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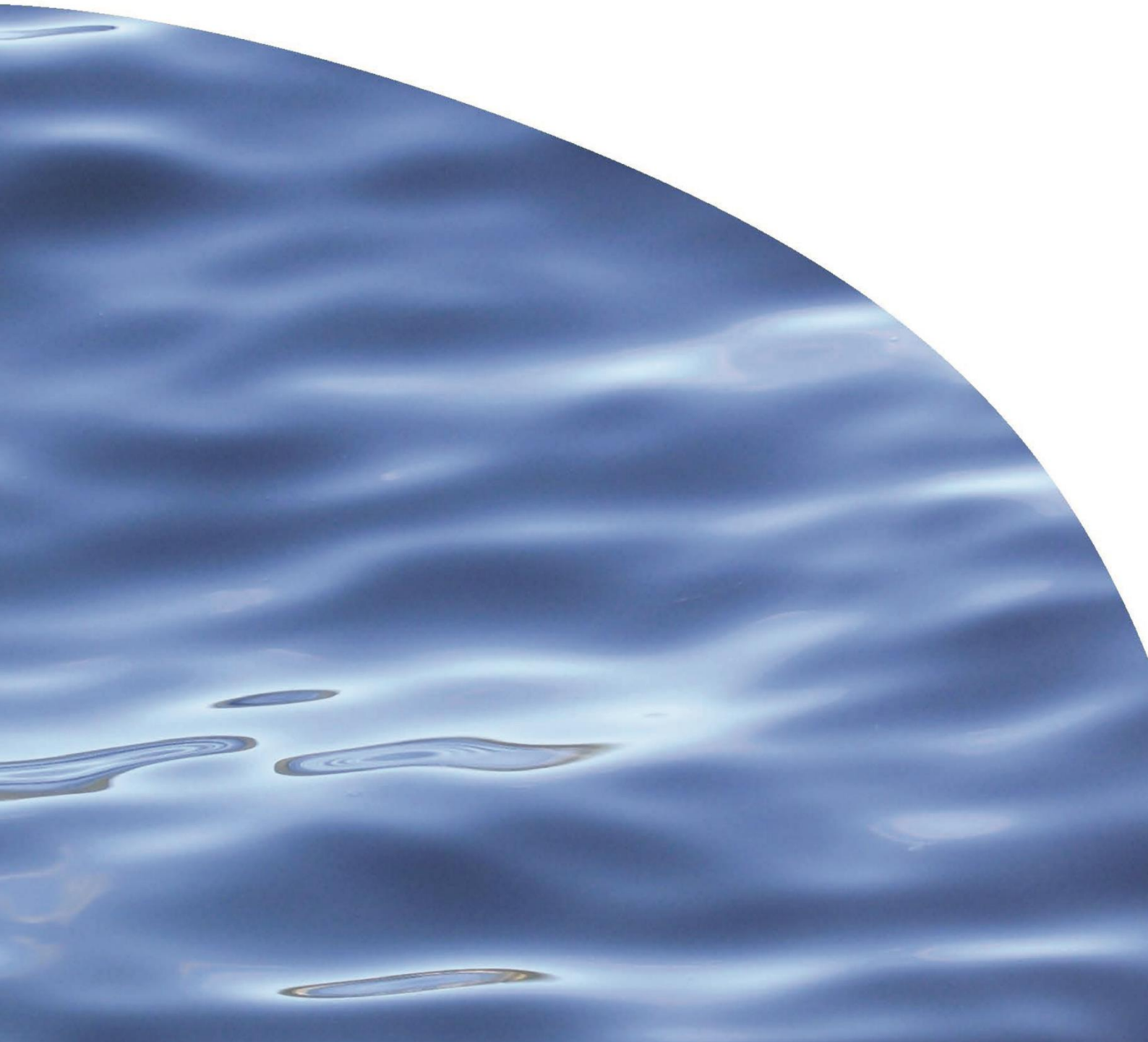

NATIVE FISH POPULATION RESPONSES TO WAITUNA LAGOON OUTLET OPEN-CLOSURE PERIODS

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1. INTRODUCTION

1.1. Purpose of this report

This short report repurposes six years of quantitative fish population data collected as part of the lower Waituna Creek rehabilitation project. I have interrogated these data to determine if Waituna lagoon opening / closure periods correlate with changes in the abundance of native fish species that require access to the ocean. The hypothesis is that diadromous fish densities in Waituna Creek will correlate with the number of days that the lagoon is open (to the sea) during species-specific peak ocean-to-freshwater migration periods. Waituna Creek is the lagoon's main tributary (c. 90% of inflow) and has the highest diversity of fish species, fish population dynamics in the Creek ought to indicate population trends in the wider catchment. The information presented here is intended to support the collaborative decision-making process currently underway to determine a management plan for the lagoon opening regime.

1.2. Background

Waituna Lagoon (Southland) is part of the wider Awarua Wetlands, which forms one of the few remaining large, (relatively) unmodified coastal wetlands in New Zealand. A feature of the lagoon is that it periodically closes to the sea (at its outlet) through the formation of a barrier beach. During closed periods, which typically last for less than a year, the water level rises and the lagoon changes from an estuary to a brackish lake. To manage the risk of inundation of marginal lands and to promote farm drainage, the lagoon is periodically opened to the sea with earthmoving machinery—in much the same way that Te Waihora (Lake Ellesmere) in Canterbury is managed (Jellyman 2012). More recently, mechanical lagoon openings have also been undertaken to regulate water quality issues that arise during prolonged closed periods as a result of land use in the catchment (Larkin 2013).

Managing the lagoon water levels is complicated, as the reasons for opening the lagoon described above can conflict with the need to maintain regular closed periods to promote the growth of *Ruppia* sp. macrophyte beds. *Ruppia* beds help maintain adequate water quality and support a range of ecological values in the lagoon (Larkin 2013). Currently, short-term consents to open the lagoon are issued by Environment Southland when a two-metre 'trigger point' water level is reached. However, work is underway as part of the Whakamana te Waituna programme to develop a longer-term adaptive management plan for the lagoon opening regime. The plan will consider a range of cultural, recreational, land use and ecological values, including managing for aquatic fauna.

The Waituna Lagoon catchment contains a reasonably diverse fish assemblage. Excluding marine wandering species (such as yellow-eyed mullet and kahawai), 12 freshwater fish occur in the catchment (Table 1). There are notable populations of

longfin eels (tuna), giant kōkopu (*Galaxias argenteus*) and kanakana (lamprey) (*Geotria australis*), all of which are considered to have nationally declining populations (Atkinson 2008). Most of the native fish present within the catchment have migratory life histories which require access to the ocean. Exceptions are giant kokopu, common bullies and common smelt, which can complete their life cycle by either migrating to the sea and / or to landlocked freshwater lakes.

Table 1. The freshwater fish community in the Waituna lagoon catchment. Conservation threat rankings are also shown (Dunn et al. 2017). Sources: Atkinson (2008) and Holmes et al. (2019).

Scientific name	Common name	Threat ranking
Anguilla australis	Shortfin eel	Not threatened
Anguilla dieffenbachii	Longfin eel	At risk – declining
Galaxias argenteus	Giant kōkopu	At risk – declining
Galaxias fasciatus	Banded kōkopu	Not threatened
Galaxias maculatus	Īnanga	At risk – declining
Geotria australis	Kanakana / Lamprey	Threatened – nationally vulnerable
Gobiomorphus cotidianus	Common bully	Not threatened
Gobiomorphus gobioides	Giant bully	At risk – naturally uncommon
Gobiomorphus huttoni	Redfin bully	Not threatened
Retropinna retropinna	Common smelt	Not threatened
Rhombosolea retiaria	Black flounder	Not threatened
Salmo trutta	Brown trout	Introduced and naturalised

2. METHODS

2.1. Fish sampling regime

Over the period 2014 to 2019 the Waituna Creek fish population has been monitored annually during mid-late March at four to eleven 40-m stream reaches. At each sample reach, stop-nets (6-mm mesh) were simultaneously placed at the upstream and downstream boundaries and fish populations within stop-netted reaches were sampled by electric fishing using the multiple depletion-pass method (Johnson et al. 2007). Electric fishing reaches were split between two c. 1-km segments of Waituna creek—one ‘rehabilitation / impact’ segment near the lagoon and an upstream control segment (Figure 1). Fish data were collected to follow the fish population response to an ongoing stream restoration project in the lower Waituna Creek. A full description of the sampling methods is provided in Holmes et al. (2019).

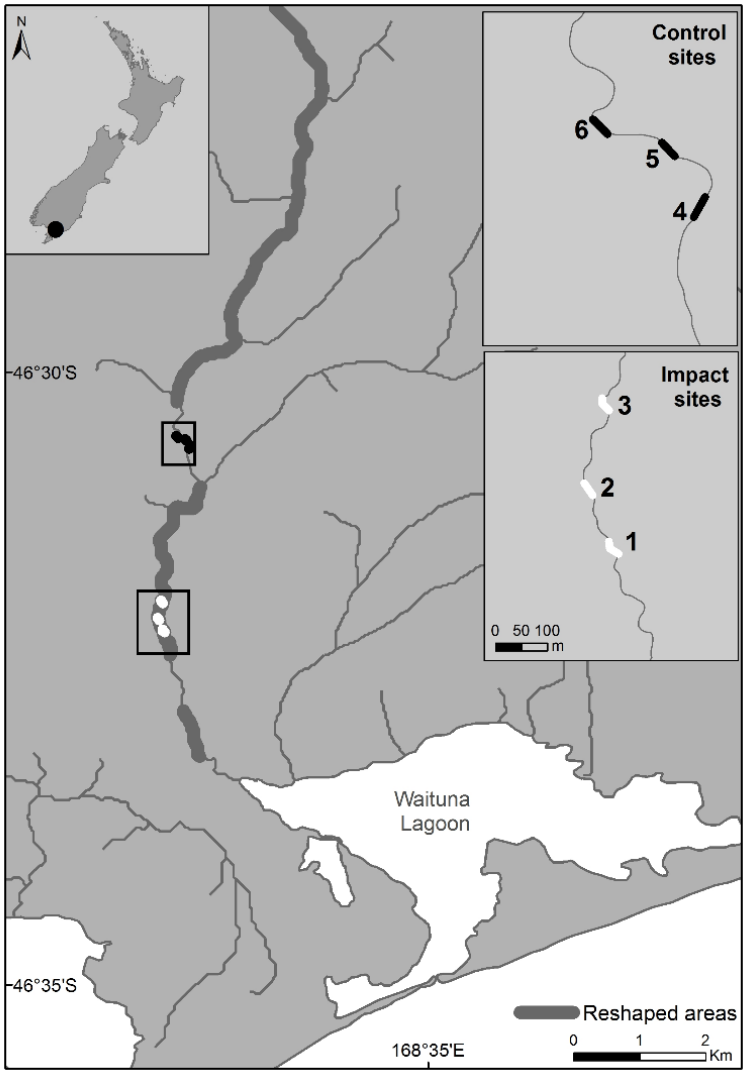

Figure 1. The Waituna catchment showing the locations of the most regularly sampled fish population monitoring reaches. Figure reproduced from Holmes et al. (2019).

The lower 'impact' segment (including reaches 1-3, Figure 1) received two substantial disturbance events over the sampling period. The first was during 2014–2015 when both banks of the entire segment were reshaped (scraped back to a 1:2 slope with a digger) to reduce erosion. The extent of reshaped area is shown by the wide grey bar in Figure 1. The second disturbance event occurred in 2018, when two impact reaches were mechanically modified (again) as part of a stream rehabilitation project. The control segment has not been mechanically modified for the duration of the fish data collection period, or for at least 10 years prior to the first sampling event in 2014.

2.2. Data processing and analysis

Total fish abundance was estimated from depletion counts using the maximum weighted-likelihood approach (Carle & Strub 1978). For īnanga and lamprey, aggregate numbers from all passes were used to determine abundance. Total abundance was divided by the electric fishing reach area to calculate densities of fish per square metre. Density data from each reach (for each year) were averaged to produce a single figure for each segment for comparison with the lagoon open-closure status data. This gave an annual segment-scale fish population time series of six years.

Environment Southland supplied data on the lagoon's open and closure periods. The days that the lagoon was open to the sea, during key ocean-to-freshwater fish migration periods, were calculated from 2010 to the present day. These data were then used for correlation against fish species density estimates. The time periods used for correlations were dependent on species life history characteristics. For example, īnanga complete their life cycle in one year, with an ocean-to-freshwater migration period from about mid-August through to the end of November (McDowall 1990). So, īnanga density data were compared with lagoon open-closure data for the spring preceding the March sampling event in any given year. Adult kanakana migrate from the ocean to spawn in fresh water during winter-spring, and juveniles spend about three to four years in fresh water (McDowall 1990). Therefore, open-closure status data were used from the winter-spring period three years previous to each yearly lamprey density estimate. The key migration periods for diadromous native fish species in Waituna catchment are shown in Table 2.

Table 2. Downstream and upstream migration periods for native fish in the Waituna Catchment (Smith 2014)

Common name	Upstream migration period	Peak upstream migration period	Downstream migration period
Shortfin eel (glass eels)	July–December	August–November	March–September
Longfin eel (glass eels)	August–January	September–December	February–July
Giant kōkopu	October–January	November	?
Banded kōkopu	August–January	September–November	March–July
Īnanga	May–December	August–December	January–May
Kanakana / Lamprey	May–December	August	March–September
Common bully	December–April	December–April	November–March
Giant bully	December–April	December–April	September–January
Redfin bully	November–April	November–April	September–December
Common smelt	August–December	September–November	November–May
Black flounder	September–December	September–December	November–May

For each species, three fish density vs. the lagoon 'open-closure status' comparisons were made. These included using average density data from 'impact reaches only', 'control reaches only' and 'all reaches' (impact + control reaches data). This was to account for the potential confounding influence of the reshaping and restoration disturbance events on the fish populations in the impact segment. In all cases, all comparisons showed the same patterns (or lack of pattern), so only the 'all reaches' data comparisons are discussed.

Correlations were performed using the 'cor.test' function from the statistics base package in *R*. Data were log-transformed before analysis. The significance of potential relationships was determined using the Pearson test statistic. Unlogged (raw) data are presented graphically below.

3. RESULTS AND DISCUSSION

Of the twelve fish species captured within the data set, only īnanga, giant bullies, common bullies, redfin bullies, lamprey, brown trout and longfin and shortfin eels occurred at sufficient densities, and regularly enough during the sampling period, to enable a meaningful comparison with the lagoon open-closure data. Below I discuss the potential patterns that were observed in relation to relevant ecological theory.

3.1. Īnanga

As expected, īnanga density in Waituna Creek was significantly correlated with the number of days that the lagoon was open to the sea during the previous spring period (R = 0.93, P = 0.01) (Figure 2). The sparse densities found during years when the lagoon was closed for the entire spring, demonstrates that īnanga in Waituna lagoon rely on ocean access. This strength of the correlation increased if the spring *and* summer period were included (R = 0.95. P = < 0.01) (Figure 3). This suggests that the īnanga population associated with Waituna might have a broad migration period. Alternatively, if the lagoon is closed during spring then fish may remain in the ocean and undertake a delayed upstream migration during early to mid-summer open periods.

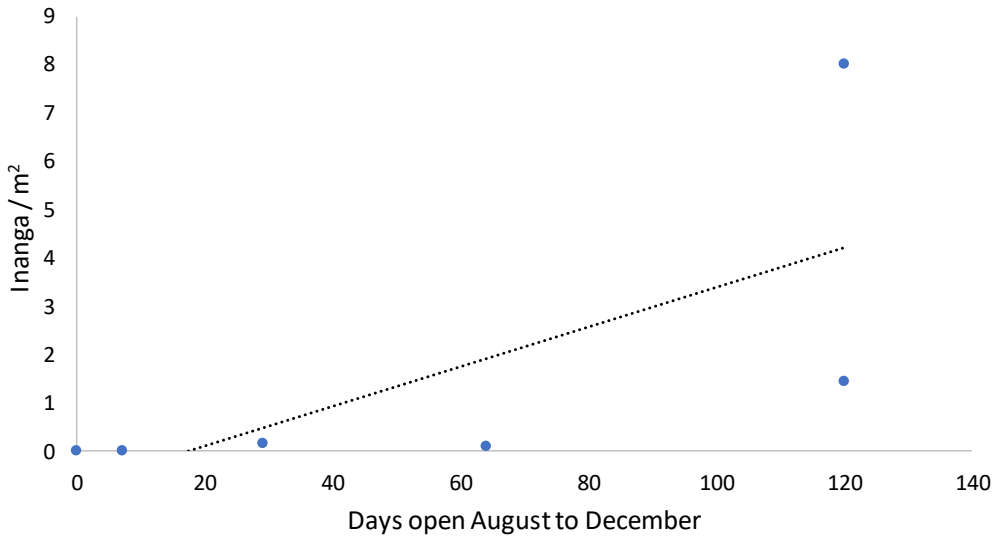

Figure 2. Average īnanga density (fish / m^2) from all sites during the annual March fish population sampling within Waituna creek (2014–2019) correlated against the number of days Waituna Lagoon was open to the sea from the preceding August (inclusive) to December period (n = 6).

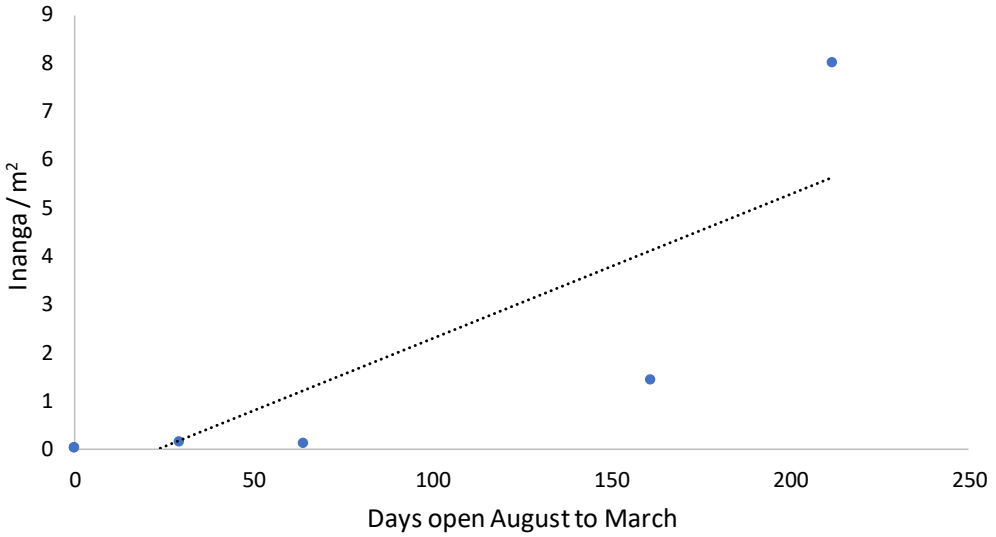

Figure 3. Average īnanga density (fish / m^2) from all sites during the annual March fish population sampling within Waituna Creek (2014–2019) correlated against the number of days Waituna Lagoon was open to the sea from the preceding August (inclusive) to March (n = 6).

3.2. Kanakana / Lamprey

There was no correlation between kanakana abundance and days open during the peak migration period of the month of August three years previously. However, Figure

4 shows a significant correlation between density and open periods during the period July to October three years previous to the sampling date (R = 0.84, P = 0.04). This period corresponds with the main adult kanakana harvest period in Southland (Kitson 2012) which occurs when the adult lamprey migrate upstream. Almost all juvenile lamprey captured during the sample record were blue / silver in colour (pers. obs. by author), indicating they were near their seaward migration phase and three to four years old. The potential relationship shown in Figure 4 suggests that mature kanakana have a reasonably broad upstream spawning migration period in Waituna Lagoon and that longer opening periods during winter and spring lead to better recruitment in the catchment.

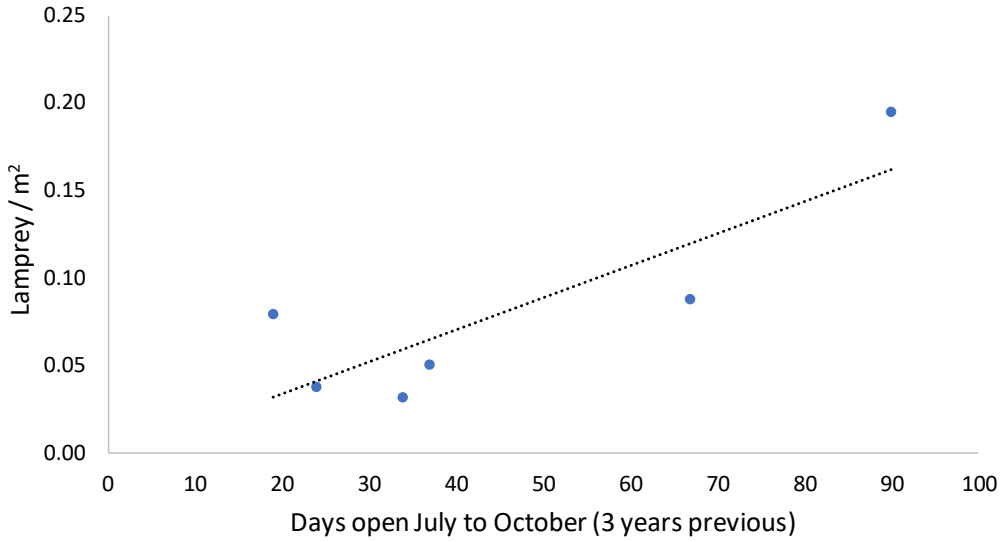

Figure 4. Average lamprey density (fish / m^2) from all sites during the annual March fish population sampling within Waituna Creek (2014–2019) correlated against the number of days Waituna Lagoon was open to the sea from July (inclusive) to October (three years previous to the sampling date) (n = 6).

3.3. Common, redfin and giant bullies

No significant correlations were observed for densities of any of the bully species and the lagoon open-closure periods. However, I did not expect any of the bully species to show a strong response for the following reasons:

1. Common bullies do not require access to the ocean to complete their life cycle and larvae probably rear in both the lagoon and the ocean.
2. Bullies complete their life cycle within two to three years (on average) and spawn at varying times throughout the year (McDowall 1990), meaning there will be overlapping cohorts within the data during any given year.

3. Redfin and giant bullies were relatively rare within the data set, so this would have introduced noise within the data reducing the ability to relate abundance to environmental variables.
4. Redfin and giant bullies are very difficult to differentiate from common bullies when small, so it is likely that there were a substantial number of misidentification errors for young fish within the data set.

Despite the above issues, there was evidence of a positive (albeit non-significant) relationship between giant bullies and lagoon open days during summer two years previous (R = 0.72, P = 0.10; Figure 5). The trend of increasing abundance with increasing open days is in line with the expected upstream migration period for giant bullies.

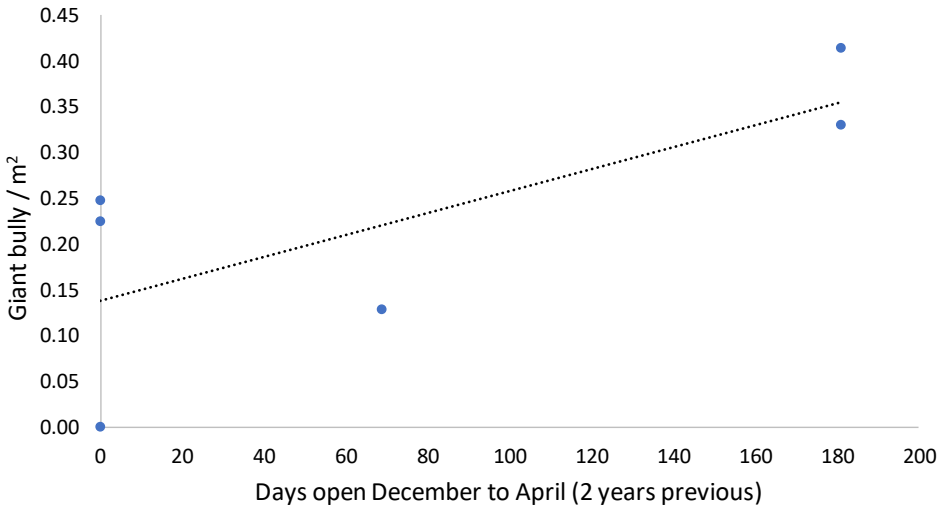

Figure 5. Average giant bully density (fish / m^2) from all sites during the annual March fish population sampling within Waituna creek (2014–2019), correlated against the number of days Waituna Lagoon was open to the sea from December (inclusive) to April (two years previous to the sampling date) (n = 6).

3.4. Tuna / Longfin and shortfin eels

No patterns were observed between eel density or biomass and lagoon opening periods. As with the bullies, I did not expect to see a strong response of eel densities to lagoon open periods because the populations of longfin and shortfin eels sampled consist of multiple year classes, making it difficult to compare densities to any single year of lagoon open-closure data. In addition, the strength of recruitment in any given year may be dependent on year class strength some 20–35 years previously, because this is approximately how long eels take to mature (McDowall 1990).

3.5. Brown trout

No patterns were observed between brown trout density (or biomass) and lagoon open-closure status. Typically, brown trout complete their three-year life cycle within fresh water. Therefore, the effects of the lagoon open and closure periods on the catchment's trout population may be indirect (e.g. through food web effects), delayed and / or subtle and so would be unlikely to be detectable within a six-year time series data set.

3.6. A note on interpreting these results

The above results must be interpreted with caution because the annual time series used for this analysis was just six years long. In general, *at least* ten years of annual monitoring is required to determine patterns in abundance for fish with a three-year life cycle (Hayes et al. 2018), and longer data sets are likely required for longer-lived species (e.g. giant kōkopu). Despite the limited time series, I did observe significant correlations for lamprey and īnanga. However, because of the low statistical power of this preliminary analysis, the lack of an apparent relationship between other species and lagoon opening periods does not provide evidence that they are not influenced by lagoon opening timing or duration.

4. CONCLUSIONS AND RECOMMENDATIONS

This preliminary analysis shows that both īnanga and lamprey abundance in Waituna Creek tends to increase with the number of days that the lagoon is open to the sea—either during the preceding spring for īnanga or the winter-spring period (three years previous) for lamprey. Giant bullies also showed a positive (but weaker) correlation with increasing open days during summer (two years previous).

These results suggest that ensuring the lagoon is open for a period between mid-August to December will maintain relatively high abundances of īnanga within the catchment. Īnanga can contribute substantially to the biomass of the fish population in Waituna Creek (in the order of 20% of total fish biomass during strong recruitment years, unpublished data) and they are a key prey item for a variety of birds, fish and humans (īnanga make up about 95% of the whitebait catch in most rivers). Therefore, abundant īnanga runs likely support a range of ecological and human-use values in Waituna Lagoon—including maintaining high growth-rates for tuna, large giant kōkopu and brown trout (all of which can prey upon īnanga).

Kanakana are highly valued as mahinga kai, especially in Southland where some populations have been harvested on an annual basis for centuries. They also have high conservation significance (listed as 'Nationally Vulnerable') due to decreasing

abundances throughout the country (Kitson 2012). Therefore, the observation that their abundance may be affected by the way in which the lagoon outlet is managed should be factored into the decision-making process regarding the lagoon opening regime. The data presented here suggest that maintaining open periods between July (inclusive) through to the start of October will increase abundance / recruitment of kanakana in the catchment.

The Waituna catchment is considered a 'stronghold' for giant kōkopu and management efforts are ongoing to preserve the health of the Waituna population (Atkinson 2008). Accordingly, any lagoon opening management plan should consider key migration periods and growth conditions for this species. Recent research suggests that giant kokopu predominantly rear in Waituna Lagoon and do not require access to the ocean. Furthermore, high water levels in Waituna Lagoon may benefit juvenile giant kokopu rearing, resulting in faster growth rates (Hicks et al. In prep). Therefore, maintaining open periods to benefit lamprey or īnanga populations could negatively impact on juvenile giant kokopu rearing conditions in the lagoon. This potential trade-off requires further consideration before acting on the information provided by this report.

Overall, this preliminary analysis demonstrates that the monitoring data associated with the lower Waituna Creek restoration project can help inform the management of fish populations more widely within the catchment. Nationally, long-term quantitative native fish monitoring data are sparse. Moreover, I am unaware of any contemporary monitoring data that can be used to assess population-level trends for kanakana / lamprey (which have exceptionally high cultural and conservation values). Consequently, I recommend that this monitoring programme is continued for at least another four years. This will enable a more robust analysis of state and trends of native fish populations in the Waituna Lagoon catchment.

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