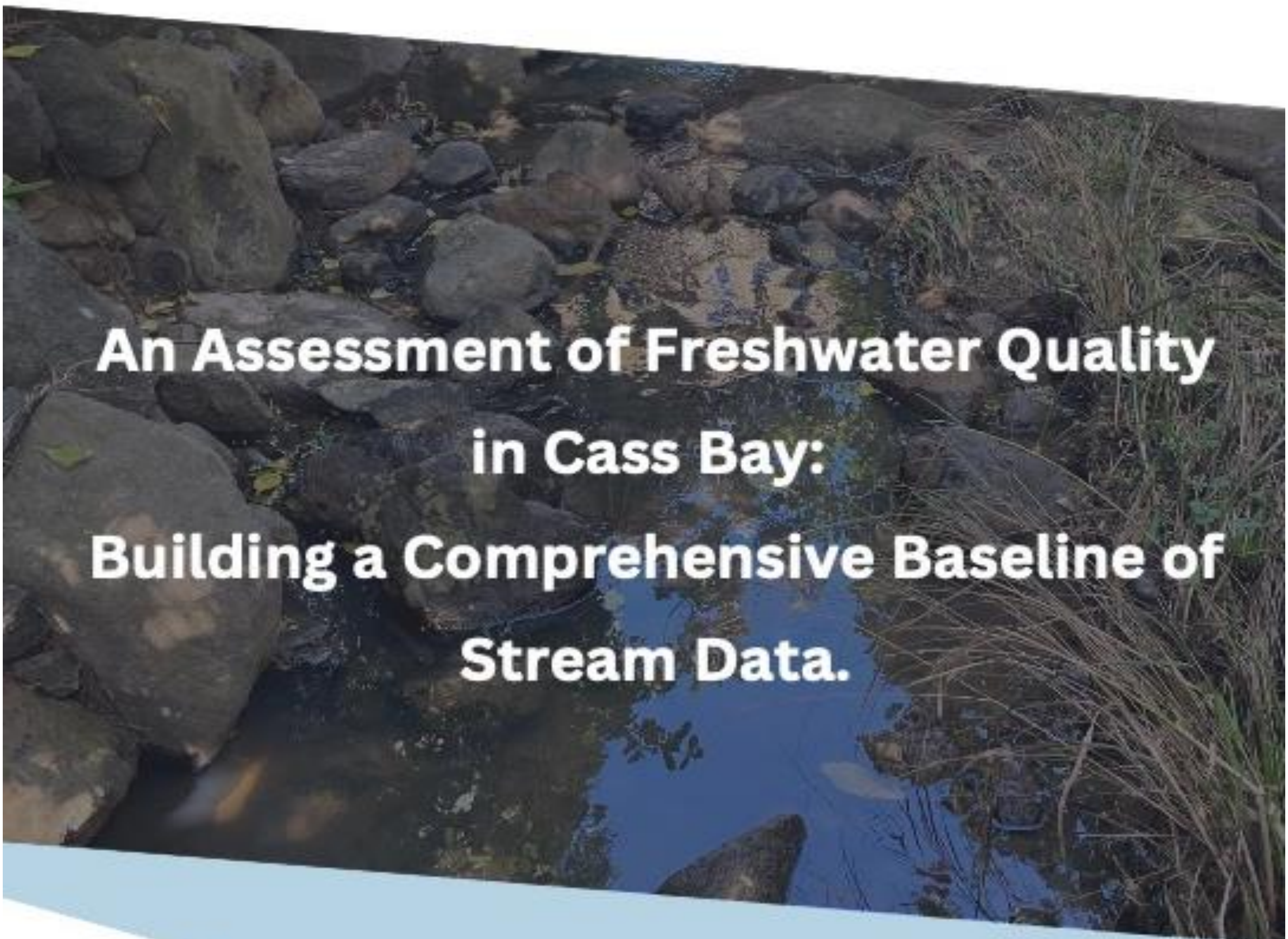
GEOG309 – Research For Resilient Environments and Communities



An Assessment of Freshwater Quality in Cass Bay: Building a Comprehensive Baseline of Stream Data.

University of Canterbury, 2023

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Table of Contents

1. Executive Summary

Research Aim

This research project aimed to assess stream water quality for the Cass Bay residential zone. The research's purpose was to establish a foundation baseline of stream health data, expanding and building on the Palmer et al. (2022) assessment of Steadfast Stream. The project maintains alignment with the objectives and values of the Whaka-ora Healthy Harbour plan (Te Hapū o Ngāti Wheke et al., 2018), contributing to positive change in the catchment.

Methods

The methodology was a continuation of that used by Palmer et al. (2022) to retain homogeneity between findings and are a commonly used practice by regional councils for water quality monitoring across the country. Primary data was obtained by macroinvertebrate sampling and in situ water chemistry measurements. Additionally, Rapid Habitat Assessments (RHA) were completed at each sample site. Data was analyzed using the Macroinvertebrate Community Index (MCI) and trigger values for water chemistry parameters, whilst RHA parameters for each site were summed to give a total habitat quality score.

Findings

MCI results suggested that the two streams observed are moderately to severely polluted. RHA findings suggest that the observed physical habitats are rated as '*good,*' except for site U1, rated as *'fair".* Water chemistry results fell within normal ranges, except for specific conductivity.

Limitations

Several major hurdles faced during sampling preparation resulted in us needing to redesign most of the study and develop a new research focus. The resulting time constraints necessitated lower quality methods and analysis that, although effective, offer less detail on stream health. Additionally, sample sites were limited by accessibility through private properties.

Future research opportunities

Heavy metal contaminant testing would be beneficial to aid the Cass Bay Residents Association (CBRA) in their endeavours to improve water quality in Steadfast Stream and increase biodiversity in the catchment. Additionally, exploring methods to improve habitat quality and quantity in the residential area of Cass Bay may be useful in aiding restoration efforts upstream.

2. Introduction

Cass Bay is situated on the northern side of Whakaraupō/Lyttleton Harbour, southeast of Christchurch City (Figure 1) and is a place of significant cultural value and heritage for local Māori (Te Hapū o Ngāti Wheke et al., 2018). Cass Bay catchment land cover can be considered stratified, with steep pastural land above coastal residential development, and the publicly accessible Steadfast Reserve located centrally. Several intermittent streams, including Steadfast Stream, begin in the upper catchment before converging and discharging into the harbour. Steadfast Reserve also has an extensive military history with 10 ammunition bunkers in varying conditions, a decommissioned firing range, and Naval Sea cadet training facilities (Hoddinott et al., 2022).

An initial research aim was developed with our community partner, Jenny Healy, on behalf of the Cass Bay Residents Association (CBRA) to investigate the cause of water quality issues in Steadfast Reserve. However, the lack of documentation regarding the clearance of the ammunition storage facilities meant we could not satisfy the University's health and safety requirements. Therefore, we were unable to undertake sampling within the reserve. Resulting time constraints required a new direction for our research that could still meet the community's needs of achieving a greater understanding of stream health in Cass Bay. After consultation with the CBRA and the University's geography faculty, with support from Te Hapū o Ngāti Wheke, we developed a new focus for our present research. The refocused project built on the findings from a previous assessment of Steadfast Stream by Palmer et al. (2022), to create a baseline of stream health data for Cass Bay. With this purpose in mind, our research aimed to:

*'**Complete an assessment of freshwater quality in Cass Bay to build a comprehensive baseline of stream health data.'***

A key requirement of our research was alignment with the values and guidelines set out in the Whaka-Ora, Healthy Harbour Plan (Te Hapū o Ngāti Wheke et al., 2018). The Plan identifies key pressures preventing healthy stream ecosystem functioning within the harbour's catchments, including Cass Bay. It details the necessary restoration actions to remediate these pressures and notes it is limited by a paucity of baseline data on the state of local ecosystems (Te Hapū o Ngāti Wheke et al., 2018).

Figure 1.

Cass Bay, situated southeast of Christchurch City.

Note. Figure retrieved from Google Earth. (2023). *Google Earth*. https://earth.google.com/web/

3. Literature Review

3.1. Impacts of Urbanization on Freshwater Quality

Urbanization is a multi-variate disturbance that impacts stream health by influencing physical, chemical, and biological factors. Urbanization does not solely impact ecosystems, rather it is a complex interaction of associated factors (White & Greer, 2006). The development of a city entails an intense transformation of natural ecosystems including alterations to catchment land cover and flow paths, riparian areas, stream habitat degradation, and channelization (Roy et al., 2016). The alterations around freshwater systems due to urbanization change the stressors that affect stream biota (Bazinet et al., 2010). These alterations can negatively influence natural ecosystem structures and functions.

Channelization often requires piping of the waterbody and the construction of artificial stream banks, resulting in the loss of bank vegetation which is an essential part of many stream habitats (NIWA, 2010). Channelizing or straightening the stream increases the velocity of water flow and reduces habitat availability (US EPA, 2015). Due to many species having specific requirements for stream velocities, increasing the velocity of a stream can dramatically reduce species richness and abundance. Additionally, a reduction in rifle pool occurrences caused by channelization also reduces habitat availability for aquatic organisms (Brooker, 1985).

Alteration of stream bed characteristics using impermeable materials causes further problems for water flow. Resulting in more frequent periods of dry stream bed which can lead to an increased likelihood of intermittent stream flow (US EPA, 2015). Furthermore, the incorporation of impermeable surfaces in streams can lead to increased stormwater runoff and peak discharges (Sohn et al., 2020). Past research has shown that impervious surface cover can increase estimated runoff by 200-500 percent (White & Greer, 2006). High quantities of stormwater run-off can negatively influence macroinvertebrate communities by flushing away food resources and introducing nutrients. Additionally, streams can also be polluted by higher loads of road particles, metals, nutrients, pesticides, and microplastics (Wang et al., 2011; Dent et al., 2023). Importantly, the interconnectivity of waterways exacerbates the issues that urbanization imposes (Wang et al., 2011).

3.2. Macroinvertebrate Index

The biological diversity of streams and moving freshwater bodies is strongly influenced by land use, both within the river's immediate vicinity and higher in the catchment. Freshwater ecosystems around New Zealand are built on the presence of macroinvertebrates (small insects that form the base of the aquatic food chain). Multiple studies support the claim that macroinvertebrates are an accurate indicator of the health of a freshwater ecosystem due to the tolerances (or intolerances) of certain species to pollutants. Palmer et al. (2022) sampled Steadfast Stream for macroinvertebrates as part of their assessment of the catchment's upper reaches. It was found that only pollutant-tolerant species like Oligochaeta (worms), Mollusca (snails), various species of Diptera etc. were present in the stream. Additionally, Palmer et al. (2022) found that the stream faced significant sedimentation issues but did not sample heavy metals.

There are competing opinions about the index that should be used to determine ecosystem health when using macroinvertebrates as an indicator. The percentage of Ephemeroptera, Plecopteran and Trichoptera (EPT) orders present in a system can show the pollutant-intolerant species relative to a stream's total taxa richness. A high percentage EPT score typically indicates good stream health. However, as found in Davis et al. (2003) the percentage EPT system can cause insufficient taxonomic resolution and impact results. This study concluded that there may be naturally few EPT taxa in some streams, to begin with. Therefore, the system is best used in addition to a more robust procedure such as the macroinvertebrate community index (MCI) or Quantitative macroinvertebrate community index (QMCI).

The presence-absence/MCI method records which species are present in the waterway and their associated pollutant tolerance values. The QMCI is based on quantitative invertebrate data and is thought to be more sensitive to subtle water quality changes (Wright-Stow & Winterbourn, 2003). This is attributed to the QMCI responding to differences in the proportions of invertebrate species compared to the MCI, which is derived from the average tolerance value of all taxa present (LAWA, 2023b). However, Hickey and Clements (1998) criticized the use of the QMCI as it did not consider the impacts of heavy metal (HM) pollution due to “incorrect HM tolerance values for some taxa”. This can be explained by the QMCI not being developed to detect metal toxicity, but instead organic pollution and nutrient enrichment (Hickey & Clements, 1998). The QMCI assessment is significantly more time-consuming than using MCI presence-absence data but overall is more robust (LAWA, 2023b).

3.3. Stream Dynamics

Both Steadfast Stream and the second unnamed stream in the catchment (Unnamed) are classified as Intermittent streams (Brennan, 2021). Intermittent streams flow only during certain times of the year when groundwater is high enough to replenish springs, with enough water to sustain connected channels (US EPA, 2010). Climatic variables have the most influence on wetted channel conditions within intermittent streams. Low levels of precipitation can reduce the volume of water being supplied to a spring-fed intermittent stream (US EPA, 2010). Lack of precipitation is an issue in Christchurch particularly under El Niño conditions, which results in dry and hot days in the summer season (NIWA, 2015).

Storey (2015) concluded that less tolerant macroinvertebrates declined in richness, density, biomass, and diversity due to the drying of intermittent streams. Results found that less sensitive macroinvertebrates exhibited adaptations to intermittent waters, which increased dramatically during drought conditions compared to that of less tolerant species (Adámek et al 2022). Many tolerant species of macroinvertebrates persisted in small permanent pools during periods of drought to survive. However, macroinvertebrates were still exposed to extreme heat and reduced dissolved oxygen because of warmer climatic conditions, leading to a decrease in overall macroinvertebrate populations (Storey, 2015).

3.4. Sedimentation

Excessive stream sedimentation is detrimental to physical stream habitats and aquatic life in multiple ways, effectively smothering the streambed, clogging porous bed space, and disrupting water flow (Bylak & Kukuta, 2022). Persistent elevated levels of sedimentation can lead to a shift in the abundance and diversity composition between pollution-sensitive or tolerant species (Nakagawa, 2021).

Chapman et al. (2014) describe the process of depositional fine sediment grains settling in porous spaces on the stream bed, effectively smothering the habitat of benthic macroinvertebrates. This results in reduced water flow through streambed substrate which reduces oxygen levels and disrupts temperatures in this zone (Chapman et al., 2014; Hauer et al., 2018). Vadher et al. (2018) demonstrated that a reduction in streambed porosity due to increased sedimentation reduced the ability of benthic macroinvertebrates to move vertically through the substrate and remain saturated during drying events.

Moreover, sediment can be enriched with contaminants such as heavy metals (zinc, lead, copper for example), pesticides and polyaromatic hydrocarbons (PAH). Aquatic macroinvertebrate assemblage is likely to be directly affected by sediment contaminant levels in urban stream reaches (Pettigrove & Hoffman, 2005). Thus, excessive and/or contaminated sediment can physically and chemically alter macroinvertebrate habitat, particularly in stream reaches exposed to urban run-off.

3.5. Analysis of Remediation Options and Effects on Biodiversity

With the loss of biodiversity experienced in many streams, remediation techniques have been utilized in hopes of restoration (Stranko et al., 2011). It is a common assumption that remediation techniques will increase biodiversity. However, there are mixed responses seen in studies. The remediation efforts saw positive effects on biodiversity through fish passage leading to an increase in fish diversity (Brennan, 2021). Furthermore, restoration techniques used by Turunen et al. (2017) found negligible effect on benthic macroinvertebrates. However, bryophyte diversity showed a positive response. Therefore, biodiversity across taxa may respond differently to remediation actions and different options should be considered if there is prioritization of species.

Results from Stanko et al. (2011) showed a failure of restoration projects to recover native biodiversity in highly degraded streams. This potentially reflects a tipping point of streams, past which there is little chance of restoring biodiversity. There is evidence of stream biodiversity recovery following short-term catastrophic disasters such as floods, point-source pollution, and logging (Stanko et al., 2011). However, biodiversity in highly degraded streams following long-term and sustained disturbance such as agriculture, may cause irreversible changes to biodiversity (Harding et al., 1998).

A common remediation technique utilized across Aotearoa is the use of riparian zones which act as a buffer between land and waterways as well as providing organic matter (Harding et al., 1998). According to Harding et al. (1998), riparian zones improve a range of ecosystem functions such as stream hydrology, water quality, and sedimentation. Land managers must understand that the restoration of Steadfast stream will need a grand-scale approach of restoration reflecting Ki uta ki tai: *from the mountains to the sea.*

4. Methodology and Analysis

4.1. Background

Primary data was collected at six individual locations across the two streams within the study area (Figure 2). Sites S1-S3 and U1 covered the urban reaches of the two streams, while sites U2 and U3 examined the middle reaches of the second unnamed stream before it entered the residential zone. Both streams converge downstream of site S2 in the central part of the residential area. Sampling began at site S1 and moved progressively upstream to not interfere with the composition of downstream communities before we had the opportunity to sample them.

The methodology used was a continuation of that used by Palmer et al. (2022) to retain homogeneity between findings. These methods are a common approach for waterway monitoring by councils and communities alike, providing a biological, physical, and chemical approach to examining stream health (Macneil & Holmes, 2021). Primary data for the two streams was obtained by macroinvertebrate sampling and in situ water chemistry measurements. Rapid habitat assessments (RHA) were also completed at each sample site. Data was analysed using the macroinvertebrate community index (MCI) and trigger values for water chemistry variables, whilst RHA parameters for each site were summed to give a total habitat condition score.

Figure 2.

Sampling site locations for Steadfast stream (S) and the second unnamed stream (U) in the lower and mid Cass Bay Catchment.

Note. Figure retrieved from Google Earth. (2023). *Google Earth*. https://earth.google.com/web/

4.2. Macroinvertebrate Community Index (MCI)

Every known species of macroinvertebrate in New Zealand is assigned a value, indicating the species' tolerance to pollutants. This is known as the macroinvertebrate community index. The MCI is commonly used as a proxy for indicating stream health, where the presence or absence of certain indicator species provides insight into the level of pollution within the aquatic environment (Stark & Maxted, 2007). Kick-net sampling was undertaken following the method proposed by Stark et al. (2001), as shown in Figure 3. Sites were tested starting from the bottom and moving to the top of the catchment to not interfere with the composition of downstream communities before they were sampled. Various habitat types were sampled including rifles, pools, and runs to accurately represent the entire site.

Figure 3.

Kick-net used to gather macroinvertebrate samples (left). A macroinvertebrate sample is shown in a Bogorov tray under a microscope (right).

Samples were then processed in a lab using the presence-absence and MCI analysis protocol. The tolerance scores for all taxa recorded at each site were averaged and multiplied by 20, resulting in a final MCI score that provides an estimate of stream pollution (Figure 4). Finally, the MCI score from each sample was interpreted using a quality classification table created by Stark & Maxted (2007) to indicate the probable level of pollution in the stream reach (Figure 4.

Figure 4.

MCI calculation for presence-absence data and interpretation of resulting MCI indices reflecting water quality class, pollution level, MCI, and SQMCI/QMCI.

$$\mathrm{MCI} = \frac{\sum_{i=1}^{i=S} a_i}{S} \times 20$$

Stark & Maxted (2004, 2007) quality class	Stark (1998) descriptions	MCI MCI-sb	SQMCI & QMCI SQMCI-sb & QMCI-sb
Excellent	Clean water	> 119	> 5.99
Good	Doubtful quality or possible mild pollution	100–119	5.00–5.90
Fair	Probable moderate pollution	80–99	4.00–4.99
Poor	Probable severe pollution	< 80	< 4.00

Note. Retrieved from Stark, J., & Maxted, J. (2007). *A User Guide for the macroinvertebrate Community Index.* Cawthron Institute.
https://environment.govt.nz/assets/Publications/Files/mci-user-guide-may07.pdf

4.3. Rapid Habitat Assessment (RHA)

The RHA is a complementary method of assessing the physical condition of the stream environment when carried out with macroinvertebrate sampling (Macneil & Holmes, 2021). It examines 10 individual parameters within the stream and riparian area for physical feature presence and percentage cover, necessary for healthy aquatic habitats.

An RHA recording sheet was completed for each sample site, with an example completed RHA field sheet shown in Appendix 1. Observed sample sites were about 8–25 meters long and constrained by built features such as culverts and fences in the residential area. Due to the subjective nature of RHA scoring, the same group member completed each assessment to eliminate inter-user variability.

Initial analysis of the RHA involved summing the 10 individual parameter scores to generate a habitat quality score for each of the six sample sites. The score then corresponds with the value range of four habitat condition classes (Table 1) provided by Macneil & Holmes (2021). This qualitative output provides a simple indication of the state of the observed physical habitat at each site.

Table 1.

Rapid Habitat Assessment Value Range and Corresponding Condition Classification.

RHA Habitat Condition Class	RHA Score
Excellent	76 - 100
Good	50 - 75
Fair	25 - 49
Poor	0 - 24

Note. Adapted from Macneil, C., & Holmes, R. (2021). *Getting started: Ecosystem health monitoring for catchment groups.* (Report No. 3704). (https://www.cawthron.org.nz/wp-content/uploads/2022/01/Getting-started-ecosystem-health-monitoring-for-catchment-groups.pdf).

4.4. Water Chemistry

Water chemistry testing was carried out at all sites to determine water quality. Turbidity was tested with a turbidity test kit measuring the fine particles within a water body using nephelometric turbidity units (NTU). The pH, specific conductivity and dissolved oxygen testing were carried out using a handheld water quality meter ensuring that the end of the water chemistry probes was submerged in the middle of the stream. No inconsistencies were found for any of these water chemistry parameters, so they were not repeated at each site.

5. Results

5.1. Macroinvertebrate Community Index (MCI)

The MCI results for all sampling sites indicate a degraded level of pollution in both streams (Table 2), following the Stark & Maxted (2007) method. However, both sites U1 and U2 returned results suggesting probable severe pollution as they had MCI scores of <80. The remaining sites had MCI scores between 80-99 suggesting probable moderate pollution. Sites U1 and U2 are on the cusp of the probable severe to moderate pollution threshold. This observed difference in MCI scores between sites could be attributed to sampling variation, and the whole catchment is likely classified under probable moderate pollution.

Table 2.

Calculated macroinvertebrate community index scores across all sampling sites according to location.

Site	MCI Tolerance Scores	Description
S1	83	Probable moderate pollution
S2	80	Probable moderate pollution
S3	83	Probable moderate pollution
U1	77	Probable severe pollution
U2	70	Probable severe pollution
U3	88	Probable moderate pollution

5.2. Rapid Habitat Assessment (RHA)

RHA scores seen in Table 3 suggest that five of six sample sites (S1-S3, U2-U3) have sufficient physical aquatic habitat features and conditions present to be considered *'good'*, with the range of values in this class falling between 55 (U2) and 74 (S3). Site U1 was the most heavily modified: a shotcrete channel with little to no suitable physical habitat or substrate features, returning an RHA score of 36, indicating a *'fair'* quality habitat. The adjacent private gardens providing shade from exotic flora and the lack of sedimentation are the individual scoring parameters responsible for U1 being classed as highly as it did. The total average RHA score (61.7) for all six sites falls directly in line with the national average of 61.6, found by Clapcott et al. (2020).

Table 3.

Rapid Habitat Assessment score results and corresponding habitat quality classification for each sample site.

Site	RHA Total Scores	Physical Habitat Condition
S1	72	Good
S2	67	Good
S3	74	Good
U1	36	Fair
U2	55	Good
U3	66	Good
Total Average	**61.7**	**Good**

5.3. Water Chemistry

Water chemistry results were compared to trigger values to identify any sampling sites outside of the normal range for freshwater lowland streams. Trigger values were obtained from government and council departments.

Turbidity values higher than 25 NTU are considered moderately turbid and threaten native fish like the banded Kokopu (NIWA, 2009b). Our turbidity results for both intermittent streams are within the recommended freshwater guidelines, showing an average of 20.6 NTU. Land Air Water Aotearoa (LAWA, n.d.) recommends the pH for freshwater bodies stay within their guidelines of pH 6.5-8.0. The pH results from our investigation came to an average of 7.4 over the two streams within the lower Cass Bay catchment, which sits well within the recommended guidelines. Guidelines set out by LAWA (2023a) show fresh groundwater streams should reach a specific conductivity of no more than 150 mS/cm. On average the streams tested in our investigation received specific conductivity results of 255.5 mS/cm, showing a higher-than-acceptable result. Finally, Guidelines set out through the National Policy Statement for Freshwater Management (2020) show that any body of water that holds more than 8.0 mg/L of dissolved oxygen causes little to no stress to aquatic organisms within it. The average dissolved oxygen of both intermittent streams within the Cass Bay catchment came to 10.2mg/L.

Table 4.

Water Chemistry results for all sites, showing values of temperature, dissolved oxygen, specific conductivity, pH, and turbidity.

Site	Temperature (°C)	Dissolved O2 (mg/L)	Specific Conductivity (mS/cm)	pH	Turbidity (NTU)
S1	11	10.7	271	7.6	25.4
S2	11	10.1	261	7.3	14.6
S3	11.5	10.5	234	7.2	34.6
U1	11.8	10.8	260	8.1	12.9
U2	10.9	9.5	253	7.3	15
U3	11.6	9.5	254	7.2	20.8
Total Average	**11.3**	**10.2**	**255**	**7.4**	**20.6**

6. Discussion

Sample site S1 is an example of an urban stream environment modified to improve the physical condition of the exposed stream reaches (Christchurch City Council, 2020). We observed the presence of artificial boulder banks, native riparian vegetation, and hydraulic features such as pools and rifles. These have been deliberately arranged to provide cover and habitat for aquatic communities. Therefore, despite their artificialness, site S1 meets the requirements for an RHA rating of *'good'*. This could explain the slightly higher average MCI and RHA values observed at this location, despite its urban setting.

Determining causation for low MCI scores in Cass Bay is problematic, without ruling out potential point and diffuse sources of contaminants such as heavy metals. As streams enter the residential zones, run-off from roads, poorly maintained septic tanks, and stormwater pose issues to biodiversity (Te Hapū o Ngāti Wheke et al., 2018). Contaminants such as heavy metals have been identified by Qu et al., (2010) as a limiting factor for macroinvertebrate diversity. Additionally, Palmer et al. (2022) noted an undesirable amount of sediment present in Steadfast Stream, which has also been found to cause low MCI scores (Allan, 2004). This finding was further supported by the Healthy Harbour plan which identified sediment as the key pollutant in waterways within Whakaraupo/Lyttleton Harbour (Te Hapū o Ngāti Wheke et al., 2018). We did not observe excessive sedimentation at any of the sites we sampled. Rather, it was noted both streams were heavily modified once they entered the residential area, reducing suitable habitat features for all taxa in both streams. This observation is commonly supported by similar research which suggests that stream modification can have detrimental effects regarding the loss of macroinvertebrate species richness and abundance (Brooker, 1985; NIWA, 2009a; US EPA, 2015).

Overall water chemistry within both Steadfast and the second intermittent stream, were generally within recommended guidelines. Specific Conductivity exceeded guideline values for all sites across both streams. However, this is not consequential due to the sampling area's proximity to the ocean (California State Water Resources Control Board, 2004). Specific conductivity results for higher in the catchment returned an average value of 178.2 mS/cm, with one site measured at 208 mS/cm (Palmer et al., 2022). Despite exceeding guidelines, values below 5000 mS/cm are not considered problematic for freshwater ecology (NIWA, 2019). Additionally, results from Palmer et al. (2022) found pH levels higher up in the Steadfast catchment reached an average of pH 6.6. The average pH in our investigation was slightly higher at 7.4 and was likely due to concrete channelization in the lower urban reaches (Purdy & Wright, 2019). Site U1 reached a slightly unusual maximum pH of 8.1, which would need to be tested further to determine a definite cause.

7. Limitations

Note that this report's research focus is an evolution of an initial desire by the CBRA to investigate water quality and its impact on the biodiversity of the stream reaches within the Steadfast Reserve. Time constraints following health and safety concerns surrounding the reserve's previous military applications and infrastructure necessitated a new research direction. Due to the changes in sampling location, the project aims, and resulting time constraints, using both abundance (QMCI) and presence-absence data (MCI) was unattainable. It was decided we would exclusively use presence-abundance data to remain homogenous with last year's project and to ensure we were able to meet our objectives in the given time.

The Rapid Habitat Pressures Assessment (RHPA) is an alternative to the RHA which may be more appropriate for future sampling (Holmes, 2022). This method considers the physical degradation of a stream reached from anthropogenic sources or exotic flora. It scores based on the diversity and percentage of detrimental habitat pressures present within or at the stream edge, such as drains or instream rubbish. Although there is no apparent relationship observed between the RHPA scores and the MCI scores, it can improve the sensitivity of the RHA assessment, painting a more detailed picture of the physical environment at the sample locations (Holmes, 2022).

Due to this project's time-limited nature, we were unable to further explore our findings' cause. In consensus with findings from Palmer et al. (2022), there may be heavy metal contamination in both streams in Cass Bay. This contamination may be attributed to point source pollution from the former military area (Skalny et al., 2021), along with diffuse sources relating to road and residential land use (Wang et al., 2011; Dent et al., 2023). Furthermore, if time had allowed it would have been beneficial to re-sample macroinvertebrates during the summer, which would have given more reliable results.

8. Conclusion

In summary, stream health in Cass Bay varies between measures. MCI results show all sites are likely within the range of probable moderate pollution, whilst specific conductivity was the only water chemistry parameter outside of recommended values. RHA results show all sites are within either the 'good' or 'fair' habitat range. However, each method is not representative of the entire aquatic environment alone and must be looked at holistically.

Our findings contribute to the overall picture of the stream health in Cass Bay and the wider Lyttleton area and are therefore beneficial to all communities involved. The key purpose of the Whaka-Ora, Healthy Habor plan is to ensure that Whakaraupō is nourished, abundant, and interconnected. Our project contributes meaningful data as it provides more comprehensive information regarding stream health in Cass Bay. Additionally, it can act as a suitable baseline for future projects and planning.

The Cass Bay Residents Association may benefit from continued research in the area, specifically directed towards heavy metal contamination testing. Additionally, it is recommended the CBRA continue with regular testing of all sites to maintain the Cass Bay stream health database.

8. Acknowledgements

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10. Appendices

Appendix 1. Example completed RHA field sheet. MacNeil & Holmes, 2021.

Habitat parameter	Condition category										SCORE
1. Deposited sediment	*The percentage of the stream bed covered by fine sediment.*										9
	0	*5*	*10*	*15*	*20*	*30*	*40*	*50*	*60*	*≥ 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
2. Invertebrate habitat diversity	*The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space score higher.*										7
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
3. Invertebrate habitat abundance	*The percentage of substrate favourable for EPT colonisation, for example flowing water over gravel-cobbles clear of filamentous algae/macrophytes.*										9
	95	*75*	*70*	*60*	*50*	*40*	*30*	*25*	*15*	*5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
4. Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.*										3
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
5. Fish cover abundance	*The percentage of fish cover available.*										9
	95	*75*	*60*	*50*	*40*	*30*	*20*	*10*	*5*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
6. Hydraulic heterogeneity	*The number of of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulance, backwater. Presence of deep pools score higher.*										7
	≥ 5	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
7. Bank erosion	*The percentage of the stream bank recently/actively eroding due to scouring at the water line, slumping of the bank or stock pugging.*										8
Left bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
Right bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
8. Bank vegetation	*The maturity, diversity and naturalness of bank vegetation.*										4
Left bank AND Right bank	*Mature native trees with diverse and intact understorey*		*Regenerating native or flaxes/sedges/tussock > dense exotic*			*Mature shrubs, sparse tree cover > young exotic, long grass*			*Heavily grazed or mown grass > bare/impervious ground.*		
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
9. Riparian width	*The width (m) of the riparian buffer constrained by vegetation, fence or other structure(s).*										3
Left bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
Right bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
10. Riparian shade	*The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).*										1
	≥ 90	*80*	*70*	*60*	*50*	*40*	*25*	*15*	*10*	*≤ 5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
TOTAL	(Sum of parameters 1-10)										60

Appendix 2. Rapid Habitat Assessment field sheet. Clapcott 2015/Cawthron 2023.

Habitat parameter	Condition category										SCORE
1. Deposited sediment	*The percentage of the stream bed covered by fine sediment.*										
	0	*5*	*10*	*15*	*20*	*30*	*40*	*50*	*60*	*≥ 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
2. Invertebrate habitat diversity	*The number of different substrate types such as boulders, cobbles, gravel, sand, wood, leaves, root mats, macrophytes, periphyton. Presence of interstitial space score higher.*										
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
3. Invertebrate habitat abundance	*The percentage of substrate favourable for EPT colonisation, for example flowing water over gravel-cobbles clear of filamentous algae/macrophytes.*										
	95	*75*	*70*	*60*	*50*	*40*	*30*	*25*	*15*	*5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
4. Fish cover diversity	*The number of different substrate types such as woody debris, root mats, undercut banks, overhanging/encroaching vegetation, macrophytes, boulders, cobbles. Presence of substrates providing spatial complexity score higher.*										
	≥ 5	*5*	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
5. Fish cover abundance	*The percentage of fish cover available.*										
	95	*75*	*60*	*50*	*40*	*30*	*20*	*10*	*5*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
6. Hydraulic heterogeneity	*The number of of hydraulic components such as pool, riffle, fast run, slow run, rapid, cascade/waterfall, turbulance, backwater. Presence of deep pools score higher.*										
	≥ 5	*5*	*4*	*4*	*3*	*3*	*2*	*2*	*2*	*1*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
7. Bank erosion	*The percentage of the stream bank recently/actively eroding due to scouring at the water line, slumping of the bank or stock pugging.*										
Left bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
Right bank	*0*	*≤ 5*	*5*	*15*	*25*	*35*	*50*	*65*	*75*	*> 75*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
8. Bank vegetation	*The maturity, diversity and naturalness of bank vegetation.*										
Left bank AND Right bank	*Mature native trees with diverse and intact understorey*		*Regenerating native or flaxes/sedges/tussock > dense exotic*			*Mature shrubs, sparse tree cover > young exotic, long grass*			*Heavily grazed or mown grass > bare/impervious ground.*		
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
9. Riparian width	*The width (m) of the riparian buffer constrained by vegetation, fence or other structure(s).*										
Left bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
Right bank	*≥ 30*	*15*	*10*	*7*	*5*	*4*	*3*	*2*	*1*	*0*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
10. Riparian shade	*The percentage of shading of the stream bed throughout the day due to vegetation, banks or other structure(s).*										
	≥ 90	*80*	*70*	*60*	*50*	*40*	*25*	*15*	*10*	*≤ 5*	
SCORE	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	
TOTAL	(Sum of parameters 1-10)										