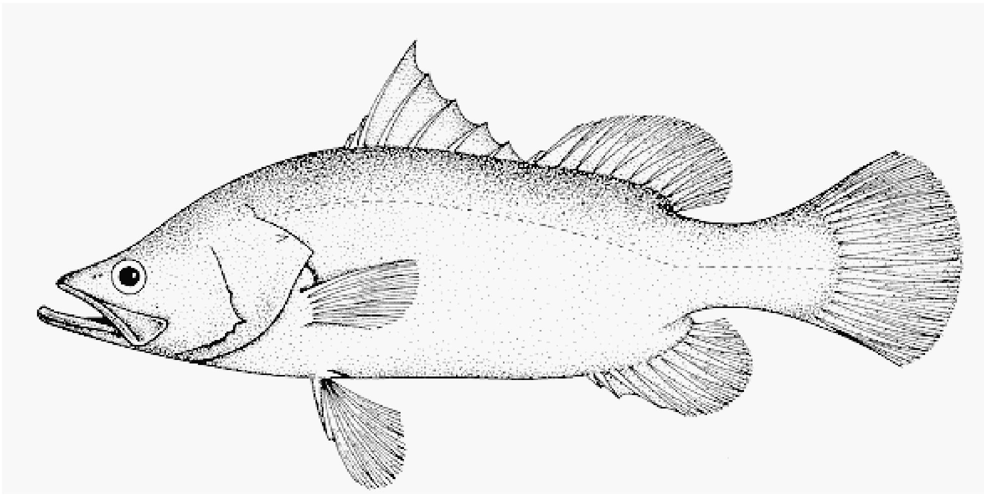
AN EXAMINATION OF THE IMPACTS OF CLIMATE VARIABILITY AND CLIMATE CHANGE ON THE WILD BARRAMUNDI (*Lates calcarifer*): A TROPICAL ESTUARINE FISHERY OF NORTH-EASTERN QUEENSLAND, AUSTRALIA.



Thesis submitted by

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James Cook University

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STATEMENT ON THE CONTRIBUTION BY OTHERS

Fees: Nil
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Balston, J.M. and Williams, A.J. (2005). Modelling impacts of climate variability on the commercial barramundi (*Lates calcarifer*) fishery of north-eastern Queensland, MODSIM 05 International Congress on Modelling and Simulation, 12-15 December 2005, Melbourne, Australia.

Balston, J.M., and Williams, A.A.J. (2006). Aquaculture and Fisheries In: Vulnerability to Climate Change of Australia's Coastal Zone: Analysis of gaps in methods, data and system thresholds. Part I: Executive and Technical Summaries (Eds: Voice, M., Harvey, N. and Walsh, K.). Report to the Australian Greenhouse Office, Canberra, Australia.

Balston, J. (2007). Climate impacts on the barramundi and banana prawns fisheries of the Queensland tropical east coast. In: Environmental flows for sub-tropical estuaries: understanding the freshwater needs of estuaries for sustainable fisheries production and assessing the impacts of water regulation (Eds: Halliday, I. and Robins, J.). Final Report for the Fisheries Research and Development Corporation Project Number 2001/022 and the Coastal Zone Cooperative Research Centre Projects FH3/AF. Queensland Department of Primary Industries and Fisheries, Brisbane, Queensland. 62-77.

Stork, N.E., Balston, J., Farquhar, G.D., Franks, P.J., Holtum, J.A.M., Liddell, J.M. (2007). "Tropical rainforest canopies and climate change". Austral Ecology 32:105-112.

Other:

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Journal articles in preparation for submission by 30th June 2007:

Balston, J.M. (in prep) "An examination of the impacts of short-term climate effects on the wild barramundi fishery of Princess Charlotte Bay and implications for management".

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ABSTRACT

Scope

As is the case overseas, the wild fisheries of Australia are under increasing threat from the pressures of over-fishing, habitat destruction and water quality degradation. In addition, inshore fisheries that are dependant on freshwater flows to provide nutrient pulses and nursery habitats are also affected by changes in natural flow regimes as a result of water impoundment and extraction (Robins, Halliday *et al.* 2005). The barramundi (*Lates calcarifer*) is an important commercial fish species in Australia worth $8.8 million in 2004/05 (ABARE 2006), and supports valuable tourism and recreational fishing industries. Commercial catch displays a high degree of inter-annual variation; a characteristic that many fishers believe is the result of climate variability. However, apart from rainfall and freshwater flow, previous studies of the barramundi have not examined the impacts from climate in any detail, and existing management strategies do not consider natural climate variability or climate change. This study examined the effects from long-term (biannual to decadal) and short-term (inter-annual) climate variability, extreme and threshold climate events, and anthropogenic climate change on the commercial catch of wild barramundi in north-east Queensland. The possibility of incorporating climate parameters into the management of the fishery was also examined.

Methods

A life cycle model of the barramundi was developed to link climate parameters with the complex developmental stages of the species from spawning in the estuary through maturation in freshwater rivers. Fisheries and climate data were extracted from a variety of sources and compiled for analysis. A gamma distributed logarithm link function model was constructed to calculate total freshwater flow for those years when records were incomplete. Correlation analysis identified significant relationships between climate parameters and catch, and forward stepwise ridge regression was used to develop a model of barramundi catch using climate parameters as predictors. The impact of threshold events was determined by non-linear analysis and the effects of extreme events on barramundi habitat were qualified against MODIS satellite imagery.

A selection of climate change scenarios from a range of global climate models (GCMs) were run through the predictive model developed to determine the likely impacts of future anthropogenic climate change on the fishery.

Results

In the near-pristine Princess Charlotte Bay area, warm sea surface temperatures, high rainfall, increased freshwater flow and low evaporation (all measures of an extensive and productive nursery habitat) were significantly correlated with barramundi catch two years later as recorded by the CFISH logbook system. These results suggest that early barramundi survival is enhanced in these conditions. Catchability was significantly increased after high freshwater flow and rainfall events in the year of catch, a result that reinforced previous observations that mature fish in freshwater habitats are flushed into the commercial estuarine fishery. October – December rainfall and April – June flow showed non-linear asymptotic relationships, and annual evaporation a quadratic relationship, with commercial catch two years later. Curves peaked at approximately 325 mm, 245 000 Ml and 2 000 mm respectively, a result that demonstrated that once these hydro-meteorological threshold events occurred, the response from the fishery was reversed and subsequent commercial barramundi catch reduced. A comparative analysis of data from the Fitzroy River area, a catchment and near shore area that has been highly modified by human intervention, showed only increased freshwater flow prior to the wet season enhanced subsequent barramundi catch. This result indicated that the anthropogenic changes to habitat either affected or masked the relationship between other climate variables and barramundi catch in the area.

Total long-term barramundi landings as recorded by the Queensland Fish Board for six regions along the north-east coast of Queensland showed a near decadal cycle. Correlation analyses returned significant relationships between catch and the January – March average *L*-index (a measure of the latitude of the subtropical ridge) two, three and four years prior to catch, and the Quasi-biennial Oscillation (QBO) three and four years prior to catch. These results suggest that each of these cycles affects climate in the north-east Queensland region and subsequent survival of barramundi in the early life cycle stages, and provides an opportunity to estimate catch a number of years in advance.

A forward stepwise ridge regression model was built to predict commercial barramundi catch in Princess Charlotte Bay. The model contained July – September rainfall and annual evaporation two years prior to catch and explained 62% of the variance in catch and had a cross validated predictive R^2 of 59%. A second model also contained April – June flow in the year of catch (a measure of catchability). This second model explained 69% of the variance in catch and had a cross validated R^2 of 61%, however, the improvement was not statistically significant.

Using the nine global climate models in the OZCLIM program set for three initiating TAR SRES markers (A1B, A2 and B1), a suite of twelve climate change scenarios was generated for the years 2030 and 2070 for Princess Charlotte Bay. These scenarios were then run through the predictive barramundi model developed. Results indicated that due to a likely increase in annual evaporation, barramundi catch in the area will decrease for all future climate scenarios including those that show an increase in July – September rainfall. An analysis to calculate future sea surface temperatures using REEFCLIM indicated that, depending on the availability of suitable habitats, it is possible that the range of the species will extend further south by up to 800 km by the year 2070 as temperatures increase.

Conclusions

Results from this study indicate that a significant proportion of the variability seen in commercial barramundi catch in north-east Queensland is driven by variability in climate. Climate signals are significant at both short and long-term time frames and for some variables the impact is non-linear beyond a defined threshold. Anthropogenic changes to the fishery habitat alter or mask the relationship between climate and barramundi catch, and possibly affect the reproductive success of the species. The likely impact of future anthropogenic climate change will be a reduction in barramundi catch in areas where an increase in evaporation results in a subsequent decrease in shallow wetland habitats essential for early life cycle survival. This thesis provides supporting evidence for policy makers to improve significantly both the prediction of future barramundi catch and the sustainable management of the species by considering the impacts of climate variability and climate change on the species, and by incorporating climate variables into catch models.

ACRONYMS

ACW	Antarctic Circumpolar Wave
BOM	Bureau of Meteorology (Australia)
CPUE	Catch per Unit Effort
CSIRO	Commonwealth Scientific Industrial Research Organisation
ENSO	El Niño Southern Oscillation
IPO	Interdecadal Pacific Oscillation
ITCZ	Intertropical Convergence Zone
JCU	James Cook University
LSTR	Latitude of the Sub-tropical ridge
MJO	Madden Julian Oscillation
NSW	New South Wales
NT	Northern Territory
PDO	Pacific Decadal Oscillation
QBO	Quasibiennial Oscillation
QDNRW	Queensland Department of Natural Resources and Water
QDPI&F	Queensland Department of Primary Industries & Fisheries
QFMA	Queensland Fisheries Management Authority
QLD	Queensland
SA	South Australia
SAM	Southern Annular Mode
SO	Southern Oscillation
SOI	Southern Oscillation Index
SPCZ	South Pacific Convergence Zone
SST	Sea Surface Temperature
SSTs	Sea Surface Temperatures
TAS	Tasmania
TRAP	Tropical Resource Assessment Program
VIC	Victoria
WA	Western Australia
ZWW	Zonal Westerly Winds

GLOSSARY

Carnivore	Animals that feed on other animals
Catadromous	Fish that migrate from fresh to salt water for spawning
Convection	Transfer of heat through fluids, such as air or water, brought about by the movement of the fluid in question
Diadromy	Fish that normally, as a routine phase of their life cycle, and for the vast majority of the population, migrate between marine and fresh waters
Fecundity	The capacity of an individual or species to multiply rapidly; in a stricter sense, the number of eggs produced by an individual
Hermaphrodite	An organism with both male and female reproductive organs
Larvae	Independently living, post-embryonic stage of an animal that is markedly different in form from the adult and that undergoes metamorphosis into the adult form
Meridional	Running from pole to pole of a structure, as along a meridian
Omnivore	Animal that eats both plant and animal food
Pelagic	Living in the sea or ocean at middle or surface levels
Protandry	Condition of hermaphrodite plants and animals where male gametes mature and are shed before female gametes mature adj. protandrous
Telosyst	Group of fish including most modern bony fishes with thin bony scales covered by an epidermis, a homocercal tail, a hydrostatic air bladder, no spiracle and no spiral valve in the gut
Zonal	Moving perpendicular to the axis of a sphere; parallel to the equator

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