ESRI

Working Paper No. 696

March 2021

An evaluation of public initiatives to change behaviours that affect water quality

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Abstract: Pollution and environmental depletion are often caused by human behaviours, where if behaviours were modified, environmental pressure could be substantially reduced. Many public programmes aim to influence people to change their unsustainable behaviours but few undertake ex post evaluations of behavioural change programmes. This paper undertakes an evaluation of a 5-year programme to understand whether community engagement activities lead to more sustainable practices. Using a treatment and control experiment, the research investigates whether programme participants are representative of the wider population, whether participation leads to sustainable practices, whether pro-environmental behaviours are sustained over time, and the relative effectiveness of different types of events on individual behaviours. Overall, results suggest that water engagement event participants are more likely to adopt sustainable behaviours, however attendees only represent a small cohort of the wider population, which possibly hinders a wider adoption of good practices. With respect to individual behaviours, different outcomes were detected for different behaviours, which suggests that not all behaviours were equally amenable to change. When comparing the impact of different events, events that are focused on building community ties were more successful than events with simple provision of information. Finally, new pro-environmental behaviours tend to be abandoned after a period of time, therefore re-engagement at regular time intervals is advised.

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An evaluation of public initiatives to change behaviours that affect water quality

1. Introduction

The world is facing several environmental challenges that represent issues of global concern, including climate change and a biodiversity crisis (IPCC, 2014; IPBES, 2019). The quality of freshwater resources and the way in which they are exploited contributes to these environmental challenges (Howells et al., 2013). The sources of environmental pollution are well understood. Within the European Union, the main significant pressures on surface water bodies are hydromorphological pressures (40 percent), diffuse sources (38 percent), particularly from agriculture, atmospheric deposition (38 percent), point sources (18 percent) and water abstraction (7 percent) (EEA, 2018). Preventing water pollution and the remediation of existing contaminated water bodies is a multifaceted and complex policy goal. Most water pressures have an element related to human behaviours, where if behaviours were modified, pollutant loads could be substantially reduced (Cooper et al., 2019; Inman et al., 2018). For example, inappropriate discharge of wastes to storm-drains or sewers can ultimately impact on water quality. Changing people's unsustainable behaviours is one of the strategies increasingly advocated to achieve a more efficient use of resources and more sustainable lifestyles (Maynard et al., 2020; Barr et al., 2011). While there are many studies on developing strategies and implementing programmes on behavioural change, most are studies undertaken during the design of behavioural change initiatives (e.g. McKenzie-Mohr, 2011). There is a paucity of *ex post* evaluations of behavioural change programmes. This paper provides an *ex post* analysis of data collected on a 5-year programme of engagements to encourage communities to take responsibility for water quality and catchment management.

There are several techniques and approaches suggested by the psychological and sociological literature to effectively encourage pro-environmental behaviours. Wallen and Daut (2018) propose a classification for the various approaches as follows: (1) Education and Awareness raising, (2) Outreach, relationship building and trust, (3) Social Influence, and (4) Behavioural Insights and nudges. Other very similar classifications also exist (Victoria, 2002; NIEA, 2012), though some include financial incentives as a fifth category (e.g. Poortinga and Whitaker, 2018; Rajapaksa et al., 2019). However, financial incentives are not considered particularly effective for achieving sustained behavioural change, especially when the incentive ceases (Maki et al., 2016). If correctly implemented all behavioural change methods can be successful to some extent and most techniques are used in behavioural change programmes (Grilli and Curtis, 2021). With respect to water management in Europe, outreach and relationship building is particularly appealing because it combines behavioural change with one of the objectives of the Water Framework Directive (2000/60/EC), i.e. participation of the public in water resource management. Community participation may range from complete indifference to active involvement in decision-making. Arnstein (1969) provides a well-used classification of community engagement, using a ladder as a metaphor, with rungs comprising of: 1) Manipulation, 2) Therapy, 3) Informing, 4) Consultation, 5) Placation, 6) Partnership, 7) Delegation and 8) Citizen control. Rungs 1 and 2 are both non-participatory and usually the objective is not to engage citizens but for "power holders to 'educate' or 'cure' the participants" (Arnstein, 1969, p.217). Rungs 3–5 are degrees of tokenism, allowing citizens to hear and have a voice. For example, communities are informed about water man-

agement issues and engage in management discussions, although power is not delegated to communities. The higher rungs of the ladder are levels with increasing degrees of active involvement by communities in decision-making, from negotiating outcomes to full managerial power. While the ladder is a simplification, it underlines that not all participation is citizen empowerment and that considerable effort is required to increase communities' involvement and encourage behavioural changes.

A concern within the behavioural change literature is quantifying the extent to which behavioural change initiatives are effective over extended periods. Even where there are careful *ex ante* treatment-control studies, including laboratory experiments, the measured impacts of behavioural interventions are usually limited to a relatively short period after the intervention. It is not clear in these instances whether the intervention will contribute to sustained behavioural change over time (e.g. Maki et al., 2016). Do changed behaviours revert to original state after some period or its intensity decay? What happens when the behavioural intervention ceases? Are there significant long-run differences among behavioural change methods? At present, these are open questions in the behavioural change literature. This current research considers behaviour change across an extended timeframe, evaluating the impact of a series of community level behavioural interventions aimed at improving water quality in Ireland across a four-year period between 2017 and 2020. Within the context of the EU's Water Framework Directive, the Irish government is developing and implementing policies to protect Ireland's water resources, as outlined in its River Basin Management Plan (RBMP) (DHPLG, 2018). One aspect of that plan is the organisation of community engagement initiatives to increase awareness and build relationships within communities, an action that is led by the Local Authority Water Programme (LAWPRO). A core aim of LAWPRO is to support communities to care for their local waters and engage with river basin planning, for example, supporting community groups in the delivery of local water quality projects and initiatives. The ambition is to promote community engagement, as described in the mid to higher rungs of Arnstein's ladder. While LAWPRO's activities are not focused on individual behaviours, participation in engagement events may also ultimately impact on individuals' adoption of sustainable behaviours. This research explores the extent to which initiatives to build community engagement on water quality and river basin management lead to more sustainable practices among (a) community groups and (b) among private individuals. The research questions are: (1) whether the individuals participating in community engagement activities are representative of the wider population or concentrated among narrower population cohorts? (2) whether participation by individuals in community engagement activities leads to participation in community-led initiatives? (3) to what extent does community engagement lead to improved knowledge and changed behaviours among private individuals? (4) which specific engagement activities are most effective in yielding behavioural change among private individuals in the water quality domain? and (5) whether there are time decay effects associated with changed behaviours? This empirical evidence, based on long-term impacts, has relevance for improving the efficacy of existing community engagement initiatives, as well as, for similar behaviour change initiatives related to water quality in other jurisdictions.

The rest of the manuscript is organised as follows. The methodological section depicts water quality events that are evaluated, questionnaire, data collection and econometric analysis of the data. Section 3 reports findings from the analysis, a discussion of which, including policy implications, is included in section 4. Section 5 ends with some conclusions.

2. Methods

2.1. Background

LAWPRO (`http://watersandcommunities.ie`) is a government funded national initiative that engages with communities and other stakeholders to achieve the objectives of the RBMP, i.e. improve water quality so that Ireland will achieve 'good' ecological status in water bodies (rivers, lakes, estuaries and coastal waters) by 2027. The programme has two teams; the Communities Team and the Catchments Team. The focus of this research is part of the work of Communities Team, who support communities and stakeholders in the delivery of local water quality projects and initiatives. LAWPRO partner with other organisations and run initiatives in parallel with third party events (e.g. World Wetlands Day), all of which are the subject of this research. The discussion of water quality and river basin management is a common theme across all these events, though LAWPRO's direct involvement in each event type varies. The following list illustrates the type of community engagement events under consideration.

- Public consultation meetings facilitated by either LAWPRO or others
- Nature themed public events (e.g. Biodiversity Week)
- Project related meetings (e.g. rural development, drinking-water source protection)
- Catchment or waterbody meetings
- Community meetings (e.g. Resident's Association)
- Water-related community meetings (e.g. angling groups, water recreation clubs)
- Educational/training events
- Farming group meetings
- Water quality related conferences

Although these events, particularly the LAWPRO organised events, do not concentrate on individual behavioural change, information received may encourage individuals to adopt behaviours that enhance water quality.

2.2. Modelling approach

The objective is to investigate the impact of water quality community engagement events on attendee's adoption of pro-environmental behaviours, which were discussed during the events. To this end, the treatment and control experiment was undertaken where individuals attending water quality community engagement events comprise the treatment group and individuals who did not attend form the control group. The experiment has several behavioural response variables, some related to community-led initiatives and others that are private actions. The behavioural response variables are recorded as dummy variables equal to 1 if respondents report adopting the specific behaviour and 0 otherwise. In this experimental setting, the estimate of interest is the Average Treatment Effect (ATE), which indicates the impact of the treatment (i.e. participation in a water quality community engagement event) on the response variable (i.e. behaviours) compared to the control group (Zhang et al., 2019). With respect to the objectives of this analysis, ATE measures the difference between the share of respondents in the treatment group that adopt the pro-environmental behaviour compared to the share of respondents in the control group. A positive and statistically significant ATE indicates that the treatment had an impact on people's adoption of the pro-environmental behaviour.

ATE estimation is conducted using statistical models. Robust statistical inference requires randomly drawn samples (Angrist and Pischke, 2008). In a randomised experiment, robust ATE estimates are attainable with a statistical model that compares average scores between the treatment and control groups, because randomness in data collection ensures that participants are equally likely to be a member of either the treatment or control group. However, this study is not random and sample selection is biased, because participation in water quality community engagement events is on a voluntary basis, which means that the allocation of participants to the treatment group is not by chance. For example, sources of selection bias are personal tastes and interests, proximity to the event venue, job type, personal commitments and exposure to event advertising. In this non-random experiment the probability of being treated is endogenous because it depends on personal characteristics, and a simple comparison of average values between treated and control groups would result in biased ATE estimates. The non-random nature of the experiment and selection bias concerns are addressed using the Propensity Score Matching (PSM) method (Rosenbaum and Rubin, 1983), which is one of the most popular approaches to derive unbiased estimates in the presence of selection in cross-sectional data. A popular alternative to PSM is the difference-in-difference (DiD) model, however a DiD implementation requires a panel dataset of at least two periods (before and after the treatment) for both treated and control groups, which is not available for this study. An advantage of the PSM approach for impact evaluation across comparable groups is that, unlike regression techniques, it does not require a specific functional form (Redmond and McGuinness, 2019). The core of a PSM investigation is to identify a sub-sample of the control group with characteristics very similar to the treatment group so that comparisons are undertaken between two similar groups (Black and Smith, 2004). The identification of a control sub-sample and estimation of the effect of treatment, T_i, using a PSM procedure involves the following steps (Cameron and Trivedi, 2005):

1. Run a binary regression model (e.g. logit) using T_i as a response variable and a set of covariates that affect the probability of being treated as predictors;
2. Calculate probabilities of being treated for both control and treatment groups;
3. Use the calculated probabilities to match each treatment observation with a control observation, using a matching procedure (e.g. nearest neighbour, Mahalanobis distance, caliper matching, exact matching);
4. Calculate the ATE for all response variables (i.e. indicators of behaviour change) on the new sample of matched (treatment and control) observations. The response variables, which are described below in section 2.5, include behaviours related to community-led initiatives and private actions.

Logit regressions are used to estimate treatment probabilities for each treatment (i.e. steps 1–2). The logit model is an econometric specification for binary outcomes, where the probability of being treated is described by the following probability distribution function (Greene, 2003):

$$Pr[T_i = 1|X_n] = \frac{\exp(X_n^T\beta)}{\exp(X_n^T\beta) + 1} \tag{1}$$

where T_i is the treatment, X_n is a matrix of socio-demographic characteristics of the individual n, β represents a vector of coefficients to estimate. The nearest neighbour approach is used as the matching procedure in step 3 for this application (Austin, 2014). ATE estimation and significance testing in step 4 is based on testing equality of means of treatment and matched control group for specified voluntary water quality activities. Means are proportions of the treatment and matched control groups that engage in voluntary water quality activities. The t-test on the ATE being equal to zero uses the Abadie-Imbens standard error

(Abadie and Imbens, 2006). The statistical analyses use the R software package; logit models for treatment probabilities are estimated using the 'glm' function from the base installation, while the ATE assessment is undertaken using the 'Match' function from the 'Matching' package (Sekhon, 2011).

2.3. Questionnaire and Data

The data for this study originated from two separate online surveys, one for the treatment group and one for the control group. Data collection capturing behavioural responses did not occur contemporaneously with LAWPRO's activities between 2017 and 2017, rather data was collected retrospectively in 2020. The treatment group survey was administered to registered participants of LAWPRO water events. LAWPRO issued an email invitation to participate in the survey with data collection occurring during June 2020. A follow-up reminder email was sent one week after the initial email. In total 436 responses were received. As some respondents failed to complete key questions relevant for the analysis here, the number of observations reduced to 385.

The control group survey was also an online survey but with a sample drawn from the panel book of a professional survey company. The company's panel comprises adults resident in Ireland but the sample drawn for this study was not designed to be representative of the population. Instead the objective was to acquire a sufficiently large control group sample to enable adequate PSM attendee matching. The planned sample size for the control group was intended to achieve an approximate 10:1 ratio between treatment and control group samples, which is considered a sufficient ratio to find a good match for each treatment group observation (Austin, 2010). The control group survey was administered in July 2020 and the total number of observations is 3,544.

The same questionnaire was administered to the two samples. The questionnaire comprised thirty-four questions organised in six thematic sections, which was drafted in consultation with LAWPRO to understand the types of events that were organised, the environmental behaviours promoted, and the information delivered to participants. The first section included warm-up questions to introduce the survey topic, understand perceptions of the water quality status of Irish waters and gather information on number and types of event attended. The second section comprised questions on the most recent water quality event attended, enabling respondents to recall details with greater accuracy. In this instance information about the type of event, when the event took place, the reason for attending and their level of satisfaction was collected. The third and fourth sections contained questions about knowledge of water issues and on behaviours that respondents undertake within their home, outside their home (i.e. in the garden) and about purchasing behaviours. The fifth section concentrated on preferences for event attributes, which is not considered in this work. The final section gathered socio-demographic information.

Descriptive statistics of the samples are reported in Table 1. The control group survey was not stratified by socio-demographic quotas and, when compared to census statistics, males were under-sampled by some 8 percent, while younger respondents were over-represented. The larger share of young respondents is common in web surveys, because older people are less likely to own a computer or an internet connection (Bethlehem, 2010) and in this instance be members of the survey company's online panel. The treatment group comprises a larger share of males and older people. The study was conducted in a quasi-experimental setting with the treatment group affected by selection bias, therefore equal representation of some population cohorts was not anticipated. Comparable data from the 2016 census of population are also reported for information purposes.

Table 1: Descriptive Statistics: Treatment and Control Groups

Variable	Treatment Group (N=385) Frequency	Control Group (N=3544) Frequency	Census† Frequency
Males	0.62	0.41	0.49
	(0.49)	(0.49)	
Age:			
18–24	0.01	0.20	0.15
	(0.10)	(0.40)	
25–34	0.04	0.25	
	(0.19)	(0.44)	0.37
35–44	0.15	0.23	
	(0.35)	(0.42)	
45–65	0.59	0.25	0.30
	(0.49)	(0.43)	
66+	0.21	0.06	0.17
	(0.41)	(0.24)	
Education:			
Secondary school or lower	0.17	0.30	0.48
	(0.37)	(0.46)	
Undergraduate/technical	0.38	0.45	0.41
	(0.49)	(0.50)	
Postgraduate	0.45	0.25	0.11
	(0.50)	(0.43)	
Net Income per month:			
<€1500	0.11	0.21	
	(0.31)	(0.41)	
€1501–2000	0.16	0.22	
	(0.37)	(0.41)	
€2001–4000	0.46	0.39	
	(0.50)	(0.49)	
€4001–6000	0.19	0.14	
	(0.39)	(0.35)	
€6000+	0.08	0.05	
	(0.26)	(0.21)	

Standard deviations in parenthesis

† Reported census of population age cohorts are ages 15–24, 25–44, 45–64, and 65+

2.4. Treatments

Several categories of treatment groups, T_i, are generated from the sample of respondents who attended community engagement events related to water quality based on number, type, and year of most recent event attended. This categorisation enables investigation of whether the level of behavioural change is associated with type, frequency and duration of community engagement activities. Seven treatments are considered, which are described in the paragraphs below.

T_1: Attendance at a minimum of one community engagement event. This is the treatment that includes all respondents of the treatment survey, i.e. all the people who attended at least one event. (N=385)

T_2: Attendance at a minimum of four community engagement events. This treatment is included as an approximation for respondents that were exposed to a greater depth of information about water quality. The survey did not elicit information on the number of events attended each year due to concerns about the ability of respondents to recall such precise information over a 4-year timeframe. So the treatment is exceeding a threshold intensity of engagement equivalent to an average of 1 event per year between 2017 and 2020.

T_3–T_5: Attendance only at specific event types. It would be preferable to undertake separate analysis for each of the 9 event types included in the survey but the number of respondents who attended some of these events is too low to achieve meaningful results. Figure 1, which reports the number of attendees within the treatment group by event type, shows that within the dataset only three event types were attended by more than 100 respondents. To avoid biases due to low sample size some similar event types were combined plus a minimum sample size of 100 was set. Specifically, these events are:

- T_3: Public meetings facilitated by LAWPRO (N = 219)
- T_4: Nature themed public events (N = 145), which comprises public events that included a water quality or catchment management related theme. Examples include events related to World Wetlands Day, Heritage Week, Biodiversity Week, as well as local events that included a catchment management related exhibit.
- T_5: Community group meetings (N = 180) which comprise local non-government organization (NGO) groups related to community development (e.g. Resident's Association) or water focused activities (e.g. angling, coastal group)

T_6: If the most recent event attended was in 2017 or 2018. The time elapsed since the most recent event attended may have an impact on individuals' behaviours. Recent attendance at a community engagement event may encourage pro-environmental behaviours in the short run but behaviours may revert after some time has elapsed.

T_7: If the most recent event attended was in 2019 or 2020. Results of the analysis of this treatment will be interpreted with those from T_6 to examine short and long run behavioural change effects associated with attendance at water quality community engagement events. The objective is to learn if the behavioural change is sustained over time.

2.5. Response Variables: Adoption of pro-environmental behaviours

Response variables fall into two categories: those related to community-led initiatives, and those related to private actions.

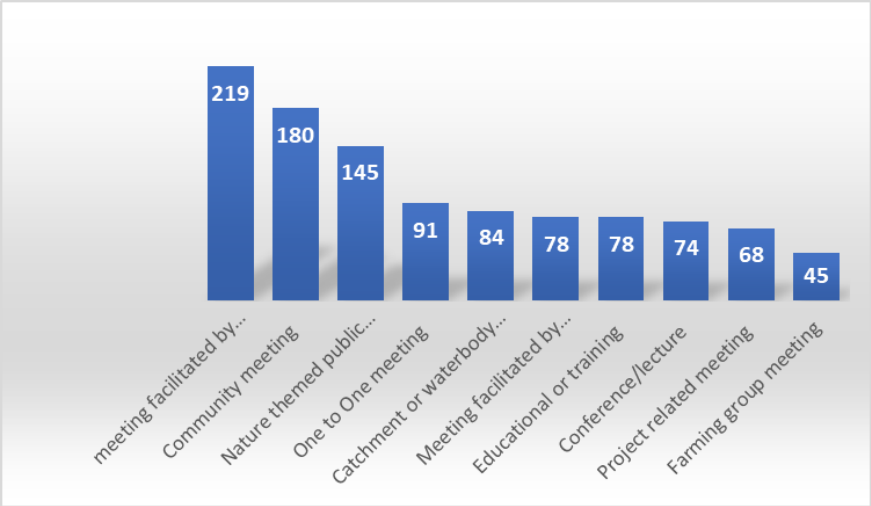

Figure 1: Number of attendees for each type of water quality event

2.5.1. Community-led initiatives

As a result of the community engagement events, whether facilitated by LAWPRO or other organisations, participants may have been sufficiently motivated to engage in community-led initiatives to improve or protect water quality in their locality. Three types of initiative are considered where the respondent:

C_1*: Organised a local water related event or project*

C_2*: Joined a local group that cares for water quality*

C_3*: Participated in a citizen science initiative (i.e. an initiative that encourages citizen participation in scientific research, e.g. water nitrogen monitoring, fish species data recording)*

For the PSM analysis the difference in shares between the treatment and control groups undertaking the action is examined in each case. Due to a survey design coding error survey respondents were only able to indicate if they had undertaken one rather than any of the activities, C_1–C_3. While this limits the nature of the data collected, it is unlikely to substantially impact on the empirical results on whether engagement events have an impact on people participating in community-led events.

2.5.2. Private actions

Participation in community engagement events may also impact on individuals' adoption of sustainable behaviours. In the case of LAWPRO, influencing individual private behaviours is not a specific objective but the theme of several treatment types is the adoption of more sustainable behaviours, including resource use, waste management, and water protection. A broad range of sustainability issues were potentially mentioned in the engagement events and are classified here into six groups: in-home behaviours, outside-home behaviours, purchasing behaviours, knowledge of water management schemes, reporting environmental damage, and workplace behaviours.

R_1*: In-home behaviours.* In-home behaviours are actions that people can take inside their home that could potentially affect water quality. The behaviours considered are $R_{1.1}$: Conserve water (e.g. owning dual flush toilet or a cistern bag); $R_{1.2}$: Avoid flushing plastic, wipes and other polluting items down the toilet; $R_{1.3}$: Use brown bins for food waste; $R_{1.4}$: Avoid the use in-sink food macerators. Answers were coded as

1 if the respondent adopted the behaviour regularly and 0 if not adopted. Individual behaviours were also aggregated in a response variable, $R_{1.C}$, capturing the total number of behaviours pursued by respondents, which ranged between 0 for respondents who did not adopt any of the behaviours to 4 for respondents who adopted all in-home behaviours. For the PSM analysis the difference in shares between the treatment and control groups undertaking the behaviour is examined in the case of $R_{1.1}$–$R_{1.4}$, while the difference in mean counts is considered for $R_{1.C}$

R_2: Outside-home behaviours. Outside-home behaviours are related to the management of garden and private outdoor spaces. The questionnaire considered five pro-environmental behaviours, $R_{2.1}$: Use a water butt to harvest rainwater for garden use; $R_{2.2}$: Avoid the use of chemical products; $R_{2.3}$: Grow vegetables organically; $R_{2.4}$: Have a private well tested annually; $R_{2.5}$: Regular maintenance of septic tank. Coding and analysis of the individual and collective behaviours is similar to those for in-home behaviours. The aggregated response variable for outside-home behaviours is labelled $R_{2.C}$.

R_3: Purchasing behaviours. Purchasing behaviours relate to the attention that people give as consumers to the products purchased. With respect to water quality impact, three behaviours were identified: $R_{3.1}$: Reduce the purchase of clothes; $R_{3.2}$: Avoid single use plastic; and $R_{3.3}$: Purchase environmentally friendly cleaning products. The aggregated purchasing behaviours variable was labelled $R_{3.C}$.

R_4: Knowledge of water management schemes. This analysis captured respondents' awareness of water management in Ireland based on one survey question and a follow-up. The first question asked respondents to indicate the level at which Irish waters are managed with four candidate answers (river level, catchment level, regional level and national level), $R_{4.1}$. Respondents who selected the correct answer (i.e. catchment level) received a follow up question, in which they were asked to indicate the approximate number of catchment management units in Ireland's RBMP, $R_{4.2}$. The PSM analysis for these indicators is the share of respondents who reported the correct answer.

R_5: Attitudes towards environmental damage reporting. Respondents were asked to indicate if they witnessed a water pollution incident in the past, which was used to assess attitudes towards reporting environmental pollution to the relevant authorities. The question was designed as a 'yes-no' question with a follow-up based on the answer. Where respondents witnessed a water pollution incident, the follow-up question asked to indicate whether they reported the incident to one of a number of relevant institutions or not. The analysis for this indicator, $R_{5.1}$, is the share of respondents who stated they reported the pollution incident.

R_6: Behaviours in the workplace. The questionnaire included two questions on behaviours in the workplace, one for farmers and one for business owners and other workers. These questions were preceded by a screening question that asked the type of occupation and automatically diverted respondents to the relevant questions. Four relevant behaviours were identified for farmers, $R_{6.1}$: Adoption of a nutrient management plan for a more targeted use of slurry and fertiliser; $R_{6.2}$: Adoption of new land management actions for nutrient retention; $R_{6.3}$: Implementation of new farmyard practices to control soiled waters; and $R_{6.4}$: Use of Protected Urea instead of Urea or CAN (calcium ammonium nitrate). A dedicated question for farmers was included because they represent an important class of stakeholders in water management with a potential high impact on water quality when best practices are not pursued. Unfortunately, farmers' recruitment in the survey of attendees was limited, therefore PSM analyses were conducted on relatively small sample sizes. Results on farmers' behaviours are displayed due to the importance of this group in water management but results should be interpreted with caution.

With respect to business owners or other workers, six behaviours are considered, $R_{6.5}$: Keep informed of best environmental practice; $R_{6.6}$: Awareness of workplace water usage and waste water treatment; $R_{6.7}$: Audited water usage and engagement in a water conservation programme; $R_{6.8}$: Understanding of environmental regulations and best practice to comply with their work/business, $R_{6.9}$: Active promotion of sustainable practices in the organisation/workplace (such as water conservation, care with chemicals, waste management, reduction of single use plastic); and $R_{6.10}$: Awareness of drainage and the need to separate clean and soiled/waste waters.

3. Results

3.1. Binary models for attendance probabilities

Across the treatment groups, T_1–T_7, the logit model estimates are generally internally consistent with each other in terms of the association between socio-demographic variables and the likelihood of treatment. Only in a small number of cases do the sign of the estimated coefficients change between models and in those instances the coefficient estimates are not significantly different from zero. This indicates that the relevant socio-demographic variable is not associated with the likelihood of treatment (i.e. attendance at requisite community engagement events). The estimated logit coefficients are not easily interpreted and instead odds ratios are reported in Table 2. Odds ratios greater than one indicate higher likelihood of being in the treatment group, while odds ratios less than one indicate the opposite. With respect to respondents' age all reported odds ratios are less than 1, which indicates that compared to the reference category of people aged above 65 years, all cohorts are less likely to be in the treatment group. For example, people aged 35–45 are 0.16 times as likely to be in the T_1 treatment group compared to those aged 66 and older. The estimated odds ratio of those aged 45–65 is not significantly different than one, which indicates that this group has a similar likelihood of being in the treatment group as the reference category. Respondents in the two highest age cohorts are equally likely to attend the water quality community engagement events, whereas the younger age cohorts have a lower likelihood of being in the treatment group.

The likelihood of being in the treatment group, i.e. attendance at community engagement events, is correlated with gender and varies across treatments. Broadly, men are more likely to attend water quality community engagement events and for some treatments, twice as likely as women. The odds ratios for household size are not significantly different than one, which suggests that there is no association with likelihood of being in the treatment group.

Respondents with a post-graduate level education are between 2–6 times more likely to attend community engagement events across the T_1-T_7 treatment groups compared to those with secondary education. The respondent attribute associated with the highest likelihood of being in any of the seven treatment groups is being a representative of an NGO. The variable indicates that the respondent was representing a voluntary organisation concerned with angling, water, local development or the environment. The likelihood of being in the treatment group is between 8–17 times higher for NGO representatives compared to non-representatives. If respondents are employed by a public body they also have a substantially higher likelihood of being in a treatment group.

Three variables were included in the logit models to capture economic or social status: occupation, income, and financial comfort. For occupation, managerial positions are the reference category and the only occupation category with a significantly different likelihood of being in any of the treatment groups is non-manual positions. With respect to income there is no association between income level and treatment group. The financial comfort variable is a respondent assessment of whether in terms of their household income they

are "struggling to make ends meet" or are "living comfortably". Those in the latter category are 2–4 times more likely to be in a treatment group.

Table 2: Logit models for the estimation of treatment probabilities in each treatment†

Dependent variable - treatment group	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Age (ref: 66+)							
18–24	0.007***	0.011***	0.008***	0.013***	0.014***	0***	0.012***
	(0.004)	(0.008)	(0.006)	(0.011)	(0.009)	(0)	(0.007)
25–34	0.022***	0.029***	0.035***	0.044***	0.031***	0***	0.036***
	(0.008)	(0.014)	(0.015)	(0.022)	(0.015)	(0)	(0.014)
35–44	0.163***	0.229***	0.192***	0.314***	0.158***	0.049***	0.21***
	(0.042)	(0.077)	(0.059)	(0.117)	(0.057)	(0.023)	(0.059)
45–65	0.808	1.198	0.755	0.901	0.834	0.626*	0.921
	(0.166)	(0.334)	(0.186)	(0.291)	(0.237)	(0.191)	(0.215)
Male (ref: female)	1.647***	2.175***	2.073***	1.037	1.467	1.359	1.852***
	(0.245)	(0.428)	(0.392)	(0.226)	(0.304)	(0.341)	(0.305)
No. of household members	1.057	1.027	1.004	1.003	1.044	1.02	1.08
	(0.061)	(0.077)	(0.07)	(0.087)	(0.082)	(0.1)	(0.068)
Education (ref: Secondary)							
Undergraduate degree	1.492	1.603	1.381	3.511*	1.904	1.2	1.499
	(0.303)	(0.439)	(0.348)	(1.359)	(0.571)	(0.379)	(0.346)
Postgraduage degree	3.36***	3.811**	2.892**	6.554**	4.468**	2.542*	3.394***
	(0.726)	(1.094)	(0.772)	(2.635)	(1.403)	(0.849)	(0.828)
NGO representative (ref: otherwise)	11.056***	17.796***	8.776***	11.977***	15.927***	14.527***	11.427***
	(1.78)	(3.524)	(1.632)	(2.623)	(3.249)	(3.835)	(1.988)
Public Employee (ref: otherwise)	2.234***	2.257**	2.418**	1.96*	1.793	2.861*	1.933**
	(0.436)	(0.546)	(0.556)	(0.531)	(0.482)	(0.995)	(0.412)
Financial Comfort (ref: struggling)							
Living Comfortably	2.442***	1.941**	2.581***	1.97*	1.923**	4.332**	2.173***
	(0.425)	(0.435)	(0.575)	(0.522)	(0.458)	(1.356)	(0.415)
Occupation (ref: Managerial)							
Manual	0.742	0.46***	0.73	0.353***	0.548**	1.433	0.638**
	(0.184)	(0.164)	(0.233)	(0.161)	(0.191)	(0.57)	(0.179)
Non-manual	0.24***	0.354***	0.327***	0.241***	0.177***	0.277***	0.263***
	(0.088)	(0.155)	(0.143)	(0.132)	(0.097)	(0.177)	(0.105)
Other	0.927	0.965	0.773	0.746	0.729	1.018	0.908
	(0.258)	(0.34)	(0.294)	(0.307)	(0.274)	(0.461)	(0.281)
Professional	0.867	0.791	1.007	0.68**	0.549***	1.271	0.855
	(0.146)	(0.169)	(0.206)	(0.163)	(0.126)	(0.374)	(0.156)
Income (ref: Less than €1500/month)							
€1501-2000/month	1.409	1.28	1.677	1.079	1.018	0.96	1.672
	(0.361)	(0.449)	(0.58)	(0.437)	(0.359)	(0.394)	(0.49)
€2001-4000/month	1.388	1.582	1.684	1.309	1.123	1.112	1.456
	(0.329)	(0.505)	(0.551)	(0.482)	(0.36)	(0.402)	(0.402)
€4001-6000/month	1.214	1.322	1.749	1.373	0.937	0.654	1.449
	(0.351)	(0.502)	(0.658)	(0.592)	(0.365)	(0.311)	(0.474)
€6000+/month	1.966	2.846	2.529	2.517	0.898	1.554	2.119
	(0.718)	(1.326)	(1.181)	(1.349)	(0.477)	(0.942)	(0.875)
Constant	0.054***	0.025***	0.012***	0.028***	0.047***	0.02***	0.029***
	(0.036)	(0.02)	(0.012)	(0.026)	(0.038)	(0.022)	(0.022)
County dummies	yes	yes	yes	yes	yes	yes	yes
Observations	3,929	3,767	3,784	3,717	3,748	3,665	3,838
Log Likelihood	-715	-456	-505	-362	-412	-285	-606
Akaike Information Criterion	1,521	1,001	1,099	814	914	659	1,303

† Logit estimates reported as odds ratios & significance tests from 1. *** p<0.01, ** p<0.05, * p<0.1

Table 3: Engagement in community-led initiatives to improve or protect water quality

	C_1 Organised water event	C_2 Member of water protection group	C_3 Joined citizen science initiative
T_1			
ATE	0.207***	0.354***	0.129***
St. Err.	(0.036)	(0.042)	(0.028)
Matched Obs	385	385	385
T_2			
ATE	0.219***	0.353***	0.088**
St. Err.	(0.058)	(0.056)	(0.043)
Matched Obs	223	223	223
T_3			
ATE	0.151***	0.446***	0.117***
St. Err.	(0.039)	(0.045)	(0.032)
Matched Obs	219	219	219
T_4			
ATE	0.285***	0.169**	0.173***
St. Err.	(0.063)	(0.066)	(0.040)
Matched Obs	145	145	145
T_5			
ATE	0.228***	0.313***	0.107***
St. Err.	(0.052)	(0.055)	(0.039)
Matched Obs	180	180	180
T_6			
ATE	0.196***	0.292***	0.156***
St. Err.	(0.054)	(0.072)	(0.045)
Matched Obs	121	121	121
T_7			
ATE	0.221***	0.419***	0.127***
St. Err.	(0.042)	(0.044)	(0.032)
Matched Obs	294	294	294

3.2. Pro-environmental behaviours: Matching results

3.2.1. Community-led events

Table 3 presents matching results for engagement in community-led initiatives related to water protection. The ATE estimates, which indicate the difference in probability of engaging in the behaviour, are all positive and statistically significant across treatments. This indicates that respondents in the treatment group are more likely to participate in community-led events compared to the control group. With respect to T_1, which comprises all attendees of at least one community engagement event, respondents were 20.7 percentage points more likely to organise water-related events, 35.4 percentage points more likely to be part of a group on water quality and 12.9 percentage points more likely to take part in a citizen science initiative. The magnitude of the ATE estimates is similar across treatments, which indicates that success in convincing people to get involved with community groups focusing on water protection does not vary with intensity or type of engagement event.

3.2.2. Private Actions

Results of private action PSM analyses are reported across three tables. Results related to individual private response variables, excluding those related to the workplace, are reported in Table 4, where information on the ATE, estimated standard errors and number of matched observations between the treatment and control groups is reported for each of the 7 treatments. The columns relate to single behaviours or response variables (e.g. $R_{1.1}$ or $R_{1.2}$) and the ATE value indicates the difference in probability of engaging in the behaviour (e.g. conserving water, or avoiding flushing plastic items down toilet) between the treatment and control groups. For example, for $R_{1.1}$ the ATE value of 0.108 for the T_1 treatment indicates that the treatment group is 10.8 percentage points more likely to engage in water conservation compared to the control group and the estimate has statistical significance at 5 percent level. In the case of $R_{1.2}$ the ATE estimate is not significant across any of the treatment groups indicating there is no observable difference in behaviour between those that attended community engagement events relative to those that did not. Treatments T_1 and T_2 refer to the attendance at a minimum of one and a minimum of four events, respectively. One would anticipate that the ATE for T_2 is not less than the ATE for T_1, which is the case in some but not all instances. One case where there is a notable difference is knowledge of water catchment management, $R_{4.1}$, where the ATE is 0.497 versus 0.315. Respondents that attended just one community engagement event, T_1, are 31.5 percentage points more likely to know the level at which Irish waters are managed compared to the control group. In the case of T_2, where respondents have attended a minimum of four community engagement events, the comparable figure is 49.7 percentage points. Treatments T_3–T_5 are differentiated by type of water quality community event; those facilitated by LAWPRO; nature themed public events; and community group meetings. Across the response indicators, $R_{1.1}$–$R_{5.1}$, the different event types appear to influence different behaviours. For example, respondents that have attended events facilitated by LAWPRO are less likely to use in-sink macerators, whereas those that attend community group meetings are more likely to segregate organic waste streams (i.e. brown bin) relative to the control group.

Table 5 presents the PSM results for response variables that capture the aggregation of individual behaviours (labelled as $R_{*.C}$). The ATE is the difference in mean counts of behaviours in the treatment versus the control group. In the case of treatment T_1 and the count of in-home behaviours, $R_{1.C}$ (e.g. conserving water, not flushing wipes, etc.), the estimated ATE is 0.265, which indicates that the treatment group, on average, undertake 0.26 additional in-home behaviours than the control group. For outside-home behaviours, $R_{2.C}$, there is a similar ATE value at 0.247, and similarly for purchasing behaviours, $R_{3.C}$, at 0.251. The final column calculates the ATE across all the individual behaviours reported in Table 4. For treatment T_1 the mean additional number of behaviours undertaken compared to the control group is 0.76. When

the treatment is T_2, which is a minimum of four water quality community engagement events, the ATE is 1.037, roughly one behaviour more than people in the control group. For treatment T_3 the mean number of additional behaviours relative to the control group is 0.535, whereas for treatments T_4 and T_5 the ATE values are higher at 1.1 and 0.87 respectively. The mean number of changed behaviours among participants at LAWPRO facilitated events is half that of participants at nature themed events. However, the standard errors for the estimates are relatively large resulting in the 95 percent confidence intervals for the point estimates overlapping to a substantial degree.

Treatments T_6 and T_7 are differentiated by the time-frame since attendance at the most recent event. For T_6 it relates to 2017–2018 and for T_7 it is 2019–2020. The ATE for the mean number of additional behaviours relative to the control under T_6 is 0.439 but the estimate is not statistically significant.[1] Under T_7 the ATE for the mean number of additional behaviours relative to the control is 0.902 and statistically significant. The implication is that there is a time decay effect associated with community engagement events that seek to change behaviours for the improvement of water quality. New pro-environmental behaviours are not indefinitely sustained.

PSM results for behaviours in the workplace are reported in Table 6. Farming related behaviours are displayed on the left and relate to just 63 matched observations, so the sample is relatively small and any conclusions are subject to greater uncertainty. Nonetheless results on farmers' behaviours are reported due to the importance of agriculture for water quality. Farmers who attended water quality engagement events (T_1 & T_2) are more likely to adopt new farmyard practices to control soiled water, $R_{6.3}$, compared to a control group of farmers that did not attend water quality events. The greatest impact on farmer behaviours appears to arise where the engagement events are facilitated by LAWPRO, i.e. T_3. Farmers engaged in such a treatment are 43 percentage points more likely to implement good farmyard practices for control of soiled water ($R_{6.3}$); are 24 percentage points more likely to adopt a nutrient management plan for more targeted use of slurry and fertiliser ($R_{6.1}$); and 18 percentage points more likely to adopt new land management actions for nutrient retention ($R_{6.2}$) compared to a control group of farmers that did not attend water quality events. Where farmers attended nature themed events (T_4) or community group meetings (T_5), there is no evidence of any additional behaviours compared to the control group, though these results are based on very small samples. Curiously, the findings for the time-decay effects are reversed compared to the wider population. Under T_6, estimated ATEs are positive and statistically significant in two instances (i.e. $R_{6.1}$ and $R_{6.3}$) but are not statistically significant in any instance under T_7. There is no intuition on why this is the case but with the small sample sizes it is unwise to draw any firm conclusions.

Table 6 also reports ATE estimates for pro-environmental behaviours among other business types, including business owners and workers. All 7 treatments (T_1–T_7) are associated with a statistically significant and positive impact for 5 of 6 of the considered behaviours, with the exception related to auditing water usage and implementation of a water conservation programme ($R_{6.7}$). With respect to the magnitude of treatment impact, differences are negligible between T_1 and T_2, and are similarly negligible between T_3, T_4, and T_5. On time-decay effects, ATE values for event attendees during 2019–2020 (T_7) are generally higher than for respondents where their most recent attended event was in 2017 or 2018 (T_6), thought the differences in ATE values between T_6 and T_7 are relatively small with overlapping confidence intervals.

[1] Though ATE estimates for some of its constituent parts are individually statistically significant, for instance, in the case of $R_{1.C}$ and $R_{4.1}$.

Table 4: PSM results for the different outcomes across treatments

	$R_{1.1}$ Conserve water	$R_{1.2}$ No flush wipes	$R_{1.3}$ Brown bin use	$R_{1.4}$ Avoid sink macera-tor	$R_{2.1}$ Collect rain water	$R_{2.2}$ Use of chemi-cals	$R_{2.3}$ Grow veg-etables organi-cally	$R_{2.4}$ Septic tank mainte-nance	$R_{2.5}$ Private well testing	$R_{3.1}$ Purchase less clothes	$R_{3.2}$ Avoid single use plastic	$R_{3.3}$ Env. friendly products	$R_{4.1}$ Knowledge of water manage-ment	$R_{4.2}$ Number of catch-ments	$R_{5.1}$ Incident report-ing
T_1															
ATE	0.108**	0.022	0.042	0.093***	0.043	-0.016	0.045	0.054	0.12***	0.121**	0.073*	0.057	0.315***	0.143*	0.034
St. Err.	(0.04)	(0.02)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)	(0.04)	(0.03)	(0.05)	(0.04)	(0.05)	(0.05)	(0.08)	(0.07)
Matched Obs	385	385	385	385	385	385	385	385	385	385	385	385	382	225	227
T_2															
ATE	0.124**	0.051	0.088	0.079**	0.077	0.045	0.067	0.089	0.108**	0.078	0.111*	0.121*	0.497***	0.159**	0.104
St. Err.	(0.06)	(0.03)	(0.06)	(0.04)	(0.07)	(0.04)	(0.07)	(0.07)	(0.04)	(0.07)	(0.06)	(0.07)	(0.06)	(0.08)	(0.07)
Matched Obs	223	223	223	223	223	223	223	223	223	223	223	223	221	147	152
T_3															
ATE	0.107**	0.026	-0.01	0.075***	-0.004	-0.04	-0.022	0.034	0.13***	0.148***	0.053	0.042	0.399***	0.188**	0.022
St. Err.	(0.04)	(0.02)	(0.05)	(0.03)	(0.05)	(0.03)	(0.05)	(0.05)	(0.04)	(0.05)	(0.04)	(0.05)	(0.05)	(0.08)	(0.07)
Matched Obs	219	219	219	219	219	219	219	219	219	219	219	219	217	145	146
T_4															
ATE	0.134**	0.019	0.121*	0.053	0.165**	0.047	0.104	0.082	0.028	0.103	0.118**	0.134*	0.318***	0.181**	-0.04
St. Err.	(0.06)	(0.03)	(0.07)	(0.04)	(0.07)	(0.04)	(0.07)	(0.07)	(0.04)	(0.07)	(0.06)	(0.07)	(0.07)	(0.08)	(0.07)
Matched Obs	145	145	145	145	145	145	145	145	145	145	145	145	145	103	108
T_5															
ATE	0.084*	-0.012	0.157***	0.017	0.019	0.007	0.094	0.01	0.073	0.159***	0.124**	0.144**	0.352***	0.074	0.071
St. Err.	(0.05)	(0.03)	(0.06)	(0.03)	(0.06)	(0.03)	(0.06)	(0.06)	(0.05)	(0.06)	(0.05)	(0.06)	(0.07)	(0.09)	(0.09)
Matched Obs	180	180	180	180	180	180	180	180	180	180	180	180	180	117	133
T_6															
ATE	0.079	0.029	0.047	0.094**	0.096	0.052	-0.021	-0.063	0.1	0.074	-0.014	-0.034	0.339***	0.174	-0.05
St. Err.	(0.08)	(0.03)	(0.08)	(0.04)	(0.08)	(0.05)	(0.08)	(0.08)	(0.06)	(0.09)	(0.06)	(0.08)	(0.08)	(0.12)	(0.12)
Matched Obs	121	121	121	121	121	121	121	121	121	121	121	121	119	60	67
T_7															
ATE	0.102**	0.002	0.109*	0.048*	0.012	-0.003	0.062	0.076	0.134***	0.156***	0.021	0.184***	0.382***	0.102	0.082
St. Err.	(0.04)	(0.02)	(0.06)	(0.03)	(0.06)	(0.04)	(0.06)	(0.05)	(0.04)	(0.05)	(0.05)	(0.05)	(0.05)	(0.08)	(0.08)
Matched Obs	294	294	294	294	294	294	294	294	294	294	294	294	291	181	178

*** p<0.01, ** p<0.05, * p<0.1

Table 5: PSM results for the count of behaviours

	$R_{1.C}$ Home behaviours	$R_{2.C}$ Outside behaviours	$R_{3.C}$ Purchasing behaviours	$R_{1.C}$ +$R_{2.C}$ + $R_{3.C}$ All behaviours
T_1				
ATE	0.265***	0.247**	0.251***	0.762***
St. Err.	(0.07)	(0.10)	(0.09)	(0.17)
Matched Obs	385	385	385	385
T_2				
ATE	0.342***	0.386***	0.309***	1.037***
St. Err.	(0.10)	(0.15)	(0.12)	(0.27)
Matched Obs	223	223	223	223
T_3				
ATE	0.194***	0.099	0.242**	0.535***
St. Err.	(0.07)	(0.11)	(0.10)	(0.18)
Matched Obs	219	219	219	219
T_4				
ATE	0.327***	0.425***	0.355***	1.107***
St. Err.	(0.11)	(0.14)	(0.12)	(0.27)
Matched Obs	145	145	145	145
T_5				
ATE	0.246***	0.202	0.427***	0.875***
St. Err.	(0.08)	(0.13)	(0.11)	(0.23)
Matched Obs	180	180	180	180
T_6				
ATE	0.249**	0.164	0.026	0.439
St. Err.	(0.11)	(0.17)	(0.13)	(0.28)
Matched Obs	121	121	121	121
T_7				
ATE	0.261***	0.281**	0.36***	0.902***
St. Err.	(0.08)	(0.12)	(0.10)	(0.20)
Matched Obs	294	294	294	294

*** p<0.01, ** p<0.05, * p<0.1

Table 6: Impact of event attendance on behaviours at workplace.

	Behaviours of farmers				Behaviours of workers and business owners					
	$R_{6.1}$	$R_{6.2}$	$R_{6.3}$	$R_{6.4}$	$R_{6.5}$	$R_{6.6}$	$R_{6.7}$	$R_{6.8}$	$R_{6.9}$	$R_{6.10}$
	Have nutrient plan	Nutrient retention	Good farmyard practices	Use protected urea	Know best practices	Aware water usage	Audit water usage	Understand env. regulation	Promote best practices	Aware of drainage
T_1										
ATE	-0.127	0.238	0.46*	0.222	0.549***	0.352***	0.028	0.433***	0.355***	0.466***
St. Err.	(0.29)	(0.25)	(0.25)	(0.23)	(0.06)	(0.07)	(0.05)	(0.06)	(0.07)	(0.06)
Matched Obs	63	63	63	63	180	180	180	180	180	180
T_2										
ATE	0.174*	0.026	0.277***	-0.029	0.586***	0.348***	0.077	0.463***	0.443***	0.489***
St. Err.	(0.10)	(0.09)	(0.10)	(0.07)	(0.07)	(0.08)	(0.05)	(0.07)	(0.08)	(0.07)
Matched Obs	29	29	29	29	111	111	111	111	111	111
T_3										
ATE	0.246***	0.181**	0.431***	0.104	0.643***	0.351***	0.014	0.389***	0.394***	0.418***
St. Err.	(0.09)	(0.09)	(0.09)	(0.08)	(0.06)	(0.07)	(0.05)	(0.08)	(0.07)	(0.07)
Matched Obs	40	40	40	40	105	105	105	105	105	105
T_4										
ATE	0.148	0.102	0.093	-0.009	0.523***	0.464***	0.101**	0.436***	0.378***	0.456***
St. Err.	(0.15)	(0.14)	(0.14)	(0.11)	(0.07)	(0.07)	(0.05)	(0.08)	(0.08)	(0.08)
Matched Obs	12	12	12	12	84	84	84	84	84	84
T_5										
ATE	0.07	-0.046	-0.046	0.019	0.622***	0.471***	-0.089	0.42***	0.471***	0.463***
St. Err.	(0.13)	(0.11)	(0.11)	(0.10)	(0.07)	(0.08)	(0.06)	(0.08)	(0.07)	(0.06)
Matched Obs	16	16	16	16	90	90	90	90	90	90
T_6										
ATE	0.303***	0.07	0.318***	0.119	0.382***	0.416***	0	0.292***	0.216**	0.271**
St. Err.	(0.11)	(0.11)	(0.12)	(0.11)	(0.11)	(0.08)	(0.08)	(0.10)	(0.10)	(0.12)
Matched Obs	21	21	21	21	52	52	52	52	52	52
T_7										
ATE	-0.062	0.208	0.479	0.25	0.649***	0.472***	-0.063	0.442***	0.34***	0.485***
St. Err.	(0.28)	(0.31)	(0.31)	(0.22)	(0.06)	(0.07)	(0.06)	(0.06)	(0.08)	(0.07)
Matched Obs	48	48	48	48	138	138	138	138	138	138

*** p<0.01, ** p<0.05, * p<0.1

4. Discussion

4.1. Participation in engagement events

While many people attend LAWPRO's community engagement events, the composition of participants is not representative of the wider adult population. From the descriptive statistics of the treatment group in Table 1, attendees are disproportionately older and more highly educated, with 80 percent aged 45 and above compared to 47 percent in the wider population, and 45 percent with post-graduate degrees compared to just 11 percent in the wider population. These findings are also reflected in the logit probability results reported in Table 2, where three additional key factors were identified as being associated with attending LAWPRO events. First, across all socio-demographic variables the highest odds ratio is associated with being a representative of an NGO. The other variables with high odds ratios are public employees and those that have sufficient income to live comfortably. These findings suggest that, at present, water quality community engagement events are attracting a narrow cohort of society and that the message on ways to protect and improve water quality in rivers lakes, groundwater, estuaries and coastal waters is not necessarily reaching all sections of the community. The high odds ratio for NGOs can be viewed as a success because the activation of communities via local NGOs to take responsibility for water quality and catchment management is part of LAWPRO's strategy to engage with the wider population. But the success of such a strategy is dependent on the ability of community NGOs to engage with all cohorts of society, which is not guaranteed.

A notable feature of recent public protests related to the climate and biodiversity crises, compared to other political issues, is the widespread involvement of younger generations. This indicates a willingness by younger generations to engage on environmental issues (Bandura and Cherry, 2019; Boulianne et al., 2020). In this regard, efforts to widen the reach of engagement events and specifically target under-represented cohorts of the population is recommended. Enhancing advertising channels or exploring new approaches to engagement may be necessary. For example, a more intense use of social networks might encourage the engagement of younger people. Another option to foster pro-environmental behaviours is to integrate existing events and activities with other initiatives of social influence (Schultz et al., 2008).

4.2. Participation in Community-led events

The analysis clearly indicates a strong relationship between attendance at engagement events and commitment to water quality initiatives. Water quality engagement event participants are more likely to organise their own water quality event, be members of water quality group, or take part in citizen science initiatives. This result is robust across treatments. Some ATE estimates are in excess of 0.40, which means that event attendees are 40 percentage points more likely to engage in water groups or initiatives compared to non-attendees. While LAWPRO's engagement initiatives may be considered successful to encourage community participation in water protection, it should be noted that the ATE estimates specific to LAWPRO events (T_3, Table 3) are not substantially different compared to non-LAWPRO types of engagement events (i.e. T_4 and T_5, Table 3). Building community participation in water protection initiatives is a complex and time-consuming endeavour, while the metrics used here to measure participation in community-led events are relatively simple (i.e. survey responses C_1, C_2 and C_3). Therefore, drawing a definitive conclusion on the relative efficacy of LAWPRO and non-LAWPRO initiatives may be beyond the scope of what is feasible here. A robust evaluation of the programme needs comprehensive data on programme inputs, as well as, quantitative demonstrative metrics of outcomes. It is imperative that programmes seeking to encourage behavioural change also contemporaneously collect data to quantitatively evaluate their success.

4.3. Increasing knowledge and changing behaviours

All behaviours are not equally amenable to change, hence the varying measured impacts of engagement programmes on different behavioural outcomes. While individuals can be encouraged to adopt some new behaviours following the provision of relevant information, the relationship is complex. Some new behaviours can be undertaken with minimal additional effort or cost. For example, conserving water within the home may have negligible additional cost or effort but reduces water abstraction pressures on the environment. In the context of water-related community engagements, the provision of information increased water conservation activities by in excess of 10 percentage points relative to the control groups for treatments T_1 and T_2. Avoiding the use of in-sink food waste macerators, which reduces the nutrient load on wastewater treatment plants, is another example of the positive impact of community engagements, with a 7–9 percentage point reduction in their use relative to the control groups for treatments T_1 and T_2. However, some behaviours may be less amenable to change even when there is an obvious water quality impact. This arises because long-standing or routine behaviours are very difficult to change and some habits require considerable effort to encourage the adoption of sustainable alternatives beyond just provision of information. An example is flushing wipes and other polluting items down the toilet where the estimated ATE is statistically insignificant ($R_{1.2}$). Another example where the estimated ATE is statistically insignificant is not using chemicals (e.g. glyosphate) in the garden ($R_{2.2}$). In these latter cases, the failure to encourage switching from a long-standing behaviour may be because people do not perceive that there are alternatives that are either similarly priced, convenient, or equally efficient.

All the examples cited in the previous paragraph, whether successful or not in changing behaviours, have low costs associated with the new behaviour. There is mixed success also when new behaviours entail substantial and unavoidable financial costs for households. Regular septic tank maintenance or private well testing are two such examples. Engagement activities are associated with a 10–12 percentage point increase in private well testing relative to the control groups for treatments T_1 and T_2 but the ATE in the case of septic tank maintenance is statistically insignificant. Why did behaviour change occur in one instance but not the other? A possible explanation is that detection of poor drinking water quality has a direct private benefit whereas the impact of poor septic tank operation on ground water quality is neither immediately obvious and may not have a direct private impact. While further research is necessary, behavioural change programmes may be more successful where there is an associated private benefit additional to any wider environmental or community benefits.

Does a higher number of community engagement events have a greater impact on participants? From the results presented in Table 5, the answer is nominally yes, as across the 3 categories of behaviours considered, the ATE under treatment T_2 is always higher than under T_1. But the 95 percent confidence intervals for the ATE estimates overlap to a substantial degree, which means that there is not statistical support to conclusively answer yes. When examining specific behaviours in Table 4, the findings are more blurred. In some instances, such as conserving water and avoiding single use plastics, the ATE is higher under treatment T_2 than under T_1. Whereas in other cases it is lower, such as, avoiding in-sink macerators and private well testing. One issue that complicates these findings is that neither treatment T_1 nor T_2 distinguish between the format or nature of the engagement events, which obviously differ in terms of scope for behavioural change. Treatments T_3–T_5 distinguish between three types of engagement but due to limitations of sample size it is not possible with the current dataset to assess how the level of behavioural change (i.e. number of new behaviours) is associated with the intensity of engagement (i.e. number of engagement events) across various format types.

4.3.1. Farms and other workplaces

The number of farmers within the dataset is relatively low, just 63 observations in our treatment group, therefore caution should be exercised in extrapolating any findings more generally. Across the different treatments and four farming-related behaviours considered ($R_{6.1}$–$R_{6.4}$), the stand-out findings relate to treatment T_3, which is meetings facilitated by LAWPRO. Only in the case of treatment T_3 are there three statistically significant ATE estimates. For the other event types, T_4 and T_5, there is no instance where the ATE estimate is statistically significant thought the sample sizes in these cases are very low. Engagement events facilitated by LAWPRO appear to make a significant impact with respect to good farm practices for nutrient management. This is a promising outcome but whether the finding is specific to the sample or more widely applicable is subject to future research.

While most water quality community engagement events target either community organisations in the case of LAWPRO events, or private individuals otherwise, the impacts are not confined to people's personal behaviours. The impacts are also noticeable in the working environment, as clearly illustrated in the results reported in Table 5. Statistically significant ATE estimates are associated with five of the six response variables ($R_{6.5}$–$R_{6.10}$) across the entire range of treatments, T_1-T_7. The exception is that there is no behaviour change in workplace auditing of water usage following participation in engagement events ($R_{6.7}$). Possibly what is most significant about the findings from workplace behaviours is the cross-over from engagement events targeting private individuals and communities. A question for future research is whether the cross-over would operate in the opposite direction? If water quality engagement events target workplaces, would employees embrace more sustainable behaviours in their personal lives? Furthermore, engagement with workplaces would help overcome the participation bias associated with voluntary community engagement events, as workplaces are likely to comprise a broader representation of the adult population.

4.4. Behavioural change and engagement event types

The extant literature suggests that the different approaches utilised within behavioural change programmes can have different levels of success (McKenzie-Mohr, 2000). The simple provision of information is not adequate to encourage a sustained behaviour in many instances unless the educational material provided matches pre-existing beliefs and dispositions (Frantz and Mayer, 2014; Carmi et al., 2015). The optimal choice of behavioural change approach is usually context-dependent and is contingent on the type of desired behaviours (Grilli and Curtis, 2021). To comprehensively evaluate methodological approaches would ideally require relevant data collection to be incorporated into programme implementation rather than retrospectively, as in the current case. In the current analysis only broad methodological approaches are investigated, as detailed information describing the specific formats and content of engagements is not available.

The current analysis considers three event types, T_3–T_5, that can be classified into two of the five approaches for encouraging pro-environmental behaviours. The nature themed public events (T_4) and community groups meetings (T_5), which provide information to participants about water quality and catchment management, are considered 'education and awareness raising'. Though T_4 and T_5 are both classed as 'education and awareness raising', the composition of the events can be substantially different, hence the separation of the two treatments for this analysis. Nature themed public events (T_4) are often active in nature, for example, tours of water ecosystems. Community group meetings (T_5) could be considered more passive in nature, often comprising a formal chaired meeting, with information conveyed to a receptive audience, or sometimes in the format of a seminar. The results in Table 5 suggest that both of these 'education and awareness raising' formats lead to a change in private behaviours relative to control groups with ATE

estimates of 1.1 and 0.87 mean additional behaviours. While the ATE for T_4 is nominally higher than that for T_5, the point estimates are not statistically different.

The public meetings facilitated by LAWPRO (T_3) focus on community ties and building relationships to achieve a common community objective related to water quality and catchment management and could be considered an 'outreach and community building' approach. Similar to earlier event types, T_4 and T_5, LAWPRO facilitated events are associated with behavioural change, with mean number of additional behaviours compared to a control group of 0.5. LAWPRO achieves success in that regard but the ATE point estimate is less than those for T_4 and T_5, 50 percent lower in the case of T_4. As noted earlier, with relatively large standard errors the 95 percent confidence intervals for the point estimates overlap to a substantial degree, so additional evidence is necessary to conclusively draw distinctions on the relative merits of different event types. Nonetheless, the point estimates suggest that some formats used in either nature themed public events or community groups meetings might be beneficially adopted within LAWPRO events. In the absence of detailed information on the format of the different event types, more precise recommendations are not possible. Further research on preferences related to engagement event attributes (i.e. content, timing, format, etc.) and efficacy for behavioural change would provide further insight.

4.5. Longevity of changed behaviours

The evidence from the analysis is that changes in behaviour are not sustained indefinitely. With respect to single behaviours (i.e. $R_{1.1}$–$R_{5.1}$), there are four behaviours with an ATE estimate statistically significant at the 5 percent level when the most recent event was in 2019 or 2020 (T_7) but none when the most recent event was in 2017 or 2018 (T_6). On summing across behaviours ($R_{1.C} + R_{2.C} + R_{3.C}$), the mean sum of new behaviours is just less than 1 for T_7 and not significantly different than zero for T_6 compared to their respective control groups. These findings confirm the phenomena prevalent in many behavioural change programmes that behaviours tend to revert to original practice with the passage of time. An implication for behaviour change programmes is that strategies to re-engage people on a recurring basis are also needed, perhaps using mechanisms common in other behavioural change programmes, such as community update reports or cross-community competitions (Grilli and Curtis, 2021).

4.6. Study limitations

The study attempts to evaluate the impact of a behavioural change programme using only *ex-post* data collection, which is a limitation. There is no baseline information on behaviours available for comparison though the methodological approach followed addresses this limitation. Ideally data should be collected contemporaneous with implementation of the behavioural change programme rather than retrospectively. Such an approach would facilitate more granular data on the format and composition of engagement events, which would enable further insights on what aspects are more effective in encouraging people to change their behaviours. Equally important to the collection of input data is the collection of metrics that measure programme outcomes.

Many organisations seek to improve water quality and independently of each other attempt to engage with members of society. This makes it challenging to isolate the specific contribution of LAWPRO initiatives in changing behaviours. Our methodological approach was to capture all types of public engagement events that people may have experienced, as ignoring third party influences on people's behaviours would be misleading. For instance, of the surveyed participants in the LAWPRO events, just under half also attended other non-LAWPRO water-related events. Furthermore, while the ultimate objective of LAWPRO's initiatives is that Ireland will achieve 'good' ecological status in water bodies (rivers, lakes, estuaries and coastal

waters) by 2027, the behaviours investigated here represent a small part of a complex, multifaceted plan to deliver on the objective.

5. Conclusion

Five research questions were posed with respect to Irish community engagement and behavioural change programme to encourage communities to take responsibility for water quality and catchment management in their locality. Invariably there are individual successes within the programme but a significant challenge in answering the research questions is the lack of sufficient data collection capturing relevant metrics to enable an assessment. A contribution of this paper is the application of econometric techniques for policy impact evaluation using an *ex-post* treatment and control experiment for data collection. A propensity score matching technique is performed to address the non-experimental nature of the data and achieve a better estimation of the average treatment effect of the behavioural change programmes.

The first research question asks whether LAWPRO's activities successfully connect with the wider public. Participants at LAWPRO events are characterised as being older, well educated, financially comfortable, and with a high likelihood of representing an NGO, such as a local community, sports, or environmental organisation. Accordingly, it is likely that LAWPRO's initiatives are overlooking a wide section of society. The high level of engagement with participants that are representing NGOs is a triumph for LAWPRO, particularly as LAWPRO's strategy is to galvanise local community groups to take responsibility for water quality and catchment management in their area. It is feasible that the socio-demographic traits of NGO representatives (i.e. being older, well educated, financially comfortable) are not reflective of the membership of their NGOs and in that circumstance the potential reach of LAWPRO's activities is wider than suggested by the analysis here.

A second question aims to understand whether attendance at water quality engagement activities is reflected in greater participation in water protection related events within communities. In this regard, indications are that event attendance encourages participation in community led initiatives but the impact varies across event types. While causal inference tools were employed to investigate this relationship, the cross-section nature of the data necessitates caution in interpreting a causal relationship between event attendance and participation in community-led initiatives. LAWPRO specifically aims to promote community involvement in water protection through local groups and community organisations but there is insufficient evidence in the analysis here to conclude that it has been more successful in this regard than community engagement initiatives by other organisations. Robust outcome metrics are needed to quantitatively assess the programme, rather than relying on *ex post* data collection.

A third question seeks to understand the extent to which engagement leads to improved knowledge and changed behaviours within the home and workplace. The balance of evidence is that attendance at water quality community engagement events is associated with a greater adoption of pro-environmental behaviours. All behaviours are not equally amenable to change and it is unclear why participants adopt some behaviours and not others, even among activities where sustainable alternatives have no obvious cost or effort barriers. The findings also suggest that the decision-making process is quite complex and not necessarily rational. Participants in community engagement events are more likely to have water quality tests for well-sourced drinking water, presumably for health-related reasons, but not pay for maintenance of septic tanks, which pose a risk for ground water and pollution of well-sourced drinking water. An obstacle to improving water quality, as well as devising successful behaviour change programmes, is deciphering the motivations behind such apparently irrational decisions.

The fourth question asks which types of engagement activities are most effective in yielding behavioural change among private individuals. Whether engagement activities by LAWPRO or other organisations, all are associated with successfully encouraging behavioural change. While there were nominal differences in the average number of behaviours changed across event types within the current dataset, it is not possible to conclusively say which approach has been more successful. Where engagement activities have experienced success (i.e. in relation to specific behaviours), the successful outcomes often differ across event types, which suggests organisations can learn from each other in terms of designing effective engagement programmes. One notable result with respect to the effectiveness of engagement programmes relates to farmers. The findings here suggest a strong uptake of good farming practices with respect to nutrient planning and management following participation in LAWPRO initiatives. However, the small number of farmers within the dataset limits the capacity to extrapolate to the wider farming community, so further research is warranted. An unexpected finding relates to other workplaces and the extent to which community focused water quality engagement activities have a cross-over impact on workplace behaviours. An unanswered question is whether engagement with workplaces on water quality and environmental issues would also have a cross-over impact on private behaviours? If such an approach is successful it would help address the self-selection bias associated with existing engagement programmes.

The final question relates to the presence of time decay effects associated with changed behaviours. There is clear evidence that behaviours examined are not sustained indefinitely, which is a result not unique to this study. The implication is that successful community engagement is not a single event or series of events, rather it is a process over an extended time-frame. Long-standing or routine behaviours are difficult to change so behavioural change programmes must continually re-engage to help people learn sustainable alternatives.

As noted in the introduction, there are many public programmes attempting to change peoples' behaviours, with most associated research occurring during the design of behavioural change initiatives (e.g. McKenzie-Mohr, 2011). Substantially less prevalent are *ex post* evaluations of behavioural change programmes, invariably because metrics on programme performance are often limited to resource inputs. Effective programme evaluation not only necessitates the collection of quantitative outcome metrics but also the collection of detailed activity metrics that record how resources (budgets and people) are deployed to affect behaviours. Without the former it is impossible to evaluate whether behaviours have changed. With the latter it is feasible to evaluate the efficient deployment of resources.

Acknowledgements

Funding from the Department of Housing, Local Government and Heritage is gratefully acknowledged. We thank Seán Keating and Bernie O'Flaherty (LAWPRO) for their cooperation and assistance with this project and also to Colin Byrne and Graham McGovern for comments on an earlier draft.

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