7. DISCUSSION AND CONCLUSIONS

7.1 Similarities and differences between trophic systems

The general understanding on similarities and differences between the trophic systems we have come to of the NWMR are summarised as follows:

General Similarities
At the NWMR scale, physical processes constrain the productivity of the trophic system. The ITF outflow, its suppression of the thermocline and instigation of the start of the Leeuwin Current are key drivers of the NWMR. Biological adaptions to low nutrient, high current stress environments have resulted in trophic components that are highly adept at rapidly stripping any nutrients out of the water column. Recycling processes sustain standing crops of plankton and nekton while new production is rapidly consumed and transported away as detrital rain. Energetic events and their interaction with the seafloor or coast are key mechanisms for the supply of new production. Under oligotrophic conditions, picoplankton, microbial and filter feeders play a key role in recycling and sustaining productivity in the surface layers. Below the surface layer, subsurface upwellings may play a key role in supplying the productivity of the NWMR. Seasonal and interannual variability in physical processes controlling the thermocline depth, such as the intensity of the ITF and wind-driven currents/mixing are key processes affecting the variability of productivity of the NWMR.

General Differences
At the NWMR scale, the broad scale differences are associated with the change from north to south in the relative influences of the ITF and the Indian Ocean Central Water mediated by the seasonal monsoonal changes in climatic variables. Thus, high seasonal variability in physical conditions is experienced, including changes in the flow of the ITF, shelf currents and productivity changes and the timing and strength of the Leeuwin Current system. On the shelf, differences in the nearness to deep water critically affect shelf productivity. In the north, the ITF brings some nutrients to the Sahul Shelf whereas in the NW Shelf, nutrients are injected at depth by the breaking of internal tides and have to make their way to the coastal system. On the slope, internal waves and boundary currents interact with topographic structures and irregularities to control the availability of subsurface nutrients. Upwelling is very limited and confined largely to the coast south of the North West Cape. Deep ocean basins exist in only two of the sub-regions we identified. The Argo Abyssal Basin is overlaid at the surface by the monsoonal ITF currents and is flanked to the north by the productive Java upwellings while the Curvier Basin is overlaid by the seasonal Leeuwin Current and may experience detrital flows along its eastern margin from the Carnarvon Slope and in the north from the Exmouth Plateau.

The individual sub-regions described in this report have some similarities, but these are usually only superficial. The communities and trophic structures are influenced by a combination of features unique to each sub-region. In general, the shelf, slope and abyssal habitats are markedly different. But even within these zones, there are no two sub-regions that appear to be similar in their habitats, communities and hence, their trophic systems. The WJBG and Kimberly Shelf sub-regions are both wide sections of the continental shelf with seasonal, coastal freshwater input, and some nutrient and larval connection. However, the WJBG has a considerably larger freshwater input and coastal boundary layer and it's outer shelf includes a large basin area and limestone pinnacles; both with unique, though largely undescribed communities and trophic relationships. The Kimberly Shelf deepens towards the shelf edge and is dominated by a series of banks and rises that is impacted by internal breaking waves and supports a unique benthic community. The NW Shelf has almost no coastal freshwater input, a relatively homogeneous shelving sea bed, a very high concentration of cyclones (Figure 5-7) and other unique features. The Carnarvon Shelf is different again being very narrow, and hence, influence strongly by shelf edge processes and the seasonal, high-nutrient Ningaloo Current which promotes high primary productivity and a unique pelagic community in the region. The Kalbarri Shelf to the south is influenced by the Indian Ocean water mass and the higher salinity waters flowing from Shark Bay. It is nutrient poor compared to the Carnarvon Shelf and supports a unique, though poorly understood trophic system.

Like the shelf sub-regions, the continental slope sub-regions each support unique communities and hence trophic structures, particularly the benthic environments. They sit in three different pelagic water masses, have different combinations of geomorphic features and associated habitats and have been shown by Last et al., (2005) to have distinctly different demersal fish communities. The Abyssal plains too are at different depths, have different geomorphic features and are influenced by different slope environments.

Trophic Summary

Physical processes strongly control the trophic systems of the NWMR which are highly adapted to take advantage of new production while being very efficient in recycling detrital matter. Trophically, the key defining drivers are the availability of new production, its duration and its frequency. The ability of recycling processes to retain detrital matter and the depth at which nutrients are available in relation to the photic depth are key aspects of the productivity and standing crop in the trophic systems. Biological migration, whether mediated by currents or not, are key perturbations of the trophic systems, particularly those that rely upon recycling. Likewise, the disturbances due to cyclones. By and large, the productivity of the sub-regions are driven by the regular and persistent processes rather than the infrequent highly energetic ones. Benthic productivity on the shelf is constrained at the coast by high turbidity and lack of nutrients while at mid-shelf, nutrients are higher and light levels are moderate. Benthic production is thus likely to increase away from the coast before declining again in deeper water in the outer shelf. Benthic trophic processes play a key role on the shelf while bentho-pelagic groups play a pivotal role in transferring productivity between the pelagic and benthic subsystems.

Differences from other Australian marine regions

The NWMR has a unique combination of features that distinguish it from the other marine regions around Australia. These include a wide continental shelf, very high tidal regimes, very high cyclone (Figure 5-7) incidence, unique current systems, warm oligotrophic surface waters, and a range of unique features including the highly productive Ningaloo reef region, the expansive Exmouth Plateau slope region and offshore reefs. Although there is some connectivity with the North Marine Region (NMR) via larval advection within the Indo-Pacific throughflow, a large proportion of the demersal and benthic fauna in particular are relatively unique to the region. There is some overlap with the NMR in that the WJBG and western extents of the NMR are show a high degree of similarity in habitats, communities, and hence their trophic systems. Similarly, the most southern sub-regions (Kalbarrri Shelf and Wallaby Saddle) are probably closer in character to the SWMR than the NWMR; to the extent that a slight manoeuvring of the boundary edges of these 'edge' regions may make more ecological sense. However, the majority of the NWMR is ecologically unique, as borne out in the limited number of studies that have assessed aspects of these communities in a broad context (e.g. Last et al., 2005; Hooper and Ekins, 2004)

Resilience and vulnerability

The resilience and vulnerability of trophic systems in the NWMR varies between different sub-regions and more locally between different trophic communities. Some communities are adapted to coping with environmental variability such as the shelf regions in the north of the NWMR, which are subject to highly variable coastal freshwater and nutrient input, highly variable tidal currents and/or sporadic major climate events such as cyclones. These environments are likely to be more resilient to other climatic variability such as variations to seasonal patterns, more frequent or more intense weather patterns. However, their tolerance to increased water temperatures is less certain, and their tolerance to anthropogenic disturbance is likely to be low, as demonstrated in marine environments elsewhere.

Other trophic communities appear to be less tolerant of environmental change, such as the offshore coral reefs that are subject to bleaching and high mortality under slightly elevated sea temperatures; or the productive trophic system adjacent to Ningaloo Reef which relies on the seasonal flow of the Ningaloo Current. The continental slope sub-regions have relatively narrow physical tolerances but are adapted to some physical disturbance such as sediment slumping. The deeper communities survive in a relatively narrow range of tolerances. They are removed from many potential sources of impact, but are unlikely to be able to tolerate physical, chemical or environmental changes.

8. REFERENCES

Althaus, F., Woolley, K., He, X., Stephenson, P. and Little, R., (2006). The spatial distribution of commercial fishery production on Australia's North West Shelf. North West Shelf Joint Environmental Management Study. Technical Report No. 10.

Benoit-Bird, K. and Au, W. W. L. (2006). Extreme diel horizontal migrations by a tropical nearshore resident micronekton community. Marine Ecology Progress Series: 319: 1-14.

Benzie, J.A.H., Frusher S. and Ballment E. (1992) Geographical variation in allozyme frequencies of populations of *Penaeus monodon* (Crustacea : Decapoda) in Australia. Aust. J. Mar. Freshwater Res., 43, 715-25

Blaber, S.J.M., Brewer, D.T. and Salini, J.P. (1994) Comparisons of the fish communities of tropical estuarine and inshore habitats in the Gulf of Carpentaria, northern Australia. International Symposium Series (Olsen & Olsen) pp. 363-372

Blaber, S.J.M., Brewer, D.T. and Salini, J.P. (1995) Fish communities and the nursery role of the shallow inshore waters of a tropical bay in the Gulf of Carpentaria. Estuarine, Coastal and Shelf Science. 40: 177-193

Brewer, D.T., Blaber, S.M. and Salini, J.P. (1991) Predation on penaeid prawns by fishes in Albatross Bay, Gulf of Carpentaria. Marine Biology, 109: 231-240.

Brewer, D.T., Heales, D.S., Griffiths, S.P., Zhou, S., Dell, Q., Tonks, M., Milton, D.A. and Kuhnert, P. (2006) Design, trial and implementation of an integrated long-term bycatch monitoring program, road tested in the NPF FRDC Project 2002/035. CSIRO Cleveland. Draft submitted to FRDC, December 2006 (2002-2006).

Bulman, C. (2006) Trophic webs and modelling of Australia's North West Shelf - Technical Report No. 9. Final Report - North West Shelf Joint Environmental Management Study. CSIRO

Burns, K.A., Greenwood, P.F., Summons, R.E., and Brunskill, G.J. (2001) Vertical fluxes of hydrocarbons on the Northwest Shelf of Australia as estimated by a sediment trap study. Organic Geochemistry 32. pp. 1241-1255.

Caputi, N., Chubb, C. and Pearce, A. (2001) Environmental effects on recruitment of the western rock lobster, *Panulirus cygnus*. Marine and Freshwater Research 52: 1167-1174.

Caputi, N., Fletcher, W.J., Pearce, A., and Chubb, C.F. (1996) Effect of the Leeuwin Current on the recruitment of fish and invertebrates along the Western Australian coast. Marine and Freshwater Research 47. pp. 147-155.

Condie, S.A., Andrewartha, J., Mansbridge, J., Waring, J. (2006) Modelling circulation and connectivity on Australia's North West Shelf. Technical Report No. 6. Final Report - North West Shelf Joint Environmental Management Study. CSIRO.

Condie, S.A. and Dunn J.R. (2006) Seasonal characteristics of the surface mixed layer in the Australasian region: implications for primary production regimes and biogeography. Marine & Freshwater Research. 57, 69-590

Cresswell, G., Frishche A., Peterson J., Quadfasel, D. (1993) Circulation in the Timor Sea. Journal of Geophysical Research 98: 369-379.

Cresswell, G.R., and Badcock, K.A. (2000) Tidal mixing near the Kimberly coast of NW Australia. Marine and Freshwater Research. 51, 641-6

DEW (2007) Characterisation of the marine environment of the North Marine Region. Outcomes of an expert workshop convened in Darwin, Northern Territory, 2-3 April 2007. Prepared by the North Marine Bioregional Planning team, Marine and Biodiversity Division, Department of the Environment and Water Resources.

Dunlop, J.N., Wooller, R.D. and Cheshire, N.G. (1988) Distribution and Abundance of Marine Birds in the Eastern Indian Ocean. Australian Journal of Marine and Freshwater Research 39: 661-669.

Feng, M., Meyers, G., Pearce, A., Wijffels, S. (2003) Annual and interannual variations of the Leeuwin Current at 32 degrees south. Journal of Geophysical Research 108: 19-11 - 19-21.

Fieux, M., Molcard, R., and Morrow, R. (2005) Water properties and transport of the Leeuwin Current and Eddies off Western Australia. Deep Sea Research (Part I, Oceanographic Research Papers) 52(9): 1617-1635.

Fulton, E., Hatfield, B., Althaus, F. and Sainsbury, K. (2006) Benthic habitat dynamics and models on Australia's North West Shelf - Technical Report No. 11. North West Shelf Joint Environmental Management Study.

Furnas, M.J., and Mitchell, A.W. (1999) Wintertime carbon and nitrogen fluxes on Australia's Northwest Shelf. Estuarine, Coastal and Shelf Science 49: 165-175.

Furnas, M. (2007) Intra-seasonal and inter-annual variations in phytoplankton biomass, primary production and bacterial production at North West Cape, Western Australia: Links to the 1997-1998 El Nino event. Continental Shelf Research 27, 958-980

Fry, G., Brewer, D.T., and Venables, W.N. (2006) Vulnerability of deepwater fishes to commercial fishing; evidence from a study around a tropical volcanic sea mount in Papua New Guinea. Fisheries Research 81, 126-141.

Gage J.D., and Tyler, P.A. (1991) Deep-sea biology: a natural history of organisms at the sea floor. Cambridge University Press, London. 504 pp.

Gersbach, G.H., Pattiaratchi, C.B., Ivey, G.N., Cresswell, G.R. (1999) Upwelling on the south-west coast of Australia—source of the Capes Current? Continental Shelf Research 19, 363–400.

Griffiths, S.P., Fry, G.F., Manson, F. and Pillans, R. (2007) Feeding dynamics, consumption rates and daily ration of longtail tuna (*Thunnus tonggol*) in Australian waters, with emphasis on the consumption of commercially important prawns. Marine and Freshwater Research 58, 376–397.

Hallengraeff, G.M., and Jeffrey, S.W. (1984) Tropical phytoplankton species and pigments of continental shelf waters of North and North-West Australia. Marine Ecology – Progress Series 20: 59-74

Hanson, C.E., Pattiaratchi, C.B. and Waite, A.M. (2005) Sporadic upwelling on a downwelling coast: phytoplankton responses to spatially variable nutrient dynamics off the Gascoyne region of Western Australia. Continental Shelf Research, 25: 1561-1582 .

Hanson, C.E., Pattiaratchi, C.B. and Waite, A.M. (2005) Seasonal production regimes off southwestern Australia : influence of the Capes and Leeuwin Currents on phytoplankton dynamics. Marine and Freshwater Research. 56: 1011-1026.

Harris, P., Heap, A., Passlow, V., Sbaffi, L., Fellows, M., Porter-Smith, R., Buchanan, C. and Daniell, J. (2005) Geomorphic Features of the Continental Margin of Australia, Geoscience Australia: Record 2003/30. 142pp.

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

Hedgepeth, J.W. (1957) Chapter 1. Introduction. In: *Treatise on Marine Ecology and Paleoecology*. Geol. Soc. Amer., Mem. 67, pp. 1-16.

Herzfeld, M., Parslow, J., Sakov, P., Andrewartha, J. (2006) Biogeochemical modelling of Australia's North West Shelf. Technical Report No. 8. CSIRO.

Heyward, A., Halford, A.R., Smith, L.D., Williams, D.B. (1997*a*) Coral reefs of north west Australia: baseline monitoring of an oceanic reef ecosystem.

Heyward, A., Pinceratto, E. and Smith, L. (1997*b*) Big Bank Shoals of the Timor Sea. An Environmental Resource Atlas. BHP Petroleum. pp 115.

Heyward, A., Revill, A., Sherwood, C. (2006) Review of research and data relevant to marine environmental management of Australia's North West Shelf. Report no.

Hill, B.J., and Wassenberg, T.J. (1990) Fate of discards from prawn trawlers in Torres Strait. Aust. J. Mar. Freshw. Res. 41, 53-64.

Hill, B.J., and Wassenberg, T.J. (2000) The probable fate of discards from prawn trawlers fishing near coral reefs: A study in the northern Great Barrier Reef, Australia. Fish. Res. 48(3), 277-286.

Holloway, P.E., Humphries, S.E., Atkinson, M., and Imberger, J. (1985) Mechanisms for Nitrogen Supply to the Australian North West Shelf. Australian Journal of Marine and Freshwater Research 36: 753-64.

Holloway, P.E. (1988) Physical oceanography of the Exmouth Plateau region, North-western Australia. Australian Journal of Marine and Freshwater Research 39: 589-606.

Holloway, P.E. (1994) Observations of internal tide propagation on the Australian North West Shelf. Journal of Physical Oceanography 24(8): 1706-1716.

Holloway, P.E., Chatwin, P.G., Craig, P. (2001) Internal tide observations from the Australian north west shelf in summer 1995. Journal of Physical Oceanography 31(5): 1182-1199.

Holloway, P.E., and Nye, H.C. (1985) Leeuwin current and wind distributions on the southern part of the Australian North West Shelf between January 1982 and July 1983. Australian Journal of Marine and Freshwater Research 36. pp. 123-137.

Hooper, J. and Ekins, M. (2004) Collation and validation of museum collection databases related to the distribution of marine sponges in Northern Australia (Contract National Oceans Office C2004/020). Unpublished Report to the National Oceans Office, Queensland Museum, Brisbane. 206pp.

Interim Marine and Coastal Regionalisation for Australia Technical Group (1998), Interim Marine and Coastal Regionalisation for Australia: an ecosystem-based classification for marine and coastal environments. Version 3.3. Environment Australia, Commonwealth Department of the Environment. Canberra.

Jenner K.C.S., Jenner M.-N.M., McCabe K.A. (2001) Geographical and temporal movements of humpback whales in Western Australia. Journal of the Australian Petroleum Production and Exploration Association: 749-765.

Lansdell, M., Young, J. (2007) Pelagic cephalopods from eastern Australia: species composition, horizontal and vertical distribution determined from the diets of pelagic fishes. Journal Reviews in Fish Biology and Fisheries. 17 (2-3), 125-138

Last, P., Lyne, V., Yearsley, G., Gledhill, D., Gomon, M., Rees, T., White, W. (2005) Validation of the national demersal fish datasets for the regionalisation of the Australian continental slope and outer shelf (>40 m depth). Department of Environment and Heritage and CSIRO Marine Research, Australia, 2005. ISBN 1 876996 87 0

Lyne, V. and Hayes, D. (2005) Pelagic Regionalisation: National Marine Bioregionalisation Integration Project Report. Department of the Environment and Heritage and CSIRO, Lyne, V., Fuller, M., Last, P., Butler, A., Martin, M., and Scott, R. (2006) Ecosystem characterisation of Australia's North West Shelf - Technical Report No. 12. North West Shelf Joint Environmental Management Study.

Lyne, V., and Last, P. (1996) Interim Marine Bioregionalisation for Australia: Towards a National System of Marine Protected Areas. CSIRO Division of Fisheries & CSIRO Division of Oceanography - Report to Environment Australia, Canberra. http://www.deh.gov.au/coasts/mpa/nrsmpa/bioregion/index.html

Mackie, C.M., Lewis, P.D., Gaughan, D.J. and Newman, S.J. (2005) Variability in spawning frequency and reproductive development of the narrow-barred Spanish mackerel (Scomberomorus commerson) along the west coast of Australia. Fishery Bulletin. 103, 344-354.

Margvelashvili, N., Andrewartha, J., Condie, S.A., Herzfeld, M., Parslow, J., Sakov, P., Waring, J. (2006) Modelling suspended sediment transport on Australia's North West Shelf. Report no.

McLoughlin, K. (2006) Fisheries Status Reports 2005: Status of Fish Stocks managed by the Australian Government. Canberra: Bureau of Rural Sciences. Report no.

McLoughlin R.J. and Young, P.C. (1985) Sedimentary Provinces of the Fishing Grounds of the North West Shelf of Australia: Grain-size Frequency Analysis of Surficial Sediments. Australian Journal of Marine and Freshwater Research 36: 671-81.

McKinnon, A.D., Meekan, M.G., Carleton J.H., Furnas M.J., Duggan S., Skirving, W. (2003) Rapid changes in shelf waters and pelagic communities on the southern Northwest Shelf, Australia, following a tropical cyclone. Continental Shelf Research, Volume 23, Number 1, pp. 93-111(19)

Meyers G., R.J. Bailey, and A.P. Worby (1995) 'Geostrophic transport of Indonesian throughflow' Deep Sea Research 42, No. 7, pp. 1163-74

Meyers, G. (1996) Variation of the Indonesian throughflow and the El Nino−Southern Oscillation. J. Geophys. Res., 101, 12255−12264.

Myers, J.D. (1998) Long-Term Monitoring Program of the Ningaloo Marine Park: Survey of Benthic Cover and Status of the Ningaloo Reef in Western Australia. Kalamazoo College.

Newman, S.J., and Dunk, I.J. (2002) Growth and age validation, mortality, and other population characteristics of the red emperor snapper, Lutjanus sebae (Cuvier, 1828), off the Kimberly coast of north-western Australia. Estuarine, Coastal and Shelf Science. 55, 67-80.

Newman, S.J. and Dunk, I.J. (2003) Age validation, growth, mortality, and additional population parameters of the goldband snapper (*Pristipomoides multidens*) off the Kimberley coast of northwestern Australia. Fishery Bulletin. 101(1), 116-128.

Norse, E.A. and Crowder, L.B. (Ed.) (2005) Marine conservation biology: the science of maintaining the sea's biodiversity. Island Press: Washington, DC (USA). 470 pp.

Nowara, G., and Newman, S. (2001) A history of foreign fishing activities and fishery-independent surveys of the demersal finfish resources in the Kimberley region of Western Australia. Department of Fisheries (WA). Report no. 125

Ovenden, J.R., Lloyd, J., Newman, S.J., Keenan, C.P. and Slater, L.S. (2002) Spatial genetic subdivision between northern Australian and southeast Asian populations of Pristipomoides multidens: a tropical marine fish species. Fisheries Research 59. pp. 57-69.

Pilling, G.M., Millner, R.S., Easey, M.W.,Mees, C.C., Rathacharen, S., Azemia, R., 2000. Validation of annual growth increments in the otoliths of the lethrinid *Lethrinus mahsena* and the lutjanid *Aprion virescens* from sites in the tropical Indian Ocean, with notes on the nature of growth increments in *Pristipomoides filamentosus*. Fish. Bull. 98, 600–611.

Pinceratto, E. (1997) Physical Environment, pp. 7-12, In, A. Heyward, E. Pinceratto, and L. Smith (eds), Big Bank Shoals of the Timor Sea: An environmental resource atlas, BHP Petroleum, Melbourne.

Pitcher, C.R., Poiner, I.R. and Burridge, C.Y. (2000) The implications of the effects of trawling on sessile mega-zoobenthos on a tropical shelf in northeastern Australia. ICES Journal of Marine Science, 57(5), pp. 1359-1368 Smith, L., C. Steingerg, *et al*. (2003). Scott Reef Field Report: March - April 2003, AIMS.

Rogers, A.D. (1994) The biology of seamounts. Advances in Marine Biology. 30, 305-350.

Ralston, S. and Williams, H.A. (1989) Numerical integration of daily growth increments: An efficient means of ageing tropical fishes for stock assessment. Fishery Bulletin. 87(1), pp. 1-16.

Sampey, A., McKinnon, A.D., Meekan, M.G., and McCormick, M.I. (2007) Glimpse into guts: overview of the feeding of larvae of tropical shorefishes. Marine Ecology Progress Series 339, 243-257

Skewes, T.D., Gordon, S.R., McLeod, I.R., Taranto, T.J., Dennis, D.M., Jacobs, D.R., Pitcher, C.R., Haywood, M.D.E., Smith, G.P., Poiner, I.R., Milton, D.A., Griffin, D., and Hunter, C. (1999) Survey and stock size estimates of the shallow reef (0-15 m deep) and shoal area (15 - 50 m deep) marine resources and habitat mapping within the MOU74 box. Volume 2: Habitat mapping and coral dieback. CSIRO Final Report to the FRRF, May 1999. 52 pp.

Sleeman, J.C., Meekan, M.G., Wilson, S.G., Jenner, C.K.S., Jenner, M.N., Boggs, G.S., Steinburg, C.C. and Bradshaw, J.A. (2007) Biophysical correlates of the megafauna distributions at Ningaloo Reef, Western Australia. Manuscript for submission to Marine and Freshwater Research.

Stephenson, P.C., Edmonds, J.S., Moran, M.J. and Caputi, N. (2001) Analysis of stable isotope ratios to investigate stock structure of red emperor and Rankin cod in northern Western Australia. Journal of Fish Biology 58: 126-144.

Stobutzki, I.C., Miller, M.J., Jones, P., and Salini, J.P. (2001) Bycatch diversity and variation in a tropical Australian penaeid fishery; the implications for monitoring. Fish. Res. 53(3), 283-301.

Taylor, J.G. and Pearce, A.F. (1999) Ningaloo Reef currents: implications for coral spawn dispersal, zooplankton and whale shark abundance." Journal of the Royal Society of Western Australia 82: 57-65.

Tomczak, M., and Godfrey, J.S. (2003) The Indian Ocean. Pages 390 in Tomczak M, Godfrey JS, eds. Regional Oceanography: an Introduction. Delhi: Daya Publishing House.

Tranter, D.J. (1977) Further Studies of Plankton Ecosystems in the Eastern Indian Ocean. 1. Introduction - The Study and the Study Area. Australian Journal of Marine and Freshwater Research 28: 529-539.

Tranter, D.J., Kerr, J.D. (1977) Further Studies of Plankton Ecosystems in the Eastern Indian Ocean III. Numerical Abundance and Biomass. Australian Journal of Marine and Freshwater Research 28: 557-583.

Tranter, D.J. and Leech, G.S. (1987) Factors influencing the standing crop of phytoplankton on the Australian Northwest Shelf seaward of the 40 m isobath. Continental Shelf Research 7(2): 115-133.

Wilson, B.R., Allen, G.R. (1987) Major components and distribution of marine fauna. Pages 43-68 in Fauna BoFa, ed. Fauna of Australia, vol. Volume 1A General Articles. Canberra: Australian Government Publishing Service.

Wilson, S.G., Carleton, J.H. and Meekan, M.G. (2003) Spatial and temporal patterns in the distribution and abundance of macrozooplankton on the southern North West Shelf, Western Australia. Estuarine Coastal and Shelf Science 56: 897-908.

Wolanski, E. and Delesalle, B. (1995). Upwelling by internal waves, Tahiti, French Polynesia, Continental Shelf Research, 15, 357-368.

Woo, M., Pattiaratchi, C., Schroeder, W. (2006) Summer surface circulation along the Gascoyne continental shelf, Western Australia. Continental Shelf Research Volume: 26, Issue: 1, pp. 132-152

Wyrtki, K. (1961) Physical Oceanography of the Southeast Asian Waters. NAGA Report vol. 2. University of California. La Jolla, USA.

Young, J. W.; Bradford, R.; Lamb, T. D.; Clementson, L. A.; Kloser, R.; Galea, H. (2001). Yellowfin tuna (*Thunnus albacares*) aggregations along the shelf break off south-eastern Australia: links between inshore and offshore processes. Marine and Freshwater Research, 52(4), 463-474.

Young, G.C., Potter, I.C. (2003) Characterisation of the inshore fish assemblages of the Pilbara and Kimberley coasts.

Young, P.C., Leis, J.M. and Hausfeld, H.F. (1986) Seasonal and spatial distribution of fish larvae in waters over the North West Continental Shelf of Western Australia. Marine Ecology Progress Series 31: 3. pp. 209-222.

Personal Communications

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APPENDICES

Appendix 1. Abiotic statistics generated for the eco-physical systems of the North-west Marine Region

Depth and slope statistics for the trophic system compartments of the North-western Marine Region. Data generated from gridded bathymetry (Geosciences Australia)

Name		Mean depth (m)	Min Depth (m)	Max Depth (m)	Mean slope (%)	Min slope (%)	Max Slope (%)
Western JBG shelf	1a1	-84.05	0	-271	0.36	0	40
Kimberley shelf	1a2	-80.28	-4	-283	0.37	0	14
Kimberley slope	1b	-1509.59	34	-5644	2.83	0	247
Argo Plain	1c	-5571.65	-3674	-5977	1.91	0	69
NW shelf	2a	-83.53	0	-378	0.27	0	20
Exmouth plateau	2b	-1614.40	-1	-5710	2.26	0	175
Carnarvon shelf	3a	-112.03	-32	-563	0.65	0	32
Carnarvon slope	3b	-2359.35	-184	-5334	3.90	0	251
Cuvier abyssal plain	3c	-5007.57	-3289	-5456	2.43	0	65
Kalbarri Shelf	4a	-115.44	-33	-320	0.26	0	12
Wallaby Saddle	4b	-2585.58	-174	-4586	1.80	0	21

Temperature (C°) for the trophic system compartments of the North-western Marine Region - annual mean (and seasonal (monthly) for SST) at the surface (SST), 150 m, 500 m, 1000 m and 2000 m; and monthly. SST from NOAA, depth data derived from CARS.

Name		SST Mean	SST Jan	SST April	SST July	SST Oct	Ave Temp 150m	Ave Temp 500m	Ave Temp 1000m	Ave Temp 2000m
Western JBG shelf	1a1	28.65	29.87	29.91	26.41	28.81	19.27	7.89		
Kimberley shelf	1a2	28.48	29.67	30.47	26.36	27.88	19.39	8.09	4.89	
Kimberley slope	1b	28.47	29.53	30.10	26.61	28.19	19.73	8.05	4.91	2.41
Argo Plain	1c	28.06	29.24	29.85	26.28	27.28	20.31	8.24	4.95	2.41
NW shelf	2a	27.35	29.61	29.72	24.50	25.73	21.11	8.27	5.03	
Exmouth plateau	2b	26.84	28.11	29.09	25.17	25.07	20.44	8.52	5.01	2.39
Carnarvon shelf	3a	24.52	24.99	27.16	23.73	22.01	21.26	8.68	4.96	
Carnarvon slope	3b	24.43	25.15	27.01	23.28	22.17	20.02	9.26	4.93	2.38
Cuvier abyssal plain	3c	24.38	24.97	26.72	23.36	22.23	19.90	9.55	4.94	2.38
Kalbarri Shelf	4a	23.19	23.47	25.51	22.77	20.88	20.53	8.96	4.48	
Wallaby Saddle	4b	22.83	23.46	25.00	21.98	20.84	18.88	9.51	4.74	2.39

Average salinity (ppt) for the trophic system compartments of the North-western Marine Region at the surface, 150 m, 500 m, 1000 m and 2000 m depth. (Derived from CARS)

Name		Mean surface salinity	Mean salinity 150m	Mean salinity 500m	Mean salinity 1000m	Mean salinity 2000m
Western JBG shelf	1a1	34.76	34.50	34.57		
Kimberley shelf	1a2	34.78	34.64	34.61	34.61	
Kimberley slope	1b	34.59	34.64	34.60	34.61	34.73
Argo Plain	1c	34.55	34.81	34.65	34.61	34.73
NW shelf	2a	35.15	34.92	34.65	34.63	
Exmouth plateau	2b	34.89	35.11	34.67	34.63	34.72
Carnarvon shelf	3a	35.19	35.39	34.66	34.63	
Carnarvon slope	3b	35.21	35.55	34.72	34.61	34.72
Cuvier abyssal plain	3c	35.19	35.55	34.75	34.61	34.72
Kalbarri Shelf	4a	35.39	35.59	34.67	34.50	
Wallaby Saddle	4b	35.45	35.75	34.75	34.57	34.72

Average Nitrate (uM) and Phosphate (uM) concentration for the trophic system compartments of the North-western Marine Region at the surface, 150 m, 500 m, 1000 m and 2000 m depth. (Derived from CARS)

Name		Mean N 0m	Mean N 150m	Mean N 500m	Mean N 1000 m	Mean N 2000 m	Mean P 0m	Mean P 150m	Mean P 500m	Mean P 1000 m	Mean P 2000 m
Western JBG shelf	1a1	0.18	16.16	36.20	38.90		0.15	1.15	2.26	38.90	
Kimberley shelf	1a2	0.21	16.06	36.37	39.31	32.35	0.19	1.15	2.21	39.31	2.52
Kimberley slope	1b	0.09	15.48	33.40	37.20	32.93	0.15	1.07	2.17	37.20	2.56
Argo Plain	1c	0.05	12.81	28.53	35.40	34.14	0.11	0.85	1.96	35.40	2.61
NW shelf	2a	0.14	11.65	29.79	38.17		0.14	0.86	1.84	38.17	
Exmouth plateau	2b	0.11	9.49	25.41	37.01	34.11	0.13	0.70	1.64	37.01	2.59
Carnarvon shelf	3a	0.03	2.03	18.80	38.52	37.57	0.15	0.30	1.26	38.52	2.52
Carnarvon slope	3b	0.04	2.71	16.40	37.33	36.91	0.14	0.32	1.16	37.33	2.53
Cuvier abyssal plain	3c	0.04	3.21	15.53	36.44	36.28	0.13	0.34	1.12	36.44	2.55
Kalbarri Shelf	4a	0.05	1.16	15.95	36.13	36.78	0.13	0.24	1.18	36.13	2.27
Wallaby Saddle	4b	0.06	1.37	13.13	34.77	35.73	0.12	0.24	1.09	34.77	2.47

Average disolved oxygen (mg/l) concentration for the trophic system compartments of the North-western Marine Region at the surface, 150 m, 500 m, 1000 m and 2000 m depth. (Derived from CARS)

Name		Mean surface DO	Mean DO 150m	Mean DO 500m	Mean DO 1000m	Mean DO 2000m
Western JBG shelf	1a1	4.55	2.84	2.12	2.25	
Kimberley shelf	1a2	4.52	2.78	2.13	2.22	3.24
Kimberley slope	1b	4.54	2.75	2.31	2.20	3.18
Argo Plain	1c	4.55	2.99	2.95	2.15	3.14
NW shelf	2a	4.61	3.27	3.48	2.19	
Exmouth plateau	2b	4.65	3.50	3.98	2.18	3.25
Carnarvon shelf	3a	4.79	4.45	5.11	2.36	3.40
Carnarvon slope	3b	4.79	4.44	5.29	2.42	3.38
Cuvier abyssal plain	3c	4.77	4.31	5.29	2.41	3.36
Kalbarri Shelf	4a	4.91	4.62	5.34	2.99	3.52
Wallaby Saddle	4b	4.91	4.78	5.43	2.79	3.44

Average silicate concentration (uM) concentration for the trophic system compartments of the North-western Marine Region at the surface, 150 m, 500 m, 1000 m and 2000 m depth. (Derived from CARS)

Name		Mean surface silicate	Mean silicate 150m	Mean silicate 500m	Mean silicate 1000m	Mean silicate 2000m
Western JBG shelf	1a1	3.52	34.50	66.10	103.28	
Kimberley shelf	1a2	5.10	34.64	57.62	99.42	134.15
Kimberley slope	1b	3.46	34.64	56.21	97.17	131.12
Argo Plain	1c	3.16	34.81	43.45	95.77	129.24
NW shelf	2a	3.53	34.92	34.18	96.77	
Exmouth plateau	2b	3.65	35.11	26.85	94.84	128.30
Carnarvon shelf	3a	3.33	35.39	10.54	86.05	119.47
Carnarvon slope	3b	3.67	35.55	8.07	84.74	118.87
Cuvier abyssal plain	3c	3.86	35.55	7.19	84.34	119.29
Kalbarri Shelf	4a	2.86	35.59	7.07	67.99	102.33
Wallaby Saddle	4b	3.21	35.75	6.10	78.18	112.61

Mean annual and and monthly Chlorophyll concentration (mg/m^3) for the trophic system compartments of the North-western Marine Region. (Derived from MODIS Aqua Ocean Colour Satellite)

Name		Mean Chlorophyl	Mean Chlorophyl January	Mean Chlorophyl April	Mean Chlorophyl July	Mean Chlorophyl October
Western JBG shelf	1a1	0.513	0.389	0.472	0.811	0.380
Kimberley shelf	1a2	0.299	0.237	0.311	0.384	0.263
Kimberley slope	1b	0.111	0.075	0.106	0.173	0.090
Argo Plain	1c	0.090	0.064	0.089	0.122	0.084
NW shelf	2a	0.357	0.329	0.381	0.407	0.314
Exmouth plateau	2b	0.125	0.070	0.092	0.180	0.157
Carnarvon shelf	3a	0.386	0.224	0.210	0.468	0.643
Carnarvon slope	3b	0.220	0.101	0.101	0.332	0.345
Cuvier abyssal plain	3c	0.192	0.096	0.097	0.295	0.278
Kalbarri Shelf	4a	0.275	0.137	0.189	0.322	0.451
Wallaby Saddle	4b	0.170	0.096	0.093	0.205	0.285

Mean wave and tidal exceedance (%) for the trophic system compartments of the North-western Marine Region generated from estimates from surface wind speed (Met Bureau regional atmospheric model) as inpout to the Wave Model, WAM. Exceedance is defined as the percentage of time that currents are predicted to mobilise sediments of a mean grain size.

Name		Mean wave exceedance	Mean tide exceedance
Western JBG shelf	1a1	0.44	25.01
Kimberley shelf	1a2	0.83	33.22
Kimberley slope	1b	1.42	8.19
Argo Plain	1c		
NW shelf	2a	1.32	24.68
Exmouth plateau	2b	0.08	9.62
Carnarvon shelf	3a	0.65	0.00
Carnarvon slope	3b	1.19	0.00
Cuvier abyssal plain	3c		
Kalbarri Shelf	4a	0.42	0.00
Wallaby Saddle	4b	0.33	0.00

Mean mixed layer depth (m) for the trophic system compartments of the North-western Marine Region, calculated from salinity cast data used to generate CARS2000.

Name		Mean mixed layer depth	Min mixed layer depth	Max mixed layer depth
Western JBG shelf	1a1	32.50	28	38
Kimberley shelf	1a2	31.39	27	38
Kimberley slope	1b	33.20	27	40
Argo Plain	1c	32.70	29	40
NW shelf	2a	29.22	18	38
Exmouth plateau	2b	35.68	30	42
Carnarvon shelf	3a	37.91	36	39
Carnarvon slope	3b	37.44	36	40
Cuvier abyssal plain	3c	37.98	34	41
Kalbarri Shelf	4a	44.48	38	49
Wallaby Saddle	4b	37.41	35	42

Mean annual and monthly surface current (m/s) for the trophic system compartments of the North-western Marine Region; surface currents are generated from steric-height fields, and tidal currents are generated from a tide model for the Australian shelf

Name		Mean Surface currents January	Mean surface currents April	Mean surface currents July	Mean surface currents October
Western JBG shelf	1a1	0.132	0.103	0.112	0.110
Kimberley shelf	1a2	0.090	0.051	0.065	0.065
Kimberley slope	1b	0.130	0.076	0.082	0.096
Argo Plain	1c	0.114	0.083	0.095	0.105
NW shelf	2a	0.033	0.040	0.060	0.037
Exmouth plateau	2b	0.046	0.055	0.052	0.057
Carnarvon shelf	3a	0.090	0.107	0.120	0.073
Carnarvon slope	3b	0.078	0.094	0.109	0.060
Cuvier abyssal plain	3c	0.048	0.047	0.081	0.044
Kalbarri Shelf	4a	0.077	0.120	0.106	0.074
Wallaby Saddle	4b	0.069	0.095	0.069	0.056

Total (1906-2000) and mean annual cyclone activity for the trophic system compartments of the North-western Marine Region, including cyclone path per square km within each compartment, and average path length for cyclones within each compartment. Data derived from Met Bureau cyclone data.

Name		Path per sq km (m)	Path per sq km per yr (m)	Average path length (km)
Western JBG shelf	1a1	125.61	1.34	157.55
Kimberley shelf	1a2	280.11	2.98	226.05
Kimberley slope	1b	185.20	1.97	255.45
Argo Plain	1c	225.63	2.40	182.66
NW shelf	2a	242.93	2.58	237.20
Exmouth plateau	2b	248.27	2.64	339.02
Carnarvon shelf	3a	112.15	1.19	44.49
Carnarvon slope	3b	171.63	1.83	139.84
Cuvier abyssal plain	3c	101.37	1.08	118.71
Kalbarri Shelf	4a	72.16	0.77	120.36
Wallaby Saddle	4b	86.98	0.93	154.23

Mean sediment parameters for the trophic system compartments of the North-western Marine Region. Mean grain size (mm) and mud etc content (weight %) were compiled from Geoscience Australia’s marine sediment database (MARS –Table includes number of samples). Sediment mobility is a representation of the relative importance of tidal currents and ocean waves in mobilising sediments of mean grain size on the seabed, as computed by Geoscience Australia’s sediment dynamics model, GEOMAT.

Name		Samples	Mean grain size (mm)	Mean % mud	Mean % sand	Mean % gravel	Mean % carbonate	Mean sediment mobility
Western JBG shelf	1a1	82503	0.22	40.98	48.23	10.76	61.06	4.65
Kimberley shelf	1a2	63868	0.72	14.92	53.51	31.57	83.02	4.48
Kimberley slope	1b	32614	0.43	24.38	61.57	14.05	84.60	2.56
Argo Plain	1c							
NW shelf	2a	100837	0.45	9.97	77.62	12.42	91.37	3.82
Exmouth plateau	2b	31258	0.31	31.20	60.33	8.48	88.13	3.22
Carnarvon shelf	3a	2543	0.79	0.27	91.87	7.88		0.39
Carnarvon slope	3b	325	0.80	0.27	91.52	8.21		0.00
Cuvier abyssal plain	3c							
Kalbarri Shelf	4a	6960	0.50				80.27	0.25
Wallaby Saddle	4b							

Appendix 2. List of GIS files/layers and other datasets provided as part of the project delivery to DEW

Public Doman (existing datasets)

1. Data summaries processed from National Marine Bioregionalisation 2005.

2. Cyclone tracks (1906-2000) for the North West Marine Region Data derived from Bureau of Meteorology data.

New Data

1. Sub-regional boundaries created for the description of trophic systems in the NWMR.

Appendix 3. Glossary of Terms

Advection Transport in a fluid from one region to another, can be vertically or horizontally.

Basin A geological feature where a large part of the earth is covered by seawater, often where the edges of the feature are shallower then the central portion.

Biodiversity In an oceans context, the variety of living organisms in the estuaries and oceans, their genes, and the ecosystems of which they form a part (National Strategy for the Conservation of Australia's Biological Diversity, 1996)

Bioregion An area defined by a combination of biological, social and geographic criteria, rather than by geopolitical considerations. Generally, a system of related, interconnected ecosystems (Commonwealth of Australia 1996).

Bioregionalisation A process of identifying and mapping broad ecologicalpatterns based on physical and/or biological attributes for planning and management purposes.

Community A group of organisms, both animals and plants, living together in an ecologically related fashion in a defined area or habitat.

Driver A feature or process that promotes or controls the onset and onward course of an action.

Ecosystem A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (UNEP Convention on Biological Diversity, June 1992)

Ecosystem structure The components of an ecosystem including plants, animals, micro-organisms and the non-living environment.

Ecosystem function The biological, physical and chemical processes that link components of the ecosystem.

EEZ The Exclusive Economic Zone. The area between the lines 12 nautical miles and 200 nautical miles seaward of the territorial sea baselines. In this area, Australia has the right to explore and exploit living and non-living resources, and the concomitant obligation to protect and conserve the marine environment.

Functional group Groups of organisms that occupy a similar position in a trophic system or food web.

Gyre	Circulation or rotation of ocean water usually dictated by prevailing winds and the Coriolis effect
Habitat	The place or type of site where an organism or population naturally occurs (UNEP 1994).
IMCRA	Interim Marine Coastal Regionalisation for Australia. An ecosystem-based classification for marine and coastal environments. It provides ecologically based regionalisations at the meso-scale (100–1000 km) and at a provincial scale (greater than 1000 km).
MPA	Marine Protected Area. An area of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means (IUCN 1994).
State waters	Australia's Offshore Constitutional Settlement established Commonwealth, State and Territory jurisdictions over marine areas. States generally have primary jurisdiction over marine areas to 3 nautical miles from the baseline.
Trophic systems	Is the interconnected web that describes the various positions which organisms that live within an area occupies in a food chain (what it eats and what eats it).
Upwelling	An oceanographic phenomenon that involves the movement of dense, cooler, and usually nutrient-rich water towards the ocean surface, replacing the warmer, usually nutrient-depleted surface water.