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Research article

Protecting and restoring freshwater biodiversity across urban areas in Aotearoa New Zealand: Citizens' reporting of pollution in stormwater drains and waterways

Lynette J. McLeod [a,*], Donald W. Hine [a], Taciano L. Milfont [b], Zack Dorner [c], Natasha A. Tassell-Matamua [d,e], Robbie D.C. Maris [f], Jane C. Kitson [g,h], Philip Stahlmann-Brown [i]

[a] School of Psychology, Speech and Hearing, University of Canterbury, Christchurch, New Zealand
[b] Ministry for the Environment and School of Psychology, University of Waikato, Tauranga, New Zealand
[c] Department of Environment Management, Lincoln University, Lincoln, New Zealand
[d] Centre for Indigenous Psychologies, School of Psychology, Massey University, Manawatū, New Zealand
[e] Te Ātiawa, Ngāti Makea kei Rarotonga, New Zealand
[f] Waikato Management School, University of Waikato, Hamilton, New Zealand
[g] Kitson Consulting Ltd, Invercargill, New Zealand
[h] Waitaha, Kāti Māmoe, Ngāi Tahu, New Zealand
[i] Manaaki Whenua - Landcare Research, Wellington, New Zealand

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ABSTRACT

Urbanization poses numerous challenges to freshwater biodiversity. This paper describes two studies with the joint aim of demonstrating the benefits of applying a systematic behaviour change framework and providing the foundational knowledge to inform future behavior change work to protect and restore urban freshwater biodiversity. In Study 1 we used a mixed-methods research design, involving 14 key informant interviews followed by an online survey targeting 17 freshwater biodiversity experts and another targeting a representative sample of 550 urban residents, to identify and prioritize the most promising resident behaviors to target to reduce stormwater pollution and improve natural waterway habitats in urban areas. Study 2 focused on the top-ranked short-term behavior identified in Study 1, citizen reporting of pollution in stormwater drains and waterways. We surveyed a representative sample of 1901 urban residents across Aoteraoa New Zealand to identify four main determinants influencing this behavior: awareness and uncertainty about reporting, lack of opportunity to report, social motivation and personal motivation to report, and five potential target audiences: 'Supportive', 'Unaware but receptive', 'Motivated but lack support', 'Reluctant', and 'Not my problem'. We make recommendations for the most appropriate intervention designs to target each of these audience segments to promote the reporting of stormwater pollution in urban areas. This knowledge will allow for a more coordinated and effective approach for addressing the 'human element' that lies at the heart of many urban freshwater management problems.

1. Introduction

Freshwater ecosystems are invaluable sources of biodiversity, supporting a wide array of plants, animals, and microorganisms. These ecosystems also provide essential services to human communities, including clean drinking water, food resources, cultural significance, and recreational opportunities (Dudgeon et al., 2006; Tipa, 2009; Vörösmarty et al., 2010). In Aotearoa New Zealand, changes in agriculture land use, human population growth and urbanization have exerted significant pressures on freshwater ecosystems, leading to a decline in freshwater quality and biodiversity (Larned et al., 2016; McDowell et al., 2023; Tanner et al., 2023; Te Aho, 2019; Tenebe et al., 2023). Given the importance of conserving these ecosystems, it is important to identify and address the primary threats to freshwater biodiversity and implement strategies to protect and restore it, particularly in urban areas (Higgins et al., 2019; Silk et al., 2005).

Urbanization poses numerous challenges to freshwater biodiversity. Expansion of cities often entails conversion of natural habitats into built

* Corresponding author.
E-mail address: lynette.mcleod@canterbury.ac.nz (L.J. McLeod).

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environments, leading to the loss and fragmentation of freshwater ecosystems (Foley et al., 2005; McDonald et al., 2020). Construction of infrastructure such as dams, reservoirs, and drainage systems further disrupt natural water flow patterns, alters river channels, and degrades habitats (Silk et al., 2005; Wu et al., 2019). Additionally, urban areas generate substantial pollution, including sewage, industrial waste, microplastics and toxic runoff from paved surfaces, which contaminates freshwater systems and harms aquatic life (Nagato et al., 2023; Persaud et al., 2016; Ward and Winter 2016). The increase in urban populations leads to more pressure from recreational activities in and around waterways and over-exploitation of local freshwater resources such as fish, molluscs, crustaceans, and waterfowl (Yan Gao, Deng and Morrison, 2019; Villamagna et al., 2014).

To safeguard and restore freshwater biodiversity in urban areas, a multi-faceted approach that integrates urban planning and policy making with conservation principles and water management practices that prioritize freshwater conservation is required (Chocat et al., 2007; Elmqvist et al., 2015; Enqvist et al., 2016; Higgins et al., 2019; Naiman and Dudgeon, 2011). Such an approach involves:

- designating and protecting green spaces, wetlands, waterways, and riparian zones within urban landscapes to provide habitats and corridors for freshwater species (e.g. Clarkson et al., 2013; McWilliam et al., 2015; Simon and Townsend, 2003);
- integrating green infrastructure solutions (e.g., constructed wetlands and rain gardens and tanks) to mitigate stormwater runoff, reduce pollution, and enhance water quality (e.g. Brown et al., 2016; Burns et al., 2015);
- implementing sustainable water use strategies (e.g., water recycling, rainwater harvesting, and efficient irrigation techniques) to reduce the demand for freshwater resources and lessen the strain on aquatic ecosystems (e.g. de Sá Silva, Bimbato, Balestieri and Vilanova, 2022; Leidl et al., 2010); and
- implementing regulations and enforcing water quality standards to prevent pollution and ensure the health and integrity of freshwater habitats (e.g. Harwood et al., 2018; Ministry for the Environment, 2023).

Beyond these more structural changes, urban residents' behavior is a fundamental part of protecting and restoring freshwater biodiversity (Jackson, 2005; Schultz, 2011; Steg and Vlek, 2009). A key challenge facing government agencies, environmental organisations, and community groups involves prioritizing a myriad of options regarding the specific freshwater problems to address and the human behaviors to target for change. Avoiding spending time, energy, and money convincing people to engage in activities that will have little impact on freshwater biodiversity and wasting resources to influence behaviors that are unlikely to be adopted or that most people are already performing is critical. Thus, identifying clearly defined behaviors is important for designing interventions, the goal of which is to focus on a small number of high-impact behaviors that have a high probability of being adopted and that currently are not yet widely practiced (Hine et al., 2020; Kneebone et al., 2017; McKenzie-Mohr, 2011; Michie et al., 2014; Stern, 2011).

1.1. Current research

To tackle the research gap in the literature on understanding urban resident's current behaviour and behaviour change potential relating to the management of urban freshwater systems, we describe two studies with the joint aim of demonstrating the benefits of applying a systematic behaviour change framework and providing the foundational knowledge to inform future behavior change work.

Study 1 aimed to identify the most promising behaviors to reduce stormwater pollution and improve natural waterway habitats in urban areas across Aotearoa New Zealand. This was achieved by first using expert knowledge to identify relevant behaviors and then ranking these behaviors using the Community-Based Social Marketing's Behavior Prioritisation Matrix (BPM) tool (McKenzie-Mohr, 2011). The BPM orders behaviors from most to least impactful based on the function of three criteria: 1) the effectiveness of the behavior in achieving the desired outcomes, 2) the likelihood of adoption of the behavior by the target population, and 3) the proportion of the target population currently not engaged in the behavior.

Study 2 aimed to identify the factors that encouraged or impeded urban residents' participation in the most promising behavior identified in Study 1, and then used this information to recommend impactful intervention designs to achieve meaningful change in reducing stormwater pollution and improving natural waterway habitats in urban areas. This was achieved by first engaging with urban residents to understand the underlying determinants of behaviors (drivers and barriers) and then identifying target audiences and the most appropriate behavior change techniques using audience segmentation and the Behaviour Change Wheel (BCW) framework (Michie et al., 2014). The BCW provides a systematic approach for selecting appropriate intervention tools based on their feasibility and effectiveness. Recognising that individuals within a target population are not homogenous, and segmenting based on demographic, psychographic, and/or behavioral variables gives a deeper understanding of the unique drivers and barriers that each subgroup faces. This knowledge enables the creation of interventions that are more personalized, relevant, and resonant with the intended audience (Hine et al., 2017; Hine et al., 2014; Rundle-Thiele et al., 2017) and allows for the allocation of limited resources more efficiently as interventions can be directed towards the segments that are most likely to benefit from them (Slater et al., 2006).

The research methodology is summarised in Fig. 1, along with the six objectives of research. In Study 1 these are: 1) to identify the key resident behaviors, 2) to measure the effectiveness of these behaviors in achieving the desired outcomes, 3) to measure the proportion of the target population currently not engaged in the behaviors and the likelihood of adoption of the behaviors by the target population, and 4) to prioritize the behaviors to identify which have the greatest potential to improve freshwater biodiversity in urban areas over both the short- and long-term. Study 2 had a further two objectives: 5) to identify the barriers and drivers to the adoption of the highest ranked behavior and target audience segments, followed by 6) recommendations of appropriate behavior change tools and intervention designs.

2. Material and methods

2.1. Study 1

A mixed-methods research design was used for Study 1. This included semi-structured key informant interviews followed by two online surveys, one targeting freshwater biodiversity experts and another targeting urban residents (Fig. 1).

2.1.1. Key informant interviews

To help understand the challenges facing freshwater biodiversity in Aotearoa New Zealand and to determine what behaviors need to change to address these challenges, we interviewed 14 key informants with expertize in freshwater biodiversity. Interviewees were a mixture of freshwater ecologists, policy makers, and practitioners in local and national agency positions and universities. We asked participants to identify potential target behaviors that urban residents could undertake to either reduce stormwater contamination or improve natural waterway habitats, either individually or with a community group. From these results, we were able to generate a list of 37 behaviors (refer to Supplementary Material). In consultation with our research partners, the list was reduced to 29 important one-off and repetitive behaviors that could be feasibly targeted in a prospective evaluation trial (Table 1).

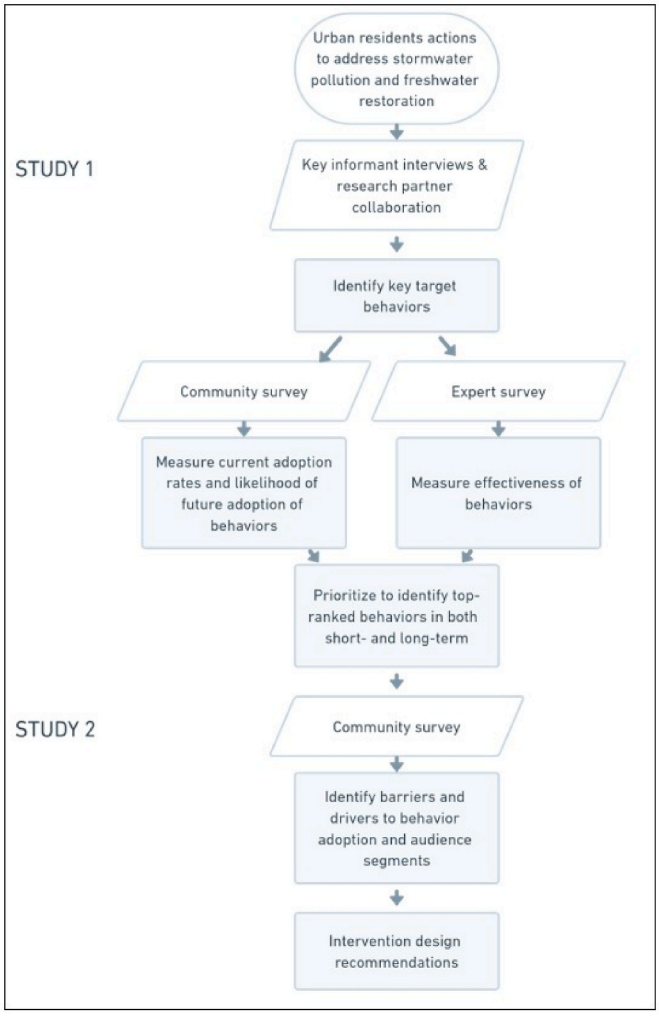

Fig. 1. Methodology flowchart for this research, including data collection inputs (unshaded parallelograms) and result objectives (shaded rectangles).

2.1.2. Online expert survey

This survey was developed and administered using the Qualtrics online survey platform. It was delivered to all 14 of the key informants who participated in the interviews as well as six other suggested experts. Drawing on their professional expertize, participants were asked to rate the effectiveness of each of the reduced list of 29 behaviors on improving freshwater biodiversity outcomes across two dimensions: 1) short-term environmental benefits, and 2) longer-term environmental benefits. Effectiveness was rated on a 10-point scale (1 = Not at all beneficial to 10 = extremely beneficial). Participants were asked to assume that a critical mass of individuals was participating in the behavior when considering their ratings.

2.1.3. Online community survey

The community survey was administered by a market research firm to an online research panel. The market research firm used interlocking quotas to ensure that the target sample of 550 participants was nationally representative by age, gender, and location. To be eligible, potential respondents had to be over 18 years of age and to reside in localities where the population exceeds 5000 people, given our focus on freshwater biodiversity in urban areas. The questionnaire (application no. 2122/21) was reviewed in accordance with the ethical review process of Manaaki Whenua – Landcare Research, within the guidelines of the Code of Ethics developed by the New Zealand Association of Social Science Researchers. This Code of Ethics emphasises informed consent, freedom from coercion to participate, individual privacy, confidentiality, and sensitivity to participants' circumstances. The survey was administered in May 2022.

Respondents were asked to indicate a) how often they currently engaged in each of the 29 behaviors (i.e., *Current Penetration*) on a 5-point scale (0 = never to 4 = very often), and b) the likelihood that they would adopt/participate in each behavior in the future (i.e., *Likelihood of Adoption*) also on a 5-point scale (0 = not very likely to 4 = highly likely). General socio-demographic data collected included current dwelling type, whether respondents were responsible for a home garden, and whether they owned their own home, they owned a car or motorbike, or they owned a dog.

Table 1
Ratings by 17 experts for the effectiveness of each behavior in improving freshwater outcomes in both the short- and long-terms (Scale: 1 = not at all beneficial, 10 = extremely beneficial).

Behavior	Short-term			Long-term		
	Mean	SD	Range	Mean	SD	Range
Install an above-ground water tank	6.59	2.24	2–10	7.35	2.62	2–10
Replace concrete with gravel or lawn	6.47	2.27	3–10	7.53	2.10	2–10
Install copper-free brake pads	6.38	2.16	3–9	7.25	2.27	2–10
Report pollution in drains and waterways	6.33	3.13	1–10	6.00	3.42	1–10
Restore natural channels - group	6.27	2.81	2–10	7.87	2.64	2–10
Pick up litter from the street	6.19	2.83	1–10	5.94	3.23	1–10
Secure garbage for kerbside collection	6.19	3.29	1–10	6.06	3.26	1–10
Install copper-free piping in house	6.18	2.32	1–10	7.47	2.12	2–10
Install zinc-free roofing on house	6.12	2.50	2–10	7.76	2.11	2–10
Pick up dog poo from the street	6.06	2.69	1–10	5.63	2.78	1–10
Design gardens for minimal run-off	6.00	2.29	2–10	6.82	2.56	2–10
Restore natural channels - themselves	5.87	2.75	1–10	7.53	2.77	1–10
Learn about Te Mana o te Wai	5.53	2.83	1–10	6.67	2.41	2–10
Report potential fish barriers	5.47	2.59	1–10	7.47	2.77	1–10
Increase garden/lawn area	5.41	2.67	2–10	6.35	2.80	2–10
Purposefully drive vehicle less	5.31	2.36	1–8	6.25	2.74	1–9
Attend workshop on freshwater issues	5.27	2.55	1–8	6.27	2.12	2–9
Purposefully use public transport more	5.25	2.29	1–8	6.00	2.9	1–10
Monitor waterway health - group	5.00	3.01	1–10	6.29	3.00	1–10
Report pests in waterways or surrounds	4.67	2.74	1–10	5.40	3.46	1–10
Control waterway weeds - group	4.57	2.21	2–10	5.29	3.00	1–9
Control waterway pests - group	4.36	2.79	1–9	5.21	3.49	1–10
Control waterway pests - themselves	4.36	2.79	1–9	5.00	3.26	1–9
Plant trees - group	4.33	2.13	1–10	7.47	2.29	3–10
Control waterway weeds - themselves	4.21	2.39	1–8	4.86	3.23	1–9
Monitor waterway health - themselves	4.14	2.74	1–10	5.79	2.69	1–10
Report weeds in waterways	4.00	2.75	1–9	4.53	3.31	1–10
Make a submission to Council	3.73	2.60	1–8	5.80	2.65	1–9
Plant trees - themselves	3.47	2.10	1–9	6.67	2.85	1–10

2.1.4. Prioritisation of behaviors

The 29 behaviors were ranked following the BPM tool (McKenzie--Mohr, 2011). Responses from the expert survey (i.e., *Effectiveness* of each behavior) and community surveys (i.e., *Maximum Possible Penetration* (value of 4, i.e. highly likely), *Current Penetration* and *Likelihood of Adoption* of each behavior) were combined to compute a 'Total Weighted Impact' (TWI) using the following algorithm:

TWI = Effectiveness x (Maximum Possible Penetration -Current Penetration) x Likelihood of Adoption

Behaviors were then ranked by their TWI scores to identify those with the greatest potential to improve freshwater biodiversity in urban areas.

2.2. Study 2

The results of Study 1 indicated that the behavior with the greatest potential to improve freshwater biodiversity in urban areas over the short-term was resident reporting of water pollution in stormwater drains and waterways. Hence, this was the focus behavior for Study 2.

2.2.1. Participants

As with the community survey described in Section 2.1.3, the survey for Study 2 was administered by a market research firm to an online research panel. For this second study, interlocking quotas were used to ensure that the target sample of 2000 was nationally representative by age, gender, and location. As above, potential respondents had to be over 18 years of age and to reside in localities where the population exceeds 5000 people. The questionnaire was reviewed in accordance with the ethical review process of Manaaki Whenua – Landcare Research (application no. 2223/04). The survey was administered in August–September 2022.

2.2.2. Measures

2.2.2.1. Socio-structural questions. Relevant demographic measures were included in the analyses as possible determinants of urban residents' reporting behavior. These were age, level of education, and gender (dummy coded as 0 = male, 1 = female).

Socio-psychological dimensions were assessed using a range of psychometric measures. Unless otherwise specified, all responses were rated on a 7-point Likert scale anchored at 1 = strongly disagree and 7 = strongly agree. Refer to Table S1 in the Supplementary Materials for further details of each item.

- Environmental Concern: Concern for the consequences of environmental problems on the biosphere, oneself, and other people was assessed using the measure developed by Schultz (2001) and validated in New Zealand samples by Milfont et al. (2006). This inventory comprises 4 items for each of the concern types, biospheric, egoistic and altruistic.
- Connectedness to Nature: A measure of individuals' emotional feelings towards nature was assessed using the measure developed by Mayer and Frantz (2004). It consisted of 14 items.
- Environmental Self-Identity: Three items were used to assess an individuals' environmental self-identity (van der Werff et al., 2013).
- National Environmental Identity: Environmentalism and a 'clean-and-green' attitude have been found to be core components of being a 'true' New Zealander (Milfont et al., 2020). Eight items captured three aspects of this dimension, national identity (Van Bavel et al., 2022), national environmental identity and feelings towards the protection of the nation's biological heritage (items generated from the New Zealand's biological heritage project website: https://bioheritage.nz/goals/stategic-objective/environmental-stewardship/).
- Sense of Community: The Brief Sense of Community Scale developed by Peterson et al. (2008) was used to assess the dimensions of needs fulfillment, group membership, influence, and shared emotional connection with an individual's community. It consisted of eight items.
- Spirituality: To assess the degree to which spirituality acts as a possible determinant for both theistic and non-theistic individuals, we used the modified six-item spirituality scale developed by Hodge (2003). Each item was measured using a 10-point scale where 0 = absence or zero amount of the attribute and 10 = the maximum amount of the attribute.

2.2.2.2. Behavior measures. Current reporting was measured on a 7-point Likert scale with 1 = never and 7 = very often with the following question: 'In the past 12 months, how often have you reported pollution in stormwater drains and/or local waterways to authorities (e.g., local Council or a Government department)'.

Willingness to participate was assessed on a 7-point Likert scale with 1 = highly likely and 7 = highly unlikely which read: 'Within the next 12 months, would you be willing to report pollution in stormwater drains and/or local waterways to authorities?'. Willingness to make a financial contribution to assist achieve outcomes was also assessed: 'Within the next 12 months, would you be willing to make a financial donation to reduce pollution in stormwater drains and/or local waterways?'

Finally, respondents were asked to rate their agreement with sixteen barrier questions listed below. These barrier items were adapted from previous research (Alhammad et al., 2021; Boulet et al., 2017; Yuling Gao, Church, Peel and Prokopy, 2018; McLeod and Hine, 2023; Pradhananga and Davenport, 2017; Schirmer and Dyer, 2018; Ward and Winter 2016) and covered an individual's capability, physical and social opportunity, and motivation to report following the methods of the Capability-Opportunity-Motivation (COM) Behaviour model which underpins the BCW framework as described by Michie et al. (2014). Responses to all items used a 7-point Likert scale with 1 = strongly disagree and 7 = strongly agree, and the four items for each of the dimensions are described below.

- Capability: 'I am not aware how stormwater pollution impacts local waterways', 'I am aware to which authority I should report pollution (reverse scored)', 'I am unsure how to report pollution', and 'I am not sure what types of pollution I should report'.
- Physical Opportunity: 'There is no way to easily report pollution to the local authorities', 'I do not have access to the reporting tool', 'I rarely spend time near waterways, so I have few opportunities to report water pollution', and 'I am too busy to report pollution to the local authorities'.
- Social Opportunity: 'My local authorities do not encourage reporting', 'My local community encourages pollution reporting (reverse score)', 'No one I know reports pollution to the local authorities', and 'People like me do not report pollution to the local authorities'.
- Motivation: 'I am not interested in reporting pollution', 'Stormwater pollution is a serious issue (reverse score)', 'It is not my responsibility to report pollution', and 'Even if I reported, the authorities would likely not act on my report'.

2.2.3. Quantitative data analysis

To consolidate the set of 16 COM barrier variables into a smaller set for analysis, we randomly split the sample into two subsamples and performed an exploratory factor analysis (EFA) on Subsample 1 (n = 951), followed by a confirmatory factor analysis (CFA) on Subsample 2 (n = 950). In determining the number of factors to extract in the EFA, we examined the descriptive values of eigenvalues, residual variances, and indicators of model fit. Both the EFA and CFA were conducted in MPlus 8.9 (Muthén and Muthén, 2017).

We then conducted a Latent Profile Analysis (LPA) to classify

residents into homogenous segments based on their responses to consolidated COM barrier factors. We firstly conducted the LPA to identify the optimal number of latent profiles using the observed variables (COM Barrier factors). The relative model fit was assessed using the Bayesian information criteria (BIC; Schwartz, 1978), relative entropy (Ramaswamy et al., 1993), and the Lo–Mendell–Rubin likelihood ratio test (LMR; Lo et al., 2001). A significant p value from the LMR test ($p = .05$) indicated that the given profile solution fitted the data significantly better than the solution with one fewer profile groups. The LPA was conducted in MPlus 8.9 (Muthén and Muthén, 2017). The quality of the LPA was then tested to ensure that our identified profiles were meaningful and not simply artifacts of the observed variables used to define them. To accomplish this, we examined the degree to which the latent profiles associated with other observed variables that were not used to define the profiles, including demographics (age, gender, education level) and socio-psychological variables (Environmental concern, Connectedness to nature, Environmental self-identity, National environmental identity, Sense of community, and Spirituality). To examine the relationship between the profiles and distal outcomes (e.g., current participation, future intentions to participate, or willingness to donate) to determine whether the identified profiles are predictive of participation, and hence useful for practitioners to target in behavior change interventions. These analyses were conducted using either a MANOVA or Pearson's chi-squared test.

3. Results

3.1. Study 1

3.1.1. Expert effectiveness ratings

Seventeen experts from the freshwater biodiversity research area completed the online survey to rate the effectiveness of the 29 identified behaviors (Table 1). Behaviors rated by the experts as the most beneficial in the short-term were installing an above-ground rainwater tanks, replacing concrete surfaces with gravel or lawn, and installing copper-free brake pads on their vehicles. Behaviors rated by the experts as the most beneficial in the long-term were residents restoring natural waterway channels with a community group, installing zinc-free roofing on their house, replacing concrete surfaces with gravel or lawn, and restoring natural waterway channels by themselves.

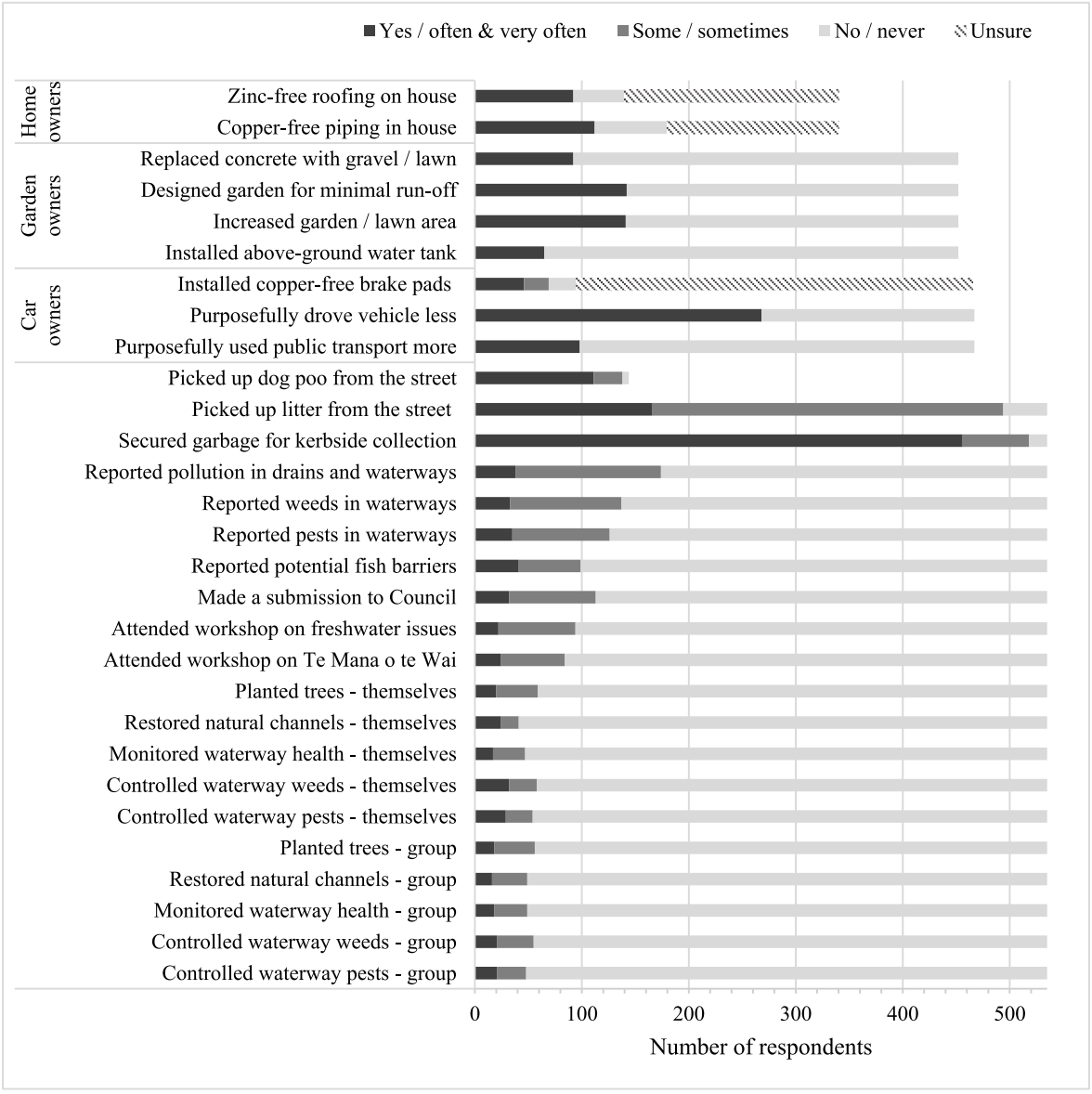

Fig. 2. Number of respondents who have participated in each of the 29 behaviors. Note: 340 House owners, 452 Garden owners, 467 Car/Motorbike owners, 144 dog owners.

3.1.2. Community survey participants

The online survey received 535 completed responses. Over half (54.2%) of the respondents were female, and one respondent identifying as non-binary. The average age of the respondents was 48.34 years (*SD* = 16.60), ranging from 18 to 90 years. The largest proportion of respondents (n = 368, 68.8%) lived in a stand-alone house with a garden for which they were responsible. Eighty-four respondents (15.7%) lived in a townhouse or apartment with a garden for which they were responsible. The remaining 83 (15.5%) respondents lived in a dwelling (whether a house, townhouse, apartment, or caravan) that did not have a garden. Most respondents (n = 365, 68.2%) owned their dwelling, while 170 (31.8%) did not. Over three quarters of respondents (n = 467, 78.3%) owned a car or motorcycle, and 144 respondents (26.9%) indicated they owned a dog.

Respondents were asked about their current participation in the 29 behaviors targeting the reduction of stormwater contamination and restoration of waterways. The results are summarised in Fig. 2. Behaviors that all respondents were most likely to have participated in included securing the garbage for kerbside collection and picking up litter from the street. Vehicle owners more often purposefully drove their vehicle less. Garden owners were more often to have increased the garden/lawn area and designed their garden for minimal run-off. There was a large proportion of homeowners who were unsure whether they had zinc-free roofing (59%) or copper-free piping (47%), and over three-quarters of vehicle owners (79%) were unsure whether their vehicles had copper-free brakes.

Respondents' willingness to participate in the 29 behaviors in the future is shown in Fig. 3. Respondents stated that they were more willing to secure their garbage for collection and pick up litter. Garden owners were more willing to design their garden to minimise run-off and vehicle owners were more willing to drive their car less. More people expressed willingness to plant trees along waterways with a group than expressed willingness to undertake other restoration activities.

3.1.3. Prioritisation of behaviors

A BPM was constructed (Table 2) from the experts' ratings, the likelihood of behavior adoption, and current adoption data following the method described by McKenzie-Mohr (2011). The top three ranked behaviors in the short-term were reporting pollution in stormwater drains and waterways, restoring natural waterway channels with a community group, and reporting potential fish barriers in waterways. The top three rated behaviors in the long-term were reporting potential fish barriers in waterways, restoring natural waterway channels with a community group, and planting trees along waterway channels with a

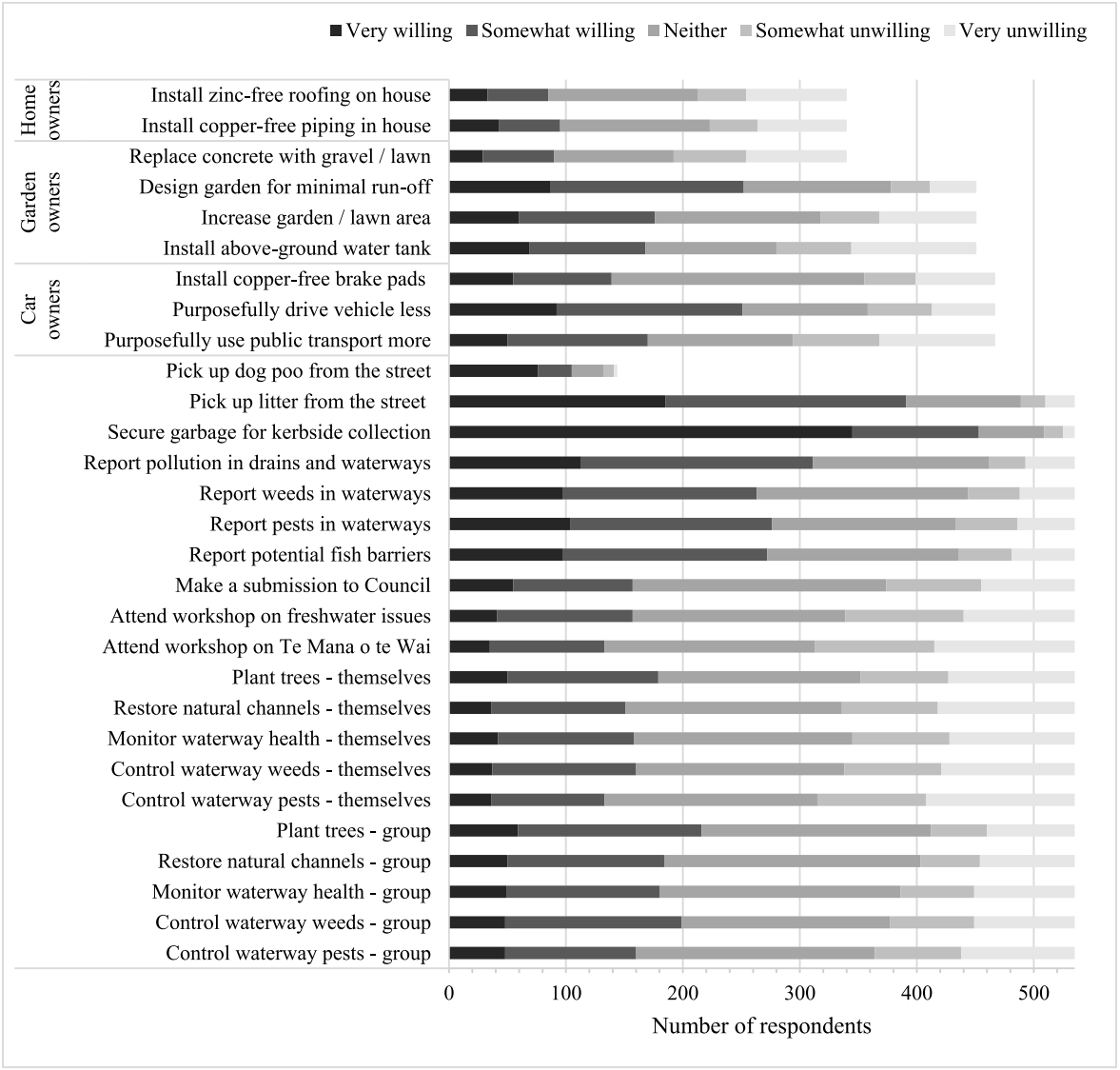

Fig. 3. Willingness to participate in the 29 identified behaviors. Note: 340 House owners, 452 Garden owners, 467 Car/Motorbike owners, 144 dog owners.

Table 2
Behavior prioritisation matrix ranking the 29 behaviors in short-term (ST) and long-term (LT) from most (1) to least (29) impactful (based on McKenzie-Mohr, 2011).

Behavior	Current participation (0–4)	Likelihood of adoption (0–4)	Effectiveness ST/LT (1–10)	TWI[a] ST/LT	Group rank ST/LT
Report pollution in drains & waterways	0.61	2.58	6.33/6.00	55.39/52.48	**1/4**
Restore natural channels with a group	0.20	2.04	6.27/7.87	48.58/60.98	**2/2**
Report potential fish barriers	0.41	2.40	5.47/7.47	47.10/64.33	**3/1**
Replace concrete with gravel or lawn	1.26	2.50	6.47/7.53	44.32/51.58	**4/5**
Report pests in waterways	0.46	2.43	4.67/5.40	40.14/46.45	**5/9**
Restore natural channels themselves	0.23	1.76	5.87/7.53	38.93/49.99	**6/6**
Monitor waterway health with a group	0.21	1.99	5.00/6.29	37.71/47.41	**7/7**
Increase garden/lawn area	0.58	1.91	5.41/6.35	35.35/41.50	**8/11**
Attend workshop on freshwater issues	0.35	1.83	5.27/6.27	35.18/41.86	**9/10**
Install a water tank	0.81	1.66	6.59/7.35	34.89/38.94	**10/16**
Plant trees with a group	0.24	2.14	4.33/7.47	34.87/60.08	**11/3**
Pick up litter from the street	2.09	2.94	6.19/5.94	34.75/33.34	**12/21**
Control weeds in waterway - group	0.24	2.01	4.57/5.29	34.55/39.95	**13/15**
Attend workshop on Te Mana o te Wai	0.32	1.67	5.53/6.67	34.01/40.97	**14/12**
Report weeds in waterways	0.48	2.41	4.00/4.53	33.93/38.46	**15/17**
Design gardens for minimal run-off	1.25	2.04	6.00/6.82	33.66/38.28	**16/18**
Purposefully use public transport more	0.84	1.89	5.25/6.00	31.36/35.83	**17/20**
Control pest in waterways with a group	0.22	1.89	4.36/5.21	31.13/37.25	**18/19**
Monitor waterway health themselves	0.20	1.82	4.14/5.79	28.65/40.01	**19/14**
Control weeds in waterway themselves	0.29	1.79	4.21/4.86	27.99/32.26	**20/22**
Control pest in waterways themselves	0.26	1.67	4.36/5.00	27.21/31.23	**21/23**
Making a submission to Council	0.42	1.95	3.73/5.80	26.06/40.49	**22/13**
Plant trees by themselves	0.26	1.88	3.47/6.67	24.37/46.87	**23/8**
Install copper-free brake pads	2.13	2.03	6.38/7.25	24.20/27.52	**24/24**
Purposefully drive vehicle less	2.30	2.39	5.31/6.25	21.58/25.39	**25/25**
Install copper-free piping in house	2.26	1.84	6.18/7.47	19.77/23.92	**26/26**
Install zinc-free roofing on house	2.26	1.72	6.12/7.76	18.31/23.24	**27/27**
Secure garbage for kerbside collection	3.36	3.42	6.19/6.06	13.54/13.27	**28/28**
Pick up dog poo from the street	3.30	3.15	6.06/5.63	13.37/12.40	**29/29**

[a] TWI (Total Weighted Index) = Effectiveness x (4 - Current Penetration) x Likelihood of adoption.

community group.

3.2. Study 2

3.2.1. Participants

The average age of the 1901 survey respondents was 47.2 years (±17.0, range 18–90). Over half of the respondents were female (n = 1098, 58%), with 794 (42%) male and nine identified as non-binary. Education level was spread amongst the categories with 559 (29%) having completed secondary education, 394 (21%) had a trade or technical qualification, 680 (36%) had completed an undergraduate degree, 140 (7%) had completed a higher degree, and 128 (7%) stipulated no qualifications or were unsure.

Most of the respondents (n = 1582, 83%) have never reported pollution in stormwater drains and waterways, 126 (7%) had reported but not often, 145 (8%) had sometimes reported, and 48 (3%) had reported often. When asked about the future intentions to report, 969 (51%) were willing to report pollution in stormwater drains and waterways in the next 12 months, 652 (40%) were somewhat willing, 134 (7%) were slightly willing, and 46 (2%) were not at all willing. When asked about their willingness to donate to reduce pollution in stormwater drains and waterways, 121 (6%) were willing to donate, 732 (39%) were somewhat willing, 452 (14%) were slightly willing and 596 (31%) were not at all willing.

3.2.2. Internal reliability of psychometric measures

All multi-item psychometric measures reflected a good internal consistency of greater than 0.80 (Table S1). Scale scores for each of these themes were computed by averaging the items which was then used for subsequent analysis.

3.2.3. COM barrier factor analysis

We ran an exploratory factor analysis on the first randomly split Subsample 1 (n = 951). We used the default settings in MPlus which uses maximum-likelihood estimation and goemin rotation to allow factors to correlate and specified the extraction of one-to four-factor solutions. Table 3 presents the fit measures. The four-factor solution showed the best model fit with the highest comparative fit index (CFI) value and the lowest Root mean-square error of approximation (RMSEA) and standardized root-mean-square residual (SRMR) values. All COM items loaded significantly on at least one of the four factors as indicated in Table 4. Examination of the loadings indicated that the first factor assessed an individual's awareness for the need to report, the second assessed their physical opportunity to report, the third component assessed social motivation to report, and the fourth component assessed their assessed their personal motivation to report.

We then ran a confirmatory factor analysis in MPlus with maximum-likelihood estimation using Subsample 2 (n = 590). The four-factor solution had a good fit to the data (X^2 (62) = 153.97, p < .001, RMSEA = 0.039 (90% CI: 0.032; 0.047), SRMR = 0.023, CFI = 0.980). For completeness we tested the four-factor solution on the full sample (X^2

Table 3
Examination of the fit measures from the exploratory factor analysis of the COM barrier items (Subsample 1, n = 591).

Factors	Eigenvalue	X^2 value	d.f.	p value	RMSEA	SRMR	CFI
1	5.21	1212.77	104	<.001	.106	.089	.754
2	1.92	412.47	89	<.001	.062	.040	.928
3	1.08	263.80	75	<.001	.051	.031	.958
4	.94	156.47	62	<.001	.040	.022	.979

RMSEA root mean-square error of approximation; SRMR standardized root mean-square residual; CFI comparative fit index.

Table 4
Goemin rotated item loading results of the exploratory factor analysis using Subsample 1 (n = 591) and confirmatory factor analysis using Subsample 2 (n = 590) (in brackets) and Cronbach α′s for the four-factor solution.

Factors Barrier variables	1 Unaware & unsure (α = .70)	2 Lack of opportunity (α = .80)	3 Socially unmotivated (α = .70)	4 Personally unmotivated (α = .80)
Unsure how to report pollution	.66 (.80)			
Unsure type of pollution to report	.65 (.70)			
Unaware of pollution impacts	.42 (.38)			
Aware to whom I should report (RS)	.41 (.50)			
Believe pollution is a serious issue (RS)	.33 (.33)			
No one I know reports	.32 (.43)			
No way to easily report pollution		.74 (59)		
No access to the reporting tool		.48 (.38)		
Authorities don't act on my report		.41 (.41)		
Community encourages reporting (RS)			.78 (.58)	
Authorities don't encourage reporting			.57 (.65)	
Not interested in reporting				.77 (79)
Too busy to report				.63 (.63)
People like me do not report				.60 (.62)
Not my responsibility to report				.59 (.72)
I have few opportunities to report				.16 (.25)

RS = reversed scored.

(62) = 240.83, $p < .001$, RMSEA = 0.039 (90% CI: 0.034; 0.044), SRMR = 0.020, CFI = 0.980), and computed the Cronbach α′s for each factor, which reflected adequate internal consistency (Table 4). Scale scores were computed by averaging the items that loaded on each factor and used for subsequent analysis.

3.2.4. Audience segmentation

To develop the most effective targeted engagement interventions, practitioners not only need to understand why urban residents are willing or not to participate in group waterway restoration, but also if these reasons are similar across all residents. We conducted a Latent Profile Analysis (LPA) using the four identified COM barrier factors (Unaware and unsure, Lack of opportunity, Socially unmotivated, Personally unmotivated), with the results indicating that the respondents could be classified into five segments. The 6-profile model had a lower BIC value, however the LMR test indicated that the more parsimonious 5-profile model fitted the data significantly better than the 6-profile solution (Table 5). The five resulting audience segments, which we have labelled Supportive (n = 168, 9%), 'Unaware but Receptive' (n = 365, 19%), 'Motivated but Lack Support' (n = 89, 4%), 'Reluctant' (n = 1153, 61%) and 'Not My Problem' (n = 126, 7%) are illustrated in Fig. 4 and the profiles are summarised below.

To evaluate the quality of our LPA results, we examined the degree to which the identified latent profiles associated with the other observed variables that were not used to define the profiles. MANOVA results indicated significant differences between the five audience segments and all the measured socio-psychological variables (i.e., Environmental concern, Connectedness to nature, Environmental self-identity, National environmental identity, Sense of community, and Spirituality): Wilk's λ = 0.12, F (16, 5784) = 371.68, $p < .001$; refer to Table 6 for more details). There was also a difference in age (F (4) = 19.83, $p < .001$, η^2 = 0.04) and gender between the segments (X^2 (4) = 15.81, $p < .01$, r = 0.08), but not education level (X^2 (16) = 23.73, p = .10, r = −0.02) (Table 7). We also examined the relationship between the segments and past behavior and future intentions. There were significant differences for all three behavioral variables (MANOVA results: Wilk's λ = .80, F (12, 5011) = 36.09, $p < .001$) (Table 6).

Members in the 'Supportive' segment are the most likely to have previously reported stormwater pollution, are most willing to report in the future, and are most willing to donate. On average, they score high across all socio-psychological variables, indicating they have a strong environmental identity, sense of community, and spirituality. Members tend to be older and score the lowest agreement ratings across all four barriers. This segment contains a higher proportion of males than females compared to the other segments.

Members in the 'Unaware but Receptive' segment are unwilling to donate and unlikely to have previously reported stormwater pollution; however, they are willing to report in the future. They tend to be older in age and, on average, they score relatively high on all environmental scales and sense of community but have a low spirituality score. Members in the 'Motivated but Lack Support' segment are also are unwilling to donate and unlikely to have previously reported stormwater pollution but willing to report in the future. On average, they score high on all environmental scales and spirituality. That said, they also have a low sense of community. Members in this segment show relatively strong agreement with all the barriers except personal motivation. This segment contains a higher proportion of females than males compared to the other segments.

Members in the 'Reluctant' segment are unlikely to have previously reported stormwater pollution, and unwilling to donate, but slightly willing to report in the future. On average, they score low across all environmental scales, indicating a weak environmental identity, and low spirituality but they have a moderate sense of community. The main barrier to reporting was unawareness and uncertainty about reporting, followed by low opportunity and social motivation.

Members in the 'Not My Problem' segment are unlikely to have previously reported stormwater pollution, are unlikely to report in the future and are unwilling to donate. Like the 'Reluctant' segment, they score relatively low across all environmental scales, indicating a weak environmental identity but have a higher sense of spirituality. Members in this segment show relatively strong agreement with all the barriers.

Table 5
Model fit indices for the Latent profile analysis solutions.

Profile solution	BIC	Entropy	LMR
2	22598.49	.83	<.001
3	22310.06	.73	<.01
4	22182.86	.73	.15
5	22112.39	.76	.05
6	22058.20	.74	.10

Notes: BIC – Bayesian information criterion; LMR – Lo-Mendell-Rubin likelihood ratio test.

3.2.5. Linking barrier factors to appropriate behaviour change techniques

A key strength of using the BCW as part of our methodology is that it provides a direct link between barrier and driver factors and appropriate behavior change techniques. An appropriate intervention for a capability barrier should aim to educate, train or support, whereas for an opportunity factor the intervention should aim to enable, facilitate,

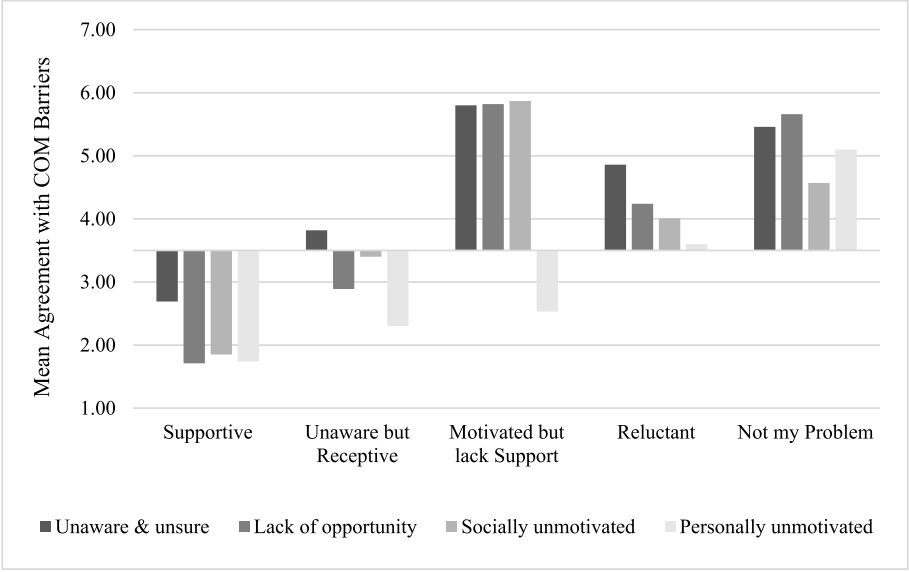

Fig. 4. Agreement with the four barrier factors across the five identified segments.

Table 6
Differences between behaviors and socio-psychological dimensions across the five observed segments.

All participants	Supportive (n = 168)	Unaware but Receptive (n = 365)	Motivated but Lack Support (n = 89)	Reluctant (n = 1153)	Not My Problem (n = 126)	Segment differences	
	Mean	Mean	Mean	Mean	Mean	F	η^2
Current participation[1]	2.16^{c}	1.55^{bc}	1.07^{a}	1.37^{ab}	1.27^{ab}	20.34*	.04
Future participation[2]	6.57^{d}	6.06^{c}	6.00^{c}	5.11^{b}	4.13^{a}	89.81*	.16
Make a donation[2]	3.58^{b}	3.05^{a}	2.58^{a}	2.86^{a}	2.66^{a}	9.20*	.02
Environmental Concern	6.27^{c}	5.85^{b}	6.21^{c}	5.54^{a}	5.43^{a}	32.06*	.06
Connectedness to Nature	5.32^{c}	4.81^{b}	5.00^{b}	4.53^{a}	4.49^{a}	44.53*	.09
Environmental Self-identity	6.05^{c}	5.45^{b}	5.42^{b}	5.01^{a}	4.88^{a}	38.93*	.08
NZ National Identity	6.49^{c}	6.11^{b}	6.09^{b}	5.62^{a}	5.77^{a}	23.64*	.05
National Environmental Identity	6.38^{c}	5.93^{b}	6.23^{c}	5.47^{a}	5.48^{a}	45.26*	.09
BioHeritage Protection	6.47^{c}	6.13^{b}	6.42^{bc}	5.65^{a}	5.59^{a}	41.62*	.08
Sense of Community	5.22^{d}	4.28^{c}	3.21^{a}	3.92^{b}	3.82^{b}	58.93*	.11
Spirituality	6.15^{c}	5.22^{ab}	5.19^{ab}	4.83^{a}	5.80^{bc}	9.66*	.02

Notes: [1] Mean scores for current participation using scale: 1 = never, 7 = very often. [2] Mean scores for future participation and donation: 1 = not at all willing, 7 = extremely willing. *$p < .001$. Means with different superscripts (in rows) differ significantly at $p < .05$ Tukey HSD. η^2 (partial eta squared) indicates effect size, where $\eta^2 = 0.01$ indicates a weak effect, $\eta^2 = 0.07$ a moderate effect and $\eta^2 = 0.14$ a strong effect.

Table 7
Demographic characteristics of members within the five segments.

	Supportive (n = 168)	Unaware but Receptive (n = 365)	Motivated but Lack Support (n = 89)	Reluctant (n = 1153)	Not My Problem (n = 126)	Segment differences		
	Mean	Mean	Mean	Mean	Mean	F	p	η^2
Age	54.55^{b}	51.35^{b}	43.21^{a}	45.48^{a}	43.21^{a}	19.83	<.001	.04
	***n* (Z_{Resid})**	***n* (Z_{Resid})**	***n* (Z_{Resid})**	***n* (Z_{Resid})**	***n* (Z_{Resid})**	**$\chi 2$**	***p***	**r**
Gender:						15.81	<.01	.08
Female	83 (−2.3)	206 (−.6)	65 (3.0)	663 (−.3)	81 (1.5)			
Male	85 (2.3)	159 (.6)	24 (−3.0)	490 (.3)	45 (−1.5)			
Education:						23.73	.10	−.02
Postgraduate	7 (−1.4)	26 (.3)	5 (.4)	78 (.1)	12 (1.3)			
Undergraduate	41 (−1.5)	102 (−.7)	28 (.4)	353 (1.4)	35 (−.4)			
Trade Certificate	41 (1.2)	97 (3.1)	16 (−.7)	222 (−2.0)	18 (−1.8)			
Secondary High	67 (1.2)	113 (−2.1)	33 (.3)	412 (.0)	55 (1.9)			
No qualification	12 (−.1)	27 (.0)	7 (.2)	88 (.6)	6 (−1.2)			

Notes: Means with different subscripts (in rows) differ significantly at $p < .05$. η^2 (partial eta squared) = effect size. Z_{Resid} = Adjusted standardised residual, where $Z_{Resid} > |2|$ is significant at $p < .05$. r = Pearson's correlation coefficient.

prompt or restrict. Motivation factors should be addressed by interventions that persuade, demonstrate, incentivize or coerce (Michie et al., 2011). Examples of interventions targeting each of the main barriers for each of the identifies audience segments are shown in Table 8.

4. Discussion

Freshwater ecosystems are invaluable sources of biodiversity and provide essential services to human communities. Yet, population growth and urbanization have led to marked declines in the health of freshwater rivers and streams. Considering that the behaviors of urban residents are a fundamental part of protecting and restoring freshwater biodiversity, we conducted two studies aimed to extend existing social and behavioral science literature in freshwater management by providing the foundational knowledge to inform future behavior change work to improve freshwater biodiversity across urban areas.

In Study 1 we applied the BPM (Behaviour Prioritisation Matrix), a key tool in Community-Based Social Marketing (McKenzie-Mohr, 2011), to identify the most promising resident behaviors that government agencies, environmental organisations, and community groups could target for change in urban areas. All but one of the top-ranked impactful behaviors identified by the BPM varied from those just rated most effective by our experts. Amongst those behaviors rated highly be the experts included many behaviors that involved residents' making changes on their own property such as replacing concrete or installing rainwater tanks, or addressing issues that the residents' were not aware of such as zinc-free roofing (59% of respondents were unsure of the type of roofing on their property) and copper-free brakes (79% of respondents were unsure whether their vehicles already possessed copper-free brakes). This highlights the importance of considering target audiences awareness, current performance and willingness as well as effectiveness when deciding which behaviors to target. Urban residents have been found to be more motivated by functional benefits than environmental benefits with respect to private property changes (Brown et al., 2016; Yuling Gao et al., 2018), so although these behaviors are relatively effective in achieving their outcomes, they would require more effort and resources to bring about effective change (Kneebone et al., 2017; McKenzie-Mohr, 2011). Reassuringly, the top-ranked behaviors for short-term beneficial outcomes in improving freshwater biodiversity in urban areas involved reporting of some type, which are relatively easy and low-cost behaviors for residents to perform. This represents positive news for interventions in this domain, and we highlight practical implications for the top-ranked behavior next.

Study 2 focused on citizen reporting of pollution in stormwater drains and waterways, the top-ranked behavior offering the best short-term benefits from our first study. This type of reporting would require urban residents to effectively document each polluting event using an appropriate reporting tool promoted by the relevant local authority (Hyder et al., 2017). Local authorities' reliance on such voluntary citizen reporting has grown in recent decades as more efficient reporting tools, using web-based or mobile app platforms, have allowed the timely sharing of relevant knowledge between both parties (e.g. Abu-Tayeh et al., 2018; Desouza and Bhagwatwar, 2012; Susanto et al., 2017).

In Study 2 we engaged with urban residents to understand the underlying determinants of voluntary reporting behavior of pollution and identify potential target audiences. To our knowledge, this was the first study to adopt the BCW and associated COM Behavioural model (Michie et al., 2014; Michie et al., 2011) to identify specific drivers and barriers in urban freshwater management in Aotearoa New Zealand. Although initially designed to modify health-related behavior, this framework has proven useful for pro-environmental behaviors such as household water conservation (Addo et al., 2018; Hine et al., 2018), encouraging cycling (Dalton et al., 2022), litter reduction (Kolodko et al., 2021), recycling (Allison et al., 2022), green consumerism (Sundaraja et al., 2021), and

Table 8
Linking identified barriers to appropriate behaviour change techniques to promote reporting of stormwater.

Barrier Factor	Focus of intervention	Recommended behaviour change techniques
Supportive segment		
Motivation		
Routine/habitual behaviour	Encourage repetition of reporting when necessary.	Provide prompts to keep people mindful of reporting. Provide feedback to reporters to create a positive experience so they will repeat. Offer a reward for reporting.
Environmental values	Build upon values (such as Environmental concern, Sense of community and Spirituality) to encourage reporting.	Adopt messages that target their environmental, community and spiritual values. Get a written or verbal affirmation that is linked to specific values and reporting outcomes.
Unaware but receptive segment		
Capability		
Awareness of stormwater pollution problems	Promote awareness of stormwater pollution problems and the beneficial role that reporting plays in resolving the problem.	Provide information on stormwater pollution problems in the local area, the need for reporting, as well as feedback from people who have reported and the outcomes that have been achieved
How to report pollution	Provide information on what constitutes stormwater pollution and how and to whom it should be reported.	Provide information on types of stormwater pollution, where and when it can occur, the best ways to report and the organisation that deals with these reports.
Motivation		
Environmental values	Build upon values (such as Environmental concern and Sense of community) to encourage reporting.	Adopt messages that target their environmental and community values. Get a written or verbal affirmation that is linked to specific values and reporting outcomes.
Motivated but lack support segment		
Capability		
See Unaware but receptive segment		
Physical Opportunity		
Convenience	Modify the environment to make it easy to report.	Have a reporting tool/ method that is accessible, doesn't take too much time and effort to use/do. Provide prompts to keep people mindful of reporting.
Social Opportunity		
Social views/values	Promote and reinforce reporting behaviour showed by similar groups of people (i.e. community norm).	Use credible community sources that people associate with and trust to deliver messages about reporting. Provide feedback of similar people's involvement and experiences.
Motivation		
Outcome expectancy	Increase understanding of the outcomes of reporting. Endorse benefits and dispel any underlying misconceptions. Provide a positive experience so people will report again.	Provide transparent information about what actions will be taken with reported information. Emphasis correct facts. Provide feedback to people who report to create a positive experience.
Personal values	Link reporting and outcomes to specific personal values and other motives	Adopt a deliberate perspective linked with personal values and

(continued on next page)

Table 8 (*continued*)

Barrier Factor	Focus of intervention	Recommended behaviour change techniques
		interests to provide information on the reporting benefits and consequences of non-action. Draw attention to discrepancies between values and current behaviour to create discomfort.
Reluctant segment		
Capability, Physical & Social Opportunity		
See Motivated but lack support segment		
Motivation		
Community values	Build upon values (such as Sense of community) to encourage reporting.	Adopt messages that target their community values. Get a written or verbal affirmation that is linked to specific values and reporting outcomes.

wildlife protection (McLeod et al., 2019). Categorising the barriers using the BCW allows for easier identification of what needs to change and the systematic selection for the best behavior change tool for the job, thus avoiding the 'it seemed like a good idea at the time' principle (Michie et al., 2014). Moreover, by considering the diverse characteristics and needs of the target audience through segmentation, relevant behavior change interventions can be further tweaked to resonate with the intended audience, maximizing their impact and helping to achieve more long-lasting and meaningful change.

We identified five segments within our urban resident audience: 'Supportive', 'Unaware but receptive', 'Motivated but lack support', 'Reluctant', and 'Not my problem'. Members of the 'Supportive' segment were willing to report stormwater pollution and were the most capable and motivated to report pollution. They were on average older residents, and this segment contained a higher proportion of males than the other segments. Recommended interventions targeting this audience group would aim to remind and reinforce the reporting behavior, providing prompts to keep the residents mindful of reporting (McKenzie-Mohr, 2011; Osbaldiston and Schott, 2012). Providing feedback to residents who have reported would create a positive experience so the behavior will be repeated (Larson et al., 2013; Schultz, 1999). Given that members of this segment scored higher in environmental, community and spiritual measures, interventions aimed at encouraging reporting could also frame the communications in terms of these members' values (Lakoff, 2010; Wallen and Kyle, 2018).

Members of the 'Unaware but receptive' segment were also willing to report stormwater pollution in the future. Their main barrier was lack of awareness related to: 1) the detrimental impacts of stormwater pollution on the waterways, 2) how to report, what to report, and to whom they should report, and 3) other residents' behavior. As for the 'Supportive' segment, members on average are older. Interventions targeting this group of residents should educate, persuade, and encourage, promoting awareness of pollution problems and how to report as well as the beneficial role that reporting plays in resolving the problem, using information channels frequented by this older age group. This can be achieved by providing information on stormwater pollution problems in the local urban area as well as feedback from people who have reported and the outcomes that have been achieved (Larson et al., 2013; Schultz, 1999). They should adopt messages framed around environmental and community values (Lakoff, 2010) and draw attention to discrepancies between values and current behavior (cognitive dissonance) to create discomfort (Dickerson et al., 1992; Osbaldiston and Schott, 2012). Written or verbal commitments that are linked to values and outcomes (e.g., environmental identity and improving freshwater biodiversity across urban areas) may provide further motivation (Lokhorst et al., 2013; McKenzie-Mohr, 2011).

Members of the 'Motivated but lack support' segment were also willing to report stormwater pollution in the future, but lacked capability, opportunity, and social motivation. Recommended interventions should enable, support, and persuade these residents, who tended to be younger than the previous two segments. Not only should interventions promote awareness of pollution problems and how to report them, using information channels used regularly by these younger residents, but they should also make it easy to report via an accessible tool that does not require too much time or effort (McKenzie-Mohr, 2011; Michie et al., 2013). Attention should be made to promoting and reinforcing the community norm of reporting (Cialdini et al., 2006; Schultz et al., 2007), using credible messengers that these younger residents associate with and trust (Cialdini, 2009), and providing feedback of similar resident's involvement and experiences (Larson et al., 2013; Schultz, 1999). Messages should be framed around their personal values and interests to provide information on the reporting benefits and consequences of non-action and to draw attention to discrepancies between values and their current behavior (i.e., not reporting) to create discomfort (Osbaldiston and Schott, 2012).

Members of the 'Reluctant' segment were less willing to report stormwater pollution in the future so would require more effort and resources to engage than the previous segments (Kneebone et al., 2017; McKenzie-Mohr, 2011). However, since this group comprises the greatest number of respondents, it would be a priority if 'boots on the ground' were important for improving the effectiveness of the reporting in mitigating the negative effects of pollution in stormwater drains and waterways. Recommended interventions would be needed to educate, enable, persuade, support, and encourage these residents. This process would need to be applied in several steps, firstly growing member's awareness of the problem and need to report, followed by encouraging participation in reporting then continued performance (Prochaska et al., 1992). Behavior change techniques like those described for the 'Motivated but lack support' segment could be applied to tackle the members' lack of awareness, physical opportunity, and social motivation, using media channels and credible messengers targeting these younger residents (Cialdini, 2009). However, messages framed around social norms and the benefits to the community, rather than personal benefits, may be more appropriate. Offering a reward for reporting pollution may further incentivize members in this segment and reinforce repeat actions; however, careful planning must be given to this option so that the intrinsic desire to report is not diminished if resources become unavailable in the future (Akers and Yasué, 2019; Frey and Oberholzer-Gee, 1997).

Finally, members of the 'Not my problem' segment were the least willing of the resident groups to report pollution. They would be the toughest group to encourage to participate, and considering their relatively small size, the least preferred group to target (Kneebone et al., 2017; McKenzie-Mohr, 2011). Members were strongly impeded by a range of capabilities, opportunities, and motivations, so interventions would need to target all elements as discussed for the above segments while accommodating members' poor environmental and social identity.

4.1. Limitations and future research

The BPM provides a very clear structure to rank the behaviors according to three criteria, but it is worth highlighting that there are many ways to populate the matrix. In Study 1, we gathered data from primary sources following the general recommendations for behavior selection outlined by Michie et al. (2014). Although we incorporated a diverse set of expert knowledge into our BPM analysis, the sample could not be considered 'random' or 'representative' in a statistical sense. It would be beneficial to conduct additional data collection on behavior effectiveness to evaluate the robustness of our findings. It is also worth noting that Study 1 included a relatively long engagement process with expert

interviews and two online surveys. We recognize that such an intensive approach may not always be feasible for practitioners who use this methodology in the 'real world' and would therefore sometimes need to rely on existing data and/or local knowledge around behavior effectiveness, current penetration, and likelihood of adoption.

The research described in Study 2 represents a starting point for further work aimed at developing more effective urban freshwater management communication and behavior change interventions. The BCW framework, associated COM Behavioural model and segmentation analysis provides practical, intuitive tools for engagement specialists to increase their understanding of behavior in context and design interventions that are most likely to be effective. However, there are practical challenges associated with identifying and targeting members from each of the identified segments. Engagement specialists would need to engage and collaborate with community leaders and representatives to seek their insights and involve them in the development of interventions to ensure relevance, accessibility, sensitivity and inclusivity (Michie et al., 2014).

An important next step is to develop and evaluate intervention strategies specifically designed to address the needs of each resident segment. More specifically, there is a need to improve our understanding of the relevant COM factors for urban contexts, which behavior change tools are most effective for encouraging participation, under what conditions, and the effectiveness of different communication channels. It is all too often the case that scientifically credible evidence about the effectiveness of a particular intervention is lacking. The effectiveness of behavior change interventions should be rigorously evaluated against program goals, using scientifically sound methods such as treatment and control groups, random assignment, and the use of appropriate statistical tests to determine whether the intervention made a difference and worked as intended (Murnane and Willett, 2010).

5. Conclusion

Urbanization poses numerous challenges to freshwater biodiversity. This paper describes two studies with the joint aim of demonstrating the use of a systematic behavior change framework and providing the foundational knowledge to inform future behavior change work to improve the management of urban freshwater systems. In Study 1 we identified the most promising urban resident behaviors to target to reduce stormwater pollution and improve natural waterway habitats in urban areas. High impact behaviors identified for short-term beneficial outcomes included reporting pollution in stormwater drains and waterways, restoring natural waterway channels with a community group, and reporting potential fish barriers in waterways, while those for longer term beneficial outcomes were reporting potential fish barriers in waterways, restoring natural waterway channels with a community group, and planting trees along waterway channels with a community group. In Study 2 we investigated the underlying capabilities, opportunities and motivations for residents' reporting of pollution in stormwater drains and waterways, the most impactful short-term behavior, and identified five potential target audiences: 'Supportive', 'Unaware but receptive', 'Motivated but lack support', 'Reluctant', and 'Not my problem'. The identification of these audience segments will allow the creation of interventions that are more personalized, relevant, and resonant with the intended audiences. This knowledge will allow for a more coordinated and effective approach for addressing the 'human element' that lies at the heart of many urban freshwater management problems.

CRediT authorship contribution statement

Lynette J. McLeod: Conceptualization, Formal analysis, Investigation, Methodology, Writing - original draft, Writing - review & editing. **Donald W. Hine:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing - original draft, Writing - review & editing. **Taciano L. Milfont:** Conceptualization, Formal analysis, Investigation, Methodology, Supervision, Writing - original draft, Writing - review & editing. **Zack Dorner:** Conceptualization, Writing - review & editing. **Natasha A. Tassell-Matamua:** Conceptualization, Writing - review & editing. **Robbie D.C. Maris:** Conceptualization, Methodology. **Jane C. Kitson:** Conceptualization, Project administration, Writing - review & editing. **Philip Stahlmann-Brown:** Conceptualization, Funding acquisition, Project administration, Writing - review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2024.120019.

References

Abu-Tayeh, G., Neumann, O., Stuermer, M., 2018. Exploring the motives of citizen reporting engagement: self-concern and other-orientation. Business & Information Systems Engineering 60 (3), 215–226. https://doi.org/10.1007/s12599-018-0530-8.

Addo, I.B., Thoms, M.C., Parsons, M., 2018. Barriers and drivers of household water-conservation behavior: a profiling approach. Water 10 (12). https://doi.org/10.3390/w10121794.

Akers, J.F., Yasué, M., 2019. Motivational crowding in payments for ecosystem service schemes: a global systematic review. Conserv. Soc. 17 (4), 377–389. https://doi.org/10.4103/cscs_18_90.

Alhammad, M.M., Hajar, L., Alshathry, S., Alqasabi, M., 2021. Motivational factors impacting the use of citizen reporting applications in Saudi Arabia: the case of Balagh Application. Int. J. Adv. Comput. Sci. Appl. 12 (6) https://doi.org/10.14569/IJACSA.2021.0120629.

Allison, A.L., Lorencatto, F., Michie, S., Miodownik, M., 2022. Barriers and enablers to food waste recycling: a mixed methods study amongst UK citizens. Int. J. Environ. Res. Publ. Health 19 (5). https://doi.org/10.3390/ijerph19052729. Retrieved from.

Boulet, M., Ghafoori, E., Jorgensen, B.S., Smith, L.D.G., 2017. Behaviour change: trialling a novel approach to reduce industrial stormwater pollution. J. Environ. Manag. 204, 272–281. https://doi.org/10.1016/j.jenvman.2017.09.003.

Brown, H.L., Bos, D.G., Walsh, C.J., Fletcher, T.D., RossRakesh, S., 2016. More than money: how multiple factors influence householder participation in at-source stormwater management. J. Environ. Plann. Manag. 59 (1), 79–97. https://doi.org/10.1080/09640568.2014.984017.

Burns, M.J., Ladson, A.R., Fletcher, T.D., 2015. Impact of rainwater tanks on urban hydrology and stormwater quality. In: Sharma, A.K., Begbie, D., Gardner, T. (Eds.), Rainwater Tank Systems for Urban Water Supply. IWA Publishing, London, United Kingdom, pp. 301–317.

Chocat, B., Ashley, R., Marsalek, J., Matos, M.R., Rauch, W., Schilling, W., Urbonas, B., 2007. Toward the sustainable management of urban storm-water. Indoor Built Environ. 16 (3), 273–285. https://doi.org/10.1177/1420326X07078854.

Cialdini, R.B., 2009. Influence. Science and Practice, fifth ed. Pearson Education, Boston, USA.

Cialdini, R.B., Demaine, L.J., Sagarin, B.J., Barrett, D.W., Rhoads, K., Winter, P.L., 2006. Managing social norms for persuasive impact. Soc. Influ. 1 (1), 3–15. https://doi.org/10.1080/15534510500181459.

Clarkson, B., Ausseil, A.-G., Gerbeaux, P., 2013. Wetland ecosystem services. In: Dymond, J.R. (Ed.), Ecosystem Services in New Zealand – Conditions and Trends. Manaaki Whenua Press, Lincoln, New Zealand, pp. 192–202.

Dalton, A.M., Burke, A., Jones, A., 2022. Free-to-use cycle provision schemes have potential to encourage cycling and reduce inequalities. J. Transport Health 26, 101391. https://doi.org/10.1016/j.jth.2022.101391.

de Sá Silva, A.C.R., Bimbato, A.M., Balestieri, J.A.P., Vilanova, M.R.N., 2022. Exploring environmental, economic and social aspects of rainwater harvesting systems: a review. Sustain. Cities Soc. 76, 103475 https://doi.org/10.1016/j.scs.2021.103475.
Desouza, K.C., Bhagwatwar, A., 2012. Citizen apps to solve complex urban problems. J. Urban Technol. 19 (3), 107–136. https://doi.org/10.1080/10630732.2012.673056.
Dickerson, C.A., Thibodeau, R., Aronson, E., Miller, D., 1992. Using cognitive dissonance to encourage water conservation. J. Appl. Soc. Psychol. 22 (11), 841–854. https://doi.org/10.1111/j.1559-1816.1992.tb00928.x.
Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.-I., Knowler, D.J., Lévêque, C., Sullivan, C.A., 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. Biol. Rev. 81 (2), 163–182. https://doi.org/10.1017/S1464793105006950.
Elmqvist, T., Setälä, H., Handel, S.N., van der Ploeg, S., Aronson, J., Blignaut, J.N., de Groot, R., 2015. Benefits of restoring ecosystem services in urban areas. Curr. Opin. Environ. Sustain. 14, 101–108. https://doi.org/10.1016/j.cosust.2015.05.001.
Enqvist, J., Tengö, M., Boonstra, W.J., 2016. Against the current: rewiring rigidity trap dynamics in urban water governance through civic engagement. Sustain. Sci. 11 (6), 919–933. https://doi.org/10.1007/s11625-016-0377-1.
Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Snyder, P.K., 2005. Global consequences of land use. Science 309 (5734), 570–574. https://doi.org/10.1126/science.1111772.
Frey, B.S., Oberholzer-Gee, F., 1997. The cost of price incentives: an empirical analysis of motivation crowding-out. Am. Econ. Rev. 87 (4), 746–755.
Gao, Y., Church, S.P., Peel, S., Prokopy, L.S., 2018. Public perception towards river and water conservation practices: opportunities for implementing urban stormwater management practices. J. Environ. Manag. 223, 478–488. https://doi.org/10.1016/j.jenvman.2018.06.059.
Gao, Y., Deng, Z., Morrison, A.M., 2019. Can urban lake recreational pressure be measured? The impacts of urbanization on Wuhan's lakes. Applied Spatial Analysis and Policy 12 (2), 255–273. https://doi.org/10.1007/s12061-017-9241-7.
Harwood, A.J., Tickner, D., Richter, B.D., Locke, A., Johnson, S., Yu, X., 2018. Critical factors for water policy to enable effective environmental flow implementation. Front. Environ. Sci. 6 https://doi.org/10.3389/fenvs.2018.00037.
Higgins, S.L., Thomas, F., Goldsmith, B., Brooks, S.J., Hassall, C., Harlow, J., White, P., 2019. Urban freshwaters, biodiversity, and human health and well-being: setting an interdisciplinary research agenda. WIREs Water 6 (2), e1339. https://doi.org/10.1002/wat2.1339.
Hine, D.W., Driver, A.B., McLeod, L.J., 2018. Developing behaviourally effective policies to manage household water use. In: Bartel, R., Noble, L., Williams, J., Harris, S. (Eds.), Water Policy, Imagination and Innovation. Routledge, pp. 193–210.
Hine, D.W., McLeod, L.J., Please, P.M., 2020. Understanding why peri-urban residents do not report wild dog impacts: an audience segmentation approach. Hum. Dimens. Wildl. 25 (4), 355–371. https://doi.org/10.1080/10871209.2020.1735579.
Hine, D.W., Phillips, W.J., Driver, A.B., Morrison, M., 2017. Audience segmentation and climate change communication. In: Oxford Handbook of Climate Change Communication. Oxford University Press, Oxford, UK.
Hine, D.W., Reser, J.P., Morrison, M., Phillips, W.J., Nunn, P., Cooksey, R., 2014. Audience segmentation and climate change communication: conceptual and methodological considerations. Wiley Interdisciplinary Reviews: Clim. Change 5 (4), 441–459. https://doi.org/10.1002/wcc.279.
Hodge, D.R., 2003. The Intrinsic Spirituality Scale: a new six-item instrument for assessing the salience of spirituality as a motivational construct. J. Soc. Serv. Res. 30, 41–61. https://doi.org/10.1300/J079v30n01_03.
Hyder, K., Wright, S., Kirby, M., Brant, J., 2017. The role of citizen science in monitoring small-scale pollution events. Mar. Pollut. Bull. 120 (1), 51–57. https://doi.org/10.1016/j.marpolbul.2017.04.038.
Jackson, T., 2005. Motivating Sustainable Consumption: a Review of Evidence on Consumer Behaviour and Behavioural Change. Sustainable Development Research Network, London.
Kneebone, S., Smith, L., Fielding, K., 2017. The Impact-Likelihood Matrix: a policy tool for behaviour prioritisation. Environ. Sci. Pol. 70, 9–20. https://doi.org/10.1016/j.envsci.2016.11.013.
Kolodko, J., Schmidtke, K.A., Read, D., Vlaev, I., 2021. #LetsUnlitterUK: a demonstration and evaluation of the behavior change wheel methodology. PLoS One 16 (11), e0259747. https://doi.org/10.1371/journal.pone.0259747.
Lakoff, G., 2010. Why it matters how we frame the environment. Environmental Communication 4 (1), 70–81. https://doi.org/10.1080/17524030903529749.
Larned, S.T., Snelder, T., Unwin, M.J., McBride, G.B., 2016. Water quality in New Zealand rivers: current state and trends. N. Z. J. Mar. Freshw. Res. 50 (3), 389–417. https://doi.org/10.1080/00288330.2016.1150309.
Larson, E.L., Patel, S.J., Evans, D., Saiman, L., 2013. Feedback as a strategy to change behaviour: the devil is in the details. J. Eval. Clin. Pract. 19 (2), 230–234. https://doi.org/10.1111/j.1365-2753.2011.01801.x.
Leidl, C., Farahbakhsh, K., FitzGibbon, J., 2010. Identifying barriers to widespread implementation of rainwater harvesting for urban household use in Ontario. Can. Water Resour. J. 35 (1), 93–104. https://doi.org/10.4296/cwrj3501093.
Lo, Y., Mendell, N.R., Rubin, D.B., 2001. Testing the number of components in a normal mixture. Biometrika 88 (3), 767–778.
Lokhorst, A.M., Werner, C., Staats, H., van Dijk, E., Gale, J.L., 2013. Commitment and behavior change: a meta-analysis and critical review of commitment-making strategies in environmental research. Environ. Behav. 45 (1), 3–34. https://doi.org/10.1177/0013916511411477.
Mayer, F.S., Frantz, C.M., 2004. The connectedness to nature scale: a measure of individuals' feeling in community with nature. J. Environ. Psychol. 24 (4), 503–515. https://doi.org/10.1016/j.jenvp.2004.10.001.
McDonald, R.I., Mansur, A.V., Ascensão, F., Colbert, M.l., Crossman, K., Elmqvist, T., Ziter, C., 2020. Research gaps in knowledge of the impact of urban growth on biodiversity. Nat. Sustain. 3 (1), 16–24. https://doi.org/10.1038/s41893-019-0436-6.
McDowell, R.W., Macintosh, K.A., Depree, C., 2023. Linking the uptake of best management practices on dairy farms to catchment water quality improvement over a 20-year period. Sci. Total Environ. 895, 164963 https://doi.org/10.1016/j.scitotenv.2023.164963.
McKenzie-Mohr, D., 2011. Fostering sustainable behaviour: an introduction to community-based social marketing. In: Gabriola Island, third ed. New Society Publishers, British Columbia.
McLeod, L.J., Hine, D.W., 2023. Understanding wild dog reporting behaviour of rural landholders: identifying options for behaviour change. J. Agric. Educ. Ext.
McLeod, L.J., Hine, D.W., Driver, A.B., 2019. Change the humans first: principles for improving the management of free-roaming cats. Animals 9 (8), 555. https://doi.org/10.3390/ani9080555.
McWilliam, W., Brown, R., Eagles, P., Seasons, M., 2015. Evaluation of planning policy for protecting green infrastructure from loss and degradation due to residential encroachment. Land Use Pol. 47, 459–467. https://doi.org/10.1016/j.landusepol.2015.05.006.
Michie, S., Atkins, L., West, R., 2014. The Behaviour Change Wheel. A Guide to Designing Interventions. Silverback Publishing, UK.
Michie, S., Richardson, M., Johnston, M., Abraham, C., Francis, J., Hardeman, W., Wood, C.E., 2013. The behavior change technique taxonomy (v1) of 93 hierarchically clustered techniques: building an international consensus for the reporting of behavior change interventions. Ann. Behav. Med. 46 (1), 81–95. https://doi.org/10.1007/s12160-013-9486-6.
Michie, S., van Stralen, M.M., West, R., 2011. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. Implement. Sci. 6 (42), 1–11. https://doi.org/10.1186/1748-5908-6-42.
Milfont, T.L., Duckitt, J., Cameron, L.D., 2006. A cross-cultural study of environmental motive concerns and their implications for proenvironmental behavior. Environ. Behav. 38 (6), 745–767. https://doi.org/10.1177/0013916505285933.
Milfont, T.L., Osborne, D., Yogeeswaran, K., Sibley, C.G., 2020. The role of national identity in collective pro-environmental action. J. Environ. Psychol. 72, 101522 https://doi.org/10.1016/j.jenvp.2020.101522.
Ministry for the Environment, 2023. National Policy Statement for Freshwater Management 2020. New Zealand Government, Wellington, NZ.
Murnane, R.J., Willett, J.B., 2010. Methods Matter: Improving Causal Inference in Educational and Social Science Research. Oxford University Press, New York.
Muthén, L.K., Muthén, B.O., 2017. Mplus: Statistical Analysis with Latent Variables: User's Guide (Version 8). Authors, Los Angeles, CA.
Naiman, R.J., Dudgeon, D., 2011. Global alteration of freshwaters: influences on human and environmental well-being. Ecol. Res. 26 (5), 865–873. https://doi.org/10.1007/s11284-010-0693-3.
Nagato, E.G., Noothalapati, H., Kogumasaka, C., Kakii, S., Hossain, S., Iwasaki, K., Takai, Y., Shimasaki, Y., Honda, M., Hayakawa, K., Yamamoto, T., Archer, S.D.J., 2023. Differences in microplastic degradation in the atmosphere and coastal water environment from two island nations: Japan and New Zealand. Environ. Pollut. 333, 122011 https://doi.org/10.1016/j.envpol.2023.122011.
Osbaldiston, R., Schott, J.P., 2012. Environmental sustainability and behavioral science: meta-analysis of proenvironmental behavior experiments. Environ. Behav. 44 (2), 257–299. https://doi.org/10.1177/0013916511402673.
Persaud, A., Alsharif, K., Monaghan, P., Akiwumi, F., Morera, M.C., Ott, E., 2016. Landscaping practices, community perceptions, and social indicators for stormwater nonpoint source pollution management. Sustain. Cities Soc. 27, 377–385. https://doi.org/10.1016/j.scs.2016.08.017.
Peterson, N.A., Speer, P.W., McMillan, D.W., 2008. Validation of a brief sense of community scale: confirmation of the principal theory of sense of community. J. Community Psychol. 36 (1), 61–73. https://doi.org/10.1002/jcop.20217.
Pradhananga, A.K., Davenport, M.A., 2017. Community attachment, beliefs and residents' civic engagement in stormwater management. Landsc. Urban Plann. 168, 1–8. https://doi.org/10.1016/j.landurbplan.2017.10.001.
Prochaska, J.O., DiClemente, C.C., Norcross, J.C., 1992. In search of how people change. Applications to addictive behaviors. Am. Psychol. 47 (9), 1102–1114.
Ramaswamy, V., Desarbo, W.S., Reistein, D.J., Robinson, W.T., 1993. An empirical pooling approach for estimating marketing mix elasticities with PIMS data. Market. Sci. 12 (1), 103–124.
Rundle-Thiele, S., Dietrich, T., Kubacki, K., 2017. Why we need segmentation when designing social marketing programs. In: Dietrich, T., Rundle-Thiele, S., Kubacki, K. (Eds.), Segmentation in Social Marketing: Process, Methods and Application. Springer Singapore, Singapore, pp. 197–214.
Schirmer, J., Dyer, F., 2018. A framework to diagnose factors influencing proenvironmental behaviors in water-sensitive urban design. Proc. Natl. Acad. Sci. USA 115 (33), E7690–E7699. https://doi.org/10.1073/pnas.1802293115.
Schultz, P.W., 1999. Changing behavior with normative feedback interventions: a field experiment on curbside recycling. Basic Appl. Soc. Psychol. 21 (1), 25–36.
Schultz, P.W., 2001. The structure of environmental concern: concern for self, other people, and the biosphere. J. Environ. Psychol. 21, 327–339. https://doi.org/10.1006/jevp.2001.0227.
Schultz, P.W., 2011. Conservation means behavior. Conserv. Biol. 25 (6), 1080–1083. https://doi.org/10.1111/j.1523-1739.2011.01766.x.
Schultz, P.W., Nolan, J.M., Cialdini, R.B., Goldstein, N.J., Griskevicius, V., 2007. The constructive, destructive, and reconstructive power of social norms. Psychol. Sci. 18 (5), 429–434. https://doi.org/10.1111/j.1467-9280.2007.01917.x.
Schwartz, G., 1978. Estimating the dimension of a model. Ann. Stat. 6 (2), 461–464.

Silk, N., Circuna, K., Braun, D., Bjorkland, R., Pringle, C., Esselman, R., Allan, D., 2005. Understanding threats to freshwater diversity and developing effective conservation strategies. In: Silk, N., Circuna, K. (Eds.), A Practitioner's Guide to Freshwater Biodiversity Conservation. Island Press, Washington, DC.

Simon, K.S., Townsend, C.R., 2003. Impacts of freshwater invaders at different levels of ecological organisation, with emphasis on salmonids and ecosystem consequences. Freshw. Biol. 48 (6), 982–994. https://doi.org/10.1046/j.1365-2427.2003.01069.x.

Slater, M.D., Kelly, K.J., Thackeray, R., 2006. Segmentation on a shoestring: health audience segmentation in limited-budget and local social marketing interventions. Health Promot. Pract. 7 (2), 170–173. https://doi.org/10.1177/1524839906286616.

Steg, L., Vlek, C., 2009. Encouraging pro-environmental behaviour: an integrative review and research agenda. J. Environ. Psychol. 29 (3), 309–317. https://doi.org/10.1016/j.jenvp.2008.10.004.

Stern, P.C., 2011. Contributions of psychology to limiting climate change. Am. Psychol. 66 (4), 303–314. https://doi.org/10.1037/a0023235.

Sundaraja, C.S., Hine, D.W., Lykins, A.D., 2021. Palm oil: understanding barriers to sustainable consumption. PLoS One 16 (8), e0254897. https://doi.org/10.1371/journal.pone.0254897.

Susanto, T.D., Diani, M.M., Hafidz, I., 2017. User acceptance of e-government citizen report system (a case study of City113 App). Procedia Comput. Sci. 124, 560–568. https://doi.org/10.1016/j.procs.2017.12.190.

Tanner, C.C., Tomer, M.D., Goeller, B.C., 2023. A framework for applying interceptive mitigations for diffuse agricultural pollution. N. Z. J. Agric. Res. 1–22. https://doi.org/10.1080/00288233.2023.2252773.

Te Aho, L., 2019. Te Mana o te Wai: an indigenous perspective on rivers and river management. River Res. Appl. 35 (10), 1615–1621. https://doi.org/10.1002/rra.3365.

Tenebe, I.T., Julian, J.P., Emenike, P.C., Dede-Bamfo, N., Maxwell, O., Sanni, S.E., Babatunde, E.O., Alves, D.D., 2023. Multi-dimensional surface water quality analyses in the manawatu river catchment, New Zealand. Water 15 (16). https://doi.org/10.3390/w15162939.

Tipa, G., 2009. Exploring Indigenous understandings of river dynamics and river flows: a case from New Zealand. Environmental Communication 3 (1), 95–120. https://doi.org/10.1080/17524030802707818.

Van Bavel, J.J., Cichocka, A., Capraro, V., Sjåstad, H., Nezlek, J.B., Pavlović, T., Boggio, P.S., 2022. National identity predicts public health support during a global pandemic. Nat. Commun. 13 (1), 517. https://doi.org/10.1038/s41467-021-27668-9.

van der Werff, E., Steg, L., Keizer, K., 2013. The value of environmental self-identity: the relationship between biospheric values, environmental self-identity and environmental preferences, intentions and behaviour. J. Environ. Psychol. 34, 55–63. https://doi.org/10.1016/j.jenvp.2012.12.006.

Villamagna, A.M., Mogollón, B., Angermeier, P.L., 2014. A multi-indicator framework for mapping cultural ecosystem services: the case of freshwater recreational fishing. Ecol. Indicat. 45, 255–265. https://doi.org/10.1016/j.ecolind.2014.04.001.

Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Davies, P.M., 2010. Global threats to human water security and river biodiversity. Nature 467 (7315), 555–561. https://doi.org/10.1038/nature09440.

Wallen, K.E., Kyle, G.T., 2018. The efficacy of message frames on recreational boaters' aquatic invasive species mitigation behavioral intentions. Hum. Dimens. Wildl. 23 (4), 297–312. https://doi.org/10.1080/10871209.2018.1434705.

Ward, E.W., Winter, K., 2016. Missing the link: urban stormwater quality and resident behaviour. WaterSA 42, 571. https://doi.org/10.4314/wsa.v42i4.07.

Wu, H., Chen, J., Xu, J., Zeng, G., Sang, L., Liu, Q., Ye, S., 2019. Effects of dam construction on biodiversity: a review. J. Clean. Prod. 221, 480–489. https://doi.org/10.1016/j.jclepro.2019.03.001.