VIII-14 Northwest Australian Shelf: LME #45

M.C. Aquarone and M. Furnas

The Northwest Australian Shelf LME extends from Northwest Cape to the Timor Sea. It encompasses a wide area of about 900,000 km^2, of which 0.68% is currently protected in reserves, and contains 1.17% of the world's coral reefs and 0.02% of the sea mounts (Sea Around Us 2007). Topographical features such as the Exmouth Plateau, the Rowley Shelf and the Sahul Shelf are found in this LME, which is positioned on the path of the Indonesian Throughflow, a low-salinity warm-water current flowing from the Pacific into the Indian Ocean. The Timor Sea is characterized by warm surface temperatures year-round and generally lower salinities than in the adjacent Indian Ocean. The Indonesian Throughflow warms the LME's sea surface and increases rainfall over Western Australia. Rainfall is strongly seasonal, with a predictable summer wet season and recurrent seasonal cyclonic disturbances. Tropical cyclones are common summer (Nov-Apr) events that exert pronounced effects on the continental shelf and on the coastal marine ecosystems. The rainfall that accompanies cyclonic weather systems is a major source of freshwater to the region, causing widespread though episodic flooding. Menon (1998) and UNEP (2003) have published a book chapter, and a report, respectively, on this LME.

I. Productivity

The Northwest Australian Shelf LME is considered a Class II, moderate productivity ecosystem (150-300 $gCm^{-2}yr^{-1}$). This estimate is largely based upon satellite imagery of the region where relatively few direct productivity measurements have been made (Jitts, 1969; Furnas, 2007). In some areas most of the phytoplankton biomass and productivity has little or no surface expression (Furnas, 2007). Brief episodes of very high primary productivity (1-8 g C m^{-2} d^{-1}) have been recorded in the vicinity of North West Cape which are linked to localized upwelling against the narrow continental shelf and enhanced vertical mixing (Hansen et al., 2005; Furnas, 2007). Productivity at North West Cape is higher during ENSO periods when transport in the Leeuwin Current is reduced. The LME supports diverse phytoplankton including the normally dominant picoplankton, but regionally or episodically, populations of diatoms or Trichodesmium can dominate. Temperature and salinity measurements of the Indonesian Throughflow and the South Equatorial Current were made as part of the World Ocean Circulation Experiment. More information is provided at www.marine.csiro.au.

The LME is characterised by high-energy and internal wave tidal regimes. Surface spring tides can reach 8 m at coastal sites in the Kimberly region of NW Australia (e.g. Broome). The sub-surface regime along the continental slope is also characterized by well-developed and persistent internal tides and internal waves generated by interactions between tidal currents and local bathymetry. These waves typically break on the mid-shelf, leading to enhanced vertical mixing. Tidal mixing is a major contributor to nutrient dynamics. Bottom friction acts in a manner analogous to wind stress on the surface to mix the water column and resuspend sediment and organic material from the bottom. Shelf upwelling and cyclonic disruptions also contribute to nutrient inputs in this LME. Because of the high levels of mixing and resuspension, the continental shelf supports a diverse demersal fish community. For a general understanding of oceanographic processes affecting nutrient dynamics and the productivity of Australian marine

ecosystems, see the State of the Environment Report (www.ea.gov.au/index.html) and Furnas (2002).

Oceanic fronts: (Belkin et al. 2009) This vast shelf is the source area of the Leeuwin Current that flows poleward along the west coast of Australia carrying warm and low-density tropical waters far south. Seasonal evolution of the frontal pattern over this shelf is somewhat similar to that west of Northwest Africa and west of the U.S. West Coast. Variations in the strength of the Leeuwin Current are linked to changes in sea level in the western Pacific Ocean and the strength of the Indonesian Throughflow. Year-to-year variations in flow have a strong influence on the productivity and fisheries yield along the western Australian coast. In summer, a multitude of small-scale fronts develops that form a chaos-like spatial pattern. As the season progresses, these small-scale fronts apparently coalesce into large-scale (hundreds km long) coherent filaments that persist for weeks and months. Tidal mixing over this shelf is deemed important, although no stable tidal mixing fronts have been detected within this LME.

Northwest Australian Shelf SST (Belkin, 2009)
Linear SST trend since 1957: 0.42°C.
Linear SST trend since 1982: 0.24°C.

This LME is interesting in that its interannual and decadal variability are small compared with other LMEs (Figure VIII-14.2). Indeed, the magnitude of interannual and decadal variability in temperature is less than 0.5°C. The only significant warm event, the all-time maximum of 1998, was associated with the El Niño 1997-98. The cold event of 1976, when SST anomaly was about -1°C relative to the long-term trend, can be associated with the cold event of 1976-77 in the North Australian Shelf LME. This is a rare example of a large signal confined to just two contiguous LMEs that comprise a relatively small area. Another cold signal, of 1968, was likely advected from the Indonesian Sea LME, where a cold event occurred in 1967. The proposed advection route is consistent with the circulation pattern (Feng et al. 2003).

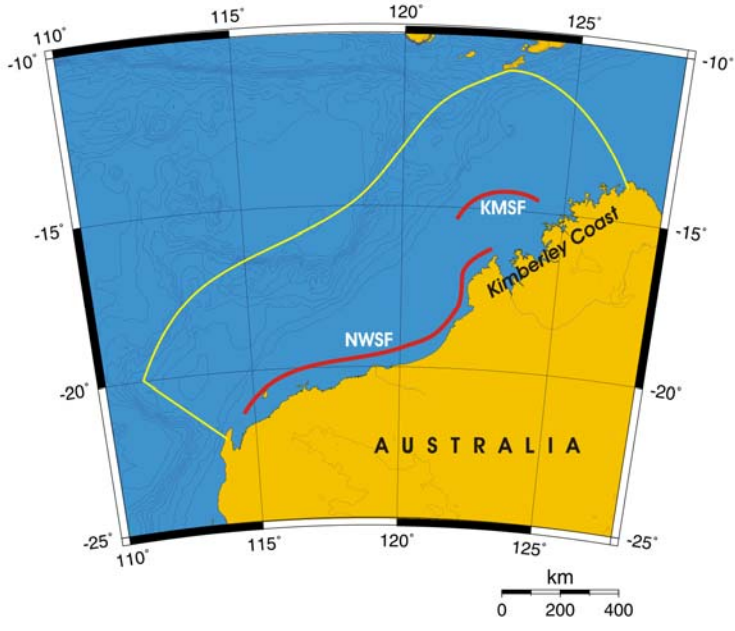

Figure VIII-14.1. Fronts of the Northwest Australian Shelf LME. KMSF, Kimberley Mid-Shelf Front; NWCF, Northwest Coastal Front. Yellow line, LME boundary. After Belkin et al. (2009).

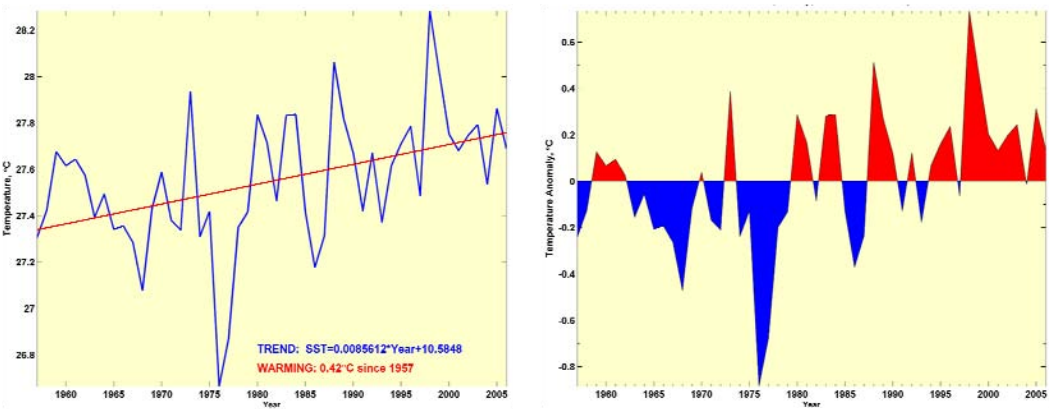

Figure VIII-14.2. Northwest Australian Shelf LME annual mean SST (left) and SST anomaly (right), 1957-2006, based on Hadley climatology. After Belkin (2009).

Northwest Australian Shelf LME Chlorophyll and Primary Productivity: The Northwest Australian Shelf LME is considered a Class II, moderate productivity ecosystem (150-300 $gCm^{-2}yr^{-1}$).

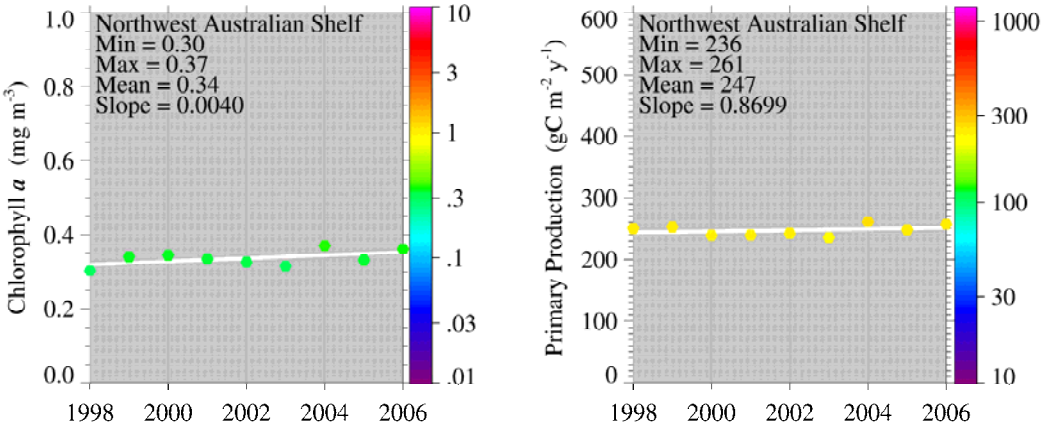

Figure VIII-14.3. Estimated Northwest Australian Shelf trends in chlorophyll *a* (left) and primary productivity (right), 1998 – 2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde.

II. Fish and Fisheries

Northwest Australian shelf waters are relatively nutrient-poor and unable to sustain large fish populations. The level of endemism in northern Australian LMEs is low, with most species distributed widely in the Indo-West Pacific region. Seasonal aggregations of plankton feeding whale sharks and manta rays occur off Ningaloo Reef, which begins at North West Cape. This LME once supported an extensive pearl shell fishery along the coast. Following depletion of stocks, this fishery has been replaced by a harvesting and grow-out aquaculture industry at a number of sites along the coast. This LME and the adjacent Northern Australian Shelf LME are major suppliers of large pearls to the international market. A small prawn fishery is located in the southern part of the LME, principally in Exmouth Gulf, near North West Cape. Reef fisheries occur in the Rowley

Shoals, Scott Reef and Ashmore Reef, a chain of coral atolls at the edge of the LME's wide continental shelf. The former site is a marine reserve. The latter two sites are primarily fished by traditional Indonesian fishermen using traditional boats, methods and gear. Demersal species fished in this LME include *Lethrinus*, *Nemipterus*, *Saurida* and *Lutjanus*, which historically have been fished by foreign fleets. Small domestic trap fisheries for *Lethrinus*, *Lutjanus* and *Epinephelus* exist in areas subjected to little trawling. Other exploited groups include *Anadara* clams, scallops and goldstripe sardinella, as well as a significant number of unidentified taxa (Figure VIII-14.4). Fishing for shark fins in the northern part of the LME has greatly depleted shark populations. FAO provides information on Australia's fisheries industry (www.fao.org). Total reported landings show a series of peaks in the 1990s over 50,000 tonnes with a record landings of 61,000 tonnes in 1999 (Figure VIII-14.4). From the early 1990s to 2004, the value of the catch increased sharply, then fluctuated between US$80 million and US$140 million (in 2000 US dollars; Figure VIII-14.5).

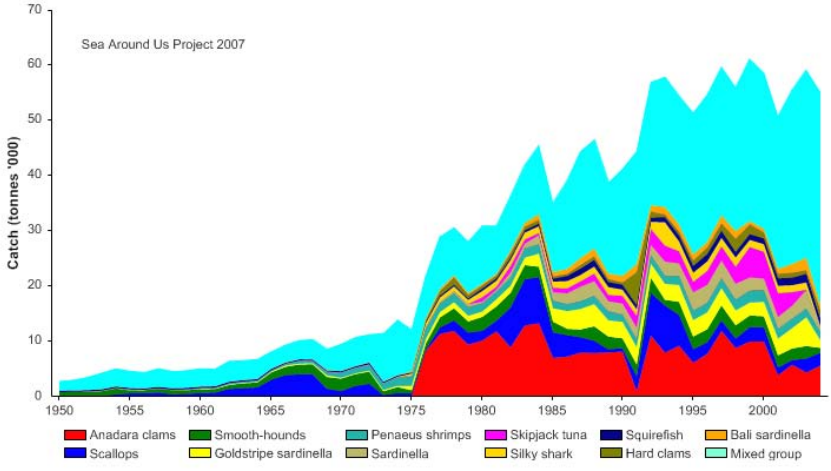

Figure VIII-14.4. Total reported landings in the Northwest Australian Shelf LME by species (Sea Around Us 2007).

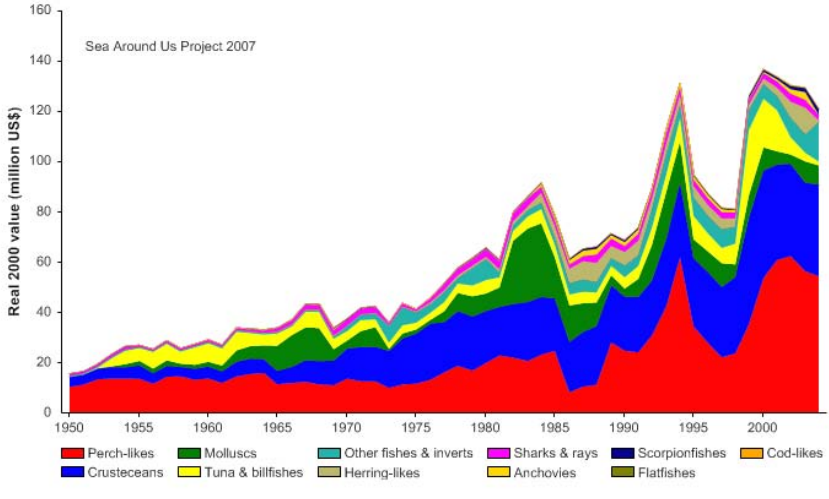

Figure VIII-14.5. Value of reported landings in the Northwest Australian Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME has reached 2.5% in the 1990s with Australia and Indonesia accounting for the largest share of the ecological footprint (Figure VIII-14.6).

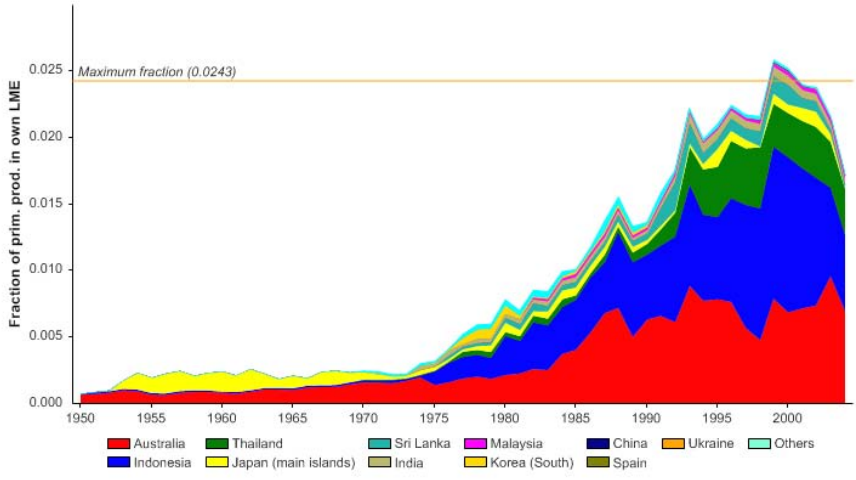

Figure VIII-14.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Northwest Australian Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

Since the mid 1980s, both the mean trophic level (i.e. the MTI; Pauly & Watson 2005; Figure VIII-14.7, top) and the FiB index (Figure VIII-14.7, bottom) showed an increase, likely a result of geographic expansion of the fisheries and targeting of large and medium pelagic species.

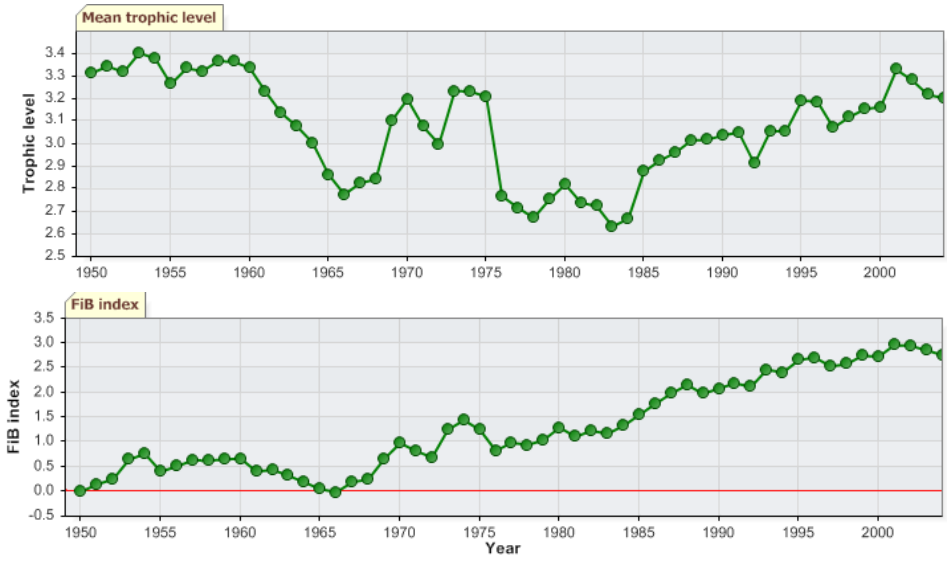

Figure VIII-14.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Northwest Australian Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that approximately 50% of the stocks have collapsed or are overexploited in the LME (Figure VIII-14.8, top). The reported landings are largely supplied by fully exploited stocks (Figure VIII-14.8, bottom).

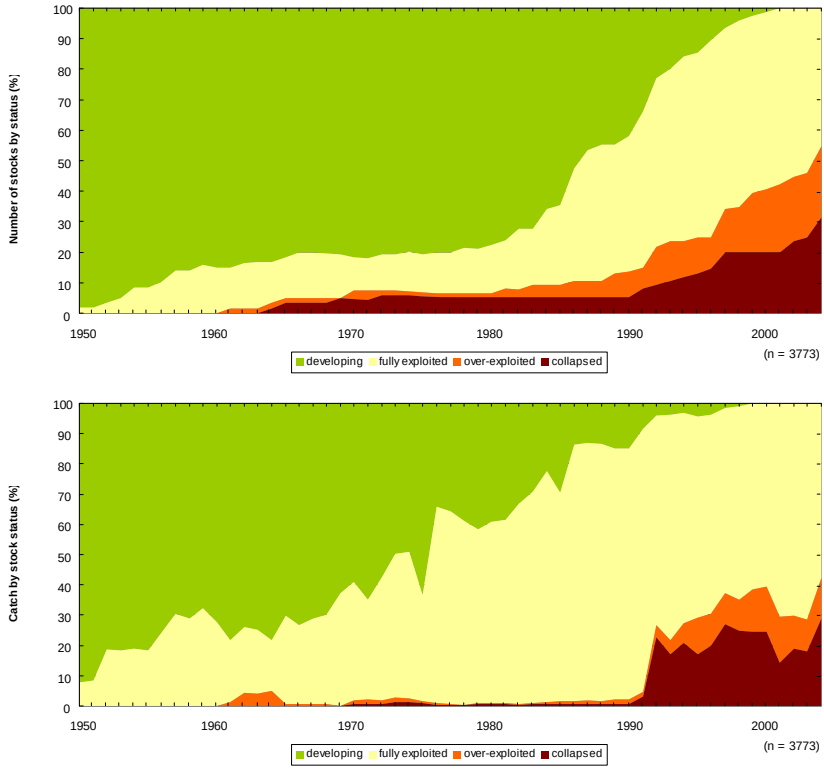

Figure VIII-14.8. Stock-Catch Status Plots for the Northwest Australian Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), 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 and the development of extensive offshore oil and gas deposits. The shelf and adjacent continental region are a major international source of iron ore, other minerals, ammonium, liquefied natural gas and other petroleum products. These exports are likely to increase for the foreseeable future. Ships empty of cargo (chiefly iron ore and LNG) 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 invertebrates and fish. There are accidental discharges of contaminants through spills and shipping accidents. This LME's coastal marine parks, home to a variety of plants, corals, fishes and marine mammals, are impacted to varying degrees by tourism. In general, numbers of tourists are still relatively low due to the remote nature of much of this LME and its bordering land mass and effects are largely localized. There is pressure, however, for increased development of tourism infrastructure. Activities associated with recreational fishing, SCUBA diving and boating have the potential to affect the coastal environment around regional towns through pollution of the water by boats and the disturbance of species and habitats. Recreational

fishermen tend to target reef ecosystems and remove larger predatory species. The effects of this selective removal of fish are largely unknown. A significant source of environmental impacts is the provision of infrastructure to support the oil and gas, and mining industries and to a lesser extent, tourism (airports, power generation facilities, accommodation, sewage treatment and disposal facilities, moorings and marine transport). This infrastructure is expanding rapidly and being located in fragile or pristine environments that are susceptible to disturbance and fragmentation. For more information, see Environment Australia for marine (www.ea.gov.au/soe/) and coastal pollution (www.ea.gov.au/coasts) issues, and the State of the Environment Report (www.ea.gov.au/SOE).

IV. Socioeconomic Conditions

FAO provides information on the characteristics and socioeconomic benefits of Australia's fishing industry (www.fao.org/fi/FCP/FICP_AUS_E.ASP). There has been exploration for oil and natural gas. A number of significant gas, and to a lesser extent, oil fields have been discovered and large-scale development of these fields is being undertaken at a range of sites (Scott Reef, Barrow Island, Dampier), principally to support exports of LNG. Hydrocarbon production and export is expected to be a significant economic activity within the region, requiring extensive infrastructure development and growing regional populations. Industry, shipping and tourism are major economic activities. Marine and coastal-based tourism is a relatively small-scale activity but important both in terms of domestic and international tourism. Some tourism activities (e.g. whale shark watching at Ningaloo Reef) are directly dependent upon marine resources and conservation activities in other LMEs.

V. Governance

The Northwest Australian Shelf LME lies off the coast of the state of Western Australia, close to Indonesia. Some governance issues in this LME pertain to fisheries management and to the establishment of marine reserves (including Ningaloo Marine Park). Indonesian fishermen using traditional craft and methods are allowed to fish at designated sites at the northern end of this LME. After examining several possible management regimes for this LME, the government of Australia divided the area into three zones and closed two of them to trawling. It is thought that there will be an expansion of trap fishing in the two closed areas after the species composition changes induced by trawling are reversed. See the North Australian Shelf LME for information on fisheries and tourism governance. 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.

CSIRO (2007). www.marine.csiro.au/PressReleasesfolder/95releases/6nov95.html).

Environment Australia. (2006) www.ea.gov.au/SOE/.
www.ea.gov.au/soe/techpapers/marine-disturbance/appendix1.html
www.ea.gov.au/coasts/pollution/index.html

FAO at www.fao.org/fi/fcp/en/AUS/profile.htm

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

Furnas, M.J. (2002). www.environment.gov.au/coasts/publications/somer/annex1/land-ea.html #HDR7

Menon, H.B. (1998). Role of oceanic fronts in promoting productivity in the Southern Indian Ocean, p 175-191 in: Sherman, K. Okemwa, E. and Ntiba, M. (eds), Large Marine Ecosystems of the Indian Ocean: Assessment, Sustainability and Management. Blackwell Science, Cambridge, MA, U.S.

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.

Sainsbury, K.J., Campbell, R.A. and Whitelaw, A.W. (1993). Effects of trawling on the marine habitat on the northwest shelf of Australia and implications for sustainable fisheries management, In: Hancock, D.A. (ed), Sustainable Fisheries through Sustaining Fish Habitat. Australian Society for Fish Biology Workshop Proceedings. Victor Harbour SA, August 1992. Australian Government Publishing Service, Canberra.

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=45

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