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Integrated coastal zone management research in Australia and China

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Abstract

This paper reviews the current Integrated and Coastal Zone Management (ICZM) research in coastal zone science and policy for Australia and China. It seeks to make a coherent contribution to understanding the Chinese and Australian research and management through a brief description of the similarities and differences in an integrated way. The paper draws together the research needs for the ICZM in both countries with the aim of justifying the research investments needed in the future. Based on this review, we recommend five research programs: Coastal Ocean Observing and Forecasting System and its Socio-economic Impact; Review and Utilization of Space-borne Observing Systems; Risk Management in Coastal Infrastructure; Policy Design for Mitigating Socio-economic Impacts of Climate Change on the Coastal Zone; and Comparative Research on Legal and Regulatory Frameworks related to ICZM in China and Australia.

Keywords

Integrated, coastal, zone, management, research, Australia, China

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INTEGRATED COASTAL ZONE MANAGEMENT RESEARCH IN AUSTRALIA AND CHINA

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Abstract

This paper reviews current research in the coastal zone science and policy work in the Integrated and Coastal Zone Management (ICZM) in Australia and China. It seeks to make a coherent contribution to understanding the Chinese and Australian research and management through a brief description of the similarities and differences in an integrated way. The paper draws together the research needs for ICZM in both countries with the aim of justifying the research investments needed in the future. Based on the review, five research programs are developed for recommendations for future ICZM studies.

1. **Introduction**

The world's oceans and coasts are under extreme pressure as a result of large populations living near the sea, more people migrating to the coasts and the likely impacts of enhanced climate change such as sea-level rise and changed weather patterns (Nicholls et al., 2007). The coastal zones are a focus of human pressures through provision of settlement, food supply, shipping, employment and recreation. As indicated by the Chinese Prime Minister Wen Jiabao in his recent address to the 60th anniversary of Chinese Academy of Science, the over-development of the coastal zones imposes far-reaching challenges on society for a sustainable use of coastal resources (http://www.bulletin.cas.cn/gkml/2010D1Q/dqml/QWL/201002/t20100205_2750169.html). The pressures have led to serious degradation of coastal ecosystems in many countries and there is an urgent need for dramatically improved management regimes to tackle the problems (Liu et al., 2009; Wang et al., 2009). Recent commitments by the Australian Government to invest over $200 million to help secure the Great Barrier Reef from climate change and declining water quality demonstrates this urgent need (http://lwa.gov.au/files/products/innovation/pn30176/reef-rescue-risk-based-investment-improving-reef-w.pdf).

Significant research into the changes in coastal areas and their causes has been undertaken (more discussion in Section 2 and 4), but this research effort has not been fully reflected in coastal zone planning and management activities, thus affecting effectiveness of the coastal zone management (CZM) system. One of the main causes of this problem is that current policy and law cannot provide effective instructions and guidance for the sustainable development of coastal zone areas (e.g. Fan and Cote,

1990). This topic is one of significant current interest of international CZM community.

The use of integrated ocean and coastal zone management (ICZM) in Australia and China continues a global tradition of integrated approaches in natural resource management (e.g. Fan and Cote, 1990) and therefore the potential for learning from comparative analysis is great (Liang, 2009; Wang and Xu, 2010). This paper reviews current research in the ICZM in Australia and China, and draws together the research needs for ICZM in both countries with the aim of justifying the research investments being made and needed in the future. It seeks to make a coherent contribution to understanding the Chinese and Australian research and management through a brief description of the similarities and differences in an integrated way. Both countries expect the integration of human and biophysical sciences will assist in making the flow of science to management a powerful driver of improvement in the sustainability of coastal zones.

The paper is divided into five sections. Section 1 is an introduction; section 2 summarizes coastal zone research both in China and Australia; a review of ICZM and policy work in both countries is provided in section 3. Recommendations for future research in ICZM are presented in section 4; and section 5 concludes the paper.

2. **Current coastal zone research in Australia and China**

Australia and China both have long coastlines and extensive coastal zones. Australia has a mainland area of about 7.7 million km^2. For Australia the coastline length is about 60,000 km (inclusive of the mainland, the islands and mangrove areas) (Short

and Woodroffe, 2009) and an ocean Exclusive Economic Zone (EEZ), inclusive of islands and the Australian Antarctic Territory, of about 16 million km^2 (Commonwealth of Australia, 1998). The coastal zone in Australia is multi-faceted, combining regions with cliffs, beaches and dunes, about 700 estuaries, mangroves (11,500 km^2), seagrass beds (~55,500 km^2), mostly in Queensland and Western Australia), saltmarshes (~13,500 km^2) and coral reefs (~63,300 km^2 surface area and about 400,000 km^2 in total area dominated by reefs). The species richness and diversity increase with latitude for saltmarshes, while the reverse is true for mangrove systems. The tidal range is mainly 0-3 m. but can rise to 9 m in northern Australia (Short and Woodroffe, 2009). In addition, particularly along the east coast of Australia, rivers may have a significant impact on coastal systems through irregular large freshwater and sediment discharges. On a global scale these discharges are small (~10 km^3/yr), but they can have significant local impacts over a period of days or weeks (ABS, 2010), e.g., the Mitchell River has discharges in February and March about 100 times those of July.

China has a mainland area of about 9.6 million km^2 and the EEZ is about 12.6 million km^2. The coastline is about 32,000 km long and spans three climatic zones: the temperate, subtropical and tropical zones (Qin et al., 2008). It therefore holds a huge variety of species in a number of different ecosystems such as tidal flatlands to river-delta ecosystems, including marine natural systems mangroves and coral reefs. Morphologically, the coast varies from bedrock to sandy beaches; some parts are subject to significant erosion. What is particularly notable is that the coastal zone in China includes three major estuaries, i.e., the Yellow River estuary in the north central, the Changjiang River (Yangtze) Estuary in the central, and the Pearl River

Estuary in the south region. The catchment area of the Yellow River and the Yangtze River is about 1.8 and 0.75 million km^2 i, respectively, and in total covers about 25% of the territory of the country (Hui et al., 2009). Characterised by extremely high turbidity, the Yellow River and the Yangtze River discharge 1.1 and 0.48 billion tons of fine-grained sediments annually to the Yellow Sea and East China Sea, respectively, between them accounting for 10% of the world's annual sediment discharge (Milliman and Syvitski, 1992; Yang et al., 2006). This huge sediment load discharge is one of the major factors affecting the balance of sedimentary and ecological environments in the coastal zone of the Bohai Sea, the Yellow Sea and the East China Sea (Zhang, 1999). The Pearl River, which has a drainage area of 0.45 million km^2, is the second largest river in China in terms of discharge (average annual discharge of ~10,524 m^3s^{-1}) and finally empties into the South China Sea (Zhang et al., 2010).

While Australia and China have vastly different populations with 1.3 billion in China and only 22.3 million in Australia (ABS, 2010), both have the majority of people living near the coast, and there is a continuing migration of people towards the coast. In Australia more than 83% of people live within 50 km of the coast (ABS, 2005), while in China, the estimate is that 60% of people live in the 12 coastal provinces (Hindrichsen, 1998). This leads to increasing pressures being put on the coastal zones and the requirement for research to better understand these complex zones and improve their management.

In Australia, a wide range of coastal zone issues have been identified (Commonwealth of Australia, 1998; DEH, 2006; Morrison, 2001). These include coastal and

international shipping (with problems of exotic species introduction and transfer through ballast water), overfishing of both fin fish and invertebrates, recreational fishing (over 3.5 million people fish in Australia), urbanisation and the impacts on surrounding coastal areas (about 88% of Australians live in or close to the 9 major coastal population centres), terrestrial runoff from poor land use practices (Packett, et al., 2009), tourism development, sediment contamination (and the related long-term release of contaminants into the water column – see, e.g., He and Morrison, 2001), eutrophication and coastal pollution from poor waste management. Mining (including sand mining) and offshore oil and gas exploration and onshore processing facilities are policy and resource issues. Significant efforts have been made in developing a system of coastal protected areas, and over 270 protected areas have been established covering an area of 3. 7 million km^2. In addition, there is major concern about the likely impacts of climate change, especially rising sea levels and the potential impacts of more intense storms.

Australia does not have a comprehensive or consistent approach to assessing changes in coastal ecosystems (DEH, 2006). In addition, coastal biodiversity assessment is limited so that some species may become extinct before they have been fully catalogued (Ponder at al, 2002). The limited information available indicates that many species are in decline, while others (e.g., mangroves) show mixed trends (increases in some areas, declines in others).

The issues mentioned above are also important in China. Because of rapid economic development and urbanization, the threat of pollution and ecosystem degradation has increased in the coastal zone. Pollution, including eutrophication, heavy metals and

organic pollutants, has been found to be very common in the Chinese coastal zone. As a result, marine biodiversity conservation efforts are facing great pressure. Eutrophication, together with other factors such as mariculture, overfishing, and climate change, has resulted in the frequent occurrence of red tides and green tides and jellyfish blooms with significant economic loss (Liu et al., 2009; Dong et al., 2010; Wang et al., 2009). The threat of sea-level rise is also a very important problem for vast coastal areas especially the river deltas and some large cities.

Research on sustainable development of coastal zone has drawn increasing attention (Yu et al., 2010). The Integrated Coastal Zone Management has been used as a governance mechanism for promoting sustainable development in Shanghai, Xiamen and Quanzhou (Chua et al., 1997; Chen et al., 2009, Shi et al., 2001). For example, since 1994, in collaboration with Global Environment Facility, United Nations Development Program and PEMSEA, Xiamen has developed and implemented an Integrated Coastal Management Program. An annual budget of US$ 6 million has been set aside to help upper cities to prevent pollutants from discharging to Jiulong River. The local government established a scientific management mechanism to supervise, monitor and control the sources of the pollutants entering the river system. In addition, public campaigns in pollution prevention have also been conducted (e.g. World Ocean Week) to raise public awareness and promote the effective utilization of marine resources.

Coastal research in Australia is currently focussing on all of the above issues plus an ongoing scientific effort to better understand the ecology, biological diversity and

transport and transformation processes occurring in the coastal zone. Specific issues that are being researched include (Morton et al, 2009):

- Response to climate change – numerous agencies – see below on reefs;
- Improving coastal water quality;
- Ecology of key species;
- Aquaculture development with environmental controls;
- Identification and protection of threatened species;
- Ecotoxicology involving metals and organic chemicals;
- Ecosystem processes in the coastal zone – connections and transfers – mangroves, seagrasses, saltmarshes;
- Improved linkages between research and planning/management;
- Database development and management for ICZM.

Coral reef ecology and management is a major coastal zone research area covering both applied and strategic studies in Australia. The ecological and tourism value of protecting the reef resources is such that substantial funding is directed into this work and numerous agencies are involved. Some of the key activities and agencies include the Great Barrier Reef Marine Park Authority where research is looking at reef vulnerability and climate change response assessments, including increasing temperature and acidification issues (http://www.gbrmpa.gov.au/, accessed on 12 June 2010). The Australian Institute of Marine Science (AIMS) has an extensive program investigating the response of corals to higher sea temperatures and capacity of corals to adapt, including short term and long term management options (http://www.aims.gov.au, accessed 15 June 2010). GeoScience Australia is involved

in a marine survey of northern Australia, particularly Northern Territory and Gulf of Carpentaria and the bathymetry of the Great Barrier Reef (http://www.ga.gov.au, accessed 15 June, 2010). The ARC Centre of Excellence for Coral Reef Studies (www.coralcoe.org.au, accessed 12 June 2010) involving James Cook University, the Australian National University, the University of Queensland, the University of Western Australia, several government agencies and the tourism industry has a wide range of research programs on reef ecology and management. These include studies on evolutionary and environmental change and social issues in reef management. Other universities, e.g., Sydney, Wollongong, New South Wales, are undertaking research on multiple issues relating to climate change impacts on reefs - ecology, geomorphology, fisheries, transport, resource use. In addition, several state government agencies have research activities focusing mainly on the management implications of changes to reefs resulting from human impacts.

State governments in Australia are also undertaking coastal zone policy and planning development with associated research activities. In some states (e.g., New South Wales and Victoria) some of this policy and planning work has been devolved to local government or broader based catchment management authorities, with activities being undertaken in consultation with local communities. Important issues being considered include sea level rise impacts, fisheries management, tourism development, sustaining agriculture and acid sulfate soils.

The scope of current coastal research in China largely overlaps that listed above for Australia. Agencies involved include the Chinese Academy of Science (CAS), the State Oceanic Administration (SOA), and universities. However, the Yantai Institute

of Coastal Zone Research (YIC), a research body affiliated to the CAS, is currently the only organization that specializes on coastal zone research in China. It was established in June 2006 jointly by the CAS, the Shandong Provincial Government, and the Yantai Municipal Government in the Shandong Peninsula. YIC has established long-term international cooperation with many academic institutions and organizations over the world, signed bilateral agreements on scientific and technological cooperation with academic units including GKSS-IFK Germany), IOW (Germany), Kiel-CoreLab (Germany), CNR-ISMAR (Italy), IMB-FEBRAS (Russia), PML(United Kingdom), CUHK (Hong Kong), and HKUST-AMCE (Hong Kong). Many regional level, national level, and even international founded projects are being carried out, e.g., algae and diatoms as environmental indicators to reflect long-term changes related to different human activities in the coastal Yellow Sea, the biogeochemistry of wetlands and ecological restoration, coastal marine ecotoxicology, coastal water pollution control, coastal sustainable development studies, developing chemical sensors and biosensors for on-site monitoring of pollutants in seawater, high-value use of biological resources.

3. **ICZM policy work in Australia and China**

Australia's marine area accounts for more than 70 % of its territory and carries jurisdictional responsibility for over 5% of the Earth's surface and nearly 4% of the ocean areas. It is a source of national pride and international attention and its coastal assets, along its extensive coastline, are both highly valued and under development pressure. Its ocean borders have deeply influenced its security and international relationships (Evans and Grant, 1991) and it was the first country to develop a comprehensive national plan to protect and manage the oceans (Bateman, 1999).

Under the United Nations Convention on the Law of the Sea, Australia has rights and responsibilities over - more than twice the area of the Australian continent (Australian Government, 2008) and this makes it the third largest ocean management area of any nation on earth (Bateman and Bergin, 2009). It continues to pursue National Representative System of Marine Protected Areas (NRSMPA) and Regional Marine Plans to apply a process of ecosystem-based allocation of resource access and use across and within sectors.

Foster et al. (2005) say the two principal reasons for developing Australia's Ocean Policy was to assert its sovereign rights over its exclusive economic zone and to ensure the ecologically sustainable development (ESD) of the Nation's oceans resources both for wealth creation and environmental protection.

These international institutional arrangements affect ICZM in Australia (Fearon et al., 2006). Ocean and coastal management and policy floats between commonwealth, state, regional and local government responsibilities in a complex mix of legislation, plans and policies. Bateman and Bergin (2009) claimed that up to 21 agencies are responsible for some aspect of oceans management and maritime security and many more are involved in coastal management. The Australian Government legislation and inter-governmental agreements regarding oceans have been described as "fragmented and complex" because it developed from combining legislation, international treaties and other related instruments (Department of the Environment Water Heritage and the Arts, 2009). That results in poorly co-ordinated research investment and policy development.

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Australia's track record in integrated oceans management has been largely about conservation and securing resources (Foster and Haward, 2003; Vince, 2006; Bateman and Bergin, 2009). It has been suggested that the fisheries research management model works well and achieves both fishing industry and government goals (FRDC 2007; Productivity Commission 2010). However, Wescott's (2000) review of the development of Australia's Ocean Policy captures the disagreement that existed on the use of an ecosystem-based management approach combined with an integrated regional planning and management system. Commercial development industries believing reform was needed while other sectors believed that explicitly integrated regional planning and management institutions with enforcement capabilities was needed.

These kinds of conflicts between sectoral interests provide an insight into whether integration is being practiced (Alder and Ward, 1999) and a lack of transparent management or new conceptual models for trade-offs in resource allocation would indicate poor integration. So far, non-legislative cooperative approaches have been used and the results have been either conservation exclusion (Australian Marine Reserves) or development (WA coastal port development). Australia has been fortunate in having an existing ESD framework and scientific foundation, few international borders and bipartisan political support for the Australian Oceans Policy. The Australian Government has also deliberately nurtured a constituency for an integrated oceans policy through the Marine and Coastal Community Network (MCCN) which is possibly, according to Wescott (2000), the most important innovation Australia can provide to the global ocean policy development community.

The Framework for a National Cooperative Approach to Integrated Coastal Zone Management (Commonwealth of Australia, 2006) followed decades of discussion about institutional arrangements for ICZM (Lazarow et al., 2006) and Dovers (2005) used his experience across natural resource management to suggest the key challenges for institutional development were:

- allowing the integration of environment, social and economic policy;
- coordinating policy development, information sharing and planning across jurisdictions;
- persistently evolving institutional and policy approaches over time;
- having timely, integrated, robust and accessible information to guide the policy community,
- and the institutions and human capacity to create and distribute it;
- sustaining participation by civil society and industry in higher-order policy formulation and evaluation; and
- integration of coastal management with other key policy sectors.

Coastcare was one of the results of the Australian Government's Resource Assessment Commission's (1993) recommendations following its inquiry into the management and use of the resources of Australia's coastal zone and sought involvement from all governments, community and industry groups with responsibility for and interests in the management of coastal zone resources. Harvey (2006) observes Coastcare's profile fell after 2002 as the importance of coastal management issues declined.

Australia's Ocean Policy (1998) set in place the framework for integrated and ecosystem based planning and management for all of Australia's marine jurisdictions – it has been mainly an environmental policy. Bateman and Bergin (2009) claim the policy was more idealistic than realistic, was poorly resourced and silo-bound, failing to get state-level or industry support; the National Oceans Office lacked support and Australia lacked capacity to collect, analyse and communicate the biophysical, social and economic data required.

This follows a broader national assessment by the Resource Assessment Commission (1993) into the Australian Coast, and the National Land and Water Resource Audits (2002) into describing the state of the coastal environment. These gathered information that OzCoasts (http://www.ozcoasts.org.au) makes available along with community capacity building information. This provides support for informed decisions by policy-makers, business and industry, resource managers and the community.

The National Land and Water Resources Audit (2002) developed a framework for consistent collection and collation of natural resource data across Australia. Its coastal indicators were developed and applied as a part of the National NRM Monitoring and Evaluation Framework (NM&EF). This was remarkably successful – integrating through the National Coordination Committee was the Intergovernmental Coastal Advisory Group (ICAG) that enabled the Australian and state governments to reach national agreement on a set of resource condition indicators that built on previous research and extension work by the Cooperative Research Centre for Coastal Zone, Estuary and Waterway Management (Coastal CRC). These nationally agreed

Resource Condition Indicators were successfully applied and were supported by a series of technical guidelines, reports and an OzEstuaries database (http://www.ozcoasts.org.au/) provides a legacy and information about Australian estuaries and coastal waterways. This information continues to help understanding of coastal environments, the complex processes that occur in them, the potential environmental health issues and how to recognise and deal with these issues. Crucially, the methods and data are credible, agreed and publically available.

Australia's mitigation and adaptation to climate change and its effects on the coast is the purpose of a first pass national assessment of *Climate Change Risks to Australia's Coast* (DCC 2009). It is one of the key actions identified in the National Climate Change Adaptation Framework endorsed by the Council of Australian Governments (COAG) in 2007.

Offshore areas provide 74 per cent of Australia's natural gas production and over 90% of Australia's liquid hydrocarbon and its shore-based processing is constrained by environmental and indigenous land rights concerns (OPSAG, 2009). Further development, OPSAG (2009: 9) suggests "development delays and uncertainties in decision making are caused by the lack of environmental information to support regulatory processes". Australia's large, and recently expanded, exclusive economic zone is prospective for energy, minerals, bio-prospecting and other emerging uses such as desalination plants for potable water, tidal and wind energy generation and biosequestration.

Australia is in a strong position (OPSAG, 2009) to ensure that fisheries and marine aquaculture are appropriately managed to maintain profitability and long-term sustainability and is achieving high level performance globally on the global stage (Pitcher et al 2009). Alongside clear regulatory guidelines Australia has taken an ecosystem rather than a stock management framework (Scandol et al., 2005). However there remains insufficient knowledge of ecosystem processes and resilience and little public information about the economic and social drivers of the industry.

China's total maritime area is 4.73 million km^2. The long involvement of China's in the United Nations Convention on the Law of the Sea and China's development of domestic legislation resulted in the Law on the Exclusive Economic Zone and the Continental Shelf being adopted in 1998 (Zou, 2001). There is more to be done in policy terms (Zou, 2001).

China's fishing interests extend globally (Xue, 2006) and China flagged ships take 17% of the world wildfish catch and this is likely to increase alongside pressure for compliance to the FAO's Code of Conduct for Responsible Fisheries (Pitcher et al., 2009). The integrated management of global fishing is part of the effort to improve oceans governance that goes beyond areas of national jurisdiction particularly as it relates to the preservation of the marine environment and marine biological diversity (Freestone et al. 2007).

In China, there are only a few published works that discuss the oceans integrated resources management at a national scale. Those works mainly focus on some specific resource management, such as fishery management or environmental management.

These studies only provide single measures of ocean governance. However, without providing a more integrated oceans management framework and developing some explicit mechanisms, it is difficult for the communities and governments to increase their capacity for effective managing or realizing the sustainable development of resources.

Discussion

Coastal zone management, like climate change, is not a discrete problem to be solved. It is unlikely there will be consensus in Australia about priorities and governance. Instead views of nature, judgments about scientific analysis, perceptions of risk and what is at risk (growth, biodiversity, lives) and whether tradeoffs are ethically, politically or economically justifiable will be resolved in nested mixtures or polycentric formal and informal governance (Roe, 2009). The dynamic challenges a "fix" mentality and requires a "process" mentality.

ICZM brings together the physical world and societies cultural imagination yet it does so at the risk or expense of cultural meanings that are rich with ideological assumptions, contradictions and different perspectives. It is also dynamic with costly changes to readjust decisions. No single discipline will provide answers to all the unasked questions of the future. It is true that R&D without social industry and social science participation and engagement is highly ineffective, often inappropriate and a poor investment. Opening up the definition of the problems to the other ways of knowing (i.e. indigenous) and opening the tent of experts (i.e. locals) is critical and the missing part of not so "integrated" fixes (Campbell and Schofield, 2006). Thus we

argue here that shifting to integrated management of coastal zone should occur sooner rather than later.

Kay and Lester (1997) argued that ICZM in Australia is so intertwined with the Australian 'psyche' that improving coastal management was really one of improving government and governance itself. This still applies.

The discord in ICZM reflects the diverse, creative and conflictual nature of humans. Disagreements here are likely to relate to deep and different histories, risk appetites, technology and well-being, ethical, ideological and political beliefs, interpretations of the past and visions for the future in the sense Hulme (2009) describes for climate change. Integration in coastal policy needs to be done with a different paradigm - that of "How does the idea of ICZM alter the way we arrive at and achieve our personal aspirations and our collective social goals?" rather than how do we "fix and solve" problems.

This policy and management context mirrors the larger change to post-normal science (Funtowicz and Ravetz 1993) where the facts are uncertain, values in contested dispute, the stakes are high and decisions urgent while also acknowledging that the knowledge we have is contingent, uncertain, values are hidden, trust is highly erodible and the local and indigenous knowledges are important.

ICZM needs to cope with understanding what science can and cannot do. It needs to manage uncertainty – ensure it is recognized, managed and communicated. Lack of certainty is the human condition yet uncertainty is a threat to collective action; it has

been called the disease that knowledge and scientific research must cure, yet policy is required to do more than heal the disease it is expected to prevent disease through wisdom.

The relationship between policy, management and science needs to be made clear. In common with other natural resource management, coastal zone management struggles to find the new institutions and processes that are useful. It is likely coastal zone policy and management will use science to deliver government determined goals, to tell truth to power, inform future policy and be involved in the co-production of applied knowledge. Experience suggests that a mixture of these uses is best.

Leading thinkers in Australian natural resource management policy (Brunckhorst and Bridgewater, 1995; Brunckhorst, 2004; Dovers, 2005; Allison and Hobbs, 2006) suggest that new ways of thinking are needed – ways that support adaptive governance and apply Holling's (1978) advice to reduce the exclusive use of centralised experts. It also seems prudent to involve other ways of knowing – such as religion and belief structures that appear far from the scientific approach.

4. Recommendations for future research in ICZM

The anticipated growth of China and Australia's coastal population will make integrated coastal zone management an even higher priority than it is today, as recognised in Australia by the 2006 Framework for a National Cooperative Approach to Integrated Coastal Zone Management (Natural Resource Management Ministerial Council). In China, the State Oceanic Administration issued the China Marine Development Report 2010 that seeks to promote China's marine development strategy

for the next ten years. The Report is arranged in five sections: macro-environment; marine laws, sea rights and benefits; marine economy, science and technology; marine ecological protection and resource development; and marine policies and management. Against these backdrops, recent ICZM workshops held in Australia and China (Wang and Xu, 2010) have identified a future ICZM research framework for next three to five years in the following areas.

Coastal ocean observing and forecasting system (COOFS) and its socio-economic impact

The Objectives of this research are to examine the development and status of COOFS in China and Australia; to explore the relationship between COOFS and potential benefit- related sectors; to evaluate the potential economic benefits that different users and public agencies can gain from COOFS information and related services. The research should focus on a couple of key benefit related sectors, e.g., maritime transport and commercial fishing. A cost-benefit analysis of COOFS will be conducted in collaboration with economists

The research will develop regional COOFS facilities in the Bohai and Yellow Seas and the Australian eastern seaboard based on larger scale observing and forecasting systems that already exist in China and Australia such as IMOS and BlueLink. The extent to which COOFS has been or will be used by coastal managers, planners and policy makers will be explored. To evaluate the potential economic benefits from COOFS, the constant percentage increase evaluation method will be the main evaluation method. But the specific percentage such as 1% increase evaluation

method may underestimate the economic benefits from the advanced ocean observing and forecasting system. Therefore more advanced model will be developed.

The deliverables of this research include (1) a regional COOFS for China and Australia; (2) a socio-economic benefits evaluation of COOFS in China and Australia that can provide economic evidences as how COOFS information could benefit potential beneficiaries; and assist in persuading the potential beneficiaries to use the products of COOFS; (3) a cost-benefits analysis report for COOFS in China and Australia; and (4) a set of management recommendations aimed at a more scientifically rigorous approach to ICZM using these COOFS facilities.

Review and utilization of space-borne observing systems

This task will examine and assess to which extent the routine measurements from spaceborne sensors are combined and used together with model-based forecasting systems. The outcome shall form the basis of a series of recommendations concerning bridging the gap of Chinese/Australian capacity for utilizing spaceborne measurements in the framework of an operational ocean forecasting system.

The research work includes: collect the information on the satellites which will be launched until 2010 in both China and Australia for coastal ocean observation (SST, wind, waves, sea ice, ocean colour and surface current); investigate if the existing algorithms of retrieving the ocean environmental parameters match the goals of ocean applications in the China Seas and Australia waters; and recommendations for future Chinese/Australian satellite programs.

This research program will deliver: (1) an inventory report of the existing spaceborne observing systems in China and Australia; (2) an inventory and assessment report of the Chinese/Australian capacity for utilizing satellite measurements for an operational coastal ocean forecasting system.

Risk management in coastal infrastructure

This program addresses engineering issues in the management of coastal infrastructure. The time scale is current to tens of years into the future, and the assumption is that infrastructure either exists or will exist in some form within the time scale being considered. The broad objectives are: to identify special loadings and management issues with coastal infrastructure; to develop risk management models; and to investigate effect of climate change and thus develop risk mitigation plan.

The research includes an evaluation of the current management practices; a structural health monitoring; extreme event analysis; probability modeling (collaboration with remote sensing); consequence analysis (collaboration with economists); the effect of climate change on the probability models (collaboration with oceanographer and/or climate specialist); and risk mitigation (engineering approach)

This research will deliver the following outcomes: (1) a risk classification and zoning; (2) disaster prevention criteria; (3) a scientific management framework; and (4) technology transfer to managers.

Policy design for mitigating socio-economic impacts of climate change on coastal zone

This task focuses on planning policy formulation to deal with the major socio-economic impacts of climate change on the coast. These appear to be driven by (1) climate-driven sea level rise, and (2) changes in storm frequency and intensity. The former is already the subject of numerous studies but this task looks at planning policies to mitigate the socio-economic impact of these drivers operating jointly

The research will review work already underway to assess the possible future impacts of sea level rise and a possible increase in storm frequency and intensity. This will provide some indication of the most vulnerable types of infrastructure. Using case studies, the research work will examine the policies which will be necessary to mitigate the impacts on existing infrastructure and the policies necessary to ensure future development is not vulnerable. It intends to pursue a current research direction which aims to provide better tools for the assessment of possible impacts of climate change induced sea level rise on coastal lands. Currently, the research is in progress on testing models on the known history of sea level rise in different coastal environments and developing a conceptual model to predict the social impacts of this phenomenon. Current field sites are in muddy coasts in Indonesia and Australia and sandy coasts in southeast Australia.

The deliverables of this program are: a review of sea level rise projections and storm frequency and intensity, and the types of coastal infrastructure at risk; presentation of the case studies; and a review of planning policy directions focussed on mitigation of the forecast rise in sea level and storm frequency on the case study examples. If the

case studies are chosen carefully, this should provide a template for future planning policy in the coastal zones of both China and Australia.

Comparative research on legal and regulatory frameworks related to ICZM in China and Australia

The objectives of this research are (1) to analyse the similarities and differences of legal and governance frameworks related to ICZM and maritime security of the two countries and provide policy recommendations in relation to these frameworks; (2) to identify what lessons Australia and China can learn from each other's experience.

The research will focus on a comprehensive assessment and analysis of legal and governance framework related to ICZM and maritime security of the two countries; a comparison of the similarities and differences of legal and governance framework related to ICZM and maritime security in the two countries; and facilitation of joint collaborative research in international law and environmental law related ICZM.

The following specific issues will also be addressed:

1. Management of environmental impact – review of environmental impact assessment processes;
2. Planning and development in the coastal zone;
3. The opportunities and constraints of local level decision-making in both countries;
4. Reconciling conflicts with stakeholders;
5. Employment of economic instruments in achieving legal and policy objectives;
6. Domestic policy-making process in China and Australia in the area of maritime

security;

7. Management of environmental impacts associated with energy exploration and exploitation (oil and gas) and off-shore renewable energy generation, shipping, fishing and pollution (both land based sources and vessel source); and
8. Australian and Chinese approaches to international law, Antarctica and the Southern Ocean.

At the completion of this research, the following outcomes will be achieved: (1) identification of the areas where the two countries can learn from each other about ICZM; and (2) provision of policy recommendations in relation to the ICZM legal and governance frameworks.

5. Conclusions

China and Australia have both recognized that increasing populations and human activities have dramatically impacted their coastal zones. Research is progressing in both countries to better understand the factors contributing to and controlling the changes occurring and to provide high-quality research outputs that will assist decision-makers in minimizing further impacts and restoring already damaged areas.

Coastal research management in Australia and China will probably need a hybrid model perhaps a form of polycentric governance (Folkeet al., 2005; Ostrom, 2010) that uses a mixture of policy styles, normative principles and ways of viewing life and the world. Although scientific evidence will be important, the adaptive management and political situation mean that its interaction with other disciplines will be essential for informing decisions made in integrated coastal zone management.

Science may solve mysteries of coastal processes yet it cannot help discover the meaning of coastal change or the purpose of ICZM. There is a need to set boundaries of dangerous coastal change at a large scale, establish a risk and information market, empower bottom-up innovation, reconsider adversarial and shortage models of management and seek abundance and collaborative models. The wicked problems as defined by Kenchington and Crawford (1993) of integrated coastal zone management do not yield to one dimensional goal setting. Five research themes are therefore recommended for future studies to address key issues of ICZM in coastal oceanography, coastal engineering, remote sensing, marine policy and law, climate change and socio-economics.

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