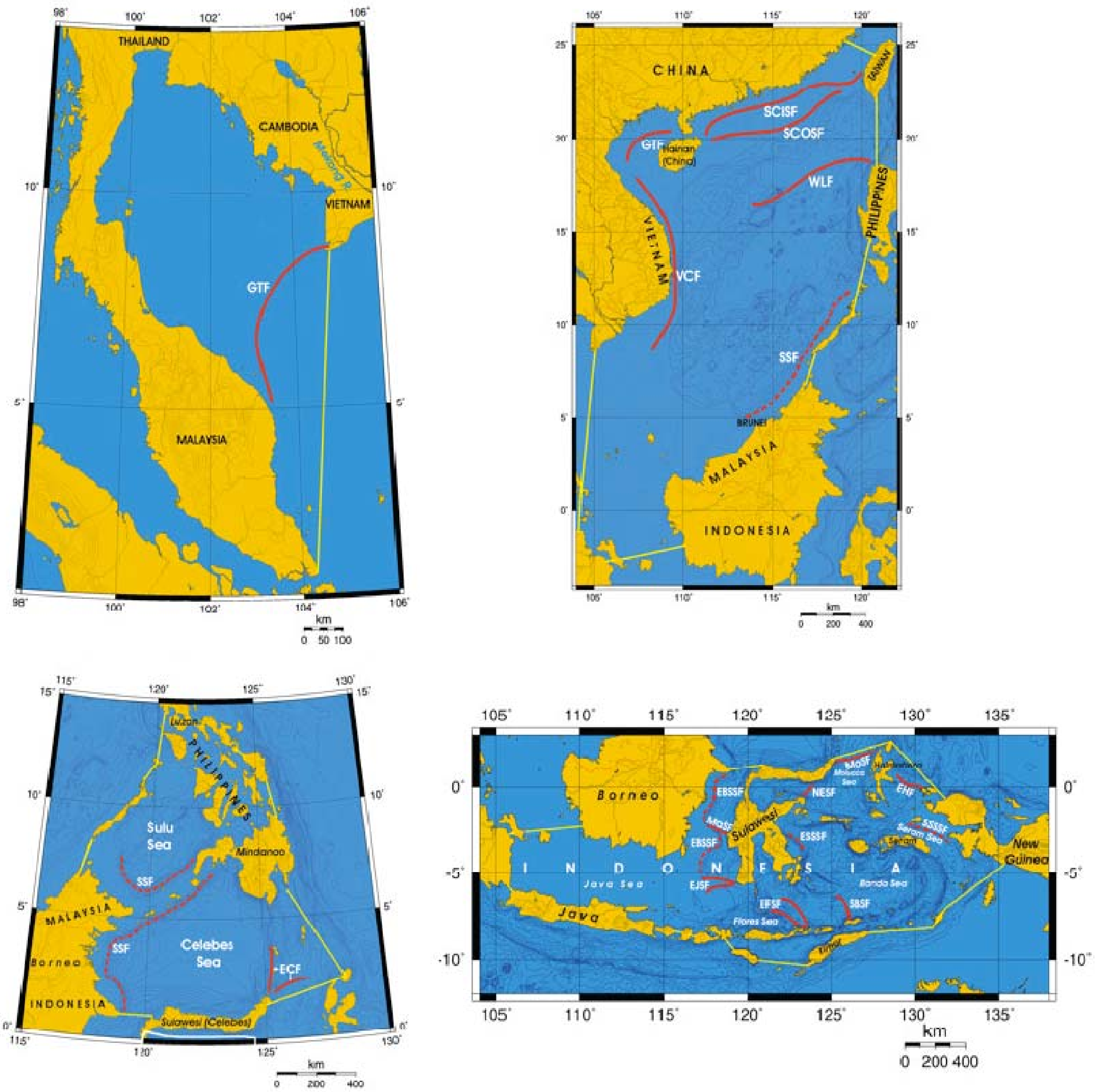


Figure 11. Fronts of the **Gulf of Thailand LME** (upper left) GTF, Gulf of Thailand Front. Yellow line, LME boundary. Fronts of the **South China Sea LME** (upper right). Gulf of Tonkin Front; SCISF, South China Inner Shelf Front; SCOSF, South China Outer Shelf Front; SSF, Shelf-Slope Front (the most probable location); VCF, Vietnam Coastal Front; WLF, West Luzon Front. Yellow line, LME boundary. Fronts of the **Sulu-Celebes Sea LME** (lower left). ECF, East Celebes fronts; SSF, Shelf-Slope Front (most probable location); Yellow line, LME boundary. Fronts of the **Indonesian Sea LME** (lower right). EBSSF, East Borneo Shelf-Slope Front; EFSF, East Flores Sea fronts; EHF, East Halmahera Front; EJSF, East Java Sea fronts; ESSSF , East Sulawesi Shelf-Slope Front; MaSF, Makassar Strait Front; MoSF, Molucca Sea Front; NESF, Northeast Sulawesi Front; SBSF, South Banda Sea Front; SSSSF, Seram Sea Shelf-Slope Front. Dashed lines show most probable locations of shelf-slope fronts. Yellow line, LME boundary. After (Belkin, Cornillon et al. 2009)

frequencies of SST fronts and their gradients. These synoptic and long-term maps were used to distinguish major quasi-stationary fronts and derive frontal schematics comprising a provisional atlas of fronts in the World Ocean LMEs (Belkin 2009; Belkin, Cornillon et al. 2009). Since SST fronts are associated with chlorophyll fronts (Belkin and O'Reilly 2009) frontal paths in these schematics, once digitized, lend themselves to studies of physical-biological correlations at fronts. Satellite-derived surface thermal fronts are typically co-located with hydrographic fronts determined from subsurface data. Front schematics for the four GEF funded LMEs in the APEC Region are provided in **Figure 11**. Measurements of ecosystem productivity can be useful indicators of the growing problem of coastal eutrophication. In several LMEs, excessive nutrient loadings of coastal waters have been related to harmful algal blooms implicated in mass mortalities of living resources, emergence of pathogens (e.g., cholera, vibrios, red tides, and paralytic shellfish toxins), and explosive growth of non-indigenous species (Epstein 1993; Epstein 2000).

4.1.3 Sea Surface Temperature, APEC region Sea Surface Temperature time series (1957 - 2006) for each LME are presented in Sherman and Hempel (2008). To establish how global warming translates into regional patterns of climate change and how these regional changes in climate affect LMEs, data from the U.K. Meteorological Office Hadley Centre SST climatology was used to compute 50-year time-series (1957-2006) of SST and examine SST trends in the World's LMEs (Belkin 2009). The U.K. Meteorological Office Hadley Center SST climatology data was selected for its superior resolution (1 degree latitude by 1 degree longitude globally), for the historic reach of the data, and for its high quality. The Hadley data set consists of monthly SSTs calculated for each 1° x 1° rectangular cell (spherical trapezoid, to be exact) between 90°N-90°S, 180°W-180°E. Annual anomalies of annual LME-averaged SSTs were calculated by computing the long-term LME-averaged SST for each LME by a simple long-term averaging of the annual area-weighted LME-averaged SSTs. Then, annual SST anomalies were calculated by subtracting the long-term mean SST from the annual SST. Both SST and SST anomalies were visualized using adjustable temperature scales for each LME in order to bring out details of temporal variability that otherwise would be hardly noticeable if a unified temperature scale were used.

Changes in ocean conditions including water temperature, ocean currents and coastal upwelling, as a result of climate change, affect primary productivity, species distribution, community and food web structure that have direct and indirect impacts on distribution and productivity of marine organisms (Cheung, Lam et al. 2009). Global warming has already significantly affected marine ecosystems e.g., (Behrenfeld, O'Malley et al. 2006; Halpern, Walbridge et al. 2008), and this impact is expected to increase in the near future owing to the current acceleration of warming (Trenberth, Jones et al. 2007). Warming of SSTs in most LMEs accelerated between 1982 and 2006. Of the 63 LMEs under study, 61 warmed and only two cooled in 1982-2006. The two cooling LMEs, the

California Current and Humboldt Current LMEs, are part of the APEC Region. Trends for each LME show a distinct global pattern of warming in three clusters—fast warming (0.67°C – 1.35°C), moderate warming (0.30°C – 0.60°C) and slow warming (0.00°C – 0.28°C) (**Figure 12**). The fast-warming LMEs are around the North Atlantic Subarctic Gyre; in the European Seas; and in the East Asian Seas (Belkin 2009; Sherman, Belkin et al. 2009). Three of the fast-warming LMEs in the area of the North Atlantic Subarctic Gyre—the Iceland Shelf, Faroe Plateau, and Norwegian Sea—responded to the accelerated warming with increasing the length of the spring plankton bloom, and the abundance of zooplankton favoring the recruitment and growth of zooplanktivorous fish species including herring, blue whiting, and capelin (Sherman, Belkin et al. 2009). The potential impact of global warming underscores the need to develop adaptation policy that could minimize climate change impacts on fisheries and marine habitats and to evaluate marine living natural resources management options under climate change.

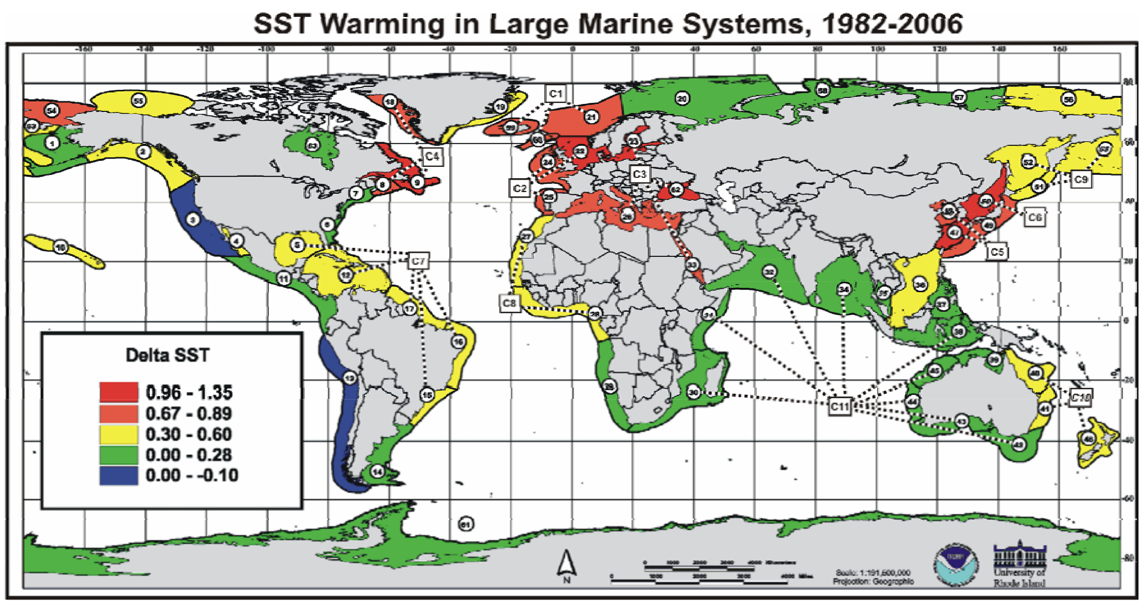


Figure 12. SST trends in the World's LMEs (1982-2006) modified after Belkin (2009). Warming Clusters of LMEs in Relation to SSTs, 1982-2006, include:.
A FAST WARMING CLUSTER (0.67°C – 1.35°C): Fast Warming East Asian LMEs, the Kuroshio Current and Sea of Japan/East Sea LMEs.
A MODERATE WARMING CLUSTER (0.30°C – 0.60°C): NW Pacific LME, SW Pacific LMEs, NE Australia, Insular Pacific Hawaiian, Gulf of Alaska, Gulf of California, and South China Sea LME.
A SLOW WARMING CLUSTER (0.00°C – 0.28°C): The LMEs of the Indian Ocean and Adjacent Waters, the East Bering Sea, the Patagonian Shelf, and the Pacific Central American Coastal LMEs.

Plots of SST and SST anomalies are available for 63 LMEs. Four examples in Southeast Asia are represented in **Figures 13** through **16** and show increasing trends of sea surface temperature (after Belkin 2009).

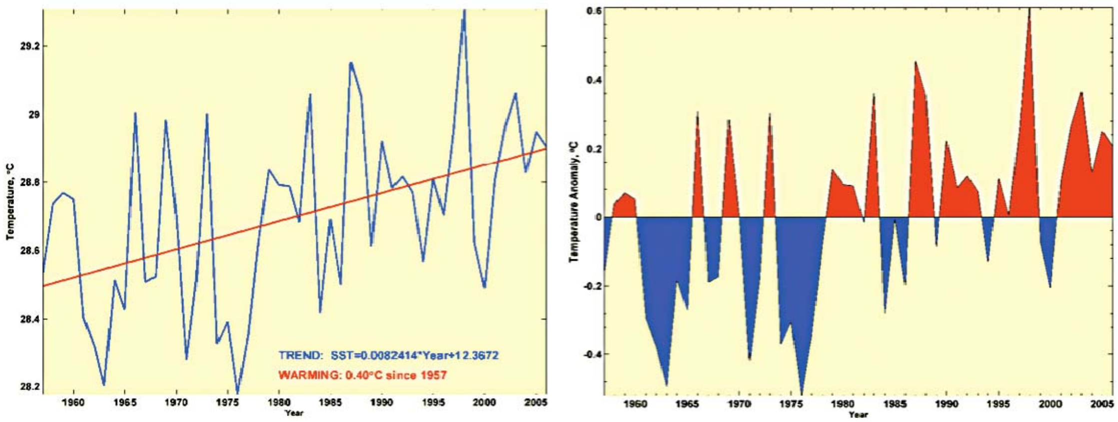


Figure 13. Annual mean Sea Surface Temperature (SST) and SST anomalies for the Gulf of Thailand LME (linear warming trend since 1957: 0.40°C), 1957-2006 based on Hadley climatology (after Belkin 2009).

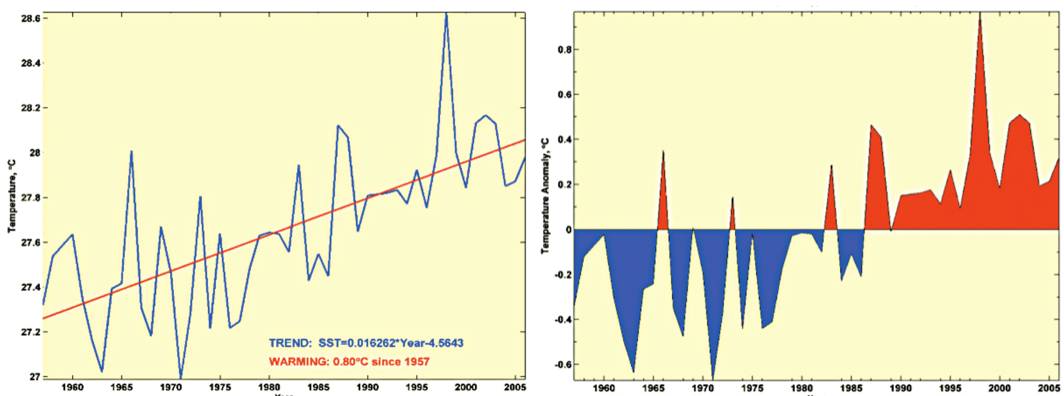


Figure 14. Annual mean Sea Surface Temperature (SST) and SST anomalies for the South China Sea LME (linear warming trend since 1957: 0.80°C). 1957-2006 based on Hadley climatology (after Belkin 2009).

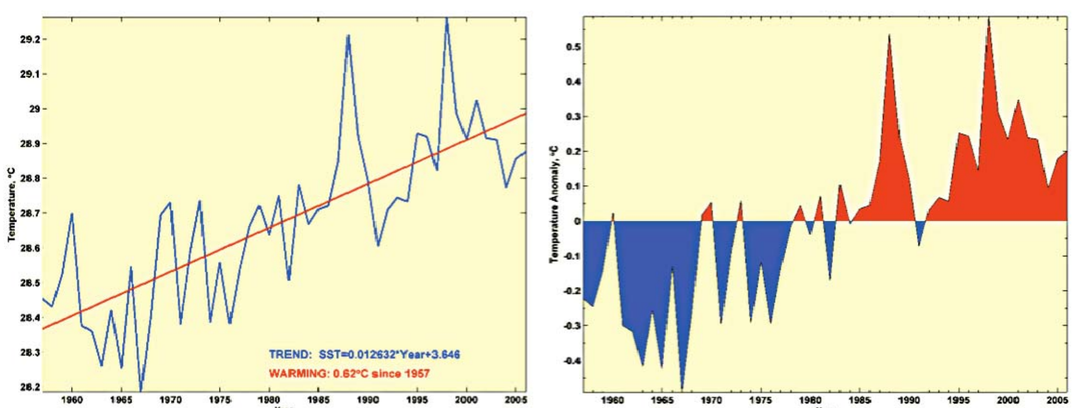


Figure 15. Annual mean Sea Surface Temperature (SST) and SST anomalies for Sulu-Celebes Sea LME (linear warming trend since 1957: 0.62°C), 1957-2006 based on Hadley climatology. (after Belkin 2009)

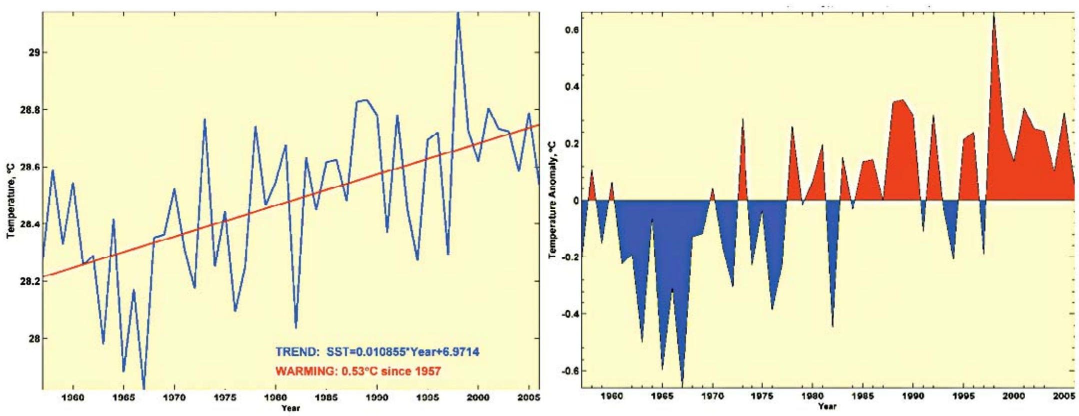


Figure 16. Annual mean Sea Surface Temperature (SST) and SST anomalies for Indonesian Seas LMEs (linear warming trend since 1957: 0.53°C), 1957-2006 based on Hadley climatology (after Belkin 2009).

4.2 The Fish and Fisheries Module

The Fish and Fisheries Module is focused on the effects of naturally occurring environmental shifts in climate regime and excessive fishing effort on species composition and abundance. LMEs produce 80% of the world's annual marine fisheries catch, providing a significant source of food, livelihoods, employment, and foreign exchange to bordering countries. Achievement of the Millennium Development Goal to eradicate hunger will be partly dependent on the capacity of marine ecosystems to supply animal protein to the populations of most developing countries (UNEP 2006). Ongoing GEF-funded LME projects in the APEC Region are supporting efforts to recover and sustain fisheries in all 27 LMEs.

4.2.1 Methodology and ecosystem Indicators: Changes in biodiversity and species dominance within fish communities of LMEs have resulted from excessive exploitation, naturally occurring environmental shifts caused by climate change, and coastal pollution. Changes in biodiversity and species dominance in a fish community can effect the food upwards in the food pyramid to apex predators, and the plankton biodiversity and abundance at the bottom of the food web. The Fish and Fisheries Module includes both fisheries-independent bottom-trawl surveys and pelagic-species acoustic surveys to obtain time-series information on changes in fish biodiversity and abundance levels (NEFSC 2002; AFSC 2006; NEFSC 2006). When employed from small calibrated trawlers, standardized sampling procedures can provide important information on changes in fish species (Sherman and Alexander 1994) . Fish catch provides biological samples for stock identification, stomach content analyses, age-growth relationships, fecundity, and coastal pollution monitoring for possible associated pathological conditions, as well as data for preparing stock assessments and for clarifying and quantifying multispecies trophic relationships. Survey vessels can also be used as platforms for obtaining water, sediment, and benthic samples. A list of indicators for the fish and fisheries module is given in **Figure 17.**

Stock assessment is the process of collecting, analyzing, and reporting demographic information for the purpose of determining the effects of fishing and natural environmental changes on fish populations. For example, stock assessments require quantitative information on the magnitude of a fish population within a Large Marine Ecosystem, and estimates of the total removals due to human activities (e.g. fishery landings, discarded by-catch, and mortality due to encounters with fishing gear). Natural causes and factors affecting stock productivity include rates of growth of fish species, average age of the onset of sexual maturity, longevity, the proportion of each age group dying each year and other population or stock demographics (NMFS 2009).

Assessment results provide the basis for setting the level of biologically acceptable yield for healthy stocks, and the expected rate of rebuilding for depleted stocks. The goal of improving fish stock assessments is to minimize the risk that fish stocks will become overfished. As assessments are improved, the types of questions posed by resource managers will increasingly emphasize multispecies aspects (e.g. biological interactions among stocks and fisheries) and argue for greater attention to ecosystem effects and shifts in carrying capacity of the LME for supporting long-term sustainable yields from the fisheries.

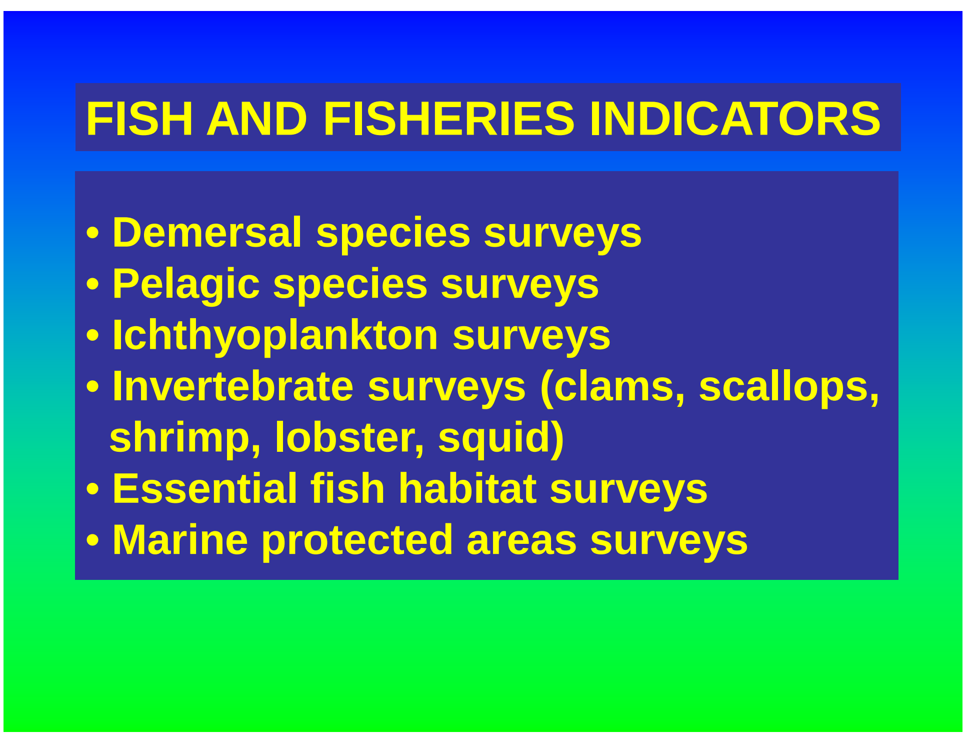


Figure 17. Indicators for the Fish and Fisheries Module.

The Northeast Fishery Science Center (NEFSC) of NOAA has the longest continuous time-series of US data and information on ecosystem changing states. It is in the US Northeast Continental Shelf Large Marine Ecosystem, extending over 260,000 km^2 from the Gulf of Maine southward to Cape Hatteras, North Carolina, where NEFSC scientists, economists, and other marine specialists have been applying ecosystem-based methods for assessing living marine resources and their environments—methods that have served as the principal prototype for the GEF-LME projects. Indicators for fish and fisheries model are based on the results of trawl surveys for demersal species and acoustic surveys for pelagic species (**Figure 18**).

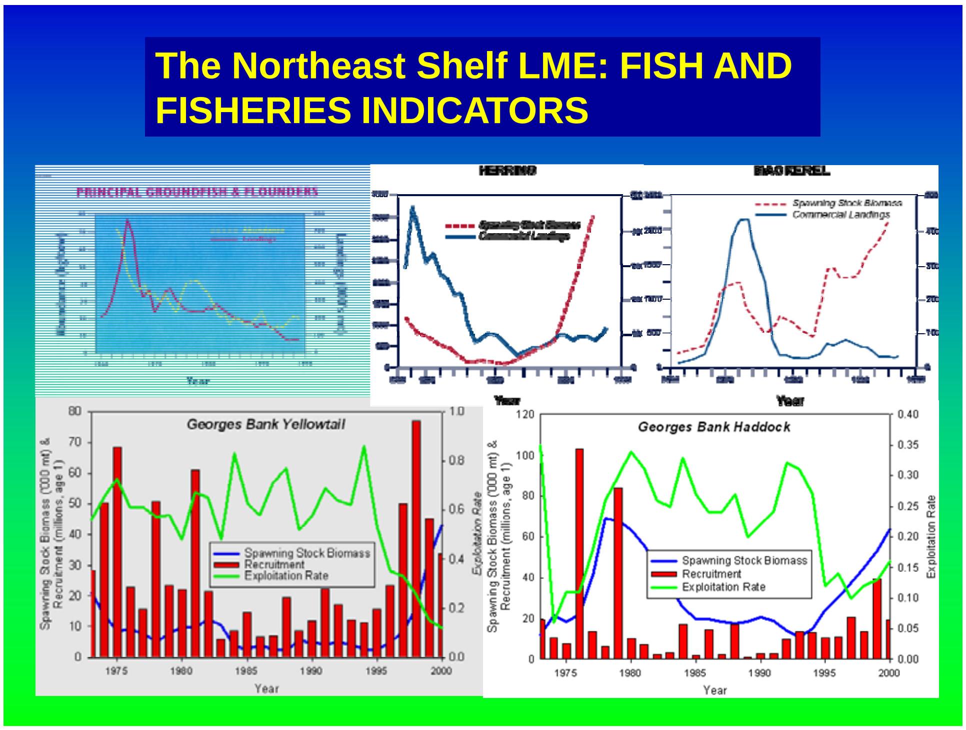


Figure 18. Fish and Fisheries indicators in the Northeast US Continental Shelf LME. The figure shows recovering trends for herring and mackerel and fluctuations in catch for flounders, Georges Bank yellowtail, and Georges Bank haddock in the Northeast US Continental Shelf LME. The recovery of certain species of fish is linked to the implementation of US legislation e.g. the Magnuson-Stevens Fishery Conservation and Management Act originally passed in 1976 and most recently amended in 2006 requiring the rebuilding of depleted fish stocks. Evidence of rebuilding success is shown in the reduction of fishing effort (exploitation rate) to increase the size of the spawning stock biomass and success in recruitment of young stages of fish into the population.

4.2.2 Data availability for the LMEs of the APEC region Daniel Pauly and his colleagues from the Sea Around Us Project at the University of British Columbia have provided fisheries indicators for all Large Marine Ecosystems of the APEC Region, including fisheries biomass yields (catch) and dollar value, stock exploitation levels, the amount of primary productivity required to support the catch, Ecopath/Ecosim modeling results depicting mean-annual trophic levels of fish catches and fisheries in balance indices, and levels of exploitation. The Sea Around Us Project has also produced stock status plots that demonstrate the extent of overfishing in the LMEs of the world (Sherman and Hempel 2008).

4.2.3 Example from the Humboldt Current LME This LME from the APEC region contains the world's largest upwelling system and is the world's most productive marine ecosystem, with landings estimated at 15-20% of the world's annual marine catch. Anchovy, sardine and horse mackerel, the dominant species in the annual catches, are used for fish meal and for human consumption. Fishing sustains thousands of fishermen and their families. While the high productivity of the HC LME is the result of upwelling processes governed by strong southerly trade winds, the upwelling is subjected to considerable interannual climatic variability, leading to variations in marine populations and catch (**Figure 19**). The normal seasonal upwelling can be interrupted by the El Niño southern oscillation (ENSO), which results in intrusions of warm water. For the long term sustainability of the pelagic and demersal fish stocks of the Humboldt Current LME, improved forecasts of climate driven fishery fluctuations are required.

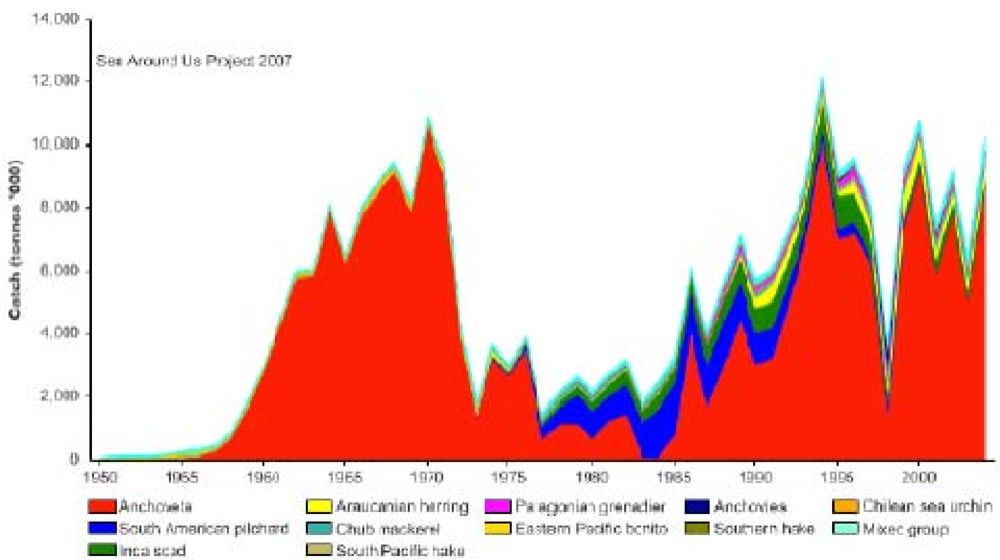


Figure 19. Total reported landings in the Humboldt Current LME by species (Sea Around Us 2007).

4.2.4 The average trophic level The Sea Around Us Project at the University of British Columbia has provided fish and fisheries indicators for 63 LMEs, including the 23 LMEs of the APEC Region (Pauly, Alder et al. 2008). The indicators include: fisheries biomass yields (catch) and dollar value, stock exploitation levels, the amount of primary productivity required to support the catch, Ecopath/Ecosim modeling results depicting mean-annual trophic levels of fish catches and fisheries in balance indices, and levels of exploitation (stock catch status plots). The average trophic level indicator can be used as a predictor and identifier of candidate situations of LME overfishing. In most of the world's LMEs, including those of the APEC Region, the mean trophic level of the reported landings has declined, an indication of a 'fishing down' of the local food webs (Pauly and Palomares 2005). At the scale of an LME, a trend reversal of the MTI may occur when the fisheries expand geographically. A time series of the Fishing in Balance (FIB) index, presented for each LME, is defined by a value that declines when both the Mean Trophic Index (MTI) and the landings decline, and increases when landings more than compensate for a declining MTI. An increase in the FIB index might indicate that a geographic expansion of the fishery has taken place.

The trophic level and FIB index for the Humboldt Current LME are presented in **Figure 20**. The Peruvian anchoveta is a localized fishery, a low trophic level species, and the largest single species fishery in the world, exhibiting extreme fluctuations in landings (Pauly, Alder et al. 2008).

Figure 20. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Humboldt Current LME (SAUP 2007).

4.2.5 Gulf of Thailand, Sulu-Celebes, South China Sea, and Indonesian Sea LMEs Graphic time-series examples of fish and fisheries indicators are provided for the four Southeast Asian LMEs funded by the GEF. Average annual fisheries landings and exploitation condition for 1950 to 2004 are shown in **Figures 21**

through **24** (Sea Around Us Project). Fisheries biomass yields are increasing in each of the four Southeast Asian LMEs, where over 40% of the mean annual landings are reported as "mixed group" species since the 1980s. The levels of fully exploited, over exploited and collapsed stocks exceed 90 percent of the fisheries biomass yields as measured by number of stocks by status and catch by stock status for all 4 Southeast Asian LMEs since 1999 (Pauly, Alder et al. 2008).

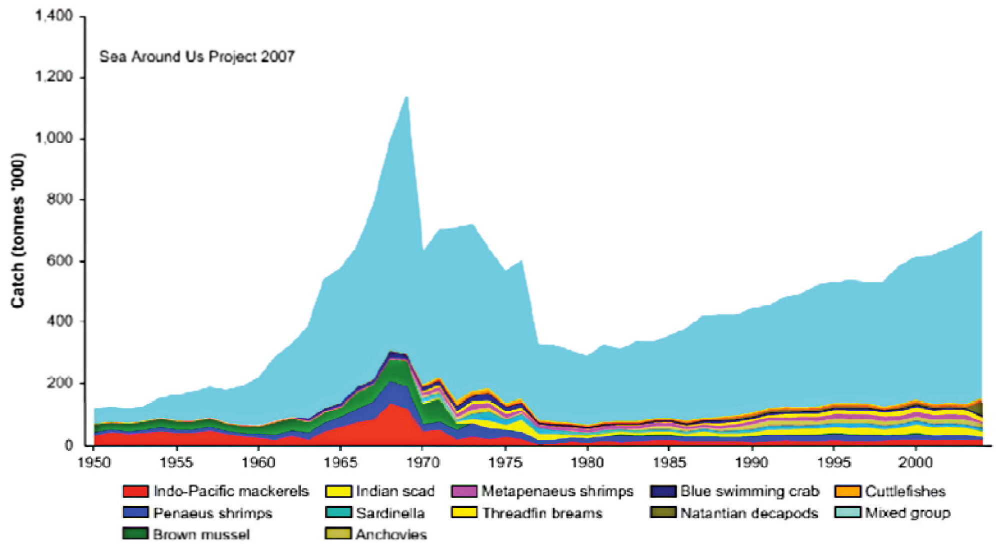


Figure 21. Total reported landings in the Gulf of Thailand LME by species (Sea Around Us 2007).

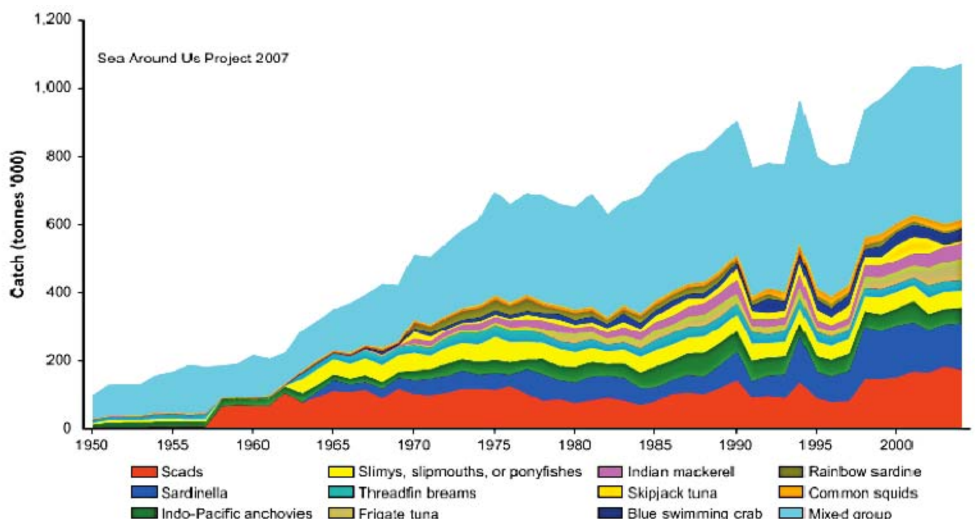


Figure 22. Total reported landings in the Sulu-Celebes Sea LME by species (Sea Around Us 2007).

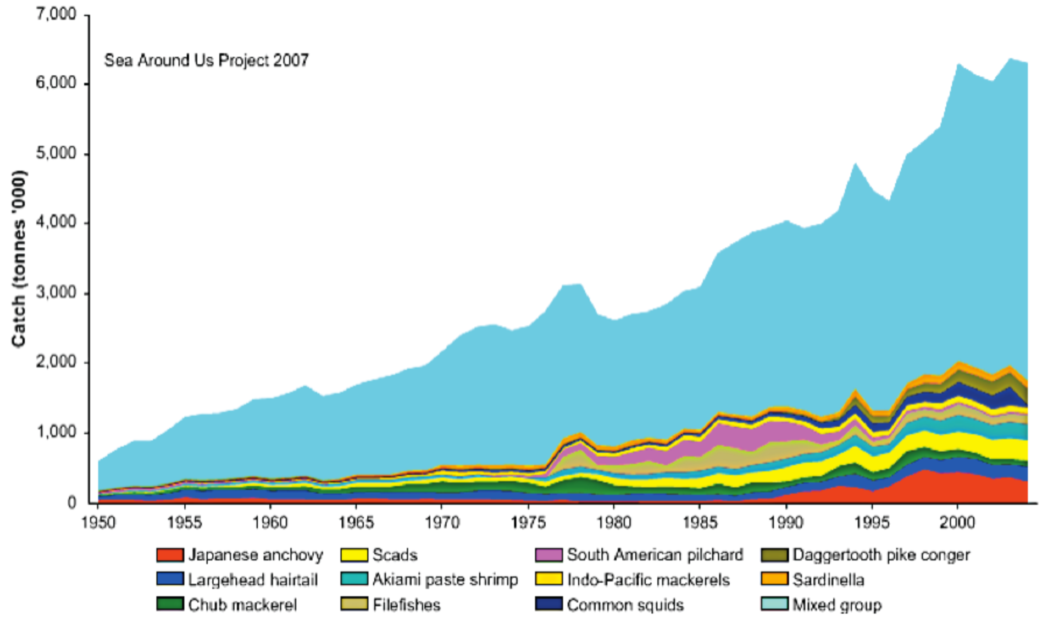


Figure 23. Total reported landings in the South China Sea LME by species (Sea Around Us 2007).

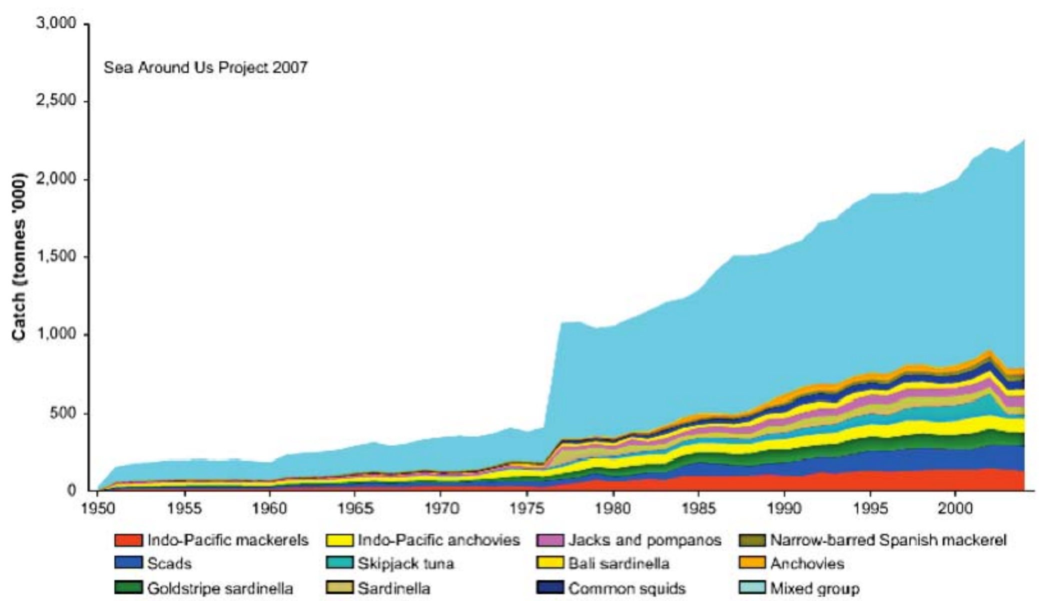


Figure 24. Total reported landings in the Indonesian Sea LME by species (Sea Around Us 2007).

4.2.6 Biomass yield trends Fisheries biomass yields were examined in relation to warming trends for 63 LMEs for the period 1982 to 2004. Fisheries biomass yield trends were plotted for each LME using the LOESS smoothing method (tension = 0.5) and the emergent increasing and decreasing patterns examined in relation to LME warming data. Observed trends were compared to earlier studies for emergent spatial and temporal global trends in LME fishery biomass yields. Fisheries biomass yields are increasing precipitously in each of the four Southeast Asian LMEs (**Figures 25** through **28**).

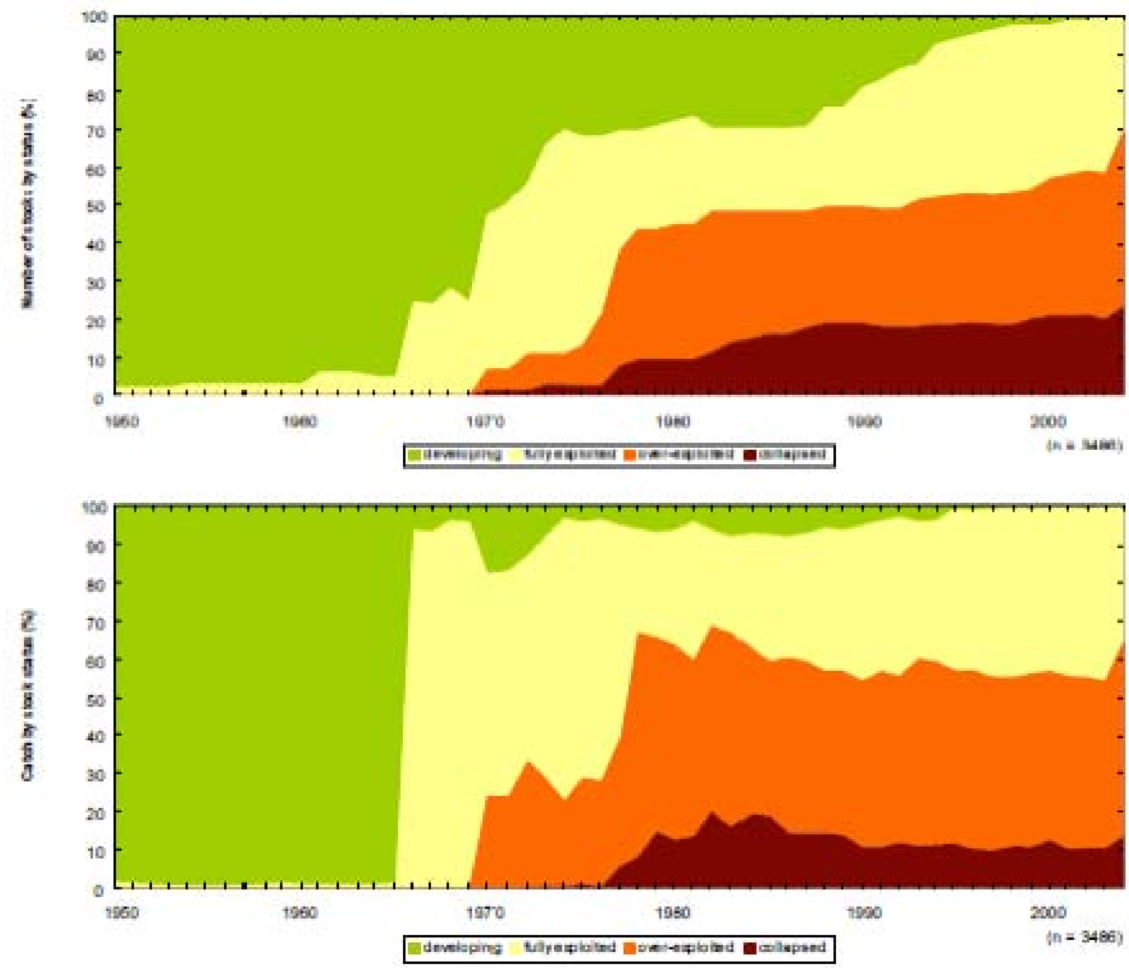


Figure 25. Stock-Catch Status Plots for the Gulf of Thailand LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (left) and by catch biomass (right) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level. Methodology is given in (Pauly, Alder et al. 2008).

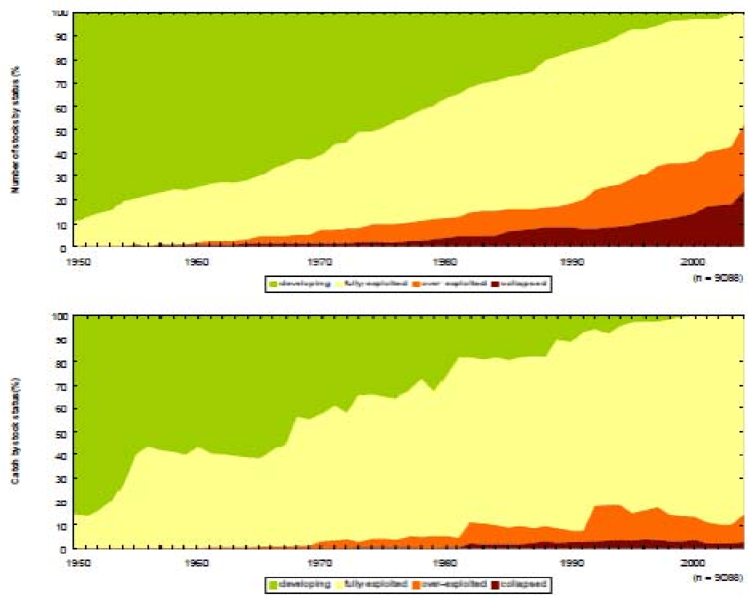


Figure 26. Stock-Catch Status Plots for the South China Sea LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (left) and by catch biomass (right) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level (Pauly, Alder et al. 2008).

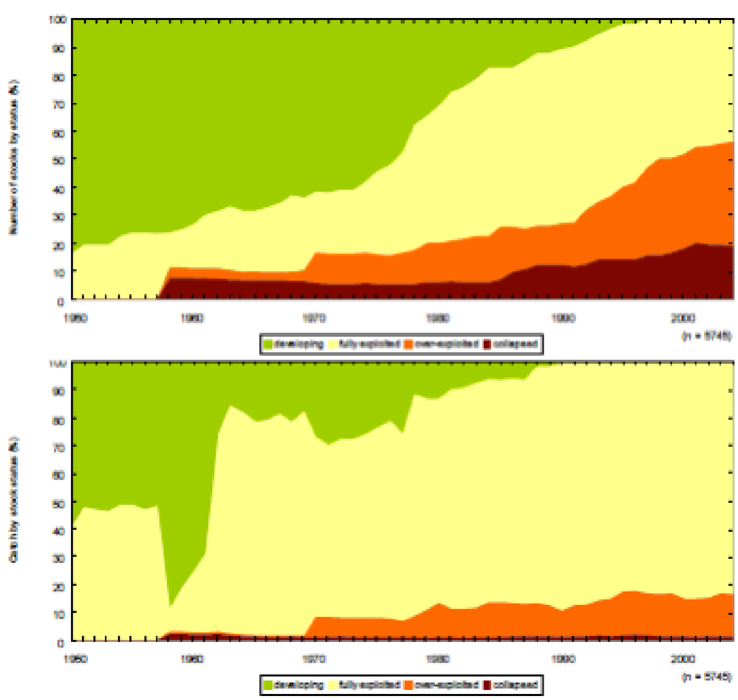


Figure 27. Stock-Catch Status Plots for the Sulu-Celebes Sea LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (left) and by catch biomass (right) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level (Pauly, Alder et al. 2008).

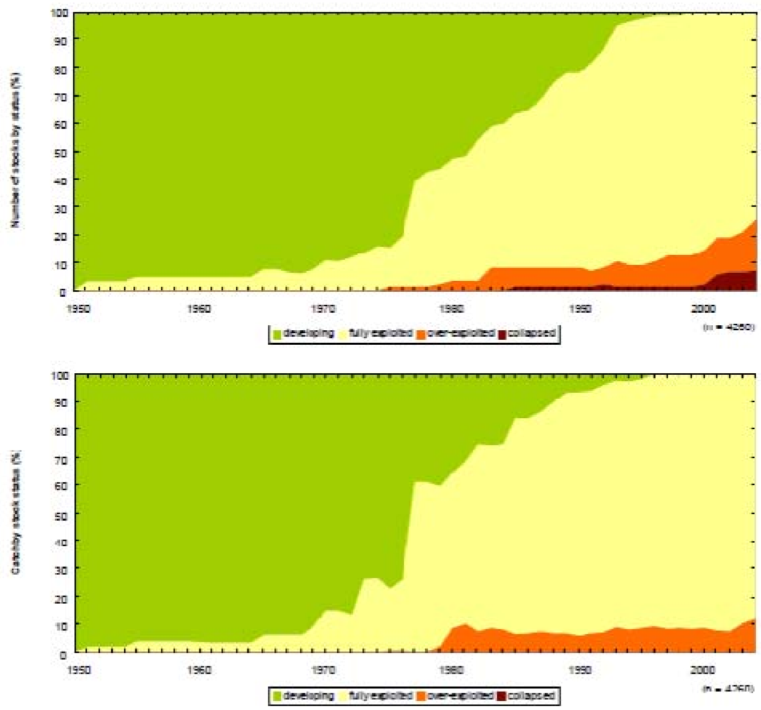


Figure 28. Stock-Catch Status Plots for the Indonesian Sea LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (left) and by catch biomass (right) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level (Pauly, Alder et al. 2008).

4.3 The Pollution and Ecosystem Health Module, Methodology and Ecosystem Indicators

Pollution and Ecosystem Health indicators are used to assess changes in coastal waters, estuaries and wetlands, and highlight eutrophic conditions. Issues addressed in this module include marine and land-based pollution, marine habitats and marine biodiversity. Pollution and habitat degradation resulting from human activities are of major concern in a number of LMEs (UNEP 2006). Pollution is often transboundary, as hydrological inter-linkages between river basins, LMEs, and the atmosphere often result in effects far from the source of emissions. The risk of transboundary impacts tends to be highest for persistent organic pollutants (POPs), particularly substances that readily migrate between water and air (e.g. DDT and mercury).

Indicators for the Pollution and Ecosystem Health module also include the condition of marine habitats (e.g. coral, seagrass, and mangroves). These habitats provide a broad range of ecosystem services with direct and indirect benefits to humans. In light of exponential human population growth, coastal habitats are increasingly under threat from a range of stressors including overfishing, pollution, invasive species, nutrient over-enrichment, and climate variability.

Increases in the frequency of occurrence and extent of oxygen-deprived “dead zones” from nutrient over-enrichment have been documented in coastal areas world-wide and serve as additional indicators of declines in LME health. In several LMEs, pollution and eutrophication are important driving forces of change in fisheries biomass yields.

4.3.1 Habitat restoration Nearly all the world’s continental shelves, and large areas of continental slopes, underwater ridges, and seamounts, have had heavy bottom trawls dragged over their surfaces. Repeated bottom trawling reduces benthic habitat diversity and changes associated communities. Fishing techniques such as dynamite fishing and cyanide fishing harm the surrounding habitat. A 2005 report of the UN Millennium Project has recommended the elimination of bottom trawling on the high seas by 2006 to protect seamounts and other ecologically sensitive habitats. In 2006, world leaders called for a moratorium on deep-sea trawling, a practice shown to often have harmful effects on sea habitat and on fish populations. Other LME habitats under stress include sea grasses, mangroves, and corals.

4.3.2 Coastal condition indicators The assessment of the changing status of pollution and health in an LME includes comparisons of ecosystem resilience and stability over time, and a resistance against external stress over time and space scales relevant to the LME (Costanza 1992). Indicators can be found in the US pollution and ecosystem health monitoring being applied by the US Environmental Protection Agency (EPA) for U.S. LMEs (USEPA 2004).

The EPA has developed a suite of five coastal condition indices: (1) water quality, (2) sediment quality, (3) benthic communities, (4) coastal habitat, and (5) fish tissue contaminants, as part of an ongoing collaborative effort with US NOAA, the US Fish and Wildlife Service, the US Geological Survey, and other agencies representing states and tribes. The EPA’s five pollution and ecosystem health indicators for LMEs and stop-light assessments of the indicators are shown in **Figure 29** (USEPA 2004) fish tissue index and the patho-biological examination of fish and fish tissue, bioaccumulation and trophic transfer of contaminants are assessed in relation to critical life history stages and selected food web organisms are examined for indicators of exposure to and effects from contaminants, effects of impaired reproductive capacity, organ disease, and contaminant-impaired growth. Estuarine and nearshore areas are monitored for contaminants and contaminant effects in the water column, substrate, and selected groups of organisms.

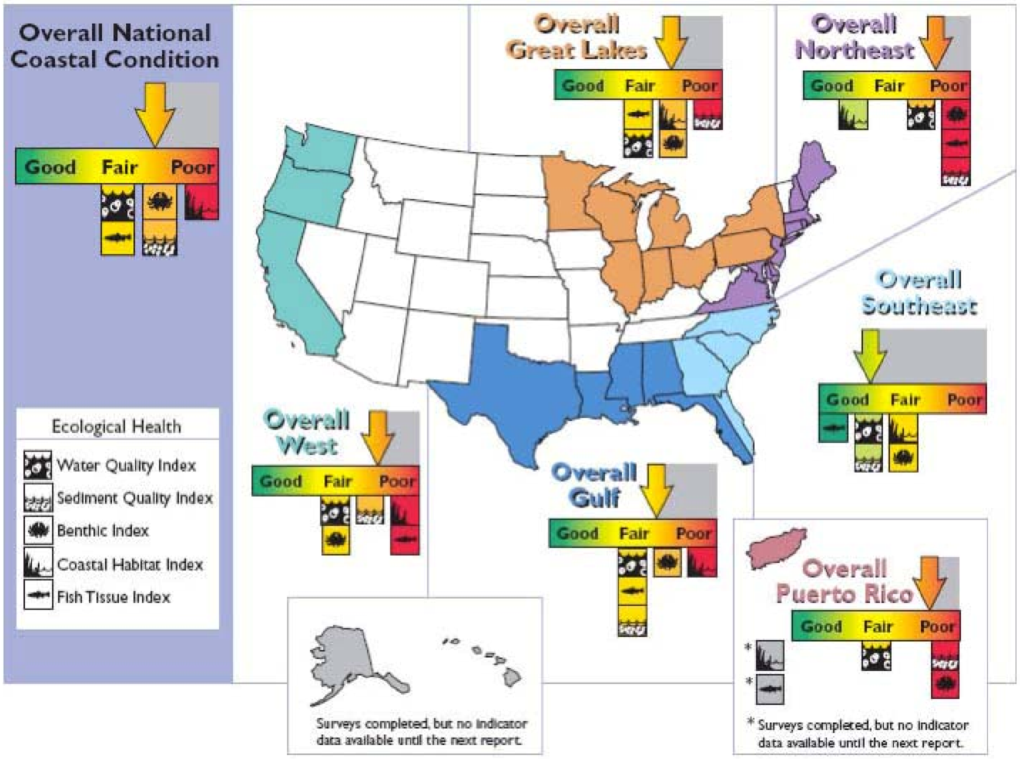


Figure 29. The Environmental Protection Agency's (EPA) five pollution and ecosystem health indicators for seven areas in the United States coinciding with LMEs, and stop-light assessments of the indicators (USEPA 2004)

The 2004 *National Coastal Condition Report II (USEPA 2004)*) includes results from the EPA's analyses of coastal condition indicators and NOAA's fish stock assessments by LMEs aligned with the EPA's national coastal assessment regions. The EPA and NOAA are jointly introducing this approach to the international GEF-supported LME projects, along with a methodology for nutrient assessment.

Excessive nitrogen loadings and oxygen depletion events are causing significant mortalities among marine resource species. In European LMEs, recent nitrogen flux increases have been recorded ranging from 3-fold in Spain to 4-fold in the Baltic Sea to 11-fold in the Rhine River basin draining to the North Sea LME. Howarth et al. (2000) and Duda and El-Ashry (2000) have described the origin of this disruption of the nitrogen cycle from the Green Revolution of the 1970s, as the world community converted wetlands to agriculture, utilized more chemical inputs, and expanded irrigation to feed the world. Significant contributors to eutrophication are sewage from drainages of large cities and atmospheric deposition from automobiles and agricultural activities, with the amounts depending on proximity of sources.

4.3.3 Data availability for the LMEs of the APEC region

In GEF-funded LME projects, countries are requesting financial support to reduce such nitrogen flux. Actions range from assisting in: (1) development of joint institutions for ecosystem-based approaches for adaptive management; (2) on-the-ground implementation of nitrogen abatement measures in the agricultural, industrial, and municipal sectors; and (3) breaching of floodplain dikes so that wetlands recently converted to agriculture may be reconverted to promote nitrogen assimilation. The excessive levels of nitrogen contributing to coastal eutrophication constitute a new global environment problem that is cross-sectoral in nature. Excessive nitrogen loadings and oxygen depletion events causing significant mortalities among marine resource species have been identified as a major coastal problem in several LMEs that are receiving GEF assistance, including in the APEC Region (e.g., Yellow Sea, South China Sea, and Bay of Bengal LMEs.

Preliminary global estimates of nitrogen export from freshwater basins to coastal waters have been determined by Kroeze and Seitzinger (1998). A GEF/LME global project, “Promoting Ecosystem-based Approaches to Fisheries Conservation and Large Marine Ecosystems”, has filled gaps relating to LME nitrogen loadings and provided forecasts for 64 LMEs (Seitzinger, Sherman et al. 2008). The project has used GIS-based models relating land use and human activities in watersheds to nutrient transport by rivers to coastal systems (**Figure 30**). The project specifically used an innovative Nutrient Export from Watersheds Model (NEWS) to predict inorganic nitrogen (N) export by rivers to the coast as a function of watershed N inputs (point and diffuse sources), hydrology, and other factors. The model was used to examine DIN export into all 64 LMEs. The aim is to optimize use of land for food and energy production while at the same time conserving coastal habitats, and to understand the links between land-based activities and nutrient inputs to coastal systems. Nutrient sources, sinks, and controlling factors in watersheds are explicit components of the model, and the effect of a range of scenarios on DIN river export can be explored.

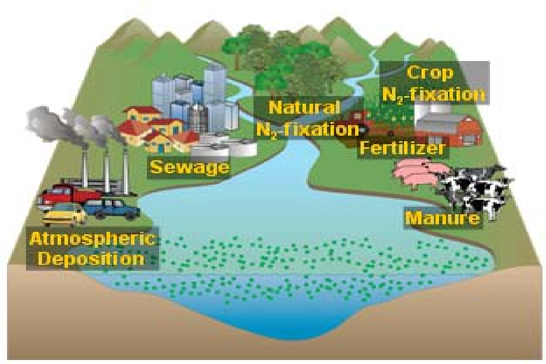


Figure 30. Watershed schematic of nitrogen inputs and transport to coastal systems. Symbols for diagram courtesy of the Integration and Application Network (ian.umces.edu/symbols) University of Maryland Center for Environmental Science (Kroeze and Seitzinger 1998).

4.3.4 A watershed perspective (NEWS) Rivers are a central link in the chain of nutrient transfer from watersheds to coastal systems. Nutrient inputs to watersheds include natural (biological N_2-fixation, weathering of rock releasing phosphate) as well as many anthropogenic sources. At the global scale, anthropogenic nitrogen inputs to watersheds are now greater than natural inputs (Galloway, Dentener et al. 2004). Anthropogenic nutrient inputs are primarily related to food and energy production to support over 6 billion people on Earth with major sources including fertilizer, livestock production, sewage, and atmospheric nitrate deposition resulting from NOx emissions from fossil fuel combustion. Uneven spatial distribution of human population, agriculture, and energy production leads to spatial differences in the anthropogenic alterations of nutrient inputs to coastal ecosystems (Howarth, Billen et al. 1996; Seitzinger and Kroeze 1998; Green, Vörösmarty et al. 2004; Seitzinger, Harrison et al. 2005). A mechanism is needed to develop a comprehensive and quantitative global view of nutrient sources, controlling factors and nutrient loading to coastal systems around the world under current conditions, as well as to be able to look at past conditions and plausible future scenarios.

4.3.5 A Global Watershed Nutrient Export Model (NEWS): In order to provide regional and global perspectives on changing nutrient transport to coastal systems throughout the world, an international workgroup, Global NEWS – Nutrient Export from WaterSheds -- has developed a spatially explicit global watershed model that relates human activities and natural processes in watersheds to nutrient inputs to coastal systems throughout the world (Beusen, Dekkers et al. 2005; Dumont, Harrison et al. 2005; Harrison, Seitzinger et al. 2005; Harrison, Caraco et al. 2005; Seitzinger, Harrison et al. 2005). Global NEWS (**Figure 31**) is an interdisciplinary workgroup of UNESCO's Intergovernmental Oceanographic Commission (IOC) focused on understanding the relationship between human activity and coastal nutrient enrichment. In addition to current predictions, the NEWS model is also being used to hindcast and forecast changes in nutrient, carbon and water inputs to coastal systems under a range of scenarios.

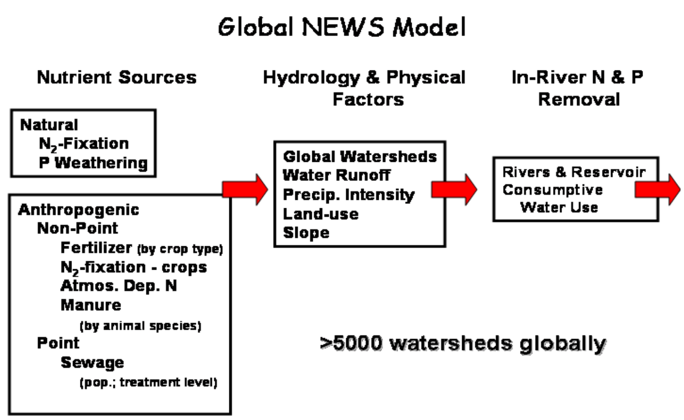


Figure 31. Schematic of some of the major inputs and controlling factors in the Global NEWS watershed river export model (Seitzinger, Sherman et al. 2008) www.marine.rutgers.edu/globalnews

4.3.6 NEWS model output: The NEWS model has provided the first spatially distributed global view of Nitrogen (N), Phosphorus (P) and Carbon (C) export by world rivers to coastal systems. At the global scale rivers currently deliver about 65 Tg N and 11 Tg P per year according to NEWS model predictions (Tg = tera gram = 10^{12} g). For nitrogen, Dissolved inorganic Nitrogen (DIN) and particulate N (PN) each account for approximately 40% of the total N input, with Dissolved Organic Nitrogen (DON) comprising about 20%. This contrasts with P, where particulate P (PP) accounts for almost 90% of total P inputs. However, while Dissolved Inorganic Phosphorus (DIP) and Dissolved Organic Phosphorus (DOP) each contribute only about 10% of total P, both of these forms are very bioreactive and thus may have a disproportionate impact relative to PP on coastal systems (**Figure 32**).

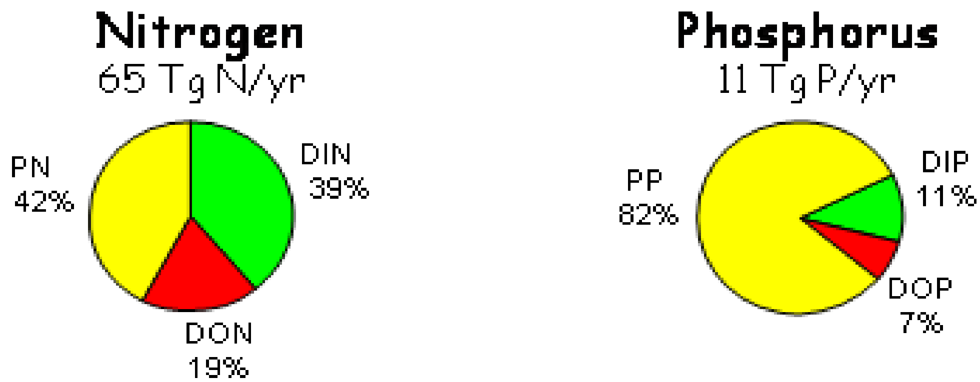


Figure 32. Global N and P river export to coastal systems by nutrient form based on the NEWS model (Dumont, Harrison et al. 2005; Harrison, Caraco et al. 2005).

There is large spatial variation around the world in river nutrient export, including different patterns for the different nutrient forms (DIN, DON and PN) (**Figure 33**). Using N yield (kg N per km^2 watershed per year that is exported to the river mouth), DIN yield shows considerable variation at regional and continental scales, as well as among adjacent watersheds.

Land-based pollution of coastal waters in LMEs can have sources in multiple countries often located upstream at a considerable distance from the coastal zone. The release of nutrients into rivers can cross national borders and create environmental, social and economic impacts along the way -- until reaching the coastal zone, which may be in a different country. Thus an LME transboundary approach is essential for identifying watershed nutrient sources and coastal nutrient loading to support policy development and implementation in LMEs that will reduce current and future coastal eutrophication.

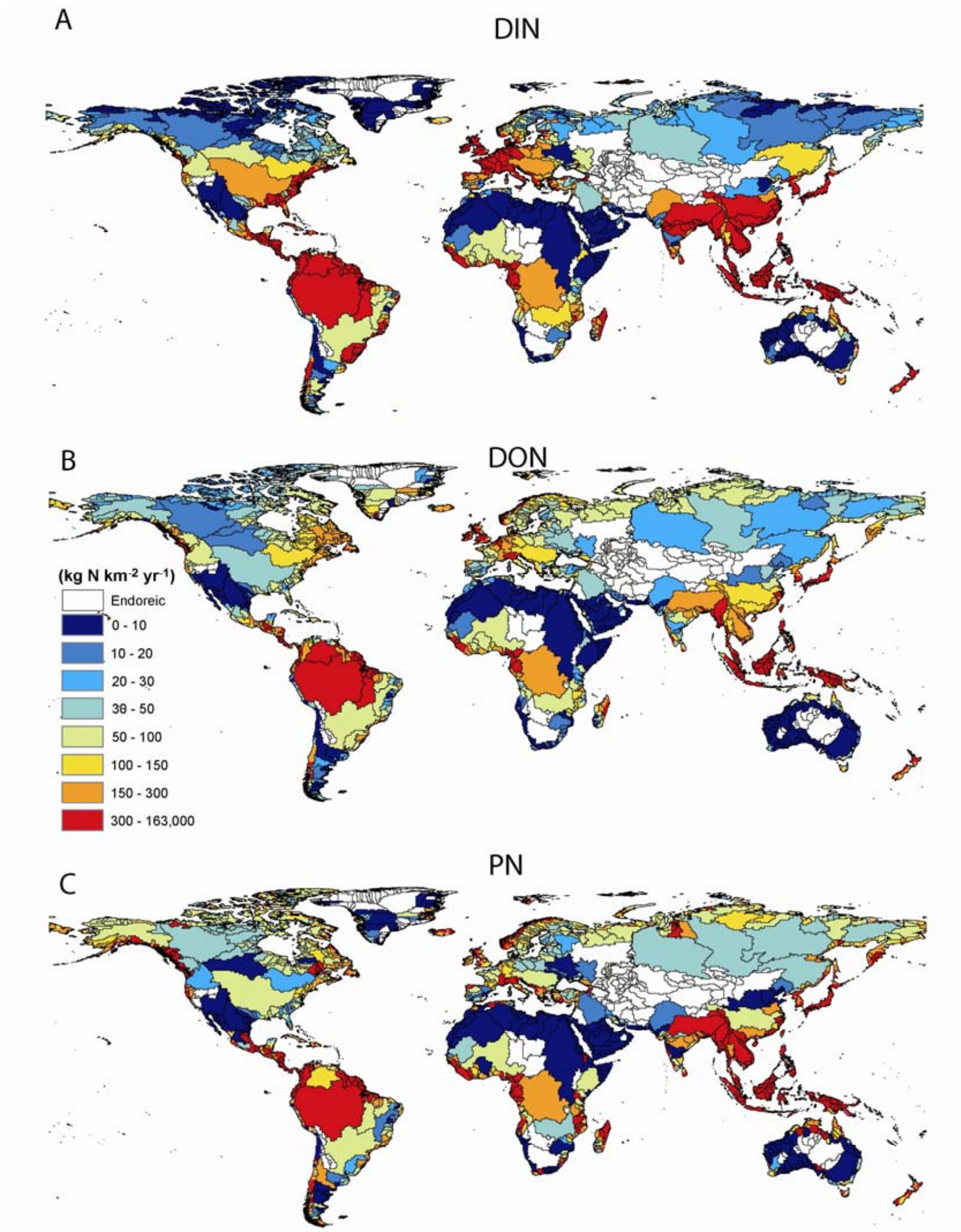


Figure 33. Three maps showing spatial variation around the world in river nutrient export, including different patterns for Dissolved Inorganic Nitrogen (DIN), Dissolved Organic Nitrogen (DON), and Particulate Nitrogen (PN).

4.3.7 Bridging the gap between land-based sources and LME waters Few estimates of nutrient loading have been made in individual LMEs, and only in the Baltic Sea LME has source apportionment been investigated (ECOPS, ESF et al. 1995; HELCOM 2001). As a first step in bridging the gap between land-based activities and LME waters, the relative magnitude and distribution of DIN loading from watersheds to LMEs globally was examined. The assessment was focused on N because it is often the most limiting nutrient in coastal waters and thus important in controlling coastal eutrophication. DIN is often the most abundant and bio-available form of nitrogen, and therefore contributes significantly to coastal eutrophication. Watershed DIN export to rivers predicted by the NEWS model described above was compiled for 63 LMEs (**Figure 33**). The Antarctic LME data base was excluded as information was limited. Total DIN load and yield to each LME was aggregated from all watersheds with coastlines along that LME for point sources and only those watersheds with discharge to that LME for diffuse sources.

DIN loading to each LME was attributed to diffuse and point sources including natural biological N_2-fixation, agricultural biological N_2-fixation, fertilizer, manure, atmospheric deposition and sewage. Dominant sources of DIN to LMEs were also identified. Agriculture is a major source of the anthropogenic DIN export to LMEs. In 91% of the LMEs with agriculture occurring in their related watersheds, over half their anthropogenic export is due to agricultural sources such as agricultural biological fixation, manure, and fertilizer. The identification of dominant sources of DIN and their relative contribution at the individual LME level is essential for developing effective nutrient management strategies on an ecosystem level.

4.3.8 Implications of future conditions in LME watersheds At the global scale, river nitrogen export to coastal systems is estimated to have approximately doubled between 1860 and 1990, due to anthropogenic activities on land (Galloway, Dentener et al. 2004). Over the next 50 years the human population is predicted to increase markedly in certain world regions, notably southern and eastern Asia, South America, and Africa (UN 1996). Growing food to feed the expanding world population will require increased use of nitrogen and phosphorus fertilizers (Alcamo, Kreileman et al. 1994; Bouwman, Vanderhoek et al. 1995; Bouwman 1997). Increased industrialization, with the associated combustion of fossil fuels and NOx production (NOx is a generic term for the mono-nitrogen oxides NO, nitric oxide, and NO_2 , nitrogen dioxide), is predicted to increase atmospheric deposition of N (IPCC 2001; Dentener, Drevet et al. 2006).

Thus, unless substantial technological innovations and management changes are implemented, increasing food production and industrialization will undoubtedly lead to increased export of N to coastal ecosystems (Galloway et al. 2004) with resultant water quality degradation. Based on a business-as-usual (BAU) scenario, inorganic N export to coastal systems is predicted to increase 3-

fold by the year 2050 (relative to 1990) from Africa and South America (Kroeze and Seitzinger 1998; Seitzinger, Kroeze et al. 2002). Substantial increases are predicted for Europe (primarily eastern Europe) and North America. Alarmingly large absolute increases are predicted for eastern and southern Asia; almost half of the total global increased N export is predicted for those regions alone.

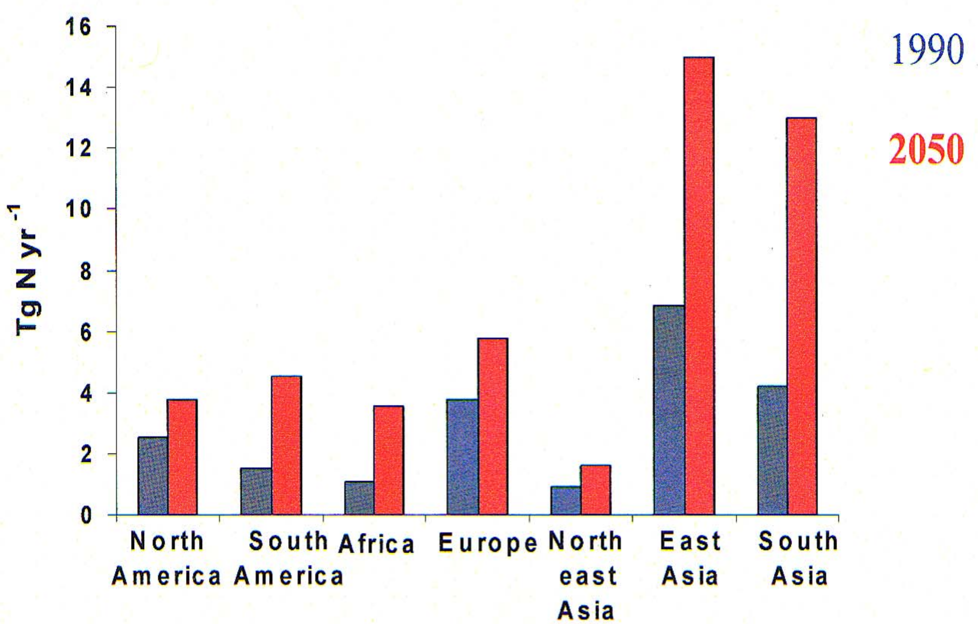


Figure 34. Predicted DIN export to coastal systems in 1990 (blue) and 2050 (red) under a business-as-usual (BAU) scenario. Modified from (Kroeze and Seitzinger 1998).

A business as usual (BAU) model of predicted increases in DIN loading for 2050 **Figure 34** was based on an earlier analysis by Kroese and Seitzinger (1998). The NEWS model has more parameters and more detail (e.g., fertilizer use by crop type, level of sewage treatment, etc.), thus facilitating more advanced scenario development and analyses. For example, it is now possible to explore the effects of a range of development strategies, effects of climate change, production of biofuels, increase in dams for hydropower, and consumptive water use (irrigation) on coastal nutrient loading.

Watershed DIN export to rivers as predicted by Seitzinger *et al*. above was compiled for 63 LMEs, including all the LMEs of the APEC Region. Among the Southeast Asian LMEs, the loadings of DIN were lowest in the Gulf of Thailand (100,000 –250,000 T/yr), highest in the South China Sea (1 million -2.5 million T/yr), high in the Sulu Celebes Seas (250-500,000 T/yr), and higher in the Indonesian Sea LME (500,000-750,000 T/yr) (**Figure 35, top**).

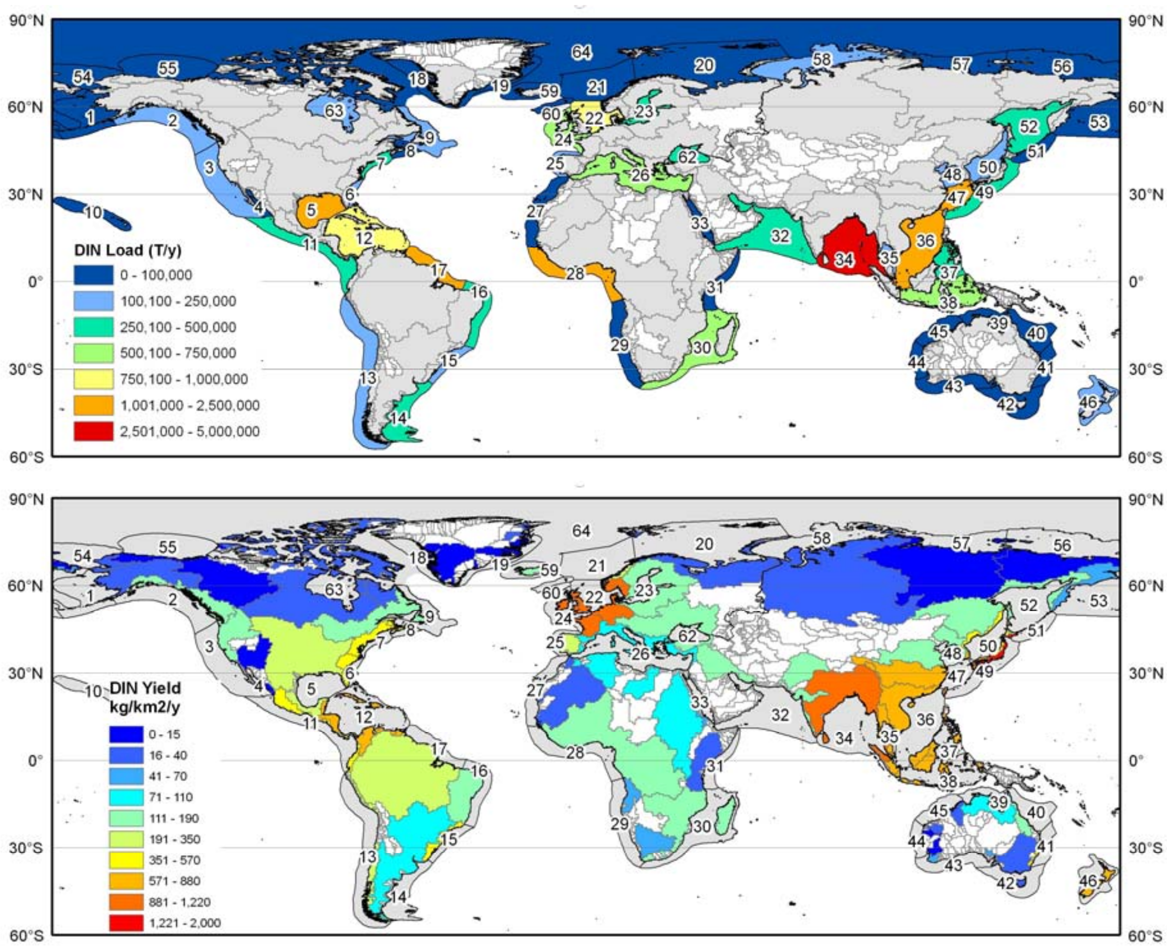


Figure 35. DIN load (top) and yield (bottom) from land-based sources to LMEs predicted by the NEWS DIN model. Watersheds discharging to LMEs are grey; watersheds with zero coastal discharge are white. See Figure 1for LME identification (Seitzinger and Harrison 2008).

4.3.9 Ecosystems disease and health Emergence of disease pathogens (e.g., cholera, vibrios, paralytic shellfish toxins and explosive growth of non-indigenous species (Epstein 1993) are indicators of ecosystem health. Excessive nutrient loadings of coastal waters have been related to harmful algal blooms causing mass mortalities of living resources. Chronic degraded health, mass mortalities, and zoonotic diseases of marine species are now widely recognized (Harvell, Kim et al. 1999). Invasive species, and illnesses affecting humans from toxic red tide organisms are events increasing in frequency and extent in LMEs around the globe (HEED. Health Ecological & Economic Dimensions of Global Change 1998). Marine disturbances in LMEs, including red tides and hypoxic events, can disrupt trophic relationships among species. Indices of ecosystem health have been developed that utilize data mining as a means for retrospectively assessing relative frequency of recurrence of anomalous multiple marine ecological disturbances (MMEDs). Descriptions of the MMED approach for assessing ecosystem health have been published (Sherman 2000; Sherman 2000; Sherman 2001). A list of eight MMED types is given in **Table 1**.

Table 1. Eight disturbance types with example indicators (categories are not mutually exclusive).

Biotoxin and Exposure	*e.g*., toxic algal blooms, human gastroenteritis
Anoxic/ Hypoxic	*e.g.,* nuisance blooms, Baltic cod/ hypoxia
Trophic Magnification	*e.g*., tainted shellfish, piscavore tumors
Mass Mortality	*e.g*., M74 salmon aquaculture losses, flatfish mortalities
Climate Forcing	*e.g*., North Atlantic Oscillation and storm damage
Disease	*e.g.* herring lymphocystis, phocine distemper virus
Novel & Invasive Disturbances	*e.g.,* ballast water discharge
Keystone & Chronic Disturbance	*e.g.,* colonial water bird mortalities, seasonal eutrophication

4.4 The Socioeconomics Module

The Socioeconomics module examines how a sustainable marine resource base contributes to the nutritional, social, economic and developmental needs of humans living in LME border countries. In terms of socioeconomic benefits, the currency value of recreational, tourism and commercial activities depends on healthy coastal, ocean and fresh water environments. Social and economic indicators need to be explicitly integrated with scientific findings from the three science-based modules of productivity, fish and fisheries and pollution and ecosystem health to form the basis of management measures. The Socioeconomic indicators module is focused on the application of socioeconomic ecosystem indicators relating to the improvement or deterioration of socioeconomic benefits to civil society from LME goods and services.

4.4.1 Methodology and ecosystem indicators An initial step toward the development of a global overview of the socioeconomic aspect of LMEs was made by the Marine Policy Center at the Woods Hole Oceanographic Institution by Hoagland and Jin (2008). These researchers used indices of socioeconomic activity based on data from several marine economic sectors. They included indices for 3 areas of ocean activity: (i) fish landings and aquaculture production, (ii) ship building, cargo traffic, merchant fleet size, oil production, and oil rig counts, and (iii) tourism. With regard to fisheries, the goal is to increase the number of fish stocks managed at sustainable levels in order to increase proceeds from fisheries and maximize socioeconomic benefits for coastal populations and those engaged in fisheries activities and related industries. Increases in marine transportation, the shipping of goods and offshore oil production can be used to evaluate efforts of these commercial activities on LME services. The coastal tourism industry, although highly sensitive to climate change and to losses due to unpredictable events, is important for its contribution to the economy of coastal states. Healthy coral reefs, for example, provide both direct economic benefits (e.g. commercial, recreational, and fishing opportunities), and ecosystem services (e.g. biodiversity). For this reason, a governance measure supporting reef protection also supports socioeconomic benefits. The data were examined for the years between 2002 and 2004. The indices are based on industrial and recreational activities occurring at the national level in coastal nations. If collected over time, such data can help identify changes in the development of the various sectors of the economy of the nations considered. An example is provided for the Yellow Sea LME (**Figure 36)**

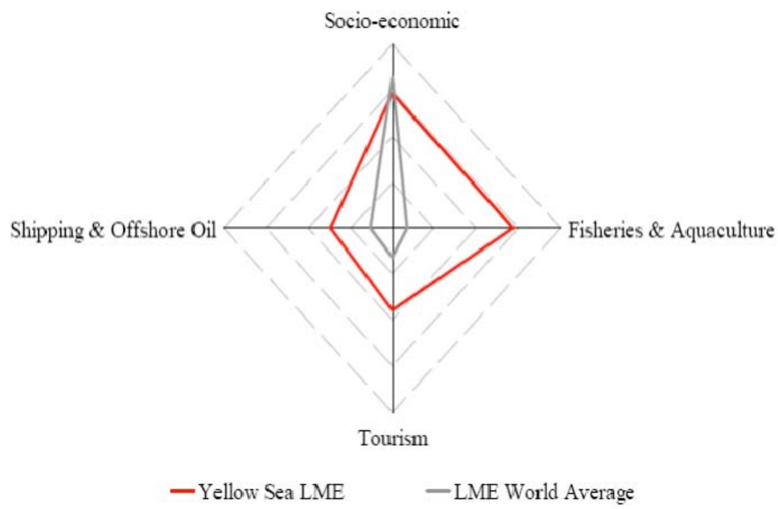


Figure 36: Yellow Sea LME activity index values for three major marine sectors and the socioeconomic sector in comparison to the LME world average. The calculated index values for the three industry sectors were greater than the world average.

A summary ranking of APEC LMEs by socioeconomic and marine industry activity indices for LMEs is shown in **Table 2**. The Yellow Sea, East China Sea, East Bering Sea, and Insular Pacific Hawaiian LMEs are ranked the four highest and are the four most economically active LMEs. It is expected that the higher levels of marine industry in those LMEs are associated with significant environmental degradation. The South China Sea, Indonesian Sea, Gulf of Thailand, and Sulu-Celebes LMEs are ranked 8th, 20th, 22nd and 25th, respectively. The Pacific Central American LME, a candidate for a future pilot LME Project funded by GEF, is ranked 21st.

Table 2. Socioeconomic and marine industry activity indexes for APEC LMEs, ranked in order of Marine Activity Index (Hoagland and Jin 2006).

LME	**LME#**	**Socioeconomic index**	**Fishery & Aquaculture Index**	**Tourism Index**	**Ship & Oil Index**	**Marine Industry Activity Index**
Yellow Sea	48	73.442	71.837	44.410	36.865	45.369
East China Sea	47	84.076	51.891	30.773	42.147	41.821
East Bering Sea	1	93.900	17.438	57.893	43.969	41.448
Insular Pacific Hawaiian	10	93.900	17.438	57.893	43.969	41.448
Kuroshio Current	49	93.629	15.456	52.758	37.861	36.360
California Current	3	88.015	12.055	43.729	35.002	32.158

Gulf of Alaska	2	94.019	13.717	48.248	32.496	31.891
South China Sea	36	73.777	34.521	22.269	14.902	20.299
Gulf of California	4	80.200	4.907	24.923	23.096	19.823
Sea of Japan / East Sea	50	83.263	13.262	3.529	23.976	17.744
Oyashio Current	51	83.278	13.031	2.138	14.904	11.976
North Australian Shelf	39	94.600	0.836	6.587	12.727	9.121
East-Central Australian Shelf	41	94.600	0.836	6.587	12.727	9.121
Southeast Australian Shelf	42	94.600	0.836	6.587	12.727	9.121
Southwest Australian Shelf	43	94.600	0.836	6.587	12.727	9.121
West-Central Australian Shelf	44	94.600	0.836	6.587	12.727	9.121
Northwest Australian Shelf	45	94.600	0.836	6.587	12.727	9.121
Northeast Australian Shelf	40	94.006	0.833	6.491	12.540	8.989
West Bering Sea	53	80.956	11.553	6.199	7.251	7.901
Indonesian Sea	38	69.200	16.159	6.686	3.872	6.892
Pacific Central American	11	77.304	2.431	8.856	7.634	6.838
Gulf of Thailand	35	73.826	7.309	13.395	3.268	6.102
Sea of Okhotsk	52	80.125	11.245	0.675	5.071	5.426
Bay of Bengal	34	63.400	7.675	4.571	4.088	4.902
Sulu Celebes	37	74.778	10.078	4.420	3.212	4.827
Humboldt Current	13	83.015	15.241	1.721	0.178	3.499
New Zealand Shelf	46	92.600	2.092	2.876	0.403	1.235

4.4.2 Data availability for the LMEs of the APEC region For fish landings, the UNEP LME report includes a time series (1950 -- 2004) of the composition of the LME catch according to the status of the stocks making up that catch. The status of the stocks is ranked as (i) underdeveloped; (ii) developing; (iii) fully exploited; (iv) over-exploited; and (v) crashed. This information is available for all 64 LMEs including the 27 LMEs of the APEC Region.

The Gulf of Thailand, South China Sea, Sulu-Celebes Sea and Indonesian Sea LMEs are under stress from overfishing and nutrient over-enrichment, coastal pollution and habitat loss. The relatively steep increases in fisheries biomass yields of the past two decades (**Figures 21-24**) and the high percentage of fisheries stocks in a fully exploited and overexploited condition (**Figures 25-28**), is cause for concern considering the dependence of the combined 350 million people of Indonesia, Malaysia, Philippines, and Thailand on fish as a critically important protein source. The per capita consumption of fish in Southeast Asia is among the highest in the world. Examination of the socioeconomic indicators provides evidence of potential for expansion of marine industrial activity that would add stress to already degraded coastal habitats and fisheries. The ministries of environment, fisheries, tourism, energy and finance of the coastal countries bordering the Southeast Asian LMEs have been informed of the problems during the preparatory phases of the GEF-supported projects for the Gulf of Thailand, South China Sea, Sulu-Celebes Sea and Indonesian Sea LMEs. Data is available on the value of reported landings for the world's LMEs (Pauly, Alder et al. 2008).

Time-series projections on the annual value of fisheries for the Gulf of Thailand, South China Sea, Sulu-Celebes Sea and Indonesian Sea LMEs are given in **Figures 37-40**.

These graphs present reported landing value by 'Commercial groups' to facilitate comparison between LMEs which may not share species. All values presented in these graphs are based on real 2000 prices, i.e., deflated nominal prices (Sumaila, Marsden et al. 2007). Note that offshore fishing grounds are not included in LMEs and are not part of the calculated value here (Pauly, Alder et al. 2008).

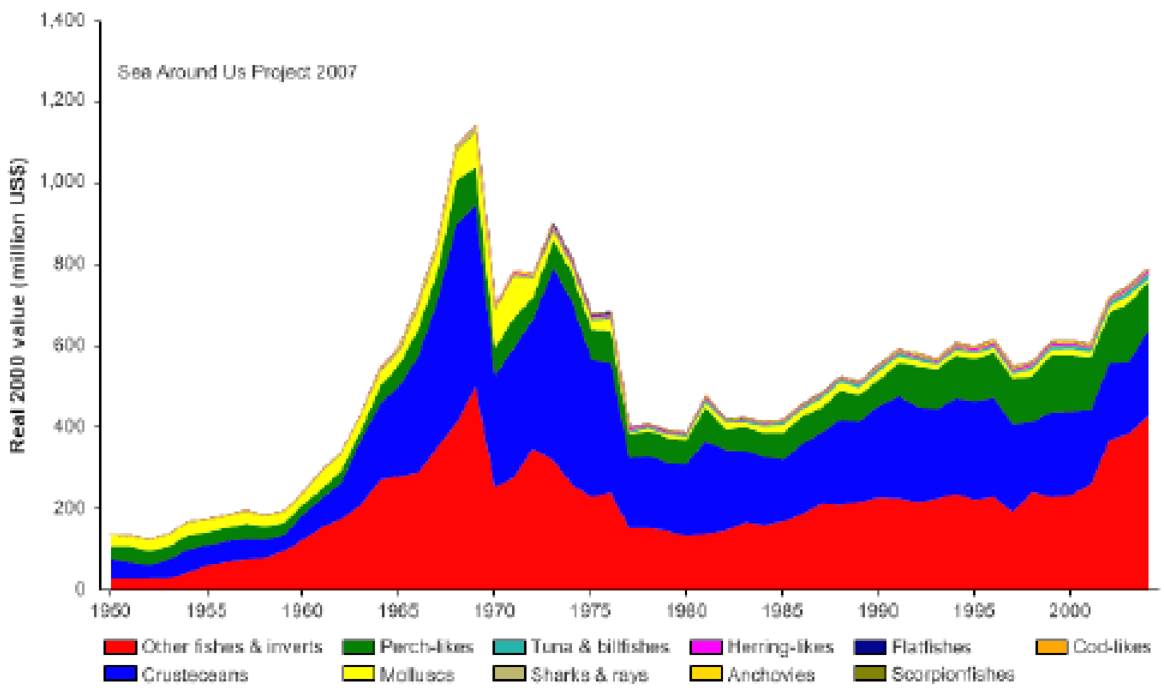


Figure 37. Value of reported landings in the Gulf of Thailand LME by commercial groups (1950 - 2004). Sea Around Us 2007.

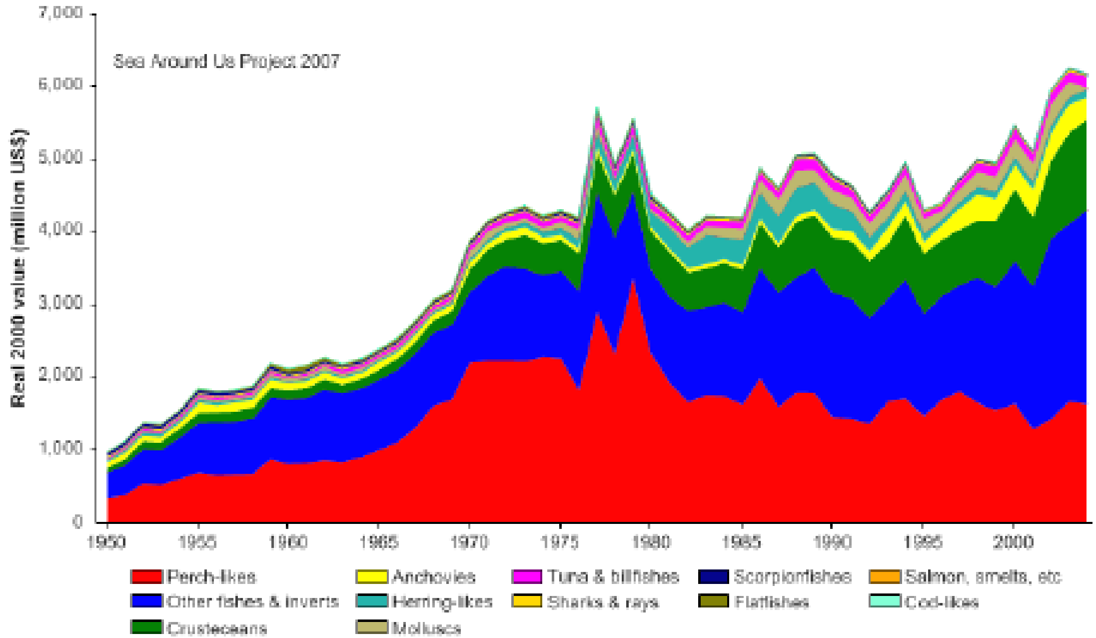


Figure 38. Value of reported landings in the South China Sea LME by commercial groups (1950 - 2004). Sea Around Us 2007.

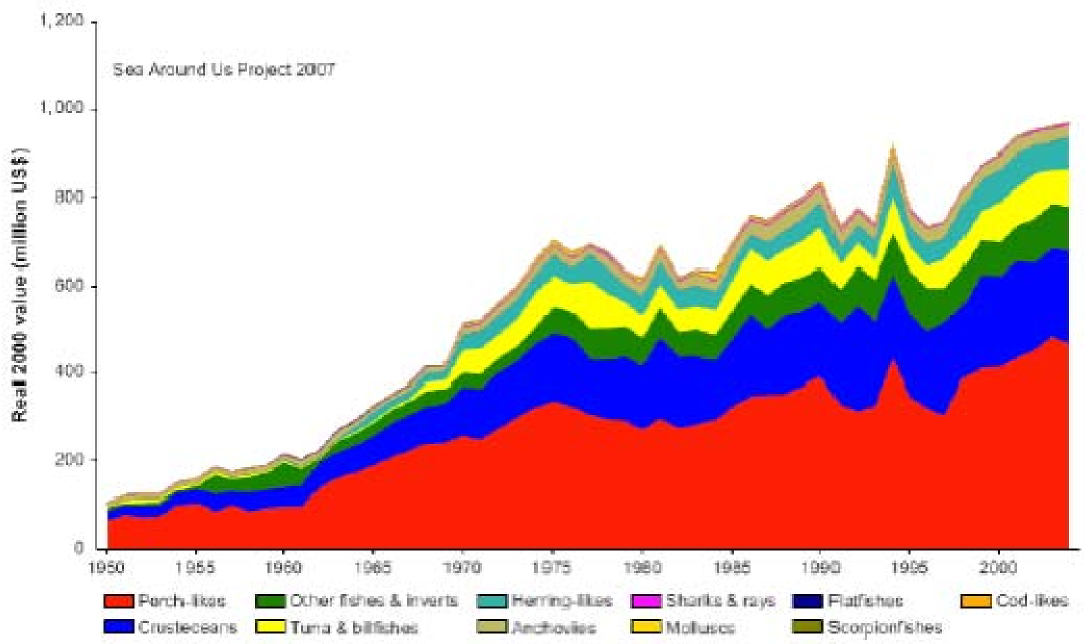


Figure 39. Value of reported landings in the Sulu Celebes LME by commercial groups (1950 - 2004). Sea Around Us 2007.

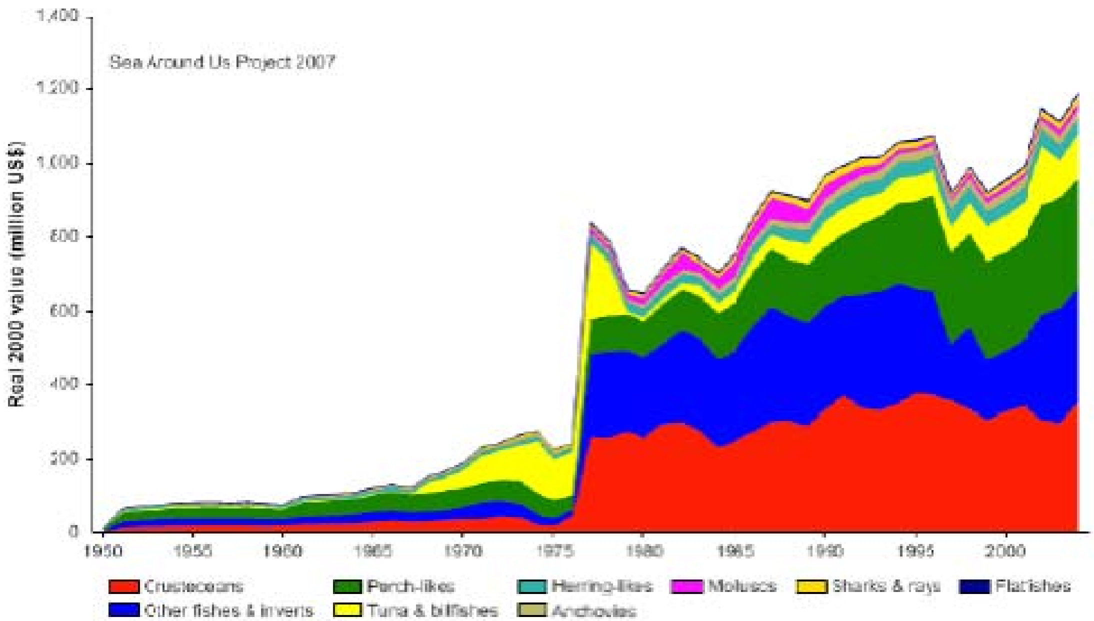


Figure 40. Value of reported landings in the Indonesian Sea LME by commercial groups (1950 - 2004). Sea Around Us 2007.

4.5 The Governance Module

The LME Governance Module engages multiple scales of national, regional, and local jurisdictional frameworks needed to select and support ecosystem-based management practices leading to the sustainable use of resources in the LME.

4.5.1 Methodology and ecosystem indicators

Governance profiles of LMEs are being explored to determine their utility in promoting long-term sustainability of ecosystem resources (Juda and Hennessey 2001; Olsen, Sutinen et al. 2006). In seeking to move toward governance arrangements that support ecosystem-based management, it is necessary to understand how existing institutional and economic systems operate, their implications for the natural environment and its resources, and how needed change may emerge, given societal structures and norms. Ecosystem-based governance actions need to consider multiple legal jurisdictions and governance levels (e.g. municipal, state, regional, national, international) as well as the interests of multiple user sectors (e.g. fisheries, mining, oil and gas production, waste disposal, transportation, recreation) and stakeholders (e.g., fishermen, corporations, real estate interests) for establishing ecosystem-based standards for the management of LME goods and services.

4.5.2 Precautionary cap and sustain action Fisheries are a vital resource for countries in the APEC region. At present, fisheries resources are at risk from overexploitation in the Gulf of Thailand, South China Sea, Sulu-Celebes Sea and

Indonesian Sea LMEs (Pauly, Alder et al. 2008). It would be prudent for countries bordering these LMEs to cap and sustain fisheries yields at a recent multiple year mean as a precautionary measure and move toward adoption of more sustainable fisheries management practices. An ecosystem-based cap and sustain adaptive management strategy for groundfish based on an annual overall total allowable catch level and agreed upon TACs for key species is proving successful in the management of the moderately warming waters of the Gulf of Alaska LME and slow warming East Bering Sea LME (Sherman, Belkin et al. 2009). In the absence of annual assessments for a large number of marine fish species in many developing countries, and in recognition of the uncertainties of the effects of climate warming, it would be prudent for the bordering countries to implement precautionary actions to protect present and future fishery yields with a cap and sustain strategy aimed at supporting long term food security and economic development needs.

4.5.3 Data availability for the LMEs of the APEC region

Matrices can be employed in an effort to understand interactions between ocean uses. Governance efforts are important for two major reasons: (i) incompatible human uses of the LME and its goods and services that result in multisectoral interference; and (ii) human uses of the LME environment that interfere with natural processes and limit the potential for future use of the LME environment. **Matrixes 1** and **2** (Juda and Hennessey 2001) directly address these matters.

Matrix 1
Use Interaction

Human Uses

Human / Uses	Shipping/ ports	Fishing	Aqua-culture	Industrial siting	Re-creation	Waste Disposal	Housing	Military Uses	Agriculture	Forestry
Shipping/ ports										
Fishing										
Aquaculture										
Industrial siting										
Recreation										
Waste Disposal										
Housing										
Military Uses										
Agriculture										
Forestry										

scale:

1 2 3 4 5 6 7 8 9 10

compatible — conditionally compatible — incompatible

Matrix 2
Effects of Human Use on Ecosystems

Ecosystem alterations

Human Use	oxygen depletion	eutrophication	habitat destruction	turbidity increase	coastal erosion	change in biodiversity	pathogen contamination	introduction of alien species	change in water temperature
Fishing									
Aquaculture									
Dredging									
Navigation									
Military Uses									
Waste Disposal									
Recreation									
Industrial Siting									
Agriculture									
Forestry									
Off-Shore Oil									

scale:

1 2 3 4 5 6 7 8 9 10

inconsequential moderate substantial

LME Governance profiles can allow for comparisons and lessons learned in assessing whether an LME governance mechanism is effective (Juda and Hennessey 2001)

Another approach to assessing governance is based on Olsen et al. (2006) who have developed tangible indicators of progress in ecosystem-based LME governance through four orders of LME outcomes. This set of governance indicators can be used to follow the LME assessment and management system as it progresses from the baseline conditions documented by the GEF TDA and SAP process to more sustainable conditions and patterns of use. The first order (i) assembles the enabling conditions for ecosystem-based management. These conditions are created by a successful TDA/SAP process in the development of an LME Project. The second order (ii) shows evidence of a successful implementation of an ecosystem-based management program. The third order outcomes (iii) mark the achievement of the program's goals, including targets achieved for the reduction of coastal pollution, the restoration of damaged habitats, the recovery of depleted fisheries, and improved local community incomes and socioeconomic conditions and benefits. The fourth order outcomes (iv) include achieving a dynamic equilibrium among both social and environmental conditions (**Figure 41**).

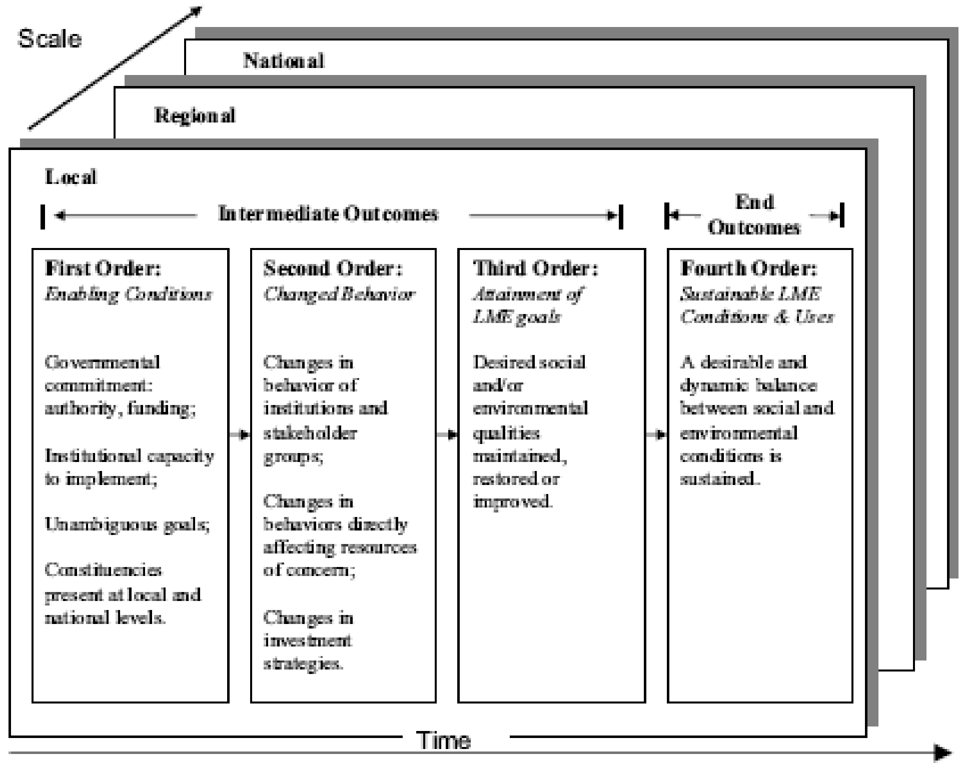


Figure 41. The Four Orders of Outcomes in Ecosystem-Based Management (Olsen, Sutinen et al. 2006)

In each of the LMEs, governance jurisdiction can be scaled to ensure conformance with existing legislated mandates and authorities (Olsen, Sutinen et al. 2006). An example of multiple governance-related jurisdictions is shown in **Figure 42** for the Northeast US Continental Shelf LME. The 260,000 km^2 spatial extent of the LME ecosystem encompasses multiple levels of marine management, governance and jurisdiction. The fisheries are managed in the Southern New England, Middle Atlantic and Georges Bank sub-areas of the LME by the New England Fishery Management Council, and the fisheries in the Mid-Atlantic sub-area, by the Mid-Atlantic Fishery Management Council. The estuaries and the ocean areas within 3 miles of the coast are under the jurisdiction of the coastal states of the United States from Maine to North Carolina. The US Environmental Protection Agency provides grants to these states for monitoring changing ecological conditions using the 5 LME pollution and ecosystem health indicators. Other governance and management units are the National Estuarine Research Reserve System (NERRS), several marine fisheries protected areas and management sites, and a national marine sanctuary. Each of the governance jurisdictions represented in Figure 47 contributes to an additive and integrated ecosystem assessment. Similarly, GEF-supported LME projects engage the governments of all the countries bordering the LME, along with their ministries of fisheries and agriculture, education, tourism, health and human services, together with major industrial groups and local stakeholders to reach agreement and prioritize actions to achieve integrated ecosystem assessments and optimize management decision-making. Other sectors also need to be considered including energy production, marine transport, hydrokinetic energy production, tourism and other special interests.

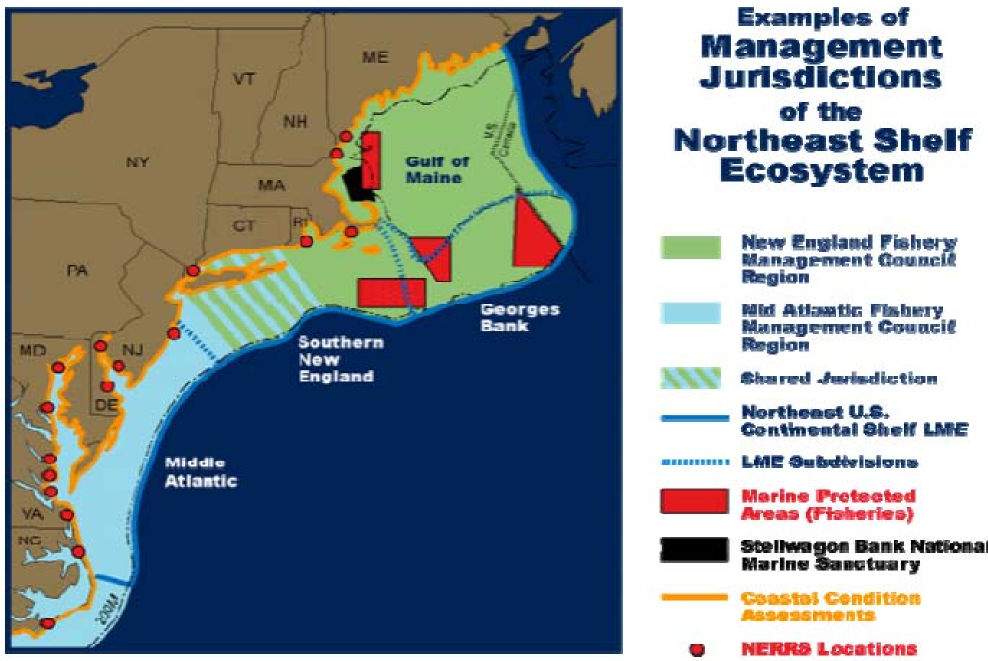


Figure 42. Multiple jurisdictions of the U.S. Northeast Continental Shelf LME.

5. GEF-FUNDED LME PROJECTS IN THE ASIA-PACIFIC REGION: TRANSBOUNDARY RESOURCES AND ECOSYSTEM CARRYING CAPACITY

There are presently 7 GEF-supported LME projects in the Asia Pacific Region: in the Bay of Bengal LME (8 APEC economies), the Gulf of Thailand LME (4 APEC economies), the Humboldt Current LME (2 APEC economies), the Indonesian Sea LME (2 APEC economies), the South China Sea LME (7 APEC economies), the Sulu Celebes LME (3 APEC economies), and in the Yellow Sea LME (2 APEC economies).

5.1 Transboundary Resources

In GEF-supported LME projects, the countries bordering an LME jointly prepare documents based on consensus that rank coastal resource issues, identify and prioritize transboundary resources and problems, analyze socioeconomic impacts, outline root causes and advance possible remedies and actions for sustaining LME goods and services. The process of planning and implementing a program to recover depleted fisheries, reduce coastal pollution and restore damaged habitats in an LME is provided financial support by the GEF for two 5-year phases. Following consensus reached on priority transboundary issues to be addressed, based on a 12-month period for completing the Transboundary Diagnostic Analysis (TDA), and reaching agreement on a Strategic Action Program (SAP), the countries adjacent to the LME and partnering agencies prepare to implement an ecosystem-based assessment and management plan for the shared LME (Duda and Sherman 2002). In the mid-1990s the scientific basis for moving toward ecosystem-based assessment and management of marine goods and services was put forward by Lubchenco (1994)and the Ecological Society of America (Christensen, Bartuska et al. 1996). This movement represents a paradigm shift, moving from single species assessments to multiple species assessments for measuring changing ecosystem states on an annual basis, with a focus on both ecosystem goods and ecosystem services (**Figure 43**).

FROM	TO
Individual species	**Ecosystems**
Small spatial scale	**Multiple scales**
Short-term perspective	**Long-term perspective**
Humans: independent of ecosystems	**Humans: integral part of ecosystems**
Management divorced from research	**Adaptive management**
Managing commodities	**Sustaining production potential for goods and services**

Figure 43. A paradigm shift to ecosystem-based management (from Lubchenco J. 1994). The scientific basis of ecosystem management. 103rd Congress, 2d session, Committee Print. U.S. Government Printing Office.

The paradigm shift toward ecosystem- based management described by Lubchenco is further defined and endorsed by 212 senior researchers (McLeod, Lubchenco et al. 2005). The approach is now being operationalized in 17 GEF-supported LME projects in Africa, Asia, Latin America, and eastern Europe.

More recent attention has been focused on the diminished services to humans of marine ecosystems and the concern that small changes in ecosystem resilience and robustness can lead to non-linear interactions, regime shifts, and collapses (Levin and Lubchenco 2008). Risks of ecosystem collapse are significantly diminished in robust and resilient LMEs. It is important to maintain close linkages among management activities framed to sustain socioeconomic and ecosystem benefits. Monitoring and assessment methodologies for measuring changing states using the 5-module suites of indicators provide a scientific foundation for management policies that must also provide for socioeconomic benefits under a mutually agreeable governance regime. The Chief Technical Advisors of the

GEF-funded LME projects are adopting the 5-module approach to accommodate the unique attributes relative to present ecosystem conditions.

5.2 The TDA and SAP Process

The TDA and SAP provide the programmatic framework for focusing actions for recovery and then sustaining now depleted fisheries, restoring degraded habitats, controlling nutrient over-enrichment and coastal pollution, conserving biodiversity, and adapting to climate change while ensuring sustainability of socioeconomic benefits of ecosystem goods and services to the populations of coastal nations participating in the GEF-supported LME projects. Each LME project's TDA and SAP process is critical for integrating science into management in a practical way (Duda 2009). The TDA process identifies key issues and is jointly prepared by participating countries who prioritize the issues with an aim to maintain LME productivity, recover depleted fisheries stocks, conserve biodiversity, restore degraded habitats (e.g. corals, sea grasses and mangroves), reduce and control pollution and nutrient over-enrichment, and mitigate and adapt to climate change.

The SAP develops a process for the states sharing an LME to remediate the issues identified in the TDA (Duda 2009). The actions taken under the framework of the SAP are meant to optimize the socioeconomic benefits produced by LME goods and services. The LME project SAP translates the shared commitment and vision into action. To ensure the country-drivenness of the project, a period of 12 to 18 months is allocated to move ahead on adding and integrating multiple sectoral indicators of changing conditions of ecosystem goods and services across the five modules.

5.3 Linking River Basins and LMEs

The Global Environment Facility (GEF) also works at other scales, in support of LMEs. GEF-supported projects are piloting and testing ways to link LMEs, coasts, estuaries and freshwater basins through an ecosystem-based approach. The projects are linking the scale of river basins draining to coasts and LMEs in order to improve water flow regimes and reduce pollution loading (Duda 2009).

An example of a successful linkage of river basins and LMEs being replicated in other projects is the Danube River and Black Sea LME. Seventeen countries rely on the Danube River basin for economic, social and environmental services (Duda 2009). The Danube River waters have been subjected to nutrient over-enrichment by nitrogen and phosphorus from agricultural, municipal and industrial sources. Partnering with UNDP and the World Bank, the countries of the Black Sea basin are aiming to reduce nitrogen pollution in the Danube River watershed, initiate pollution reforms, restore wetlands and habitats, and invest in pollution reduction.

An ongoing project, funded by the GEF and supported by UNDP, is the *Partnerships in Environmental Management for the Seas of East Asia* (PEMSEA) Program, with its focus on integrated coastal management (ICM) and LMEs (Duda 2009). In the GEF-supported South China Sea and Gulf of Thailand LME Project, areas have been identified that are sensitive to inputs of nutrients from rivers bordering the South China Sea LME. A model is being developed for riverine inputs of nutrients to the South China Sea LME that can be used in management decision-making (www.thegef.org).

5.4 Securing Valuable Habitats for Communities' Livelihood and Food Security

In the South China Sea and Gulf of Thailand LMEs, there are 58 pelagic and 29 demersal fish species, 15 cephalopods, and 18 crustaceans of transboundary significance. The GEF-supported UNEP South China Sea and Gulf of Thailand LME project addresses the over exploitation of fish stocks, land based pollution, and habitat degradation and loss including sea grasses, mangroves and corals. Participating countries are China, Indonesia, Cambodia, Malaysia, Philippines, Thailand and Vietnam. The project builds on community knowledge of fish reproduction, is developing fish refugia and is establishing gear limits and fishing limits at critical periods of life cycles to sustain fisheries (Duda 2009). A procedure is being developed for determining regional values of coastal ecosystem goods and services (www.thegef.org).

5.5 Governance Mechanisms for Ecosystem-based Management

The LME Project SAP serves as an agreed-upon document guiding the implementation of actions identified in the TDA. Through GEF LME projects, countries are moving towards joint governance arrangements to address the priority transboundary issues identified in the LMEs they share. The process used to make determinations on priority issues relating to governance is a bottom-up, country-driven process. LME projects that have included in their SAPs issues to be resolved within the framework of a governance mechanism are the Guinea Current LME Project, the Benguela Current LME Project, and the Yellow Sea LME Project.

6. BEST PRACTICE APPLICATION OF THE GEF-LME PROJECT TRANSBOUNDARY DIAGNOSTIC ANALYSIS (TDA) AND STRATEGIC ASSESSMENT PROGRAM (SAP) PROCESS APPLIED INTHE YELLOW SEA LME PROJECT

The Yellow Sea Large Marine Ecosystem (YSLME) is a large shallow continental shelf area bordered by China and the Korean Peninsula. The Kuroshio Current coming from the East drives shelf water circulation. Oceanic fronts affect YSLME productivity. A schematic of thermal fronts is provided for the YSLME in **Figure**

44 (Sherman, Aquarone et al. 2009). Ten major estuaries discharge directly into the Yellow Sea LME. River discharges peak in the summer and have important effects on the LME's salinity and hydrography. Other major potential sources of

Figure 44. Fronts of the Yellow Sea LME. BSF, Bohai Sea Front; JF, Jiangsu Shoal Front; KyBF, Kyunggi (Kyonggi) Bay Front; SPF, Shandong Peninsula Front; WKoBF, West Korea Bay Front. Yellow line, LME boundary [after Belkin et al.(2009)].

nutrient input into the Yellow Sea LME are the atmosphere. The Yellow Sea is a very fast warming ecosystem, with an increase in SST since 1957 of 0.97ºC and 0.67ºC since 1982 (Sherman and Hempel 2008).

6.1 Application of the YSLME TDA Process and Five-module Methodology

The preliminary TDA was updated by China and South Korea, the two participating countries in the LME Project, in 2007. The TDA is a mechanism and process recommended by the GEF to ensure that nations sharing a Large Marine Ecosystem begin to address coastal and marine issues by jointly analyzing factual, scientific information on transboundary concerns (UNDP/GEF 2007). The TDA process involves all 5 modules of (i) productivity, (ii) fish and fisheries, (iii) pollution and ecosystem health, (iv) socioeconomics, and (v) governance. The first three modules are science-driven, while two modules address the socio-economic and political process (UNDP/GEF 2007).

The TDA aims to identify, quantify, and set priorities for the environmental problems that are transboundary in nature, and to identify the immediate, underlying and root causes of these transboundary problems. The TDA yields a list of priority issues and identifies "*transboundary effects and causes*" that make it "*desirable that the TDA process be conducted multilaterally*". *"The evaluation of priorities is based on the severity of the problem in the context of its effects on those drawing their livelihood from the water area concerned."* It is an examination of the *"reduction in economic gains from the area in relation to its potential"*. The TDA designates *"relative weightings to the causes at each level of hierarchy for each of the problems at the base of the causal chain analysis"* (UNDP/GEF 2007).

The causal chain analysis is an analytical tool helping to identify the causes of a problem with its effects. A simple causal chain is one-dimensional. Most often there are inter-linkages between causes and effects, and sectoral dimensions that also need to be taken into account. Immediate causes are usually a physical, biological or chemical variable (e.g. eutrophication). Underlying causes are those that contribute to the immediate causes, and can broadly be defined as underlying resource uses and practices, and their related social and economic causes. The social and economic causes might include waste management procedures, demand and supply market patterns, demographic pressure on coastal areas, environmental values and norms, access to information, democratic processes, etc. Some of these causes are of national origin, and others are of transboundary origin. Some are related to the symptoms of climatic change. Transboundary causes *"cannot be addressed by individual national actions alone"* (UNDP/GEF 2007).

6.1.1 YSLME (TDA) Productivity The Yellow Sea LME is a Class I, highly productive ecosystem (>300gCm^2yr) that supports substantial populations of fish, invertebrates, marine mammals and seabirds (Sherman and Hempel 2008). Ecosystem trends identified in the TDA show major changes over the past decades. There are signs of LME deterioration such as the decline of commercially important fish landings, increase of algal blooms and jellyfish blooms. The increase in the abundance of jellyfish in recent years is a *"reflection of changes in primary and secondary productivity in the system and alterations to the food web of the Yellow Sea"*. While it might appear that increased primary production (from nutrient over-enrichment) *"would be beneficial to the Yellow Sea system, it results in reduced diversity among algal and zooplankton species and some of the dominant algae may be harmful to higher organisms such as fish"* (UNDP/GEF 2007).

6.1.2 YSLME (TDA) Fish and Fisheries *"The Yellow Sea overall remains a productive fisheries area yielding over 2.3 million t. of wild fish*". *"The commercial catches in the Yellow Sea are mainly of migratory species and this intrinsically makes the nature of the issue a transboundary one."*. The principal issue in fish and fisheries is the decline in landings of many traditional commercially important species such as the Pacific Herring, and increased landings of low value species (UNDP/GEF 2007). Overfishing of pacific herring *"has undoubtedly contributed to the decline of this fishery with climatic changes also playing a role"*. The TDA identifies a reduction of benthos from 170 species in the 1950s to some 70 species in the 1980s. Marine and coastal living resources are overexploited (Tang 2009). In addition, climate change has contributed to an observed decline in landings of commercially important and vulnerable species that are important components of Yellow Sea biodiversity. The introduction of *Spartina* has altered the ecology of the YSLME system, further reducing biodiversity (UNDP/GEF 2007).

The increase in the abundance of jellyfish in recent years has caused interference with fishing activities. Issues identified include the overcapacity of the fishing sector, the lack of alternative livelihoods to fisheries, the unchecked demand for seafood, and bad fishing practices. Mariculture production grew to over 6 million t. in 2004, but its practices are unsustainable (UNDP/GEF 2007). Overfishing can disrupt food webs by targeting specific, in-demand species.

6.1.3 YSLME (TDA) Pollution and Ecosystem Health A summary of the types and nature of environmental problems relating to pollution is provided in the YSLME TDA. *"The primary cause of increased eutrophication is an increased supply of dissolved nitrogen through riverine and wastewater discharge.". "The adverse effects associated with eutrophication are excessive algal blooms that decrease water transparency and give rise to high concentrations of organic matter in surface waters often referred to as 'red tides'"*. It will be important to introduce buffer zones between agricultural activities and freshwaters to reduce runoff of agricultural contaminants including pesticide and fertilizer residues and animal sewage (UNDP/GEF 2007).

More than 30% of mud foreshores and lagoons have been lost over the past 30 years. The main effect of habitat loss is on the composition of communities and biodiversity in tidal mudflats. The loss of marshlands has caused a reduction in habitat for waterfowl and birds. The main cause of habitat loss, especially in estuaries and shallow bays, has been land reclamation for the purpose of mariculture, industrial development, salt pans, agriculture, and tourism facilities. Measures, however, have been taken to protect salt marshes (UNDP/GEF 2007).

Alien species have been introduced, primarily for aquaculture and mariculture. Scallops are an important mariculture species, introduced from Japan and the United States. Alien species have also been introduced inadvertently through ballast water in ocean transportation (UNDP/GEF 2007). A map prepared by the Korea Ocean Research and Development Institute (KORDI) and the World Wildlife Fund identifies priority areas for biodiversity conservation (**Figure 45**).

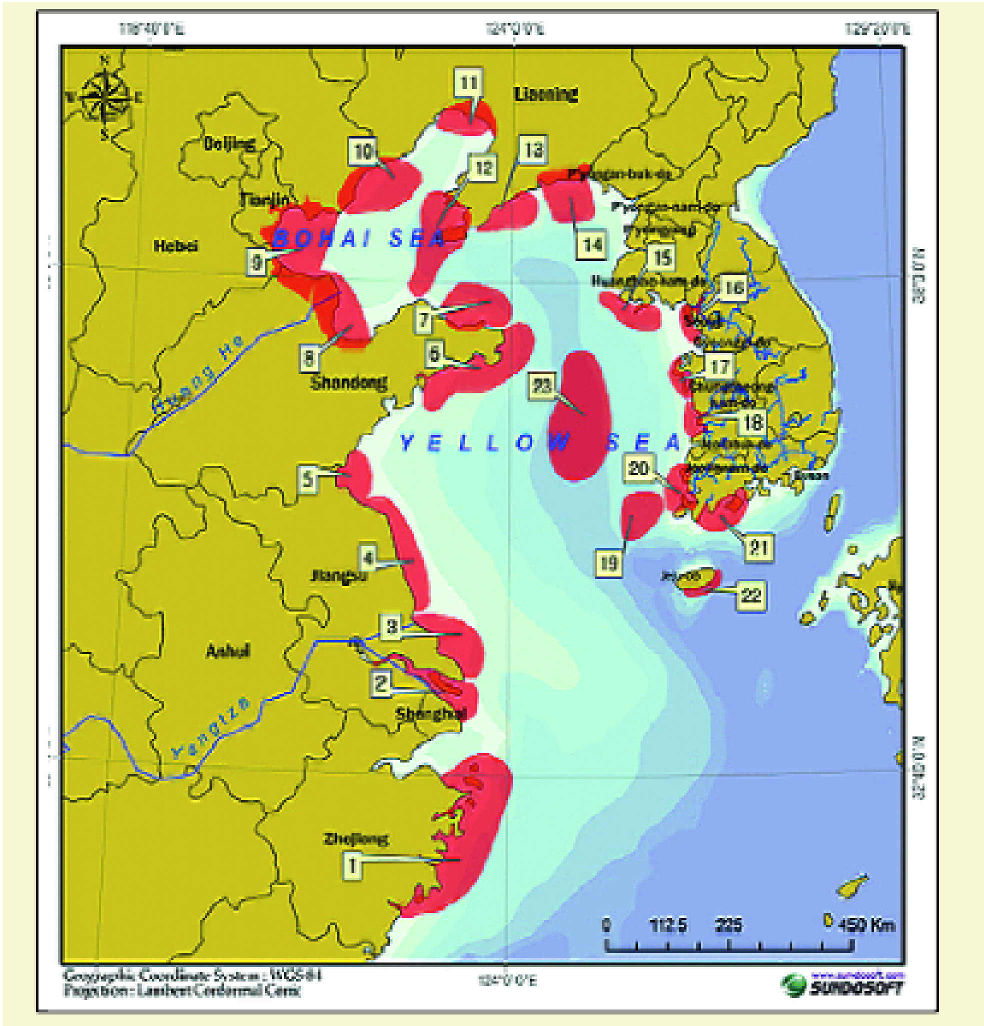


Figure 45. Priority areas for biodiversity conservation in the YSLME. After WWF et al. 2006. (UNDP/GEF 2007).

Releases from industrial, agricultural and municipal sources along with sewage from surrounding urban centers contribute to eutrophication, fecal contamination and marine litter. The release of excessive nutrients, bacteria, viral and fecal matter, and food residues has caused adverse effects on e.g. the production of penaeid shrimps, and also on environmental and human health concerns. The presence of toxic substances constitutes a *“hazard to human health that can result in reduced tourism opportunities and income as well as reduced value of seafood” (UNDP/GEF 2007)* . So far, there have been incremental investments in infrastructure for waste management, especially in China. Both the People’s Republic of China and the Republic of Korea are experiencing rapid economic and social development.

YSLME/ River Watershed Interface: Changing river discharge is clearly relevant to the status of LME biodiversity as it alters both the salinity and temperature regimes of estuaries and coastal areas directly influenced by freshwater discharge. This is especially true of freshwater discharge in summer and winter from the Yellow River. Other smaller rivers have seen their flow modified by engineering works in their drainage basins. An example of linkage between a river basin and the Yellow Sea LME is the GEF-supported Hai Basin Initiative led by China with assistance from the World Bank.

6.1.4 YSLME (TDA) Socioeconomics The areas draining into the Yellow Sea LME are inhabited by an estimated 600 million people. Large coastal cities depend on the LME as a source of food, economic development, recreation and tourism. The coastal areas are experiencing a growth in shipping and international trade. Fishing and mariculture constitute an important source of food, employment and foreign exchange to the states bordering the Yellow Sea LME (Sherman and Hempel 2008). Over the past decades, increased pollution has had severe socioeconomic impacts. The TDA identifies a need to take more account of environmental threats and achieve a balance in policies relating to economic expansion and environmental protection. Marine and coastal living resources are overexploited. Issues identified include the overcapacity of the fishing sector, the lack of alternative livelihoods to fisheries, the unchecked demand for seafood, and bad fishing practices (UNDP/GEF 2007).

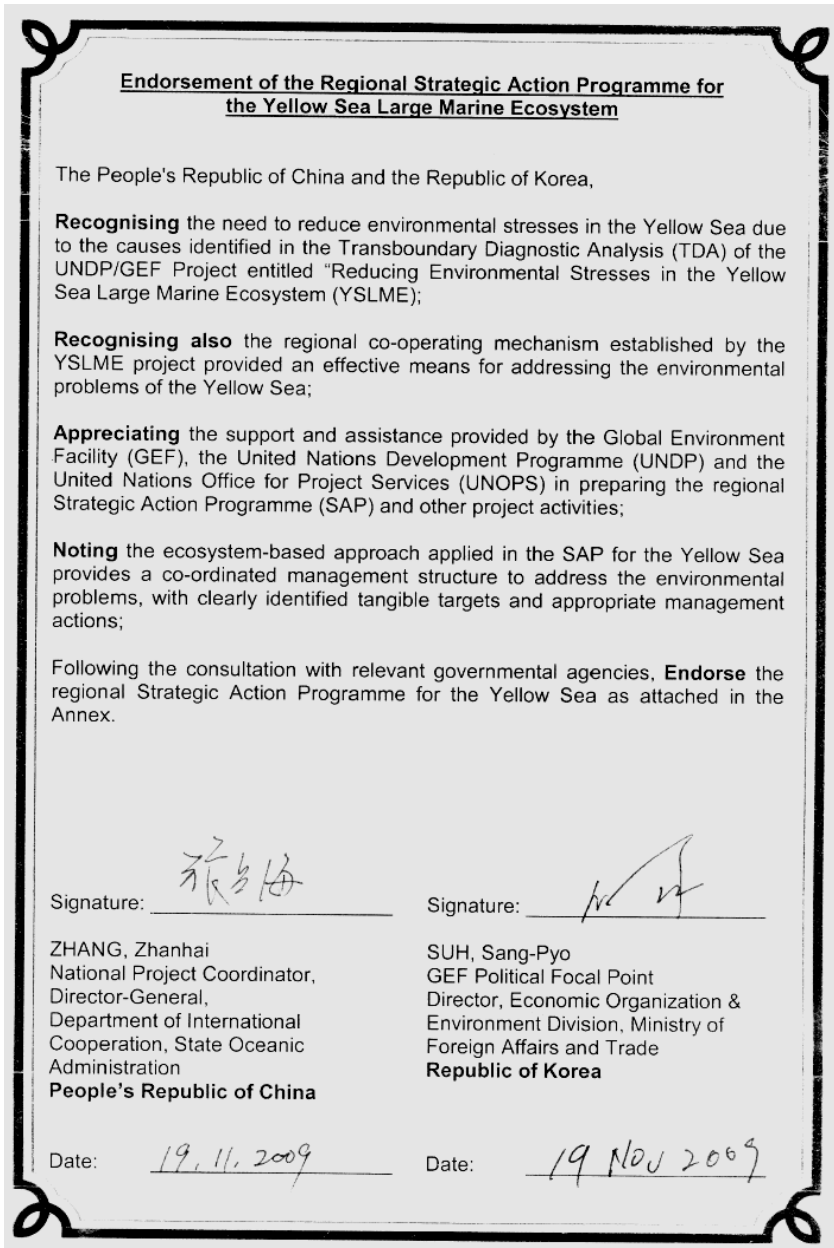
An imperative put forward by the GEF in its support of LME projects is to secure livelihoods while reversing natural resource depletion and degradation (Duda 2009) The economic evaluation of environmental goods and services is *"not sufficiently advanced to be used for the purposes of including in the TDA the cost of adverse effects on the environment associated with contemporary problems in the Yellow Sea" (UNDP/GEF 2007)*.

6.1.5 YSLME (TDA) Governance Governance of the YSLME is shared by the People's Republic of China, the Republic of Korea, and the Democratic People's Republic of Korea (DPRK). Presently, the DPRK is not participating in the YSLME project. The TDA identifies the lack of a comprehensive and coherent legislative framework to address transboundary problems in the Yellow Sea Large Marine Ecosystem, inadequate enforcement of legislation relating to coastal zone management and coastal protection, and illegal fishing activities (UNDP/GEF 2007). It is expected that the TDA document will serve as a basis for facilitating governance agreements between China and South Korea.

6.2 Application of the YSLME SAP Process and Five module Methodology

The Project TDA provided a basis for the subsequent formulation of the SAP. The aim of the SAP is "*to restore and preserve the YSLME. It will adopt a comprehensive approach and will address land and sea-based sources of marine pollution, degradation of critical habitats and over-fishing*". The SAP reiterates some of the environmental challenges identified in the Project TDA. Water is exchanged only every 7 years making the Yellow Sea LME vulnerable to pollution (UNDP/GEF 2009). The LME is described as very productive as it supports substantial populations of fish, birds, mammals, invertebrates. A huge human population resides in the coastal areas adjacent to the LME.

The SAP was endorsed at a high governmental level on 19 November 2009 by the People's Republic of China and the Republic of Korea (**Figure 46**).



Endorsement of the Regional Strategic Action Programme for the Yellow Sea Large Marine Ecosystem

The People's Republic of China and the Republic of Korea,

Recognising the need to reduce environmental stresses in the Yellow Sea due to the causes identified in the Transboundary Diagnostic Analysis (TDA) of the UNDP/GEF Project entitled "Reducing Environmental Stresses in the Yellow Sea Large Marine Ecosystem (YSLME);

Recognising also the regional co-operating mechanism established by the YSLME project provided an effective means for addressing the environmental problems of the Yellow Sea;

Appreciating the support and assistance provided by the Global Environment Facility (GEF), the United Nations Development Programme (UNDP) and the United Nations Office for Project Services (UNOPS) in preparing the regional Strategic Action Programme (SAP) and other project activities;

Noting the ecosystem-based approach applied in the SAP for the Yellow Sea provides a co-ordinated management structure to address the environmental problems, with clearly identified tangible targets and appropriate management actions;

Following the consultation with relevant governmental agencies, **Endorse** the regional Strategic Action Programme for the Yellow Sea as attached in the Annex.

Signature: ____________________

ZHANG, Zhanhai
National Project Coordinator,
Director-General,
Department of International Cooperation, State Oceanic Administration
People's Republic of China

Date: 19. 11. 2009

Signature: ____________________

SUH, Sang-Pyo
GEF Political Focal Point
Director, Economic Organization & Environment Division, Ministry of Foreign Affairs and Trade
Republic of Korea

Date: 19 NOV 2009

Figure 46. Endorsement of the Strategic Action Programme (SAP) for the Yellow Sea Large Marine Ecosystem by the People's Republic of China and the Republic of Korea on 19 November 2009.

The three main goals of the YSLME Project as outlined in the project SAP are:

1. to improve carrying capacity, sustain YSLME services, and provide food and genetic resources to meet the requirements of human wellbeing;

2. to improve sewage treatment and water quality regulation, and control disease;

3. to sustain YSLME cultural services for improved aesthetic values and attractiveness for recreation and ecotourism, by reducing marine litter and contaminants around bathing beaches and other recreational waters, and establishing nationally acceptable levels of pollution.

To achieve these goals, 12 selected targets are outlined in the Strategic Action Plan: (UNDP/GEF 2009).

6.2.1 YSLME SAP—Productivity The project TDA had found evidence of changes in the composition of both phytoplankton and zooplankton communities in the Yellow Sea LME, resulting in changes in the food web and threats to food supplies for living marine resources at higher trophic levels (UNDP/GEF 2007). Korea identified *"change in dominant groups of zooplankton"*, while China observed a changed ratio of diatoms to dinoflagellates. Two project targets for LME productivity are: to monitor and assess ecosystem structure and productivity; and to better predict ecosystem change. *"Monitoring is a continuous or periodic function that uses systematic collection of data, qualitative and quantitative, for the purposes of keeping activities on track"*. A goal is the establishment of a YSLME cross basin monitoring network and the implementation of regional monitoring activities, including scientific research. In the YSLME, the warming trend is significant and has been accelerating, leading to a northward movement of isothermals during that period. Climate change will affect marine ecosystems by altering large scale oceanic circulation patterns. Intensified stratification can reduce the productivity of the upper layer (UNDP/GEF 2009). The increase in carbon dioxide emissions is also causing acidification of sea water. Measures will include the development of a monitoring and assessment strategy and an assessment of pollution. A regional workshop will be held every 5 years, focused on monitoring and assessment technology.

6.2.2 YSLME (SAP) Fish and Fisheries Two targets for the fish and fisheries module are: to increase fisheries by reducing fishing pressures through a 25-30% reduction in fishing effort and a reduction in the number of fishing boats; and to rebuild over-exploited fish stocks. Presently, the level of fisheries exploitation is not sustainable. Fish catches are now dominated by short lived, smaller, lower trophic level and less valuable species such as anchovy and sandlance. The loss of key fish species through overfishing is thought to allow the blooms of flagellate and jellyfish. Rebuilding over-exploited fish stocks will need to be combined with reducing pollutant discharge. Other management measures will include an increase of mesh size to reduce the percentage of juveniles caught and the use of more selective fishing gear. Consideration is being given to the establishment of 10 protected areas for fishery resources in the YSLME (UNDP/GEF 2009).

6.2.3 YSLME (SAP) Pollution and Ecosystem Health Six targets for this module are: to monitor the impacts of nutrient ratio change and climate change; reduce nutrient loading; reduce marine litter and the contamination of beaches; improve the biodiversity status; maintain habitats; and reduce the risk from introduced species. The Yellow Sea LME has two seasonal water circulation patterns, *"but water circulation is weak, meaning that coastal areas are susceptible to localised pollution discharges"* (UNDP/GEF 2009).

The LME is also very vulnerable to eutrophication, which *"promotes phytoplankton growth to such an extent that the bloom collapses, and the resulting bacterial decomposition causes oxygen depletion in the surrounding water causing fish kills and mass mortality of other less mobile organisms."* A stated goal is to control total loading of pollutants, and to establish a regional conservation plan to protect endemic and vulnerable species. Another goal is to establish new MPAs and improve the effectiveness of existing nature reserves to reduce stress, loss or modification of critical marine habitats. The project aims to update knowledge of current waste treatment facilities, improve treatment systems and capacities, and establish new facilities (UNDP/GEF 2009).

6.2.4 YSLME (SAP) Socioeconomics The USLME Strategic Action Programme set two targets for capture fisheries to be realized by 2020: (i) a 33% reduction of fishing effort for capture fisheries and (ii) rebuilding of fish stocks. Management actions have already been implemented to reduce fishing effort by reducing the size of the fishing fleet, limiting the places and seasons of fishing, and controlling mesh sizes (Walton and Jiang 2009). The demand for fisheries products during the reduction in fishing effort will be met by scaling up advanced technological methods for increasing the carrying capacity of coastal mariculture through the application of integrated multi-trophic aquaculture (**Figure 47**).

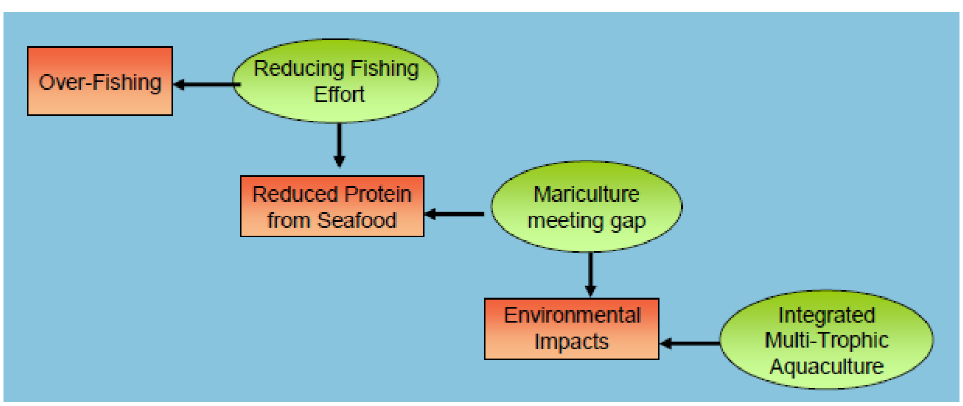


Figure 47. Logical considerations of management implementation (after Walton & Jiang 2009)

It is expected that scaling up of Integrated Multi-trophic Aquaculture IMTA methodology will result in improved water quality and greatly expanded production of shrimp, mollusks and other invertebrate species (e.g., abalone, bay scallops, sea cucumbers) to one million tons per year by 2020. Included in the SAP will be (1) demonstrated effectiveness of closed areas and seasons in the capture fisheries, (2) demonstrated effectiveness of stock enhancement practices and (3) demonstrated effectiveness of an accelerated vessel buy-back effort. In addition, the Republic of Korea will be significantly expanding sea sampling operations. The recovery actions, based on spatial oriented fisheries carrying capacity models will result in significant socioeconomic benefits to China and Korea from sustainable yields to be derived from both the capture fisheries recovery effort and the IMTA technology supporting large scale mariculture expansion (Walton and Jiang 2009) .

6.2.5 YSLME (SAP) Governance The governance target outlined in the SAP is to meet international contaminant requirements. The countries bordering the LME have chosen a combination of improvements in environmental legislation and enforcement, and aim to improve regional coordination and cooperation within national government agencies. The YSLME Commission is being planned as an institutional vehicle, serving to coordinate national efforts and to enhance the effectiveness of regional efforts. It is to be a soft, non legally binding, cooperation-based institution. It will be based on a joint declaration or MOU. Efforts will be made to ensure the DPRK's full participation in the YSLME Commission. The SAP, endorsed at a high governmental level by the People's Republic of China and the Republic of Korea, identifies the need for process indicators to characterize this institutional process (UNDP/GEF 2009). The YSLME Commission will focus effort on the recovery and sustainability of the present degraded state of transboundary goods and services.

6.3 YSLME Best Practices and Carrying Capacity

Project best practices for the YSLME can be identified at the all planning phases. The YSLME Project has well defined goals and a time line that were agreed upon in the project TDA and SAP. The rationale for the LME project along with a summary of project goals are described in project newsletters and book chapters (UNDP/GEF 2009; Walton and Jiang 2009). The project manager is in charge of financial aspects and constraints, the definition of project tasks, their sequence and duration, and problem solving. The project manager also understands how the existing governance system works. Good communication skills are critical. While each LME is unique, the YSLME project outcome can be replicated in other LME projects with similar conditions along with some of its best practices.

The SAP defines "ecosystem carrying capacity" as the capacity of the ecosystem to provide its services or the sum of all the ecosystem services it can provide (UNDP/GEF 2009). The SAP provides a road map for improving the carrying capacity of the YSLME. Over the past decades there have been signs of ecosystem deterioration, such as the decline of commercially important fish landings, increase of algal blooms and jellyfish blooms. The problem can be summarized in five broad categories: unsustainable fisheries, pollution, habitat modification, climate change, and unsustainable mariculture.

The goal of ecosystem management is to maximize and sustain ecosystem services. Because there are linkages and tradeoffs among services, if aquaculture production, for instance, is unsustainably maximized, then other services will be diminished in addition to reduction of wild fish catch (UNDP/GEF 2009). This is why sectoral approaches to assessment and management have not been very successful. Another issue is that not all the drivers of ecosystem change are controllable (e.g. climate change).

The YSLME SAP states the need for a holistic and comprehensive approach based on carrying capacity, determined by the various ecological processes that are interdependent, "which in turn are determined by ecosystem configuration and state". While environmental conditions change, management efforts can focus on an adaptive, learning based process that applies the principles of scientific methods to the process of management For pollution, it may be possible to estimate conservatively the capacity of the marine environment to assimilate waste materials based on current knowledge of physical, chemical, and biological conditions in the YSLME. Such assimilative capacities would be calculated to also define the density of acceptable coastal development (TDA p. 75). It should be possible to calculate the assimilative capacity of coastal embayments and the YSLME as a whole, and determine acceptable limits)(TDA p. 94). Actions to be undertaken, based on ecosystem carrying capacity, are listed in the YSLME SAP action plan and summarized in **Figure 48**. The full text of the Strategic Action Programme for the YSLME (ISBN: 978-89-964543-0-4 93530) is available online from the YSLME website at www.yslme.org/pub/SAP.pdf.

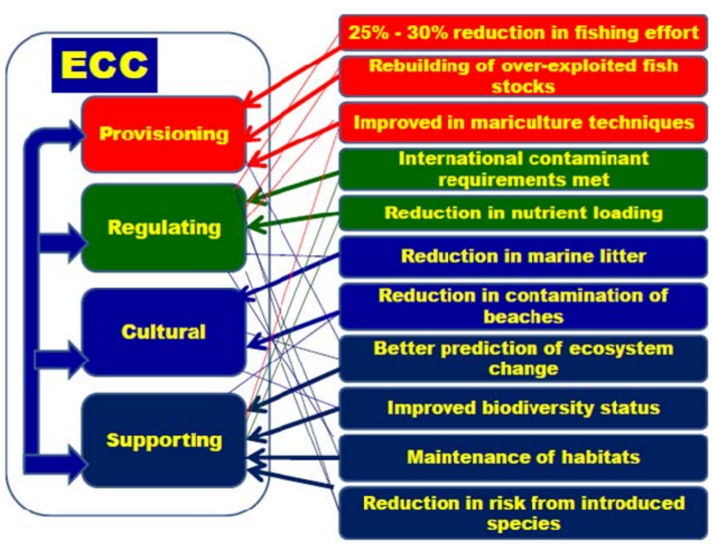


Figure 48. The relationship between Ecosystem Carrying Capacity (ECC), ecosystem services (left) and the YSLME targets (right) that seek to maintain these services (UNDP/GEF 2009).

REFERENCES CITED

AFSC (2006). Cooperative Acoustic Surveys, year index available for all years online at <http://www.afsc.noaa.gov/quarterly/amj2006/divrptsREFM7.htm>, NOAA, NMFS, Alaska Fisheries Science Center.

Aiken, J., R. Pollard, et al. (1999). Measurements of the upper ocean structure using towed profiling systems. Large marine ecosystems of the Pacific Rim: Assessment, sustainability, and management. K. Sherman and Q. Tang. Malden, MA, Blackwell Science, Inc**:** 346-362.

Alcamo, J., J. J. G. K. Kreileman, M.S., et al. (1994). "Modeling the global society-climate system: Part 1: Model description and testing." Water Air Soil Pol. **76**: 1-35.

Beddington, J. R. (1995). "The primary requirements." Nature **374**: 213-214.

Behrenfeld, M. J. and P. G. Falkowski (1997). "Photosynthetic rates derived from satellite-based chlorophyll concentration." Limnology and Oceanography **42**((1)): 1-20.

Behrenfeld, M. J., R. O'Malley, et al. (2006). "Climate-driven trends in contemporary ocean productivity." Nature **444**: 752-755.

Belkin, I. (2009). "Rapid warming of Large Marine Ecosystems." Progress in Oceanography **81**(1-4): 207-213.

Belkin, I. M., P. C. Cornillon, et al. (2009). "Fronts in Large Marine Ecosystems " Progress in Oceanography, **81**(1-4): 223-236.

Belkin, I. M. and J. E. O'Reilly (2009). "An algorithm for oceanic front detection in chlorophyll and SST satellite imagery." Journal of Marine Systems **78**( ): 319-326.

Berman, M. S. and K. Sherman (2001). "A towed body sampler for monitoring marine ecosystems." Sea Technology **42**(9): 48-52.

Beusen, A. H. W., A. D. Dekkers, et al. (2005). "Estimation of global river transport of sediments and associated particulate C, N and P." Global Biogeochemical Cycles **19**(4): GB4S06.

Bouwman, A. F. (1997). Long-term scenarios of livestock-cropland use interactions in developing countries. Land Wat. Bull. 5. Rome, Italy, Food and Agriculture Organization of the United Nations.

Bouwman, A. F., K. W. Vanderhoek, et al. (1995). "Uncertainties in the global sources distribution of nitrous oxide." Journal of Geophys Res-Atmos. **100**: 2785, 2800.

Cayula, J.-F. and P. Cornillon (1992). "Edge detection algorithm for SST images " J. Atm. Oc. Tech. **9**((1)): 67-80.

Cayula, J.-F. and P. Cornillon (1995). "Multi-image edge detection for SST images." J. Atm. Oc. Tech. **12**(4): 821-829.

Cayula, J.-F. and P. Cornillon (1996). "Cloud detection from a sequence of SST images." Rem. Sens. Envir. **55**(1): 80-88.

Cheung, W. L., V. W. Y. Lam, et al. (2009). "Projecting global marine biodiversity impacts under climate change scenarios." Fish Fisheries **10**: 235-251.

Christensen, N. L., A. M. Bartuska, et al. (1996). "Report of the Ecological Society of America committee on the scientific basis for ecosystem management." Ecological Applications **6**(3): 665-691.
Christensen, V., C. J. Walters, et al. (2009). "Database-driven models of the world's Large Marine Ecosystems." Ecological Modelling **220**: 1984-1996.
Costanza, R., R. d'Arge, et al. (1997). "The value of the world's ecosystem services and natural capital." Nature **387**(15 May 1997): 253-260.
Dentener, F. J., J. Drevet, et al. (2006). "Nitrogen and sulfur deposition on regional and global scales: A multimodel evaluation." Global Biogeochemical Cycles **20**: GB4003, doi: 4010.1029/2005GB002672.
Duda, A. M. (2009). GEF Support for the Global Movement toward the Improved Assessment and Management of Large Marine Ecosystems. Sustaining the World's Large Marine Ecosystems. K. Sherman, M. C. Aquarone and S. Adams. Gland, Switzerland, International Union for Conservation of Nature and Natural Resources (IUCN)**:** viii+140p.
Duda, A. M. and M. T. El-Ashry (2000). "Addressing the global water and environmental crises through integrated approaches to the management of land, water, and ecological resources." Water International **25**: 115-126.
Duda, A. M. and K. Sherman (2002). "A new imperative for improving management of large marine ecosystems." Ocean and Coastal Management **45**(2002): 797-833.
Dumont, E., J. A. Harrison, et al. (2005). "Global distribution and sources of dissolved inorganic nitrogen export to the coastal zone: Results from a spatially explicit, global model." Global Biogeochemical Cycles **19**(4): GB4S02.
ECOPS, ESF, et al. (1995). Joint Baltic Sea ecosystem studies: A science plan for an interdisciplinary ecosystem analysis in the Baltic Sea. Report of 4 international Baltic Sea workshops: 18-19 March 1993; 4-10 November 1993; 6-8 June 1994; 22-25 January 1995. Helsinki, HELCOM.
Epstein, P. R. (1993). "Algal blooms and public health." World Resource Review **5**(2): 190-206.
Epstein, P. R. (2000). "Algal blooms and public health." World Resource Review, 1993: The state of the world fisheries and aquaculture. FAO Rome 2000 **5**(2): 190-206. 142p.
Galloway, J. N., F. J. Dentener, et al. (2004). "Nitrogen cycles: Past, present and future." Biogeochemistry **70**: 153-226.
Galloway, J. N., F. J. Dentener, et al. (2004). "Nitrogen cycles: Past, present and future." Biogeochemistry **70**: 153-226.
Green, P. A., C. J. Vörösmarty, et al. (2004). "Pre-industrial and contemporary fluxes of nitrogen trough rivers: A global assessment based on topology." Bioigeochemistry **68**: 71-105.
Halpern, B. S., S. Walbridge, et al. (2008). "A global map of human impact on marine ecosystems." Science **319**: 948-949.
Harrison, J. A., S. P. Seitzinger, et al. (2005). "Dissolved inorganic phosphorous export to the coastal zone: Results from a new, spatially explicit, global model (NEWS-SRP)." Global Biogeochemical Cycles **19**(4): GB4S03.

Harrison, J. H., N. F. Caraco, et al. (2005). "Global patterns and sources of dissolved organic matter export to the coastal zone: Results from a spatially explicit, global model." Global Biogeochemical Cycles **19**(4): GBS406.
Harvell, C., K. Kim, et al. (1999). "Emerging marine diseases--Climate links and anthropogenic factors." Science **285**: 1505-1510.
HEED. Health Ecological & Economic Dimensions of Global Change (1998). Marine Ecosystems: Emerging Diseases as Indicators of Change. Year of the Ocean Special Report on Health of the Oceans from Labrador to Venezuela. P. R. Epstein, B. H. Sherman, E. S. Siegfriedet al. Cambridge, MA, The Center for Health and the Global Environment, Harvard Medical School.
HELCOM (2001). Environment of the Baltic Sea area. Baltic Sea Environment Proceedings No. 82A, Helsinki Commission**:** 23p.
Hoagland, P. and D. Jin (2006). Accounting for economic activities in Large Marine Ecosystems and Regional Seas, UNEP Regional Seas Reports and Studies 181. Nairobi, Kenya, UNEP Regional Seas Programme.
Hoagland, P. and D. Jin (2008). "Accounting for marine economic activities in large marine ecosystems." Ocean & Coastal Management **51**(3): 246-258.
Howarth, R., D. Anderson, et al. (2000). "Nutrient pollution of coastal rivers, bays and seas." ESA Issues in Ecology **7**: 1-15.
Howarth, R. W., G. Billen, et al. (1996). "Regional nitrogen budgets and riverine N & P fluxes for the drainages to the North Atlantic ocean: Natural and human influences." Biogeochemistry **35**: 75-139.
IPCC (2001). Climate Change 2001: Synthesis Report. A Contribution of WorkingGroups I, II and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, NY, USA, Cambridge University Press**:** 398p.
Juda, L. and T. Hennessey (2001). "Governance profiles and the management of the uses of large marine ecosystems." Ocean Development and International Law **32**: 41-67.
Kroeze, C. and S. P. Seitzinger (1998). "Nitrogen inputs to rivers, estuaries and continental shelves and related nitrous oxide emissions in 1990 and 2050: A global model." Nutrient Cycling in Agroecosystems **52**: 195-212.
Levin, S. A. and J. Lubchenco (2008). "Resilience, robustness, and marine ecosystem-based management." Bioscience **58**(1): 27-32.
Lubchenco, J. (1994). The scientific basis of ecosystem management: Framing the context, language, and goals. Ecosystem management: Status and potential. J. Zinn and M. L. Corn, 103rd Congress, 2d Session, Committee Print. U.S. Government Printing Office, Superintendent of Documents. 33-39.
McLeod, K. I., J. Lubchenco, et al. (2005). "Scientific Consensus Statement on Marine Ecosystem-Based Management. Signed by 221 academic scientists and policy experts with relevant expertise.", from www.compassonline.org/pdf_files/EBM_Consensus_Statement_v12.pdf.
NEFSC (2002). Assessment of 20 Northeast groundfish stocks through 2001: A Report of the Groundfish Assessment Review Meeting (GARM), 8-11 October 2002. Woods Hole, MA, Northeast Fisheries Science Center.

NEFSC (2006). Northeast Fisheries Science Center research vessel groundfish surveys overviews. www.nefsc.noaa.gov/sos/vesurv/vesurv.html , A description of the Alaskan Fisheries Science Center 2006 Aleutian Islands.

NMFS (2009). Our Living Oceans. Report on the status of U.S. living marine resources, 6th edition. NOAA Tech.Memo NMFS-F/SPO-90, U.S. Dep. Commer. **:** 369.

Olsen, S. B., J. G. Sutinen, et al. (2006). A Handbook on Governance and Socioeconomics of Large Marine Ecosystems. Kingston, RI, Coastal Resources Center, University of Rhode Island**:** 94.

Pauly, D., J. Alder, et al. (2008). Fisheries in large marine ecosystems: Descriptions and diagnoses. The UNEP Large Marine Ecosystems Report: A Perspective on Changing Conditions in LMEs of the World's Regional Seas. K. Sherman and G. Hempel. Nairobi, Kenya, UNEP.

Pauly, D. and V. Christensen (1995). "Primary production required to sustain global fisheries." Nature **374**: 255-257.

Pauly, D. and M. L. Palomares (2005). "Fishing down marine food webs: It is far more pervasive than we thought." Bulletin of Marine Science **76**(2): 197-211.

SAUP (2007). "Sea Around Us Project at www.saup.org."

Seitzinger, S., K. Sherman, et al. (2008). Filling Gaps in LME Nitrogen Loadings Forecast for 64 LMEs, Intergovernmental Oceanographic Commission Technical Series 79. Paris, France, UNESCO.

Seitzinger, S. P. and J. A. Harrison (2008). Land-Based Nitrogen Sources and Their Delivery to Coastal Systems. Nitrogen in the Marine Environment, 2nd edition. C. Capone, D. A. Bronk, M. R. Mulholland and E. Carpenter. Amsterdam, Elsevier**:** 469-510.

Seitzinger, S. P., J. A. Harrison, et al. (2005). "Sources and delivery of carbon, nitrogen and phosphorous to the coastal zone: An overview of global nutrient export from watersheds (NEWS) models and their application." Global Biogeochemical Cycles **19**(4): GB4S01.

Seitzinger, S. P., J. A. Harrison, et al. (2005). "Sources and delivery of carbon, nitrogen and phosphorous to the coastal zone: An overview of global nutrient export from watersheds (NEWS) models and their application." Global Biogeochemical Cycles **19**(4): GB4S01.

Seitzinger, S. P. and C. Kroeze (1998). "Global distribution of nitrous oxide production and N inputs to freshwater and coastal marine ecosystems." Global Biogeochemical Cycles **12**: 93-113.

Seitzinger, S. P., C. Kroeze, et al. (2002). "Global patterns of dissolved inorganic and particulate nitrogen inputs to coastal systems: Recent conditions and future projections." Estuaries and Coasts **25**(4b): 640-655.

Sherman, B. (2000). "Marine ecosystem health as an expression of morbidity, mortality, and disease events." Marine Pollution Bulletin **41**(1-6): 232-254.

Sherman, B. H. (2000). "Marine Disease, Morbidity and Mortality, Toward a Baltic Sea Information System." Bulletin of the Sea Fisheries Institute **3**(151): 2-17.

Sherman, B. H. (2001). "Assessment of multiple marine ecological disturbances: Applying the North American prototype to the Baltic Sea Ecosystem." Human and Ecological Risk Assessment **7**(5): 1519-1540.

Sherman, K. (1994). "Sustainability, biomass yields and health of coastal ecosystems: An ecological perspective." Marine Ecology Progress Series **112**: 277-301.
Sherman, K. (2005). The large marine ecosystem approach for assessment and management of ocean coastal waters. Sustaining the Large Marine Ecosystem: the human dimension. T. Hennessey and J. Sutinen. Amsterdam, Elsevier. **13:** 3-16. 368p.
Sherman, K. and S. Adams, Eds. (2010). Sustainable Development of the World's Large Marine Ecosystems during Climate Change: A commemorative volume to advance sustainable development on the occasion of the presentation of the 2010 Goteborg Award. Gland, Switzerland, IUCN, International Union for Conservation of Nature.
Sherman, K. and L. M. Alexander (1994). Management of large marine ecosystems. Encyclopedia of Environmental Biology. W. A. Nierenberg, ed. San Diego, CA, Academic Press, Inc.
Sherman, K., M. C. Aquarone, et al., Eds. (2009). Sustaining the World's Large Marine Ecosystems. Gland, Switzerland, IUCN.
Sherman, K., I. Belkin, et al. (2009). "Accelerated warming and emergent trends in fisheries biomass yields of the world's large marine ecosystems." Ambio **38**(4): 215-224.
Sherman, K., I. Belkin, et al. (2009). Indicators of Changing States of Large Marine Ecosystems. Sustaining the World's Large Marine Ecosystems. K. Sherman, M.-C. Aquarone and S. Adams. Gland, Switzerland, IUCN**:** 13-49.
Sherman, K., P. Celone, et al. (2004). NOAA Fisheries Service's Large Marine Ecosystems Program: Status Report, NOAA Technical Memorandum NMFS-NE-183, NOAA, NEFSC.
Sherman, K. and G. Hempel, eds. (2008). The UNEP Large Marine Ecosystem Report: A perspective on changing conditions in LMEs of the world's Regional Seas UNEP Regional Seas Report and Studies No. 182. Nairobi, Kenya, UNEP**:** 872p.
Sumaila, R., A. D. Marsden, et al. (2007). "A global ex-vessel price database: Construction and applications." Journal of Bioeconomics **9**: 39-51.
Tang, Q. (2009). Changing States of the Yellow Sea Large Marine Ecosystem: Anthropogenic Forcing and Climate Impacts. Sustaining the World's Large Marine Ecosystems. K. Sherman, M.-C. Aquarone and S. Adams. Gland, Switzerland, IUCN.
Trenberth, K. E., P. D. Jones, et al. (2007). Observations: Surface and Atmospheric Climate Change. Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. S. Solomon, D. Qin, M. Manninget al. Cambridge, UK and NY, Cambridge University Press**:** 235-336.
UN (1996). Country population statistics and projections 1950-2050. Report. U. Nations. Rome, FAO.
UNDP/GEF (2007). "Project: Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem. Transboundary Diagnostic Analysis." 98.
UNDP/GEF (2009). "Project: Reducing Environmental Stress in the Yellow Sea Large Marine Ecosystem, Strategic Action Programme for the Yellow Sea Large Marine Ecosystem." 56.

UNEP (2006). "Challenges to International Waters - Regional Assessments in a Global Perspective. United Nations Environment Programme, Nairobi, Kenya.".
USEPA (2004). National Coastal Condition Report. Washington, DC, United States Environmental Protection Agency**:** 286.
Walton, M. and Y. Jiang (2009). Some Considerations of Fisheries Management in the Yellow Sea Large Marine Ecosystem. Sustaining the World's Large Marine Ecosystems. K. Sherman, M.-C. Aquarone and S. Adams. Gland, Switzerland, IUCN.

ANNEX

Asia – Pacific Economic Cooperation

APEC LME Workshop on Marine Ecosystem Assessment and Management

Report of the
APEC MARINE RESOURCES Conservation Working Group

Seoul, Republic of Korea
8 – 9 September 2009

Korea Ocean Research and Development Institute (KORDI)
National Oceanic and Atmospheric Administration (NOAA), USA
Ministry of Land, Transport and Maritime Affairs (MLTM), Republic of Korea
UNDP/GEF YSLME Project
Asia Pacific Economic Cooperation (APEC)

TABLE OF CONTENTS

1. INTRODUCTION

The APEC Region comprises 21 Member Economies which account for approximately 41% of the world's population, 55% of world GDP and 49% of world trade. The marine goods and services of the Region contribute substantially to the annual GDP of the Member states. At present the marine resources are in a downward economic spiral resulting from overfishing, pollution, habitat degradation, nutrient over enrichment, climate warming and loss of biodiversity.

In recognition of the need to reverse the downward trend, the APEC Marine Resource Conservation Working Group organized its first scientific workshop on the assessment and management of APEC Large Marine Ecosystems (LMEs) in Qingdao, China in 2007. Co-chaired by the People's Republic of China and the United States, the workshop began the process of describing the Large Marine Ecosystems of the Asia-Pacific Region.

During the course of the first phase of the APEC LME project (2007 – 2008), the LMEs of the APEC region were described. The Project developed science based criteria to be used in identifying suites of indicators to monitor and assess change in LMEs. It also produced a map of the LMEs of the APEC Region (see ANNEX 3).

Phase 2 of the APEC LME Project aims to continue to assess LME goods and services of the APEC Region, with a particular focus on the economic benefits of a sustainable marine resource base, and on the legal and administrative support needed for ecosystem-based management practices.

The LME approach to assessment and management of marine goods and services combines the application of five modular suites of biological, physical, chemical, economic and governance indicators into an adaptive system for ecosystem-based management. The LME approach was developed by NOAA over the past 15 years and has been carried forward in partnership with UNDP, UNEP, UNIDO, IOC-UNESCO, FAO and IUCN. It is strongly supported by the Global Environment Facility (GEF), which funds 16 LME projects in Africa, Asia, Latin America and Eastern Europe. The 7 GEF funded LME projects in the APEC region are: the Yellow Sea, Bay of Bengal, Humboldt Current, South China Sea, Gulf of Thailand, Indonesian Sea, and Sulu Celebes LMEs.

2. WORKSHOP GOALS

The workshop in Seoul, Korea was convened to:

(i) report on the status of the Large Marine Ecosystems of the APEC region and on efforts to assess and manage them;

(ii) identify best practices of ecosystem assessment and management;

(iii) identify possible pilot projects in the LMEs of the APEC Region;

(iv) and establish and regular APEC LME Forum.

3. WORKSHOP PRESENTATIONS

Nine APEC economies were represented at the workshop in Seoul, Korea. The workshop included the representatives of Korea, China, Vietnam, the United States, Mexico, Indonesia, Malaysia, the Philippines, and Peru. The powerpoint presentations, meeting agenda, list of participants and photos of the meeting are available at: http://www.yslme.org/doc/apec/apec.htm. The agenda is listed in ANNEX I. The list of participants is in ANNEX II.

3.1 Introduction and Welcome

Mr. **Byoung-Gyu Seo**, Director General for Marine Environment Policy of the Ministry of Land, Transport, and Maritime Affairs of the Korean Government, opened the meeting and welcomed the participants from the nine APEC Economies. He underlined the importance of an ecosystem-based approach to management particularly at a time of global economic crisis.

Mr. **Seong-in Kim**, Deputy Director-General of the Multilateral Trade bureau of the Ministry of Foreign Affairs and Trade of the Korean Government, also welcomed the APEC participants and raised the issue of climate change and its impacts on the APEC region and its issues.

Dr. **Sinjae Yoo**, the principal research scientist of the Korea Ocean Research and Development Institute (KORDI), introduced the workshop's four terms of reference: (i) to review the status of APEC LMEs (ii) to identify best practices; (iii) to identify 2 pilot projects; and (iv) to network and establish a regular APEC LME forum. He made a presentation on the linkages and tradeoffs among ecosystem services, and ecosystem carrying capacity as a unifying target in a rapidly changing world, with modeling and scenarios useful on an LME scale.

3.2 LME Methodology

Dr. **Kenneth Sherman** presented the LME 5-module approach and newly published UNEP LME Report, which provides synopses of ecological conditions for each of the world's 64 LMEs, based on the five module assessment framework of (i) productivity, (ii) fish and fisheries, (iii) pollution and ecosystem health, (iv) socioeconomics, and (v) governance. The LME briefs are available to download from the website at: www.lme.noaa.gov. He congratulated the Yellow Sea Large Marine Ecosystem (YSLME) Project managers for placing this advanced LME project at the cutting edge of the success of the ecosystem based approach that established adaptive management protocols for recovering degraded conditions within the YSLME.

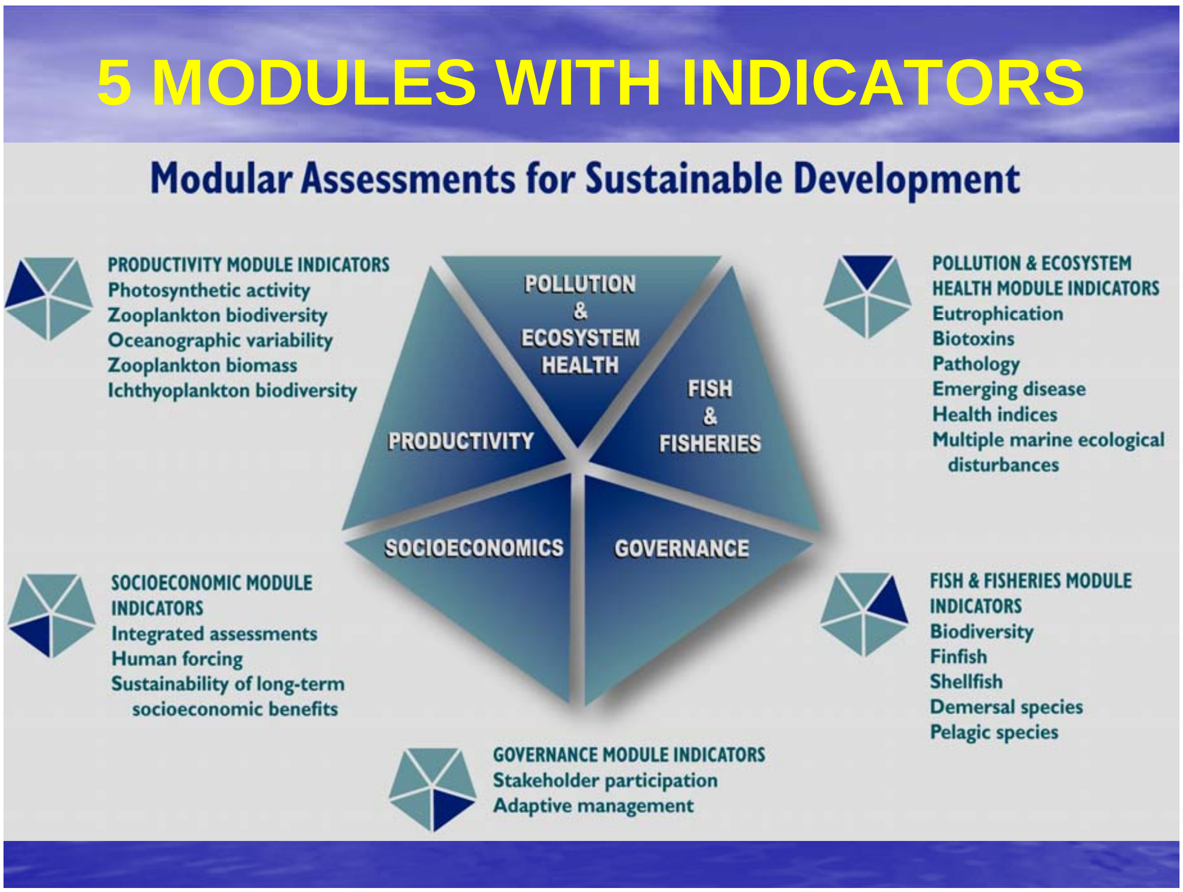


Figure 1. The LME approach uses indicators of ecosystem (i) productivity, (ii) fish and fisheries, (iii) pollution and ecosystem health, (iv) socioeconomics, and (v) governance. Taken together, the five LME modules provide indicators and metrics that can determine the changing states of LMEs and support actions for the recovery, sustainability, and management of marine resources and their habitats (Sherman et al. 2005).

The work on the LME productivity cycle of Dr. John O'Reilly and his colleagues from the NOAA laboratory in Narragansett, Rhode Island, and of the APEC LMEs, was shown for the first time. The video depicted the annual cycle of primary productivity encompassing daily, monthly, seasonal and annual levels for 2005 to 2009 for the whole APEC Region and for the East and West APEC Regions. The productivity projections are key ecosystem measures used as inputs to models of LME carrying capacity for fishery resources of LMEs (Christensen et al 2009).

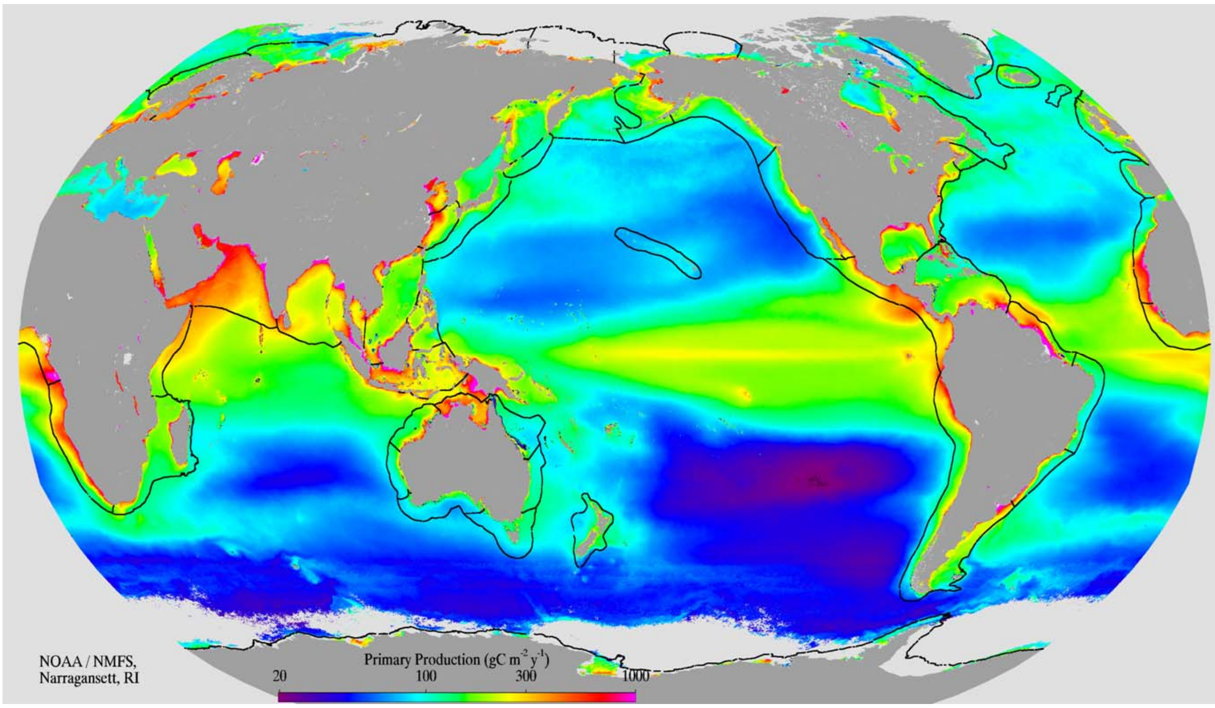


Figure 2. Productivity is measured in grams of carbon per square meter per year (gCm^{2}yr). This metric is a basic input to LME fisheries carrying capacity models (Christensen et al 2009), and serves as a useful indicator of the growing problem of coastal eutrophication. The UNEP LME Report (2008) contains information on the productivity of each LME.

3.3 Overview of the APEC funded Marine Resource Conservation Working Group and LME project

Dr. **Marie-Christine Aquarone,** the APEC LME Project overseer, provided an overview of the APEC funded Marine Resource Conservation Working Group (MRCWG) LME Project and LME map of 27 Large Marine Ecosystems of the APEC Region, produced in phase one of the project, now completed. Phase 2 will review the status of APEC LMEs, identify two pilot projects and identify best practices, to be included in a desktop analysis and publication in 2010.

Dr. **Hyung Tack Huh** reported on the APEC workshop and meetings of both the MRCWG and Fisheries WG that took place in June 2009 in Vancouver, Canada. Climate change was factored into the discussions, along with sharing best practices and tools for implementing both ecosystem-based management and the ecosystems approach to fisheries.

3.4 The Yellow Sea LME (YSLME) Project and Best Practices

Professor **Qisheng Tang** outlined the long term changes regarding regime shifts, marine species composition, and the complexity of control mechanisms in the Yellow Sea LME, where fisheries are changing to smaller size fish and lesser monetary value. In China, 300,000 fishing vessels are to be purchased by the national government and taken out of use. The displaced fishermen are to be retrained for other jobs.

Dr. **Sukgeun Jung** presented new information on climate driven ecosystem shifts indicated in fishery catch statistics (1968-2008) from Korean waters. The catch stabilized in the 1980s. He compared time series of saury, sardine, squid, Pollock, anchovy, mackerel, hairtail and croaker, investigating changes in species dominance, their sensitivity to climate, and the extent to which fluctuating catches and change in the dominant fishery species in Korean waters is overfishing or climate.

Professor **Qilun Yan** gave a thorough description of the Pollution and Ecosystem health Module for the Yellow Sea LME project and provided excellent summaries of nutrient over enrichment in East Asian LMEs. Nutrient rich rivers to the Yellow Sea LME are decreasing biodiversity and increasing the incidence of harmful algal blooms. Dr. Sherman made the comment that the issue of waste water treatment is not lost on the GEF. A GEF initiative with the World Bank is making $1.0 billion in funds available to build water treatment plants in East Asian LMEs and reduce the effects of point source nutrient over-enrichment.

Mr. **Yihang Jiang**, Project Manager, presented the ecosystem based approach taken by the YSLME Project. An oceanographic cruise was successfully implemented, and scientific observations have contributed to a better understanding of fisheries and harmful algal blooms. Dr. Sherman made the comment that the YSLME represents the world’s largest single effort to address the restoration of a highly degraded LME. Mr. Jiang answered that both governments of China and Korea have provided a very positive response by undertaking a massive effort to control capture overfishing, as described by Dr. Walton.

Dr. **Mark Walton** described the application of adaptive management practices of the fish and fisheries module in the Yellow Sea LME project and the 'cap and sustain' approach for sustaining fisheries yields, through massive reductions in fishing effort (30%), stock enhancement, habitat restoration, improved water quality, and the restoration of reefs. The fish caught in the LME are younger and smaller than in the past. Increasing numbers of large jellyfish are posing problems for fishermen. The Chinese Government is retraining the fishermen at great expense. The resulting estimated annual decline of 1.0 million tons of capture fisheries is expected to be replaced by advanced integrated multi trophic aquaculture (IMTA) practices during the rebuilding period of the capture fisheries. The IMTA process is expected to be expanded to produce an estimated 1.0 million metric tons of fisheries product annually. Initial results of the pilot project have demonstrated its efficiency in fisheries production and water quality improvement.

Professor **Suh-Yong Chung** discussed the institutionalization of the UNDP/GEF YSLME Project into a more permanent LME Commission that will build on the significant accomplishments of the project's first phase.

3.5 Reports on the assessment and management of Large Marine Ecosystems of the APEC Region

While Dr. **Marcelo Nilo,** of Chile, was unable to attend the meeting, he prepared a powerpoint of the Humboldt Current LME project which was presented to the meeting and well received. The project is back on track and will focus on Humboldt Current conservation, fisheries and climate change issues.

Dr. **Si Tuan Vo,** representing Vietnam, made a presentation on the South China Sea (SCS) LME project on reversing environmental degradation trends in the SCS and Gulf of Thailand and opportunities for extending the GEF Phase 1 Project. The project involves 7 countries. The area is still experiencing difficulties with maritime boundary delimitations. A project SAP was initiated in 2008, focused on fisheries refugia. Dr. **Azhar Hussin**, representing Malaysia on the same topic, underlined the importance of conserving the resources of the SCSLME including its islands, atolls, reefs and seagrass areas.

Dr. **Sapta Putra Ginting**, representing Indonesia, described the LME related GEF projects in the Indonesian Sea and the serious issue of IUU fishing and unsustainable fishing techniques. Indonesia participated in the South China Sea LME project executed by UNEP. The Coral Triangle Initiative by Indonesia is to promote marine resource conservati0n through the establishment and management of marine proteced areas. The successful community based management movement in Indonesia that also trains local people for coral reef monitoring might be a replicable practice. Indonesian policy is to stabilize the fish catch through 'cap and sustain' precautionary actions, and expand mariculture.

Dr. **Theresa Mundita S. Lim**, representing the Philippines, described the Sulu Celebes (or Sulu Sulawesi) LME activities and threats to corals in the large Coral Triangle area that covers several LMEs. Indonesia, Malaysia and the Philippines share the resources of the Sulu Celebes LME. The main issues are poaching, establishing and managing MPAs, and adapting to climate change.

Dr. **Antonio Diaz de Leon Corral** representing Mexico presented on the socioeconomic Benefits of the LME approach in the Gulf of California and Pacific Central American LMEs. Mexico has 5 LMEs and many conflict uses between industrial and artisanal fisheries, tourism and conservation, requiring a better understanding of the interconnections between economic, social and ecological systems, and an evaluation and prediction of socioeconomic impacts derived from the degradation of natural systems. Mexico and the US are jointly operationalizing the TDA and SAP process as part of a GEF supported LME project for the Gulf of Mexico LME.

3.6 Opportunities for pilot projects in the LMEs of the APEC Region

Dr. **Kenneth Sherman** made brief remarks on issues to keep in mind while considering the next step forward in APEC LME activities. These included global warming in all LMEs except for the California Current and the Humboldt Current; fairly serious fisheries overexploitation trends among the APEC member economies and LMEs, requiring a ‘cap and sustain’ approach at a five year average catch level; and the relative importance of marine goods and services to overall economic viability. Mangroves, corals, and nutrient over-enrichment are also important considerations. This was followed by a discussion on possible pilot LME projects in the APEC Region.

3.7 Establishing a regular APEC LME Forum

Mr. **Sunbae Hong,** representing the Korean Ministry of Land, Transport and Marine Affairs, presented a proposal for the continuation of an APEC LME Forum and regular LME workshop to facilitate ecosystem-based LME projects in the APEC region, enhance synergy effects between LME Projects and provide scientific information to the APEC MRCWG for its decision making. The main activities of the workshop would be to report ecosystem changes in the APEC LMEs, share know-how and best practice of LME projects in APEC region, and consider joint cooperative projects between APEC economies. A regular workshop would take place every year or every 2 years and would rotate among the various APEC economies. RO Korea would contribute some amount of financial support for the workshop.

4. DISCUSSION AND PLANNING FOR 2009-2010

The workshop participants discussed the Korean proposal for establishing a regular APEC LME Forum and Workshop, beginning in 2010. Regarding two possible pilot LME projects funded by the GEF in the APEC Region, Dr. Sherman explained that the GEF is supportive of a global LME movement that introduces ecosystem-based management to developing countries through country driven projects that can complement UNEP's Regional Seas activities. Two pilot projects discussed were the Indonesian Sea LME, which was welcomed by the Indonesian representative, and the Pacific Central American LME, which already has the attention and interest of several countries bordering the LME.

5. ADOPTION OF WORKSHOP RECOMMENDATIONS

- Two Pilot projects recommended: Indonesian Sea LME and Pacific Central American LME projects;
- Support Korea proposal for continuation of APEC LME Forum and Workshop on a regular basis to increase APEC economies ecosystem based capacity;
- Proposal for regular APEC LME workshop to be submitted at MRC WG (June 2010) and senior officials meeting (also in 2010).
- Proceed with a NOAA request for support by the APEC Secretariat of a Phase III project to support participation of the APEC community in a working group meeting for 2011. The meeting would be held in partnership with the Korean members of the LME APEC working group with the following terms of reference: (i) report on the status of large marine ecosystems of the APEC region in relation to climate change; and (ii) review best practices for LME assessment and management.

AGENDA 2009

APEC-LME Workshop on

Marine Ecosystem Assessment and Management

Seoul, Republic of Korea, 8-9 September 2009

Korea Ocean Research and Development Institute (KORDI)

National Oceanic and Atmospheric Administration (NOAA), USA

Ministry of Land, Transport and Maritime Affairs (MLTM), Republic of Korea

UNDP/GEF YSLME Project

Asia Pacific Economic Cooperation (APEC)

1. Purposes

The workshop aims:

- To report on the status and baseline assessment of the APEC region's Large Marine Ecosystems
- To identify the best practices of ecosystem assessment and management
- To seek opportunities for possible pilot projects in the LMEs of the APEC region, and
- To promote networking of APEC LMEs and establishing a regular forum.

2. Programme

- The list of participant will be uploaded soon.

DAY 1 – September 8, 2009

TIME	TOPIC	SPEAKER
09:00 – 12:00	**Session 1: Chairperson, Sinjae Yoo**	
09:00~09:15	Welcome Addresses	Byoung-Gyu Seo & Seong-in Kim
09:15~09:30	Introduction	Sinjae Yoo
09:30~10:00	The LME 5-Module Approach and UNEP LME Report	Kenneth Sherman
10:00~10:30	Ecosystem Carrying Capacity as a Unifying Target of Ecosystem Management	Sinjae Yoo
10:30 ~ 11:00	**COFFEE/TEA**	
11:00~11:30	Overview of APEC Funded MRCWG Large Marine Ecosystem Project and LME Map	Marie-Christine Aquarone
11:30~12:00	Report on APEC Workshop and Meetings in June 2009 in Vancouver I, II	Hyung Tack Huh
12:00~13:30	**LUNCH**	
13:30– 17:00	**Session 2: Chairperson, Marie-Christine Aquarone**	
13:30~14:00	Long Term Changes in the Yellow Sea Large Marine Ecosystem	Qisheng Tang
14:00~14:30	The Yellow Sea LME Project	Yihang Jiang
14:30~15:00	The Humboldt Current LME Project	M. Nilo
15:00~15:30	**COFFEE/TEA**	
15:30~16:00	The South China Sea LME: Opportunities for Extending the GEF Phase 1 Project	Si Tuan Vo & Azhar Hussin
16:00~16:30	Sulu Celebes LME Activities and Coral Triangle Initiative	Theresa Mundita S. Lim
16:30~17:00	The Indonesian Sea LME-related GEF Projects	Sapta Putra Ginting
17:00	**ADJOURN**	

DAY 2 – September 9, 2009

TIME	TOPIC	SPEAKER

09:00 ~12:00	Session 3: Chairperson, Kenneth Sherman	
09:00~09:30	Eleven Years of Ocean Productivity in the APEC Region (movie)	Kenneth Sherman & Marie-Christine Aquarone
09:30~10:00	The Pollution & Ecosystem Health Module: Nutrient Over-enrichment in East Asian LMEs	Qilun Yan
10:00~10:30	The Fish and Fisheries Module and the Cap and Sustain Approach for Sustaining Fisheries Yields	Mark Walton
10:30~11:00	**COFFEE/TEA**	
11:00~11:30	Climate-driven Ecosystem Shifts Indicated in Fishery Catch Statistics (1968-2008) from Korean Waters	Sukgeun Jung
11:30~12:00	Socioeconomic Benefits of the LME Approach in the Gulf of California and Pacific Central American LMEs	Antonio Diaz de Leon Corral
12:00~13:30	**LUNCH**	
13:30– 17:00	**Session 4: Chairperson, Sinjae Yoo**	
13:30~14:00	Institutionalizing UNDP/GEF YS LME Project	Suh-Young CHUNG
14:00~14:30	Future Plan for APEC LME Activities	Kenneth Sherman
14:30~15:00	Possible Pilot LME Projects in the APEC Region	ALL
15:00~15:30	**COFFEE/TEA**	
15:30~16:00	A Proposal for Continuation of APEC – LME Forum	Sunbae Hong
16:00~17:00	Discussion and Planning for 2009-2010 Adoption of Workshop Recommendations	ALL
17:00	**ADJOURN**	

Participants List 2009

APEC-LME Workshop on
Marine Ecosystem Assessment and Management

Seoul, Republic of Korea, 8-9 September 2009

Korea Ocean Research and Development Institute (KORDI)
National Oceanic and Atmospheric Administration (NOAA), US
Ministry of Land, Transport and Maritime Affairs (MLTM), Republic of Korea
UNDP/GEF YSLME Project
Asia Pacific Economic Cooperation (APEC)

List of Participants

Dr. Kyoung Ho AN
Director
Fisheries Resources and Environment Division
West Sea Fisheries Research Institute
National Fisheries Research and Development Institute
707, Eulwang-dong, Jung-gu
Incheon, 400-420, Korea
Tel: 82 32 745 0660
Fax: 82 32 74 0678
Email: khan@nfrdi.go.kr

Dr. Jung Hee CHO
Associate Research Fellow
Korea Maritime Institute
1652, Sangam-dong, Mapo-Gu
Seoul, 121-270, Korea
Tel: 82 2 2105 2856
Fax: 82 2 2105 2859
Email: jcho5901@kmi.re.kr

Prof. Joongki CHOI
Professor
Inha University
253 Yonghyundong Namgu
Incheon 402-751, Korea
Tel: 82 32 860 7704
Mobile: 82 10 8778 8094
Email: jkchoi@inha.ac.kr

Dr. Marie-Christine AQUARONE
Deputy Director
NOAA LME Program
28 Tarzwell Drive
Narragansett, RI 02882-1199, USA
Tel: 1 401 782 3288
Fax: 1 401 782 3201
Email: mc.aquarone@noaa.gov

Ms. Young Rae CHOI
Research Scientist
Strategy Development Team
Ocean Policy Division
Korea Ocean Research and Development Institute
Conservation Coordinator, WWF/KORDI
Yellow Sea Ecoregion Support Project
1270 Sa-2dong Sangnok-gu Ansan-si
Gyeoniggi-do 426-744 Republic of Korea
Tel: 82 31 400 7757
Fax: 82 31 400 6505
E-mail: yrchoi@kordi.re.kr

Prof. Suh-Yong CHUNG
Associate Professor
Division of International Studies
Korea University
5-1 Anam-dong Seonbuk-gu
Seoul 136-701, Korea
Tel: 82 2 3290 2424
Fax: 82 2 303 7838
Email: mahlerchung@korea.ac.kr
mahlerchung@yahoo.com

Dr. Antonio DIAZ de LEON CORRAL
Director General
Environment policy, Regional and Sectoral Information
Secretaria de Medio Ambiente y Recursos Naturales
Blvd. Adolfo Ruiz Corinez 4209 4 to piso Ala "A"
Col. Jardines en la Montana CP 14210
Mexico, D.F., Mexico
Tel: 52 (55) 56 28 07 49
Fax: 52 (55) 56 28 07 53
Email: adiazdeleon@semarnat.gob.mx

Dr. Shanti Dewi HAFSANITA
Research Cooperation and Communication Officer
Research Cooperation and Communication Division
Agency for Marine and Fisheries Research
JL. Pasir Putih Timur 1 Ancol Jakarta Utara 14430 Indonesia
Tel: 62 21 64711583
Fax: 62 21 64711438
Email: ksp.brkp@gmail.com

Dr. Seung HEO
Researcher
Marine Environment Division
West Sea Fisheries Research Institute
National Fisheries Research and Development Institute
707, Eulwang-dong, Jung-gu, Incheon, 400-420, Korea
Tel: 82 32 745 0675
Fax: 82 32 745 0678
Email: sheo2001@nfrdi.go.kr
seungheo@hanmail.net

Mr. Sun-Bae HONG
Assistant Director
Marine Environment Policy Division
Marine Policy Bureau
Ministry of Land, Transport and Maritime Affairs
2F, K-water, 188 Joongang-ro
Gwacheon-City, Gyeonggi-Do
Korea 427-100
Tel: 82 2 504 6747
Fax: 82 2 503 2070
Email: hong0610@mltm.go.kr

Dr. Hyung Tack HUH
Sr. Scientist Emeritus
Korea Ocean Research and Development Institute
12-41 Bangbae-dong, Seocho-gu
Seoul 137-060, Korea
Tel: 82 31 400 6201
Fax: 82 31 408 5934
Mobile: 82 11 743 0231
Email: hthuh@kordi.re.kr

Dr. Sik HUH
Principal Research Scientist
Marine Resources in the Korea EEZ and the Northeastern Asia Research Group
Korea Ocean Research and Development Institute
1270, Sa 2-dong, Sangnok-gu
Ansan City, 426-744 Gyeonggi –do, Korea
Tel: 82-31-400-6269
Fax: 82-31-400-6269
Email: sikhuh@kordi.re.kr

Dr. Azhar HUSSIN
Deputy Director
Institute of ocean and Earth Sciences (IOES)
University of Malaya
50603 Kuala Lumpur, Malaysia
Tel: 60 3 7967 6995
Fax: 60 3 7967 6994
Email: hhazhar@yahoo.co.uk

Dr. Sun-Do HWANG
Research Scientist
West Sea Fisheries Research Institute
National Fisheries Research and Development Institute
707, Eulwang-dong, Jung-gu, Incheon, 400-420, Korea
Tel: 82 32 745 0565
Fax: 82 32 745 0569
E-mail: sdhwang@nfrdi.go.kr

Dr. Yang-Jae IM
Researcher
West Sea Fisheries Research Institute
National Fisheries Research and Development Institute
707, Eulwang-dong, Jung-gu Incheon, 400-420, Korea
Tel: 82 32 745 0560
Fax: 82 32 745 0569
Email: ocean1982@korea.kr

Mr. Ismail Bin ISHAK
Head of Biotechnology and Fisheries Division
Biotechnology and Fisheries Division
Fisheries Research Institute, Department of Fisheries Malaysia
Jalan Batu Maung
11960 Batu Maung, Pulau Pinang, Malaysia
Tel: 60 4 6263925/3926/2981
Fax: 60 4 6262210
Email: anasofiah@hotmail.com

Prof. Jong-Chul JEONG
Professor
Namseoul University
21 Maeju-ri, Seongwan-eup, Cheonan City
Choongnam 330-800, Korea
Tel: 82 41 580 2375
Email: jjc1017@gmaul.com

Mr. Yihang JIANG
Project Manager
UNDP/GEF Yellow Sea Project
Korea Ocean Research and Development Institute
1270 Sa-2dong Sangnok-gu Ansan-si
Gyeoniggi-do 426-744 Republic of Korea
Tel: 82 31 400 7832
Fax: 82 31 400 7826
Email: yihang@yslme.org

Dr. Hyun-Su JO
West Sea Fisheries Research Institute
National Fisheries Research and Development Institute
707, Eulwang-dong, Jung-guIncheon, 400-420 Korea
Tel: 82 10 4800 9415
E-mail: hsjo@nfrdi.go.kr

Dr. Sukgeun JUNG
National Fisheries Research and Development Institute
408-1 Sirang-ri, Gijang-eup, Gijang-gun
Busan, 619-902, Korea
Tel: 82 51 720 2293
Mobile: 82 10 9880 4162
Email: sukgeun.jung@gmail.com

Dr. Woong-Seo KIM
Principal Research Scientist
Team Leader, Yeosu Expo Task Force
Korea Ocean Research and Development Institute
1270 Sa-dong Sangnok-gu Ansan-si
Gyeonggi-do 426-744, Korea
Tel: 82 31 400 6217
Fax: 82 31 418 7780
Email: wskim@kordi.re.kr

Dr. Kyungjin KIM
Post Doc. Researcher
Marine Resources in the Korea EEZ and the Northeastern Asia Research Group
Korea Ocean Research and Development Institute
1270, Sa 2-dong, Sangnok-gu, Ansan City
Gyeonggi–do 426-744, Korea
Tel: 82 31 400 7667
Fax: 82 31 406 6925
Email: kjkim@kordi.re.kr

Mr. Seong-in KIM
Deputy Director-General
Multilateral Trade Bureau
Ministry of Foreign Affairs and Trade
37 Sejongno Jongro-ku
Seoul, Republic of Korea
Tel: 82 2 2100 7447
Fax: 82 2 2100 7980
Email: sikim59@mofat.go.kr

Dr. Daehyeon KWON
Researcher
West Sea Fisheries Research Institute
National Fisheries Research and Development Institute
707, Eulwang-dong Jung-gu
Incheon 400-420, Korea
Tel: 82 32 745 0563
Mobile: 82 16 552 5406
Email: dhkwon@nfrdi.go.kr

Mr. Jeong- Hyun LEE
Deputy Director
Marine Environment Policy Division
Marine Policy Bureau
Ministry of Land, Transport and Maritime Affairs
2F, K-water, 188 Joongang-ro
Gwacheon-City, Gyeonggi-Do
Korea 427-100
Tel: 82 2 504 6747
Fax: 82 2 503 2070
Email: jih1501@mltm.go.kr
duqqkd13@korea.kr

Ms. Youngju LEE
Ph.D student
Inha University
253 Yonghyundong,Namgu
Incheon 402-751, Korea
Mobile: 82 17 226 5209
Email: yjulee38@gmail.com

Dr. Sukjae KWON
Executive Director
Office of Policy Research, Korea Ocean Research and Development Institute
1270 Sa 2-dong Sangnok-gu Ansan City
426-744 Gyeonggi–do, Korea
Tel: 82 31 400 6502
Fax: 82 31 400 6505
Email: sjkwon@kordi.re.kr

Ms. Soo-jin LEE
Second Secretary
Regional Cooperation Division
Multilateral Trade Bureau
Ministry of Foreign Affairs and Trade
37 Sejongno Jongro-ku
Seoul, Republic of Korea
Tel: 82 2 2100 7657
Fax: 82 2 2100 7980
Email: sojlee08@mofat.go.kr

Dr. Youn-Ho LEE
Principal Research Scientist
Korea Ocean Research and Development Institute
1270 Sa 2-dong Sangnok-gu Ansan City
426-744 Gyeonggi –do, Korea
Tel: 82 31 400 6428
Fax: 82 31 406 2495
E mail: ylee@kordi.re.kr

Dr. Theresa Mundita S. LIM
Director
Protected Areas and Wildlife Bureau
Department of Environment and Natural Resources
Ninoy Aquino Parks and Wildlife Nature Center
Quezon Avenue, Diliman, Quezon City
Philippines, 1100
Tel: 63 2 9204417
Fax: 63 2 9204417
Email: munditalim@yahoo.com
pawbdir@yahoo.com

Dr. Dae-Yeon MOON
Director
Cetacean Research Institute
National Fisheries Research and Development Institute
139-29, Maeam-Dong, Nam-Gu
Ulsan, Korea 680-050
Tel: 82 52 270 0900
Fax: 82 52 270 0913
Email:dymoon@nfrdi.go.kr

Dr. Jae Ryoung OH
Laboratory Head
Marine Environment Laboratories
Department of Nuclear Sciences and Applications
International Atomic Energy Agency (IAEA)
4 Quai Antoine 1er, MC98000, Monaco
Tel: 377 97 97 72 36
Fax: 377 97 97 72 76
Email: j.oh@iaea.org

Prof. Gyungsoo PARK
Professor
Anyang University
San 102 Samsung-ri, Bulunmyeon Gangwha-gun Incheon City 417-833, Korea
Tel: 82 32 930 6032
Fax: 82 32 930 6215
Mobile: 82 10 2051 8699
Email: gspark@anyang.ac.kr

Dr. Ji-Young PARK
Researcher
West Sea Fisheries Research Institute
National Fisheries Research and Development Institute
707, Eulwang-dong, Jung-gu Incheon, 400-420, Korea
E-mail:apple_1128@nfrdi.go.kr

Dr. Sara PURCA
Head of Oceanographic
Biological Fisheries Modelling Center
Peruvian Marine Research Institute
Esquina Gamarra y Gral. Valle S/N.
Chucuito.Callao
Peru
Tel: 51 1 6250836
Fax: 51 1 4296069/4535053
Email: spurca@imarpe.gob.pe
spurca@gmail.com

Dr. Sapta PUTRA GINTING
Deputy Director for Coastal Community Empowerment
Directorate General of Marine Coasts and Small Islands
Ministry of Marine Affairs and Fisheries
Jl. Medan Merdeka Timur No. 16
Indonesia
Email: sapta_ginting@yahoo.co.id
sapta@cbn.net.id

Dr. Jin-Goo RHOW
Researcher
West Sea Fisheries Research Institute
National Fisheries Research and Development Institute
707, Eulwang-dong, Jung-gu Incheon, 400-420, Korea
E-mail: freeteens@nfrdi.go.kr

Dr. Kenneth SHERMAN
Director
NOAA LME Program
28 Tarzwell Drive
Narragansett, RI 02882-1199, USA
Tel: 1 401 782 3288
Fax: 1 401 782 3201
Email: Kenneth.Sherman@noaa.gov

Mr. Byoung-Gyu SEO
Director General for Marine Environment Policy
Ministry of Land, Transport and Maritime Affairs
2F, K-water, 188 Joongang-ro
Gwacheon-City, Gyeonggi-Do
Korea 427-100
Tel: 82 2 504 4045~6
Fax: 82 2 503 2070
Email: sooboogo@korea.kr

Prof. Qisheng TANG
Professor
Functional Laboratory on Marine Fishery Sciences
Yellow Sea Fisheries Research Institute
106 Nanjing Road
Qingdao 266071, China
Tel: 86 532 85836200
Fax: 86 532 85811514
Email: ysfri@public.qd.sd.cn

Dr. Alexander TKALIN
Coordinator
Northwest Pacific Action Plan
United Nations Environment Programme
NOWPAP RCU
152-1 Haean-ro, Gijang-up, Gijang-gun
Busan 619-705, Republic of Korea
Tel: 82 51 720 3001
Fax: 82 51 720 3009
Email: alexander.tkalin@nowpap.org

Mr. Sadayosi TOBAI
Yellow Sea Ecoregion Planning Programme Ecoregion Coordinator
WWF Japan
Nihonseimei Akabanebashi Bldg., 6Fl.
3-1-14 Shiba Minto-ku
Tokyo 105-0014, Japan
Tel: 81 3 3769 1783
Fax: 81 3 3769 1717
Mobile: 81 80 6652 6009
Email: tobai@wwf.or.jp

Dr. Si Tuan VO
Vice Director
Institute of Oceanography
01 Cau Da Street
Nha Trang, Vietnam
Tel: 84 58 3590033
Fax: 84 58 3590034
E-mail: thuysinh@dng.vnn.vn
vosituan@gmail.com

Dr. Mark WALTON
Fisheries and Biodiversity Officer
UNDP/GEF Yellow Sea Project
Korea Ocean Research and Development Institute
1270 Sa-2dong Sangnok-gu Ansan-si
Gyeonggi-do 426-744 Republic of Korea
Tel: 82 31 400 7832
Fax: 82 31 400 7826
Email: mark@yslme.org

Mr. Shouqiang WANG
Associate Expert
UNDP/GEF YSLME Project
Korea Ocean Research and Development Institute
1270 Sa-2dong Sangnok-gu Ansan-si
Gyeonggi-do 426-744 Republic of Korea
Tel: 82 31 400 7831
Fax: 82 31 400 7826
Email: shouqiang@yslme.org

Prof. Qilun YAN
Professor
Marine Environmental Ecology
National Marine Environmental Monitoring Center
State Oceanic Administration
Linghe Street 42
Dalian 116023, China
Tel: 86 411 8478 2578
Fax: 86 411 8478 2578
Email: qlyan@nmemc.gov.cn

Dr. Sinjae YOO
Principal Research Scientist
Korea Ocean Research and Development Institute
National Project Coordinator, UNDP/GEF YSLME Project
1270 Sa 2-dong, Sangnok-gu
Ansan City 426-744 Gyeonggi–do, Korea
Tel: 82 31 400 6221
Fax: 82 31 408 5934
Email: sjyoo@kordi.re.kr

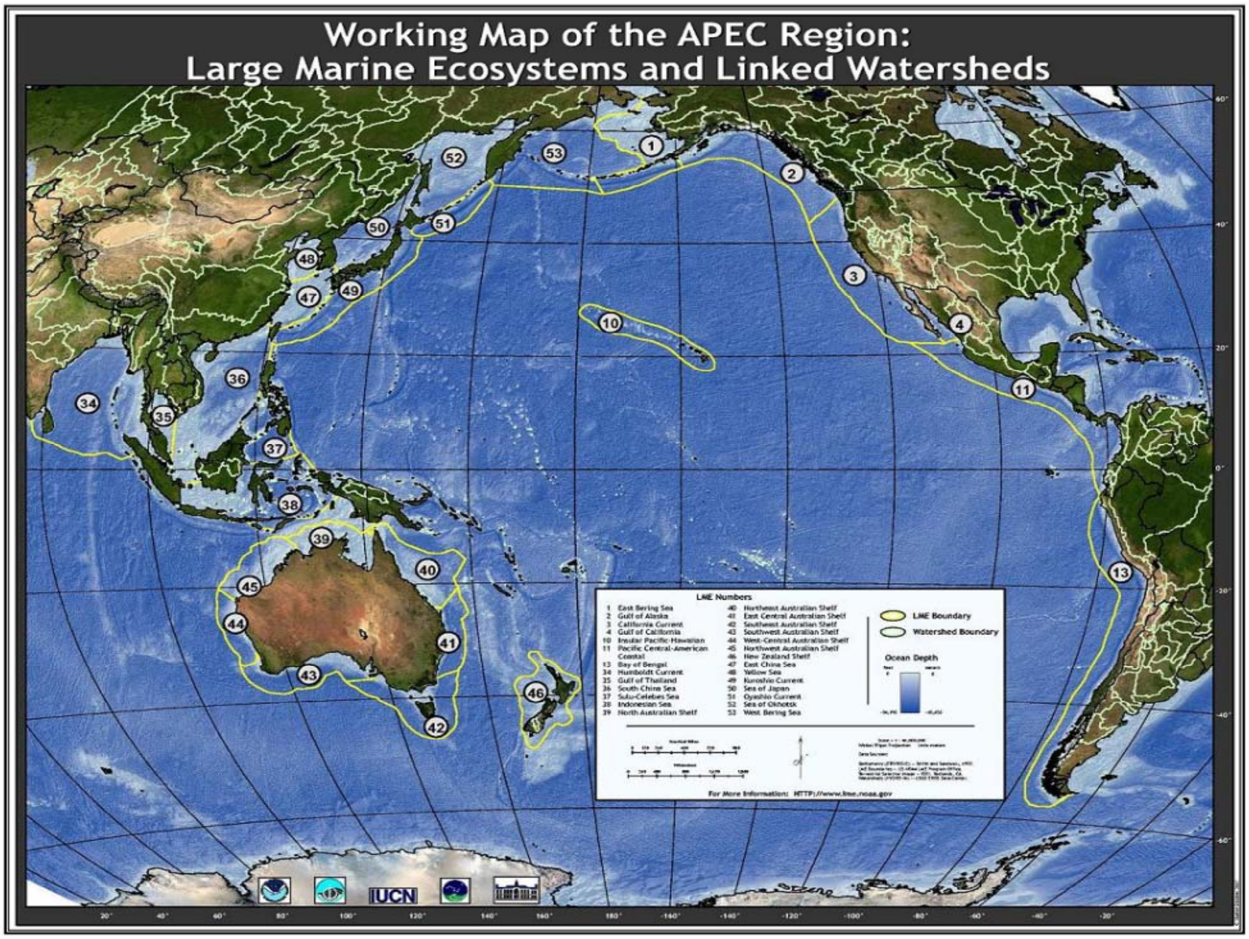
CONFERENCE SECRETARIAT

Ms. Euidea YUN
IT Specialist
UNDP/GEF Yellow Sea Project
Korea Ocean Research and Development Institute
1270 Sa-2dong Sangnok-gu Ansan-si
Gyeonggi-do 426-744 Republic of Korea
Tel: 82 31 400 7830
Fax: 82 31 400 7826
Email: euidea@yslme.org

Dr. Hyun-Hee JU
Research Scientist
Ocean Policy Research Division
Korea Ocean Research and Development Institute
1270 Sa-2dong Sangnok-gu Ansan-si
Gyeonggi-do 426-744, Korea
Tel: 82 31 400 7742
Fax: 82 31 400 6505
Email: hhju@kordi.re.kr

Ms. Sunyoung CHAE
Assistant to the ROK National Project Coordinator, UNDP/GEF YSLME Project
Korea Ocean Research and Development Institute
1270 Sa-2dong Sangnok-gu Ansan-si
Gyeonggi-do 426-744, Korea
Tel: 82 31 400 7794
Fax: 82 31 400 7826
Email: sunyoung@kordi.re.kr
sunyoung@yslme.org

ANNEX III



27 Large Marine Ecosystems (LMEs):

East Bering Sea, Gulf of Alaska, California Current, Gulf of California, Insular Pacific-Hawaiian, Pacific Central American, Humboldt Current, Bay of Bengal, Gulf of Thailand, South China Sea, Sulu Celebes Sea, Indonesian Sea, North Australia, Northeast Australia, East-Central Australia, Southeast Australia, Southwest Australia, West-Central Australia, Northwest Australia, New Zealand Shelf, East China Sea, Yellow Sea, Kuroshio Current, Sea of Japan/East Sea, Oyashio Current, Sea of Okhotsk, and West Bering Sea LMEs.