VIII-13 North Australian Shelf: LME #39

M.C. Aquarone and M. Furnas

The North Australian Shelf LME is a tropical sea lying between the Pacific and the Indian Oceans. It extends from the Timor Sea to the Torres Strait and includes the Arafura Sea and Gulf of Carpentaria. The LME covers an area of nearly 800,000 km^2, of which 2.17% is protected, and contains 0.70% of the world's coral reefs (Sea Around Us 2007). A broad continental shelf links Australia with eastern Indonesia and Papua New Guinea. Despite high local currents, there is very little net exchange of water between the Pacific and Indian Oceans through the shallow Torres Strait. It is bordered by the Timor Trough to the north. The Indonesian Throughflow, a warm-water current flowing from the Pacific into the Indian Ocean, crosses the north-western part of this LME and plays a vital role in driving the world's climate system, carrying up to 10,000,000 cubic meters per second from the Pacific Ocean into the Indian Ocean. The Throughflow is of particular importance to Australia since it helps warm the sea surface of the Indian Ocean and is a major driver of climate in northern Australia. The region has a monsoonal climate and tropical cyclones are common seasonal events. A report pertaining to this LME is given by UNEP (2003).

I. Productivity

The North Australian Shelf LME is a Class I, high productivity ecosystem (>300 $gCm^{-2}yr^{-1}$), although offshore areas are more oligotrophic (Rothlisberg et al., 1994). Northern Australian waters are dominated by picoplankton-sized cyanobacteria, although the large colony-forming N-fixing cyanobacterium Trichodesmium is often abundant in these waters. Nutrient discharge from rivers is restricted to the summer wet season and is highly variable within and between years. Tidal mixing is a major contributor to the nutrient dynamics of this generally shallow LME. Bottom friction acts in a manner analogous to wind stress on the surface to mix the water column. Monsoonal winds and tropical cyclones also contribute to nutrient enrichment of shelf waters in this LME. Well-developed mangrove creeks occur along much of the coastline which is characterized by fine sediment and low relief. Tropical cyclones have a pronounced effect on the continental shelf and on the coastal ecosystems. The episodic rainfall that accompanies cyclonic weather systems can be a major source of freshwater to the region, causing widespread flooding. Supra-tidal mud flats are found along coastal areas throughout the region, particularly the arid and dry-tropical coastline in areas of low relief of the southern Gulf of Carpentaria. These flats concentrate salt and nutrients for extended periods following tidal inundations and rainfall, then release salty, nutrient-laden water into the coastal zone (Wolanski and Ridd, 1990). The quantitative contribution of these processes to the coastal zone is not well known.

Temperature and salinity measurements of the Indonesian Throughflow and the South Equatorial Current which flow into the LME region were made as part of the World Ocean Circulation Experiment. Volumetric estimates of the Indonesian Throughflow are still not well constrained, but are known to vary with large-scale climate variability processes such as ENSO. Surface waters in the Timor and Arafura Seas are generally lower in salinity than adjacent oceanic waters due to higher precipitation. High salinities can occur in many coastal areas due to enhanced evaporation, particularly at the end of the dry season. For information on the marine environment around Australia, see CSIRO (2007). A general description of oceanographic processes affecting the nutrient

dynamics and productivity of Australian marine ecosystems is given in the State of the Environment Report (www.ea.gov.au/index.html). For more information on productivity, see Furnas (2002) and Rothlisberg et al. (1994).

Oceanic fronts (Belkin and Cornillon, 2003; Belkin et al., 2009): The Gulf of Carpentaria is the largest physiographic province within this LME and is surrounded by a major seasonal coastal front (Gulf of Carpentaria Front, GCF) (Figure VIII-13.1). The offshore Cape Arnhem Front (CAF) and Cape York Peninsula Front (CYPF) emerge seasonally near the northwest and northeast entrances to the Gulf, respectively. Farther west, the coastal Arafura Sea Front (ASF) is observed north of Arnhem Land, while the coastal Joseph Bonaparte Gulf Front (JBGF) develops in the southern part of the Timor Sea. In the past, a significant amount of pelagic fishing activity has been concentrated in the region of the Arafura Sea Front. These fronts are likely to play an important role in the ecology of commercially important prawns (Belkin and Cornillon 2003).

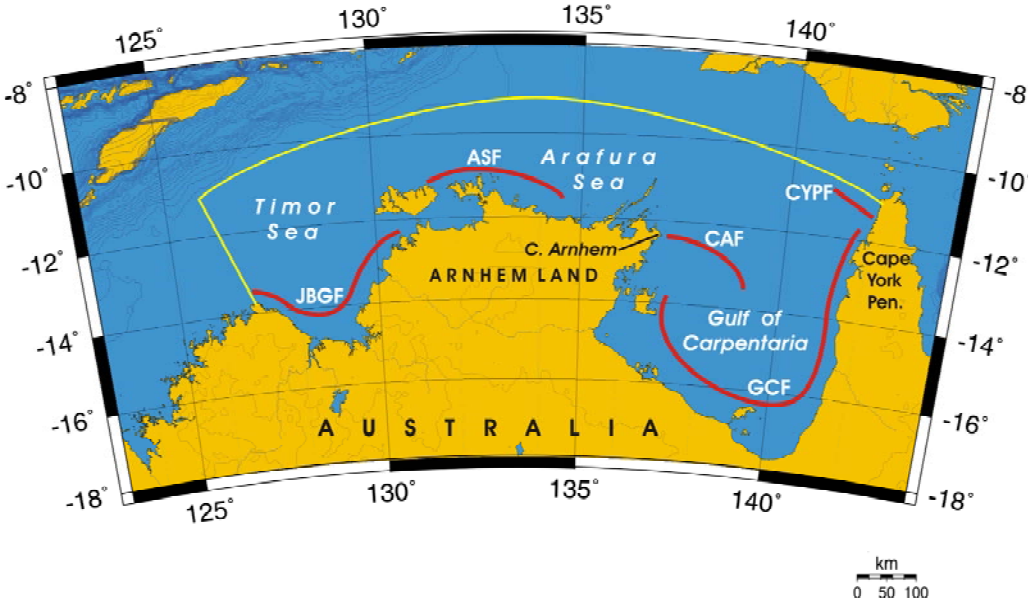

Figure VIII-13.1. Fronts of the North Australian Shelf LME. ASF; Arafura Sea Front; CAF, Cape Arnhem Front; CYPF, Cape York Peninsula Front; GCF, Gulf of Carpentaria Front; JBGF, Joseph Bonaparte Gulf Front. Yellow line, LME boundary. After Belkin et al. (2009) and Belkin and Cornillon (2003).

North Australian Shelf SST (after Belkin 2009)
Linear SST trend since 1957: 0.42°C.
Linear SST trend since 1982: 0.17°C.

Like the adjacent Indonesian Sea LME, the North Australian Shelf LME underwent a cooling that lasted through 1977, after which SST rose steadily (Figure VIII-13.2). The observed similarity of thermal histories of these LMEs is expected since the North Australian Shelf is oceanographically connected to the Indonesian Sea by the Indonesian Throughflow. The all-time minimum of 1976-77 is similar to the 1976 all-time minimum observed in the Northwest Australian Shelf LME. The all-time maximum of 1998 coincided with the El Niño 1997-98 which had significant oceanographic impacts throughout the Indonesian Archipelago and along the western Australian coast. The warm event of 1988 occurred simultaneously with the Sulu-Celebes LME, Northeast Australian Shelf LME, East-Central Australian Shelf LME, and only a year later in the

Southeast Australian Shelf LME. The twin peaks of 1970-1973 occurred simultaneously in the adjacent Northeast Australian Shelf LME and the East-Central Australian Shelf LME, especially the warm event of 1973. Interannual variability of SST in this LME is substantial, partly explained by the very shallow upper mixed layer in the tropics.

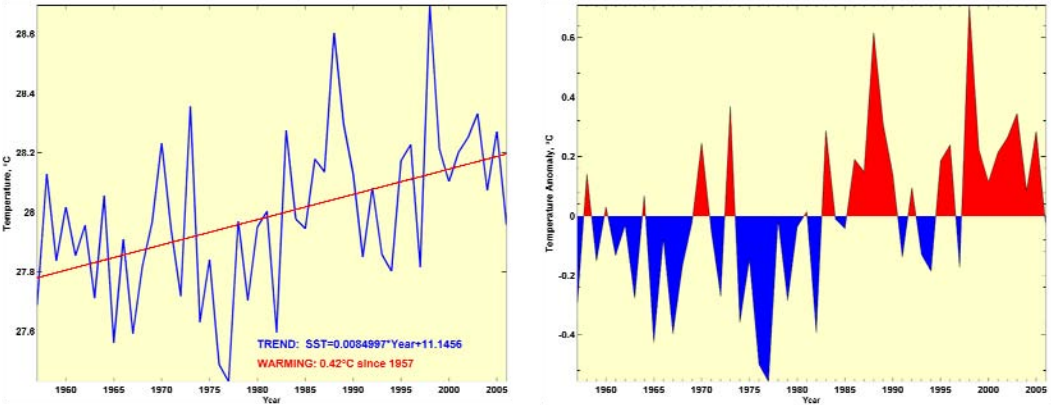

Figure VIII-13.2. North Australian Shelf LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2008).

***North Australian Shelf LME Chlorophyll and Primary Productivity*:** The North Australian Shelf LME is a Class I, high productivity ecosystem (>300 $gCm^{-2}yr^{-1}$), although offshore areas are more oligotrophic (Rothlisberg et al., 1994). These estimates are largely based upon ocean color satellite imagery and the optical properties of northern Australian waters are poorly characterized at present.

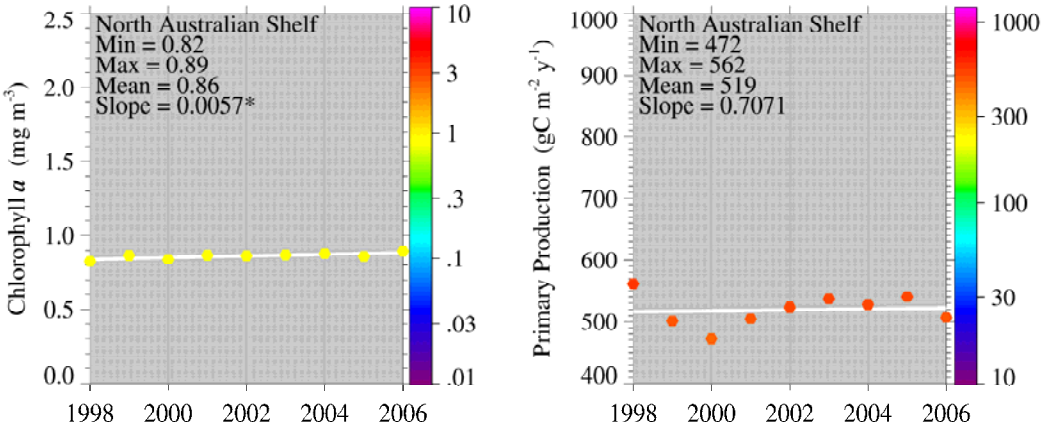

Figure VIII-13.3. Estimated North Australian Shelf trends in chlorophyll *a* (left) and primary productivity (right) from ocean color imagery, 1998 – 2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O Reilly and K. Hyde.

II. Fish and Fisheries

Fish stocks in the North Australian Shelf LME are small but diverse. The level of endemism in the northern Australian LMEs is low, with most species distributed widely in the Indo-West Pacific region. Commercially fished species in the LME include northern prawns (Gulf of Carpentaria and Joseph Bonaparte Gulf), threadfin bream, skipjack tuna,

Indo-Pacific anchovies, mud crab, barramundi, salmon, shark, Spanish mackerel, as well as snappers and reef fish. About half of the reported landings consist of mixed taxa (Figure VIII-13.4). In the Arafura Sea and Gulf of Carpentaria, the prawn fishery is almost fully exploited. Crustaceans and molluscs dominate the catch, particularly in the Gulf of Carpentaria where prawns are targeted. Shark populations have been significantly depleted as a result of the shark fin fishery. Information on Australia's fisheries is provided by FAO (www.fao.org/fi/FCP/FICP_AUS_E.ASP). Total reported landings grew steadily to ~87,000 tonnes in 2004 (Figure VIII-13.4). The value of the reported landings showed a general increase, with a maximum value of just under US$300 million (in 2000 US dollars) in 2001 (Figure VIII-13.5). Penaeid shrimps and tuna are the two most important groups in terms of value.

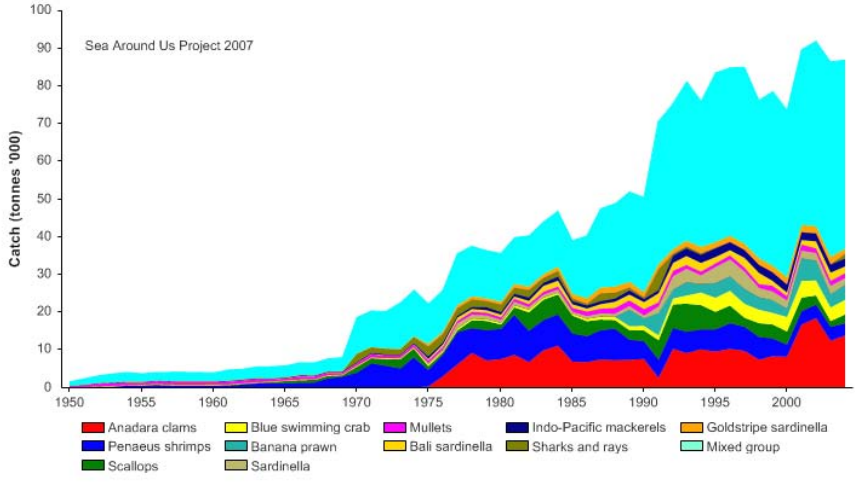

Figure VIII-13.4. Total reported landings in the North Australian Shelf LME by species (Sea Around Us 2007).

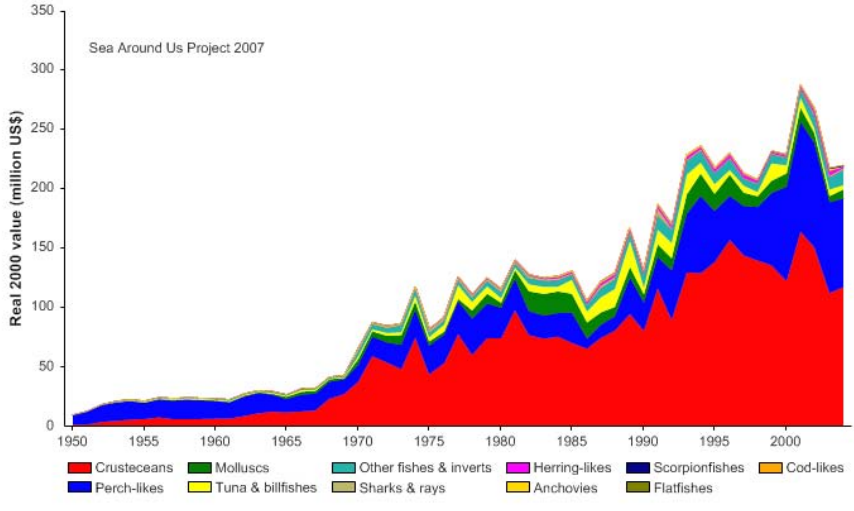

Figure VIII-13.5. Value of reported landings in the North Australian Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME is still below 2%--much lower than other LMEs of comparable characteristics (Figure VIII-13.6) although this is not surprising given the high rates of *in*

situ recycling. Australia, Indonesia and Thailand account for the largest share of the ecological footprint in the LME.

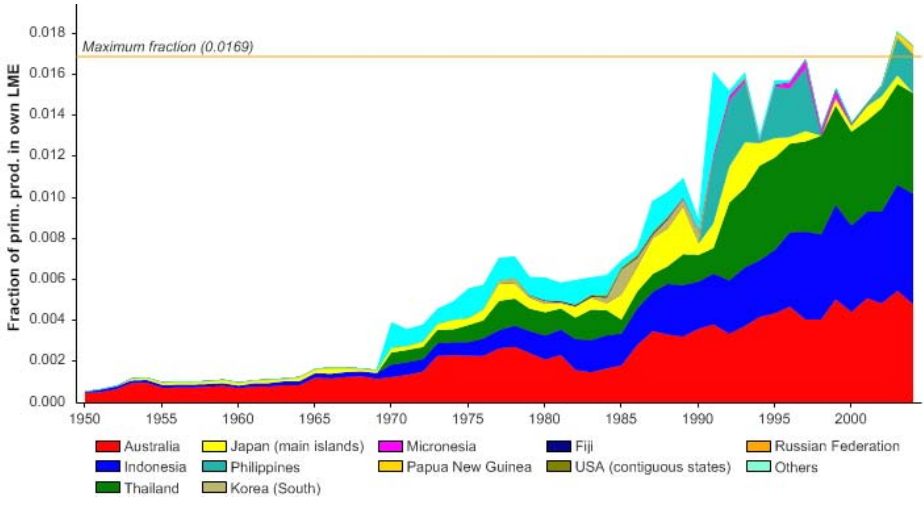

Figure VIII-13.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the North Australian Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The long term trend of the mean trophic level (i.e., the MTI; Pauly & Watson 2005) for this LME is one of a decline from 1950 to the mid 1980s (Figure VIII-13.7, top), indicating a 'fishing down' of the food web (Pauly *et al.* 1998); followed by an increase, which coincides with the increased landings of tuna and other large pelagic species. The pattern is confirmed by the FiB index (Figure VIII-13.7, bottom), which also suggests a steady expansion (Pauly & Watson 2005).

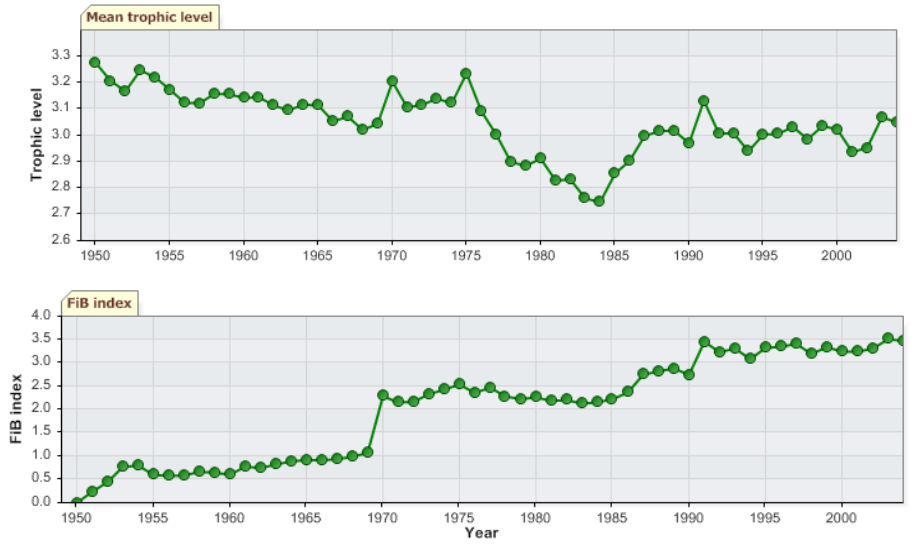

Figure VIII-13.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the North Australian Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that only a few of the exploited stocks can be considered collapsed or overexploited (Figure VIII-13.8, top). The majority of the reported landings come from fully exploited stocks (Figure VIII-13.8, bottom).

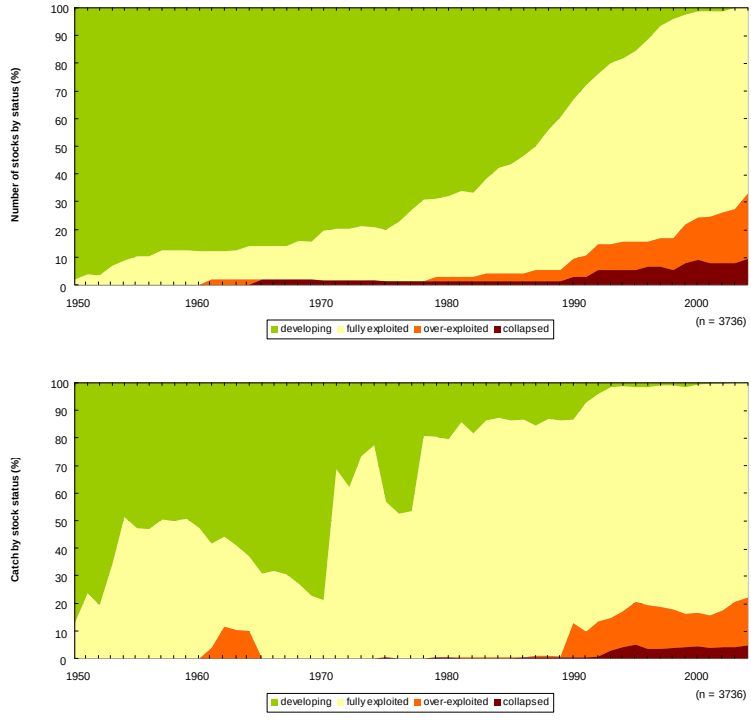

Figure VIII-13.8. Stock-Catch Status Plots for the North Australian Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number of 'stocks', i.e., individual landings time series, only include taxonomic entities at species, genus or family level, i.e., higher and pooled groups have been excluded (see Pauly *et al*, this vol. for definitions).

III. Pollution and Ecosystem Health

The LME is threatened by an increase in shipping, mining activity in adjacent watersheds and by the production and transportation of oil and other hydrocarbons. Ships empty of cargo that enter the ports of northwest Australia are ballasted with water collected in the last port of call. This ballast water has been shown to contain organisms including bacteria, viruses, algal cells, plankton and the larval forms of many invertebrate and fish species. One significant introduction of an exotic mollusc (Zebra mussel) was found and contained at an early stage in one coastal port. The source was either a small fishing vessel or yacht. There are accidental discharges of contaminants through spills and shipping accidents. The dominant human impacts are related to fisheries and terrestrial runoff from deforestation, overgrazing by livestock, and certain agricultural practices. Compared with most countries, however, these impacts are quite modest. For more information on marine pollution in this LME, see Environment Australia (www.ea.gov.au) and a technical paper from EA on marine disturbances.

IV. Socioeconomic Conditions

Many residents are involved in the marine-related sectors of the economy. There are economically significant aquaculture activities, at a number of coastal sites, based on oyster pearls, and to a much lesser extent, prawns. Industry (mining, oil and gas

extraction), shipping and tourism are major economic activities. Marine and coastal-based forms of tourism are important both in terms of domestic and international tourism. A significant proportion of the local Australian population is involved in recreational fishing and boating. Tourists prize the coral reefs and the natural and largely unspoilt marine environment. There are, however, social, cultural, economic and environmental impacts caused by tourism. Tourism may affect the lifestyle of residents in ways they perceive as intrusive. Australia's Aborigines, and the Torres Strait Islanders who occupy parts of the far northeast of the land area, have traditionally made considerable use of reef and coastal resources. The FAO (see website above) provides information on the characteristics and socioeconomic benefits of Australia's fishing industry.

V. Governance

The North Australian Shelf LME lies off the coast of the states of Western Australia, Northern Territory and Queensland. Some governance issues in this LME pertain to the Aboriginal coastal populations, who have considerable rights regarding their traditional use of coastal habitats. However, coastal population densities throughout much of this region low. Australian fisheries resources are managed under both Commonwealth and State/Territory legislation. The demarcation of jurisdiction and responsibilities among these various governments has been agreed to under the Offshore Constitutional Settlement, under which the states and territories have jurisdiction over localised, inshore fisheries. The Commonwealth has jurisdiction over transboundary, foreign and offshore fisheries or those extending to waters adjacent to more than one state or territory. Each government has separate fisheries legislation and differing objectives. Under the Environment Protection and Biodiversity Conservation Act 1999, the Commonwealth Government now has a framework that helps it to respond to current and emerging environmental problems. An important goal is to ensure that the exploitation of fisheries resources is conducted in a manner consistent with the principles of ecologically sustainable development. This includes the need to assess the impact of fishing activities on non-target species and the long-term sustainability of the marine environment. Illegal and unlicensed fishing activity is a significant and ongoing problem in the region. By agreement with Indonesia, groups of Indonesian fishers retain rights to fish at a number of offshore island and reef sites using traditional craft and methods. For more information on the governance of Australia's fisheries, see the FAO website given above.

Reserves have been declared to help protect rocky shore habitats and marine life, provide opportunities for research and education conserve Australia's cultural heritage and help boost ecotourism. In 2001, a Government-held consultation process indicated strong community support to further protect these aquatic reserves. The marine tourism industry has produced a code of conduct that covers issues such as anchoring, removal of rubbish, fish feeding and the preservation of World Heritage values. Australia declared a 200-nautical-mile EEZ in 1978. The LME falls within the UNEP-administered East Asian Regional Seas Programme.

References

Belkin, I.M. (2009) Rapid warming of Large Marine Ecosystems, Progress in Oceanography, in press.

Belkin, I.M., Cornillon, P.C. and Sherman, K. (2009) Fronts in Large Marine Ecosystems of the world's oceans. Progress in Oceanography, in press.

Belkin, I. M. and Cornillon, P. C. (2003). SST Fronts of the Pacific Coastal and Marginal Seas, Pacific Oceanography, 1(2): 90-113.

Environment Australia technical paper at www.ea.gov.au/soe/techpapers/marine-disturbance/appendix1.html.

Environment Australia www.ea.gov.au/coasts/pollution/index.html

FAO (2003). Trends in Oceanic Captures and Clustering of Large Marine Ecosystems -2 Studies Based on the FAO Capture Database. FAO Fisheries Technical Paper 435.

Feng, M., Meyers, G. Pearce, A. and Wijffels, S. (2003) Annual and interannual variations of the Leeuwin Current at 32°S, *Journal of Geophysical Research*, **108**(11), 3355, doi:10.1029/2002JC001763.

Hayes, D., Lyne, V. Condie, S., Griffiths, B.. Pigot, S and Hallegraeff, G. (2005) Collation and analysis of oceanographic datasets for National Marine Bioregionalisation, A report to the Australian Government, National Oceans Office. CSIRO Marine and Atmospheric Research, 229 pp.

Pauly, D, Christensen, V., Dalsgaard, J., Froese, R. and Torres, F. Jr. (1998). Fishing down marine food webs. Science 279:860-863.

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

Pauly, D. and Watson, R. (2005). Background and interpretation of the 'Marine Trophic Index' as a measure of biodiversity. Philosophical Transactions of the Royal Society: Biological Sciences 360: 415-423.

Pogonoski, J.J., Pollard, D.A. and Paxton, J.R. (2002). Conservation Overview and Action Plan for Australian Threatened and Potentially Threatened Marine and Estuarine Fishes. Environment Australia, February 2002. www.ea.gov.au/coasts/species/marine-fish/pubs/marine-fish.pdf

Rothlisberg, P.C., P.C. Pollard, P.D. Nichols, D.J.W. Moriarity, A.M.G. Forbes, C.J. Jackson and D. Vaudrey 1994 Phytoplankton community structure and productivity in relation to the hydrological regime of the Gulf of Carpentaria, Australia, in summer. Australian Journal of Marine and Freshwater Research 45: 265-282

Sainsbury, K.J. (1988). The Ecological Basis of Multispecies Fisheries, and Management of a Demersal Fishery in Tropical Australia, p 349-382 in Gulland, J.A. (ed), Fish Population Dynamics: The Implications for Management. John Wiley and Sons, New York.

Sea Around Us (2007). A Global Database on Marine Fisheries and Ecosystems. Fisheries Centre, University British Columbia, Vancouver, Canada. www.seaaroundus.org/lme/SummaryInfo.aspx?LME=39

UNEP (2003). Barnett, B., Lawrence, D., DeVantier, L., Skelton, P. and Wilkinson, C. North Australia Shelf, GIWA Regional Assessment 58. University of Kalmar, Kalmar, Sweden.

Wolanski, E. and P. Ridd 1990 Mixing and trapping in Australian tropical coastal waters. p 165-180 in Cheng, R.T. (ed), Coastal and Esturarine Studies: Residual and Long-term Transport. Springer-Verlag, New York.