Ecological Engineering 81 (2015) 233–242

Contents lists available at ScienceDirect

Ecological Engineering

journal homepage: www.elsevier.com/locate/ecoleng

Modified tide gate management for enhancing instream habitat for native fish upstream of the saline limit

Paul A. Franklin[a,*], Michelle Hodges[b,1]

[a] National Institute of Water and Atmospheric Research Ltd., P.O. Box 11 115, Hamilton, New Zealand
[b] Waikato Regional Council, Private Bag 3038, Hamilton Mail Centre, Hamilton, New Zealand

ARTICLE INFO

Article history:
Received 2 October 2014
Received in revised form 24 February 2015
Accepted 5 April 2015
Available online 14 April 2015

Keywords:
Tide gate
Flood gate
Fish migration
Aquatic habitat
Fish passage
River connectivity

ABSTRACT

Tide and flood gates are used widely throughout the world to facilitate drainage of lowland areas and provide flood protection to valuable agricultural land and human infrastructure. However, these structures can impact on aquatic communities by disrupting connectivity and altering physical habitat conditions. Complete removal is rarely feasible in the short-term because of the competing flood mitigation and land use interests. However, in many cases it is likely that the structure and/or its operation can be modified to enhance connectivity for migratory species and reduce the severity of impacts on instream habitats.

This study describes the results of a short-term trial investigating the effects of modified tide gate management on instream habitat and fish communities in a small tidal stream in the North Island of New Zealand. The study site was located upstream of the saline limit and thus does not directly address this potential limitation on managing the effects of some tide gates. The main objective of the study was to understand whether improvements in tidal flushing could mitigate the negative effects of tide gates on upstream habitats, thus improving their suitability for native fish communities.

The trial demonstrated that in impacted lowland river reaches, the reintroduction of limited tidal exchange upstream of tide gates reduced negative impacts on instream habitat by restoring hydrological variability, increasing minimum dissolved oxygen concentrations and potentially also reducing water temperatures. However, it was also shown that the recovery may not be uniform and can be dependent on interactions with other stressors. The trial illustrated the potential for using modified tide gate management to mitigate the environmental effects associated with their operation, and to restore habitat conditions so that they are more favourable for the persistence of native fish species.

1. Introduction

Connectivity plays a critical role in defining the structural and functional attributes of riverine ecosystems (Fullerton et al., 2010; Lake et al., 2007). Fragmentation and disconnection of habitats as a result of water resource development is a key factor in the loss of biodiversity of freshwater ecosystems (Dudgeon et al., 2006; Rolls et al., 2013). Disconnections in rivers are particularly damaging because the dendritic structure of river networks restricts dispersal potential, with important consequences for population persistence (Fagan, 2002). Consequently, there is a need for improved understanding of how instream infrastructure, e.g. tide gates, weirs and dams, impacts on aquatic communities and how their effects can be mitigated and managed.

The impacts on fish communities of large barriers, such as hydroelectric dams, have been well documented (e.g. Williams, 2008; Morita et al., 2009) and attention is now increasingly turning to the potential effects of dam removal (Bednarek, 2001; Mclaughlin et al., 2013; Gangloff, 2013). However, smaller obstructions, such as weirs culverts and tide gates, are the most frequently encountered fish migration barriers in many catchments (Gibson et al., 2005; Warren and Pardew, 1998). Consequently, there has been a recent increase in efforts to design, test and implement cost-effective solutions for overcoming these small scale barriers (e.g. Franklin and Bartels, 2012; David et al., 2014; Newbold et al., 2014). Cote et al. (2009) and Rolls et al. (2014) demonstrated that barriers located near to the river mouth can have a large impact on fish with a diadromous life history, i.e. fish that need to migrate between marine and freshwater environments in order to complete their life cycles. Tide gates are used

* Corresponding author. Tel.: +64 7 8591882; fax: +64 7 8560151.
E-mail address: paul.franklin@niwa.co.nz (P.A. Franklin).
1 Present address: Latitude Planning, P.O. Box 12760, Hamilton, New Zealand.

http://dx.doi.org/10.1016/j.ecoleng.2015.04.004
0925-8574/

widely throughout the world to facilitate drainage of lowland areas and provide flood protection to valuable agricultural land and human infrastructure. Understanding the effects of tide gates on the movement of fish and their habitats is essential as they are often the first barrier that many upstream migrating diadromous fishes will encounter.

There are many types of tide and flood gates, but most tide gates operate as a one-way valve, allowing water to drain out, but preventing tidal water ingress. This process is generally driven by the relative water levels on the upstream and downstream sides of the tide gate, with the gate closing during the incoming tide and opening during the ebb tide. This results in significant alterations to the hydrological regime, connectivity and instream habitats in adjacent stream reaches. While some effort has been put in to the development of "fish friendly" tide gates, the physical effects on the environment have received relatively little attention.

Intuitively, when tide gates are closed they act as a physical barrier to fish migration. This has been demonstrated in paired studies of gated and un-gated stream systems where fish communities upstream of gated systems are impoverished relative to the un-gated systems (Pollard and Hannan, 1994; Kroon and Ansell, 2006; Doehring et al., 2011). Case studies of adapted tide gate management have also been used to demonstrate that when tide gates are opened, the upstream passage of target fish species is increased (Mouton et al., 2011; Boys et al., 2012). However, as well as directly restricting fish passage, tide gates can indirectly affect fish behaviour and community composition through alterations to the instream environment, particularly upstream of the gates. By blocking the normal bi-directional movement of water the upstream hydrological regime is altered; the velocity, turbulence and pattern of freshwater drainage is modified; the normal gradual transition in salinity is disrupted; and the stagnation of freshwater above the tide gates can result in sedimentation and increased water temperatures (Pollard and Hannan, 1994; Kroon and Ansell, 2006; Halls et al., 1998). This is likely to interrupt rheotactic and olfactory cues for migrating fish species (e.g. Knights and White, 1998), but also modifies estuarine and lowland stream habitats such that they may no longer be suitable or available for those species that would normally utilise them (Kroon and Ansell, 2006) and may impact on the migration of diadromous species.

Complete removal of existing tide gates is rarely feasible in the short-term because of competing flood mitigation and land use interests. However, in many cases it is likely that the structure and/ or operation of tide gates can be modified to enhance connectivity for migratory species and reduce the severity of impacts on instream habitats. A number of studies have illustrated the benefits of adapted tide gate management for enhancing fish passage. For example, Mouton et al. (2014) showed that glass eel (*Anguilla anguilla*) migration was improved at an estuarine barrier as a consequence of increased barrier opening during tidal rise and Boys et al. (2012) observed improvement in both fish and crustacean communities following floodgate remediation. However, there has been little consideration given to mitigating the impact of tide gates on instream habitat.

This study describes the results of a trial investigating the effects of modified tide gate management on instream habitat and fish communities in a small tidal stream in the North Island of New Zealand (see Section 2.1 for further details of the tide gates at the site). The main objective of the study was to understand whether improvements in tidal flushing could mitigate the negative effects of tide gates on upstream habitats, thus improving their suitability for native fish communities. Secondarily, the physical barrier effect of the tide gates on fish community structure was also considered. The tide gates involved in the trial were located upstream of the saline limit and therefore impacts on salinity were not considered. The results of the trial are now being used by local catchment managers to identify where modified tide gate management can be used to reduce the environmental effects of flood mitigation infrastructure at other locations.

2. Methods

2.1. Study site

Kurere Stream is a small tributary of the Waihou River, located in the North Island of New Zealand (37°32′S, 175°67′E). The stream flows for approximately 5.5 km through hill country and flat farmland before entering the Waihou River (Fig. 1). It is located upstream of the limit of saline influence in the Waihou River. Under a natural flow regime, the lower 2.5 km of the stream would be influenced by tidal water level fluctuations, but this is prevented by a triple 1.5 m diameter twin-pipe floodgate with double hinged top-hung wooden tide gates situated across the stream mouth.

The lower reaches of Kurere Stream are approximately 10–12 m wide and have been artificially straightened, widened and deepened. Levées have also been constructed on both banks to contain flood waters. As a consequence of this channel engineering and the tide gates, instream habitat in the lower reaches of the river is now relatively homogenous and characterised by slow water velocities, fine substrates and a proliferation of aquatic macrophytes. Riparian vegetation cover is limited to pasture grasses and sedges.

The middle and upper reaches of the stream are typically 1–3 m wide (wetted width) and significantly less impacted by human channel modifications. Physical habitat is relatively diverse and characterised by a combination of pools, riffles and cascades, with the substrate dominated by cobbles and boulders. In the upper reaches, riparian cover increases, with the headwaters flowing through native bush.

2.2. Modified tide gate management trial

In collaboration with the catchment managers (Waikato Regional Council) and co-operation of the local landowners, a trial was carried out during the summer of 2011 whereby limited tidal flushing was restored to the lower Kurere Stream by means of manually opening one of the six tide gates. Previous surveys had indicated that instream habitat upstream of the tide gates was impaired as a result of the tide gates, with dissolved oxygen concentrations falling below recommended protection levels for native fish communities (Franklin and Hodges, 2012). The modified tide gate management trial was to run from 12 January 2011 to 30 March 2011. However, the trial had to be temporarily halted for a week at the start of February as a consequence of a summer storm event that resulted in high flows in the Waihou River and required the tide gates to be closed for flood defence purposes.

Prior to the trial, modelling was undertaken to evaluate the expected level of tidal inundation in the lower reaches of the stream. The mean high tide level downstream of the tide gates is approximately 1.4 m relative to the Tararu Vertical Datum 1952. Inundation scenarios were modelled for the lower river at tide levels of 1.4–2.4 m in 0.2 m increments in ArcGIS using a digital elevation model based on LIDAR data (vertical accuracy ±0.10 m). This provided reassurance to local landowners regarding the expected level of inundation during the trial. Observed levels of inundation during the trial matched well with the modelled data.

2.3. Monitoring

The monitoring regime followed a before-after-control-impact (BACI) design based around the trial opening of the tide gates, with monitoring of physico-chemical conditions and fish communities