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Research priorities to sustain coastal fisheries resources in the Great Barrier Reef region

A scoping study for the Tully-Murray catchment

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CSIRO

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Executive Summary

Historically, fisheries sciences have tended to focus on either freshwater or marine systems, despite the continuous gradient from freshwater, through estuarine to marine habitats. Accordingly, the interfaces between systems have received less emphasis than is warranted by their ecological and economic importance. The increasing realisation that land-based processes within catchments contribute significantly to ecological processes in rivers, estuaries and coastal environments has led to a need for a systems-scale approach that transcends traditional salinity-based boundaries of fisheries sub-disciplines. This report presents the marine catchment basin concept as a basis for integrating the different system components that link catchments, river networks, estuaries and coastal ecosystems in the Great Barrier Reef region, in a fisheries context.

Marine catchment basins consist of five broad ecological zones governed by different material transport and productivity processes: (1) montane and slopes river reaches upstream of the floodplain; (2) lowland floodplain reaches; (3) saline estuarine reaches; (4) the coastal river plume extending seaward; and (5) coastal waters outside the river plume. Prominent models describing processes governing aquatic production, habitat use by fish, fish recruitment in coastal systems, and the role of environmental disturbance in sustaining the diversity and production of fish are considered with respect to these broad ecological zones within the hierarchical habitat structure of marine catchment basins.

Development of large-scale system understanding of the responses of fish to catchment change within the GBR region is dogged by serious deficiencies in current knowledge of coastal fish ecology extending from freshwater to marine environments. Major knowledge gaps include sparse information on the patterns of faunal composition, distribution and abundance of fish assemblages and the physical, chemical and biological processes driving the patterns.

Despite persistent, widely-held beliefs that estuaries provide critical refuge and nursery habitats for many species from freshwater and marine environments, the concept of estuary dependence and the nursery function of habitats has received only superficial attention, mostly for high profile species such as barramundi and mangrove jack, and requires a more critical and sophisticated approach to improve its relevance to catchment-scale management.

Knowledge of aquatic food webs supporting fish production is limited to a small number of studies in the GBR region. Popular paradigms espousing the importance of mangroves, seagrasses, and benthic algae as the main primary producers supporting fish food webs are each supported to some degree by different studies, raising questions about the importance of spatial scale, site-specificity, and flexibility in the diets of fish. But with current catchment management strategies focussing strongly on improving water quality in aquatic systems, the implications of such changes for production in fish food webs, and the scales at which the changes are likely to be manifest, is a high research priority.

The ability of fish to move in both upstream and downstream directions and among habitats sets them apart from other ecological material transport processes dominated by downstream movement only. Connectivity among habitats over a range of spatial and temporal scales that make up the coastal habitat mosaic is vital to fish life cycles. However, the wider importance of biological connectivity has received little recognition and there has been little effort directed to integrated study at a process level, in the coastal zone of the GBR region.

The conventional dichotomy of fisheries research and management into freshwater and marine components is unhelpful in the context of improving catchment-scale land and water use. This artificial dichotomy constrains scientific thinking and fishery management to a scale below the operational focus of contemporary catchment management. If the marine catchment basin scale is to be managed effectively, then new ecological conceptual models

that deal with the whole fishery resource are required. This report has identified knowledge gaps that limit our ability to develop more appropriate conceptual models of ecological function at the marine catchment basin scale. As these gaps are addressed and conceptual models become more refined, it will be possible to develop better predictive fisheries models to explore consequences of management scenarios within marine catchment basins of the GBR.

This broader approach will empower fisheries stakeholders to become more effective in participating in management of marine catchment basins beyond the traditional fisheries jurisdictions to improve the sustainability of the fishery resources of the GBR. Conversely, this approach will also facilitate a better appreciation by catchment users and managers of downstream and system-scale implications of their decisions and actions.

Knowledge gaps emerging from this analysis fall into two types, concerning impediments to improved management to sustain coastal fisheries based on existing conceptual models, and scientific knowledge gaps that limit the applicability of existing conceptual models. The primary knowledge gaps fall into six categories:

i. Effects of climate change;
ii. Fishery issues for ecosystem sustainability;
iii. Knowledge limitations in fish ecology;
iv. Understanding of ecosystem processes reflected in food web structure and function
v. Understanding the importance of habitats and threats to habitats for improved habitat management; and
vi. Data limitations impeding better information integration.

Categories ii, iv, v and vi are considered to be high priority issues for the Tully-Murray system. In addressing these issues, additional knowledge gained on fish ecology will have broader relevance to major fisheries locations elsewhere.

Recommendations

(i) Develop a conceptual model of ecological production for the Tully-Murray marine catchment basin that identifies indicators of ecosystem health pertinent to fish production for monitoring responses to catchment change. Such a model will be critical to facilitate effective participation by upstream and downstream stakeholders in priority setting within the catchment.

(ii) Develop a quantitative model of the responses of aquatic organisms to changes in habitat availability and water quality, based on Recommendation (i), to predict risks and trade-offs for aquatic resources and fisheries associated with catchment management scenarios.

Important knowledge gaps to support conceptual and predictive model development are:

(iii) Quantify how coastal food webs that support fisheries vary spatially within the Tully-Murray marine catchment basin between marine, estuarine, freshwater and wetland habitats, and over time between wet and dry seasons. This recommendation includes the food requirements for fish production and the implications of changing stoichiometry for fish nutrition, as well as determining how these processes are influenced by catchment change.

(iv) Develop innovative, cost-effective technology for monitoring responses of fish populations to catchment change at the marine catchment basin scale within the Tully-Murray system.

(v) Quantify the contribution of wetlands to fish production at the Tully-Murray marine catchment basin scale to identify potential large-scale benefits of wetland rehabilitation.

(vi) Identify the importance of habitat diversity and connectivity for fish production at the marine catchment basin scale, with respect to effects of catchment change on aquatic habitats and connectivity.

(vii) Identify the processes influencing and controlling recruitment of fish to the Tully-Murray marine catchment basin, including the role of nursery habitats within the system, and risks associated with different reproductive strategies.

(viii) Undertake strategic research to quantify effects of catchment impacts and effectiveness of intervention within the Tully-Murray catchment on water quality, habitat availability, fish biodiversity, population dynamics and food web dynamics to support modelling efforts at the marine catchment basin scale.

(ix) Identify the scale-dependence of information from the Tully-Murray system and transferability to other marine catchment basins, and to other regional scales such as the Wet Tropics, and the whole GBR.

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Introduction

The status and trends in estuarine and coastal fishery production in the Great Barrier Reef region of eastern Australia reflect a composite of features common to similar fisheries around the world. Global fisheries production from marine, inland and aquaculture sectors is approximately 125 million tonnes per year (UN Atlas of the Oceans 2005), of which Australia produces just 276,000 tonnes, or 0.2% of the world total (ABARE 2005). Queensland production contributes 33,700 tonnes annually, of which wild capture from the Great Barrier Reef region accounts for approximately 22,000 tonnes, or 8% of the national total (Williams 2002, ABARE 2005). Many of the species caught from the GBR region depend on estuaries or nearby coastal waters for at least part of their life cycle (Robertson and Duke 1990b). In 2003, the value of commercial and recreational fisheries in the GBR was estimated at $359 million (Productivity Commission 2003). In addition to this estimate, freshwater ecosystems draining coastal catchments in the GBR support strong recreational fisheries, with many of these freshwater species also depending on estuaries for part of their life cycle.

Many fish species are held in high esteem by society for their eating qualities, angling opportunities, and conservation values, so that managing targeted species and fishers, and protecting non-target species and their habitats requires an added economic cost that is largely not reflected in estimates of landed catch value. In 2004 DPIF alone spent $44 million across all fishery resource management activities for the State. When contributions from other management agencies and research organisations are included, fisheries-related investments in the GBR region alone may greatly exceed $44 million per year in addition to the value of the landed catch.

Accordingly, although the economic value of fisheries in the GBR region may be small by global standards, fish production, recreational fishing expenditure, and investment in fish conservation measures are significant components of the economy at regional and State levels.

At a global scale, estuaries are the most economically valuable natural ecosystems by area in the world (Costanza et al. 1997), closely followed by floodplain wetlands, seagrass and algal beds, and tidal marshes and mangroves. At US$521 ha^{-1} for estuaries and US$466 ha^{-1} for tidal marshes and mangroves, the value of food production from these ecosystems is more than double the value of coral reefs, their nearest rival. In Australia, Morton (1990) estimated the value of commercial fish alone in Moreton Bay mangroves at $8000 ha^{-1}, an order of magnitude greater than the global estimate. Morton's estimate does not account for the non-commercial species consumed as prey by commercial species, nor does it include crustaceans that also have a significant commercial value. As a result, the values reported here are likely to significantly underestimate the true value of estuarine and associated ecosystems.

Historically, fisheries and related aquatic sciences have tended to focus on either freshwater or marine systems, despite the continuous gradient from freshwater, through estuarine to marine habitats. Accordingly, the interfaces between systems have received less emphasis than is warranted by their ecological and economic importance. However, with the increasing realisation that land-based processes within catchments contribute significantly to ecological processes in rivers, estuaries and coastal environments, there is an increasing need for a systems-scale approach that transcends traditional salinity-based boundaries of fisheries sub-disciplines. This report presents the marine catchment basin concept, as defined by Caddy (2000), as a basis for integrating the different system components that link catchments, river networks, estuaries and coastal ecosystems in the GBR region, in a fisheries context.

Throughout this report, coastal systems refer to aquatic ecosystems including freshwaters, estuaries, and coastal environments that are directly influenced by water and materials that come from coastal catchments. Coastal fisheries include all fishing activities occurring within this loose definition of coastal systems.

The marine boundary of this definition of coastal systems is blurred, since the extent of river plumes varies spatially between rivers, and temporally between high and low flow events. The boundary is further blurred by the varying influence of coastal currents. But the marine extent of catchment basin effects is of low importance for the purposes of this report, since the focus is on the internal interfaces between freshwater and marine habitats rather than the outer boundaries. Furthermore, the ecology of coral reef fishes and their associated fisheries is a long established specialist area of fisheries research, and will not be considered further within this review except where life history stages of reef species inhabit estuaries and coastal waters.

Global fisheries are currently exposed to a number of threats that can be briefly summarised as:

i. alteration of flow regime flushing estuaries and providing habitat connectivity;
ii. changes in transport of sediments, nutrients and other contaminants affecting water quality and primary production in food webs;
iii. land-use changes in agricultural and urbanised catchments;
iv. loss of fish habitats;
v. increased fishing pressure and over-fishing;
vi. prospects for climate change, and changes in sea level.

These categories are not independent, since increasing agricultural or urban development is likely to result in increased water demand and altered river flows, loss of fish habitats through coastal land clearing, and increased contaminant loads entering rivers. If fish stocks decline as a result of these impacts without a commensurate reduction in fishing effort, then the risk of over-fishing increases. As catchment development expands to meet the demands of human population growth, effects on regional and global climates are likely to increase, which will eventually result in altered rainfall and runoff patterns, and further changes in river flow.

Tropical estuarine fisheries worldwide are threatened by overfishing, with most fisheries being either fully exploited or over-exploited, and habitat loss or degradation resulting from human activity (Blaber 2000). These concerns are evident in the inshore fisheries of the Great Barrier Reef region with large increases in fishing effort for some species and on-going habitat degradation in estuarine and inshore habitats (Williams 2002).

Large-scale habitat degradation has been observed through changes in freshwater flows to estuaries and coastal ecosystems (Gillanders and Kingsford 2002). Caddy (2000), in his comparison of marine catchment basin effects with fisheries impacts, recognised several ecological features that are common to both overexploited and nutrient-enriched systems. He hypothesised that more eutrophic systems will have: relatively small sizes of fish and short life spans; short, simple food webs with low mean trophic level or diversity; few large, long-lived benthic organisms; predominance of small pelagic planktivorous species over demersal, piscivorous species, and hypoxic or anoxic conditions close to the bottom of the water column. Given the concerns about inshore fishery trends and nutrient loads entering the GBR lagoon from coastal rivers, Caddy (2000) provides testable hypotheses regarding fishery trends and environmental health of the GBR.

Responses to these threats involve action across a hierarchy of scales ranging from global initiatives to local rehabilitation efforts. Sustaining fishery production at global, regional and local scales in the face of these interacting forces is complex and dynamic. The Great Barrier Reef region and local-scale catchments within the region present a microcosm of the issues facing global fisheries. Conversely, identifying issues and research needs to sustain fisheries at the local and regional scales in the GBR contributes directly to the development of solutions for a global problem of natural resource sustainability. The degree of interaction among these processes means that management of individual threats without due recognition of ecosystem linkages and the scales at which these processes operate, carries a risk of unexpected side effects, and reduces the potential effectiveness of efforts through a piecemeal approach. Consequently, a unified approach is required which captures the scale of ecosystem processes and the linkages between system components so that efforts to manage threats are synergistic and not counterproductive.

Scope of this report

The scope of systems considered here is depicted as a template of the main components of marine catchment basins (Figure 1).

Freshwater reaches above the floodplain (1) transport water, sediments, nutrients and other materials coming off the catchment. In areas modified by urban and rural development, the natural hydrology is often altered with the flow carrying elevated loads of suspended and dissolved materials. These reaches are typically erosional or transport functional process zones within the river system. Physical barriers such as dams and weirs impede upstream and downstream migrations of fish and other organisms. Fishery issues in these reaches are dominated by recreational fisheries, and strong efforts in fish conservation as part of broader river health initiatives. There are no commercial freshwater fisheries in the GBR region, although some species of commercial and recreational importance migrate from the estuary and spend part of their life history in freshwater habitats.

Floodplain freshwater reaches (2) are affected by the same processes as upstream reaches, but the impacts are delivered in different ways. As floodwaters spill over the floodplain and lose their energy, they deposit their sediment load on the floodplain. Accordingly floodplain reaches are typically considered as depositional functional process zones. But where floodplain vegetation has been modified or removed, the modern floodplain may erode and become a source of new sediment to the river. Upstream changes in hydrology may lead to floodplains not being inundated as frequently, or being inundated for shorter periods, with the result that wetlands are not connected as frequently as would normally occur. These changes mean that some fish nursery habitats have disappeared, or have a diminished role, whilst freshwater fish that live in wetlands only and avoid main channel habitats may experience a decline in habitat quality and quantity. A larger number of species that inhabit floodplain reaches and floodplain habitats are important for recreational and commercial fisheries.

As waters become more saline at the head of the estuary (3), species of commercial importance become more abundant. Bi-directional tidal flushing is added to the downstream river flow, making estuarine habitats more complex hydrologically than the riverine reaches upstream. Freshwater flowing into the estuary carries a load of suspended sediment and nutrients that influence biological production in the estuary. Tidal water movement also carries this material into the intertidal zone, which may support seagrass, mangrove or saltmarsh habitats. These habitats provide some degree of protection for estuarine species from larger predators, whilst other species gain significant food resources from different parts of the estuary. Many species of freshwater fish, and marine fish, either migrate to estuaries to spawn, or rely on currents to carry their young to productive estuarine habitats. As these juveniles mature, many leave the estuary to reach their freshwater or marine adult habitats. Large estuaries are accessible to a diverse range of commercial fishing methods, and provide catches ranging from prawns to large predatory fish and sharks, as well as smaller benthic species.

River plumes (4) carry water and suspended and dissolved material from the estuary into the marine environment. Depending on the degree of mixing in the estuary and the amount of freshwater flow, the plume may carry relatively low salinity water some distance offshore, or along the coast. Where coastal waters are protected from wave energy by islands or offshore reefs, they may display conditions very similar to an estuary, with relatively high turbidity, fluctuating salinity, and low wave energy, so that they are functionally similar to estuaries and support the same range of species. Because of the more open habitat, river plumes provide access to large-scale net, trawl and line fisheries. The process by which marine species

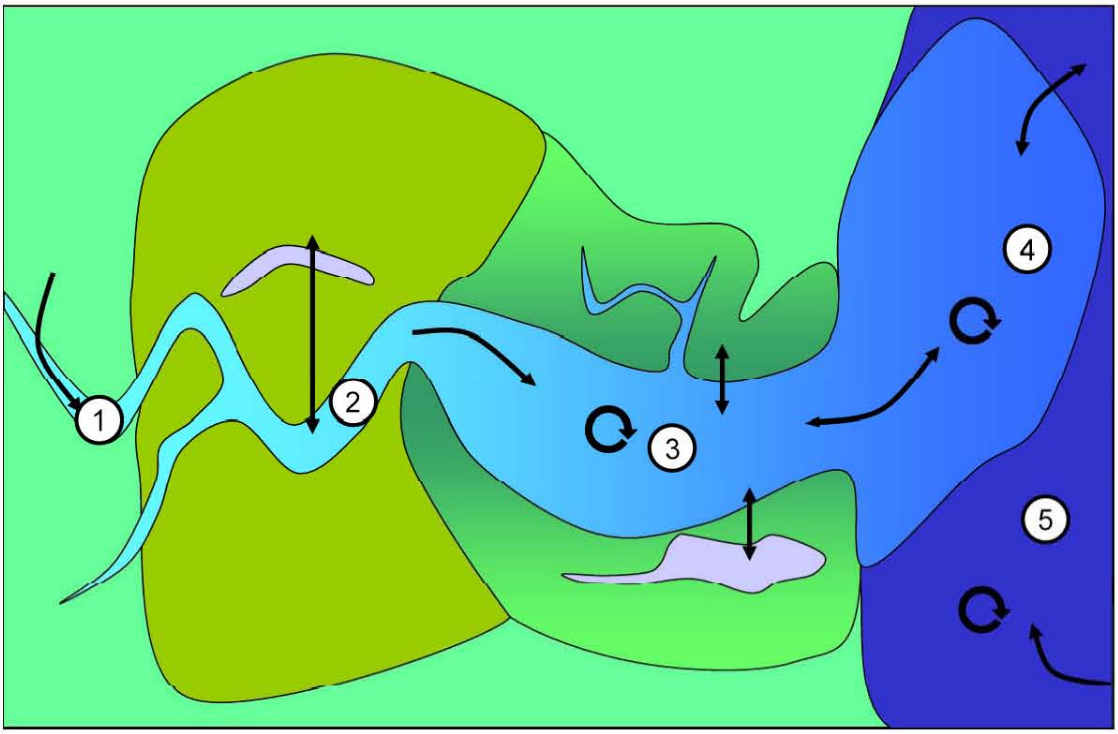

Figure 1. *Scope of this study depicted as major sub-components of the marine catchment basin template. Arrows indicate direction of major material transport within numbered zones. Circular arrows show major zones of material recycling. 1. Montane and slopes river reaches upstream of the lowland floodplain reaches, dominated by allochthonous material inputs and primary production, 2. Lowland reaches characterised by well-developed floodplain with freshwater wetlands, dominated by lateral autochthonous and allochthonus inputs and primary production; 3. Estuarine reaches with salt-tolerant riparian vegetation and brackish wetlands, dominated by allochthonous upstream inputs, tidal autochthonous inputs and autochthonous production ; 4. River plume extending seaward, dominated by catchment inputs and autochthonous production. Depending on flow conditions and tidal currents, imports of marine material may dominate catchment inputs 5. Coastal waters outside the river plume, dominated by autochthonous inputs and primary production.*

make their way into estuaries is not known, but it is likely to involve a combination of active responses to environmental gradients such as depth, salinity, turbidity, wave action, and currents, and passive dispersal.

Coastal waters outside the river plume (5) provide similar physical habitats to those found in the plume, because the timing of tidal currents, prevailing coastal currents, and freshwater flow events mean that the plume may cover different areas at different times. These waters are readily accessible to commercial and recreational fishers, whose skill in locating fish requires an understanding of fish behaviour and the way fish respond to changes in their environment.

This scoping report briefly reviews existing knowledge of the ecological processes that support ecological fish production in tropical estuaries in the Great Barrier Reef region to identify gaps in current understanding that impede implementation of environmental management strategies to sustain regional fisheries. In this context, fish production within aquatic ecosystems is distinct from fisheries production, which refers to a measure of landed catch by the fishing industry. For a fishery to be sustainable over time, fishery production

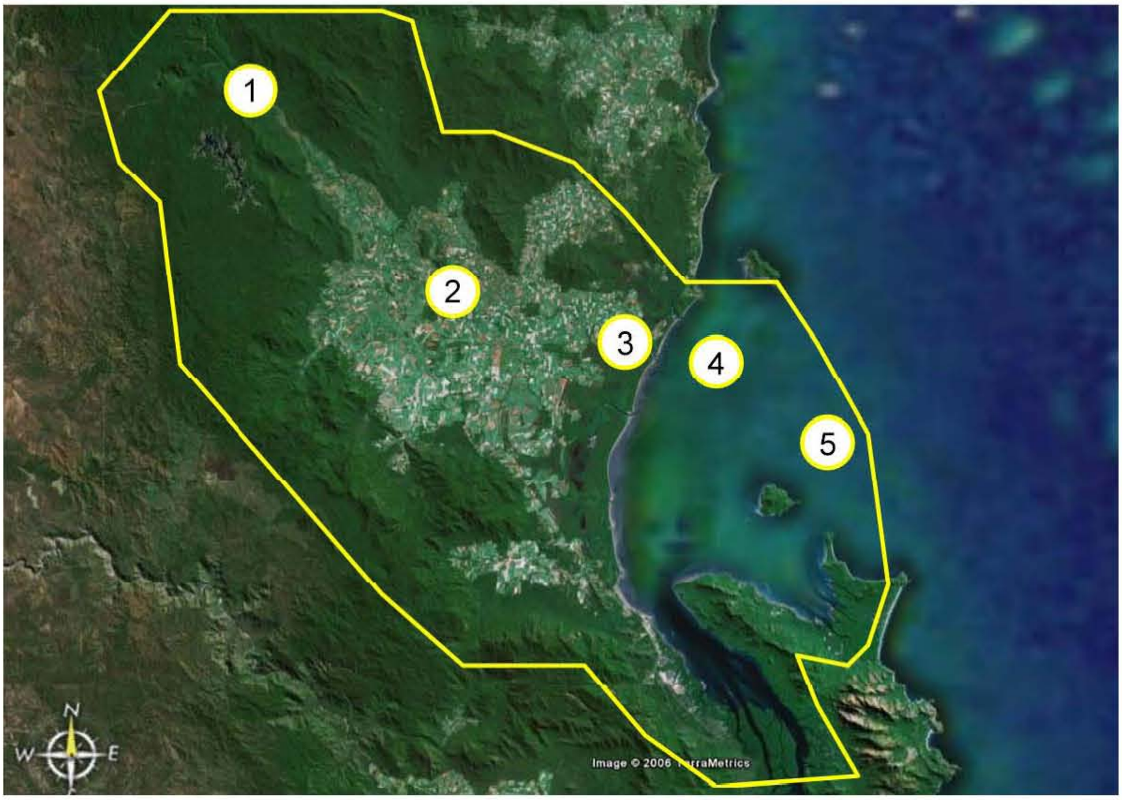

Figure2. *Approximate geographical scope of the Tully-Murray marine catchment basin, with numbered zones corresponding to Figure 1. The southern boundary in Hinchinbrook Channel is somewhat arbitrary depending on the influence of freshwater inflows and tidal dynamics from the channel network on the distribution of material within Rockingham Bay. The outer marine boundary is also arbitrary, and is determined by the bathymetry of Rockingham Bay, and the magnitude of seasonal and episodic high flow events.*

must generally represent only a small proportion of total fish production within the defined system. Accordingly, this report emphasises research needs to sustain fishery resources, and does not consider the more specific research needs of the fishing industry. We then synthesise this information into a hierarchical structure to identify research priorities to promote the sustainability of coastal fisheries in an era of coastal catchment change. To maximise the applicability of our recommendations, we have focussed on generic issues common throughout the GBR, and then refined them for specific application in the Tully-Murray marine catchment basin.