CITIZEN SCIENCE:
THEORY AND PRACTICE

Mac Domhnaill, C, et al. 2020. The Citizens in Citizen Science: Demographic, Socioeconomic, and Health Characteristics of Biodiversity Recorders in Ireland. *Citizen Science: Theory and Practice*, 5(1): 16, pp. 1–17. DOI: https://doi.org/10.5334/cstp.283

RESEARCH PAPER

The Citizens in Citizen Science: Demographic, Socioeconomic, and Health Characteristics of Biodiversity Recorders in Ireland

Ciarán Mac Domhnaill, Seán Lyons and Anne Nolan

Citizen science allows members of the public to engage with scientific inquiry, and is increasingly being employed to monitor environmental change. Some previous research explores the demographic characteristics of participants in environmental citizen science projects. Design of recruitment campaigns and selection of activities for citizen science projects could benefit from a better understanding of participants' demographic and socioeconomic characteristics, as well as participants' health, their well-being status, and their level of physical activity. In addition, this type of information can provide a baseline for examining effects of engaging in citizen science on participants' health and well-being in later research. This paper reports results from a survey of a group of environmental citizen scientists engaged in observation and monitoring activities who have recently registered as biodiversity data recorders in Ireland. The survey employs questions drawn from existing large-scale socioeconomic surveys in Ireland, so the characteristics of biodiversity recorders can be compared with those of the wider population. Differences in proportions are tested for statistical significance, and Blinder-Oaxaca decomposition methods are applied to strip out compositional differences when comparing health status and physical activity. Results show that biodiversity recorders are more highly educated, more middle-aged, more rural, better-off, and more active in the labour force than the general population. They are deeply concerned about threats from the decline or extinction of species and ecosystems, they classify environmental protection as very important, and they believe that individuals have a role to play in protecting the environment. Biodiversity recorders are more physically active than the wider population, and mixed results are found for generalised health and mental health status.

Keywords: citizen science; biodiversity recorders; attitudes; demography; health; Ireland

Introduction

Citizen science allows members of the public to engage with scientific inquiry, and is increasingly being employed to address environmental change and conservation issues (Turrini et al. 2018; Johnson et al. 2014). There have been many studies focused on the contribution of environmental citizen science to science and research (Ballard, Dixon, and Harris 2017; Chandler et al. 2017; Theobald et al. 2015; Pandya 2012; Raddick et al. 2009). One benefit for researchers is that some projects that were previously impossible can be rapidly completed with the help of citizen science (Raddick et al. 2009). For society in general, environmental citizen science can help to generate new knowledge, to raise awareness, and to enable civic participation in conservation (Turrini et al. 2018).

Past research also explores the effect of citizen science on participants, including on the scientific knowledge and attitudes of participants (Price and Lee 2013; Crall et al. 2013; Pandya 2012; Raddick et al. 2009; Brossard, Lewenstein, and Bonney 2005; Overdevest, Huyck Orr, and Stepenuck 2004). Several studies examine the demographic characteristics of people who participate in citizen science, often finding citizen scientists or volunteers to be more highly educated, more affluent, more rural-based, more middle-aged, and overwhelmingly white compared with the general population (Committee on Designing Citizen Science to Support Science Learning et al. 2018; Merenlender et al. 2016; West and Pateman 2016; Pandya 2012; Hobbs and White 2012; Evans et al. 2005; Overdevest, Huyck Orr, and Stepenuck 2004; Trumbull et al. 2000). In addition, persons with disabilities are found to be underrepresented by one study (West and Pateman 2016). Barriers to participation for groups that are traditionally underrepresented in citizen science are considered in the literature to be the money or time associated with volunteering; a perception that volunteering necessarily involves physical activity; a lack of access to natural settings among urban dwellers; a lack of familiarity with

Economic and Social Research Institute, IE
Corresponding author: Ciarán Mac Domhnaill (ciaran.macdomhnaill@esri.ie)

scientific methods among people with lower levels of education; and a perception among some people from ethnic minority groups in some regions that the countryside is predominantly populated by white people (West and Pateman 2016; Merenlender et al. 2016; Pandya 2012). It is also noted in the literature that while some population groups are generally underrepresented in citizen science projects, there is some evidence of citizen science being employed by groups, including marginalized groups (Kullenberg 2015), in support of a political agenda.

A better understanding of the sociodemographic characteristics of groups participating in environmental citizen science could help researchers target recruitment campaigns and design activities suitable for involving citizen scientists. Knowledge of the educational attainment and other capabilities of citizen scientists could help researchers evaluate the potential to broaden the involvement of citizen scientists to a wider range of research-related activities. Participation in citizen science mostly takes the form of contributory projects designed by researchers, with citizen scientists' efforts focused on voluntary data collection (Kullenberg and Kasperowski 2016). However, some research suggests there is potential to increase the involvement of citizen scientists in other aspects of research, such as the development of research questions, data analysis, and the dissemination of findings. This could in turn further enhance the strategic knowledge environment as well as the scientific literacy and empowerment of citizen scientists (Schröter et al. 2017). With this in mind, this paper contributes to the evidence base on participants in environmental citizen science activities by assessing demographic, socioeconomic, and health characteristics of biodiversity recorders in Ireland.

A better understanding of the attitudes of citizen scientists at the early stages of participation should cast light on the scope for using these programmes to inform and engage these individuals in support of conservation objectives, as well as provide a baseline for studying how participation affects attitudes and enthusiasm about conservation. Some previous research shows evidence of behavioural change in individuals as a result of participation in citizen science, particularly increased engagement in wider conservation activities or increased appreciation of habitats (Lewandowski and Oberhauser 2017; Evans et al. 2005). Other studies, however, find little or no evidence of changes in environmental attitudes due to participation in citizen science (Crall et al. 2013; Brossard, Lewenstein, and Bonney 2005). As an initial step in this direction, we also examine the environmental attitudes of biodiversity recorders in Ireland.

Moreover, it would be useful to know whether these activities improve the health and well-being of participants. Further evidence of benefits to participants could provide additional justification for funding these activities and could help support recruitment. It has previously been suggested that participation in environmental citizen science increases self-efficacy (Johnson et al. 2014). In general, however, the effects of environmental citizen science activities on the health and well-being of participants receives relatively little attention in the literature. The wider literature relevant to the potential health and well-being benefits of participation in environmental citizen science can be divided into two main categories: the effects of interaction with green spaces and natural environments; and the effects of social engagement and volunteering.

Environmental citizen science, particularly observation and monitoring activities such as recording biodiversity, can bring participants into contact with green spaces. Exposure to green spaces may be associated with a lower likelihood of becoming obese or overweight, a lower risk of developing heart conditions, and better mental health outcomes (Dempsey, Lyons, and Nolan 2018; James et al. 2015). Increased physical activity, greater social network opportunities, decreased exposure to environmental hazards, and a sense of restoration or stress reduction in natural outdoor environments are all possible mechanisms through which such environments, particularly green spaces, are associated with better physical and mental health (Dadvand et al. 2016; James et al. 2015; Triguero-Mas et al. 2015; Van Dillen et al. 2011; Maas 2006; de Vries et al. 2003). Another potential health benefit to being an environmental citizen scientist stems from interaction with nature and biodiversity. The healthy development of microbiota of human skin and gut is dependent on exposure to microbes from environmental sources (Sandifer, Sutton-Grier, and Ward 2015).

The second category of potential health and well-being benefits, based on increased social engagement and volunteering, can apply to any form of environmental citizen science. Much of the literature in this area focuses on the cognitive effects of increased social engagement or volunteering on older adults (Huang 2018; Lee and Jean Yeung 2018). Older adult participation in socially productive activities enhances perceptions of self-worth and health, results in individuals being more socially integrated and physically active, and acts as a buffer against depression or stress triggered by negative age-related events. This, in turn, leads to better cognitive functioning (Lee and Jean Yeung 2018). Volunteering can provide mental, physical, and social stimulation simultaneously, and can thus act as a protective factor specifically against the aggravation of cognitive ageing brought about by retirement (Gupta 2018). Environmental concern, particularly at high levels, increases the likelihood of volunteering and becoming a member of an environmental organisation, and positively impacts subjective well-being (Binder and Blankenberg 2016).

To assess potential impacts of participation in citizen science on health and well-being in future research, an understanding of participants' baseline health, well-being, and level of physical activity is required. Therefore, in addition to broadening the evidence base of demographic, socioeconomic, and health characteristics of people who decide to participate in citizen science, we establish the health and well-being status and level of physical activity of biodiversity recorders in Ireland in the early stages of their participation in recording activities. To our knowledge, this is the first paper to characterise a group of people who engage in environmental citizen science activities in terms of their health, well-being, and physical activity. The most similar past work compares the general health status of older people who engage in volunteer activities

with those who do not volunteer (Gupta 2018), with volunteering defined as either formal (for religious, educational, health-related, or other charitable organisations) or informal (helping friends, family, or neighbours). Other similar past work explores the motivations of participants in environmental citizen science (Merenlender et al. 2016; Johnson et al. 2014; Hobbs and White 2012).

We collaborate with the National Biodiversity Data Centre to carry out a survey on a group of environmental citizen scientists engaged in observation and monitoring activities who have recently registered as biodiversity data recorders in Ireland. The survey employs questions drawn from existing large-scale socioeconomic surveys in Ireland, which allows us to compare the demographic, socioeconomic, and health characteristics of biodiversity recorders with the attributes of the wider population, and statistically test for differences between them.

The Materials and Methods section outlines the survey data used in our research, and the statistical methods employed to analyse these data. Results of this analysis are discussed in the Results section, and the final section sets out some conclusions and suggestions for further research.

Materials and Methods

Population data sources

To obtain information on the health, well-being, and physical activity characteristics of the general population, we use two sources of microdata: The Irish Longitudinal Study on Ageing (TILDA) and Healthy Ireland (HI). In addition, population data on environmental attitudes is sourced from a Special Eurobarometer public opinion survey on the environment.

The Irish Longitudinal Study on Ageing

TILDA (Donoghue et al. 2018; Kearney et al. 2011) is a nationally representative longitudinal study of more than 8,000 people aged fifty and over in Ireland, which collects information on all aspects of health as well as economic and social circumstances.[1] Data collection for the third wave of the survey, which is employed in this paper, was carried out between March 2014 and October 2015 on 6,566 individuals aged fifty and over. TILDA data is collected using three different methods. First, interviews are conducted by trained interviewers in each respondent's home using Computer Assisted Personal Interviewing. Second, participants are given a self-completed questionnaire, which captures more potentially sensitive data, to fill out and return by post. Finally, respondents are invited to attend a nurse-led health assessment at specialised Health Assessment Centres, or a modified partial assessment in their homes if travel to a centre is not practicable.

Healthy Ireland

HI is a government programme that includes an annual cross-sectional survey of the health and well-being of adults in Ireland (Ipsos MRBI 2010). More than 7,500 people aged 15 years and over participated in each of four annual cross-sectional rounds of the survey. This paper uses data from the first round of the survey, data collection for which took place between October 2014 and August 2015 on 7,539 participants. Participants complete the survey questionnaire through a face-to-face interview, and are then invited to undertake a physical measurement module. The HI survey covers different topics in each round. The main topics included in the first round are health, utilisation of health services, smoking, alcohol use, diet, exercise, well-being, and sexual health.

Eurobarometer

Special Eurobarometer 468 (European Commission, 2017) is a public opinion survey on the attitudes of European citizens towards the environment, the impact of environmental issues, ways of taking action to tackle environmental issues, and the role of the European Union in environmental protection, ecolabels and air pollution. Fieldwork for the Irish sample was carried out in the form of face to face interviews in the homes of 1,002 participants between September and October 2017.

Biodiversity Recorder Survey

For this research, we targeted a group of citizen scientists who are registered as biodiversity data recorders with the National Biodiversity Data Centre (NBDC) in Ireland. Citizen scientists record biodiversity sightings through the NBDC's online Citizen Science Portal, recording information such as species name, activity, abundance, and sighting location. Recording biodiversity through the NBDC is open to anyone who wishes to participate, regardless of previous knowledge or experience.[2] To focus the research on a relatively homogeneous group of newly recruited citizen scientists, the survey was sent to all recorders who had registered in the past year (approximately 2,000).

We created a new online survey instrument with the purpose of capturing the demographic, socioeconomic, attitudinal, and health characteristics of these biodiversity recorders during the early stages of their participation in recording activities. To allow consistent comparisons with population characteristics, questions were copied directly from our population data sources. The survey consists of a brief introductory section; an environmental attitude section containing questions from Eurobarometer; a social connectedness section that contains variables used to generate a Berkman-Syme Social Network Index, a measure used by TILDA (Berkman and Syme 1979); and a health and well-being section consisting of questions that ask for self-reported conditions and questions employed by TILDA to generate more objective measures such as a Center for Epidemiological Studies depression (CES-D) score (O'Halloran, Kenny, and King-Kallimanis 2014; Radloff 1977). In addition, an International Physical Activity Questionnaire (IPAQ) is included in the Biodiversity Recorder Survey, as in TILDA and HI, to measure the physical activity of respondents (Craig et al. 2003). Finally, a sociodemographics section concludes the survey. Our survey also asks for information on household income for comparison with TILDA on socioeconomic status. For comparison with HI, which does not capture income data, we employ a dummy variable of whether or not a respondent has private health insurance as a proxy for socioeconomic status. The questionnaire is provided in Supplemental File 1, Appendix A.

The survey was sent by the NBDC to biodiversity recorders via email in February 2019, and each respondent was restricted to one survey response. Respondents were required to complete a consent form before commencing the survey, having been provided a Participant Information Sheet and a Data Protection Privacy Notice online. Responses from 14 recorders residing outside the Republic of Ireland were omitted from our dataset. The survey was also restricted to recorders aged 18 and over. A validity test was included in the health and well-being section, whereby a response was required before proceeding with the survey and respondents were asked to simply select "Agree" from a Likert scale. Twenty-three responses failed this validity test and were thus dropped from the dataset. The survey was closed in April 2019, and 438 valid responses were submitted in total with the sample size varying between questions. Average response rates ranged from 73% for the physical activity section to 95% for the section on environmental attitudes. It should be noted that the Biodiversity Recorder Survey collected data in 2019, while Eurobarometer data are from 2017, and data from HI and TILDA were collected between 2014 and 2015. This mismatch in dates is a limitation of the study, but its practical effect may be limited given that socioeconomic and health characteristics of the population tend to change slowly over time.

Methodology

Comparisons of average characteristics

To compare the health and demographic characteristics of our sample of biodiversity recorders with the population data sources, we test the hypothesis that the difference between two characteristic variables is equal to zero. In the case of categorical variables, such as the age category respondents fall into, the null hypothesis is that the proportion of the sample attributed to the category in question is equal between the Biodiversity Recorder Survey and the population data source. The null hypothesis in the case of continuous variables, such as the age of respondents, is that the mean is the same in both data sources. Conversely, the alternative hypothesis states that the proportion or mean of the respective characteristic variable is significantly different between our sample of biodiversity recorders and the population. In these analyses, sampling weights for TILDA and HI are used to adjust for aspects of sample design and differential response (see Supplemental File 2, Appendix B).

Decomposition analysis

To test for differences between demographic characteristics of biodiversity recorders and the wider population, comparison of mean characteristics is sufficient. However, when it comes to checking for differences in health status between these samples, a more sophisticated approach is required. This is because health status can itself depend upon demographics and other personal characteristics, so any health status between groups might be affected by differences in sample composition. For example, suppose biodiversity recorders turn out to be more highly educated on average than the general population. This would suggest they might also be healthier, since many health indicators are positively associated with education. To get at the innate differences in health between citizen scientists and others, it would be helpful to strip out the component due to observed personal characteristics.

To help strip out compositional differences, we employ a Blinder-Oaxaca decomposition (Blinder 1973; Oaxaca 1973).[3] This is a statistical method originally employed in labour economics (Oaxaca 1973), but it is increasingly applied in other fields such as health (Shackleton et al. 2019). This apportions the proportion of any gap in mean outcomes between what can be explained by group differences in observed characteristics, and what cannot be explained by these differences. The proportion of the mean outcome gap "unexplained" by differences in endowed characteristics is considered to be due to group differences in the coefficients of characteristics, as well as in the interactions between characteristics and coefficients. In other words, this technique can be used to reveal differences in outcomes between our sample of biodiversity recorders and the general population that would exist even if our sample was endowed with the same demographic characteristics as the population. Statistical analysis is conducted using the Stata 14 and R 4 software packages. Code for this analysis is provided in Supplemental Files 3–6.

Results

Sociodemographic characteristics

Table 1 provides an overview of how the demographic characteristics of our sample of biodiversity recorders relate to all adults in Ireland as captured in HI. Tests reveal several statistically significant differences. Firstly, as illustrated in **Figure 1**, the age distribution of biodiversity recorders is significantly different from the wider population. While the mean age of biodiversity recorders is significantly higher than that of the population,[4] more biodiversity recorders fall into the 45–64 age range with fewer recorders in all other age categories, indicating a more middle-aged sample. Biodiversity recorders appear to be much more highly educated than the population generally, as illustrated by **Figure 2**, with a significantly larger proportion having attained a bachelor's degree or higher. Biodiversity recorders are significantly more likely to be married, and more of them live in rural areas than the population as a whole. We find no statistically significant difference in the gender profile of biodiversity recorders compared with the general population.

Having private health insurance is often used as a proxy for socioeconomic status in studies focusing on Ireland. We find that a significantly higher proportion of biodiversity recorders has private health insurance compared with the general population, which may suggest that the sample is of a higher average socioeconomic status. In addition, a significantly higher proportion of biodiversity recorders is employed, with lower proportions unemployed, caring for the home or family, and in education.

A comparison between the proportion of our biodiversity recorder sample aged fifty or over and TILDA in **Table 2** supports the findings that biodiversity recorders

Table 1: Demographic characteristics of biodiversity recorders compared with adult population in Ireland using Healthy Ireland Survey.

Characteristic	y_{brs} (%)	y_{pop} (%)	$y_{brs} - y_{pop}$ (%)
Lives in urban area	41.06	63.30	−22.25***
Male	44.68	49.12	−4.44
Age class:			
18–24 years	2.37	9.77	−7.40***
25–44 years	35.21	41.18	−5.97**
45–64 years	51.18	31.85	19.33***
65+ years	11.24	17.20	−5.96***
Highest education attained:			
None to lower secondary	4.46	30.93	−26.47***
Upper secondary to post-secondary non-tertiary	30.36	38.00	−7.65***
Bachelor's degree or above	65.18	31.07	34.11***
Employment status:			
Retired	14.04	12.23	1.81
Employed	68.71	54.68	14.03***
Unemployed	2.92	8.12	−5.20***
Permanently sick/disabled	2.63	3.94	−1.31
Caring for home/family	5.85	13.95	−8.10***
In education/training	4.39	6.57	−2.18*
Marital status:			
Married/civil partnership	72.94	59.61	13.34***
Single	17.35	30.12	−12.77***
Separated	3.24	3.14	0.09
Divorced	3.24	18.04	1.43
Widowed	2.65	5.33	−2.68***
Has private health insurance	63.17	42.53	20.65***

y_{brs} denotes proportion of biodiversity recorders; y_{pop} denotes proportion of the population.
*** denotes significance at the 99% level.
** denotes significance at the 95% level.
* denotes significance at the 90% level.

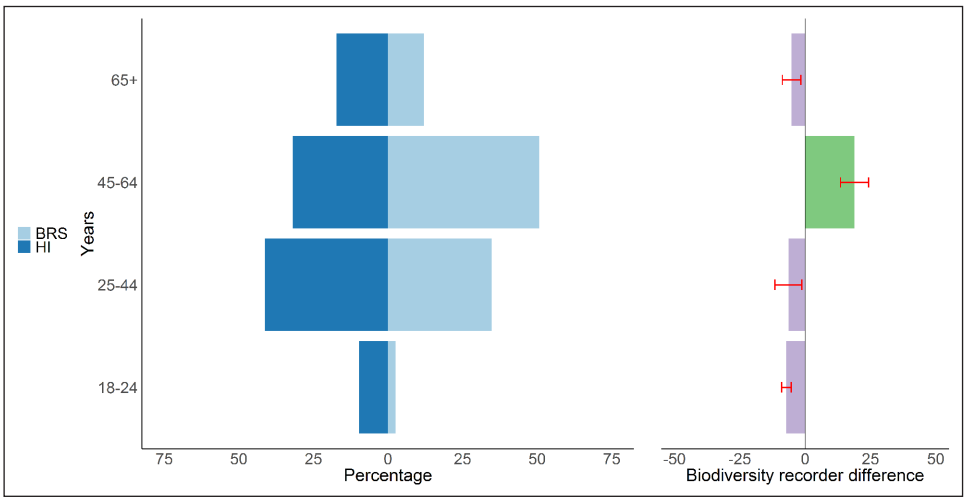

Figure 1: Age distribution of biodiversity recorders compared with adult population in Ireland using Healthy Ireland Survey (HI).

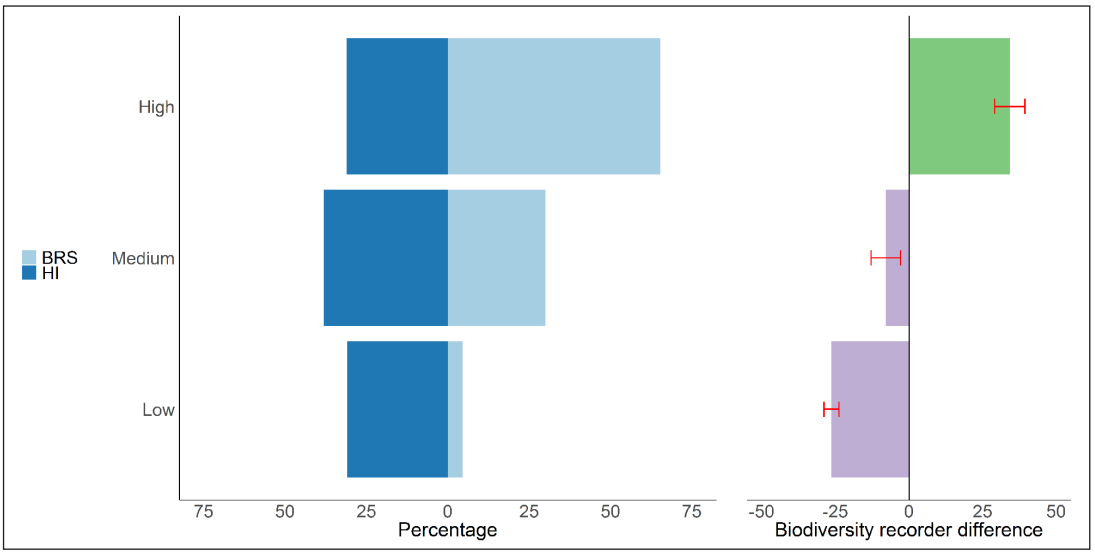

Figure 2: Highest education attainment of biodiversity recorders compared with adult population in Ireland using Healthy Ireland Survey (HI). Low indicates less than primary, primary, and lower secondary education; medium indicates upper secondary and post-secondary non-tertiary education; high indicates short-cycle tertiary, bachelors, masters, and doctoral education. 95% confidence intervals are based on difference in proportions tests.

Table 2: Demographic characteristics of biodiversity recorders compared with older adult population in Ireland using The Irish Longitudinal Study on Ageing (TILDA).

Characteristic	y_{brs} (%)	y_{pop} (%)	$y_{brs} - y_{pop}$ (%)
Lives in urban area	35.50	56.44	−20.94***
Male	50.60	47.84	2.76
Age class:			
50–64 years	76.97	44.51	32.46***
65+ years	23.03	55.49	−32.46***
Highest education attained:			
None to lower secondary	4.88	58.14	−53.26***
Upper secondary to post-secondary non-tertiary	39.02	31.82	7.20*
Bachelor's degree or above	56.10	10.04	46.06***
Employment status:			
Retired	28.40	46.74	−18.34***
Employed	33.73	19.80	13.92***
Self-employed	22.49	10.81	11.68***
Unemployed	2.37	3.92	−1.55
Permanently sick/disabled	4.14	5.20	−1.06
Caring for home/family	4.14	12.48	−8.34***
In education/training	2.37	0.34	2.03*
Marital status:			
Married	70.24	63.00	7.24**
Living with partner	7.14	2.20	4.94**
Single	7.14	10.99	−3.85*
Separated	3.57	4.08	−0.51
Divorced	5.36	2.99	2.37
Widowed	5.36	16.74	−11.38***

(Contd.)

Characteristic	y_{brs} (%)	y_{pop} (%)	$y_{brs} - y_{pop}$ (%)
Household income:			
€0–10 000	3.27	10.97	–7.70***
€10 000–20 000	10.46	23.34	–12.88***
€20 000–40 000	32.03	35.03	–3.01
€40 000–70 000	33.99	21.27	12.72***
€70 000–120 000	9.80	7.22	2.58
€120 000+	2.61	2.17	0.45
Has private health insurance	64.67	53.28	11.39***

y_{brs} denotes proportion of biodiversity recorders; y_{pop} denotes proportion of the population.
*** denotes significance at the 99% level.
** denotes significance at the 95% level.
* denotes significance at the 90% level.

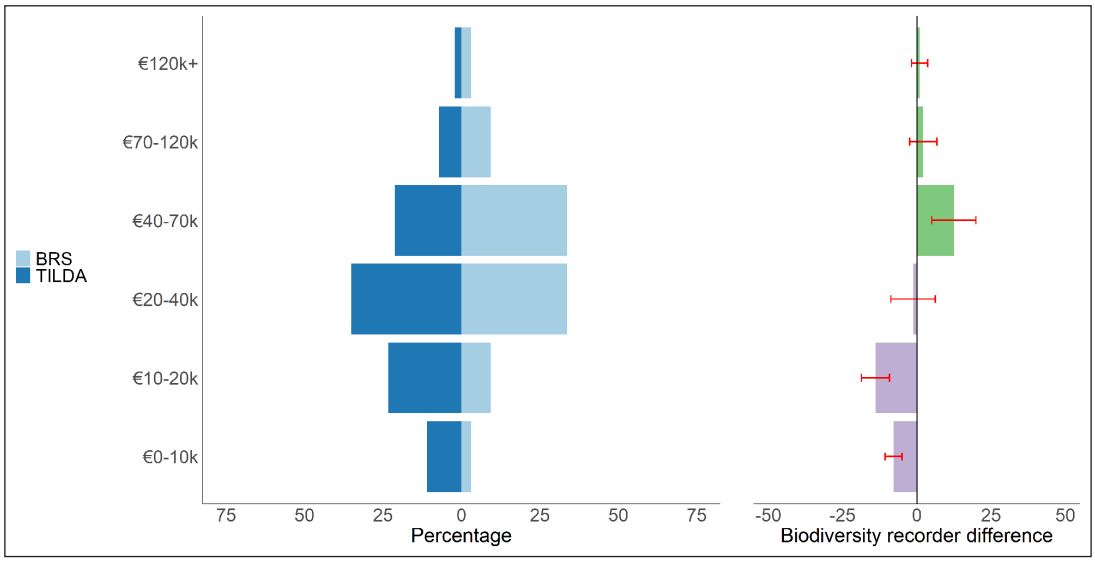

Figure 3: Household income distribution comparison of biodiversity recorders with older adult population in Ireland using The Irish Longitudinal Study on Ageing (TILDA). Note that 95% confidence intervals are based on difference in proportions tests.

are more middle-aged, more highly educated, and more rural. Biodiversity recorders are also more likely to be married and employed. In relation to the finding that biodiversity recorders tend to be better-off (measured using the proxy of private health insurance), comparing recorders aged fifty and over with TILDA allows us to analyse self-reported household income levels, depicted in **Figure 3**. A significantly lower proportion of the biodiversity recorder sample aged fifty and over reports household income of €0 to €10,000 or €10,000 to €20,000, while a significantly higher proportion reports a household income of €40,000 to €70,000. There is no significant group difference in proportions for higher bands of household income, however. These results suggest that biodiversity recording activities draw a relatively high share of their membership from the middle class, and this is further supported by biodiversity recorders aged fifty or over being more likely than the general population of older adults to have private health insurance.

Our results in relation to sociodemographic characteristics share many similarities with previous research that considers the characteristics of citizen scientists and environmental volunteers (Committee on Designing Citizen Science to Support Science Learning et al. 2018; Merenlender et al. 2016; West and Pateman 2016; Pandya 2012; Hobbs and White 2012; Evans et al. 2005; Overdevest, Huyck Orr, and Stepenuck 2004; Trumbull et al. 2000). Our sample of biodiversity recorders are more highly educated, more affluent, more rural-based and more middle-aged than the general population. In addition, we find that biodiversity recorders are more likely to be married. Some of our results are in contrast with research comparing volunteers and non-volunteers, however. While volunteers tend to be younger and are more likely to be male than non-volunteers (Gupta 2018), our sample of biodiversity recorders is more middle-aged, and there is no significant difference in gender profile. In addition, our finding that biodiversity

recorders are more likely to be employed is in contrast with Gupta (2018), who finds that volunteers are more likely to be retired.

Health status and physical activity – descriptive analysis

In terms of health characteristics, Gupta (2018) finds volunteers to be generally healthier than non-volunteers. Digging deeper into the health characteristics of the full sample of biodiversity recorders using self-reported measures of health, we find a more mixed picture, as presented in **Figure 4** and in **Table 3**. We find biodiversity recorders to be more positive in relation to their self-reported health status than the wider population, with a higher proportion reporting either "good" or "very good" health. Interestingly, however, a higher proportion of biodiversity recorders also reports being limited by their health, although a lower proportion reports a "severe" health limitation. While a lower proportion of our sample of biodiversity recorders reports a diagnosis of heart or respiratory conditions than the general population reports, a higher proportion reports being diagnosed with an allergy and with depression.

Using the International Physical Activity Questionnaire (IPAQ) to measure physical activity, we find our sample of biodiversity recorders to be considerably more physically active than the broader population, with our sample reporting higher mean metabolic equivalent (MET) minutes across all categories of physical activity. In addition, as shown in **Figure 5**, a higher proportion of the sample achieves a "high" physical activity score and a lower proportion achieves a "low" score, while there is no statistically significant difference in relation to the proportion achieving a "moderate" score.

Table 3: Health and well-being characteristics of biodiversity recorders compared with those of adult population in Ireland using Healthy Ireland Survey (HI).

Characteristic	y_{brs} (%)	y_{pop} (%)	$y_{brs} - y_{pop}$ (%)
Self-reported health:			
Very good	39.34	42.10	–2.77
Good	48.75	42.47	6.28**
Fair	8.59	12.91	–4.32***
Bad	3.05	2.06	0.99
Very bad	0.28	0.45	–0.17
Long-term health limitation:			
Severe	1.39	3.41	–2.03***
Not severe	22.16	16.45	5.71**
No limitation	75.90	80.01	–4.11*
Health conditions:			
Respiratory condition	6.16	8.52	–2.35*
Heart condition	10.27	14.17	–3.90**
Allergy	17.09	9.90	7.19***
Depression	13.68	6.14	7.53***
IPAQ score:			
High	43.53	30.27	13.26***
Moderate	38.80	38.72	0.08
Low	14.20	22.06	–7.86***

y_{brs} denotes proportion of biodiversity recorders; y_{pop} denotes proportion of the population.
*** denotes significance at the 99% level.
** denotes significance at the 95% level.
* denotes significance at the 90% level.

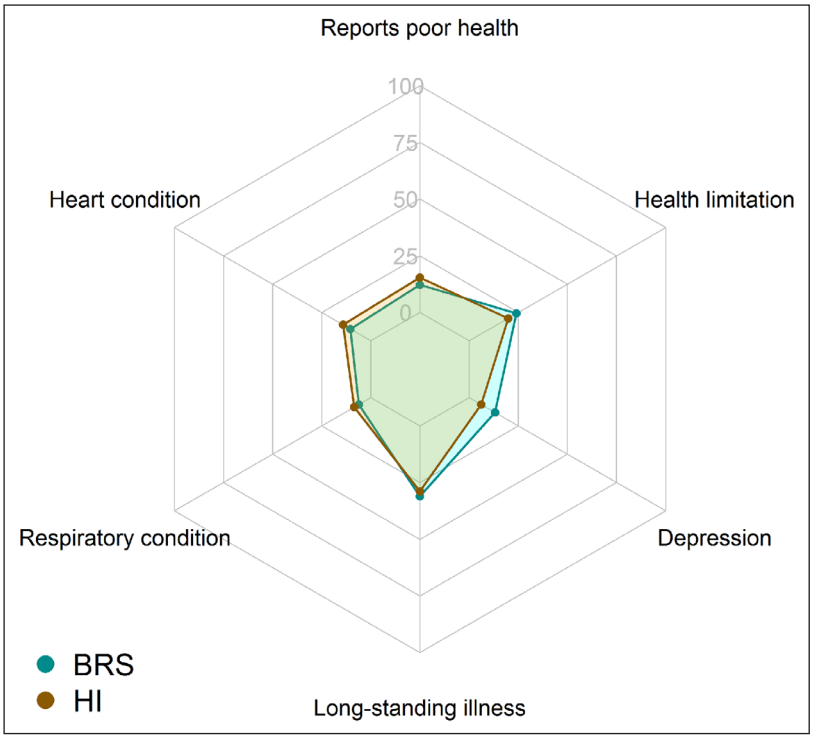

Figure 4: Health and well-being characteristics of biodiversity recorders compared with those of adult population in Ireland using Healthy Ireland Survey (HI).

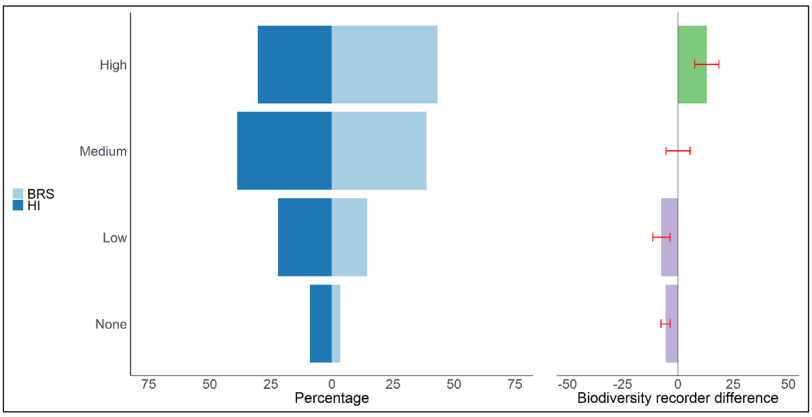

Figure 5: International Physical Activity Questionnaire (IPAQ) score distribution of biodiversity recorders compared with that of older adult population in Ireland using Healthy Ireland Survey (HI). Note that 95% confidence intervals are based on difference in proportions tests.

Focusing on the subset of our sample aged fifty and over in **Table 4** allows us to analyse additional health and well-being characteristics available in the TILDA dataset that are not included in HI. Similar to the comparison with HI, the sample of biodiversity recorders aged fifty and over is more positive in self-reporting general health than the population of older adults. A higher proportion of recorders reports a health limitation, but a lower proportion reports a severe limitation. In addition, a higher proportion of recorders aged fifty and over reports having received a diagnosis of depression than the population of older adults. TILDA also includes a questionnaire that scores respondents on the Center for Epidemiological Studies depression (CES-D) scale as a more robust measure of depression. **Figure 6** illustrates the distribution of CES-D scores for biodiversity recorders and for the population. Despite biodiversity recorders being more likely to report a diagnosis of depression, and while our sample of recorders has a higher mean CES-D score than the older adult population, we fail to reject the hypothesis that there is no group difference in the proportion that registered a CES-D score of nine or above to indicate clinical depression.

We also derive a Berkman-Syme Social Network Index for respondents and find in **Figure 7** that our sample of biodiversity recorders aged fifty and over is generally more isolated than the general population of older adults. A closer inspection of this finding in **Table 4**, however, reveals that it appears to be driven by differences in attendance at religious services, with a significantly lower proportion of biodiversity recorders attending religious services on a weekly basis than the general population. A significantly higher proportion of biodiversity recorders reports membership of a club or community group, and the sample of biodiversity recorders has a significantly higher mean number of close relatives and close friends.[5] This indicates a more nuanced picture in terms of social connectedness than suggested by the Social Network Index, and reveals a potential shortcoming in the Social Network Index as a contemporary measure of social connectedness in that such an emphasis is placed on weekly attendance at religious services. Finally, the finding that the whole sample of biodiversity recorders is significantly

Table 4: Health and well-being characteristics of biodiversity recorders compared with those of older adult population in Ireland using The Irish Longitudinal Study on Ageing (TILDA).

Characteristic	y_{brs} (%)	y_{pop} (%)	$y_{brs} - y_{pop}$ (%)
Self-reported health:			
Very good	35.64	13.00	22.64***
Good	51.06	31.96	19.10***
Fair	9.58	35.24	–25.67***
Bad	3.19	16.09	–12.90***
Very bad	0.53	3.71	–3.18***
Long-term health limitation:			
Severe	1.60	8.30	–6.71***
Not severe	23.94	18.51	5.43*
No limitation	73.94	73.18	0.76
Health conditions:			
Respiratory condition	5.66	2.61	3.05**
Heart condition	13.96	6.83	7.13***
Depression	13.51	2.47	11.04***
Physical activity (IPAQ) score:			
High	44.59	25.80	18.79***
Moderate	38.85	34.33	4.52
Low	11.47	23.48	–12.01***
Social Network Index:			
Most isolated	9.09	9.64	–0.55
Moderately isolated	33.94	27.30	6.64*
Moderately integrated	40.00	39.67	–0.33
Most integrated	15.76	22.88	–7.12**
Weekly attendance at religious services	19.65	65.39	–45.74***
Membership of club/ community group	69.43	47.72	21.71***

y_{brs} denotes proportion of biodiversity recorders; y_{pop} denotes proportion of the population.
*** denotes significance at the 99% level.
** denotes significance at the 95% level.
* denotes significance at the 90% level.

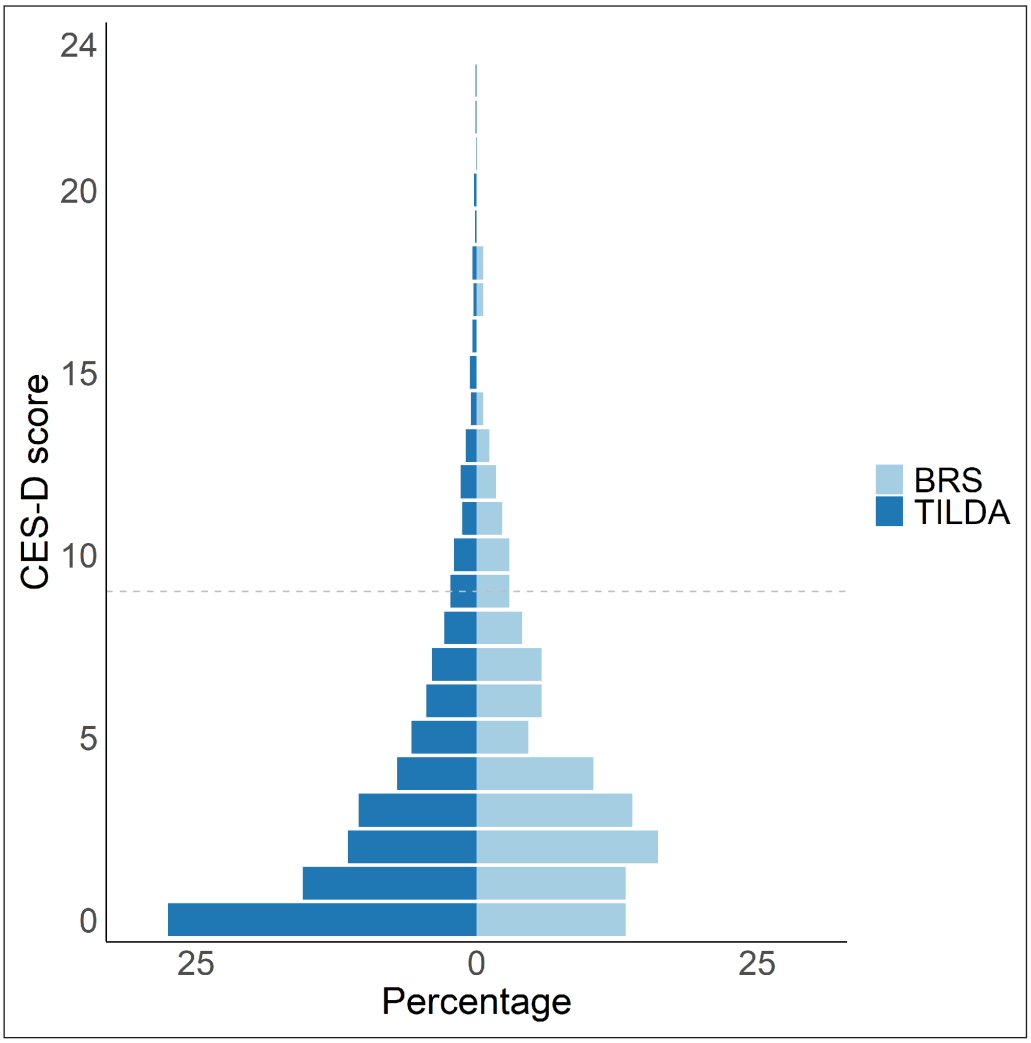

Figure 6: Center for Epidemiological Studies depression (CES-D) score distribution of biodiversity recorders compared with that of older adult population in Ireland using The Irish Longitudinal Study on Ageing (TILDA). A CES-D score of 9 or above indicates clinical depression.

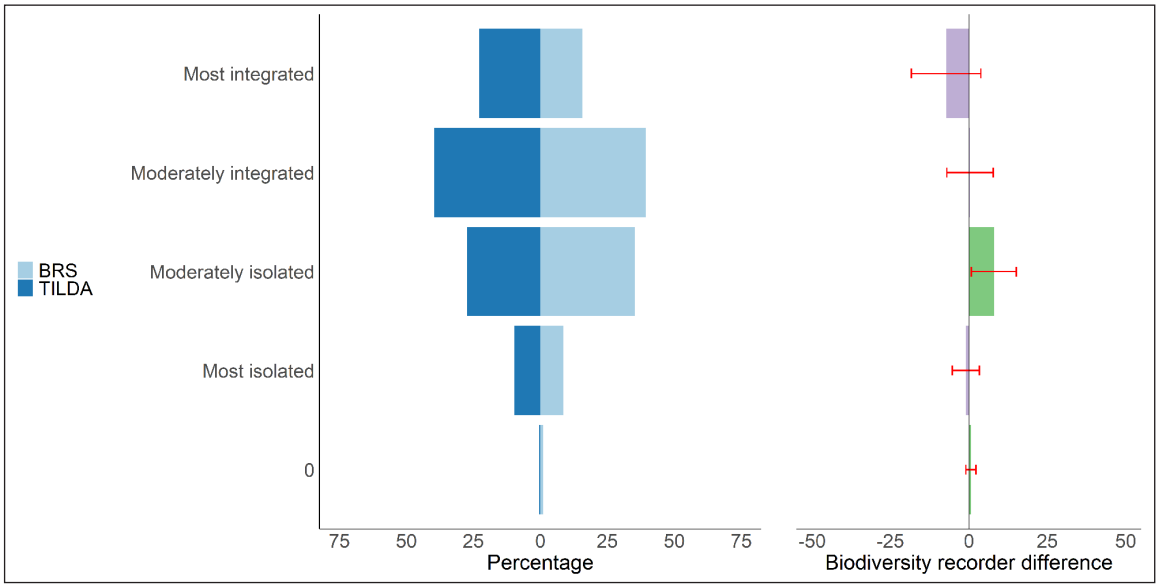

Figure 7: Berkman-Syme Social Network Index distribution of biodiversity recorders compared with that of older adult population in Ireland using The Irish Longitudinal Study on Ageing (TILDA). Note that 95% confidence intervals are based on difference in proportions tests.

more physically active than the wider population is also reflected in the comparison with TILDA.

Health status and physical activity – decomposition models

When interpreting differences in health characteristics between biodiversity recorders and the population, it is worth exploring whether any of the difference remains unexplained after accounting for the significant differences in demographic characteristics outlined above. This is done using a Blinder-Oaxaca decomposition, as discussed in the Materials and Methods section and Supplemental File 2, Appendix B. **Table 5** presents decomposition results for three binary outcome variables, each using HI and TILDA as the population data source. The models consider (I) whether or not a respondent reports either "good" or "very good" general health, (II) whether or not a respondent reaches a minimum recommended level of physical activity as defined by their IPAQ score (i.e., an IPAQ score of moderate or high), and (III) whether or not a respondent has been diagnosed with depression (as measured by a self-report). Using HI as the population source, results for general health indicate that while a higher proportion of biodiversity recorders report either "good" or "very good" general health, group differences in other characteristics suggest that this proportion should be even higher. While 85% of the population reports positive general health, the corresponding figure for biodiversity recorders is 87%, a difference of 2 percentage points. Group differences in characteristics explaina difference of 6 percentage points; however, they also indicate an unexplained gap of minus 4 percentage points that is reducing the overall difference. This suggests that even if our sample of biodiversity recorders was endowed with the same demographic characteristics as the population, the recorders would be 4 percentage points less likely to report either "good" or "very good" general health. In the case of physical activity, meanwhile, very little of the difference can be explained by group differences in characteristics. The probability of engaging in at least moderate levels of physical activity is 82% for biodiversity recorders and 69% for the HI population, and less than one percentage point of this difference can be explained by different group characteristics. This suggests that even if our sample of biodiversity recorders was endowed with the same demographic characteristics as the population, the recorders would still be 13 percentage points more likely to achieve a minimum recommended level of physical activity.

The decomposition results are also interesting in the case of depression, where biodiversity recorders have a 14% probability of reporting a depression diagnosis while the equivalent probability for the population is 6%, an overall difference of 8 percentage points. The portion of this gap explained by group differences in characteristics, however, is –3%. This implies that given their demographic profile, biodiversity recorders should be 3 percentage points less likely to suffer from depression than the general population. The unexplained gap is thus 10 percentage points, indicating that if biodiversity recorders were endowed with the demographic characteristics of the population they would be 10 percentage points more likely to have depression.

Table 5: Blinder-Oaxaca decomposition of health and well-being outcomes using Healthy Ireland Survey (HI) and The Irish Longitudinal Study on Ageing (TILDA).

Models	I: Healthy (%)	II: Active (%)	III: Depression (%)
Population: HI			
$Pr(y_{brs} \neq 0)$	87.11	82.01	13.87
$Pr(y_{pop} \neq 0)$	84.58	69.10	6.16
$Pr(y_{brs} \neq 0) - Pr(y_{pop} \neq 0)$	2.53	12.91	7.72
Explained	5.99	0.15	–2.67
Unexplained	–3.46	12.76	10.39
Population: TILDA			
$Pr(y_{brs} \neq 0)$	85.00	83.57	13.77
$Pr(y_{pop} \neq 0)$	44.54	60.26	2.48
$Pr(y_{brs} \neq 0) - Pr(y_{pop} \neq 0)$	40.45	23.22	11.29
Explained	14.82	11.93	–0.36
Unexplained	25.63	11.29	11.65

y_{brs} denotes proportion of biodiversity recorders; y_{pop} denotes proportion of the population.

Models I, II, and III are logit models that control for age, gender, urban or rural residence, marital status, highest education attained, employment status, socioeconomic status, and (for TILDA only) social connectedness. For all models, the reference category is the population (i.e., equation (4) in Supplemental File 2, Appendix B). Models I and III also control for level of physical activity.

Model I outcome variable is whether respondent reports "very good" or "good" general health.

Model II outcome variable is whether respondent achieves "moderate" IPAQ score or higher.

Model III outcome variable is whether respondent reports having been diagnosed with depression.

Using TILDA as the population source and focusing on older adults in our sample, similar patterns are evident for physical activity and self-reported depression, with even larger unexplained differences. In the case of self-reported general health, however, biodiversity recorders are 40 percentage points more likely to report good health, and 28 percentage points of this remain unexplained. This suggests that older adults are substantially more likely to report positively on their general health if they are biodiversity recorders, a finding that is not reflected when studying all adults.

The strikingly higher level of self-reported depression among biodiversity recorders, evident both when analysing all adults and when focusing on older adults, is hard to interpret. When we restrict our analysis to older adults in the sample and compare them with TILDA, we find no significant group differences in the proportions with a high CES-D score. There are at least three possible explanations for these findings. First, it may be that the unexplained difference in depression based on self-reports of a professional diagnosis reflects access to healthcare; i.e., perhaps biodiversity recorders are more likely to engage with health professionals and obtain a diagnosis, despite similar levels of depressive symptoms to the general population. A second possible explanation is that biodiversity recorders are simply more willing to report depression in a survey, or that respondents to an online survey are more likely than respondents in an interview setting to self-report depression. A further possibility is that there are other unobserved factors affecting our results, such as the personality of respondents (Malouff, Thorsteinsson, and Schutte 2005). Further research is required to validate and interpret this result.

Environmental attitudes

Finally, in **Table 6** we compare the attitudes towards the environment of our full sample of biodiversity recorders with the attitudes of the population using the Special Eurobarometer 468 public opinion survey. Overall, as expected given the nature of their voluntary conservation work, biodiversity recorders appear to be more engaged with environmental protection than the wider population. Nearly 88% of biodiversity recorders, a significantly higher proportion than the wider population, classify environmental protection as "very important." A substantially higher proportion of recorders also agrees that environmental issues have a direct effect on daily life and health. In addition, however, biodiversity recorders are much more likely to agree that they, as individuals, can play a role in protecting the environment in Ireland, another result that can be viewed as unsurprising given their engagement in conservation through environmental citizen science.

Respondents were also asked to choose up to four environmental issues most important to them, and **Figure 8** conveys which issues were attributed the highest importance by each group. The larger area covered by the Biodiversity Recorder Survey plot in **Figure 8** is driven by the fact that a higher proportion of Eurobarometer respondents chose less than four issues of importance. As expected in a survey of citizen scientists recording biodiversity, 93% of our sample of recorders indicate that the

Table 6: Attitudes towards the environment in biodiversity recorders compared with those of adult population in Ireland using Special Eurobarometer 468.

Characteristic	y_{brs} (%)	y_{pop} (%)	$y_{brs} - y_{pop}$ (%)
Environmental issues of concern[1]*:*			
Decline/extinction of species and ecosystems	92.82	25.00	67.82***
Shortage of drinking water	11.01	32.00	–20.99***
Increasing frequency of floods/droughts	8.85	29.00	–20.15***
Pollution of rivers/lakes	54.07	45.00	9.07***
Marine pollution	47.37	20.00	27.37***
Air pollution	12.44	36.00	–23.56***
Noise pollution	2.15	14.00	–11.85***
Climate change	55.50	49.00	6.50***
Increasing levels of waste	52.63	46.00	6.63***
Agricultural pollution	53.35	30.00	23.35***
Environmental protection "very important"	87.44	59.00	28.44***
Environmental issues have direct effect on daily life and health	73.74	48.00	25.74***
Individual can play role in environmental protection	72.15	64.00	8.15***

y_{brs} denotes proportion of biodiversity recorders; y_{pop} denotes proportion of the population.
*** denotes significance at the 99% level.
** denotes significance at the 95% level.
* denotes significance at the 90% level.
[1] Respondents were asked to choose up to four issues that were of highest importance to them.

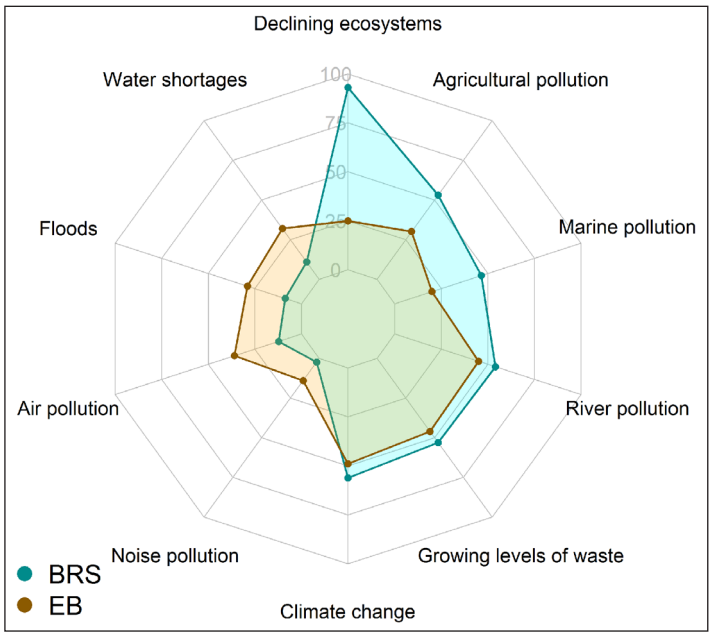

Figure 8: Environmental issues of concern for biodiversity recorders compared with those of adult population in Ireland using Eurobarometer (EB).

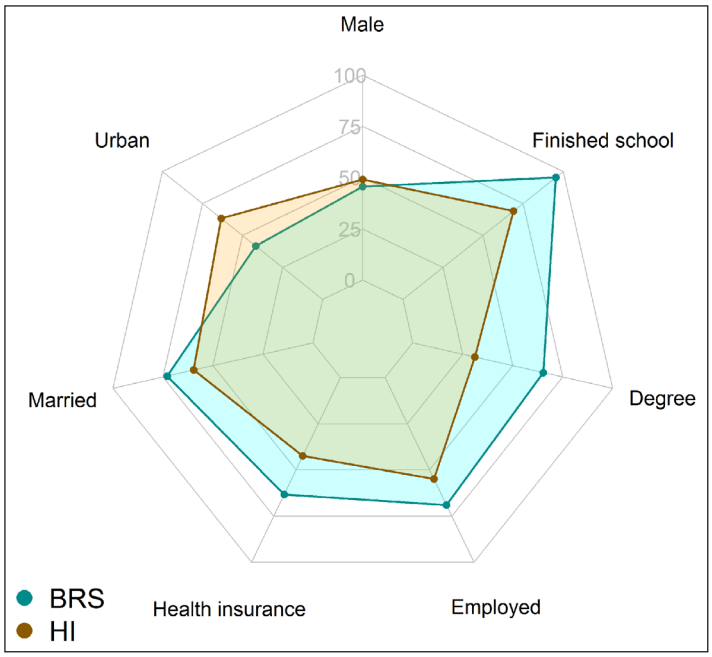

Figure 9: Demographic characteristics of biodiversity recorders compared with those of adult population in Ireland using Healthy Ireland Survey (HI).

decline or extinction of species and ecosystems is among their four most important issues, a substantially higher proportion than in the rest of the population. In general, issues that could be regarded as having a more direct impact on biodiversity appear to be assigned more importance by biodiversity recorders. These include the pollution of rivers and lakes, marine pollution, and agricultural pollution. Meanwhile, other issues that may affect biodiversity and natural ecosystems less directly such as noise pollution, air pollution,, and shortages of drinking water are selected as important by a significantly lower proportion of biodiversity recorders than by the wider population.

Conclusions

Citizen science is an increasingly important tool for assessing environmental change, allowing members of the public to contribute to research and to engage and interact with conservation efforts. We contribute to a growing literature exploring the benefits of citizen science to conservation by characterising the people who participate in biodiversity monitoring in terms of demographic, socio-economic, attitudinal and health attributes.

Overall, as summarised in **Figure 9**, the demographic picture of biodiversity recorders broadly concurs with previous research on environmental citizen scientists in showing them to be more highly educated, more

middle-aged, more rural, better-off, and more active in the labour force than the general population. The finding that environmental citizen scientists tend to be highly educated supports the argument that the involvement of citizen scientists in conservation and research could be broadened (Schröter et al. 2017), although it is also worth noting that environmental citizen scientists are more likely to be employed and thus may have limited spare time to devote to voluntary conservation activities.

As a corollary, our data suggests that younger people, people who live in urban areas, people who are unemployed, and people with lower levels of education are all currently underrepresented in our sample of biodiversity recorders—a finding that is also in broad agreement with previous literature. That environmental citizen science projects often rely on an unrepresentative participant base is of potential concern (Committee on Designing Citizen Science to Support Science Learning et al. 2018). There may be scope for campaigns designed to increase overall participation in environmental citizen science and conservation to focus on these groups. However, the present study does not examine the marginal costs of recruiting participants from different groups, so the practicability of exploiting these groups' untapped potential for participation in biodiversity recording activities remains to be established.

Another dimension worth considering is the intensity of participation in environmental citizen science activities. It could be that different groups within the population represent most of the highly active citizen scientists, i.e., those who contribute the most to scientific activities and presumably derive the greatest health and well-being benefits from it. Previous research finds that a small cohort of environmental volunteers generally contributes the most to environmental volunteering projects, while the majority of volunteers contribute little (Seymour and Haklay 2017). In future work, we hope to link survey data to administrative information on biodiversity recording activity to examine how participants' characteristics relate to their participation in citizen science activities.

To the extent that one objective of citizen science projects involving the observation and monitoring of flora and fauna is to foster enthusiasm for biological conservation among participants, our results suggest that newly recruited biodiversity recorders are already about as concerned as our metrics can record about the environmental threats from the decline or extinction of species and ecosystems. They also classify environmental protection as very important and they believe that individuals have a role to play in protecting the environment. In future work, we hope to check whether these attitudes strengthen further after extended participation in citizen science, but given the strength of feeling reported soon after recruitment, it is hard to see how there could be much scope for further attitudinal change. This may help explain the observation reported in Turrini et al. (2018) that it is difficult to realise goals such as adoption of pro-environmental attitudes and behaviours among citizen science project participants. Other, less pre-committed, groups might be better targets for those wishing to bring about significant change in public attitudes.

The final and most unique objective of this study is to gather baseline information on the health, well-being, and physical activity of newly recruited biodiversity recorders. In this paper we employ Blinder-Oaxaca decomposition methods to reveal differences in health and well-being outcomes between biodiversity recorders and the population that cannot be explained by group differences in other characteristics. Biodiversity recorders tend to be substantially more physically active, even after stripping out the effects of sociodemographic background. There are mixed results concerning their relative levels of generalised health and mental health. Biodiversity recorders tend to be slightly more negative in reporting on their general health, and they are also more likely to have been diagnosed with depression. Further research is required to validate and explain these differences. In future years, we hope to re-survey this sample to see whether participation in biodiversity recording activities is associated with more favourable trajectories in health and well-being, compared with control groups from other surveys.

Data Accessibility Statement

Researchers interested in using TILDA data may access the data through the TILDA website: www.tilda.ie. Researchers interested in using Healthy Ireland Survey data may access the data through the Irish Social Science Data Archive.

Notes

[1] TILDA is harmonised with the Survey of Health, Ageing and Retirement in Europe (SHARE), the English Longitudinal Study of Ageing (ELSA), the Health and Retirement Survey (HRS) and the HRS international network of studies.

[2] Further details on becoming a biodiversity recorder through the NBDC are available at https://www.biodiversityireland.ie/record-biodiversity/.

[3] Specifically, we employ an extension of the Blinder-Oaxaca decomposition proposed by Fairlie (2005) for binary outcome variables. This is done using the fairlie command in the Stata 14 software package. See Supplemental File 2, Appendix B for further details.

[4] The mean age of biodiversity recorders is 49.25, and 46.17 for the Healthy Ireland Survey.

[5] Biodiversity recorders have a mean of 4.86 close relatives and a mean of 4.67 close friends, while the equivalent figures for TILDA are 3.18 and 3.42.

Supplementary Files

The supplementary files for this article can be found as follows:

- **Supplemental File 1.** Appendix A. DOI: https://doi.org/10.5334/cstp.283.s1
- **Supplemental File 2.** Appendix B. DOI: https://doi.org/10.5334/cstp.283.s2
- **Supplemental File 3.** Stata do file 1. DOI: https://doi.org/10.5334/cstp.283.s3
- **Supplemental File 4.** Stata do file 2. DOI: https://doi.org/10.5334/cstp.283.s4

- **Supplemental File 5.** Stata do file 3. DOI: https://doi.org/10.5334/cstp.283.s5
- **Supplemental File 6.** R script 1. DOI: https://doi.org/10.5334/cstp.283.s6

Acknowledgements

This research is supported by the Economic and Social Research Institute's Environment Research Programme, which is funded by the Environmental Protection Agency's Research Programme 2016–2020. The funder had no role in study design; in the collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the article for publication. The authors are grateful to the National Biodiversity Data Centre for assistance with the Biodiversity Recorder Survey. We also thank TILDA and Healthy Ireland for microdata access.

Competing Interests

The authors have no competing interests to declare.

Author Contributions

All authors made substantial contributions to the design and drafting of this work, and to the interpretation of data for the work.

References

Ballard, HL, Dixon, CGH and **Harris, EM.** 2017. Youth-focused citizen science: examining the role of environmental science learning and agency for conservation. *Biological Conservation*, 208: 65–75. DOI: https://doi.org/10.1016/j.biocon.2016.05.024

Berkman, LF and **Syme, SL.** 1979. Social Networks, Host Resistance, and Mortality: A Nine-Year Follow-Up Study of Alameda County Residents. *American Journal of Epidemiology*, 109(2): 186–204. DOI: https://doi.org/10.1093/oxfordjournals.aje.a112674

Binder, M and **Blankenberg, AK.** 2016. Environmental Concerns, Volunteering and Subjective Well-Being: Antecedents and Outcomes of Environmental Activism in Germany. *Ecological Economics*, 124: 1–16. DOI: https://doi.org/10.1016/j.ecolecon.2016.01.009

Blinder, AS. 1973. Wage Discrimination: Reduced Form and Structural Estimates. *The Journal of Human Resources*, 8(4): 436. DOI: https://doi.org/10.2307/144855

Brossard, D, Lewenstein, B and **Bonney, R.** 2005. Scientific Knowledge and Attitude Change: The Impact of a Citizen Science Project. *International Journal of Science Education*, 27(9): 1099–1121. DOI: https://doi.org/10.1080/09500690500069483

Chandler, M, See, L, Copas, K, Bonde, AMZ, Claramunt López, B, Danielsen, F, Legind, JK, et al. 2017. Contribution of Citizen Science towards International Biodiversity Monitoring. *Biological Conservation*, 213: 280–294. DOI: https://doi.org/10.1016/j.biocon.2016.09.004

Committee on Designing Citizen Science to Support Science Learning, Board on Science Education, Division of Behavioral and Social Sciences and Education, and National Academies of Sciences, Engineering, and Medicine. 2018. *Learning Through Citizen Science: Enhancing Opportunities by Design*. Pandya, R and Dibner, KA (eds.). Washington, DC: National Academies Press. DOI: https://doi.org/10.17226/25183

Craig, CL, Marshall, AL, Sjostrom, M, Bauman, AE, Booth, ML, Ainsworth, BE, Pratt, M, et al. 2003. International Physical Activity Questionnaire: 12-Country Reliability and Validity. *Medicine & Science in Sports & Exercise*, 35(8): 1381–95. DOI: https://doi.org/10.1249/01.MSS.0000078924.61453.FB

Crall, AW, Jordan, R, Holfelder, K, Newman, GJ, Graham, J and **Waller, DM.** 2013. The Impacts of an Invasive Species Citizen Science Training Program on Participant Attitudes, Behavior, and Science Literacy. *Public Understanding of Science*, 22(6): 745–64. DOI: https://doi.org/10.1177/0963662511434894

Dadvand, P, Bartoll, X, Basagaña, X, Dalmau-Bueno, A, Martinez, D, Ambros, A, Cirach, M, et al. 2016. Green Spaces and General Health: Roles of Mental Health Status, Social Support, and Physical Activity. *Environment International*, 91: 161–167. DOI: https://doi.org/10.1016/j.envint.2016.02.029

De Vries, S, Verheij, RA, Groenewegen, PP and **Spreeuwenberg, P.** 2003. Natural Environments—Healthy Environments? An Exploratory Analysis of the Relationship between Greenspace and Health. *Environment and Planning A*, 35(10): 1717–1731. DOI: https://doi.org/10.1068/a35111

Dempsey, S, Lyons, S and **Nolan, A.** 2018. Urban Green Space and Obesity in Older Adults: Evidence from Ireland. *SSM – Population Health*, 4: 206–15. DOI: https://doi.org/10.1016/j.ssmph.2018.01.002

Donoghue, OA, McGarrigle, CA, Foley, M, Fagan, A, Meaney, J and **Kenny, RA.** 2018. Cohort Profile Update: The Irish Longitudinal Study on Ageing (TILDA). *International Journal of Epidemiology*, 47(5): 1398–1398l. DOI: https://doi.org/10.1093/ije/dyy163

Evans, C, Abrams, E, Reitsma, R, Roux, K, Salmonsen, L and **Marra, PP.** 2005. The Neighborhood Nestwatch Program: Participant Outcomes of a Citizen-Science Ecological Research Project. *Conservation Biology*, 19(3): 589–94. DOI: https://doi.org/10.1111/j.1523-1739.2005.00s01.x

Fairlie, RW. 2005. An Extension of the Blinder-Oaxaca Decomposition Technique to Logit and Probit Models. *Journal of Economic and Social Measurement*, 30: 305–16. DOI: https://doi.org/10.3233/JEM-2005-0259

Gupta, S. 2018. Impact of Volunteering on Cognitive Decline of the Elderly. *The Journal of the Economics of Ageing*, 12: 46–60. DOI: https://doi.org/10.1016/j.jeoa.2018.01.002

Hobbs, SJ and **White, PCL.** 2012. Motivations and Barriers in Relation to Community Participation in Biodiversity Recording. *Journal for Nature Conservation*, 20(6): 364–73. DOI: https://doi.org/10.1016/j.jnc.2012.08.002

Huang, LH. 2018. Well-Being and Volunteering: Evidence from Aging Societies in Asia. *Social Science & Medicine*,

September. DOI: https://doi.org/10.1016/j.socscimed.2018.09.004

Ipsos MRBI. 2010. Healthy Ireland Technical Report. Dublin: Ipsos MRBI. https://www.ucd.ie/t4cms/14-050310%20Healthy%20Ireland%20-%20Technical%20Report%20(Final).pdf.

James, P, Banay, RF, Hart, JE and **Laden, F.** 2015. A Review of the Health Benefits of Greenness. *Current Epidemiology Reports*, 2(2): 131–142. DOI: https://doi.org/10.1007/s40471-015-0043-7

Johnson, MF, Hannah, C, Acton, L, Popovici, R, Karanth, KK and **Weinthal, E.** 2014. Network Environmentalism: Citizen Scientists as Agents for Environmental Advocacy. *Global Environmental Change*, 29: 235–245. DOI: https://doi.org/10.1016/j.gloenvcha.2014.10.006

Kearney, PM, Cronin, H, O'Regan, C, Kamiya, Y, Savva, GM, Whelan, B and **Kenny, RA.** 2011. Cohort Profile: The Irish Longitudinal Study on Ageing. *International Journal of Epidemiology*, 40(4): 877–84. DOI: https://doi.org/10.1093/ije/dyr116

Kullenberg, C. 2015. Citizen Science as Resistance: Crossing the Boundary Between Reference and Representation. *Journal of Resistance Studies*, 1(1): 50–76.

Kullenberg, C and **Kasperowski, D.** 2016. What Is Citizen Science? – A Scientometric Meta-Analysis. Dorta-González, P (ed.), *PLOS ONE*, 11(1): e0147152. DOI: https://doi.org/10.1371/journal.pone.0147152

Lee, Y and **Yeung, WJ.** 2018. Gender Matters: Productive Social Engagement and the Subsequent Cognitive Changes among Older Adults. *Social Science & Medicine*. DOI: https://doi.org/10.1016/j.socscimed.2018.08.024

Lewandowski, EJ and **Oberhauser, KS.** 2017. Butterfly Citizen Scientists in the United States Increase Their Engagement in Conservation. *Biological Conservation*, 208: 106–12. DOI: https://doi.org/10.1016/j.biocon.2015.07.029

Maas, J. 2006. Green Space, Urbanity, and Health: How Strong Is the Relation? *Journal of Epidemiology & Community Health*, 60(7): 587–592. DOI: https://doi.org/10.1136/jech.2005.043125

Malouff, JM, Thorsteinsson, EB and **Schutte, NS.** 2005. The Relationship Between the Five-Factor Model of Personality and Symptoms of Clinical Disorders: A Meta-Analysis. *Journal of Psychopathology and Behavioral Assessment*, 27(2): 101–14. DOI: https://doi.org/10.1007/s10862-005-5384-y

Merenlender, AM, Crall, AW, Drill, S, Prysby, M and **Ballard, H.** 2016. Evaluating Environmental Education, Citizen Science, and Stewardship through Naturalist Programs: Naturalists and Citizen Science. *Conservation Biology*, 30(6): 1255–65. DOI: https://doi.org/10.1111/cobi.12737

O'Halloran, AM, Kenny, RA and **King-Kallimanis, BL.** 2014. The Latent Factors of Depression from the Short Forms of the CES-D Are Consistent, Reliable and Valid in Community-Living Older Adults. *European Geriatric Medicine*, 5(2): 97–102. DOI: https://doi.org/10.1016/j.eurger.2013.12.004

Oaxaca, R. 1973. Male-Female Wage Differentials in Urban Labor Markets. *International Economic Review*, 14: 693–709. DOI: https://doi.org/10.2307/2525981

Overdevest, C, Huyck Orr, C and **Stepenuck, K.** 2004. Volunteer Stream Monitoring and Local Participation in Natural Resource Issues. *Human Ecology Review*, 11(2): 177–85.

Pandya, RE. 2012. A Framework for Engaging Diverse Communities in Citizen Science in the US. *Frontiers in Ecology and the Environment*, 10(6): 314–17. DOI: https://doi.org/10.1890/120007

Price, CA and **Lee, H.** 2013. Changes in Participants' Scientific Attitudes and Epistemological Beliefs during an Astronomical Citizen Science Project: Citizen Science Literacy. *Journal of Research in Science Teaching*, 50(7): 773–801. DOI: https://doi.org/10.1002/tea.21090

Raddick, MJ, Bracey, G, Carney, K, Gyuk, G, Borne, K, Wallin, J and **Jacoby, S.** 2009. Citizen Science: Status and Research Directions for the Coming Decade. *AGB Stars and Related Phenomenastro 2010: The Astronomy and Astrophysics Decadal Survey*. https://d1wqtxts1xzle7.cloudfront.net/30554144/raddick_citizen_science_epo.pdf?1360394283=&response-content-disposition=inline%3B+filename%3DCitizen_Science_Status_and_Research_Dire.pdf&Expires=1591973882&Signature=cvrOh7nwtC8NHRbhI41Go9P2RHt2n8ab6-~lGminmkTpTyl~1fT1iVqfslCY8bj1FoKbeFBVpl8OiLmneVOLCiebTERAdCNHbSMpq1xWZoHl4T3Zfo~oxEaRWMSFO8d3oc2eAhdBihI~FFuIbAH5Z0xmeqjO4C~w5190srUbu-ZuAbT-UWPeCI1TkCFNj~zkuosziFbIPmBfM7P0JnG3nAUZEy9I5YB5tYDRZYkRsLj34AJhhbqV0Br8kc5fF8XD-9Ce7BEmgt-mrTyCAO3-K6CcNoPl~6-hulQ~m~QMsVhlVr1dbnP7k6eUOwnLBljuA49qPn-XN5ja4AzgBr1xPA__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA.

Radloff, LS. 1977. The CES-D Scale: A Self-Report Depression Scale for Research in the General Population. *Applied Psychological Measurement*, 1(3): 385–401. DOI: https://doi.org/10.1177/014662167700100306

Sandifer, PA, Sutton-Grier, AE and **Ward, BP.** 2015. Exploring Connections among Nature, Biodiversity, Ecosystem Services, and Human Health and Well-Being: Opportunities to Enhance Health and Biodiversity Conservation. *Ecosystem Services*, 12: 1–15. DOI: https://doi.org/10.1016/j.ecoser.2014.12.007

Schröter, M, Kraemer, R, Mantel, M, Kabisch, N, Hecker, S, Richter, A, Neumeier, V and **Bonn, A.** 2017. Citizen Science for Assessing Ecosystem Services: Status, Challenges and Opportunities. *Ecosystem Services*, 28: 80–94. DOI: https://doi.org/10.1016/j.ecoser.2017.09.017

Seymour, V and **Haklay, MM.** 2017. Exploring Engagement Characteristics and Behaviours of Environmental Volunteers. *Citizen Science: Theory and Practice,* 2(1): 5. DOI: https://doi.org/10.5334/cstp.66

Shackleton, N, Derraik, JGB, Audas, R, Taylor, RW, Glover, M, Morton, SMB, Tautolo, E, et al. 2019. Decomposing Ethnic Differences in Body Mass Index and Obesity Rates among New Zealand Pre-Schoolers.

International Journal of Obesity, 43(10): 1951–60. DOI: https://doi.org/10.1038/s41366-019-0390-4

Theobald, EJ, Ettinger, AK, Burgess, HK, DeBey, LB, Schmidt, NR, Froehlich, HE, Wagner, C, et al. 2015. Global Change and Local Solutions: Tapping the Unrealized Potential of Citizen Science for Biodiversity Research. *Biological Conservation*, 181: 236–244. DOI: https://doi.org/10.1016/j.biocon.2014.10.021

Triguero-Mas, M, Dadvand, P, Cirach, M, Martínez, D, Medina, A, Mompart, A, Basagaña, X, Gražulevičiene, R and **Nieuwenhuijsen, MJ.** 2015. Natural Outdoor Environments and Mental and Physical Health: Relationships and Mechanisms. *Environment International*, 77: 35–41. DOI: https://doi.org/10.1016/j.envint.2015.01.012

Trumbull, DJ, Bonney, R, Bascom, D and **Cabral, A.** 2000. Thinking Scientifically during Participation in a Citizen-Science Project. *Science Education*, 84(2): 265–75. DOI: https://doi.org/10.1002/(SICI)1098-237X(200003)84:2<265::AID-SCE7>3.0.CO;2-5

Turrini, T, Dörler, D, Richter, A, Heigl, F and **Bonn, A.** 2018. The Threefold Potential of Environmental Citizen Science – Generating Knowledge, Creating Learning Opportunities and Enabling Civic Participation. *Biological Conservation*, 225: 176–186. DOI: https://doi.org/10.1016/j.biocon.2018.03.024

Van Dillen, SME, de Vries, S, Groenewegen, PP and **Spreeuwenberg, P.** 2011. Greenspace in Urban Neighbourhoods and Residents' Health: Adding Quality to Quantity. *Journal of Epidemiology and Community Health*, 66(6): e8–e8. DOI: https://doi.org/10.1136/jech.2009.104695

West, S and **Pateman, R.** 2016. Recruiting and Retaining Participants in Citizen Science: What Can Be Learned from the Volunteering Literature? *Citizen Science: Theory and Practice*, 1(2): 15. DOI: https://doi.org/10.5334/cstp.8

How to cite this article: Mac Domhnaill, C, Lyons, S and Nolan, A. 2020. The Citizens in Citizen Science: Demographic, Socioeconomic, and Health Characteristics of Biodiversity Recorders in Ireland. *Citizen Science: Theory and Practice*, 5(1): 16, pp. 1–17. DOI: https://doi.org/10.5334/cstp.283

Submitted: 03 October 2019 **Accepted:** 02 July 2020 **Published:** 06 August 2020

]u[*Citizen Science: Theory and Practice* is a peer-reviewed open access journal published by Ubiquity Press.

OPEN ACCESS