ECOENGINEERING FRESHWATER FLOWS FOR ESTUARY HYDROLOGICAL STATE

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INTRODUCTION

The quantity, quality and timing of freshwater inflow into estuaries is critical to support estuarine ecosystem health. However, most estuaries are affected by upstream manipulation of freshwater inflows. Coinciding with the United Nations Decade of Restoration (2021-2030), there is great interest in re-creating functional estuarine ecosystems, including by modifying the physio-chemical characteristics with the premise that a functional ecosystem will follow (ecoengineering). To restore estuarine ecology, the physical processes of the system must first be conductive to supporting the re-establishment and sustenance of biota. These physical processes are generally under-monitored and often not used as a measure of restoration success.

PRESSURE - STATE - RESPONSE

We explore ecoengineering to restore freshwater inflows to estuaries, focused on hydrological state. We use the *Pressure–State–Response* (PSR) framework to set the context for this review. This is a modification of the PSR framework developed in the late 1980s (OECD, 1993). *Pressure* refers to anthropogenic pressures on freshwater inflows into estuaries. Pressure affects *State*, referring to the physical estuarine condition (hydrological state) (Figure 1). A degraded state may result in information flow, such as from monitoring, and in turn may lead to a societal *Response* - a decision or action that attempts to prevent or reduce these pressures, such as through incentives or regulations. Ideally, goal(s) with clear and measurable targets are set before the response action. Whether these targets have been attained is later assessed in a monitoring plan with specific metrics to determine the trajectory of the restoration. We explore case studies of estuarine restoration by restoring some component of previous freshwater inflows and discuss the importance of holistic management of rivers and estuaries in an era of rapid environmental change.

ECOENGINEERING ESTUARY FRESHWATER FLOWS

There has been extensive work on establishing environmental flow requirements in rivers to support ecoengineering (Tharme, 2003), but there has been little work undertaken in estuaries. Pressures affecting freshwater flows into estuaries are external such as dams, gates and culverts, and internal such as dredging and artificially breaching estuarine mouths to the sea. The response of estuarine state to these pressures is nonlinear, but generally includes changes to salinity structure, flushing, sediment dynamics, morphology, and nutrients. Ecoengineering responses aimed at reducing pressures to estuarine freshwater flows include dam removal, river rediversion, reconnection of tidal channels, dam release combined with mechanical mouth breaching and estuarine dredging. We discuss a range of cases studies using various techniques and how they fit into the pressure-state-response framework.

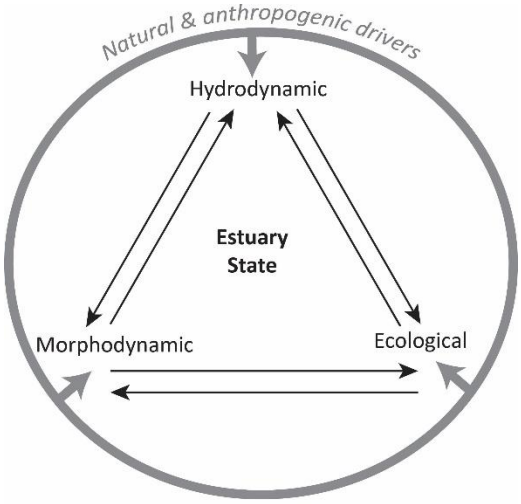

Figure 1 - Schematic of drivers impacting estuary state.

RESTORATION "SUCCESS"?

Judging restoration success remains difficult and is often a quality judgement with inherent observer bias (Elliot et al., 2007). Most targets for improved state focus on ecological expectations and metrics, rather than hydrological state. Moreover, often the reference condition for estuaries is poorly defined, compared to rivers and lakes. In Aotearoa New Zealand, it is becoming more common to first identify values (including from Māori, the Indigenous peoples) to set environmental outcomes based on Te Ao Māori (Māori world view) that are holistic, and inherently include a wealth of Indigenous knowledge; in this case, mātauranga Māori (Māori knowledge). As values are increasingly used as a tool to frame management protocols, a more holistic approach is gradually gaining momentum. However, connecting the less quantifiable values to attributes which can be engineered is an ongoing challenge.

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