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National Water Quality Values in New Zealand: Policy-Relevant Stated Preference Estimates

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Abstract:

Governments need tools to analyze trade-offs and inform freshwater policy. Although there is a large stated preference (SP) literature valuing changes in freshwater quality, the estimates often cannot be transferred to policy analyses. Obstacles to benefit transfer include (i) difficulties in scaling up local estimates to the national level, (ii) the use of water quality attributes that cannot be linked to policy-relevant measures, and (iii) surveys with water quality changes that don't represent realistic policy. Focusing on rivers and streams in New Zealand, a country that has received international attention for efforts to protect its water resources, we develop and implement a nationwide discrete choice SP study that can be more appropriately used in benefit transfer. The stated provision mechanism and environmental commodity being valued are specified at the regional council-level, which is the administrative unit for policy implementation. The survey is administered on a national scale, to just over 2,000 respondents. Therefore, our results can easily be applied to regional freshwater policies or scaled up to inform federal actions. The discrete choice experiment attributes – nutrients, water clarity, and e. coli – were chosen because they align with government policy levers and were found to be the most relevant and salient to the general public. Estimation results suggest people are willing to pay for improvements in all three water quality attributes with magnitudes that are roughly comparable to a recent Auckland referendum vote on a water quality tax. We also find that willingness to pay varies across regions, types of recreation that a user engages in, and other respondent characteristics, although notable unobserved heterogeneity remains unexplained. To illustrate the utility of our study, we apply the results to a recent policy analyzed by New Zealand's Ministry for the Environment and estimate nationwide annual benefits of NZ \$115 million (\$77 million USD).

Keywords: Water Quality, Benefit-Cost analysis, Stated Preference, Choice Experiment, Willingness to pay, Valuation

JEL Codes: Q25, Q51, Q58

DISCLAIMER

The views expressed in this paper are those of the author(s) and do not necessarily represent those of the U.S. Environmental Protection Agency (EPA). In addition, although the research described in this paper may have been funded entirely or in part by the U.S EPA, it has not been subjected to the Agency's required peer and policy review. No official Agency endorsement should be inferred.

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I. Introduction¹

New Zealand's freshwater is a critically important resource that fuels agriculture, recreation, cultural practices, and various other activities and productive resources. New Zealand has had many national and regional efforts aimed at improving water quality² and received international attention in 2017 by declaring the Whanganui River a legal person.³ However, the quality of New Zealand's freshwater waterbodies continue to decline: more than two-thirds of rivers exceed the government's nitrogen or phosphorous limits (MFE and Stats NZ 2019), and in a recent national survey the public ranked the condition of rivers and lakes the lowest among New Zealand's environmental amenities (Hughey et al. 2016). To inform substantive change, the government needs tools to analyze trade-offs in water quality policy options. Section 32 of New Zealand's Resource Management Act (1991) requires an identification and assessment of the benefits and costs of environmental policies and rules, but existing literature is not well-suited to analyze national policy, especially with water quality.

Although there are multiple studies on water quality valuation in New Zealand, including several stated preference (SP) studies (see (Marsh and Mkwara 2013) and (Harris et al. 2016)), applying this existing literature to government policies has been difficult. These difficulties arise from several issues, including scaling up local estimates to the national level, studies using large water quality changes that do not represent actual policy changes, and the use of subjective or aggregate water quality variables that cannot be linked to policy-relevant measures. These are common issues found throughout the international literature on water quality valuation (Moran and Dann 2008, Griffiths et al. 2012, Newbold et al. 2018).

We designed and implemented a national SP survey with explicit attention given to the use of the results for future benefit transfer. Our discrete choice experiment utilizes three water quality parameters – nutrients, water clarity, and e. coli levels—chosen to align with government policy levers and to be relevant and salient to the public. The choice experiment presents policy changes at the regional council level, which corresponds to the administrative unit for most environmental policies in New Zealand.⁴ The policy changes presented to respondents are also more in-line with the outcomes of actual policies, as compared to many past studies that present unrealistically large water quality changes in the environmental commodity (Newbold et al. 2018). Furthermore, the borders of New Zealand's regional councils are based around watersheds and catchments, so there are less cross-boundary pollution concerns compared to administrative units in other countries. The results of this study are particularly useful for benefit cost analysis within New Zealand, and the methods provide a framework for studies in other countries to better align with policy.

We find that people are willing to pay for improvements in all three water quality parameters, and identify respondent characteristics that drive observed heterogeneity in willingness to pay (WTP). Accounting for such heterogeneity allows the results to be tailored to sub-national areas in a benefit transfer, at the same time we do find and control for significant unobserved heterogeneity in WTP. We apply our results to a recent water quality policy proposed by New Zealand's Ministry for the Environment (MFE), to reduce sediment runoff (Neverman et al., 2019). Benefits transfer based on our survey results suggests nationwide annual benefits of about NZ \$144 million (2018, or approximately \$99 million USD), and illuminates notable differences between regional councils. We compare our results to a recent municipal vote on an Auckland property tax designed to raise over \$500 million NZD in the next ten years for water quality improvements. The vote was successful, with the resulting tax applied to commercial and residential buildings, which exemplifies the large values residents have for water quality.

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² <https://www.pce.parliament.nz/publications/managing-water-quality-examining-the-2014-national-policy-statement>

³ <https://www.nationalgeographic.com/culture/2019/04/maori-river-in-new-zealand-is-a-legal-person/>

⁴ New Zealand is composed of 16 different regional council areas.

II. Background

Freshwater resources are an integral part of the cultural heritage, economic development, and national character of New Zealand (NZ) (Ambrey et al. 2017, Awatere et al. 2017). From a Māori world view, the separation of Ranginui (sky father) and Papatūānuku (earth mother) produced freshwater, emphasizing both its importance and connection to Māori people, who share a whakapapa (genealogy) with Ranginui and Papatūānuku.⁵ Given this importance, there are several existing water quality valuation studies, but many are unpublished, in the grey literature, or are government reports (Miller 2014, Phillips 2014, Tait et al. 2016) or consulting reports that do not yield original estimates (Marsh and Mkwara 2013). Several studies focus on only one region of NZ (Tait et al. 2011, Marsh and Phillips 2015). Transferring the results of these case studies to policies and populations in other areas or at the national level is difficult and could result in large errors (Smith and Pattanayak 2002).

The NZ-based SP literature has examined several different water quality indicators. Some of these indicators are related to agricultural practices, such as riparian buffer restoration (Cullen et al. 2006) or nutrient leaching (Baskaran et al. (2009), Takatsuka et al. (2009)). Tait et al. (2011) value the ecological condition of waterbodies using poor, fair, and good quality categories. These categories are described by the type of weeds present, percent algae cover, and the types of insects and fish species present. Swimming suitability indicators of waterbodies have also been used (Marsh (2012), Miller (2014), Miller et al. (2015)) to represent recreation and health impacts. Marsh and Phillips (2015) use several different indicators of water quality alongside a qualitative swimming suitability measure, including ecological health, salmon and trout condition, and tributary water quality, presented qualitatively as good, satisfactory, not satisfactory, or poor. Translating many these indicators and qualitative categories to marginal changes, as predicted from policy projections, is difficult and generally inappropriate. Tait et al. (2017) use qualitative indicators like poor, moderate, and good for water clarity and ecological quality. However, they directly link each of their attributes to objective ranges in the underlying water quality parameters. For instance, poor ecological quality is defined as a Macroinvertebrate Community Index score less than 80, and poor clarity is defined as visibility of less than 1.1 meters (although it is not clear if those ranges were presented to respondents).

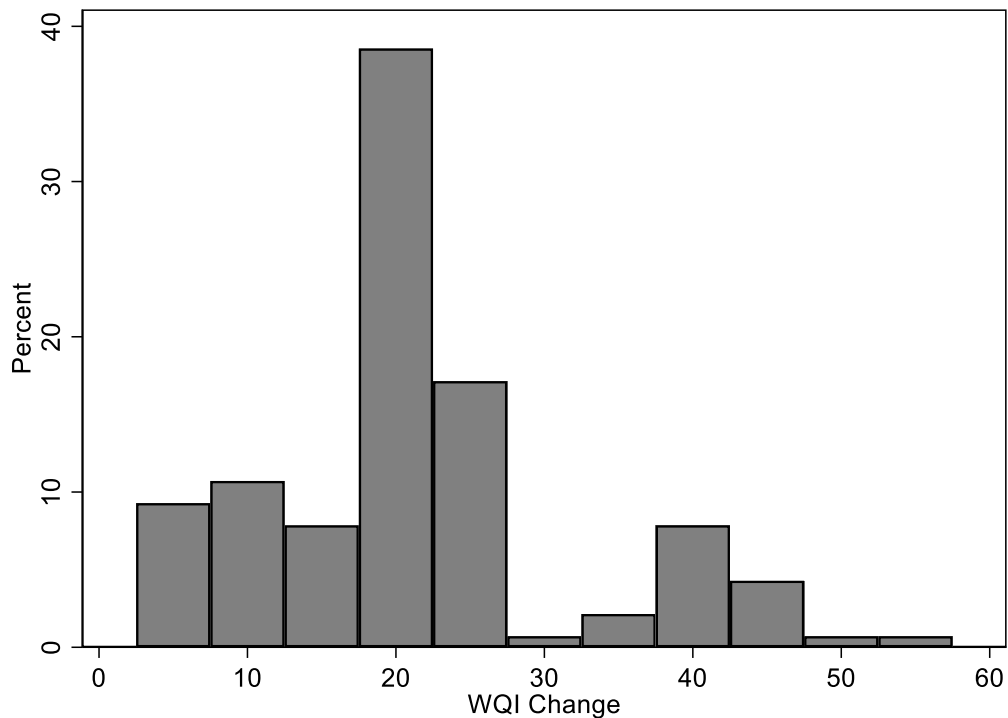
Johnston et al. (2012) provide guidelines for including ecological content in SP surveys. They note that less structured treatment of attributes can cause problems with subsequent welfare estimation as respondents' internal conceptualization of the commodity may be different from that presented or intended by the researchers. This can be a complicated balancing exercise with water quality because the commodity itself has multiple dimensions that can be difficult to communicate to survey participants.

The size of the change presented to respondents creates another issue with using previous SP estimates for benefit transfer. Miller et al. (2015), for example, have respondents compare policies that result in 0%, 20%, or 40% improvements in the percent of sites suitable for swimming. There are few plausible policies that could improve water quality (or reduce nutrient inputs) by that large of a change. Large changes in the corresponding water quality measures, on the order of 20% to 50%, are often posited in surveys (e.g. (Baskaran et al. 2009)). A meta-analysis of 140 observations from 51 stated preference studies of water quality (USEPA 2015), where quality was represented on a scale of 0-100 with 100 representing pristine waterbodies found that less than 10% of the observations used water quality indices measures under 10 (Figure 1).⁶

⁵ See <https://environment.govt.nz/assets/Publications/Files/our-freshwater-2020.pdf> for additional detail.

⁶ The 0-100 scale is the water quality index, which has been used in the stated preference literature and EPA regulation.

Figure 1: Distribution of Water Quality Index (WQI) Changes in 51 Stated Preference Surveys (USEPA, 2015)



III. Survey Design and Implementation

We considered all of the aforementioned gaps when designing the SP survey instrument used in this study; including: identifying water quality measures and changes that matter to the general public and that could be accurately understood by respondents, are realistic, and that could be directly linked to objective policy-induced changes. The ultimate commodity being valued in the SP survey is improvements in the quality of rivers and streams in the regional council where a respondent resides. The survey was implemented in 2018 and 2019. There are two versions of the survey, one for the North Island and one for the South Island of New Zealand. The surveys are identical except for bar graphs illustrating current attribute levels for each region on that island.

The survey instrument was developed and refined using focus groups and cognitive interviews.⁷ Six focus groups were conducted in total during May and June 2018 at three different locations: two focus groups each at two urban locations (Auckland and Wellington) and two in a rural area (Hawke’s Bay). Input from them was used to refine the survey text and questions, identify relevant water quality attributes, and communication and presentation. To further refine the survey instrument, ten cognitive interviews were conducted. Eight of the cognitive interviews were in Wellington and two were held in the rural Wairarapa area.⁸

Depending on where a respondent lives, the survey begins with a map of the North or South Island that includes the regions and the major rivers on that island. To emphasize consequentiality and credibility of the survey, the instructions remind respondents’ that their “... answers will help inform policy makers” and that the baseline data are provided by the MFE and regional councils. Respondents are then asked questions on recreational use and

⁷ The consultancy firm Colmar Brunton was used to help organize and run the focus groups and cognitive interviews.

⁸ A diverse set of participants were recruited for the focus groups and cognitive interviews. For example, the participants in the cognitive interviews had the following attributes – Gender: 4 male, 6 female; Age: 18-39 years (4), 40-59 years (5), 60 years and over (1); Ethnic groups: NZ European (7), Māori (3); Educational history: School leavers / no qualifications (5), Tertiary-educated (5); Household income: up to \$70,000 (3), over \$70,000 (7).

visitation to rivers and streams in their region, followed by introductory text defining each water quality attribute and figures of the current baseline levels in each region. Questions about awareness of the attributes are also presented.

The policy scenarios, provision mechanism, and payment vehicle for public programs to improve water quality in a respondent's region are then introduced. To minimize hypothetical bias and enforce consequentiality (Johnston et al. 2017, Vossler and Zawojka 2020) respondents are reminded to act as though their household is actually facing the costs presented and that their responses could influence future policies and programs, as well as costs to their household. A generic regional policy is described as the provision mechanism. The payment vehicle is specified as a permanent increase in a household's general cost of living. We provide examples of how a household's monthly living costs may increase, including increases in home maintenance costs, utility bills, rent, and food and other prices.

The survey then presents respondents an example choice question, followed by three separate discrete choice questions. Each choice scenario includes a status quo option and two policy alternatives. In the status quo option water quality attributes remain at their current levels, while in the two policy options there are improvements in one or more of the water quality attributes, as well as an associated permanent increase in monthly living costs.

The final survey instrument includes three water quality parameters: water clarity, nutrients, and e. coli. These parameters appear in several upcoming NZ freshwater policies and are well known to the public.⁹ Statistics NZ includes these parameters in their list of central water quality tracking indicators (see <https://www.stats.govt.nz/indicators/>). The representation of each parameter is also chosen to match policy-levers and is informed by input from the focus groups and cognitive interviews. Water clarity is expressed as the average visibility for rivers and streams in a respondent's region, and is measured as Secchi disk. Nutrients are measured as the percent of rivers and streams in the region that have nutrient levels considered acceptable for aquatic life by official nutrient limits.¹⁰ Similarly, E. coli is measured as the percent of rivers and streams in the region where concentrations are low enough to be considered suitable for swimming, wading, and fishing.¹¹

While the three water quality attributes described are correlated and the ecological endpoints that individuals directly care about may relate to more than one attribute in some cases (Tait et al. 2011), distinctions are drawn in the survey as to what each attribute primarily reflects. Excessive levels of nutrients are described as adversely impacting aquatic ecosystems, although reduced aesthetics are also mentioned. Water clarity is described as how "murky or cloudy" the water visually appears. E. coli is described in terms of how it affects the health of people who swim, wade, or fish in the water. Based on the past literature and our own focus group and cognitive interview findings, these categories reflect what the general public find to be the most relevant endpoints related to surface water quality. An example choice question from the survey appears in Figure 2.

⁹ For additional context, see the National Policy Statement for Freshwater Management (NPSFM) <https://www.mfe.govt.nz/fresh-water/freshwater-acts-and-regulations/national-policy-statement-freshwater-management>.

¹⁰ More information on New Zealand's nutrient limits can be found at the Statistics NZ page on river water quality: <https://www.stats.govt.nz/indicators/river-water-quality-nitrogen>.

¹¹ The Statistics NZ page on E. Coli can be found here: <https://www.stats.govt.nz/indicators/river-water-quality-escherichia-coli>

Figure 2: Example Choice Question

Which outcome do you prefer for rivers and streams in your regional council area?

	Outcomes by 2025		
	Outcome A	Outcome B	Outcome C
Nutrients <i>Increase in the percent of rivers and streams with acceptable levels. For example, a change from 25% of rivers and streams to 27% is a change of +2 percentage points</i>	No change	+ 5 percentage points	+ 1 percentage points
Water Clarity <i>Increase in average visibility in rivers and streams</i>	No change	+ 1 metre	+ 0.5 metre
E. coli <i>Increase in the percent of rivers and streams suitable for swimming, wading, and fishing. For example, a change from 32% of rivers and streams to 35% is a change of +3 percentage points</i>	No change	+ 6 percentage points	+ 8 percentage points
Permanent Increase in the Cost of Living for your Household	\$0 per month	\$6 per month (\$72 per year)	\$3 per month (\$36 per year)
Your Choice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Please select your preferred outcome	Outcome A (No change)	Outcome B	Outcome C

The size of the water quality changes presented to respondents are based on the magnitude of changes in national targets from the National Policy Statement for Freshwater Management (NPSFM; (MFE 2020), p. 64). Table 1 shows the national targets for improvements in primary contact suitability across different waterbody categories, with red being the lowest quality rivers and blue being the highest quality rivers.¹² For example, between 2017 and 2030, the goal is to have a five percentage point reduction in rivers in the worst category (red) and a three percentage point increase in rivers classified in the highest category (blue). These changes are smaller than the scenarios presented in many previous SP surveys (US EPA 2015).

Table 1: National Targets for Improvements in Primary Contact Water Bodies

Waterbody quality categories	2017 to 2030	2031 to 2040	Total change in % of water bodies
Red (lowest quality)	-5%	-6%	-11%
Orange	-4%	-4%	-8%

¹² The full figure this is drawn from appears in Appendix C.

Yellow	3%	2%	5%
Green	3%	3%	6%
Blue (highest quality)	3%	5%	8%

Each attribute and the posited changes in the attribute levels in the survey are presented in Table 2. A Bayesian efficient design was developed for the choice questions using Ngene software (ChoiceMetrics 2018). Although there is not much information on the priors for each coefficient, the sign of each parameter was informed by past NZ-based literature (Marsh et al. 2011, Tait et al. 2011, Marsh and Phillips 2015, Tait et al. 2017). One advantage of Bayesian efficient designs is that they are more robust than other designs to mis-specification of the priors (ChoiceMetrics 2018).

Table 2: Changes in Survey Attribute Levels

Attribute	Metric	North Island	South Island
Nutrients	Change in % of rivers and streams that are acceptable for aquatic life	2, 4, 8	2, 4, 8
Clarity	Change in average visibility (meters)	0.1, 0.4, 0.8	0.1, 0.4, 1
E. Coli	Change in % rivers and streams that are suitable for recreation	1, 5, 7	1, 3, 6
Cost	Permanent increase in monthly cost of living (\$NZ)	2, 6, 10, 14, 18, 20	2, 6, 10, 14, 18, 20

The SP survey module concludes with a series of questions to gauge the respondent's perceived consequentiality of their responses, and flag individuals potentially exhibiting protest and warm-glow behaviors. Such questions are used to screen the sample of respondents exhibiting potentially biasing behaviors and assess the robustness of our results. The broader survey includes socio-economic questions to allow us to examine preference heterogeneity, and possibly further tailor such heterogeneity when extrapolating benefit estimates to the broader population.

The survey was administered online by Horizons Research as a separate module in a broader survey on environmental preferences in NZ that is implemented every few years by Lincoln University (Hughey et al. 2019). Horizon Research maintains an internet panel of approximately 7,000 people. The survey was open from March to April of 2019, and 2,007 respondents participated in this effort. When compared to population data from the Census, our survey sample overrepresents individuals 60-69 years of age, those with a tertiary education, and urban populations, and under-represents individuals 18-19 years of age, people with only high school qualifications, and rural populations.¹³

IV. Methodology

We employ a random utility model (RUM) framework to analyze the data from this discrete choice experiment. In these models utility is divided into a deterministic component and a random component, represented by $v(\cdot)$ and ϵ , respectively. The utility that household i receives from alternative j is:

¹³ Details of the comparison to Census data by group can be found in Appendix 2 of Hughey et al. (2019).

$$u_{ij} = v(\mathbf{a}_j, I_i - C_j) + \varepsilon_{ij} \quad (1)$$

This specification assumes that the first component of utility is a function of the group of attributes defining each alternative \mathbf{a}_j , along with numeraire consumption ($I_i - C_j$), which is the difference between household income I_i and the cost of the alternative C_j .

In the empirical models, we also add a status quo constant (sqc_i), which represents respondents' preferences for or against the status quo option, irrespective of the attributes defining the alternative policy options. We allow for unobserved heterogeneity in the sqc_i by estimating it as a normally distributed random parameter in a mixed logit framework. In doing so, we accommodate respondents that have a bias towards or against the status quo (Moore et al. 2018).

We assume a linear specification for $v(\cdot)$. RUMs are often estimated as conditional or mixed logit specifications (Greene 2000, Haab and McConnell 2002). The conditional probability that household i would choose alternative j appears in equation (2).¹⁴

$$P_i(j | a_n, C_n) = \frac{\exp(sqc_i D_j + \beta a_j + \delta C_j)}{\sum_n \exp(sqc_i D_n + \beta a_n + \delta C_n)} \quad (2)$$

In this formulation, n refers to alternative options in a given choice occasion, D is an indicator variable denoting the status quo alternative, β is a vector of coefficients to be estimated, and δ is the coefficient on the cost attribute. δ can be interpreted as the negative of the marginal utility of income. We explore individual-level preference heterogeneity in two ways. First, we include several interaction terms between the main choice attributes and observed household characteristics, including household-specific socio-economic variables like income and household size, recreational user-related variables, and baseline regional water quality. Second, we explore possible unobserved preference heterogeneity by allowing β to vary as a random coefficient across respondents with each element of β following an independent normal distribution. The cost parameter δ is held fixed to ensure MWTP has defined moments (Layton and Brown 2000, Revelt and Train 2001, Daly et al. 2012). The mixed logit models and subsequent calculations are estimated using Stata statistical software (StataCorp 2021).

Welfare measures can be inferred from the estimated parameters. For example, under the linear specification in equation (2), the vector of household marginal willingness to pay (MWTP) estimates can be calculated as:

$$MWTP = -\frac{\beta}{\delta} \quad (3)$$

¹⁴ Subscript t denoting each choice occasion is omitted here for notational ease, but note that each respondent faces T=3 choice questions in the empirical analysis. When estimating the individual-level parameters in the mixed logit models we account for the fact that each respondent faces multiple choice questions, and allow the disturbances (ε_{ij}) to be correlated across all alternatives and choice occasions an individual faces.

Given a projected policy change in the attribute levels from the baseline of a^0 to a^1 , and based on our assumed linear functional form, we can calculate the non-marginal welfare change for a household as

$$WTP = MWTP \times (a^1 - a^0) \quad (4)$$

Notice that we exclude the sqc_i estimates from our welfare calculations. This status quo term captures a respondent’s tendency to favor or disfavor the status quo option irrespective of the improvements and costs defining the alternative policy options. The status quo term could therefore be capturing alternative, omitted variable biases that would otherwise confound the welfare estimates (Moore et al., 2018). For example, sqc_i could be capturing the “warm-glow” of environmental action, which is not directly related to the policy change or attribute levels. Alternatively, this term could be capturing legitimate preferences for or against a policy and therefore could be included it in welfare calculations. However, the implications of including sqc_i in welfare calculations for benefit transfer is unclear, especially if the same primary study estimates are transferred to numerous, iteratively implemented policies, as is often the case (Petrolia et al. 2021). To be conservative and ensure that the welfare calculations are as unbiased as possible, we exclude sqc_i from the welfare calculations.

V. Data

Of the 2,007 respondents that took the survey, 1,736 completed all three choice questions (86%), 26 completed two (1.3%), and 7 respondents completed only one (<1%). The remaining 238 respondents (12%) did not respond to the choice questions and are excluded from the analysis. Among the 1,769 respondents that answered at least one choice question, 73% are from the North Island (especially Auckland, Bay of Plenty, Waikato, and Wellington), 24% of the respondents are from the South Island (and in particular, Canterbury), and 3% did not provide their region (Table 3).

Table 3. Sample size by regional council in the North and South Islands.

North Island	Unscreened	Fully screened	South Island	Unscreened	Fully screened
Auckland	509	413	Canterbury	238	178
Bay of Plenty	106	89	Marlborough	24	20
Gisborne	12	11	Nelson	27	23
Hawkes Bay	55	47	Otago	80	63
Manawatu-Wanganui	96	73	Southland	27	17
Northland	65	53	Tasman	16	15
Taranaki	37	34	West Coast	9	9
Waikato	128	102			
Wellington	281	217			
Total	1,289	1,039	Total	421	325

Note: Among the n=1,769 respondents, 59 did not provide information on the region where they live and are excluded from the above table.

To reduce the potential influence of biasing behaviors sometimes associated with stated preference methods, we screen the sample based on a combination of responses to the choice and debriefing questions. Based on the criteria below we identify and flag respondents as potentially exhibiting the following behaviors:

- *Consideration of other waters omitted from the choice experiment:* Respondents who disagreed with the statement that they only considered rivers and streams in their region.

- *Hypothetical bias due to warm-glow*: Respondents who always chose the highest cost option in each choice question they were presented, and who agreed with the statement that it is important to improve water quality no matter how high the costs.
- *Treated responses as nonconsequential*: Respondents who disagreed with the statement that they made their choices as if the presented water quality improvements or increased costs would actually be experienced.
- *Protest response*: Respondents who always chose the status quo option, and who agreed with one of the following statements: (i) that they value water quality improvements but their household should not have to pay for it, or (ii) that they are against more regulations and government spending.

Table 4 shows how the sample size changes as we screen out respondents exhibiting responses that one would expect to bias MWTP upwards (going from left to right), and that could bias MWTP downwards (going from top to bottom). The diagonal displays the sample sizes as we treat potential upward and downward biases symmetrically (Banzhaf et al. 2006, Moore et al. 2018). The upper left-corner shows the full sample size of 1,769 respondents who answered at least one choice question and the bottom-right corner shows that 1,364 respondents remain after fully screening out those who were flagged as exhibiting potentially biasing behaviors.

Table 4. Number of respondents in sample under alternative screening criteria.

		Eliminate upward biasing behaviors		
		<i>None</i>	<i>Other waters</i>	<i>Other waters and Warm-glow</i>
Eliminate downward biasing behaviors	<i>None</i>	1,769	1,525	1,480
	<i>Nonconsequential</i>	1,612	1,444	1,405
	<i>Nonconsequential and Protest</i>	1,564	1,403	1,364

When estimating the regression models, observations are weighted to account for differences in sampling intensity, response rates, and sample screening across regions. We weight the observations in our regression models to ensure that the sample appropriately represents the population across the regions, which in turn allows interpretation of the estimates as national averages. The weight assigned to each respondent is the total population in their council region divided by the region-specific sample size after screening.

The survey also included several questions about respondents’ recreational activities in rivers and streams and respondents’ awareness of existing water quality levels in their region. Respondents were asked about activities they did at rivers and streams in their regional council area in the last 12 months, and could choose multiple options from the following categories:

- Swimming or wading
- Fishing
- Boating, including sailing, and motor boating
- Water skiing, jet skiing, or kayaking
- Actively viewing nature (for example: bird watching)
- Biking or walking on trails/paths alongside the water
- I didn’t visit rivers or streams in my regional council area in the last 12 months

The responses to these questions were aggregated into three user categories: Contact Users (including water skiing, jet skiing, or kayaking, swimming or wading), non-Contact Users (including fishing, sailing, or motor boating), and Passive Users (those actively viewing nature, biking, or walking). Respondents can fall into more than one user category. After respondents were presented with baseline graphs and explanations of each water quality parameter, they were asked if they were aware of the characteristics or impacts of nutrients and E. Coli, and whether clarity levels met their expectations. Table 5 summarizes the percent of respondents that fall into the user categories and percent of respondents who were aware of existing water quality levels.

There is some noticeable variation in how respondents use the rivers and streams in their regions (Table 5). For example, Nelson and Marlborough are areas known for their beaches and coastal amenities and so it is no surprise that a high proportion of respondents engage in water contact recreation in rivers and streams as well. Respondents in the West Coast Region also had very high participation in recreation, although the number of respondents there was small (see Table 3).

Table 5: Types of Users of Rivers and Streams and Percent Aware of Existing Water Quality Levels by Regional Council

Regional Council	% Contact User	% Non-Contact User	% Passive User	% Aware Nutrients	% Aware Clarity	% Aware E. Coli
Auckland	39.8	47.7	43.8	56.1	67.8	49.6
Bay of Plenty	41.5	66	62.3	66.4	77.6	43
Canterbury	37.7	53.1	50	59.4	74.1	47.9
Gisborne	50	33.3	33.3	69.2	61.5	38.5
Hawke's Bay	56.7	60	60	72.7	89.1	49.1
Manawatu-Whanganui	42.3	55.8	53.8	69.8	83.3	41.7
Marlborough	75	66.7	66.7	62.5	87.5	58.3
Nelson	75	50	41.7	55.6	70.4	44.4
Northland	44	56	52	69.2	72.3	46.2
Otago	56.1	53.7	51.2	73.8	81.3	55
Southland	42.9	50	42.9	59.3	70.4	29.6
Taranaki	43.8	25	18.8	60.5	81.6	23.7
Tasman	57.1	85.7	85.7	76.5	76.5	47.1
Waikato	40.6	55.1	53.6	62.8	70	47.7
Wellington	33.3	45.1	43.8	65.2	78.2	42.4
West Coast	100	100	100	100	88.9	77.8

VI. Results

Regression Results

Results from the econometric models estimated using the fully screened sample of respondents are presented in Table 6. The first column shows the results from our base model that includes only the water quality attributes, the cost parameter, and a status quo constant (SQC), with standard errors appearing in parentheses. In this model and each of the subsequent variations, the coefficients corresponding to the water quality variables are treated as random parameters. In models (2)-(5) additional variables are interacted with the water quality variables. The coefficients on those interaction terms are held fixed. In essence, the interaction terms capture observed heterogeneity by shifting the distributions of the random coefficients, which capture any unobserved heterogeneity.

The positive and statistically significant coefficients corresponding to the water quality attributes in Model (1) suggest that respondents are more likely to choose an option with larger improvements in water clarity, and higher proportions of waters meeting the government standards for nutrient and E. Coli levels. The coefficient corresponding to the cost attribute is negative and significant, suggesting that respondents are less likely to choose an option as costs increase, which is consistent with having a positive marginal utility of income. Finally, the SQC is negative and statistically significant; suggesting a tendency for respondents, on average, to favor a policy option irrespective of the improvements and costs defining that option. Such potentially biasing tendencies are controlled for by the inclusion of the SQC and are not included in subsequent welfare calculations. The large and statistically significant standard deviation estimate for the SQC suggests significant heterogeneity across respondents. Similarly, the statistically significant standard deviation terms for the water quality attributes in model 1 suggest significant unobserved heterogeneity in preferences for water quality across respondents. In the subsequent models we add interaction terms to try and better explain some of this preference heterogeneity.

Model (2) adds interaction terms between each water quality attribute and (i) the corresponding region-specific baseline level of that attribute and (ii) a measure of the quantity (total length) of rivers in the regional council area. Both attributes were presented to respondents in the survey information (see Appendix). The nutrients improvement interaction with river km is positive and significant while the clarity interaction with river km is negative. The clarity result goes against initial expectations that WTP would increase with the quantity of waters that experience an improvement but may reflect the importance of substitutes. Perhaps respondents do not care about clarity improvements as much if they live in areas where there is an abundance of rivers to choose from. On the other hand, this finding may also reflect differences in preferences between urban and rural areas. Two of the three largest cities in New Zealand are in the Auckland and Wellington regions, which have comparatively low total lengths of rivers (see Appendix). The positive coefficient corresponding to the nutrients and river km interaction term provides some evidence of scope sensitivity – i.e., respondents WTP is increasing for improvements that occur to a greater quantity of waters.

Models (3)–(5) include additional interactions with the user-related variables. Across these models, non-contact users, or people that fish and boat, are willing to pay less for improvements in each water quality parameter. Although excess nutrients are generally bad for aquatic environments (especially in large levels), some fisherwomen and men may believe that more nutrients equal more fish. While some species do benefit from additional nutrients, those benefits stop after a certain point (National Research Council 2000). The positive coefficient estimates on *E.Coli*Passive* and *Clarity*Passive* suggest that passive users have a greater preference for reductions in *E. Coli* contamination and improvements in clarity relative to nonusers (all else constant). These results are not completely robust across models (3)-(5), however.

Model (4) includes interaction terms between each water quality attribute and (i) an indicator for achieving at least a Bachelor's degree and (ii) with variables describing respondents' awareness of the negative effects of elevated nutrient and E. Coli levels, and of current clarity levels.¹⁵ The results from the previous models are robust. We find, a positive and significant interaction with *Bachelors* and *Clarity*, suggesting that more educated respondents value improvements in clarity more. Otherwise, there is no evidence of preference heterogeneity with respect to education.

The coefficients corresponding to the *Nutrients*Aware* and *Clarity*Aware* interaction terms are positive and significant, while the *E.Coli*Aware* coefficient is significant and negative. These finding suggest that respondents who are aware of the negative impacts of nutrients and whose priors for clarity matched current levels are willing to pay more, while those informed of the negative effects of E. Coli are willing to pay less. The descriptive statistics

¹⁵ The nutrient and E. Coli awareness variables are based on a binary variable denoting whether respondents said they are aware of “the negative effects that nutrients can have on aquatic plants and animals” and “the negative effects E. coli can have on the suitability of rivers and streams for swimming, wading, and fishing.” The awareness variable for clarity asks respondents how the provided average clarity level in their region compares to their priors. In these regressions, a dummy is used for “about what I expected.”

(Table 5) show that awareness of E. Coli's negative effects was much lower than the other measures in every region, with less than 50% in all but 3 regions.

Model (5) includes all the previous variables and an interaction term between a dummy variable denoting high income earners and the cost parameter. That interaction term is insignificant (as was a low-income interaction in an alternate model), indicating that the impact of policy cost does not vary across respondents of different income levels. The results from model (5) are mostly consistent with the earlier models in terms of the signs and significance of coefficients. However, the *Clarity*Passive* and *Clarity*Baseline* variables are now significant at the 10% level.

At the bottom of the table, the estimated standard deviation terms remain statistically significant and similar in magnitude across all the models suggesting that there is still unobserved preference heterogeneity across respondents, despite our best efforts to identify and control for the sources of such heterogeneity. Comparisons of the AIC and BIC criteria across all models support Model (5), the most complex model in terms of included covariates, as the best overall model in fitting the data.¹⁶

Table 6: Econometric Coefficient Results using the Fully Screened Sample

Model	(1)	(2)	(3)	(4)	(5)
Cost	-0.0057*** (0.0008)	-0.0054*** (0.0008)	-0.0056*** (0.0008)	-0.0055*** (0.0008)	-0.0053*** (0.0008)
Nutrients	0.1444*** (0.0264)	0.0639 (0.0626)	0.1412*** (0.0305)	0.1028*** (0.0375)	0.0498 (0.0656)
Clarity	0.6908*** (0.1720)	0.8352*** (0.2724)	0.6234*** (0.1922)	0.6850*** (0.2213)	0.7387** (0.3117)
E Coli	0.1499*** (0.0208)	0.1130*** (0.0361)	0.1422*** (0.0251)	0.0702** (0.0338)	0.0383 (0.0438)
Status Quo	-2.0161*** (0.3738)	-1.8620*** (0.3789)	-2.1118*** (0.3708)	-2.0902*** (0.3735)	-1.7709*** (0.3748)
Nutrients*Baseline		0.0009 (0.0013)			0.0001 (0.0013)
Clarity*Baseline		0.1423 (0.1076)			0.1756* (0.1049)
E.Coli*Baseline		0.0014* (0.0008)			0.0013* (0.0008)
Nutrient*river(1000km)		0.0018** (0.0008)			0.0020** (0.0008)
Clarity*river(1000km)		-0.0133*** (0.0047)			-0.0122*** (0.0045)
E.Coli*river(1000km)		-0.0001 (0.0008)			-0.0001 (0.0008)
Nutrients*Contact User			0.0017 (0.0368)	0.0087 (0.0359)	-0.0002 (0.0370)
Clarity*Contact User			-0.0563 (0.2186)	-0.0219 (0.2152)	-0.0473 (0.2201)
E.Coli*Contact User			-0.0404 (0.0326)	-0.0319 (0.0317)	-0.0319 (0.0334)
Nutrients*NonContact User			-0.1044** (0.0429)	-0.1068** (0.0419)	-0.1006** (0.0445)
Clarity*NonContact User			-0.5757** (0.2634)	-0.4920* (0.2609)	-0.4929* (0.2749)
Ecoli*NonContact User			-0.0968*** (0.0367)	-0.0934*** (0.0358)	-0.1078*** (0.0387)
Nutrients*Passive User			0.0290 (0.0345)	0.0118 (0.0347)	0.0233 (0.0349)

¹⁶ Models with other interaction terms were also explored, including population, population density, North vs. South Island, and percent urban. Those interactions were not significant and their inclusion did not affect the other model results.

Clarity*Passive User			0.3230 (0.1978)	0.3002 (0.1978)	0.3617* (0.2026)
E Coli*Passive User			0.0695** (0.0312)	0.0462 (0.0305)	0.0540* (0.0322)
Nutrients*Bachelors				0.0013 (0.0330)	0.0226 (0.0338)
Clarity*Bachelors				0.3543* (0.1951)	0.5160** (0.2066)
E Coli*Bachelors				0.0330 (0.0295)	0.0470 (0.0311)
Nutrients*Aware				0.0776** (0.0338)	0.0776** (0.0340)
Clarity*Aware				0.0919*** (0.0325)	0.0881*** (0.0341)
E Coli*Aware				-0.4183** (0.1877)	-0.4355** (0.1925)
Cost*High Income					0.0008 (0.0011)
<hr/>					
S.D.					
Nutrients	0.3234*** (0.0313)	0.3206*** (0.0310)	0.3102*** (0.0298)	0.3080*** (0.0295)	0.3047*** (0.0288)
Clarity	1.2142*** (0.2243)	1.1609*** (0.2434)	1.1416*** (0.2026)	1.0815*** (0.2071)	1.1541*** (0.2210)
E Coli	0.2499*** (0.0361)	0.2559*** (0.0356)	0.2122*** (0.0356)	0.2131*** (0.0336)	0.2354*** (0.0365)
Status Quo	3.7548*** (0.3259)	3.7462*** (0.3177)	4.0239*** (0.3621)	3.9518*** (0.3294)	3.6753*** (0.2893)
Observations	12,219	12,219	12,219	12,177	11,835
AIC	18,942,062.5	18,884,903.0	18,870,771.2	18,701,703.0	18,167,150.4
BIC	18,942,129.2	18,885,014.1	18,870,904.6	18,701,880.7	18,167,379.2

Note: Standard errors appear in parentheses. ***, **, and * denote significance at the 99%, 95%, and 90% levels, respectively.

Willingness to Pay Estimates

To illustrate the practical implications of the econometric results, Table 7 contains the marginal WTP estimates for the first (1) model specification. That model did not include interaction variables, so (assuming the weighted sample of respondents is representative of the population) the calculated marginal WTP values represent national household averages. Results indicate that people are willing to pay up to \$25.30 annually (\$NZ, 2018) for a one percentage point increase in regional council rivers meeting nutrient standards and are thus considered acceptable in terms of ecological health. Results also suggest that respondents hold an average annual marginal WTP (MWTP) of \$12.10 for a 10 cm increase in average river water clarity. Finally, we see a \$26.25 annual MWTP for a one-percentage point increase in the quantity of rivers within a region that meet E. Coli standards and are therefore deemed safe for swimming.

Table 7: Marginal Willingness to Pay in NZD for Model 1

	Model 1
Nutrients MWTP (+1 percentage point)	25.30*** (7.02)
Clarity MWTP (+10 cm Secchi disk depth)	12.10** (4.30)
E. Coli MWTP (+1 percentage point)	26.25*** (6.24)

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

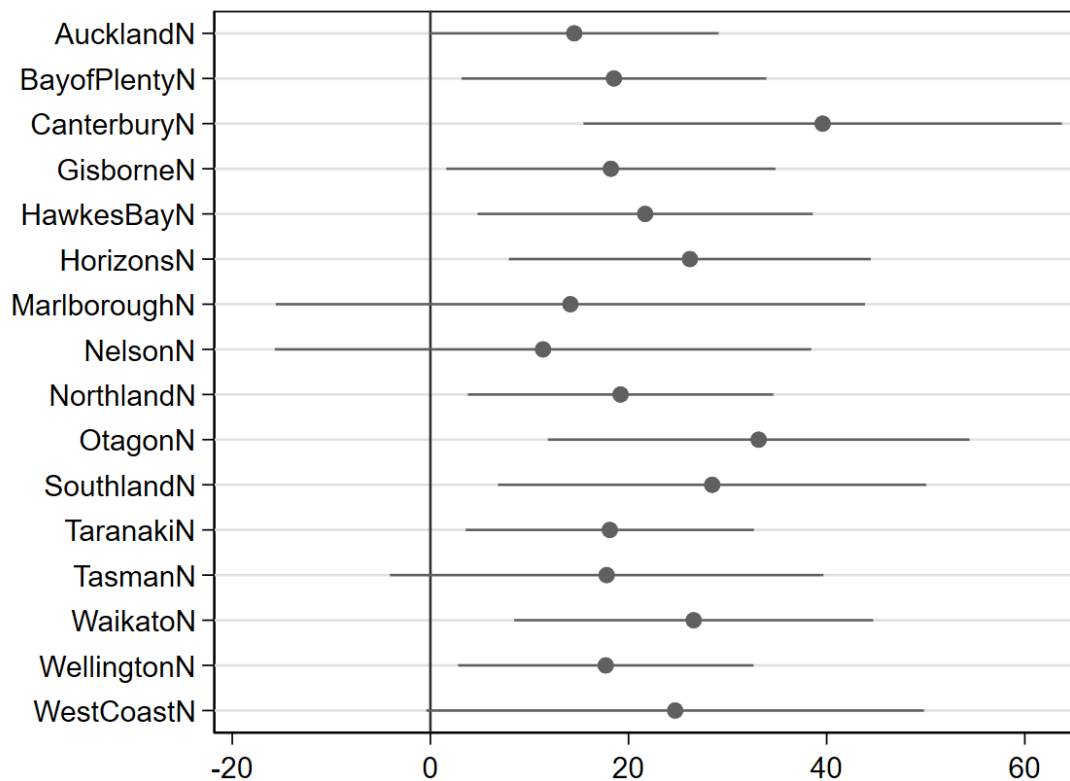
The other estimated models include several interaction terms with variables that allow the MWTP to vary across regions. The region-specific values for baseline water quality and quantity levels can be plugged directly into the parameterized model to predict region-specific MWTP estimates. In later models, regional population averages (or proportions) based on the NZ census are entered in for the sociodemographic characteristics. Finally, sample proportions of respondents in each region falling under the different user and awareness categories are used to estimate the region-specific population percentages and are in turn plugged into the parameterized model.

The “average” MWTP values for each region and water quality attribute based on estimates from model (5) appear in Figure 3 along with their 95% confidence intervals. For example, the circles in the first panel show that a region-wide average one-percentage point improvement in rivers meeting the nutrient criteria is valued in the range of (a statistically insignificant) \$11.37 in Nelson to \$39.60 in Canterbury. The second panel in Figure 3 shows the MWTP values for a region-wide 10 cm increase in average clarity. These values range from \$34.12 to \$254.88. The final graph in the figure depicts the MWTP estimates for a percentage point increase in regional waterbodies meeting their E. Coli criteria, ranging from \$11.60 to \$30.07.

Overall, the results show that people are willing to pay positive amounts for improvements in water quality, on average, with notable differences across regions. There are some statistically significant differences between regions, such as between Canterbury’s MWTP for nutrients and Marlborough and Nelson’s MWTP.¹⁷ However, there is no statistically significant difference between the MWTPs that are closer to the middle of the range, like Auckland and Bay of Plenty. The MWTP in a region can also vary across the different water quality attributes. Canterbury, for instance has the highest value for nutrients, but the lowest value for clarity.

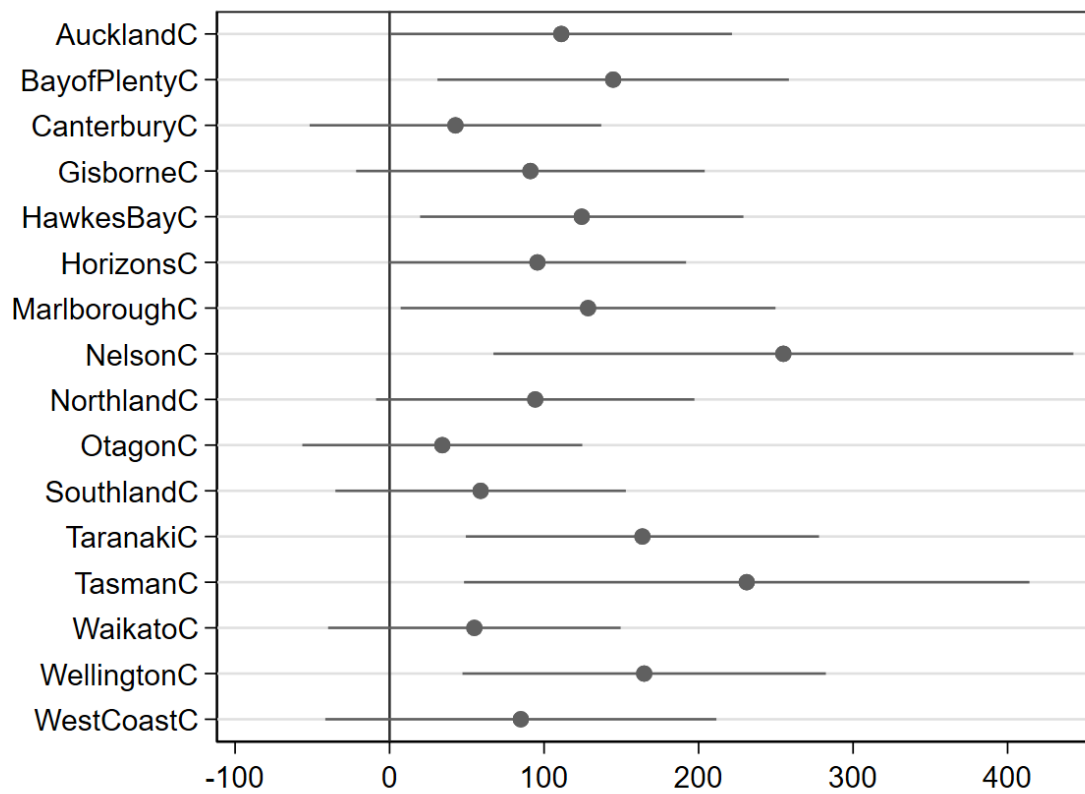
Figure 3: Average MWTP Values for each Water Quality Parameter, Across Regions

Panel 1 - Nutrients

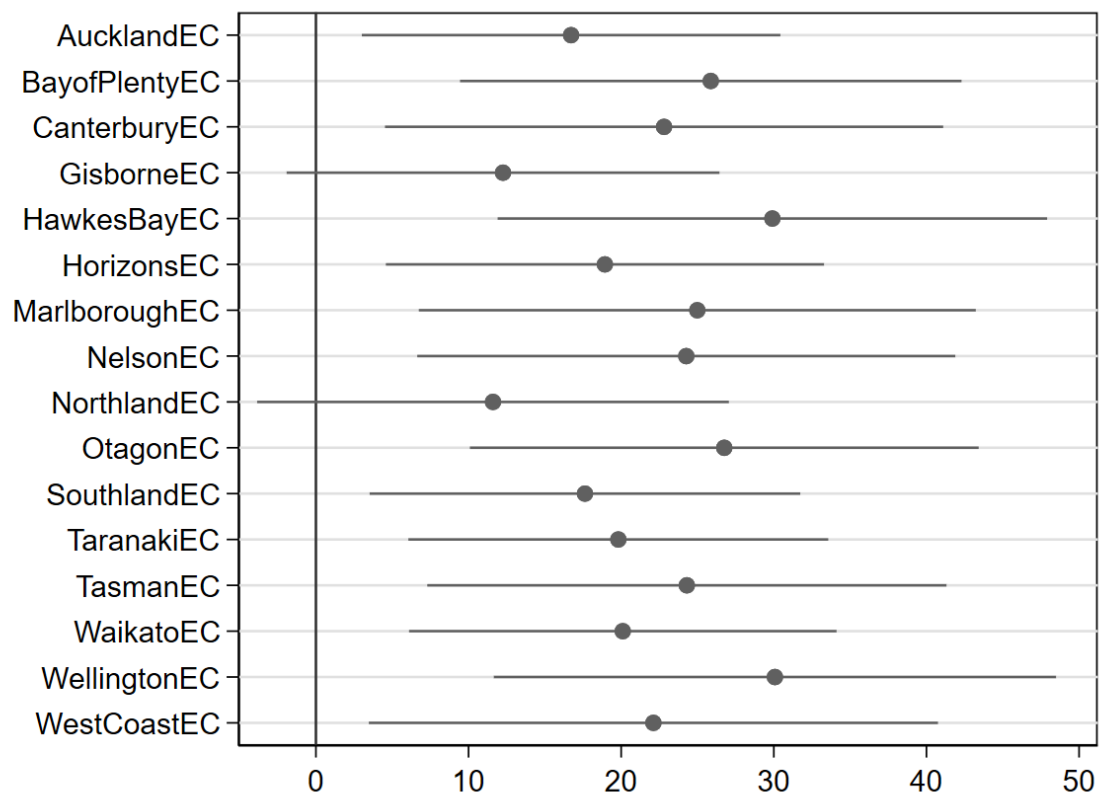


¹⁷ Based on a Wald Test that the two coefficients are equal.

Panel 2 - Clarity



Panel 3 - E. Coli



Notes: Horizontal lines in figure denote the 95% confidence intervals. The actual MWTP estimates and levels of statistical significance are presented in the Appendix.

VII. Policy Illustration

To demonstrate how these values might be applied in a policy setting, we perform a benefit transfer on a simulated national water quality improvement that was previously modeled by the National Institute of Water and Atmospheric Research (NIWA) (Hicks et al. 2016, Hicks et al. 2019). Sediment was identified as a high priority freshwater contaminant of to manage. The National Policy Statement for Freshwater Management (NPSFM) did not previously have sediment as a target, so the Ministry for the Environment (MFE) was interested in identifying the impact of proposed catchment sediment load limits.¹⁸ Catchment load limits could be achieved through land use conversions (such as converting erodible pasture into forestry) and other erosion best management practices aimed at reducing sediment from reaching waterbodies. Both in-stream sediment criteria and clarity criteria were formulated that would meet nationwide “bottom lines” in each of these four primary state variables.¹⁹ We use the NIWA modeling data on clarity that project feasible improvements in clarity as a result of catchment load limits. The modeling identifies streams and rivers with a median clarity that is below the threshold and simulates the potential improvement from the practices aimed to reduce catchment sediment loads.

To obtain the regional-council level changes for a benefit transfer, those water quality improvements are then weighted by the length of each stream/river and added together to get the reach-weighted average clarity change for each regional council area r , as in the following equation, where N_r denotes the total number of river segments in region r :

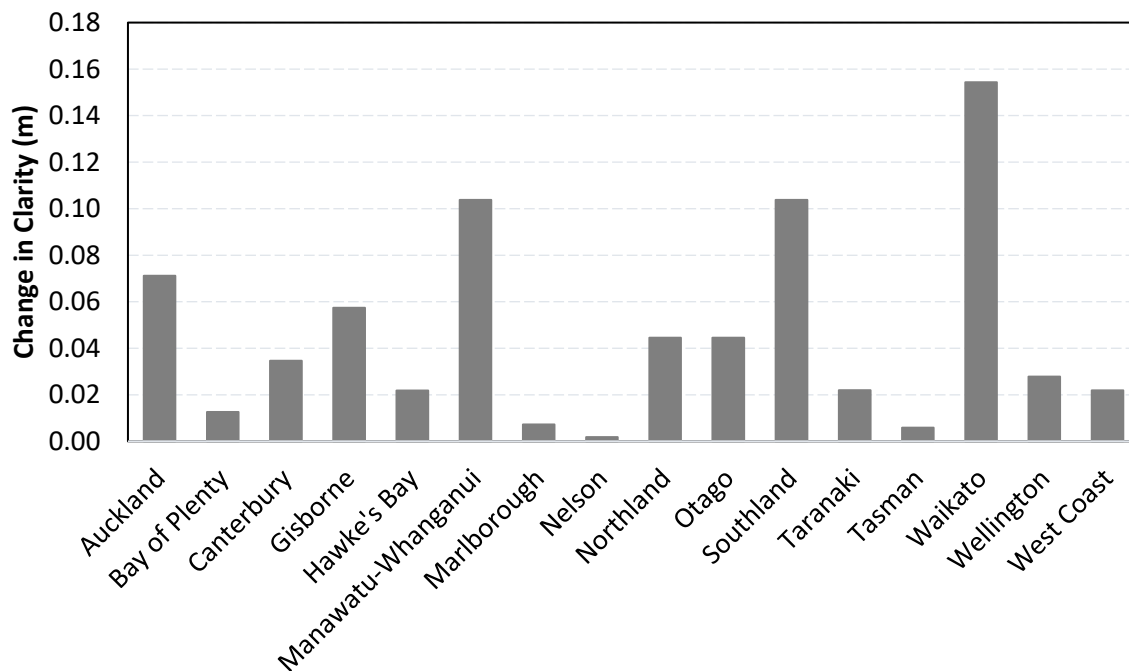
$$\text{Mean Clarity Change}_r = \sum_{j=1}^{N_r} \left(\frac{\text{Length}_{jr}}{\sum_{i=1}^{N_r} \text{Length}_{ir}} \text{Clarity Change}_{jr} \right) \quad (5)$$

A summary of these average clarity improvements appears in Figure 4. Most of the regional councils see a small average change in clarity, of under 0.1 m, with the largest change in Waikato, at 0.154 m. These changes are proportionally smaller than the changes desired by the national policy statement, pictured in Appendix C, with some changes smaller than those presented in our choice experiment questions. This exercise further illustrates the difficulty in achieving long-term goals for water quality.

¹⁸ The current version of the NPS FM can be found here: <https://environment.govt.nz/acts-and-regulations/national-policy-statements/national-policy-statement-freshwater-management/>

¹⁹ Neverman et al (2019) used a combination of economic and environmental modeling to explore cost-effective ways to achieve the suspended sediment concentration criteria.

Figure 4: Projected Mean Regional Council Clarity Improvements (m)



Although we have data on changes in clarity, we also need changes in nutrients and E. Coli. This is a common problem with monetizing water quality policy: the need to convert between different parameters (Walsh and Wheeler 2013, US EPA 2015). It is likely that the policies used to improve sediment or clarity will also improve E. Coli and nutrients. For instance, to achieve sediment load targets, Neverman et al. (2019) simulate the impact of whole farm planning and afforestation, which will also improve E. Coli and nutrient leaching to waterways.

To calculate the subsequent changes in E. Coli and nutrients associated with the clarity improvements, we use data from NZ Statistics, who publish modeled segment-level data on several water quality parameters, resulting in almost 600,000 observations for each parameter.²⁰ For E. Coli, total nitrogen, and total phosphorous, we use a regression to model the relationship between each indicator (WQ) and clarity, as shown in equation (6). Several control variables are included in X: elevation and dummies for stream order and the dominant surrounding land cover. The regression also includes regional council fixed effects, and the E. Coli regression includes dummies for the baseline “letter grade” of the stream (Appendix C). Note that to properly model the ecological relationship between these variables, a more in-depth approach should be used. However, for the purposes of this benefit transfer, these regressions establish a reasonable relationship.

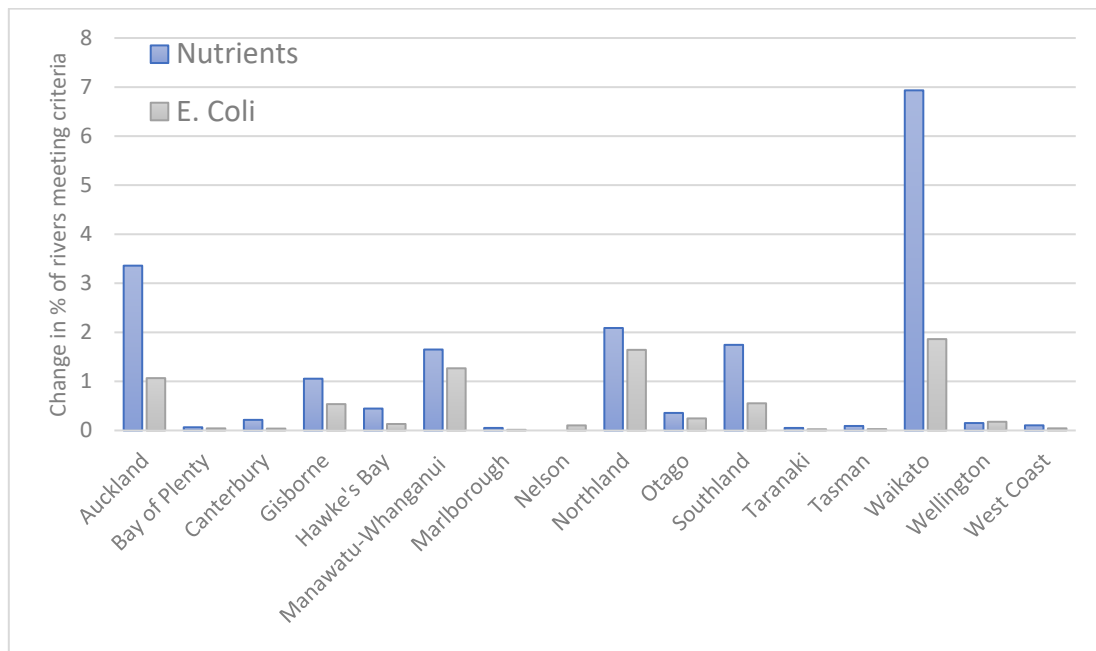
$$\ln(WQ) = \beta \ln(Clarity) + \delta X + \gamma + \varepsilon \quad (6)$$

Regression results appear in Appendix E, and exhibit significant negative relationships between the natural log of clarity and each indicator. The estimated relationship with E. Coli is slightly lower than Davies-Colley et al. (2018), however they use a simple correlation coefficient of -0.54. Our estimated coefficients are used to translate the change in clarity into the other indicators. Using the government thresholds referenced above, we can then determine which changes result in a waterbody moving from exceeding the threshold to not exceeding. For instance, with the E. Coli government criteria, river and stream segments are assigned a letter grade from A to E,

²⁰ For instance, modeled E. Coli data for each river and stream segment can be downloaded from <https://www.stats.govt.nz/indicators/river-water-quality-escherichia-coli>.

with D and E being unsafe for swimming.²¹ If the forecast E. Coli change bumps the waterbody from unsafe for swimming to safe, it is counted as no longer exceeding. The TP and TN results are combined into a nutrients indicator, so that if either exceeds its threshold the waterbody is still counted as exceeding. The projected increase in rivers meeting the E. Coli and nutrient criteria appear in Figure 5. The values in Figure 4 and Figure 5 highlight the difficulty in achieving meaningful water quality changes. Only 3-5 regional councils in each graph see water quality changes that are within the scope of the attributes presented in our survey (see Table 2).

Figure 5: Projected Improvements in the Percent of Rivers Meeting E. coli and Nutrient Criteria



The average clarity changes are monetized using the results of our preferred Model (5), the regional council level averages of the relevant interaction variables for each model, and the number of households from Stats NZ.²² Based on equation (4), the annual benefits for regional council area r in year t is calculated for each water quality attribute, using clarity as an example in equation (6), where the middle term is the mean clarity change from equation (5) above.

$$RC \text{ Annual Clarity Benefits}_{rt} = MWTP_r \times \text{Mean Clarity Change}_r \times HH_{rt} \tag{7}$$

HH_{rt} is the number of households in regional council area r in year t . The estimated average annual benefits at the household level from the change in each quality attribute appear in

Table 8, with regional council level benefits in Table 9. Waikato had the largest estimated clarity changes (Figure 5), which translate into the highest household-level benefits for two of three water quality attributes (Table 8). At the regional council level (Table 9), the largest total benefits accrue in Auckland (which also has the largest population), with approximately \$42.2 million in benefits in our preferred model. Marlborough had the lowest annual benefits at \$45 thousand.

²¹ Parameters for the criteria can be found here: <https://environment.govt.nz/assets/Publications/Files/report-on-e.coli-and-swimming-risk-may-2017.pdf>.

²² Data on households are obtained from NZ Stat: <https://www.stats.govt.nz/topics/households>. Estimates of recent annual growth in the number of households from NZ Stat are used to project the number of households for each regional council into the future.

Table 8: Annual Household-Level Benefits from Policy Illustration (in NZD)

Parameter Model	Clarity (5)	Nutrients (5)	E. Coli (5)
Auckland	7.91**	48.79*	17.84**
Bay of Plenty	1.82**	1.20**	1.09***
Canterbury	1.48	8.55***	0.87**
Gisborne	5.24	19.23**	6.58*
Hawke's Bay	2.71**	9.68**	3.94***
Manawatu-Whanganui	9.93**	43.22***	24.00***
Marlborough	0.93**	0.73	0.32***
Nelson	0.47***	0.00	2.50***
Northland	4.20*	40.10**	19.06
Otago	1.52	11.84***	6.57***
Southland	6.11	49.63***	9.76**
Taranaki	3.59***	0.93**	0.48***
Tasman	1.36**	1.63	0.67***
Waikato	8.47	184.26***	37.44***
Wellington	4.58***	2.67**	5.32***
West Coast	1.86	2.57*	0.95**

Table 9: Regional Council-Level Annual Benefits (in NZD)

	Clarity	Nutrients	E. Coli	Total
Auckland	4,475,665	27,603,716	10,092,862	42,172,243
Bay of Plenty	236,617	156,165	141,440	534,223
Canterbury	386,477	2,237,734	227,669	2,851,880
Gisborne	98,597	362,088	123,975	584,660
Hawke's Bay	183,148	653,555	266,049	1,102,752
Manawatu-Whanganui	1,032,266	4,492,181	2,494,089	8,018,536
Marlborough	21,343	16,639	7,353	45,335
Nelson	10,216	0	54,677	64,893
Northland	344,698	3,292,130	1,565,021	5,201,849
Otago	159,721	1,243,578	690,515	2,093,814
Southland	274,869	2,231,400	438,707	2,944,977
Taranaki	182,062	47,022	24,201	253,286
Tasman	32,735	39,226	16,075	88,037
Waikato	1,712,758	37,272,414	7,573,493	46,558,665
Wellington	942,873	549,718	1,094,999	2,587,589
West Coast	32,841	45,450	16,726	95,017

The estimated national annual benefits of this policy change is approximately \$115 million (Table 9). To illustrate the sensitivity of our overall estimates to model choices, Table 10 contains the total national benefits for each model. The table shows the highest benefits for the more parsimonious models (1) and (2). Our preferred model, the model that best fit the data based on BIC and AIC, yields total benefit estimates squarely in the middle of all our specifications.

Table 10: National Annual Benefits Across Models (in NZD)

Model	(1)	(2)	(3)	(4)	(5)
Clarity	1,405,058	1,516,302	9,404,867	8,732,744	10,126,886
E. Coli	36,064,345	38,449,151	26,674,132	25,025,484	24,827,850
Nutrients	99,082,639	103,796,435	70,258,975	72,620,167	80,243,018
Total	136,552,042	143,761,889	106,337,974	106,378,395	115,197,754

VIII. Discussion

Overall, our estimated choice model results show consistent positive values for several dimensions of water quality and a benefit transfer exercise demonstrated substantial benefits from even small water quality improvements. It is worth noting that although we calibrated the attribute levels in our choice sets with official government targets, many of the regional council-level changes in our policy simulation were still below those levels. This further highlights the difficulty in achieving policy-relevant changes in water quality in practice.

To further put these results into context, our estimates can be compared to recent New Zealand policy action on water quality. Auckland Council recently implemented a vote on additional taxes to improve water quality in that region.²³ The goal of the additional taxes was to raise \$400 million over 10 years through taxes on residential and business properties, as summarized in Table 11. The funds would be used for new stormwater infrastructure and other policies and programs dedicated to reducing wastewater, sediment, and other pollution.²⁴ The vote passed with approximately 65% of people voting for the rates. The vote presented residents with a choice of the status quo versus a water quality tax where both water quality and household costs would increase. This revealed preference setting overlaps with our SP discrete choice experiment. Many of the same water quality issues apply, such as reduced beach closures, reduced septic tank overflows, reduced fecal contamination, reduced sediment contamination, rehabilitation of urban and rural streams, and better stormwater infrastructure. In material distributed from the council about the targeted rate, the Council noted that an average valued home would pay an additional amount of \$66 per year.²⁵ That vote directly illustrates a positive WTP for water quality improvements in the Auckland Region and reinforces the plausibility of our estimates. For example, our policy illustration suggested the average Auckland resident is willing to pay NZ \$74.53 (\$49.94 USD) per year for moderate improvements in clarity, nutrients, and E. Coli. Without details on projected water quality improvements to result from the Auckland tax, we cannot carry out a formal test for convergent validity, but this comparison does lend credibility to our SP-based estimates.

Table 11: Description of Auckland's Water Quality Targeted Rate (Tax)

Option	Description	Outcomes
Status Quo	Continue with existing plans for water quality management under current budget.	Reduce wastewater overflows in the Western Isthmus by 2028
Institute a water quality property tax	“Deliver the best water quality outcomes” Leverage existing investments in stormwater and water quality management to achieve improved water quality outcomes in 10 years Additional stormwater infrastructure Rehabilitate urban and rural streams	Reduce wastewater overflows in the Western Isthmus by 2028 by more than current plans Reduce fecal contamination of waterways in high-risk areas.

²³ More details about the targeted tax rate (Rēti matawhāiti mō te whakapiki i te kōunga o te wai) can be found here: <https://ourauckland.aucklandcouncil.govt.nz/media/Oiyhgxcj/attachment-b-water-quality-targeted-rate.pdf> and here: <https://www.aucklandcouncil.govt.nz/environment/looking-after-aucklands-water/water-quality-targeted-rate/Pages/default.aspx>

²⁴ A video summary was also produced by the Council: <https://youtu.be/YO9ku68PwNI>.

²⁵ See <https://ourauckland.aucklandcouncil.govt.nz/media/Oiyhgxcj/attachment-b-water-quality-targeted-rate.pdf>

Introduce septic tank monitoring Total additional cost of \$856 million. \$452 million to be financed by the proposed property tax	Reduce sediment runoff to the Kaipara harbor. Improved urban and rural stream conditions.
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IX. Conclusion

This paper reports the results of a choice experiment that focused on three water quality parameters: nutrients, clarity, and E. coli. The choice experiment was administered to a national sample of respondents with the goal of instituting a rigorous study aimed at future benefit transfer. Several aspects of our approach should serve as a guide for future studies with a similar goal. First, the study used water quality measures that are not only salient and understandable to respondents, but that can be directly linked to policy for analysis. This was done by focusing on parameters that people care about, are relatively straightforward to communicate, and are relevant policy-levers. Each of the three measures in our survey are targeted by the New Zealand government’s water quality goals. Our experimental design also posed water quality changes that are more in line with the size of improvements experienced or projected from actual policy. Many previous studies use large changes in water quality that would be difficult to achieve. Finally, the choice experiment focused on water quality improvements in freshwater rivers and streams at the regional council level in New Zealand. Since regional councils are typically responsible for implementing water quality policies passed by the central New Zealand government, this represents a realistic management unit. Furthermore, New Zealand is unique in that its Regional Council borders are aligned with catchment boundaries, so there is very little cross-border pollution.

Across several model specifications, we find significant and positive values for improvements in all three water quality parameters. Our results also suggest that WTP varies with the types of recreation that a user engages in and across regions, as well as education and existing knowledge about water quality. At the same time, there is significant unobserved preference heterogeneity that is accounted for, but despite numerous attempts, remains unexplained by our models.

The utility of the results are demonstrated using a policy simulation of water clarity improvements based on recent government modeling (Hicks et al. 2019) aimed at achieving catchment-level sediment load targets. This exercise highlighted the difficulty in specifying the size of the water quality changes on a survey, as several of the simulated regional council-level improvements in water quality were lower than those in our survey. We estimate the changes in clarity, E. coli, and nutrients associated with those sediment reductions across New Zealand and apply our results in a benefit transfer exercise. The estimated annual average national benefits of a fully implemented policy are approximately NZ \$115 million (\$77 million USD) using our preferred model. Although we do not have estimates of the costs for those clarity changes, the monetized benefits should serve as a useful comparison. The benefit transfer exercise we demonstrate is straightforward and should be applicable to many upcoming policy proposals put forth by the central and regional council governments in New Zealand.

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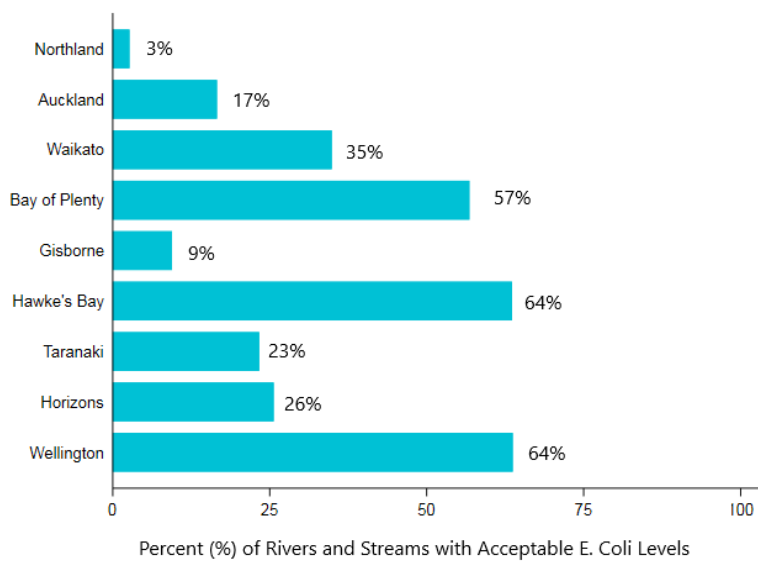
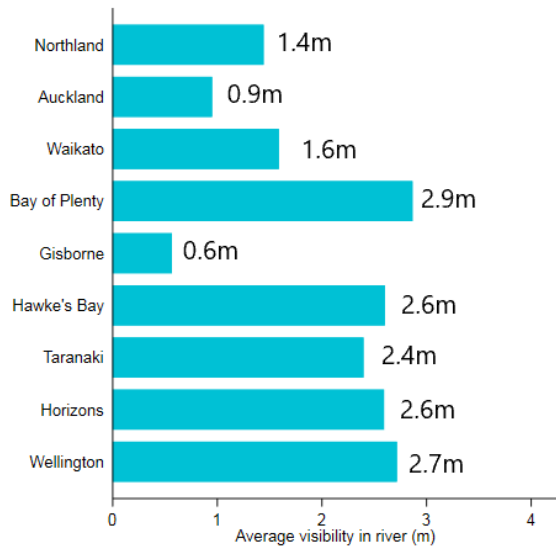
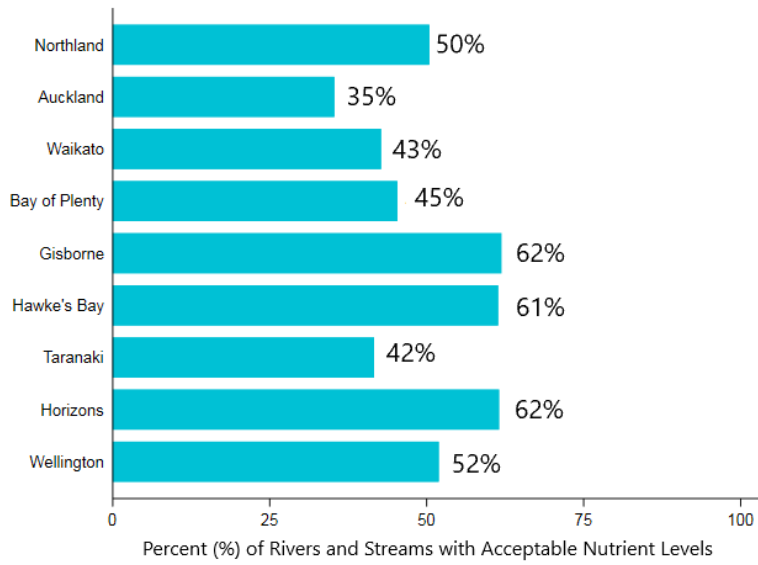
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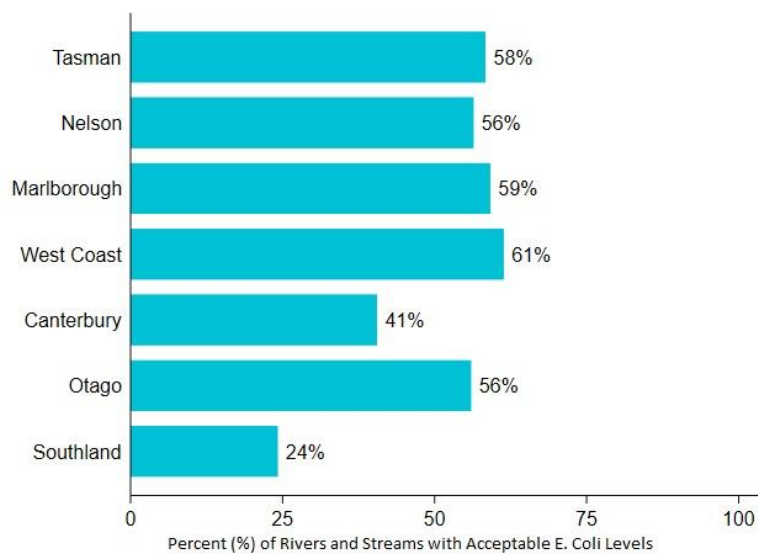
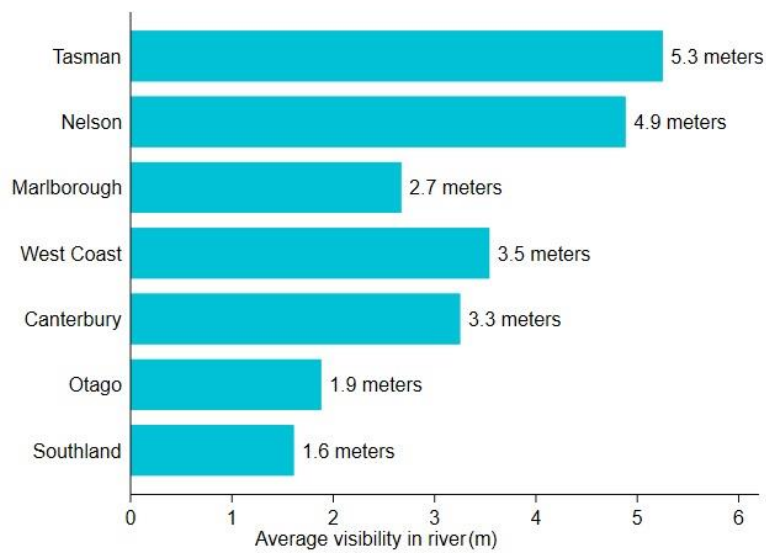
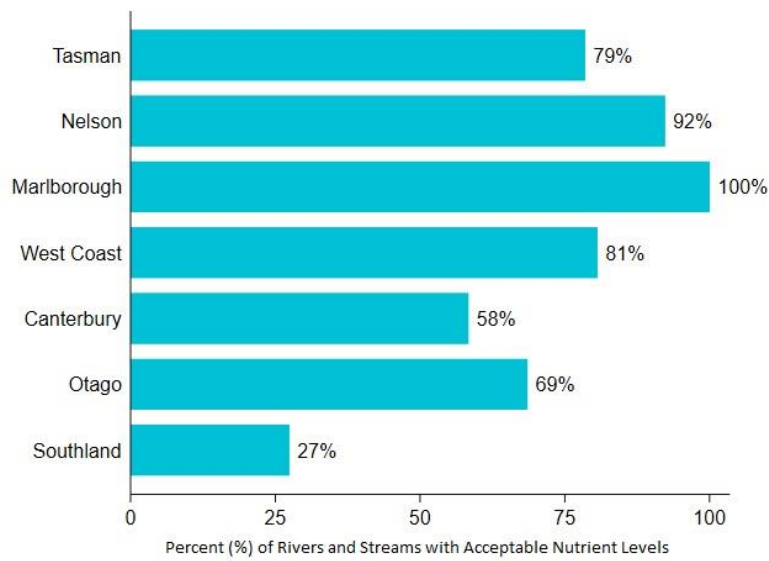
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Appendix A

Appendix Figure A1: Baseline Graphs Presented to North Island Survey Respondents



Appendix Figure A2: Baseline Graphs Presented to South Island Survey Respondents



Appendix Table A1: River Lengths and Baseline Levels

Region	River lengths (1000 km)	Baseline Nutrients	Baseline Clarity	Baseline E.Coli
Auckland	6.798	35	0.9	17
Bay of Plenty	19.283	45	2.9	57
Canterbury	70.41	58	3.3	41
Gisborne	12.655	62	0.6	9
Hawke's Bay	22.798	61	2.6	64
Manawatu-Whanganui	36.725	62	2.6	26
Marlborough	14.466	100	2.7	59
Nelson	0.598	92	4.9	56
Northland	18.558	50	1.4	3
Otago	50.269	69	1.9	56
Southland	43.604	27	1.6	24
Taranaki	12.666	42	2.4	23
Tasman	14.311	79	5.3	58
Waikato	39.641	43	1.6	35
Wellington	12.786	52	2.7	64
West Coast	35.051	81	3.5	61

Notes: Data obtained from Land Air Water Aotearoa, at <https://www.lawa.org.nz/>. LAWA is a collaboration between NZ's Central government and local government.

Appendix B

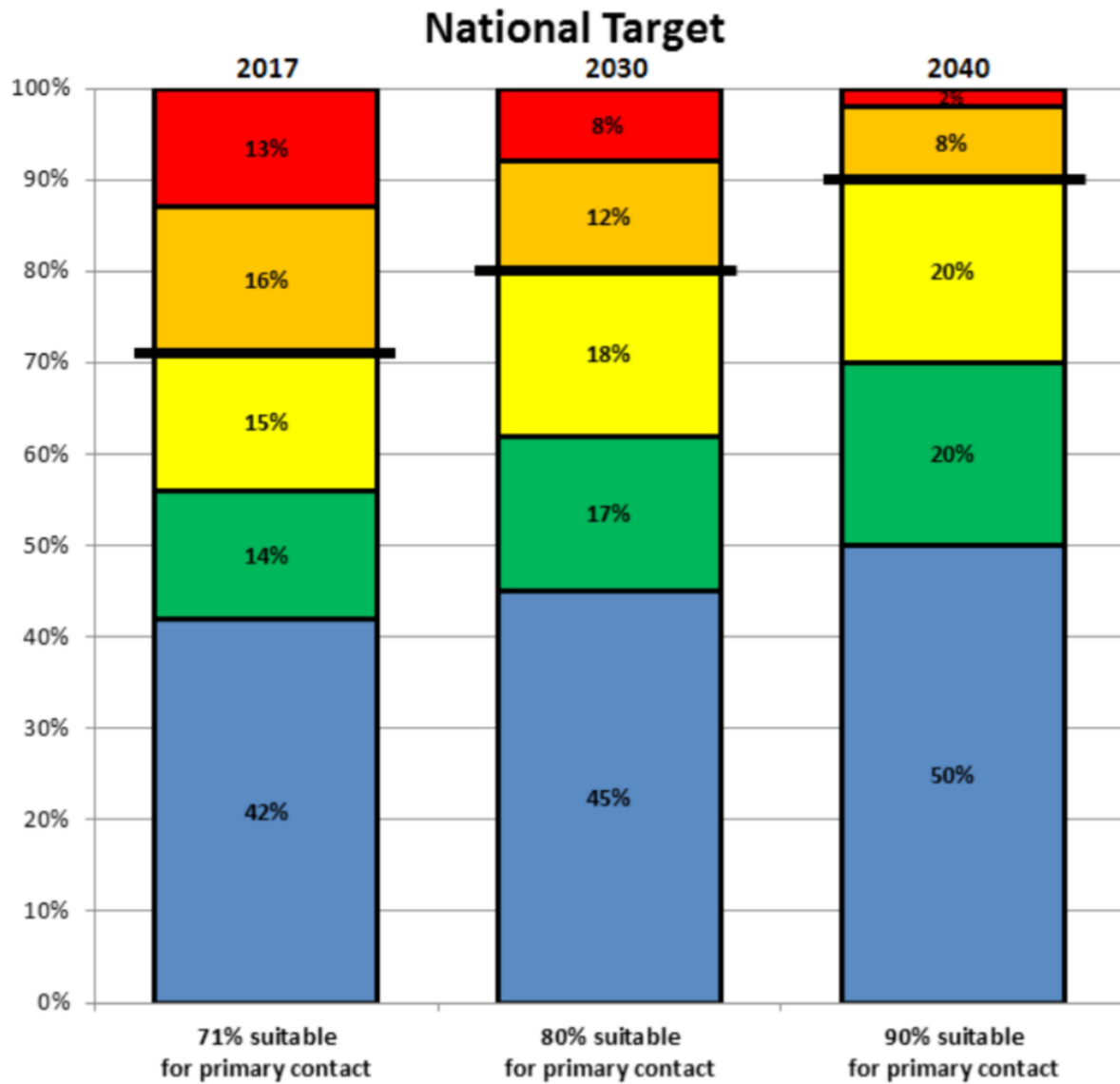
Appendix Table B1: Average Marginal WTP values from Model (5)

	Nutrients	Clarity	E Coli
Auckland	22.13** (10.93)	189.75** (87.03)	26.98** (10.72)
Bay of Plenty	23.19** (11.38)	201.16** (86.19)	35.86*** (12.42)
Canterbury	40.71** (16.21)	78.17 (66.10)	26.52** (12.50)
Gisborne	17.97* (10.91)	171.52* (88.24)	23.08** (10.98)
Hawkes Bay	21.45* (11.35)	186.58** (81.63)	37.65*** (12.95)
Horizons	26.00** (12.35)	154.15** (75.66)	25.04** (10.62)
Marlborough	6.28 (17.61)	221.76** (97.02)	35.25*** (13.58)
Nelson	5.01 (15.93)	273.38** (121.34)	36.25*** (13.22)
Northland	22.35** (11.08)	174.87** (83.43)	20.31* (11.50)
Otago	29.75** (13.62)	106.44 (70.67)	32.20*** (11.90)
Southland	37.90** (15.47)	109.58 (69.85)	23.85** (10.29)
Taranaki	23.25** (10.47)	188.73** (80.52)	26.20*** (10.07)
Tasman	12.83 (13.37)	256.58** (120.04)	35.05*** (12.82)
Waikato	32.34** (13.32)	131.47* (75.38)	28.63*** (10.80)
Wellington	20.55* (10.61)	214.82** (87.19)	40.80*** (13.64)
West Coast	17.30 (15.57)	193.62* (99.65)	30.51** (13.86)
Observations	7014	7014	7014

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Appendix C

Appendix Figure C1: National Freshwater Targets for Primary Contact



Note: From the National Policy Statement on Freshwater Management, 2020 <https://environment.govt.nz/assets/Publications/Files/national-policy-statement-for-freshwater-management-2020.pdf>

Appendix D - Full Example Survey Instrument

NORTH ISLAND RIVERS AND STREAMS

The next part of the survey is about the water quality of rivers and streams in the North Island, and asks some questions about your experiences with these rivers and streams. Your answers will help inform policymakers.

The information described in this survey was provided by the Ministry for the Environment and regional councils. Please keep in mind *this survey is only about flowing rivers and streams*, so please do not consider lakes or the sea when answering questions.

North Island Rivers



Major rivers are coloured in dark blue, and Regional Council boundaries appear in grey.

1. Over the last 12 months, have you done any of the following activities in or near **rivers and streams** in the **regional council area** where you live? Tick all that apply

Swimming or wading	<input type="checkbox"/>
Fishing	<input type="checkbox"/>
Boating, including sailing, and motor boating	<input type="checkbox"/>
Water skiing, jet skiing, or kayaking	<input type="checkbox"/>
Actively viewing nature (for example: bird watching)	<input type="checkbox"/>
Biking or walking on trails/paths alongside the water	<input type="checkbox"/>
I didn't visit rivers or streams in my regional council area in the last 12 months	<input type="checkbox"/>
Other activity: _____	<input type="checkbox"/>

2. How much do you agree or disagree with each of the following statement?

	Strongly Disagree				Strongly Agree		
	1	2	3	4	5	6	7
I would be more likely to visit rivers and streams in my regional council area if the water quality was better.							

River and Stream Water Quality in the North Island

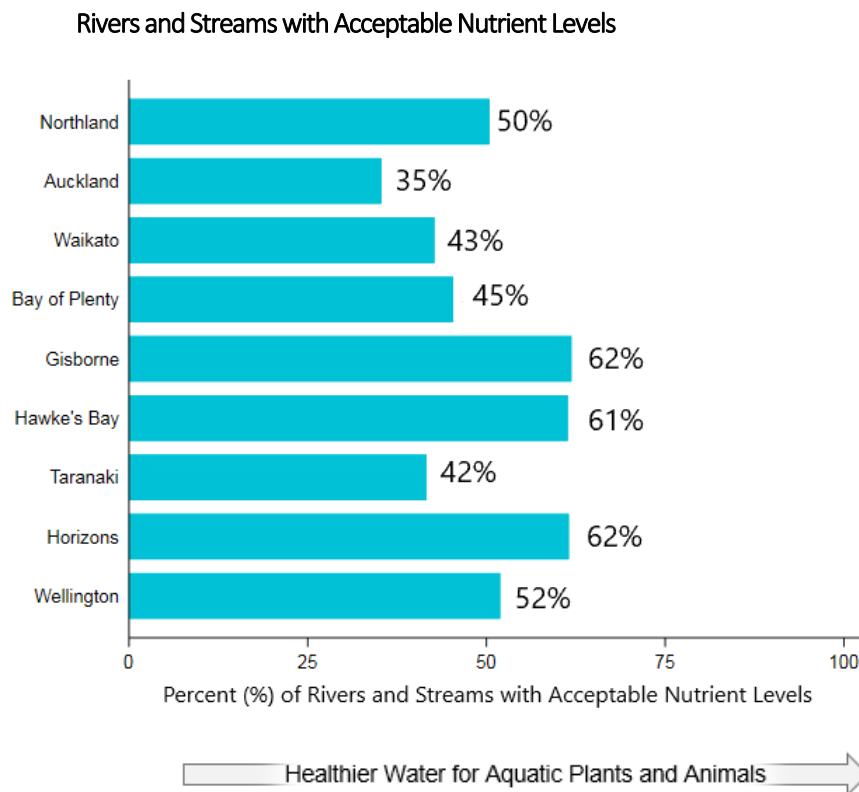
Some information appears below about three key things that affect water quality in rivers and streams: nutrients, water clarity, and E. coli.

This survey will ask you to consider different programmes to improve water quality in your regional council area. It's important to first read the information below because it will help you when answering questions later.

Nutrients. Nitrogen and phosphorous are naturally occurring nutrients, but too much can lead to excessive algae growth that harms underwater habitat, affecting fish, aquatic plants, and other organisms. Sources of excessive nutrients include fertilizers, livestock manure, and wastewater treatment plants. Regional councils set nutrient limits to reduce algae growth and protect aquatic animals and plants. Waters with nutrient levels above these limits can look and smell bad, and/or be unhealthy for aquatic animals and plant life.

How is it measured?

Regional councils report the **percentage of rivers and streams meeting nutrient limits**. The following figure shows the percent of rivers and streams in each region that have acceptable nutrient levels. For example, 61% of rivers and streams (or 6 out of 10) in Hawke's Bay have acceptable nutrient levels. A larger bar means that rivers and streams are better for aquatic animals and plant life.



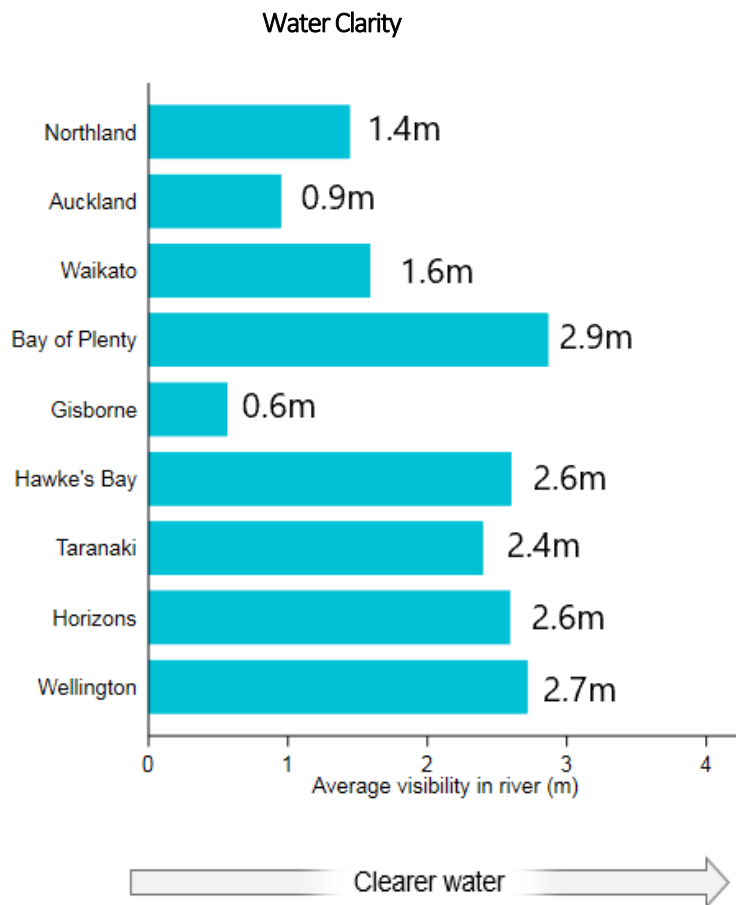
3. Before taking this survey, were you aware of the negative effects that nutrients can have on aquatic plants and animals?

- Yes
- No

Water clarity. Excessive pollution makes the water murky or cloudy, and may make the water look less pleasing.

How is it measured?

Water clarity is measured by how far you can see in the water, **in metres**. At one metre of clarity you can see your feet if standing up to your waist in the water. The following figure shows average water clarity levels (in metres) across different regions. A larger bar means that, on average, rivers and streams are clearer.



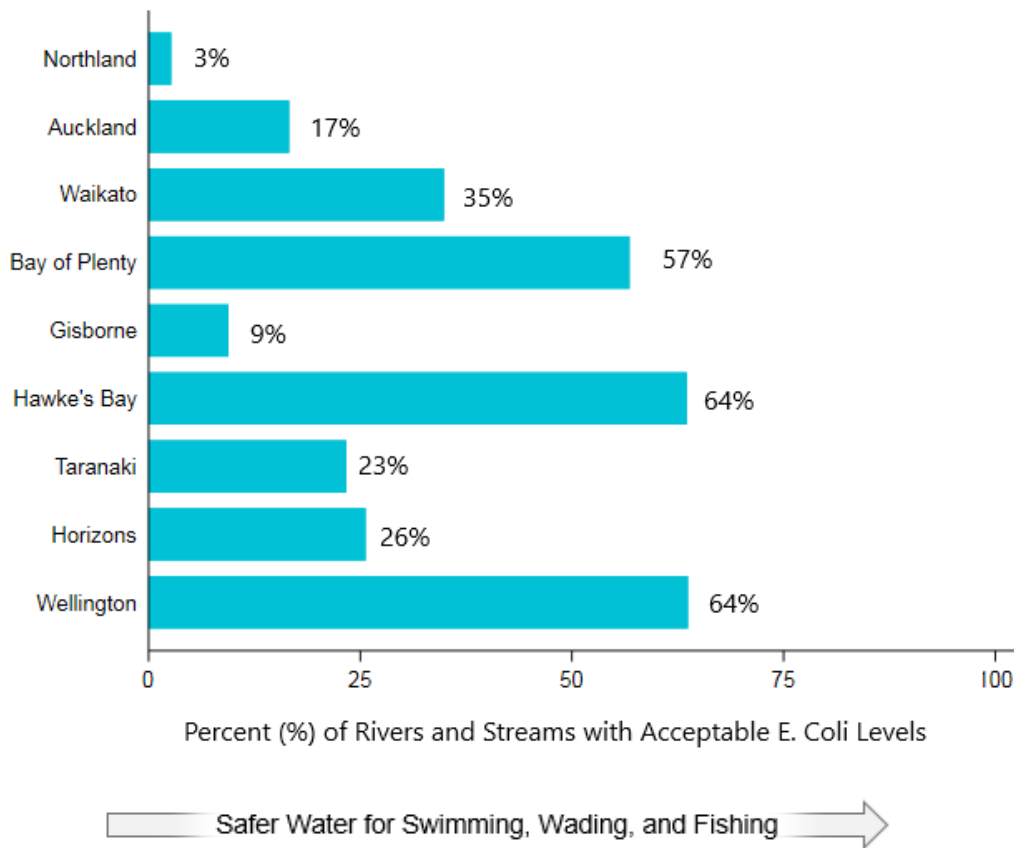
4. How does water clarity in **your regional council area** compare to your impressions before taking this survey?
- Lower (worse) than I expected
 - About what I expected
 - Higher than I expected
 - I had no expectations about water clarity

E. coli are bacteria found in sewage and human and animal excrement. It is natural for rivers and streams to have small amounts of *E. coli*, but too much can lead to a higher chance of getting sick if you swim or wade in that water, or eat fish that live there. Regional councils set *E. coli* limits in order to better ensure that rivers and streams are suitable for swimming, wading, and fishing.

How is it measured?

Regional councils report **the percentage of rivers and streams that meet *E. coli* limits and are suitable for swimming, wading, and fishing**. The following figure shows the proportion of rivers and streams in each regional council that meet *E. coli* limits. For example, 35% of rivers in Waikato are suitable for swimming, wading, and fishing. A larger bar indicates more rivers and streams are safe to swim or fish in.

Rivers and Streams with Acceptable *E. Coli* Levels for Swimming, Wading, and Fishing



5. Before taking this survey, were you aware of the negative effects that *E. coli* can have on the suitability of rivers and streams for swimming, wading, and fishing?

- Yes
- No

Improvements in River and Stream Water Quality in your Regional Council Area

To achieve water quality goals in your region, your regional council and the central government would need to implement and fund new and/or improved programmes to reduce water pollution and improve water quality. **If implemented, programme changes would be gradually phased in and be in full effect by the year 2025.**

Such programmes could, for example, require and/or fund:

- Planting natural vegetation in areas along rural and urban stream and river banks.
- More advanced water treatment technologies at sewage plants.
- Reduce the amount of paved surface when developing new residential or commercial areas, to decrease stormwater runoff
- More environmentally friendly fertilizers for your garden and lawn care at home.
- Tree planting in urban or eroded areas.
- Programmes for farmers to better manage their soil or use some of their land to plant natural vegetation.

The design of the programme can cause it to have different effects on nutrients, water clarity, and E. coli.

Funding Water Quality Programmes

If implemented, the changes required under such programmes would result in higher costs, and some of these costs would be passed on to your household.

Costs to Your Household

Some of the basic things people spend money on would become slightly more expensive. For example:

- Homeowners will experience increased requirements and maintenance costs for sewage and septic systems,
- Homeowners and renters will get higher rates or costs on their sewage and water bills.
- Renters will experience increased rent.
- Prices for some products like food or other goods you buy will also increase, due to increased costs to businesses as a result of the programmes.

Programmes to improve water quality, if implemented, would **permanently increase the cost of living for your household starting next month.**

Even though the increase in the cost of living to your household would begin next month, it will take some time for the programmes to be fully implemented. The ***improvements described would be fully achieved by 2025.***

Deciding Future Outcomes

Each of the next few questions presents three different potential outcomes for the water quality of rivers and streams in your regional council area water quality and costs to your household. Each question asks you to **choose the outcome you like the best**. Your responses will guide future policy decisions and programmes that would, if implemented, actually improve the quality of rivers and streams in your regional council area. They would also increase costs to your household.

When choosing the outcome you like best, please take time to consider both the benefits and the costs to **your household**. Ask yourself if the outcomes for rivers and streams in your regional council area are worth the additional cost to your household.

We urge you to respond as though costs for your household really would go up as described under each outcome, and that the environmental improvements described (and only those improvements) really would occur. Paying the costs means you would have less money to spend on other things such as food, clothes, going on trips, and even towards resolving other environmental problems you care about.

If you choose an outcome that results in a cost to your household, you would be making a commitment to pay the additional cost every month from now on, so please choose carefully.

Remember that:

- The results of this survey will inform regional council and central government policymakers about actual policies.
- Improvements in water quality apply ***only to flowing rivers and streams in your regional council area***.
- Improvements in water quality would be fully achieved **by the year 2025**.
- Your household costs would increase starting **next month**.

Please study the table below.

Question 1.

Which outcome do you prefer for rivers and streams in your regional council area?

	Outcomes by 2025		
	Outcome A	Outcome B	Outcome C
Nutrients <i>Increase in the percent of rivers and streams with acceptable levels.</i> <i>For example, a change from 25% of rivers and streams to 27% is a change of +2 percentage points</i>	No change	+ 5 percentage points	+ 1 percentage points
Water Clarity <i>Increase in average visibility in rivers and streams</i>	No change	+ 1 metre	+ 0.5 metre
E. coli <i>Increase in the percent of rivers and streams suitable for swimming, wading, and fishing.</i> <i>For example, a change from 32% of rivers and streams to 35% is a change of +3 percentage points</i>	No change	+ 6 percentage points	+ 8 percentage points
Permanent Increase in the Cost of Living for your Household	\$0 per month	\$6 per month (\$72 per year)	\$3 per month (\$36 per year)
Your Choice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Please select your preferred outcome	Outcome A (No change)	Outcome B	Outcome C

Thanks for answering the first question. You will next see two more questions about different programmes. As you answer the next questions please remember:

- Each question presents a new set of outcomes.
- Consider each question separately. Do not compare across questions.
- Forget about the previous question, and now imagine that the listed outcomes in each of the next questions are the only ones you can choose from.

Please study the table below.

Question 2.

Which outcome do you prefer for rivers and streams in your regional council area?

	Outcome by 2025		
	Outcome A	Outcome B	Outcome C
<p>Nutrients <i>Increase in the percent of rivers and streams with acceptable levels. For example, a change from 25% of rivers and streams to 27% is a change of +2 percentage points.</i></p> <p>Water Clarity <i>Increase in average visibility in rivers and streams</i></p> <p>E. coli <i>Increase in the percent of rivers and streams suitable for swimming, wading, and fishing. For example, a change from 32% of rivers and streams to 35% is a change of +3 percentage points</i></p>	No change	+ 5 percentage points	+ 7 percentage points
<p>Permanent Increase in the Cost of Living for your Household</p>	\$0 per month	\$7 per month (\$84 per year)	\$20 per month (\$240 per year)
<p>Your Choice</p> <p>Please select your preferred outcome</p>	<input type="checkbox"/> Outcome A (No change)	<input type="checkbox"/> Outcome B	<input type="checkbox"/> Outcome C

Please study the table below.

Question 3.

Which outcome do you prefer for rivers and streams in your regional council area?

	Outcomes by 2025		
	Outcome A	Outcome B	Outcome C
Nutrients <i>Increase in the percent of rivers and streams with acceptable levels.</i> <i>For example, a change from 25% of rivers and streams to 27% is a change in +2 percentage points</i>	No change	+ 15 percentage points	+ 3 percentage points
Water Clarity <i>Increase in average visibility in rivers and streams</i>	No change	+ 1.6 metre	+ 0.5 metre
E. coli <i>Increase in the percent of rivers and streams suitable for swimming, wading, and fishing.</i> <i>For example, a change from 32% of rivers and streams to 35% is a change of +3 percentage points</i>	No change	+ 12 percentage points	+ 4 percentage points
Permanent Increase in the Cost of Living for your Household	\$0 per month	\$25 per month (\$300 per year)	\$5 per month (\$60 per year)
Your Choice	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Please select your preferred outcome	Outcome A (No change)	Outcome B	Outcome C

6. *Thinking about how you decided which outcomes to choose* in the previous questions, please rate how much you agree or disagree with each of the following statements.

	Strongly Disagree						Strongly Agree
I made my choices as if the water quality improvements described actually would be achieved.	1	2	3	4	5	6	7
I made my choices as if my household actually would have to pay the additional monthly costs.	1	2	3	4	5	6	7
When making my choices I only considered flowing rivers and streams in my regional council area.	1	2	3	4	5	6	7
It is important to improve waters in my regional council area, no matter how high the costs.	1	2	3	4	5	6	7
I am against any more regulations and/or government spending.	1	2	3	4	5	6	7
I want better water quality, but my household should not have to pay to fund it.	1	2	3	4	5	6	7
I believe the data collected with this survey will inform future policies to improve water quality.	1	2	3	4	5	6	7

Appendix E – Water Quality Regressions

	ln(TP)	ln(TN)	ln(E. Coli)
ln(Clarity)	-0.5333*** (0.0015)	-0.5054*** (0.0019)	-0.2827*** (0.0019)
Landcover Data Missing	0.3365*** (0.0548)	0.5668*** (0.0312)	-0.4756*** (0.0270)
Landcover Native	-0.3093*** (0.0021)	-0.5155*** (0.0027)	-0.3219*** (0.0022)
Landcover Other	-0.0697*** (0.0094)	-0.2025*** (0.0116)	-0.1217*** (0.0115)
Landcover Pastoral	0.1299*** (0.0020)	0.5798*** (0.0026)	0.2622*** (0.0022)
Landcover Urban	0.2945*** (0.0054)	0.7816*** (0.0066)	0.5169*** (0.0055)
Stream Order=2	-0.0892*** (0.0013)	-0.0712*** (0.0017)	0.0513*** (0.0015)
Stream Order =3	-0.2249*** (0.0017)	-0.1685*** (0.0021)	0.0595*** (0.0019)
Stream Order =4	-0.3954*** (0.0024)	-0.2987*** (0.0029)	0.0065** (0.0027)
Stream Order =5	-0.5065*** (0.0036)	-0.3921*** (0.0043)	-0.0179*** (0.0039)
Stream Order =6	-0.6486*** (0.0050)	-0.6413*** (0.0063)	-0.1655*** (0.0054)
Stream Order =7	-0.8029*** (0.0065)	-0.7170*** (0.0094)	-0.2860*** (0.0095)
Stream Order=8	-1.1810*** (0.0167)	-1.3324*** (0.0192)	-0.4156*** (0.0160)
Elevation	-0.0010*** (0.0000)	-0.0010*** (0.0000)	-0.0017*** (0.0000)
nof swim=2			0.5045*** (0.0024)
nof swim=3			1.2165*** (0.0032)
nof swim=4			1.7509*** (0.0033)
nof swim=5			2.0637*** (0.0038)
Constant	3.7353*** (0.0023)	6.2039*** (0.0031)	3.3444*** (0.0043)
Observations	587,939	587,939	587,939
R ²	0.7799	0.7790	0.9216

Notes – all models include regional council fixed effects. Standard errors appear in parentheses. Standard errors appear in parentheses. ***, **, and * denote significance at the 99%, 95%, and 90% levels, respectively. The omitted dominant landcover category is exotic forest.