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Applicability of market-based instruments for safeguarding water quality in coastal waterways: Case study for Darwin Harbour, Australia

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SUMMARY

Water pollution of coastal waterways is a complex problem due to the cocktail of pollutants and multiplicity of polluters involved and pollution characteristics. Pollution control therefore requires a combination of policy instruments. This paper examines the applicability of market-based instruments to achieve effective and efficient water quality management in Darwin Harbour, Northern Territory, Australia. Potential applicability of instruments is examined in the context of biophysical and economic pollution characteristics, and experience with instruments elsewhere. The paper concludes that there is potential for inclusion of market-based instruments as part of an instrument mix to safeguard water quality in Darwin Harbour. It recommends, in particular, expanding the existing licencing system to include quantitative pollution limits for all significant point polluters; comprehensive and independent pollution monitoring across Darwin Harbour; public disclosure of water quality and emissions data; positive incentives for landholders in the Darwin Harbour catchment to improve land management practices; a stormwater offset program for greenfield urban developments; adoption of performance bonds for developments and operations which pose a substantial risk to water quality, including port expansion and dredging; and detailed consideration of a bubble licensing scheme for nutrient pollution. The paper offers an analytical framework for policy makers and resource managers tasked with water quality management in coastal waterways elsewhere in Australia and globally, and helps to scan for MBIs suitable in any given environmental management situation.

1. Introduction

Water pollution has become a major public concern in many parts of the world (Schwarzenbach et al., 2010), causing human health issues and decline of aquatic biodiversity in many places (Vörösmarty et al., 2010). Many coastal and inshore waterways receive substantial amounts of material from adjacent developed catchments, which have been shown to affect the ecological integrity of inshore ecosystems and adjacent coral reefs (Schaffelke et al., 2012).

Darwin Harbour, located in the Northern Territory (NT) of Australia, accommodates a major shipping port and has important recreational use values for the resident population of approximately 120,000 people, as well as aesthetic and biodiversity values (DHAC, 2010). In tourism brochures, the Harbour is being touted as a 'pristine' waterway and indeed, whole-of-harbour water quality is good. However, past urban, industrial and agricultural development in the catchment area have caused significant anthropogenic impacts on water quality at the local scale with pollution hot-spots emerging (McKinnon et al., 2006; Padovan, 2001; Wolanski and Ducrotoy, 2014). Darwin Harbour is now experiencing a phase of rapid port expansion, industrialisation and urban development. The situation is symptomatic of the economic development trajectory of many coastal waterways with port facilities in northern Australia and driven predominantly by the rapid expansion of the oil, gas and mining industries (Allen et al., 2012; Cagnazzi et al., 2013; Grech et al., 2013). Coastal waterways in wet tropical regions in eastern Australia are already showing rapid increases in pollutant loads (Tsatsaros et al., 2013).

A water quality protection plan for the Darwin Harbour catchment is under development to ensure that 'community values for waterways are protected' (Drewry et al., 2009). Safeguarding water quality by controlling water pollution requires a carefully considered planning and policy approach, which efficiently integrates both point and non-point pollution (Shortle and Horan, 2013). According to Perry and Vanderklein (1996), effective water quality planning and policy entails three elements namely, water quality goals, an understanding of the current resource condition and its potential to deliver desired ecosystem services, and the appropriate physical and institutional mechanisms to accomplish the goals. To find

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effective and efficient solutions to water pollution problems, instruments need to consider the pollution impact and be tailored to the pollution characteristics (Sterner, 2003). A clear diagnostic understanding of environmental problems within their social-ecological systems context is therefore a necessary condition of effective policy design (Cox, 2011), meaning a sound understanding of the biophysical dimensions as well as drivers—social, economic, technical and other—that directly or indirectly cause pollution.

This paper contributes to the understanding of the role that market-based instruments (MBIs) can play in coastal water quality management. MBIs provide an alternative to traditional command-and-control approaches. The paper provides a synthesis of empirical and theoretical evidence about different types of MBIs in the context of coastal water quality protection. It develops and implements an analytical framework for the systematic consideration of MBIs in a case study context, which is transferable to applications elsewhere in Australia or globally. Section 2 conceptualises water pollution as an economic problem and provides a summary analysis of the water pollution problem in Darwin Harbour to set the relevant biophysical parameters. Section 3 provides a literature review of MBI theory and offers pertinent examples of application. Section 4 discusses the potential of MBIs in the Darwin Harbour context. Section 5 offers concluding comments and reflects on the broader relevance of the findings.

2. Water pollution: concepts and situation in Darwin Harbour

2.1. Conceptualisation of water pollution

Water pollution can be defined as damage to the ecosystem services provided by the aquatic environment caused by the disposal of waste from production and consumption activities into waterways (William, 1982). Two types of pollution are differentiated on the basis of identifiability of individual polluters and measurability of pollution: point source and diffuse-source pollution.

'Point source pollution' refers to pollutant discharge into a receiving water body at an identifiable single-point location or identifiable multiple-point locations (Novotny, 2003). While there are differences between legal and operational definitions, point source pollution generally includes municipal and industrial wastewater effluent, runoff and leakage from solid waste disposal sites and concentrated animal feeding and raising operations, runoff from industrial and construction sites, runoff and drainage water from active mines and from oil and gas fields, stormwater and sewer outfalls from urban centres, sewer overflows and bypasses, other sources such as discharges from vessels, damaged storage tanks and storage piles of chemicals, and dredging of port waterways.

Non-point source pollution—also called diffuse pollution—is, by definition, pollution other than point source as the entry point into the waterway is not (easily) traceable (Novotny, 2003). Diffuse source pollution includes return flow from irrigated agriculture and horticulture, runoff from agricultural land (including horticultural and pastoral) and roads, urban runoff from small communities with storm sewers and from unsewered settlement areas, outflows and overflows of septic tanks, wet and dry atmospheric deposition over a water surface, and activities on land that generate wastes and contaminants such as wetland drainage, land development other than construction, and military training, manoeuvres and shooting ranges; and mass outdoor recreation and gatherings.

2.2. Overview of Darwin Harbour

Darwin Harbour is an estuary located in the wet–dry tropics of northern Australia (Padovan, 2001; Fig. 1), located at latitude 12°28′S, longitude 130°50′E, on the southern shore of the Beagle Gulf in the Timor Sea. It encompasses approximately 1000 km^2 of open water. It harbours a major port, which had 5500 vessel calls in 2009/10 and transferred 4.5 million tonnes of goods in that same year (DPC, 2013). As a coastal waterway in direct proximity to the Northern Territory's major population centres Darwin and Palmerston, it provides a range of ecosystem services including cultural, recreational and biodiversity services (NRETAS, 2010), which require high water quality standards to sustain them (ANZECC and ARMCANZ, 2000; DHAC, 2010).

Darwin Harbour is surrounded by a comparatively small catchment area of 2417 km^2 (NRETAS, 2005; Padovan, 2001; SEWPaC, 2011). The cities of Darwin and Palmerston are located within the catchment, and, together with adjacent rural areas, are home to approximately 120,000 people. There has been no evidence to suggest that anthropogenic nutrient inputs may have substantial effects on primary production in Darwin Harbour (Burford et al., 2008). Light industrial development in the catchment means that heavy metal concentrations in organisms are much lower compared to heavily industrialised harbours such as Port Philip Bay (Hanley and Couriel, 1992). The catchment is the predominant source of water pollution (NRETAS, 2010). It is anticipated that ongoing industrialisation and urbanisation of the catchment, and port development, will place increasing pressure on Darwin Harbour and lead to a more widespread decline in water quality. Increased runoff and waste water discharge will cause higher turbidity and nutrient and contaminant loads (Drewry et al., 2009; McKinnon et al., 2006; SEWPaC, 2011). Typically large daily tidal movements and high inflow of sediment into the harbour during the wet season mean that the water is naturally turbid though dissolved nutrient concentrations vary spatially and temporally (McKinnon et al., 2006). The tides help dilute anthropogenic contaminants (Hanley and Couriel, 1992). Port dredging leads to resuspension of marine sediments and creates a turbid plume around the dredge activity (Capello et al., 2010). Increased dredging (and associated spoil disposal) as part of the port expansion is therefore likely to cause increased turbidity in some parts of Darwin Harbour (URS, 2011).

Darwin Harbour is considered a water quality 'hot spot' in Australia. It holds significant ecological values as it supports a number of rare and threatened species of birds, fish, cetaceans and turtles. Its mangrove fringes hold 36 mangrove species, which is half of the world's mangrove species, and provide habitat for 60 fish, 36 crustacean and 31 mollusc species (McKinnon et al., 2006). It also holds important social and recreational values, in particular it supports a key recreational fishery in northern Australia (NAFF, 2013). Release of a comprehensive water quality protection plan for Darwin Harbour is expected in the near future.

2.3. Water pollution in Darwin Harbour

Darwin Harbour is the receiving water body of a cocktail of pollutants including sediments, nutrients, heavy metals, hydrocarbons, pathogens and chemicals (Drewry et al., 2010). Detailed causal attribution of water pollution is hindered by a lack of monitoring data and/or inaccessibility of data (DHAC, 2005). Of measured contaminants, those showing large relative load increases compared to pre-urbanisation are phosphorus, zinc and lead. Phosphorus load has increased by a factor of 5.9, caused predominantly by treated sewage inflow. Zinc and lead loads have increased 3.1-fold and 3.8-fold, respectively, and are attributed to surface run-off (McKinnon et al., 2006). Sewage outflows have been linked to increased nutrient loads and harmful algal blooms (Burford et al., 2012; Smith et al., 2012). Modelling of known and assumed processes has been employed to enhance systems understanding. Modelling results highlight increasing pollutant