IX SOUTH PACIFIC

IX-18 East-Central Australian Shelf LME
IX-19 New Zealand Shelf LME
IX-20 Northeast Australian Shelf LME
IX-21 Southeast Australian Shelf LME

IX-18 East-Central Australian Shelf LME

M.C. Aquarone, S. Adams, I.M. Suthers and M.E. Baird

The East-Central Australian Shelf LME extends from the southern edge of the Great Barrier Reef off Fraser Island, Queensland (24.5ºS) to Cape Howe (37.5 ºS), at the southern end of the state of New South Wales. It covers a surface area of 650,000 km^2, of which 2.66% is protected, and contains 0.18% of the world's coral reefs and 0.20% of the world's sea mounts, as well as 15 major estuaries (Sea Around Us 2007). A narrow continental shelf (only 20-60 km wide) that is bordered by the Tasman abyssal plain and a temperate climate characterise the LME. The South Equatorial Current from the Pacific Ocean gyre flows westward towards the Australian coast, bifurcates with the southern branch bending south (left) under the influence of wind stress and topography to become the East Australian Current (EAC, Ridgeway and Dunn 2003). The EAC is Australia's largest current and is typically 30 km wide, 200 m deep and traveling up to 4 knots (2 ms^{-1}), with a variable annual transport variously estimated as 20-30 Sv (Ridgeway & Dunn 2003 and references therein). For comparison, the EAC has ~5 fold greater volume transport than the seasonally flowing Leeuwin Current on the west coast. The EAC intensifies in the northern part of this LME, before separating from the coast 31-33 ºS, leaving behind a southward trending eddy field. The EAC's mesoscale variability is so large that a single continuous current can often not be identified, and distinguishes it from other western boundary currents. After separation the EAC retroflects northward and can feed back into the EAC, as an anticyclonic eddy. Further separations and retroflections are evident along the NSW coast around 34 and 37ºS (Ridgeway & Dunn 2003). The eddies are formed at 90 to 180 d intervals driven in part by intrinsic instabilities (Marchesiello and Middleton 2000; Bowen et al. 2005). The anticyclonic eddies may transport considerable amounts of heat into the Tasman Sea, or may turn northeast and coalesce back into the main current. The strengthening of the EAC is predicted to warm Australian waters by 1-2ºC by 2030 and 2-3 ºC by 2070s, particularly off Tasmania (Poloczanska et al. 2007). This has already affected growth rates of commercial fish (Thresher et al. 2007). Ridgeway (2007) and others have noted the remarkable impact of the EAC's southward penetration off Tasmania. Using the Maria Island long term quasi-monthly monitoring station (since 1944), they report the warming rate of 2.3 ºC per century and increasing salinity of 0.34 per century. A book chapter and report pertaining to this LME are Morgan (1989) and UNEP (2003).

I. Productivity

The East-Central Australian Shelf LME is considered a Class III, low productivity ecosystem 86 – 177 gCm^{-2}yr^{-1}) (Sea Around Us 2007; www.science.oregonstate.edu/ocean.productivity/). At this latitude, water temperature, levels of wind mixing and light intensity go through seasonal cycles. During the winter, strong winds and cool surface water temperatures enhance vertical mixing processes, breaking down vertical density gradients and allowing nutrient-rich waters to mix into the surface layer. However, the overall productivity of this temperate Australian LME is restricted by the poleward transport of low-nutrient tropical waters along the continent's eastern margin by the EAC. There are no widespread seasonal blooms producing large surpluses of organic matter. Localised coastal blooms occur as a result of wind-driven and current-driven upwelling and occur throughout the year (Ajani, 2001; Baird et al., 2006). Localised blooms can produce ecosystem responses such as red-tides (Dela-Cruz et al., 2003), but are not sufficiently large to support a large demersal fishery such as those which characterise northern hemisphere continental shelf systems.

For a general understanding of oceanographic processes affecting the nutrient dynamics and productivity of Australian marine ecosystems, see the Australian State of the Environment Reports at www.deh.gov.au/soe where the reports are listed by date. For more information on productivity, see Furnas (1995). For information on ocean surface environmental data (currents, temperatures, winds), see the website www.marine.csiro.au for the Commonwealth Scientific and Industrial Research Organisation, CSIRO, and David Griffin's CSIRO site at www.marine.csiro.au/%7Egriffin/. Regularly updated information on climate impact, fisheries and marine sciences, including an online Atlas of Australian Marine Fishing and Coastal Communities is available from the Australian Department of Agriculture, Fisheries and Forestry, Bureau of Rural Sciences at http://adl.brs.gov.au together with lists of publications on species, bycatch, the role of marine reserves and other important topics broken out by regions.

Oceanic fronts: The westward South Equatorial Current impinges on the east coast of Australia and bifurcates, with the two branches flowing north or south, along the coast (Belkin & Cornillon 2003, Belkin *et al*. 2008) (Figure IX-18.1). The southward branch is the East Australian Current (EAC), a strong poleward flowing western boundary current that carries tropical waters into the LME. A distinct front exists between tropical Coral Sea waters and the Tasman Sea waters at between 31-37ºS, the Tasman Front. The EAC is a highly energetic current that shifts between a dominating poleward extension that flows past Tasmania, and a Tasman Front extension, which flows eastward towards Lord Howe Island, eventually forming the East Auckland Current. With currents more than 1 ms^{-1}, water flowing in from the north, surface waters can move though the LME in as little as a month. The poleward extension of the EAC has strengthened due to recent climatic changes, resulting in a significant warming of waters of southern NSW and Tasmania (Cai, 2006).

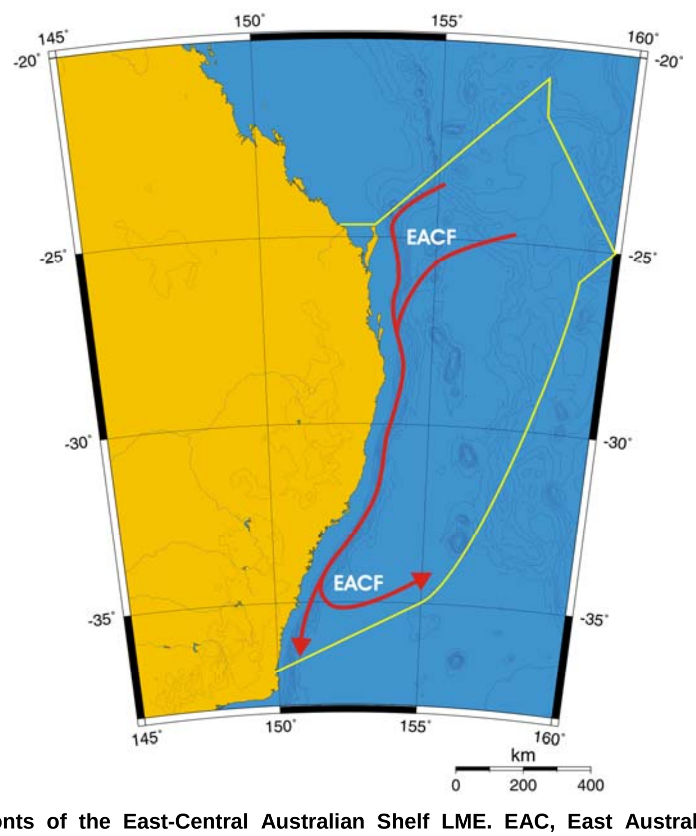


Figure IX-18.1. Fronts of the East-Central Australian Shelf LME. EAC, East Australian Curent; TF, Tasman Front. Yellow line, LME boundary (after Belkin et al. 2008).

East-Central Australian Shelf SST
Linear SST trend since 1957: 0.56°C.
Linear SST trend since 1982: 0.35°C.

The steady warming of the East-Central Australian Shelf was punctuated by two warm events, in 1973 and 1998. The 1973 peak was a large-scale event that occurred simultaneously in the Indonesian Sea LME, North Australian Shelf LME, and Northwest Australian Shelf LME. The above-noted synchronism can only be explained by large-scale atmospheric forcing (teleconnections). Indeed, oceanic advection by currents must be ruled out because the entire Northeast and East Australian coastal and offshore region (basically, most of the Coral Sea and northern part of the Tasman Sea) is dominated by the South Equatorial Current and its extension, East Australian Current, whereas the Indian Ocean inflow via Torres Strait is negligible.

The 1998 all-time maximum was a manifestation of the 1997-98 El Niño. The summer of 1997-1998 was the hottest recorded on the Great Barrier Reef, causing bleaching of two thirds of inshore reefs (Berkelmans and Oliver 1999).. Otherwise, the interannual variability of this ecosystem was rather small, with year-to-year variations less than 0.5°C (CSIRO 2007). Causes of the annual variation in the EAC eddies are still a puzzle, driven by intrinsic instabilities (Bowen et al. 2005).

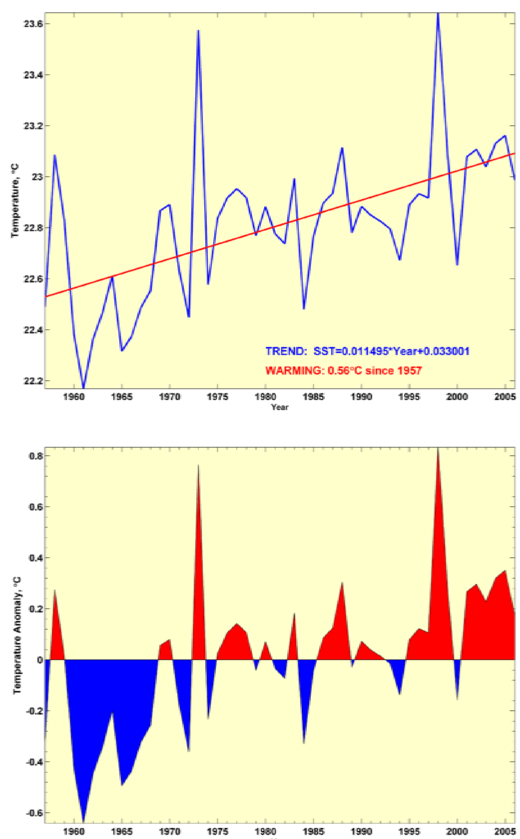


Figure IX-18.2. East Central Australian Shelf LME Mean Annual SST, 1957-2006 (top) and SST anomalies, 1957-2006 (bottom) based on Hadley climatology, after Belkin et al. 2008.

***East Central Australian Shelf LME, Chlorophyll and Primary Productivity*:** The East-Central Australian Shelf LME is considered a Class III, low productivity ecosystem at 86 – 177 $gCm^{-2}yr^{-1}$ (Sea Around Us 2007; www.science.oregonstate. edu/ocean.productivity/).

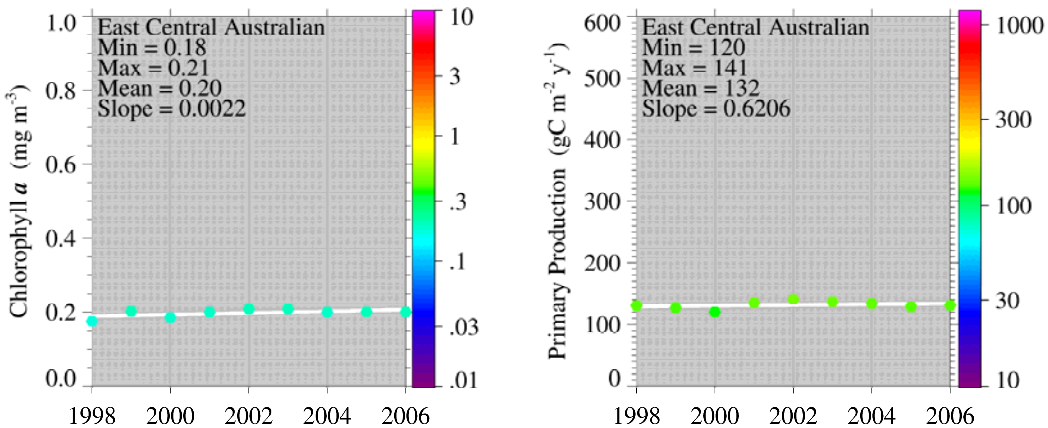


Figure IX-18.3. East Central Australian Shelf trends in chlorophyll a and primary productivity, 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

Australian waters are relatively nutrient-poor and unable to sustain large fish populations. Approximately 1 in 4 of the 4,482 species found in Australian waters are endemic (Hoese et al. 2006). Off the coast of New South Wales, 1,748 fish species are recorded of which 22% are Australian endemics. For information on South-East Fisheries, see the AFMA websites or DEWR reports. Federal, commercial fishing is not large in the Australian East Marine Planning region (approximates the East Central Australian LME) valued in 2002-2006 at around $320 m and 1% of the national value of commercial fisheries. These AFMA managed fisheries http://www.afma.gov.au/fisheries/default.htm include the East Coast Deepwater trawl fisheries, (10 concessions, using demersal and midwater trawling); the Commonwealth Trawl Sector (formerly South East Trawl Fishery), with nearly 60 concessions, 54 vessels using otter trawl and danish seine methods, some midwater trawling; the Eastern Tuna and Billfish Fishery (ETBF) with over 100 permits, 72 vessels using pelagic longline, minor line (handline, troll, rod and reel). The vast bulk of the landings are restricted to the very narrow continental shelf (Moore et al. 2007). Three of the more significant commercial fisheries are the various estuarine and ocean prawn trawl fisheries to 3 nautical miles, and the federally managed South East Trawl and the East Coast tuna fishery. FAO provides information on Australia's fisheries and the characteristics of the industry (www.fao.org). Reported landings in the LME include mullet, shrimps and prawns, butterfishes and tunas (skipjack, yellowfin and bluefin) and have fluctuated over the last 50 years with peaks in the mid 1970s, late 1980s and early 2000s with over 30,000 tonnes recorded in mid 1970s, late 1980s and again in 2002-2005 (Figure IX-18.4). The value of the reported landings reached nearly 300 million US$ (in 2000 real US$) in the mid 1970s and 100 million US$ in recent years (Figure IX-18.5). For 2000/01, FAO reports landed catch in Queensland fisheries alone at 31,250 tonnes (excluding aquaculture), valued at 741 millions $AUD. The ADL Bureau of Rural Science estimates that the Eastern Central Region's commercial fisheries caught 31,500 tonnes with Gross Value of Products (GVP) at 315 million $AUD in 2002.

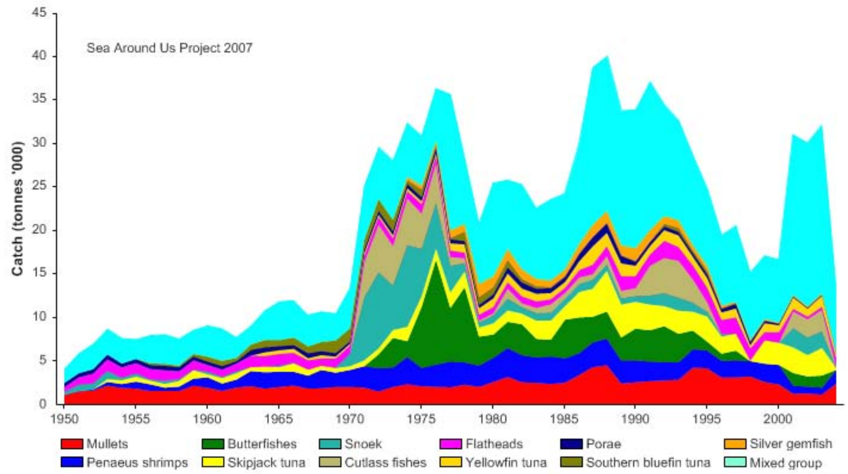


Figure IX-18.4. Total reported landings in the East-Central Australian Shelf LME by species (Sea Around Us 2007). Note that Porae =Blue Morwong.

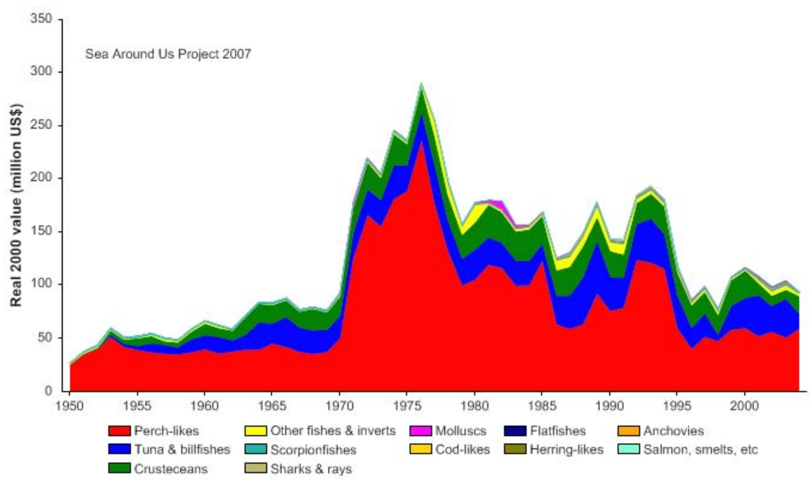


Figure IX-18.5. Value of reported landings in the East-Central Australian Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME is currently below 4% with Australia and New Zealand, as well as few distant water fishing countries, namely Japan and South Korea, historically accounting for the large share of the ecological footprint (Figure IX-18.6).

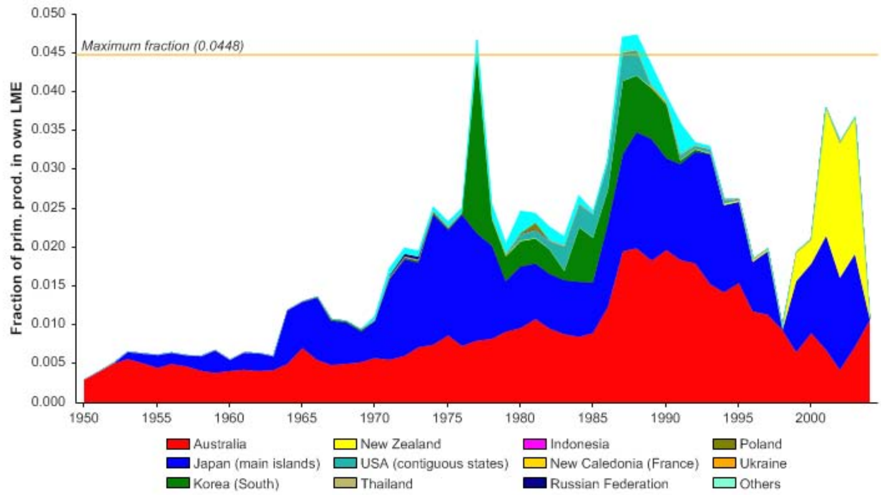


Figure IX-18.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the East-Central Australian Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

Both the mean trophic level (i.e., the MTI; Pauly & Watson 2005) and the FiB index vary widely and no clear interpretation on the state of the LME or its fisheries can be made based on these indices (Figure 18.7). It is likely that such variation in the two indices is due to the low level of exploitation in the region.

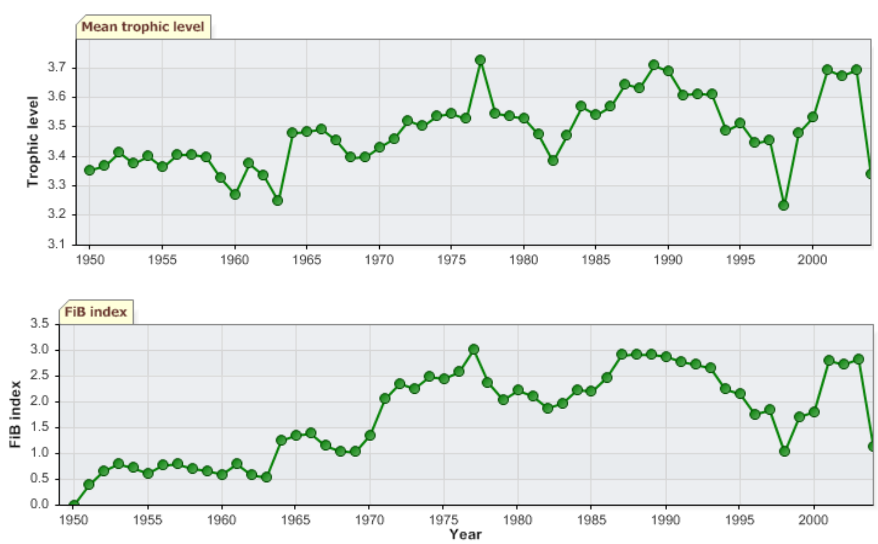


Figure IX-18.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the East-Central Australian Shelf LME (Sea Around Us 2007)

The fluctuations in the reported landings are also making interpretation of the Stock-Catch Status Plots difficult (Figure IX-18.8). Whilst these plots imply approximately 20% and 40% of stocks being collapsed and overexploited, respectively (Figure IX-18.8 top), the causes are complex including changes to gear and management, price and especially multispecies effects (over 200 species are processed by the Sydney Fish Markets, Moore et al. 2007).

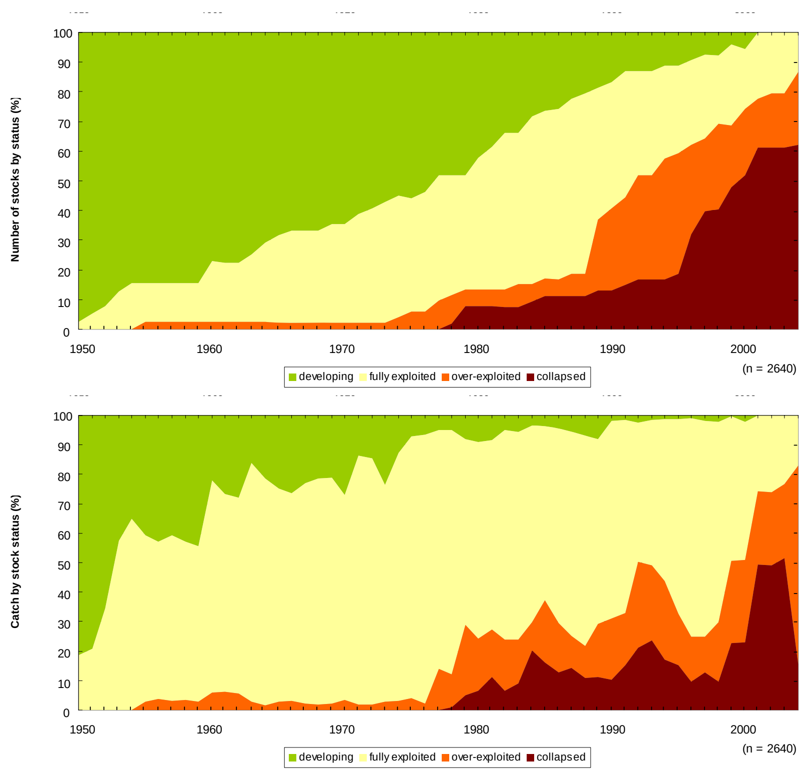


Figure IX-18.8. Stock-Catch Status Plots for the East-Central Australian Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), 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). See also Moore et al. (2007) for a fisheries status overview.

III. Pollution and Ecosystem Health

The major problems for this coastline are real estate value, urbanization, water quality, freshwater, and beach erosion. The coastline of NSW alone has over 450 coastal discharge sites along the NSW coast, the largest three being off Sydney amounting to nearly 1000 $ML.d^{-1}$ or primary treated sewage Desalination plants are planned or being constructed for the Gold Coast, Sydney (Kurnell) and Melbourne (at Wonthaggi on the South Gippsland coast). There are no mining activities in the LME but there is potential for sand mining, manganese nodule harvesting, or base/precious metals on the Lord Howe Rise. Sand mining has the greatest potential for NSW in light of beach erosion and construction needs. There is a pilot wave-energy generator at the breakwater of Port Kembla www.oceanlinx.com/ .

For 2005-2006, ports of the East Marine Planning region (mostly Newcastle, Sydney, Brisbane and Port Kembla) accounted for 42% of the nation's exports and 51% of national imports by tonnage (Anon. 2007). These ports accounted for 18% of freight loaded and 67% unloaded by all Australian ports. The busiest sea lanes are through the Coral Sea. The LME may be threatened by an increase in shipping. Ship ballast water has been shown to contain organisms including bacteria, viruses, algal cells, plankton and the larval forms of many invertebrates and fish. Two of Australia's largest three cities and four of the largest 10 ports are located in this LME, and it is the most urbanized coastline in Australia. Pressure is increasing on natural environments, productive agricultural land, water resources, sewage treatment and waste disposal systems. There are environmental impacts caused by tourism and related infrastructure (airports, power generation facilities, accommodation, sewage treatment and disposal facilities, moorings and marine transport). For more information on coastal and marine pollution issues in this LME, see the Australia State of the Environment Reports indexed by date at www.deh.gov.au/soe/index.html.

.

IV. Socioeconomic Conditions

Australia's Bureau of Rural Sciences estimates that, on average, 5% of the population of the Eastern Central and Norfolk Regions is employed in the fishing industry (http://adl.brs.gov.au/). FAO provides information on the characteristics and socioeconomic benefits of Australia's fishing industry (www.fao.org/). The Eastern Central region contains 165 towns, and large cities and ports, including Sydney (Port Jackson and Botany Bay), Brisbane, Newcastle, and Port Kembla. Shipping and marine tourism are major economic activities and the cities absorb much of the country's population growth. The Australian Bureau of Statistics http://www.abs.gov.au/ estimates the current coastal population in this LME at 8 million, mostly living in Sydney and Brisbane, with a quarter in the large coastal non-metropolitan centres like Newcastle, Wollongong, Gold and Sunshine Coasts, Coffs and Bundaberg (http://adl.brs.gov.au/).

The largest marine industry is marine tourism, contributing 22% of the national marine industry ($27 billion in value added during 2002-03, The Allen Report 2004). The value of the marine industry (i.e. all recreational and light commercial vessels) in NSW is valued at over $2 billion pa and employs over 11,000 – both figures are almost equivalent to all other states combined (mostly Victoria and Queensland, http://www.bia.org.au/data.html). Over a third of the national marine industry employment (36%) is in NSW – and mostly in marine tourism. These figures are more remarkable considering that our estuaries, while numerous (>130) are small and we have the nation's narrowest continental shelf. The Australian Bureau of Statistics estimates at www.abs.gov.au/ausstats/ that, in the entire country, over 5 million Australians take part in recreational fishing in Australia as a leisure activity (i.e. 20% fish at least once a year), with some 120,000 people identified as members of fishing clubs in 1996-97, and that recreational fishing supports about 90,000 Australian jobs especially in industries supplying tackle and bait and recreational boating. The Bureau of Statistics estimates that international tourists spend over $200m on fishing in Australia each year. A survey undertaken by the ABS in the early 1990s showed that recreational fishing accounted for 23,000 tonnes of fish, 2,800 tonnes of crabs and approximately 1,400 tonnes of freshwater crayfish. In NSW the recreational catch is about 30% of the commercial catch, but for 6 major species the recreational catch is actually greater than the commercial. In NSW the recreational fishing fee bought out commercial fishing licenses in 25 estuaries in 2001, now described as recreational fishing havens. Most of Australia's recreational fishing is undertaken along the coast and estuaries of New South Wales, Queensland and Victoria, reflecting both the excellent fishing areas and the geographic spread of Australia's population.

V. Governance

The East-Central Australian Shelf LME is bordered only by Australia and falls within the non-UNEP administered Pacific Regional Seas Programme. In 2003, Australia's Natural Resource Council endorsed a framework for a national cooperative approach to Integrated Coastal Zone Management. State jurisdiction is generally limited to the 3 nautical mile limit, but many state managed fisheries extend into federal waters to 200 nautical miles. Governance issues in this LME pertain to fisheries management and to the establishment of marine reserves. Lord Howe Island (33.5S, 159E) and the Solitary Islands (30.2S off northern NSW) were declared state marine parks in 1998/1999. Four other NSW marine parks have been declared over the past 6 years, which extend out to the 3 nm mile limit of state waters: Cape Byron (22,000 ha), Batemans Bay (85,000 ha), Jervis Bay (21,000 ha) and the largest, Port Stephens-Great Lakes (98,000 ha). The Batemans Bay and Port Stephens parks have been the most controversial with the recreational fishing community, and have challenged in state parliament the science on which they are based. The NSW Marine Parks Authority (MPA) through NSW Department of Environment and Climate Change aims to establish and manage a system of multiple-use marine parks designed to conserve marine biodiversity, maintain ecological processes and, provide for ecologically-sustainable use, public appreciation, education, understanding and enjoyment of the marine environment. Key issues remaining are larval connectivity amongst areas, and the degree of “spill-over”.. See the North Australian Shelf LME (Chapter VIII, this volume) for more information. NSW Department of Primary Industries is the principal agency responsible for conserving the aquatic environment and managing the fisheries resources of this LME. It is responsible for protecting and restoring fish habitats, promoting responsible and viable commercial fishing and supporting aquaculture industries.

The South Pacific Regional Environment Programme (SPREP), a regional intergovernmental organisation now based in Apia, Samoa, was initially established in 1982 as a programme of the South Pacific Commission. SPREP is the primary regional organisation concerned with environmental management in the Pacific, and serves as the Secretariat for three Conventions. The 1986 Convention for the Protection of the Natural Resources and Environment of the South Pacific region entered into force in 1990. The 1976 Convention on the Conservation of Nature in the South Pacific (Apia Convention), came into force in 1990. The Pacific Islands Forum is the key regional political organization in the Pacific representing the 14 Island countries as well as Australia and New Zealand. Australia ratified the United Nations Law of the Sea Convention (UNCLOS) in 1996. The 1995 Convention to Ban the Importation into Forum Island Countries of Hazardous and Radioactive Wastes and to Control the Transboundary Movement and Management of Hazardous Wastes within the South Pacific Region (Waigani Convention) entered into force in 2001. Australia’s indigenous peoples are re-emerging in the environmental management process as a result of native title rights. The Pacific Islands Forum is the key regional political organization in the Pacific, representing the 14 island countries as well as Australia and New Zealand. The Action Plan has identified four broad priorities for the region: natural resources management, pollution prevention, climate change and variability, and sustainable economic development. The Australian Government’s Department of the Environment and Heritage regularly updates a coasts and oceans website at: www.deh.gov.au/coasts/.

References

Ajani, P., Hallegraeff, G.M., Pritchard, T., 2001. Historic overview of algal blooms in marine and estuarine waters of New South Wales, Australia. Proc. Linn. Soc. N. S. W. 123, 1– 22.
Australia State of the Environment (2006) at www.deh.gov.au
Australian Bureau of Agriculture and Resource Economics (ABARE) www.abare.gov.au/
Australian Bureau of Statistics (ABS) www.abs.gov.au/
Australian Bureau of Statistics at www.abs.gov.au/ausstats/abs
Australian Government, Department of Agriculture, Fisheries and Forestry, Bureau of Rural Sciences at www.daff.gov.au/fisheries_marine

Australian Marine Fishing and Coastal Communities,"Pilot" Atlas, Eastern Central and Norfolk regions at http://adl.brs.gov.au/mapserv/fishcoast/eastern_central_norfolk_region

Anonymous 2007. East Marine Planning Region. Non-fisheries resource use activities in the east marine planning region. Sinclair Knight Mertz report to DEWR. www.environment.gov.au /coasts /mbp/publications/general/marine-economic.html

ABARE 2007, Australian Fisheries Statistics 2006, Canberra June. ISSN 1037-6879

Baird, M. E., Timko, P. G., Suthers, I. M., and Middleton, J. H. (2006). Coupled physical–biological modelling study of the East Australian Current with idealised wind forcing. Part I: Biological model intercomparison. *Journal of Marine Systems* **59**, 249–270

Belkin, I. M. and Cornillon, P. C. (2003). SST fronts of the Pacific coastal and marginal seas. Pacific Oceanography 1(2):90-113.

Belkin, I.m., Cornillon, P.C., and Sherman, K. (2008). Fronts in large marine ecosystems of the world's oceans: An atlas. Progress in Oceanography, submitted.

Berkelmans R and Oliver JK. 1999. Large-scale bleaching of corals on the Great Barrier Reef. Coral Reefs 18(1):55 - 60

Bureau of Rural Sciences (BRS) www.brs.gov.au/, fisheries and the marine environment, and Marine Matters reports.

Cai, W. 2006. Antarctic ozone depletion causes an intensification of the Southern Ocean super-gyre circulation, Geophys. Res. Lett. 33: L03712.

CSIRO. (2007) Commonwealth Scientific and Industry Research Organization at www.csiro.gov.au/ 59th Annual Report.

Dela-Cruz, J., Middleton, J.H., Suthers, I.M., 2003. Population growth and transport of the red tide dinoflagellate, Noctiluca scintillans, in the coastal waters off Sydney Australia, using cell diameter as a tracer. Limnol. Oceanogr. 48, 656– 674

Fisheries Research Development Corporation (FRDC) www.frdc.com.au/

Furnas, M. J. 1995. Land-sea interactions and oceanographic processes affecting the nutrient dynamics and productivity of Australian marine ecosystems, p. 61-74. In L. P. Zann (ed.),SOMER Technical Annex 1. Great Barrier Reef Marine Park Authority, Townsville, Australia.

Henry GW, Lyle JM (2003) 'The national recreational and indigenous fishing survey.' Australian Government Department of Agriculture, Fisheries and Forestry, Canberra.

Hoese, D.F., Bray, D.J., Paxton, J.R. & G.R. Allen. 2006. Fishes. In Beesley, P.L. & A. Wells. (eds) Zoological Catalogue of Australia. Volume 35. ABRS & CSIRO Publishing: Australia. parts 1-3, Pp. 1-2178.

Moore et al. 2006. Regional Profile – East Marine Region. Description of commercial, recreational and charter fishing activities. Report for Bureau of Rural Science. www.environment.gov.au/coasts/mbp/publications/general/marine-economic.html

Morgan, J. (1989). Large Marine Ecosystems in the Pacific Ocean, p 377-394 in: Sherman, K. and Alexander, L.M. (eds), Biomass Yields and Geography of Large Marine Ecosystems. AAAS Selected Symposium 111. Westview Press, Boulder, 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.

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.deh.gov.au/coasts/publications/marine-fish-action /index.html

Ridgway, K. R., and J. R. Dunn. 2003. 'Mesoscale structure of the mean East Australian Current System and its relationship with topography'. *Progress in Oceanography* 56:189-222.

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), Fishery Population Dynamics: The Implications for Management. John Wiley and Sons, New York, U.S.

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=41

The Allen Report. 2004. The economic contribution of Australia's marine industries. 1995-96 to 2002-03. Report to the National Oceans Office.

UNEP (2003). Wilkinson, C., Reichelt, R., DeVantier, L. and Lawrence, D. Great Australian Bight and Murray Darling Basin. GIWA Regional Assessment 61. University of Kalmar, Kalmar, Sweden.

IX-19 New Zealand Shelf LME

M.C. Aquarone and S. Adams

The New Zealand Shelf LME stretches across from the subtropics to the sub-Antarctic. It covers a surface area of nearly one million km^2, of which 0.03% is protected, and contains 0.08% of the world's sea mounts (Sea Around Us 2007). The shelf surrounding New Zealand's North Island and South Island vary in width from a few tens to several hundred kilometres. This LME is characterised by its temperate climate, influenced by the warm Tasman and North Cape currents in the north and by the cooler Southland Current in the South. The marine environment is diverse and includes estuaries, mudflats, mangroves, seagrass and kelp beds, reefs, sea mount communities and deep sea trenches. Morgan (1989) and UNEP (2003) pertain to this LME.

I. Productivity

The New Zealand Shelf LME is a Class III, low productivity (<150gCm^{-2}yr^{-1}) ecosystem. See also Bradford-Grieve et al. (2003, 2006). While the southern Plateau region subantarctic water, limited by iron availability, is low a productionsystem, the productivity of the Chatham Rise, eastern Cook Strait, and the NE shelf are considerably more productive. For a study of ocean fronts and their contribution to marine productivity in this LME, see the National Institute of Water and Atmospheric Research website, www.niwa.co.nz. View a SeaWiFS image of ocean chlorophyll in New Zealand coastal waters at www.niwa.cri.nz. In the southern part of this LME, there is higher productivity in the fiord ecosystems. The current definitive data on marine species in the New Zealand flora and fauna from the National Institute of Water and Atmospheric Research of New Zealand (NIWA) are a maximum of 16,214 species in total, including known, undescribed species.

Oceanic fronts: This LME features several well-defined fronts (Figure IX-19.1) that together determine the ecological regime of the New Zealand shelf (Belkin and Gordon 1996; Belkin and Cornillon 2003; Belkin et al. 2008). In the north, the Tasman Front and its extension associated with the North Cape Current bring warm and salty tropical waters to the east coast of North Island. This influx, together with vigorous tidal mixing thanks to rough bathymetry, is largely responsible for the exceptionally high productivity off the Bay of Islands, where big game fish like marlins and kingfish come unusually close to the mainland coast, forming fishing grounds just a few miles offshore, for example, off Cape Brett. West of North Island, the southern branch of the Tasman Front heads toward Cook Strait. In the south, the Southland Current Front runs northward along the east coast of South Island toward Banks Peninsula. East of New Zealand, the double Subtropical Frontal Zone that consists of the North and South STF extends eastward along the north and south flanks of the Chatham Rise up to Chatham Island and beyond. This double Subtropical Frontal Zone is similar to the double frontal zones found in other subtropical oceans (Belkin, 1988, 1993, 1995, 2005; Belkin and Gordon, 1996). See also Bradford-Grieve et al. (2006).

New Zealand Shelf SST (Belkin 2008)
Linear SST trend since 1957: 0.11°C.
Linear SST trend since 1982: 0.32°C.

The New Zealand Shelf features strong interannual variability, with a magnitude exceeding 1°C, superimposed over a slow-warming trend (Figure IX-19.2). Any correlation between this LME and the upstream LMEs off Australia can only be rather tenuous since different parts of the New Zealand Shelf are advectively affected by different Australian LMEs. For example, the North Island is oceanographically linked to the Northeast Australian Shelf LME, whereas the South Island is linked to the Southeast Australian Shelf LME. The all-time maximum of 1971 in New Zealand occurred two years prior to the near-all-time maximum of 1973 in the East Central Australian Shelf LME, therefore these events could not have been advectively connected.

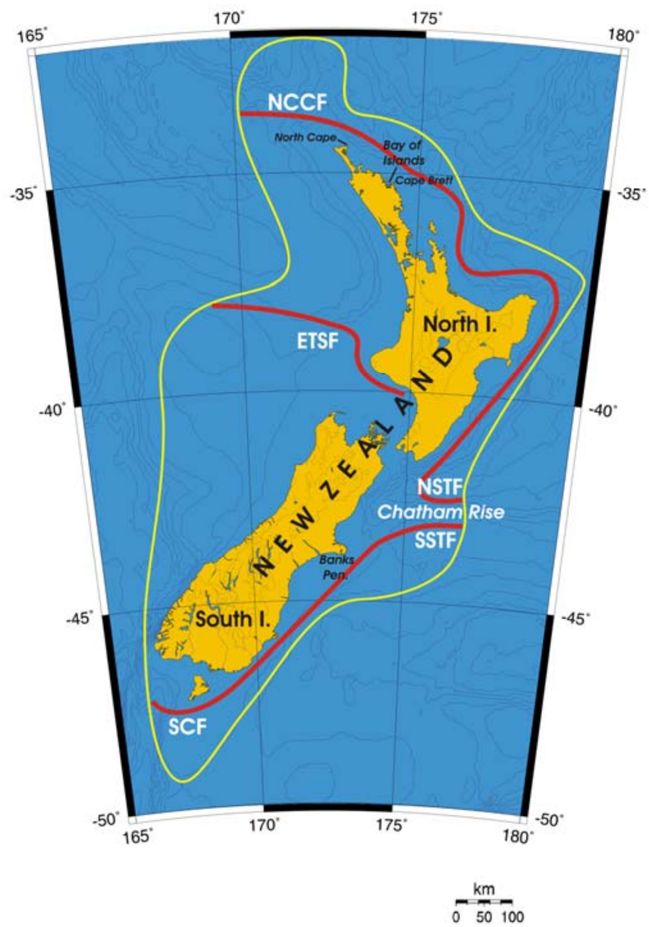


Figure IX-19.1. Fronts of the New Zealand Shelf LME. ETSF, East Tasman Front; NCCF, North Cape Current Front; NSTF, North Subtropical Front; SCF, Southland Current Front; SSTF, South Subtropical Front. Yellow line, LME boundary. After Belkin et al. (2008), Belkin and Cornillon (2003), and Belkin and Gordon (1996).

Another warm peak, of 1974, occurred off New Zealand a year after the 1973 warm peak in the East-Central Australia LME; these events may have been advectively connected. The warm events of 1971-1974 were confined to these two LMEs connected by the East Australian Current and its eastward extensions, namely Tasman Front (TF), North Cape Current Front (NCCF), and East Tasman Sea Front (ETSF) (Figure IX-19.1).

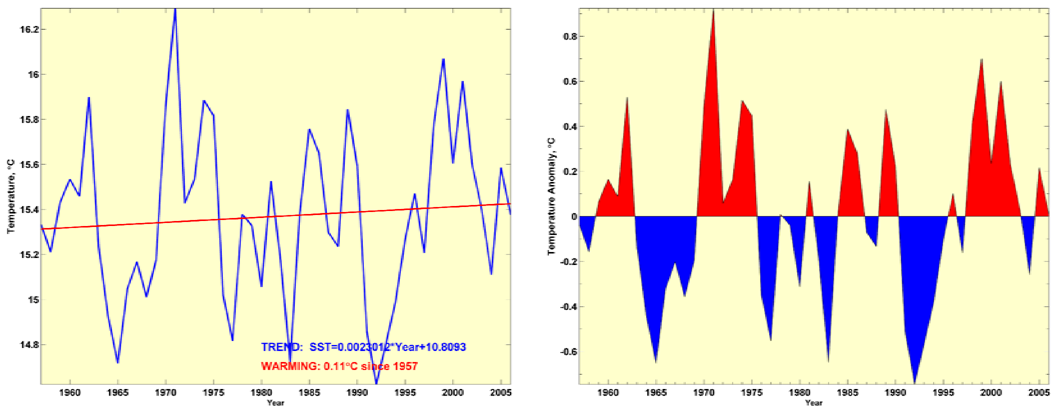


Figure IX-19.2. New Zealand Shelf LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2008).

New Zealand Shelf LME Chlorophyll and Primary Productivity

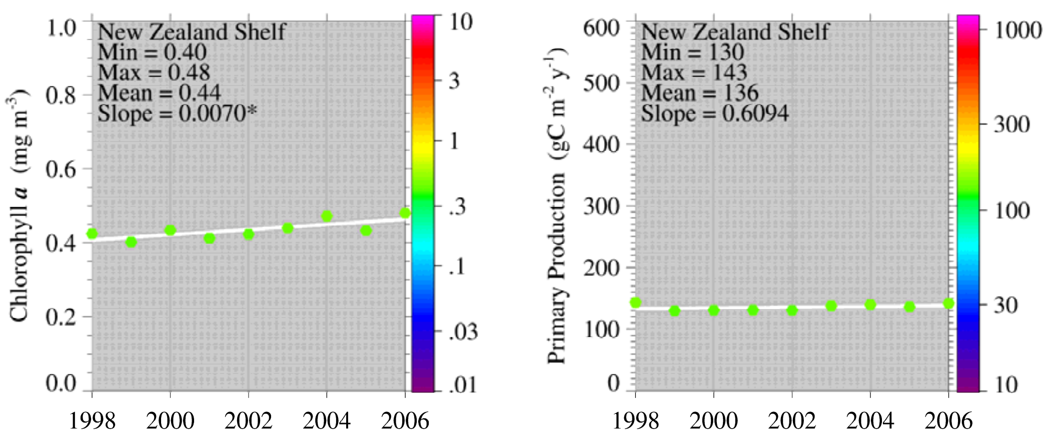


Figure IX 19.3. New Zealand Shelf LME annual trends in chlorophyll *a* (left) and primary productivity (right), 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

I. Fish and Fisheries

The New Zealand Ministry of Fisheries estimates about 750,000 tonnes of seafood is harvested annually from New Zealand's fisheries—70% from deepwater and midwater fisheries, 11% pelagic, 10% farmed species, and 9% from their inshore fisheries. Note that the Chatham Rise and the Southern Plateau, 2 major fishing regions, are not entirely included in the LME. The Ministry also estimates that 20% of the population engages in marine recreational fishing annually and that the expenditure made by recreational fishers to catch five key recreational species is nearly NZ$1 billion per year (www.govt.nz/en-nz). Among the important fisheries in this LME are those for migratory apex predators such as tuna, billfish, and shark, squid, hoki, orange roughy, rock lobster, mussels (cultured) and snapper are key export species. According to the Ministry, the value of fish exports in 2004 grew more than the volume and generated NZ$1.2 billion, NZ$1.0 billion from capture fisheries and NZ$200 million from aquaculture.

Fisheries policies in New Zealand hope to secure a long-term future for the industry by setting sustainable catch limits and providing harvesting rights to benefit all New Zealanders, including the indigenous Maori. Fiords in the southern part of this LME support commercial and recreational fisheries as well as traditional Maori fisheries. Information on the fisheries in this LME is available on the FAO website (www.fao.org/). For information on areas closed to fishing, see the New Zealand Department of Conservation (www.doc.govt.nz/).

Total reported landings show a sharp spike in 1977 of 220,000 tonnes, likely associated with the declaration of the 200 nautical mile Exclusive Economic Zone around this LME by New Zealand, followed by a continuous increase through the 1980s and 1990s and a decline in the 2000s (Figure IX-19.4). The value of the reported landings reached US$583 million (in 2000 US dollars) in 1984, followed by a decline to between US$260 million and US$450 million in recent years (Figure IX-19.5).

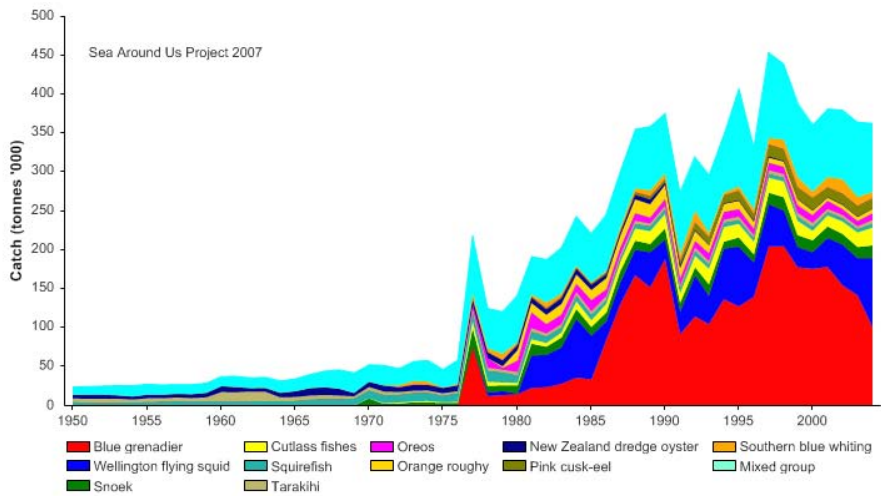


Figure IX-19.4. Total reported landings in the New Zealand Shelf LME by species (Sea Around Us 2007).

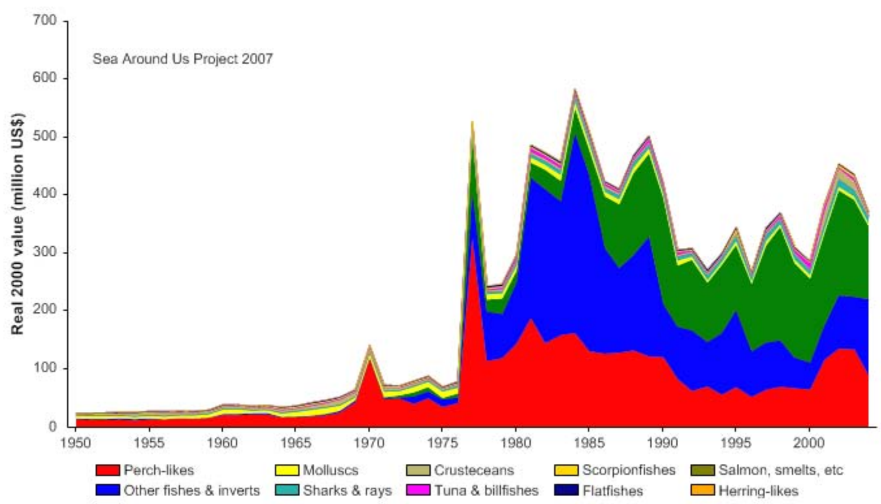


Figure IX-19.5. Value of reported landings in the New Zealand Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings is currently below 4% with New Zealand accounting for the great majority of the ecological footprint in the LME (Figure IX-19.6).

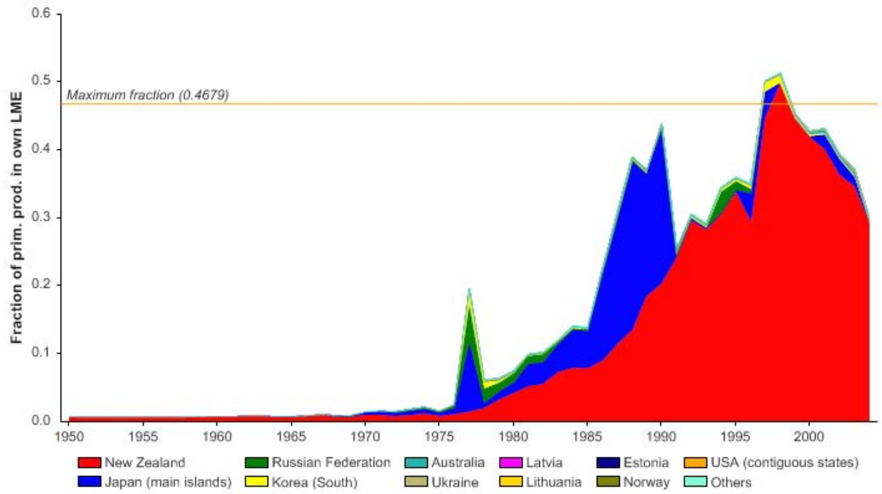


Figure IX-19.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the New Zealand Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005) has been on a rise since the mid-1970 (Figure IX-19.7, top) as has the FiB index (Figure IX-19.7, bottom). Together with the data presented in Figure IX-19.6, such trends suggest the development of previously under-utilized, high trophic fisheries resources by local as well as foreign fleets.

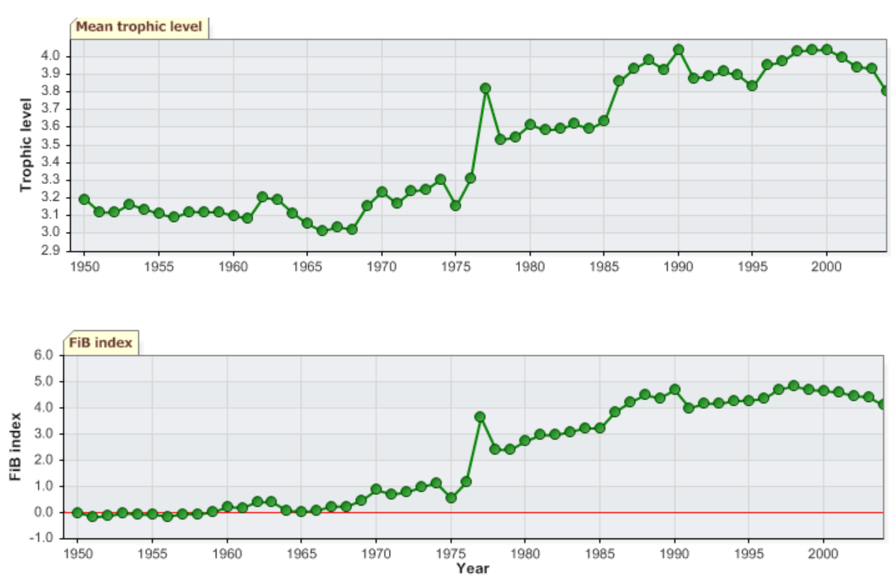


Figure IX-19.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the New Zealand Shelf LME (Sea Around Us 2007).

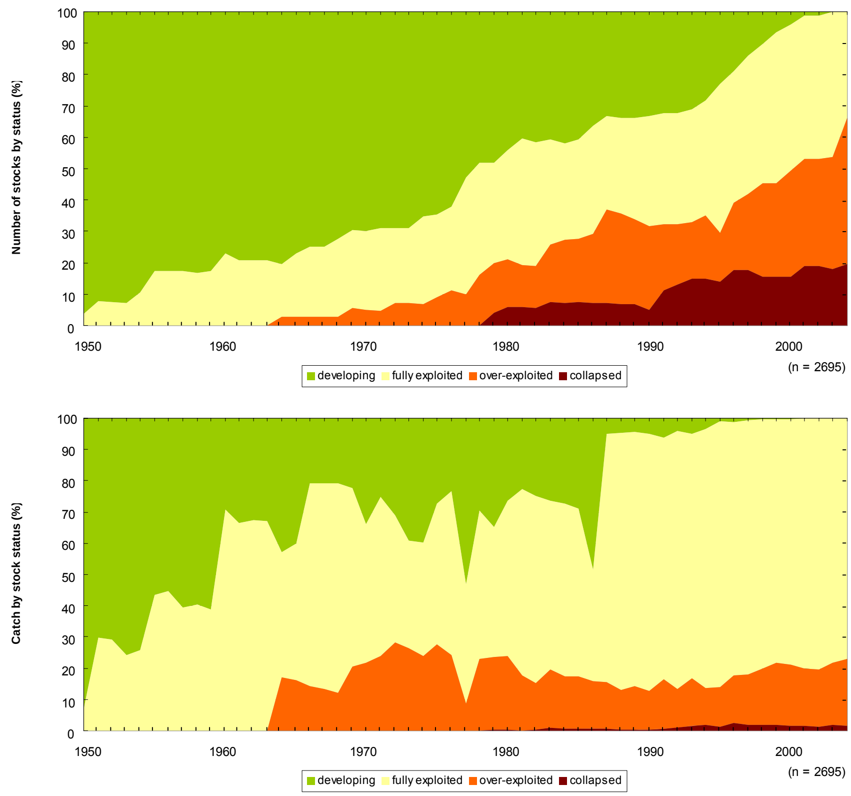


Figure IX-19.8. Stock-Catch Status Plots for the New Zealand Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the number 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).

The Stock-Catch Status Plots for the LME illustrate that more than half of the stocks in the region are currently either overexploited or have collapsed (Figure IX-19.8, top). However, the majority of the reported landings are supplied by stocks classified as 'fully exploited' (Figure IX-19.8, bottom).

III. Pollution and Ecosystem Health

Fisheries impacts on the environment are not completely understood and the data is incomplete. Gill nets pose a risk to marine birds, particularly if set near feeding or breeding areas. Yellow-eyed penguins appear most at risk from nets set by commercial fishermen for bottom dwelling species such as rig and dogfish. The nets are set well within the feeding range of these penguins. Fiord ecosystems in the southern part of this LME are in need of protection. In that region, the crested penguin, *Eudyptes pachyrhynchus*, is at risk. Native flora and fauna are affected by invasions of the Asian kelp, *Undaria*, and toxic micro-algae. Additional information on marine invasions, ballast water, marine toxins, harmful algal blooms and diarrheic shellfish poisoning, is given www.cawthron.org.nz. Studies are underway to assess trawling damage to benthic species and to deepwater seamount habitat.

It has been suggested that changes in sea surface conditions have contributed to the spread of toxic algae and invasive seaweeds in New Zealand waters. Toxic algal blooms occurring in the 1990s have killed marine life and caused illness in humans. Other issues affecting the marine environment are waste and hazardous substances. New Zealand produces a higher rate of municipal waste (two thirds of a tonne per person each year) than most other developed countries. Industrial waste is estimated at 300,000 tonnes a year. Another ecosystem health issue is climate change. Gases released into the atmosphere are enhancing the natural greenhouse effect at a rate that could extensively damage the LME's biophysical systems. Atmospheric levels of carbon dioxide and methane - two of New Zealand's major greenhouse gases – are rising. Studies are underway to assess the impact of terrestrial runoff on coastal ecologies and marine communities.

IV. Socioeconomic Conditions

The population of New Zealand is exceeds 4 million and impacts the marine environment through commerce, recreation (including whale watching), indigenous fishing (Maori and Pacific Islanders), commercial fisheries, marine aquaculture, trade, defence and security. The ocean floor is explored and mined for minerals, natural gas and oil. Ports and harbours in this LME are Auckland, Christchurch, Dunedin, Tauranga and Wellington. Statistics New Zealand has developed socioeconomic indicators for the environment that complement the Ministry for the Environment's Environmental Performance Indicators programme (www.stats.govt.nz/). The Ministry of Fisheries estimates direct full-time employment in commercial fisheries and aquaculture at 10,500, and direct and indirect full-time employment in those jobs at 26,000 (www.fish.govt.nz/). Commercially important species are managed under the quota management system (the QMS). The Ministry lists 2,200 persons as holding a quota and a total quota value of $3.5 billion. The Māori now own 40% of quota and have additional involvement in 20% of quota (www.fish.govt.nz/). Recommended TACs for various species for 2006/2007are listed at www.fish.govt.nz/ and in 2006 it was thought that some TAC levels were still too high to be sustainable. Of the 93 stocks on which New Zealand has information for current stock size, 76 (82%) are at or near target levels.

V. Governance

This LME is governed by New Zealand, and is included within the UNEP Pacific Regional Seas Programme. Managing the marine environment is a complex process involving overlapping and conflicting interests, agencies and legislation. Issues arising between commercial fisheries and conservation interests are addressed under different regulations administered by the Department of Conservation and the Ministry of Fisheries. The latter, since the 1930s, has been responsible for the sustainable use of fisheries for the social, economic and cultural well-being of the people. All stakeholders of the marine environment are included in the advancement of sustainable management. There are currently 97 species groupings in the QMS, divided into 629 fishstocks or geographic Quota Management Areas (QMAs). Of the 629 fishstocks, 280 have TACCs of 10 tonnes or less, leaving approximately 349 significant fishstocks that need to be closely monitored (www.fish.govt.nz).

New Zealand is in the process of developing a comprehensive National Oceans Policy which aims to address a range of marine issues including fisheries, maritime transport and protection of the marine environment. New Zealand's Department of Conservation is responsible for marine reserves and for marine mammals such as dolphins, whales, sea lions and fur seals. New Zealand has a number of coastal national parks (Bay of Islands Maritime and Historic Park, Hauraki Gulf Maritime Park).. The New Zealand Biodiversity Strategy (2000) goal includes having 10% of the marine environment in a network of Marine Protected Areas by 2010. For more information on marine reserves see the Department of Conservation website at (www.doc.govt.nz/). The Ministry of Foreign Affairs and Trade is responsible for New Zealand's international effort to address environmental pressures arising from climate change, conservation of species, protection of ocean biodiversity, hazardous substances, and international agreements on environmental goods and services. The Environment Division leads this work and all multilateral environmental agreements, such as the United Nations Framework Convention on Climate Change (ministry web site at www.mfat.govt.nz/).

References

Belkin, I.M. (1988) Main hydrological features of the Central South Pacific, in: Ecosystems of the Subantarctic Zone of the Pacific Ocean, edited by M.E. Vinogradov and M.V. Flint, Nauka, Moscow, 21-28 [Translated as “Pacific Subantarctic Ecosystems”, pp.12-17, New Zealand Translation Centre Ltd., Wellington, 1996].

Belkin, I.M. (1993) Frontal structure of the South Atlantic, in: Pelagic Ecosystems of the Southern Ocean, edited by N.M. Voronina, Nauka, Moscow, 40-53.

Belkin, I.M. (1995) Remote sensing and in situ observations of subtropical fronts, in: Proceedings of the COSPAR Colloquium "Space Remote Sensing of Subtropical Oceans", September 12-16, 1995, Taipei, Taiwan, 14B3-1÷14B3-5.

Belkin, I.M. (2008) Rapid warming of Large Marine Ecosystems, Progress in Oceanography, in press.

Belkin, I.M., and Gordon, A.L. (1996) Southern Ocean fronts from the Greenwich meridian to Tasmania, J. Geophys. Res., 101(C2), 3675-3696.

Belkin, I.M., Cornillon, P.C., and Sherman, K. (2008). 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.

Boyd, P.W., LaRoche, J., Gall, M., Frew, R. and McKay, R. (1999). Role of iron, light, and silicate in controlling algal biomass in subantarctic waters SE of New Zealand. Journal of Geophysical Research 104(13):391-404.

Bradford-Grieve, J.M., Boyd, P., Chang, F.H., Chiswell, S., Hadfield, M., Hall, J.A., James, M.R., Nodder, S.D. and Shushkina, E.A. (1999). Ecosystem functioning in the subtropical front region east of New Zealand in austral winter and spring 1993. Journal of Plankton Research 21(3):405-428.

Bradford-Grieve, J.M., Probert, P.K.; Baker, A.N., Best, H.A., Boyd, P., Broekhuizen, N., Childerhouse, S., Clark, M.; Hadfield, M., Hall, J.A.; Hanchet, S.; Nodder, S.D.; Safi, K.; Thompson, D.; Wilkinson, I.; Zeldis J. (2003) Pilot trophic model for subantarctic water over the Southern Plateau, New Zealand: a low biomass, high efficiency system. Journal of Experimental Marine Biology and Ecology 289(2): 223 – 262.

Bradford-Grieve, J., Probert, K., Lewis, K., Sutton, P., Zeldis, J., Orpin, A. (2006). Chapter 36. New Zealand shelf region. In: The Sea, Volume 14: "The Global Coastal Ocean: Interdisciplinary Regional Studies and Syntheses" Part B. (eds) A. Robinson and H. Brink, Wiley, New York. Pp 1451-1492.

Cawthron (2007) www.cawthron.org.nz//what_biosecurity_main.htm. (for information on invasive species). Cawthron’s funding comes from the Foundation for Research, Science & Technology and a range of commercial clients to which it provides consulting and analytical services. Cawthron scientific and technical staff are based in Nelson and Marlborough.

FAO. Fisheries at www.fao.org/docrep/003 /w4248e/AREA81

Forrest, B., Taylor, M. and Hay, C. (1997). Foreign marine species in New Zealand: Towards a risk assessment and management model. Cawthron Report 424.

Gall, M., Hawes, I. and Boyd, P. (1999). Predicting rates of primary production in the vicinity of the subtropical convergence east of New Zealand. New Zealand Journal of Marine and Freshwater Research 33(3):443-455.

Hall, J.A., James, M.R. and Bradford-Grieve, J.M. (1999). Structure and dynamics of the pelagic microbial food web of the subtropical convergence region east of New Zealand. Aquatic Microbial Ecology 20(1):95-105.

Hay, C. (1998). Marine and freshwater invaders. Water and Wastes in New Zealand November/December issue:27-29.

Hay, C. and Taylor, M. (1999). Biosecurity in ports: Pros and cons of an "Insurance Assessment" approach, in: Hillman, S.P. (ed), The Ballast Water Problem - Where to from here? Proceedings of a workshop, 5-6 May 1999, Brisbane, Australia. EcoPorts Monograph Series 19.

Hunter K.A. and Boyd, P.W. (1999). Biogeochemistry of trace metals in the ocean. Marine and Freshwater Research 50(8):739-754.

Morgan, J. (1989). Large Marine Ecosystems in the Pacific Ocean, p 377-394 in: Sherman, K. and Alexander, L.M. (eds), Biomass Yields and Geography of Large Marine Ecosystems. AAAS Selected Symposium 111. Westview Press. Boulder, U.S.

New Zealand National Institute of Water and Atmospheric Research at www.niwa.cri.nz/ pgsf/Ocean Fronts/images/nz2/gif for Sea WiFS image.

New Zealand Department of Conservation at www.doc.govt.nz/ Conservation/Marine-and-coastal/index.asp

New Zealand Government Environment Publications at www.govt.nz/en-nz/Publications/); www.stats.govt.nz/domino/external/web/prod_serv.nsf/htmldocs/Socioeconomic+indicators+indicators+for+the+environment)

New Zealand Ministry of Fisheries at www.fish.govt.nz
www.fish.govt.nz/en-nzFisheries+at+a+glance/default.htm (for labor statistics)
www.fish.govt.nz/en-nz/Press/September+2006/Sustainability (for 2006-2007 TAC statistics)
www.fish.govt.nz/en-nz/Publications/Ministerial+Briefing+04/F (for Maori catch quotas)

NOAA (1991). Report of the ad hoc Committee on Large Marine Ecosystems. NOAA Technical Memorandum NMFS-F/NEC-92.

Paulin, C., Stewart, A., Roberts, C. and McMillan, P. (1989). New Zealand Fish – A complete guide. National Museum of New Zealand Miscellaneous Series No 19.

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.

Roberts, R., Hay, C. and Rhodes, L. (1997). Marine invaders. The Royal Society of New Zealand, Alpha Series 92.

Safi, K.A. and Hall, J.A. (1999). Mixotrophic and heterotrophic nanoflagellate grazing in the convergence zone east of New Zealand. Aquatic Microbial Ecology 20(1):83-93.

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=46

UNEP (2003). Deese, H., de Ronde, C., DeVantier, L., Hall, J., Howard-Williams, C., Johnson, D., Mosbauer, A., Murdoch, R., Nodder, S., Pearson, C., Reichelt, R. and Wilkinson, C. Tasman Sea, GIWA Regional Assessment 63. University of Kalmar, Kalmar, Sweden.

IX-20 Northeast Australian Shelf LME

M.C. Aquarone, S. Adams, and J. Brodie

The Northeast Australian Shelf/Great Barrier Reef LME lies in the Pacific Ocean off the coast of the State of Queensland, Australia. It is bounded by the Coral Sea to the east and by the Torres Strait, which separates Australia from Papua New Guinea, to the north, covering an area of 1.3 million km^2 of which 28.06% is protected (Sea Around Us 2007). The LME is characterised by a tropical climate, with tropical cyclones being common seasonal events. The South Equatorial Current, a part of the Pacific Ocean counterclockwise gyre, and the Great Barrier Reef (GBR), a system of coral reefs that stretches 2,000 km along Australia's northeast coast, are notable features of the LME (Brinkman et al., 2002). It has the largest system of corals and related life forms in the world, with 13.51% of the world's coral reefs, in addition to 0.26% of the world's sea mounts (Sea Around Us 2007). Nutrient enrichment is due to land-based sources as well as small upwelling areas and advection while mixing in this LME is due to tidal effects and the wind regime in inshore areas. Intensive fishing is an important force driving the LME but the combined stresses of climate change, terrestrial pollution and over-harvesting are degrading the system in similar ways to other global coral reef systems (Pandolfi et al., 2003; Bruno and Selig, 2007). Book chapters and articles pertaining to this LME include Bradbury & Mundy (1989), Morgan (1989), Kelleher (1993), Brodie (1999, 2003), Furnas (2003), Hopley et al. (2007), Johnson and Marshall (2007), and UNEP (2003).

I. Productivity

The Northeast Australian Shelf LME is considered a Category III, low productivity (<150 $gCm^{-2}yr^{-1}$) ecosystem. Ocean currents and wind systems along this coast inhibit the development of highly productive upwelling systems. On this continental shelf, sources of nutrients are Coral Sea surface water, Coral Sea local upwellings of deep sea water, terrestrial runoff and atmospheric inputs. Tidally-induced mixing in the GBR is a major contributor to the nutrient dynamics of this ecosystem. For more information on oceanographic processes in this LME, see Wolanski, 1994, Wolanski et al., 2001 and Brinkman et al., 2002. For large-scale shifts in biomass of the GBR, see Bradbury & Mundy (1989).

There has been a steady accumulation of knowledge and understanding of the structure and dynamics of this system. There is high biological diversity in this LME, with high numbers of rare species. On the GBR are found 350 species of hard corals, along with 1,500 species of fish, 240 species of seabirds, and at least 4,000 species of molluscs (see Brodie 1999). The physical and biological structure of the GBR is complex. For a map of the GBR region, see Kelleher (1993). The abundance of hard corals has been reduced by at least 50% in areas where there is intense crown-of-thorns starfish activity. For more information about the large-scale effects of crown-of-thorns starfish outbreaks on the benthic community, and for the propagation of effects into the fish and plankton communities, see Bradbury & Mundy (1989) and Brodie et al. (2005).

Oceanic fronts: From satellite data (Belkin & Cornillon 2003, Belkin et al. 2008), the GBR is marked by a seasonal thermal front (GBRF) that peaks during the austral winter (Figure IX-20.1). This front is better defined off southern Queensland, whereas the fronts' extension off northern Queensland is less robust. Satellite data analysis revealed another, inner shelf front that runs off the Queensland coast (QISF). This front appears to consist of three segments, northern, central and southern, whose possible connectivity is not yet established. In addition, a coastal region affected by terrestrial material is evident (Brodie et al., 2007) separated from the oceanic regions off the shelf in deeper waters.

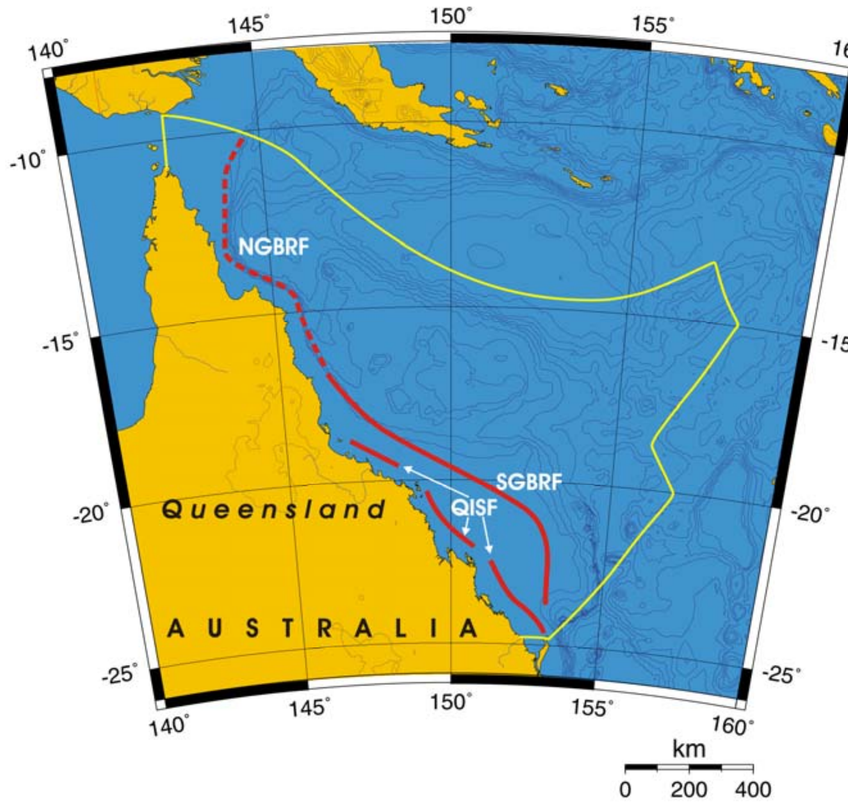


Figure IX-20.1. Fronts of Northeast Australian Shelf/Great Barrier Reef LME. NGBRF, North Great Barrier Reef Front (most probable location); QISF, Queensland Inner Shelf Front; SGBRF, South Great Barrier Reef Front. Yellow line, LME boundary. After Belkin et al. (2008).

Northeast Australian Shelf SST (after Belkin 2008)
Linear SST trend since 1957: 0.46°C.
Linear SST trend since 1982: 0.37°C.

Interannual and long-term variability of SST in this LME (Figure IX-20.2) are correlated with a few neighboring LMEs. For example, the twin peaks of 1970-1973 occurred simultaneously in the North Australian Shelf LME. The local minimum of 1982 occurred at the same time in the Indonesian Sea LME and in the Australian Shelf LME. The all-time maximum of 1998 was a local manifestation of the global warming effect of the El Niño 1997-98. The absolute minimum of 1964-65 occurred concurrently with the Southeast Australian Shelf LME. This cold anomaly probably originated upstream, in the South Equatorial Current.

High SST exceeding the coral colony' tolerance threshold is the primary cause of coral bleaching (Hoegh-Guldberg, 1999; Liu et al., 2003). In 2002, the Great Barrier Reef suffered from the worst coral bleaching event ever, which affected up to 60% and severely damaged 5%, of reefs surveyed (Berkelmans et al., 2004). Further severe bleaching and damage is predicted under the current climate change predictions and in association with ocean acidification (Lough, 2008, Hoegh-Guldberg et al., 2007).

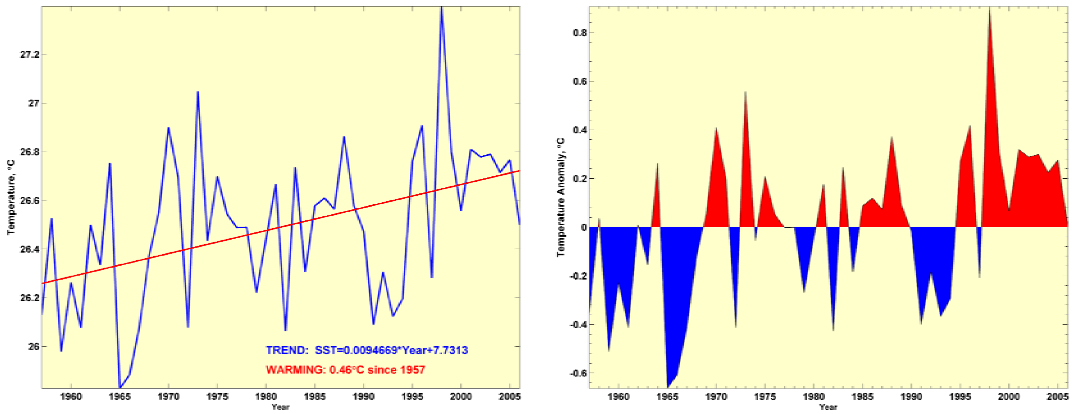


Figure IX-20.2. NE Australian Shelf mean annual SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology. After Belkin (2008).

Northeast Australian Shelf Chlorophyll and Primary Productivity

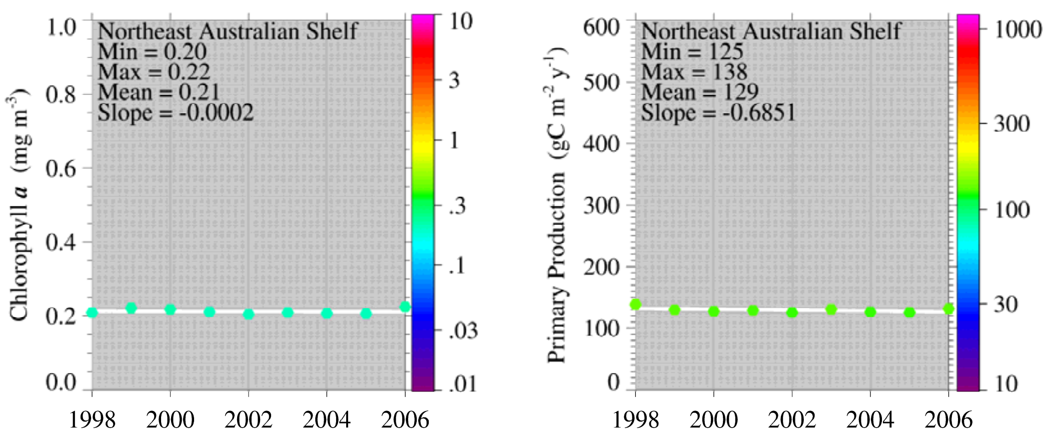


Figure IX-20.3. Northeast Australian Shelf Trends in chlorophyll-*a* and primary productivity, 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

The relatively nutrient-poor waters of the Northeast Australian Shelf are unable to sustain large fish populations. The trawl fishery (Brodie 1999) targets tiger prawns, banana prawns and king prawns. Commercial and recreational fishing remain a huge industry in the Northeast Australian Shelf/Great Barrier Reef LME. The commercial sector in the state of Queensland annually harvests about 24,000 tonnes of seafood while the 800,000 recreational fishers in Queensland annually catch between 3,500 and 4,300 tonnes (www.oceanatlas.org). The Bureau of Rural Sciences estimates a total commercial fisheries production in national waters in 2002 at 15,600 tonnes with a value of AU$165 million (http://adl.brs.gov.au/). The annual catch of scallops and prawns is about 8,000 tonnes. Scallops are caught in the southern section of the GBR Marine Park. The Torres Strait prawn fishery is fully-exploited while the Torres Strait lobster is still underexploited. Information on Australia's fisheries is also available on the FAO website (www.fao.org/). Total reported landings of the LME comprised mainly of tunas (mostly of skipjacks but also yellowfin, bigeye and albacore), shrimps and prawns, and squids (from the late

1980s to early 1990s) and recorded 62,000 tonnes in 1990 (Figure IX-20.4). The landings have since declined to about half of the peak landings. The trend in the value reflected that of the landings, rising to about US$250 million (in 2000 US dollars) in 1989 (Figure IX-20.5).

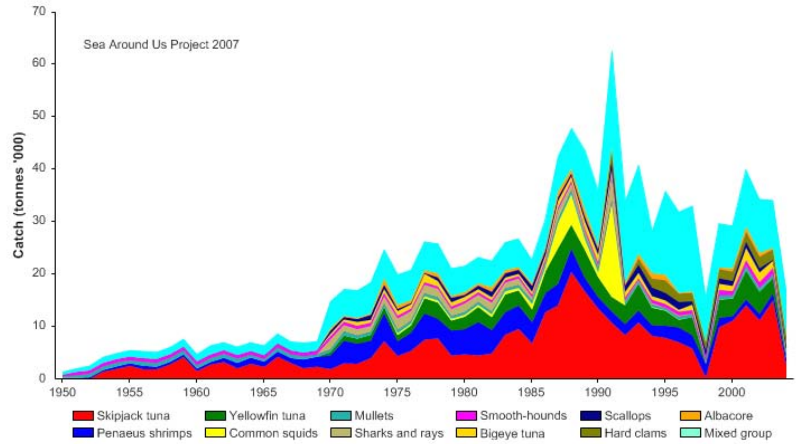


Figure IX-20.4. Total reported landings in the Northeast Australian Shelf LME by species (Sea Around Us 2007)

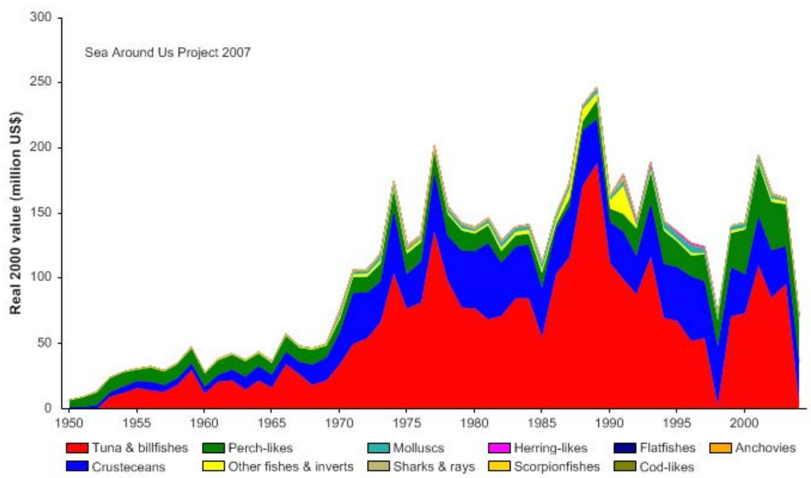


Figure IX-20.5. Value of reported landings in Northeast Australian Shelf LME by commercial groups (Sea Around Us 2007).

The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME reached to 5% of the observed primary production in the late1980s, but still is relatively low, considering the high proportion of high trophic pelagic species in the landings (Figure IX-20.6). Japan, with its distant water tuna fleets, account for the largest footprint in the region.

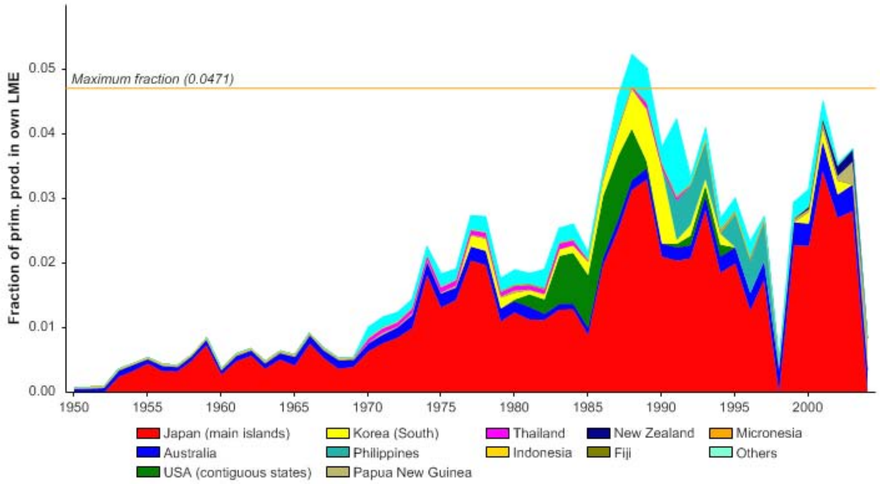


Figure IX-20.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Northeast Australian Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

The mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005; Figure) in the LME is still high, except for 1998 and 2004 when the landings of tuna were unusually low (Figure IX-20.7, top), while the FiB index has been stable following an increase from 1950 to the mid-1970s (Figure IX-20.7, bottom). These trends imply a growth of fisheries in the region with no clear signs of a 'fishing down' (Pauly *et al*. 1998)..

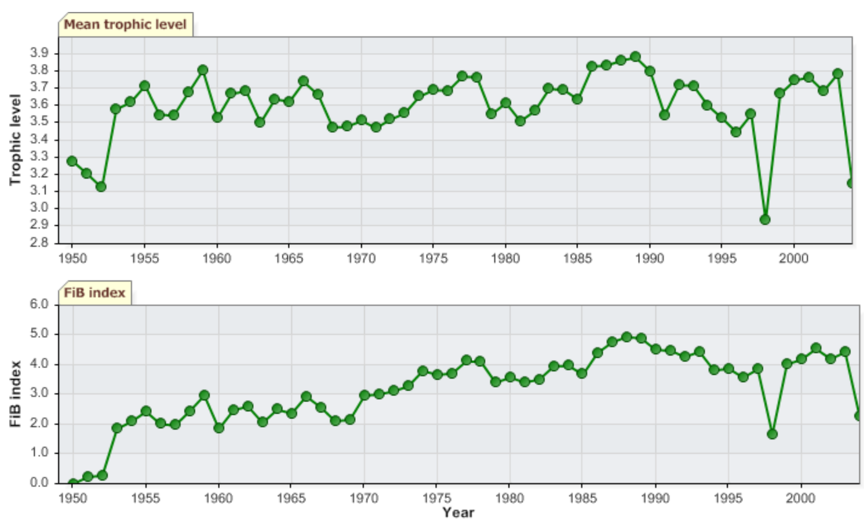


Figure IX-20.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Northeast Australian Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots indicate that more than half of the stocks in the region are currently either overexploited or have collapsed (Figure IX-20.8, top) and that half of the reported landings is supplied by such stocks (Figure IX-20.8, bottom).

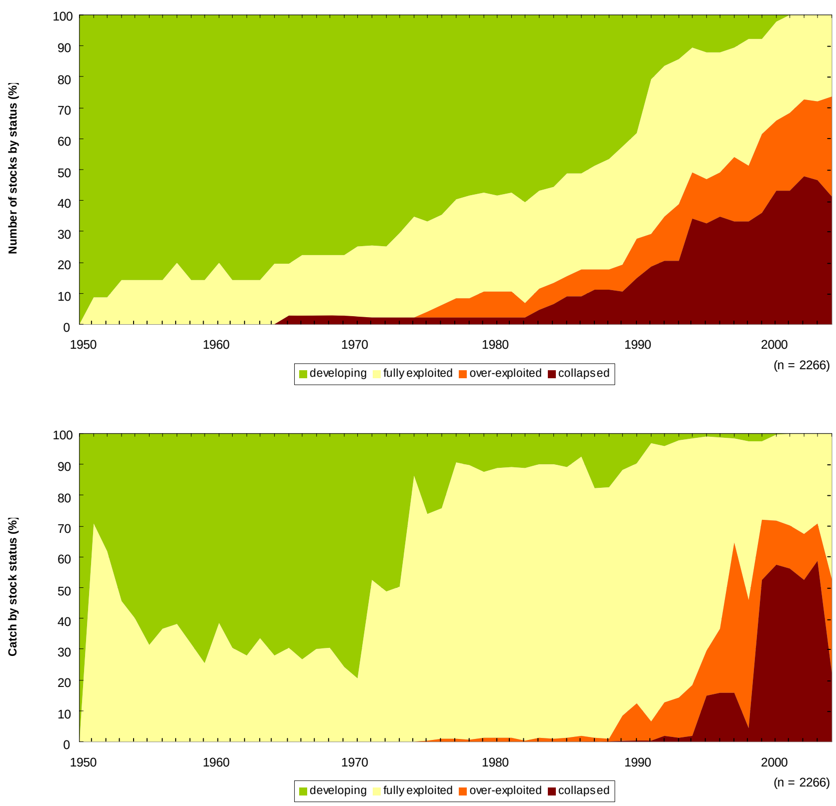


Figure IX-20.8. Stock-Catch Status Plot for the Northeast Australian Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the 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 Northeast Australia LME has been perturbed by the crown-of-thorns starfish (*Acanthaster planci*) that has devastated reefs (Kelleher 1993). There is uncertainty as to whether the outbreaks are human-induced or a natural part of the ecological variability of the GBR (Brodie 1999). Possible anthropogenic causes are the overfishing of crown-of-thorns predators such as fish or the triton shell, and enhanced nutrient runoff from coastal development (Brodie et al., 2005). The large-scale effects of crown-of-thorns starfish outbreaks on the benthic community have been discussed in Bradbury & Mundy (1989) and in the State of the Environment Report (www.deh.gov.au/soe/index).

The GBR is also threatened by increased shipping. A number of ports line the GBR coastline (Brodie 1999), and navigation in the Torres Strait is intense. Ballast water introductions of toxic dinoflagellates have caused serious ecological problems in other parts of Australia but so far no undesirable introduction has been detected in the GBR region. One significant anthropogenic impact on the GBR region is the change in the water quality of terrestrial runoff (Brodie 1999). Excess nutrients affect coral and coral reef systems (Kinsey 1991). There is considerable evidence that reefs, particularly inshore fringing reefs, are now muddier and have less coral cover and more algal cover (Fabricius et al., 2005). Reef ecosystem damage is evident in a large area of the north-central GBR (Devantier et al., 2006) coinciding with the area known to be exposed to polluted terrestrial runoff (Devlin and Brodie, 2005). Recreational fishermen tend to target reef ecosystems and remove larger predatory species. The effects of this selective removal of fish are largely unknown. Shore-based recreational fishing can affect shore populations of invertebrates that are collected for bait in intensively visited areas.

Environmental impacts on the Great Barrier Reef also stem from tourism. Large numbers of people are engaged in recreational fishing, SCUBA diving and boating. The expanding marine tourism industry is a major contributor to the Australian economy and now supports more than 820 operators, generates $4.2 billion annually, and accommodates 1.8 million visitors each year (www.oceansatlas.org). Activities associated with this level of recreational use can affect the environment through the pollution of water by boats and the disturbance of species and habitats (including mangroves). A major source of environmental impacts is the provision of infrastructure to support tourism (airports, power generation facilities, accommodation, sewage treatment and disposal facilities, moorings, and marine transport, including high-speed ferries). Often, this infrastructure is located in fragile or pristine environments that are susceptible to disturbance and fragmentation. For more information on pollution control in the GBR, see Kelleher (1993).

IV. Socioeconomic Conditions

According to the Bureau of Rural Statistics, the North Eastern Region of Australia has a population of 441,300 of whom 90% reside in 66 medium-to-large coastal towns. (http://adl.brs.gov.au). Employment within the fishing sector is heavily concentrated in the commercial sector, and involves from 1% to 5% of total employment. Total commercial fisheries production for the region in 2002 was estimated at 15,600 t with a GVP of AU$165 million (http://adl.brs.gov.au/). FAO provides information on Australia's fisheries and the socioeconomic benefits of the industry (www.fao.org/fi). Marine and coastal-based tourism is the main industry of the GBR, an internationally recognised tourist site and one of Australia's six World Heritage Sites (see Brodie 1999). In the 1980s, tourism in the GBR was evaluated at 150,000 visitor-days. In the late 1990s, tourism was worth US$1 billion, with 1.5 million visitor-days. Whale-watching takes place off the coast of Queensland. Tourism clearly depends on sustaining environmental and heritage values. Tourism can affect the lifestyle of community residents in ways they perceive as intrusive. In terms of fisheries, for instance, there can be tensions between recreation, commercial and indigenous interests. Traditional fishing by Aborigines and Torres Strait islanders is confined to areas close to Aboriginal communities (Brodie 1999). Shipping is a major activity. Mining including extraction of petroleum is not permitted within the Marine Park boundary. For more information about human uses of the GBR, see Kelleher (1993) and Brodie (2003).

V. Governance

This LME falls within the Pacific Regional Seas Programme (see the East-Central Australian Shelf LME). The main governance issues in this LME pertain to fisheries management and to the Great Barrier Reef Marine Park and Great Barrier Reef World Heritage Area. See the North Australian Shelf LME (Chapter VIII) for more information. For sustainable fishing issues in the GBR, see Kelleher (1993). Under the offshore constitutional settlement between the Australian states and the federal government, the management of most fisheries within the GBR is the responsibility of the Queensland government (Brodie 1999). Fishery Management methods covering recreational and commercial fishing are: input controls (gear restrictions, limited entry licenses, area and seasonal closures); output controls (TAC, ITQs, bag limits and size limits), measures for species and habitat protection. There is often a 'user pays' approach in which users (usually fishers) pay the full cost of supporting management and compliance for their fisheries, including substantial license or access fees (www.fao.org/). In 2003 the Australian Government Representative Areas Program for the GBR was introduced where the area of highly protected status (no take) was increased from 6 to 30 % of the total (Fernandes et al. 2004). More information on the governance of Australia's fisheries is available at the FAO website.

The GBR Marine Park Act was one of the first pieces of legislation in the world to apply the concept of sustainable development to the management of a large natural area. The GBR Marine Park Authority was established in 1975 to manage the multi-use park. The Authority aims to protect the natural ecosystems of the GBR, and ensures that fishing does not have unacceptable ecological impacts on the fished areas and the reefs. For more information on the history and zoning system of the GBR Marine Park, see Brodie (1999) and Kelleher (1993). Compulsory pilotage in the area reduces the risk of collision with reefs.

On the national level, the Commonwealth Government developed a National Action Plan for Tourism in 1998. The Plan, which identifies conservation and careful management of the environment as essential to the long-term viability of the tourism industry, makes a commitment to ecologically sustainable tourism development and recognises that environmental considerations should be an integral part of economic decisions.

References

Belkin, I.M. (2008) Rapid warming of Large Marine Ecosystems, 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.

Belkin, I.M., Cornillon, P.C., and Sherman, K. (2008) Fronts in large marine ecosystems of the world's oceans: An atlas. Progress in Oceanography, in press.

Bell, P.R.F. (1991). Status of eutrophication in the Great Barrier Reef lagoon. Marine Pollution Bulletin 23:89-93.

Berkelmans, R., De'ath, G., Kininmonth, S. and Skirving, W. (2004) A comparison of the 1998 and 2002 coral bleaching events on the Great Barrier Reef: spatial correlation, patterns and predictions, *Coral Reefs*, **23**(1), 74-83.

Bradbury, R.H. and Mundy, C.N. (1989). Large-scale Shifts in biomass of the Great Barrier Reef ecosystem, p 143-168 in: Sherman, K. and Alexander, L.M. (eds), Biomass Yields and Geography of Large Marine Ecosystems. AAAS Selected Symposium 111. Westview Press,. Boulder, U.S.

Brinkman, R., Wolanski, E., Deleersnijder, E., McAllister, F. and Skirving, W.: 2002, Oceanic inflow from the Coral Sea into the Great Barrier Reef. *Estuarine, Coastal and Shelf Science* **54,** 655-668.

Brodie, J. (1999). Management of the Great Barrier Reef as a Large Marine Ecosystem, p 428-437 in: Sherman, K. and Tang, Q. (eds), Large Marine Ecosystems of the Pacific Rim – Assessment, Sustainability and Management. Blackwell Science, Malden, U.S.

Brodie, J. (2003). The Great Barrier Reef: 25 years of management as a Large Marine Ecosystem, p 313 - 336 in: Hempel, G. and Sherman, K. (eds), Large Marine Ecosystems of the World: Trends in Exploitation, Protection and Research. Elsevier, The Netherlands.

Brodie, J. and Furnas, M. (1994). Long term monitoring programmes for eutrophication and the design of a monitoring programme for the Great Barrier Reef. Proceedings of the Seventh International Coral Reef Symposium, Guam 1:77-84.

Brodie, J.E. (1995). Management of sewage discharges in the Great Barrier Reef Marine Park, p 457-465 in: Bellwood, O., Choat, H. and Saxena, N. (eds), Recent advances in Marine Science and Technology '94. James Cook University, Townsville, Australia.

Brodie J., Fabricius K., De'ath G. and Okaji K. 2005. Are increased nutrient inputs responsible for more outbreaks of crown-of-thorns starfish? An appraisal of the evidence. *Marine Pollution Bulletin*, 51 (1-4): 266-278.

Brodie, J., De'ath, G., Devlin, M., Furnas, M., and Wright, M. 2007. Spatial and temporal pattern of near-surface chlorophyll-*a* in the Great Barrier Reef lagoon. Marine and Freshwater Research, 58: 342-353.

Bruno, J. and Selig, E. 2007. Regional decline of coral cover in the Indo-Pacific: timing, extent and sub-regional comparisons. PLoSONE, 8.

DeVantier, L., De'ath, G., Turak, E., Done, T. Fabricius, K. 2006. Species richness and community structure of reef-building corals on the nearshore Great Barrier Reef. Coral Reefs, 25: 329-340.

Devlin, M.J. Brodie, J. 2005. Terrestrial discharge into the Great Barrier Reef Lagoon: nutrient behaviour in coastal waters. Marine Pollution Bulletin, 51: 9-22.

Fabricius, K.E., De'ath, G., McCook, L.J., Turak, E., Williams, D. (2005). Coral, algae and fish communities on inshore reefs of the Great Barrier Reef: Ecological gradients along water quality gradients. Marine Pollution Bulletin 51: 384-398.

FAO. (2003). Information on Fisheries Management in Australia. www.fao.org/ fi/fcp/en/AUS/body.htm (for access fees); www.fao.org/ fi/FCP/FICP_AUS_E.ASP)

Fernandes, L., Day, J., Lewis, A., Slegers, S., Kerrigan, B., Breen, D., Cameron, D, Jago, B., Hall, J., Lowe, D., Innes, J., Tanzer, J., Chadwick, V., Thompson, L., Gorman, K., Simmons, M., Barnett, B., Sampson, K., De'ath, G., Mapstone, B., Marsh, H., Possingham, H., Ball, I., Ward, T., Dobbs, K., Aumend, J., Slater, D. and K. Stapleton (2005) Establishing representative no-take areas in the Great Barrier Reef: large-scale implementation of theory on marine protected areas. Conservation Biology: 1733-1744.

Furnas, M.J. (1995). Land-sea interactions and oceanographic processes affecting the nutrient dynamics and productivity of Australian marine ecosystems. www.ea.gov.au/coasts/ publications/somer/annex1/land-sea.html#HDR7

Furnas, M.J. (2003). Catchments and Corals: Terrestrial Runoff to the Great Barrier Reef. Australian Institute of Marine Science and Reef CRC, Townsville.

Hoegh-Guldberg, O. (1999) Coral bleaching, climate change and the future of the world's coral reefs, *Marine and Freshwater Research*, **50**(8)**,** 839-866.

Hoegh-Guldberg, O., Mumby, P.J., Hooten, A.J. et al (2007). Coral reefs under rapid climate change and ocean acidification. Science 318, 1737-1742.

Hopley D, Smithers SG, Parnell KE 2007 The Geomorphology of the Great Barrier Reef: development, diversity, and change, Cambridge University Press, ISBN: 978-0-521-85302-6.

Johnson JE and Marshall PA (editors) (2007) Climate Change and the Great Barrier Reef. Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia

Kelleher, G. (1993). Sustainable development of the Great Barrier Reef as a Large Marine Ecosystem, p 272-279 in: Sherman, K., Alexander, L.M. and Gold, B.D. (eds), Large Marine Ecosystems – Stress, Mitigation and Sustainability. AAAS Press, Washington D.C., U.S.

Kinsey, D. (1991). Water Quality and its Effect on Reef Ecology, Land Use Patterns and Nutrient Loading of the Great Barrier Reef Region. James Cook University, Townsville, Australia.

Lassig, B. and Englehardt, U. (1994). Crown-of-thorns starfish – Another outbreak looms. Search 25(3):66-68.

Liu, G., Strong, A.E., and Skirving, W. (2003) Remote sensing of sea surface temperatures during 2002 Barrier Reef coral bleaching, *Eos*, **18**(15), 137-144.

Lough, J.M. 2008. 10th Anniversary Review: a changing climate for coral reefs. Journal of Environmental Monitoring 10, 21-29.

Morgan, J. (1989). Large Marine Ecosystems in the Pacific Ocean, p 377-394 in: Sherman, K and Alexander, L.M. (eds), Biomass Yields and Geography of Large Marine Ecosystems. AAAS Selected Symposium 111. Westview Press, Boulder, U.S.

Pandolfi, J.M. Bradbury, R.H. Sala, E. Hughes, T.P. et al. 2003. Global trajectories of the long-term decline of coral reef ecosystems. Science, 301: 955-958.

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.

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

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.deh.gov.au/coasts/publications/marine-fish-action/ index.html

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=40

Steinberg, C. (2007) Chapter 3 Impacts of climate change on the physical oceanography of the Great Barrier Reef, in: *Climate Change and the Great Barrier Reef*, Johnson, J.E., and P.A. Marshall (eds.), Great Barrier Reef Marine Park Authority and Australian Greenhouse Office, Australia.Australian Department of Agriculture, Fisheries and Forrestry, Bureau of Rural Sciences http://adl.brs.gov.au/mapserv/fishcoast/north_eastern_region.html

UNEP (2003). DeVantier, L., Wilkinson, C., Lawrence, D. and Barnett, B. Great Barrier Reef, GIWA Regional Assessment 60. University of Kalmar, Kalmar, Sweden.

Wolanski, E. (1994). Physical Oceanographic Processes of the Great Barrier Reef. CRC Press, Boca Raton, U.S.

E. Wolanski (ed). (2001). Oceanographic Processes of Coral Reefs: Physical and Biological Links in the Great Barrier Reef. CRC Press, Boca Raton, Florida, 356 pp.

IX-21 Southeast Australian Shelf LME

M.C. Aquarone, S. Adams, S. Frusher, and I.M. Suthers

The Southeast Australian Shelf LME extends from Cape Howe, at the southern end of the State of New South Wales, to the estuary of the Murray-Darling river system in the State of South Australia. It borders the Southern Ocean and the western boundary currents flowing into the West Wind Drift, which circulates around the continent of Antarctica. The LME has a surface area of about 1.2 million km^2, of which 0.17% is protected (Sea Around Us 2007), and contains the island of Tasmania and the Bass Strait, which separates the island from the mainland state of Victoria. There are over 50 islands in Bass Strait, the largest and inhabited ones being Kings Island and Flinders Island. The Murray-Darling river system has a large catchment area, and it used to transport nutrients and sediments from the land into the coastal waters, but the river is heavily exploited and river flow is minimal. A book chapter on this LME has been published by Morgan (1989).

The region is characterised by sub-tropical species with southern Tasmania being Australia's main temperate region. The area has a large and variable marine flora and fauna including a large number of endemic species and is of high conservation value (Hoese et al. 2006).

The southeast region is the meeting place of two of Australia's main currents. The East Australian current (see Eastern Australian LME) brings low nutrient waters into south eastern Australia before heading offshore off eastern Tasmania. The Leeuwin Current (see Western Australian LME) brings low nutrient waters into southern Australia and down the western region of Tasmania. Off western Tasmania this current is often referred to as the Zeehan Current (Baines et al. 1983). Higher nutrient waters are brought to southern Tasmania from the sub-Antarctic waters. The Flinders Current is a westward flow along the 600 m isobath, from western Bass Strait to Kangaroo Island (Middleton and Bye 2007). An upwelling system off the Bonney Coast between southeastern South Australia and Victoria also brings nutrients to the surface.

I. Productivity

The Southeast Australian Shelf LME has a diversity of habitats such as seagrass beds, mud flats, intertidal and sub-tidal rocky reefs, kelp forests and pelagic systems. It is considered a Class III, low productive ecosystem (<150 $gCm^{-2}yr^{-1}$). Estimates of the mean annual primary productivity from 1998-2006 of the southeast Australian continental shelf vary between 68 and 251 $gCm^{-2}d^{-1}$ (www.science.oregonstate.edu/ocean.productivity/) depending whether the estimate is based on chlorophyll or particulate carbon concentration, and if a temperature correction is applied. The Sea Around Us project estimates mean primary productivity at 187 g C m^{-2} d^{-1}. The large range of values may result from the atypically low nutrient concentrations for a shelf system at this latitude - a result of low continental discharge and poleward flowing boundary currents.
It is a temperate marine environment inhabited by communities rich in species, many of which are endemic to Australia. Investigations in Bass Strait and the south-eastern slope have revealed soft-bottom benthic communities more diverse than anywhere else in the world. For example of the 638 species of fish recorded for Tasmania, 38 (6%) are endemic to Tasmania and 273 (43%) are endemic to Australia (Hoese et al. 2006).

Near the island of Tasmania, seasonal storm events accelerate the mixing of nutrients onto the shelf. Runoff from the Murray-Darling river system was a regional contributor to shelf nutrient processes and fluxes. For a general understanding of oceanographic processes affecting the nutrient dynamics and productivity of Australian marine ecosystems, see Australia's State of the Environment (SOE) Report 2006 (www.deh.gov.au/soe/index.html). Reports by States and Territories and National environment audits are available from this index. For more information on productivity, nutrient dynamics and land-sea interactions, see Furnas (1995) and UNEP (2003).

In the southwest of this LME strong westerly winds drive colder nutrient rich sub-antarctic waters up the east coast of Tasmania. These waters are characterised by high nitrate and dissolved organic nitrogen concentrations in surface waters. These cooler windy periods result in less oligotrophic conditions with the phytoplankton dominated by large diatoms and the zooplankton by larger species such as krill. In years of strong westerlies the phytoplankton biomass and productivity increases and the spring bloom lasts longer. In such years, the zooplankton biomass increased 10 fold in late spring. In contrast, the surface waters in the summer and autumn period (January to July) reflect the intrusion of sub-tropical water which can be detected by increased salinities and very low dissolved inorganic phosphorus. This period coincides with a reduction in the westerly wind stress. These calmer warmer periods result in more oligotrophic conditions when the phytoplankton is dominated by small dinoflagellates and the zooplankton by small copepods (Harris et al, 1988; Harris et al, 1991; Clementson et al, 1989).

Productivity in the northwest of the LME is dominated by summer upwelling events. The largest of these is the Bonney upwelling in southeastern South Australia adjacent to the Victorian border. During winter the Leeuwin Current moves eastwards along the south Australian coast to the southern tip of Tasmania (Cirano and Middleton 2004; Cresswell and Peterson 1993; Godfrey et al. 1986). In the summer, the coastal wind reverses and changes to induce upwelling producing a westward flow at the coastal boundary (Middleton and Platov 2005). Sub-surface upwelling extends in an almost continuous band from the Bonney Coast to western Tasmania. Extensive areas of krill have been observed along this shelf margin, Hunter group of islands and King Island and the region has high conservation values, including the pygmy blue whale (Butler et al. 2002).
La Nina years are associated with a weaker influence of the East Australian Current in Eastern Bass Strait and the Leeuwin Current in western Bass Strait. During this time cooler waters enter Bass Strait from the Bonney upwelling and the Flinders Current.

Oceanic fronts: The East Australian Current (EAC) carries tropical waters from the East-Central Australian Shelf LME into the Southeast Australian Shelf LME to feed a southward EAC and mesoscale eddies off eastern Tasmania (Figure IX-21.1). The Zeehan Current is the final extension of the Leeuwen Current along western Tasmania. East of Kangaroo Island the Flinders Current is probably responsible for intermittent upwelling in the deep canyon systems off the western Victorian Shelf. The Kangaroo Island Front (KIF) develops seasonally southeast of Kangaroo Island caused by wind-driven coastal upwelling (Belkin & Cornillon 2003, Belkin *et al*. 2008.

Southeast Australian Shelf LME
Linear SST trend since 1957: 0.53°C.
Linear SST trend since 1982: 0.20°C.

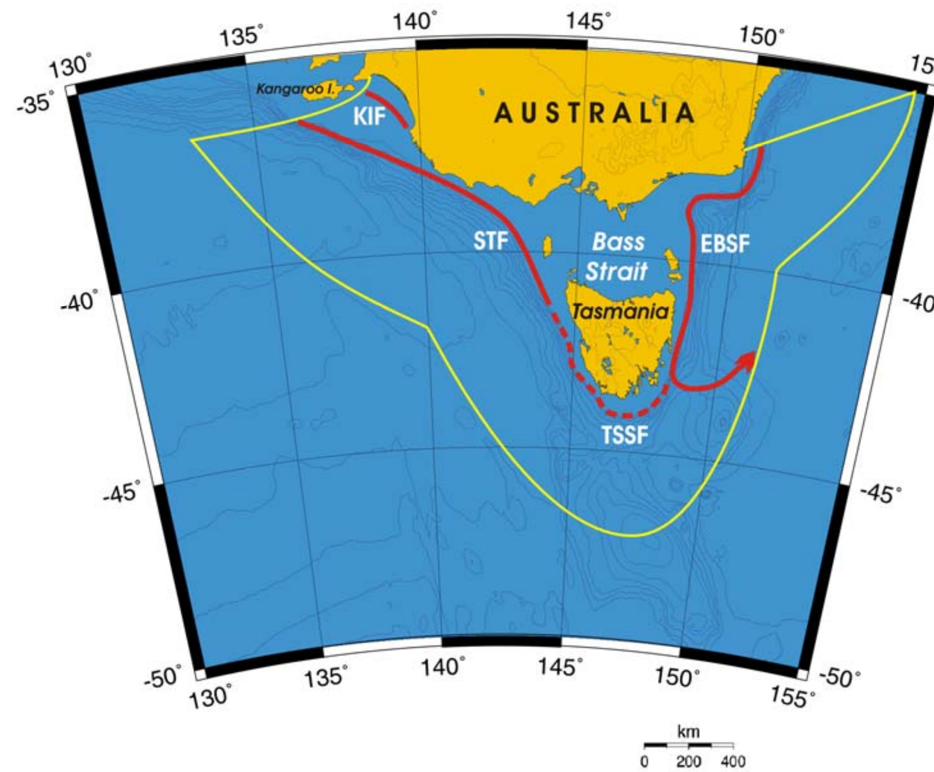


Figure IX-21.1. Fronts of the Southeast Australian Shelf LME. EBSF, East Bass Strait Front; STF, Subtropical Front; TSSF, Tasmania Shelf-Slope Front (most probable location). Yellow line, LME boundary. (after Belkin et al. 2008)

The thermal history of this LME features a long-term ascending trend, although this warming was quite erratic, including major reversals. Some peculiarities of this LME's thermal history are likely caused by its location as the southernmost Australian LME. Therefore this LME is affected by the Subantarctic and Antarctic (via atmospheric teleconnections) more strongly than are other Australian LMEs. The East Australian Current is a dominant warm current and its role increased over the last half-century as this current penetrated farther south by ~350 km over the 1944–2002 period, thus effectively warming up the East Tasmanian waters at a rate of 2.28°C/century (Ridgway, 2007).

The most striking difference between this LME and other Australian LMEs is the absence of a major peak in 1998 that could have been a manifestation of the 1997-98 El Niño, as observed elsewhere. Instead, SST peaked in 2001, possibly a delayed response to the El Niño 1997-98. A similar warm event peaked in 2000 in the adjacent Southwest Australian Shelf LME. The all-time maximum of 1989 can be tentatively correlated with the peak of 1988 in the Sulu-Celebes Sea LME, North Australian Shelf LME, West-Central Australian Shelf LME, and lesser peaks of 1989 in the Southwest Australian Shelf LME and of 1988 in the Northwest Australian Shelf LME. The peak of 1961 occurred simultaneously in the adjacent Southwest Australian Shelf LME. The cold events of 1964 and 1996 cannot be readily linked to similar events elsewhere. This asymmetry between warm and cold events suggests a weaker correlation between cold events versus a stronger correlation between warm events.

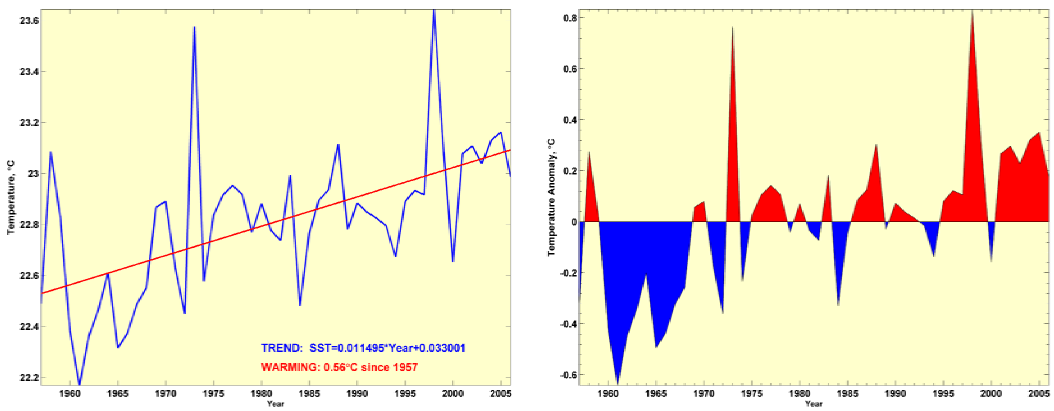


Figure IX-21.2. SE Australian Shelf LME annual mean SST (left) and SST anomalies (right), 1957-2006, based on Hadley climatology (after Belkin 2008).

***Southeast Australian Shelf LME, Chlorophyll and Primary Productivity*:** The Southeast Australian Shelf is considered a Class III, low productive ecosystem (<150 $gCm^{-2}yr^{-1}$).

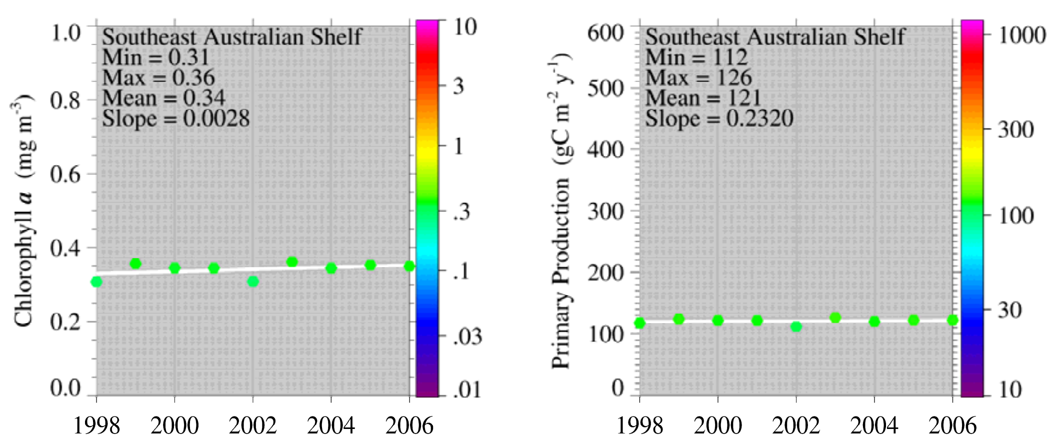


Figure IX-21.3. Southeast Australian Shelf LME trends in chlorophyll a and primary productivity, 1998-2006. Values are colour coded to the right hand ordinate. Figure courtesy of J. O'Reilly and K. Hyde. Sources discussed p. 15 this volume.

II. Fish and Fisheries

Fig. IX-21.4 and IX-21.5 present the estimates of the Sea Around Us Project for the capture fisheries landings in this LME, and their ex-vessel value. Australian sources suggest that the combined capture fisheries and aquaculture production in the southeastern Australian LME is 121.5 thousand tonnes, valued at $1.05 billion Australian dollars, with the wild fish sector accounts for 60% of the weight and 50% of the value of production in this region, suggesting that the Sea Around Us figures are underestimates. The main groups fished include lobster, abalone, scallops, crabs, prawns, snapper, sardines, blue grenadier and flathead. The aquaculture sector includes atlantic salmon, southern bluefin tuna, oysters and mussels. ABARE provides additional information on the characteristics of Australia's fishing industry (www.abare.gov.au).

The region is a mix of high valued export fisheries, which includes nearly 50% of the global wild caught abalone production, and the bulk of the domestic fish market in Sydney and Melbourne. The small pelagics fishery has undergone substantial fluctuations over the decades with large catches of jack mackerel (*Trachurus declivis)* dramatically declining in eastern and southern Tasmania. Recently there has been an increase in redbait (*Emmelichthys nitidus*) (Anon. 2008a) In addition to the small pelagics fishery, dramatic fluctuations in recruitment of scallops and striped trumpeter (*Latris lineata*) reflect the dynamics of the physical environment (Anon. 2008b).

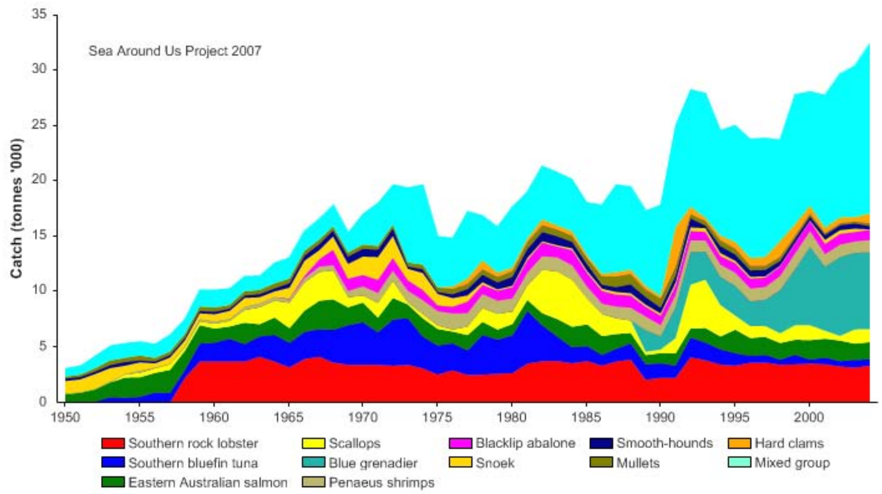


Figure IX-21.4. Total reported landings in the Southeast Australian Shelf LME by species (Sea Around Us 2007).

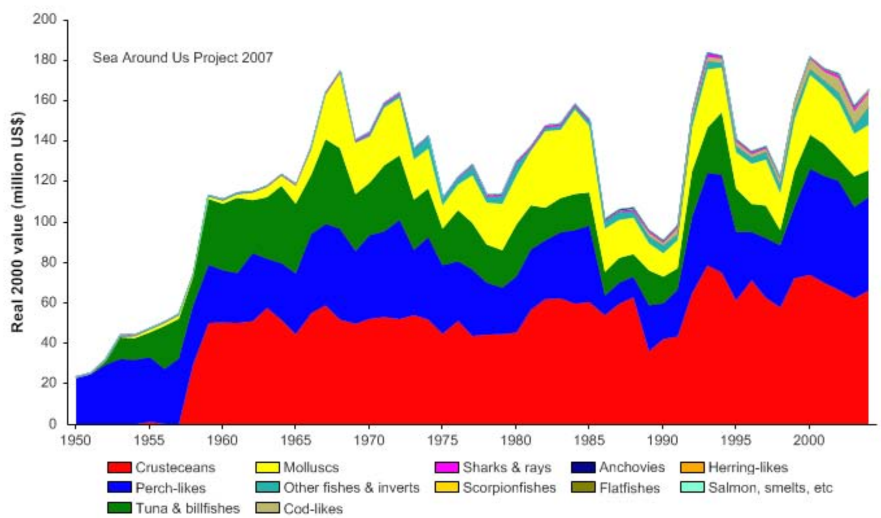


Figure IX-21.5. Value of reported landings in the Southeast Australian Shelf LME by commercial groups (Sea Around Us 2007).

ABARE estimates for 2006/2007 (including aquaculture) for fisheries production in Victoria was 8,243 t valued at $93.934 millions $AUD; South Australia production was 60,548 tonnes at a value in millions of $AUD of $426,499; Tasmania fisheries production in totalled 36,413 tonnes at a value in millions of $AUD $475,429 and Commonwealth managed fisheries harvested 16,328 tonnes at a value in millions of $AUD $54.539. (www.abare.gov.au). Quota management has been introduced into many of the more valuable fisheries over the last 20 years. This has resulted in substantial rebuilding of the biomass in several fisheries such as rock lobster (Haddon and Gardner 2008). The primary production required (PPR; Pauly & Christensen 1995) to sustain the reported landings in this LME is currently below 2.5% with Australia accounting for the largest share of the ecological footprint (Figure IX-21.6).

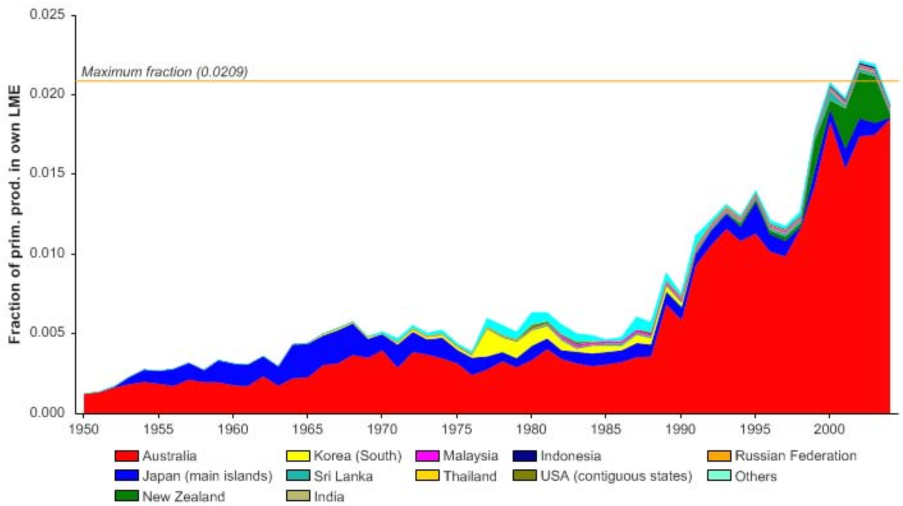


Figure IX-21.6. Primary production required to support reported landings (i.e., ecological footprint) as fraction of the observed primary production in the Southeast Australian Shelf LME (Sea Around Us 2007). The 'Maximum fraction' denotes the mean of the 5 highest values.

Over the past twenty years, both the mean trophic level of the reported landings (i.e., the MTI; Pauly & Watson 2005) and the FiB index have increased in the LME, indicating a development of new offshore fisheries from the late 1980s to the 1990s.

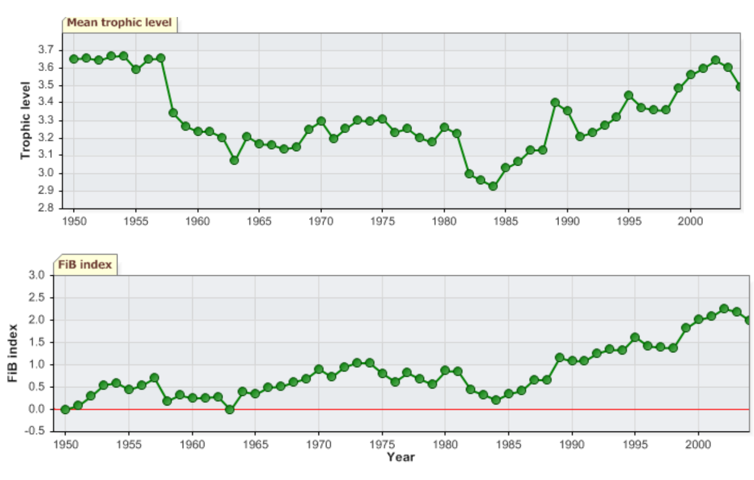
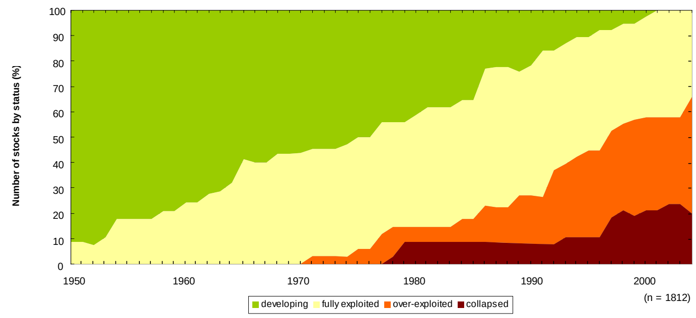


Figure IX-21.7. Mean trophic level (i.e., Marine Trophic Index) (top) and Fishing-in-Balance Index (bottom) in the Southeast Australian Shelf LME (Sea Around Us 2007).

The Stock-Catch Status Plots suggest that while a sizeable fraction of the stocks in this LME may have been overexploited (Figure IX-21.8, top), about half of the catch biomass originates from stocks that are fully exploited (Figure IX-21.8, bottom). Moreover, changes to gear, management, fleet dynamics/fisher behaviour, market forces, as well as discarding, unstandardised catch data and climate (e.g. the jack mackerel fishery) prevent further interpretation. There is limited or no fishery independent data for many species, and recruitment records are unknown. Recent changes to management have improved the stock status of many fisheries.



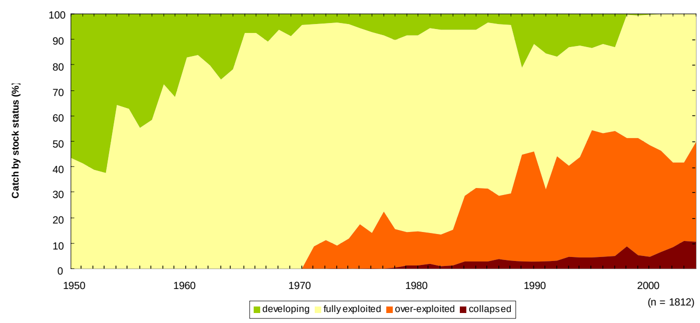


Figure IX-21.8. Stock-Catch Status Plots for the Southeast Australian Shelf LME, showing the proportion of developing (green), fully exploited (yellow), overexploited (orange) and collapsed (purple) fisheries by number of stocks (top) and by catch biomass (bottom) from 1950 to 2004. Note that (n), the 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

Land use impacts within the Murray Darling Basin, nutrient loading from diffuse and point sources, soil erosion, soil salinisation, and dry climate with intermittent flows and natural salt stores in the landscape have resulted in significant or major nitrogen exceedances in the Lower Murray, Myponga, Fleurieu Peninsula and Willochra Creek River basis. In several of these river basins, guidelines for salinity, phosphorus and for turbidity have also been exceeded (http://audit.ea.gov.au/ ANRA/water/quality/). A major problem in this LME is the introduction of exotic marine organisms from the hulls of ships or as a consequence of discharging ballast water. A recent inventory of introduced marine pests found 57 species in Victoria, 45 in Tasmania and 43 in South Australia (www.marine.csiro.au/crimp/nimpis). These introduced marine species threaten native marine flora and fauna and local marine diversity as well as fishing and aquaculture. Introduced species in this LME include the North Pacific sea star (*Asterias amurensis*), Japanese kelp (*Undaria pinnatifida)*, the New Zealand screw shell (*Maoricolpus roseus*), European fan worm (*Sabella spallanzanii*) and the toxic dinoflagellate (*Gymnodinium catenatum*). The North Pacific sea star native to northern China, Korea, Russia and Japan, was first found in Tasmania in 1986, but was misidentified as a native species until 1992. The sea star has since spread to Victoria. At present, its distribution in Australia appears to be limited to these two States. However, suitable conditions exist for its survival and reproduction in the West-Central Australian Shelf LME. The sea star is a voracious predator of shellfish, thus posing a serious threat to mariculture and wild shellfish fisheries. While significant research is being undertaken on the potential impacts of the sea star in Australia, the available data are still not adequate to conclusively determine if it is having an impact on Australian fisheries. Japanese kelp has appeared in near-shore habitats along the east coast of Tasmania and is spreading fast with the potential to invade the entire southern coastline. For more information on pollution issues see www.deh.gov.au/coasts/pollution/index.html, the State of the Environment Reports at www.deh.gov.au/soe and CSIRO's Center for Introduced Marine Pests at www.marine.csiro.au/crimp/. Climate change is also impacting on the distribution of species in southeastern Australia. The magnitude and poleward distribution of the East Australian Current (EAC) has increased over the last 60 years (Ridgway, 2007) and is expected to increase due to climate change with predictions that southeastern Australian marine waters will be the fastest warming in the southern hemisphere. With the increased penetration of the East Australian Current there has been an increase in the number and southerly distribution of sub-tropical species into Tasmania. The most notable of these is the long-spined sea urchin, which forms extensive barrens habitat (Johnson et al., 2005). These barrens habitats lead to substantial changes in productivity and biodiversity (Ling, 2008) with flow on impacts on fisheries. Initially, range expansion was by way of larval transport from NSW via the EAC. With increasing warmer waters, the conditions for *C. rodgersii* to complete it larval cycle *in-situ* in eastern and southern Tasmanian become more favourable (Ling et al., 2008). The dinoflagellate *Noctiluca scintillans* has also dramatically increased with summer blooms impacting on coastal salmon farms (www.tafi.org.au/zooplankton).

In the northwestern region of the LME climate change is expected to increase the strength and duration of upwelling winds (Bakun 1990). This is expected to result in a stronger Bonney upwelling and for increased sub-surface upwelling events that extend from western Victoria to western Tasmania. An increase in these upwelling events at the beginning of summer accelerates primary and secondary productivity.

Climate change simulations are currently being improved for the Australian region at CSIRO, particularly in modeling the Southern Ocean, developing a more realistic Antarctic Circumpolar Current, and modeling the transport of surface water into the deep ocean. The latter process is particularly important in the sequestering of heat and carbon into the deep ocean, which influences the rate and pattern of warming globally.

IV. Socioeconomic Conditions

In the Southeast Australian Shelf LME, the population is 1,465,200 persons and between 5% and 10% of the total employment is in the fish industry--fisheries, aquaculture and processing sectors. The region is socially diverse, with some small, isolated communities and some major metropolitan centres, with the population growth highest in coastal metropolitan areas and large coastal regional centres (especially Melbourne). The two main industries for the LME are marine tourism and oil and gas. Bass Strait accounts for about 20% of the nation's oil and gas (Love 2004). In the Atlas of Australian Marine Fishing and Coastal Communities, (http://adl.brs.gov.au/), the region is characterised by a lower proportion of Indigenous persons, by younger median ages in coastal metropolitan areas and large coastal regional centres, by higher child dependency in many regional areas, and by higher socio-economic disadvantage in many non-metropolitan areas of coastal Tasmania with strong links to the fish industry. The southern rock lobster fishery is the most valuable in this region and was estimated in 2003 to provide 3,381 employment opportunities either directly or indirectly with a total economic impact of almost 0.5 billion dollars into regional economies. A record low catch rate in the South East coast is being reported for rock lobster in October, 2008 according to John Ashby, president of the Port MacDonnell Fishermen's Association (http://fis.com/fis/worldnews 16 October 2008). The South East Fishery, which includes both the trawl and gillnet, trap and line fisheries, is a major fish industry with landings in 2006/7 being 20,578 tonnes worth an estimated $AUD 78 million. Salmon aquaculture is carried out in Tasmania and its production was valued at $271 million in 2006/7 (www.abare.gov.au). Recreational fishing is an important pastime in this region with approximately 1 million people participating in the 12 months prior to May 2000. Participation rates were estimated at 29.3%, 24.1% and 12.7% in Tasmania, South Australia and Victoria respectively (Henry and Lyle 2003). The Southeast Australian Shelf LME contains a number of cities and ports, including Melbourne. Industry, shipping and tourism are major economic activities. There is offshore oil and gas off the Victoria coast. Marine and coastal-based tourism is important in this LME, both in terms of domestic and international tourism.

V. Governance

The Southeast Australian Shelf LME lies off the coast of four Australian States: New South Wales, Victoria, Tasmania and South Australia. The main governance issues of this LME pertain to industrial and agricultural degradation of the water quality, fisheries management and to the establishment of marine reserves. Fisheries are managed by either State or Commonwealth agencies. Most of the states manage the fisheries out to 5.5 km offshore and the Commonwealth manages fisheries beyond this zone. Several fisheries that are within the 5.5 km zone are managed by the Commonwealth (e.g. small pelagics) and other outside this limit by the State (eg. giant crab). Some fisheries have both Commonwealth and State zones (e.g. scallops). Most of the valuable fisheries in the region are managed under output controls and many have seen substantial rebuilding of legal sized biomass since the introduction of quota management systems. The less valuable fisheries tend to be managed through input controls that restrict effort. These include gear limits and seasonal and regional closures. Both State and Commonwealth fishiers have established management advisory committees that usually involve industry, managers and research providers in the co-management of the resource. See the North Australian Shelf LME (Chapter VIII) for more information on fisheries management. Coastal marine reserves are managed by Conservation agencies in most States whereas offshore marine reserves are managed by the Australian Department of Environment, Water and Heritage.

References

Anon. 2008A. Fishery Status review: Small Pelagics Fishery, affashop.gov.au/ PdfFiles/17_fsr06_spf.pdf)

Anon. 2008b.http://www.environment.gov.au/coasts/mbp/publications/south-east/se-fisheries.html

ANRDL. Australian Natural Resources Data Library [and the Bureau of Rural Sciences] at http://asdd.ga.gov.au/tech/node/brs-4.html

Atlas of Australian Marine Fishing and Coastal Communities at http://adl.brs.gov.au/mapserv/ fishcoast/south_ eastern_region html

Australia Land and Natural Resources Audit results for water quality in South Australia at www.epa.sa.gov.au/water_threatened.html

Australian Government; Department of Agriculture, Fisheries and Forestry; Bureau of Rural Sciences; Marine Matters: Australian Marine Fishing and Coastal Communities at http://adl.brs.gov.au/mapserv/fishcoast /south_eastern_region.html.

PG Baines, RJ Edwards and CB Fandry 1983. Observations of a new baroclinic current along the western continental slope of Bass Strait. Australian Journal of Marine and Freshwater Research 34(1) 155 - 157

Belkin, I. M., and P. C. Cornillon (2003) SST fronts of the Pacific coastal and marginal seas. Pacific Oceanography 1(2):90-113.

Belkin, I.M., Cornillon, P.C., and Sherman, K. (2008) Fronts in large marine ecosystems of the world's oceans: An atlas. Progress in Oceanography, submitted.

Butler E, Althaus, Furlani DM, Ridgeway (2002) Assessment of the conservation values of the Bonney upwelling area.

Cirano M, Middleton JF (2004) The mean wintertime circulation along Australia's southern shelves: a numerical study. *J. Phys. Oceanogr.* **34**, 668-684.

Clementson, Harris, Griffiths and Rimmer (1989). Seasonal and inter-annual variability in chemical and biological parameters in Storm Bay, Tasmania. 1. Physics, chemistry and the biomass of components of the food chain. *AJMRF*. 40:25-38.

Cresswell GR, Peterson JL (1993) The Leeuwin Current of Western Australia. *Aust. J. Mar. Freshw.* **44**, 285-303.

CSIRO Center for Introduced Marine Pests at www.marine.csiro.au/crimp/.

CSIRO Marine and Atmospheric Research (2004) SE Australian waters report and circulation map available online at www.srfme.org.au/news/mar04.htm.

Furnas, M.J. (1995). Land-sea interactions and oceanographic processes affecting the nutrient dynamics and productivity of Australian marine ecosystems. www.ea.gov.au/coasts/ publications/somer/annex1/land-sea.html#HDR7

Godfrey JS, Vaudrey DJ, Hahn SD (1986) Observations of the shelf-edge current south of Australia. *J. Phys. Oceanogr.* **16**, 668-679.

Haddon, M and Gardner, C (2008). Rock lobster fishery assessment. 21(3):29-30.

Harris, Davies, Nunez and Meyers (1988) Interannual variability in climate and fisheries in Tasmania. *Nature* 333: 754-757.

Harris, Griffiths, Clementson, Lyne and Van der Doe (1991). Seasonal and interannual variability in physical processes, nutrient cycling and the structure of the food chain in Tasmanian shelf waters. *Journal of Plankton Research* 13: 109-131.

Henry, G.W., and Lyle, J.M. (2003). The national Recreational and Indigenous Fishing Surveys. NSW Fisheries Final report Series No. 48. 188pp.

Jenkins, G.P., 2005. Influence of climate on the fishery recruitment of a temperate, seagrass-associated fish, the King George whiting *Sillaginodes punctata*. Marine Ecology-Progress Series, 288: 263-271.

Love G. 2004. Key economic issues facing marine based industries in the south east marine region, ABARE report for NOO, Canberra July 2004 www.environment.gov.au/ coasts/mbp/publications/south-east/se-economic.html

Ling, S.D., Johnson, C.R., Frusher, S.D. and King, C.K. (2008). Reproductive potential of a marine ecosystem engineer at the edge of a newly expanded range. Global Change Biology. 14: 907-915.

Ling, S.D. (2008) Range expansion of a habitat-modifying species leads to loss of taxonomic diversity: a new and impoverished reef state. Oecologia 156:883–894

Middleton, J. F., and M. Cirano (2002), A northern boundary current along Australia's southern shelves: The Flinders Current, *J. Geophys. Res.*, *107*(C9), 3129, doi:10.1029/2000JC000701.

Middleton JF, Platov G (2005) Hydrodynamic model of the Great Australian Bight. In 'Tropho-dynamics of the GAB: Assessing the need for an ecological allocation in the SA Pilchard fishery'. (Eds T Ward, SD Goldsworthy, BC Page) pp. 51-99. (SARDI FRDC Report 2003/072: Adelaide).

Middleton JF and JAT Bye. 2007 A review of the shelf-slope circulation along Australia's southern shelves: Cape Leeuwin to Portland. Progress in Oceanography 75: 1-41

Morgan, J. (1989). Large Marine Ecosystems in the Pacific Ocean, p 377-394 in: Sherman, K. and Alexander, L.M. (eds), Biomass Yields and Geography of Large Marine Ecosystems. AAAS Selected Symposium 111. Westview Press, Boulder, 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.

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

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 at www.deh.gov.au/coasts/publications/marine-fishaction/index.html

Ridgway, K. R. (2007) Long-term trend and decadal variability of the southward penetration of the East Australian Current, *Geophysical Research Letters*, **34**, L13613, doi:10.1029/2007GL030393.

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=42

UNEP (2003). Wilkinson, C., Reichelt, R., DeVantier, L. and Lawrence, D. Great Australian Bight and Murray Darling Basin. GIWA Regional Assessment 61. University of Kalmar, Kalmar, Sweden.