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# **A framework for improving understanding of volunteers' motivations to monitor and control invasive alien species**

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2 **control invasive alien species**

3

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24

25 **Abstract:**

26 Citizens make an important contribution to the study and management of biological invasions, as  
27 many monitoring and control projects rely heavily on volunteer assistance. Understanding the  
28 reasons why people participate in such projects is critical for successful recruitment and retention  
29 of volunteers. While research attention for this topic is growing, it is published in journals from  
30 different disciplines. We used a meta-synthesis approach to extract, analyze and synthesize the  
31 available information from 28 selected studies investigating motivations of volunteers to engage

32 in monitoring and control of invasive alien species (IAS). Our findings show how motivations fit  
33 three broad themes, reflecting environmental concerns, social motivations, and personal reasons.  
34 An important outcome of this study is the description of motivations that are unique to the IAS  
35 context: supporting IAS management, protecting native species and habitats, and  
36 livelihood/food/income protection or opportunities. In addition, our study reflects on important  
37 methodological choices for investigating volunteer motivations as well as ethical issues that may  
38 arise in practice. We conclude with a set of recommendations for project design and future research  
39 on volunteer motivations in IAS contexts, emphasizing the importance of collaboration with social  
40 scientists.

41

## 42 **Keywords**

43 citizen science, motivations, biological invasions, biodiversity monitoring, public engagement

44

## 45 **Introduction**

46

47 Public involvement in the monitoring and control of invasive alien species (IAS) contributes to  
48 both increased scientific understanding and effective management of biological invasions in  
49 multiple ways (Hester and Cacho 2017; Roy et al. 2018, Larson et al 2020a; Pawson et al. 2020).  
50 Species occurrence data collected by volunteers can improve our understanding of IAS  
51 distributions and inform modeling of species range expansion (Brown et al. 2008; Bois et al. 2011;  
52 Gallo and Waitt 2011; Crall et al. 2015; Grason et al. 2018; César de Sá et al. 2019; Giovos et al.  
53 2019; Lehtiniemi et al. 2020). Citizens can also play an important role in the early detection of  
54 IAS (Looney et al. 2016; Carnegie and Nahrung 2019; Epanchin-Niell et al. 2021). For example,  
55 in New Zealand, 63% of detections of new pest incursions were attributed to the general public  
56 (Bleach 2018 in Epanchin-Niell et al. 2021), while in the United States, the general public and  
57 private owners of nurseries and farms detected 27% of new alien pests found between 2010 and  
58 2018, including a large number of species with high economic or environmental impact (Epanchin-  
59 Niell et al. 2021). Citizens can also play active roles in the capture, control and removal of IAS  
60 (Bryce et al. 2011; Kobori et al. 2016; Marchante and Marchante, 2016; Dechoum et al. 2019;  
61 Jubase et al. 2021). Additional benefits of engaging citizens in IAS projects include increased  
62 public awareness of IAS (Jordan et al. 2011), potentially resulting in the prevention of new

63 introductions (Azevedo-Santos et al. 2015) and wider acceptance and support of IAS control and  
64 eradication (Larson et al. 2016; Novoa et al. 2017; Dunn et al. 2018, 2021; Bailey et al. 2020;  
65 Phillips et al. 2021).

66  
67 Understanding volunteer drivers and motivations is critical for effective volunteer recruitment,  
68 retention, and the long-term sustainability of volunteer-driven projects (Wright et al. 2015;  
69 Cardoso et al. 2017; Veeckman et al. 2019; Rüfenacht et al. 2021). Different theories have been  
70 proposed to explain why people spend time and effort on volunteer tasks (see West and Pateman  
71 2016 for a recent synthesis). Such motivations may be intrinsic (i.e. offering internal rewards  
72 stemming from participation) or extrinsic (i.e. offering external rewards) (Finkelstien 2009).  
73 Recognizing that “acts of volunteerism that appear to be quite similar on the surface may reflect  
74 markedly different underlying motivational processes” (Clary et al. 1998, p. 1517), social  
75 psychologists suggest that motivations of individuals may be derived from values (i.e. finding it  
76 important to help others), understanding and knowledge (i.e. wanting to learn), social connections  
77 (i.e. strengthening relationships or sense of community) , career perspectives (i.e. gaining career-  
78 related experience, self-protection (i.e. reducing negative feelings), or personal development (e.g.  
79 growing or developing psychologically) (Clary et al. 1998; Clary and Snyder 1999; Omoto and  
80 Packard 2016).

81  
82 Research on environmental volunteering, including volunteer motivations, gained traction in the  
83 last two decades, especially in countries with a long tradition in citizen involvement in biodiversity  
84 monitoring, such as the United Kingdom, the Netherlands, Australia and the United States  
85 (Measham and Barnett 2008; Geoghegan et al. 2016; Merenlender et al. 2016; Ganzevoort 2021),  
86 or countries with a long history of managing IAS, such as South Africa (Shackleton et al. 2019;  
87 Jubase et al. 2021). Previous studies have empirically tested and classified different motivations  
88 in an environmental context (e.g. Bruyere and Rappe 2006; Measham and Barnett 2008; Larson et  
89 al. 2020b). For example, Measham and Barnett (2008) present a set of six broad motivations  
90 underpinning environmental volunteering (i.e. contributing to community, social interaction,  
91 personal development, learning about the environment, a general ethic of care for the environment,  
92 and attachment to a particular place or species) and five different modes through which  
93 volunteering is manifested (i.e. activism, education, monitoring, restoration, and promoting

94 sustainable living). Large scale surveys among environmental volunteers have shown that they can  
95 have multiple reasons for participating, and that motivations vary by socio-demographic attributes  
96 and the type and extent of participant involvement (Ganzevoort et al. 2020; Larson et al. 2020b).

97  
98 One environmental area in which participation of volunteer citizens is increasing is biological  
99 invasions (Johnson et al. 2020; Price-Jones et al., *unpublished data*). The ability to purposefully  
100 design projects for monitoring and controlling IAS requires knowledge of the motivations of  
101 individuals to participate (Hobbs and White 2012; Roy et al. 2018; Pocock et al 2020; Encarnaçã  
102 et al. 2021). While the number of studies investigating public perceptions of IAS and public  
103 engagement in management is slowly increasing (Shackleton et al. 2019; Kapitza et al. 2019;  
104 Cordeiro et al. 2020), we are not aware of any study that has captured the current knowledge on  
105 volunteer motivations in this area. To fill this gap, our primary objective was to synthesize existing  
106 knowledge about the diverse motivations of volunteers to participate in IAS monitoring (e.g.  
107 citizen science initiatives) and control projects (i.e. hands-on activities to manage IAS). Although  
108 these two types of activities are different, they are closely linked as monitoring or observing IAS  
109 often contributes to decisions about management actions. This connection is sometimes very clear,  
110 for example in early detection and rapid response (de Groot et al. 2020), but there are also more  
111 implicit ways in which monitoring data inform decision-making in IAS management and science  
112 (Groom et al. 2019). In this paper, we simply refer to ‘IAS projects’ including both monitoring  
113 and control activities, but as motivations may differ for the two, we emphasize important  
114 differences when they arise.

115  
116 To achieve our objective, we used a meta-synthesis approach to extract, analyze and synthesize  
117 the available information about volunteer motivations from relevant scientific and grey literature.  
118 This approach is useful for analyzing a relatively small number of studies on a selected topic (Hoon  
119 et al. 2013) and is increasingly applied in the context of environmental and other interdisciplinary  
120 studies (e.g. Carlson and Palmer 2016; Garavan et al. 2019).

121  
122 Although initially our synthesis focused on documenting and better understanding the diversity in  
123 volunteer motivations, while conducting our meta-synthesis, we further identified important  
124 methodological and practical implications of study and project design. First, we found large

125 differences in how and to what extent studies investigated motivations, ranging from very limited  
126 quantitative reports to in-depth qualitative inquiries. This led us to document the different  
127 approaches and methodologies that were used for measuring volunteer motivations and to what  
128 extent they were reported in the articles. Second, we also paid close attention to ethical and  
129 practical dilemmas reported in the studies. At the end of the paper, we provide a number of  
130 recommendations for (i) designing projects that consider the diverse motivations of participants to  
131 maximise recruitment and retention and (ii) future research on volunteer motivations in IAS  
132 contexts.

133

## 134 **Methods**

### 135 *Bibliographic analysis*

136

137 We searched for relevant publications using multiple databases and sources for peer-reviewed and  
138 grey literature. A bibliographic search was conducted using both Web of Science (WoS) on  
139 February 10, 2021 and SCOPUS on March 5, 2021. The search string captured three main topics  
140 (i.e. motivations, citizen science and invasive alien species) and we included multiple synonyms  
141 for each topic: (motivation\* OR engag\* OR incentive\*) AND (“citizen science” OR volunteer\*  
142 OR community) AND (“invasive species” OR “invasive plant\*” OR “alien species” OR “exotic  
143 species” OR “non-native” OR “nonnative” OR “non-indigenous” OR invas\*). We used the  
144 filtering options of the databases to exclude publications from other fields (e.g. healthcare,  
145 physics). This search resulted in a list of 267 bibliographic references in WoS and 302 in SCOPUS.  
146 Next, we scrutinized the title and abstract and, if needed, the full text of the articles, to further  
147 exclude articles that did not relate to IAS or did not contain any information pertaining to volunteer  
148 motivations to participate in IAS projects. Combining the searches from WoS and SCOPUS  
149 databases, we selected 18 relevant articles (of which six were found using SCOPUS, but not  
150 included in WoS).

151

152 Additionally, we conducted a search using the Google and Google Scholar search engines using  
153 (variations of) the same search string and reviewing the first 50 results. This yielded three  
154 additional references. We also requested information from working group leaders of the EU  
155 Cooperation in Science and Technology (COST) Action, AlienCSI ([www.alien-csi.eu](http://www.alien-csi.eu)) via email,

156 obtaining one additional unpublished dataset (Marchante et al., pers. comm.) and one recently  
 157 published paper. Finally, we included five additional papers obtained via the snowball sampling  
 158 strategy, i.e. by retrieving relevant papers from the reference lists of the selected papers.

159  
 160 Altogether, 28 sources were selected for inclusion in the meta-synthesis. Despite using different  
 161 search strategies covering academic and non-academic literature, we did not find any grey  
 162 literature sources. This may be a limitation of our search being in English only, as such reports are  
 163 likely to be published in native languages.

164  
 165 *Data analysis*

166  
 167 Each of the selected papers was read in full by the first and last author who made extensive notes  
 168 about the study context, methodologies and findings. First, we documented the specific context of  
 169 each study using the questions and categories in Table 1. Second, we listed each phrase or text  
 170 fragment referring to motivations (hereafter ‘motivation statement’) that was presented in the  
 171 paper. A more detailed explanation of how we categorized these motivations is given below. Third,  
 172 we collected detailed information about the methodology and/or approach that was used for  
 173 measuring motivations using the questions and categories in Table 2. Finally, we systematically  
 174 listed important findings or recommendations that linked motivations to the design and evaluation  
 175 of IAS volunteer projects. These findings were grouped and summarized according to specific  
 176 themes.

177  
 178 **Table 1.** Questions and categories used for describing study contexts

Name	Question	Categories
Year	In which year was the paper published?	Free text
Country	In which country did the study take place?	Free text
Volunteer type	Which type of volunteers were involved in the project?	1) IAS project volunteers 2) specific target audiences (e.g. landowner, hunter, divers, etc.) 3) the general public 4) other

Project type	What was the main aim of the project in which volunteers participated?	Control, detection/monitoring or other
Target species	What was the target species?	Free text
Target species group	To what species group does the species belong?	Bird, fish, insect, mammal, plant, reptile or other
Habitat type	Which habitats did the study cover?	Terrestrial, freshwater, marine, island

179

180 **Table 2.** Questions and categories used for describing study methodologies for measuring  
 181 motivations.

Name	Question	Categories
Data collection	What was the main method used for data collection?	Surveys, interviews, both or other
Respondent number	How many respondents answered the question about motivations?	Free text (number)
Question type	What type of question was used to measure motivations?	Open, closed, both or other
Documentation	Did the study provide adequate information about the data collection method and (survey) questions (either in the main text or in an appendix)?	Yes or no

182

183 *Classification of motivations for participating in IAS projects*

184

185 We collated a list of 233 motivation statements retrieved from the 28 papers (See supplementary  
 186 file 1). The listed motivations were assigned to broader categories using iterative coding (c.f. Asah  
 187 et al. 2014). The iterative coding process was both deductive (i.e. based on previously known  
 188 motivation categories; Measham and Barnett 2008; Wright et al. 2015; West and Pateman 2016;  
 189 Larson et al. 2020b) and inductive (i.e. by identifying and grouping motivations that did not  
 190 resemble previously known motivations categories and assigning them to new categories).  
 191 Visualization of the resulting conceptual framework was done using open source diagrams.net  
 192 software (<https://www.diagrams.net/>).

193

194 Some statements included multiple motivations, for example, when the participants expressed both  
 195 an attachment to a particular place and a more general desire to help the environment, or by a wish

196 to contribute to science, while experiencing fun and enjoyment at the same time. In such cases, the  
197 motivation statement was assigned to multiple categories, thus resulting in a higher number of  
198 recorded motivations than the total number of recorded statements (264 vs. 233, respectively).  
199 While a number of motivation statements were assigned to preexisting motivation categories (e.g.  
200 contribution to science, helping the environment, social interaction, attachment to a particular  
201 place, or wanting to share existing knowledge with others), others required us to develop a new  
202 set of categories unique to volunteers participating in IAS projects.

203  
204 To decrease subjective interpretations, the categorization was performed by a team of four  
205 researchers. The first author developed the initial categorization scheme and started the process of  
206 ascribing motivations to appropriate categories. Three of the co-authors joined the process of  
207 categorization by providing their own views on the appropriate categories, thus ensuring that the  
208 final result of the categorization was not influenced solely by the perspective of one author.  
209 Motivations which were categorized differently were discussed until consensus was reached.

210

## 211 **Results and Discussion**

### 212 *Study contexts*

213

214 All papers included in the analysis (See supplementary file 2) were published in the last ten years  
215 (2012 – 2021) except for one study (Krasny and Lee 2002). Most studies were conducted in Europe  
216 (n = 12) and North America (n = 9), with three conducted in Australia and one study each in South  
217 Africa, the Caribbean, Hawaii and the Canary Islands. Studies reporting on terrestrial ecosystems  
218 (n = 24) strongly outnumbered those related to marine environments (n = 4). Majority of the studies  
219 (n = 20) reported volunteer motivations for participating in control projects only, while six studies  
220 reported on monitoring projects and one each on the training of IAS monitoring and management  
221 planning. The projects often targeted a specific IAS and these were mostly plant (n = 11) and  
222 mammal (n = 5) species, or both (n = 1), while the remaining were focused on invasive fish (n =  
223 3), birds (n = 3), reptiles (n = 2), insects and tree insect and fungal pest species (one study each).  
224 The one remaining study did not specify the target group of IAS. The reviewed studies investigated  
225 motivations of groups of volunteers committed to participating in IAS projects (n = 14), or specific

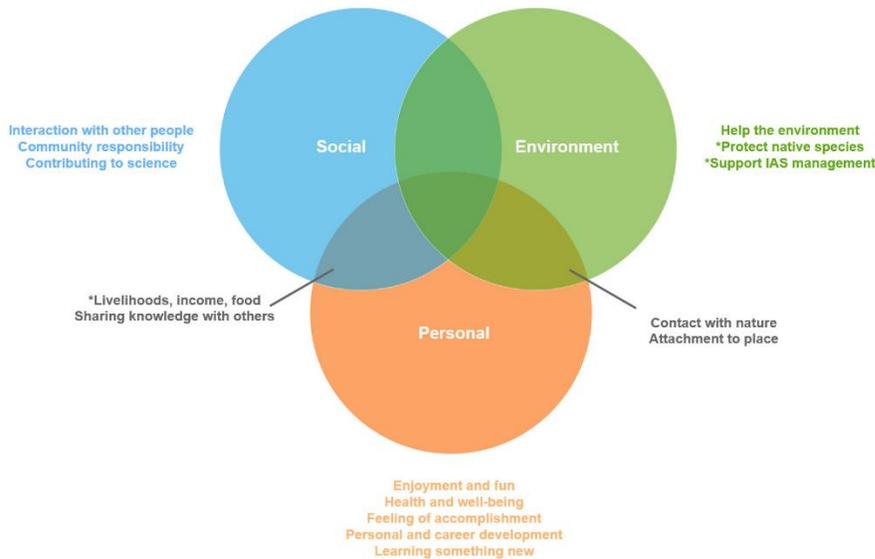
226 target audiences (e.g. land-owners, hunters, divers, etc.; n = 11), while the remaining studies  
 227 focused on the general public (n=3) or the participants of a training program on invasive species  
 228 (n=1).

229

230 *Motivations*

231 Iterative categorization of the 233 motivation statements resulted in 15 different motivations  
 232 affecting the participation of volunteers in IAS projects (Table 3). The conceptual framework  
 233 presented in Fig. 1 shows how these motivations fit three broad themes, reflecting primarily (1)  
 234 environmental concerns (i.e. supporting IAS management, helping the environment, and  
 235 protecting native species and habitats), (2) social motivations (i.e. social interaction, community  
 236 responsibility, and contribution to science) and (3) personal reasons (i.e. learning something new,  
 237 personal and career development, feeling of accomplishment, health and wellbeing, and enjoyment  
 238 and fun). A number of motivations belong to more than one theme. For example, contact with  
 239 nature and attachment to a particular place are motivations which include both a personal and an  
 240 environmental aspect, while the desire to share existing knowledge and livelihood/food/income  
 241 protection or opportunities are influenced by the social and personal aspect of motivations (Fig.  
 242 1).

243



244

245 **Figure 1** Conceptual framework for understanding volunteer motivations for participating in  
 246 monitoring and control of invasive alien species along three main themes. Newly identified  
 247 motivations unique to the IAS context (compared to existing literature) are marked with an asterisk

248

249 Three motivations unique to the IAS context emerged during the analysis: 1) supporting IAS  
250 management (Environment theme), 2) protecting native species and habitats (Environment theme),  
251 and 3) livelihood/food/income protection or opportunities (Social/Personal theme). We describe  
252 these motivations in more detail in Section Motivations specific to IAS context. In addition, eleven  
253 motivations were described in previous literature (Clary and Snyder 1999; Measham and Barnett  
254 2008; Finkelstien 2009; West and Pateman 2016; Larson et al. 2020). Eight statements could not  
255 be categorized and were termed ‘Other’ (Table 3). Five of these statements were related to previous  
256 experience of participating in citizen science initiatives (Marchante et al. 2017; Garrard et al. 2020;  
257 Jubase et al. 2021; Phillips et al. 2021; Marchante et al. pers. comm.) which led people to take part  
258 in subsequent activities. The remaining three were fear of the species itself (Servia et al. 2020),  
259 “desire to preserve environmental aesthetics” (Jubase et al. 2021, p. 4), and cost, with participation  
260 in the project being “cheaper than a normal biology course or dive” (Cerrano et al. 2017, p. 316).

261 **Table 3.** Motivations of volunteers participating in invasive alien species monitoring and management projects (categories  
 262 unique/specific for IAS contexts are given in **bold**)

THEME	MOTIVATION	DESCRIPTION	EXAMPLES	REPORTED IN <sup>a</sup> :
ENVIRONMENT	<b>supporting IAS management</b>	a desire to participate in IAS control and eradication	see Section <i>Motivations specific to IAS context</i>	[3], [4], [7], [8], [9], [10], [11], [12], [13], [14], [16], [17], [18], [19], [20], [21], [22], [23], [24], [26], [27], [28]
	helping the environment	a desire to help the environment	“help nature” “protect the environment” “assist with conservation efforts”	[1], [3], [4], [5], [7], [9], [10], [11], [13], [14], [16], [17], [18], [19], [21], [22], [28]
	<b>protecting native species and habitats</b>	a desire to protect native species and habitats	see Section <i>Motivations specific to IAS context</i>	[4], [6], [8], [9], [11], [12], [16], [20], [21], [22]
ENVIRONMENT/ PERSONAL	contact with nature	opportunity to experience nature, being in close contact with the natural world, unique experiences in nature	“opportunity to work in close contact with the natural world” “opportunity to experience impressive nature”	[1], [2], [5], [10], [12], [16], [18], [21], [22], [23], [28]
	attachment to a particular place	feeling of attachment to local places	“personal attachment to local places” “taking care of favourite dive sites”	[1], [5], [9], [22]
PERSONAL	learning something new	a general interest in acquiring new knowledge	“to learn more about the environment/IAS” “learning something new”	[1], [2], [4], [5], [7], [10], [12], [13], [14], [18], [21], [28]
	personal/career development	interest in acquiring new skills; education, or career progression	“learning job skills” / “skill development” “gaining additional field experience” “use of novel technologies”	[1], [2], [4], [5], [7], [10], [14], [17], [18], [21], [22]
	enjoyment/fun	expressions of positive emotions like enjoyment and fun	“thrill seeking” “exciting experience”	[1], [2], [3], [4], [5], [12], [13], [15], [16], [23], [28]
	health and wellbeing	references to mental and physical health	“to get out of the house” “to get exercise” “a good form of relaxation”	[1], [2], [9], [13], [21], [22], [28]
	feeling of accomplishment	feelings of pride, satisfaction and doing something that is meaningful	“to show that I can make a difference” “I feel I'm doing it right and I am proud”	[1], [2], [5], [12], [18], [19]

PERSONAL/SOCIAL	<b>livelihood/food/income protection or opportunities</b>	references to protecting or improving livelihoods and incomes	see Section <i>Motivations specific to IAS context</i>	[2], [3], [4], [6], [8], [11], [19], [20], [22], [25], [27], [28]
	wanting to share existing knowledge	wish to share existing knowledge with others	“to let children/grandchildren know the sea” “to teach others about invasive species”	[2], [3], [5], [13], [14], [18]
SOCIAL	contribution to science	wish to contribute to or take part in scientific research	“because data can be useful for science” “participation in exciting discoveries”	[5], [15], [17], [18]
	community responsibility	feeling a sense of responsibility / duty of care / giving something back to the community	“for the future generations” “showing that one can make a difference” “moral duty to manage the consequences”	[1], [2], [3], [4], [5], [6], [8], [12], [13], [16], [18], [19], [21], [22], [24]
	social interaction	spending time with friends, family, or like-minded people	“spending time with friends/family” “being with people that share interests” “a sense of belonging to a group”	[1], [2], [4], [5], [9], [12], [13], [14], [18], [21], [22], [28]

264 *Motivations specific to IAS context*

265

266 As stated above, three motivations unique to the IAS context emerged (Table 3). Supporting IAS  
267 management emerged as a leading motivation of volunteer participation (expressed through 30  
268 statements in 20 papers, Table 3). This category groups motivations that start from an  
269 understanding of the harmfulness or alien status of IAS, leading to a desire to assist in their  
270 management/eradication. While some simply expressed a desire to remove the IAS “to aid  
271 conservation management” (Stien and Hausner 2018, p. 189) or for the “chance of keeping them  
272 [tree pests or diseases] at bay or eradicating them” (Pocock et al. 2020, p. 724), others recognized  
273 that IAS are not meant to be in the introduced area (e.g. “carp don’t belong here and there are too  
274 many of them” in Atchinson et al. 2017, p. 340).

275

276 Protecting native species and habitats was documented in ten of the papers, where participants  
277 were motivated primarily by the wish for protecting native species in their surroundings (e.g.  
278 Niemiec et al. 2016; Cerri et al. 2018; Crowley et al. 2018; Pagès et al. 2018, 2019; Dunn et al.  
279 2021) or for protecting native habitats (e.g. Harvey et al. 2016; Pagès et al. 2018) they are familiar  
280 with. This motivation reflects the close relationship and affection and attachment people feel  
281 towards native species (e.g. red squirrels in Crowley et al. 2018; puffins in Pagès et al. 2018) and  
282 habitats (e.g. native broadleaved woodlands in Crowley et al. 2018), and consequently their desire  
283 to protect these from the impacts of IAS. The respondents reported that they feel that native species  
284 are more valuable than alien species (Pagès et al. 2019) and that humans are responsible for the  
285 introduction of alien species, making it our moral duty to control them (Crowley et al. 2018).  
286 Similarly, the study of Jubase et al. (2021) also reports this motivation, expressed as a desire to  
287 preserve the native fynbos biome.

288

289 Livelihood/food/income protection or opportunities refers to the protection or improvement of  
290 livelihoods and incomes in cases where IAS cause crop damages (e.g. Cerri et al. 2018; Saavedra  
291 and Medina, 2020) or have a negative effect on business profitability and property value (e.g.  
292 Marshall et al. 2016; Pagès et al. 2019). This motivation also includes IAS as a new source of food  
293 or income (e.g. Carballo-Cárdenas and Tobi, 2016; Atchinson et al. 2017), where local

294 communities have recognized the potential of either eating a particular IAS, or by selling products  
295 and services related to the target IAS (e.g. lionfish in Carballo-Cárdenas and Tobi 2016).

296

297 *Observed differences in motivations*

298

299 Our meta-synthesis indicated some minor (and expected) differences in motivations between  
300 volunteers participating in either detection/monitoring or control projects. Participants in control  
301 projects did not report being motivated by ‘contributing to science’, while participants in  
302 detection/monitoring projects did not report ‘protecting native species/habitats’ or ‘health and  
303 wellbeing’ as motivations. However, these findings are based on a limited number of studies and  
304 most of these were linked to control projects. In order to provide more insights, we need  
305 comparative study designs measuring the types and strength of motivations in different kinds of  
306 projects.

307

308 We observed some interesting patterns of motivations for different target groups. Land-owners  
309 and local residents (Marshall et al. 2016; Niemiec et al. 2016; Saavedra and Medina 2020; Dunn  
310 et al. 2021) have a vested interest in their own neighborhoods or properties, are more locally  
311 oriented, and therefore motivated by the desire to protect their livelihood/food/income  
312 opportunities, develop social interactions with their neighbours and contribute to their community.  
313 Hunters (Stien and Hausner 2018) and divers (Carballo-Cárdenas and Tobi 2016; Cerrano et al.  
314 2017) are often motivated by the opportunity for fun and enjoyment, outdoor recreation/sport, and  
315 contact with nature. Additionally, divers reported an attachment to a particular place (e.g. a  
316 preference for certain diving spots; Cerrano et al. 2017), a desire to contribute to science, share  
317 knowledge and develop personally/career-wise.

318

319 Pagés et al. (2019) observed differences in motivations within groups of project volunteers  
320 controlling the same IAS, ranging from helping nature to protecting private property or seeing the  
321 IAS as threatening their recreational activities. They also found differences in motivations between  
322 groups of volunteers controlling different target IAS (i.e. grey squirrel vs. Himalayan balsam). The  
323 most notable difference was that while supporting IAS management was seen as the leading  
324 motivation in the group of volunteers controlling Himalayan balsam, those tasked with killing

325 invasive grey squirrels saw it as a disincentive for participation, rather than motivation (a more  
326 detailed discussion on the ethical problems of killing animals is made in Section *Ethical and*  
327 *practical dilemmas*). In other studies, the participants taking part in the control of invasive  
328 mammals (e.g. squirrels; Crowley et al. 2018; Dunn et al. 2021) and reptiles (e.g. Burmese  
329 pythons; Harvey et al. 2016) were motivated to protect native species and habitats.

330 Methodologies and approaches used for measuring motivations

331

332 *Descriptive findings*

333

334 The majority of the studies (n = 17) used online or paper surveys for data collection, five studies  
335 conducted interviews, three studies used both surveys and interviews, and two were based on  
336 participant observations. Generally, the survey studies included closed questions (e.g. multiple  
337 choice, ranking). Interestingly, very few of the survey studies draw upon existing typologies from  
338 social science literature (the exception being Asah and Blahna 2012; Asah et al. 2014 who adopt  
339 a functionalist perspective), pointing to an obvious research gap as well as a lack of scholarly  
340 exchange between disciplines. Interviews with open questions gathering qualitative data provided  
341 more novel insights, which informed our section on ‘new motivations’ (Section *Motivations*  
342 *specific to IAS context*). Less than half of the studies (n = 12) provided a copy of their questionnaire  
343 or survey as supplementary material, or adequately explained their methods in the text. Our  
344 synthesis approach did not answer questions of relative importance of motivations, or directly  
345 compare outcomes from different studies. This was difficult due to the great diversity in methods  
346 used to measure motivations, lack of reporting on methodological procedures and outcomes, and  
347 large differences in target groups and sample sizes.

348

349 *Initial and sustained motivation: changes over time*

350

351 A number of studies, mainly related to IAS control, investigated temporal dimensions of  
352 motivations, by measuring them at several points in time. For example, in their study of volunteers  
353 in urban conservation via invasive plant control, Asah and Blahna (2012) found that social and  
354 personal benefits were better predictors of the frequency of participation than more often reported  
355 environmental-related reasons. In a similar vein, Carballo-Cárdenas and Tobi (2016) reported that

356 participant motivations shifted from collective reasoning (i.e. to help the environment) to  
357 individualistic reasoning, including promoting commercial and recreational harvesting of lionfish.  
358 In this case, sustained interest was thus mainly driven by self-interest. This confirms findings from  
359 previous research that self-reported motivations (often measured at the start of a project) are not  
360 necessarily influential motivations that predict the duration of the engagement (Ryan et al. 2001).

361

362 Pagès et al. (2018) studied volunteers' initial and sustained motivations by surveying and  
363 interviewing prospective, new, returning, experienced and inactive volunteers in invasive plant  
364 management on islands. They found that motivations changed from identifiable functional reasons  
365 to start volunteering (i.e. personal goals/circumstances and project aims) to more complex  
366 attachments to the place and group over time. This implies that experiences during volunteer  
367 activities influence motivations, however, this change in motivation can be both positive or  
368 negative. Creating unique experiences for participants, e.g. by visiting places which are otherwise  
369 off limits can be an incentive to participate and can also result in a greater sense of responsibility  
370 for the volunteer or better relations between volunteers, stakeholders and management authorities  
371 based on trust (Cerrano et al. 2017; Pagès et al. 2018).

372

373 Another study noted that the perceptions of control feasibility can shift initially optimistic views  
374 to more nuanced, realistic or even pessimistic perspectives on the effectiveness of IAS control  
375 (Pagès et al. 2019). This in turn can affect volunteer retention, as participants may become  
376 disengaged over time, doubting or questioning the value of what they are doing (Atchinson et al  
377 2017). One way of dealing with this specific issue is to design the project in such a way that  
378 volunteers can see tangible results and feel like they are making a difference, e.g. by first clearing  
379 a field of weeds mechanically before bringing in volunteers to remove the last remaining plants  
380 (Pagès et al. 2019). Early detection of species is a rare event which may also reduce motivation to  
381 participate in monitoring (Pocock et al. 2020). In such cases, it is important to carefully  
382 communicate about the species' detectability to foster realistic expectations and avoid backlash  
383 where people's participation results in reduced concern about IAS because they cannot find it (Falk  
384 et al. 2016; Harvey et al. 2016).

385

386 *Ethical and practical dilemmas*

387

388 Motivations of project organizers and volunteers can differ substantially, leading to practical and  
389 ethical dilemmas. Pocock et al. (2020) give some clear examples from the context of early  
390 detection of tree pests and diseases and how this may affect motivations of participants to join or  
391 stay engaged in citizen science projects. One dilemma is that local communities can be  
392 disproportionately affected by actions following detection of pests and diseases as negative  
393 impacts, while the benefits of these actions are more likely gained at a larger scale. People may  
394 stop reporting due to concerns about the impacts of eradication measures, both due to the method  
395 used (e.g. killing, pesticides) or their outcome (e.g. felling trees or restricting access, sometimes  
396 resulting in a loss of income). Thus, in contrast to their expectation of doing good for the  
397 environment (e.g. to save trees), participants' efforts in reporting may lead to unintended  
398 consequences (e.g. as saving trees involves felling some of them). Similarly, Pagès et al. (2019)  
399 point to the potential failure in reconciling multiple goals of participation (e.g. gathering more data  
400 vs. empowering people) and warn that an overemphasis on conservation and cost-effectiveness  
401 criteria can fail to address local communities' concerns.

402

403 Another issue is that volunteers may be regarded as an answer to labour shortages and escalating  
404 costs. Some of the studies reported that detecting and monitoring species in marine environments  
405 is relatively expensive. Engaging volunteers can reduce costs for working hours and equipment,  
406 but resources can also be a constraint for volunteers to participate (Carballo-Cárdenas and Tobi  
407 2016). In general, citizen science and volunteering should not be regarded as free labour of any  
408 kind, as it may actually result in higher associated costs for stakeholders or organizations (e.g. due  
409 to high workload in confirming observations, communication or training of volunteers).

410

411 Awareness of volunteer perceptions is especially important when their activities involve or  
412 contribute to the killing of animals. Studies report that this can be an emotional burden on people,  
413 especially with charismatic invasive animal species such as grey squirrels or Asian carp (Atchinson  
414 et al. 2017; Crowley et al. 2018; Dunn et al. 2021). Killing invasive animals brings combined  
415 ethical and practical constraints. For example, even in large scale invasive animal control projects  
416 (involving hundreds of thousands of animals being killed, e.g. Bonnet et al. 2021), the majority of  
417 volunteers may not have access to the most humane methods of dispatch, forcing them to rely on

418 a blow to the head or to drowning the target animals (e.g. Crowley et al. 2018). Olszańska et al.  
419 (2016) have shown that such methods received lower support or were even opposed by the public,  
420 making it vitally important to communicate, promote and make the most humane methods for  
421 killing the target IAS more accessible, as they are often either not known or not practiced by a  
422 broader audience (e.g. Atchinson et al. 2017). The discourse of ethics should not be confined solely  
423 to methods used for killing animals. Rather, it also needs to consider the potentially negative  
424 impacts on the wellbeing (both health and safety) of volunteers and the social implications (e.g.  
425 being regarded as animal killers) for people who volunteer in such eradication campaigns.

426  
427 A number of studies recommended to let people experience the negative impacts of IAS first-hand,  
428 as a way to encourage their involvement in control. This can be framed from a conservation  
429 perspective, where volunteers get to witness impacts on ecosystems and native biodiversity  
430 (Crowley et al. 2018; Dunn et al. 2018; Stien and Hausner 2018; Larson et al. 2016), or from the  
431 point of view of specific stakeholders, for example by exposing the effects of IAS on timber quality  
432 (Crowley et al. 2018), crop yield (Cerri et al. 2018) or decline in native game species (Cerri et al.  
433 2018).

434  
435 A final dilemma concerns the decision to reward volunteers or not. Several studies report on the  
436 risk of crowding out intrinsic motivations if authorities promote personal benefits such as financial  
437 rewards (Stien and Hausner 2018; Garrard et al. 2020). On the other hand, it may promote  
438 inclusiveness by enabling participation of diverse volunteers that could have financial barriers  
439 (Pateman et al. 2021). The examples we found were linked to (semi)professional hunters receiving  
440 a reward per animal. As a rule, the other volunteer activities were unpaid, even though it is  
441 important to highlight that reimbursements can be important in enabling volunteer participation.

442

### 443 *Recommendations*

#### 444 *Recommendations for future research*

445  
446 Our synthesis revealed that studies of volunteer motivations in IAS contexts are often pragmatic  
447 without making reference to theoretical frameworks. Inadequate reporting of methods was another  
448 issue. Our findings also point towards the importance of considering situation-specific drivers and

449 temporal changes when measuring motivations. In addition to scoring or ranking motivations, it is  
450 thus also important to test whether such self-reported motivations actually influence behaviors and  
451 whether they change over time. Such longitudinal and explanatory studies remain scarce within  
452 the context of volunteer projects and require more attention. Differences in motivations between  
453 and within specific volunteer groups highlight the need to understand the target group of  
454 volunteers. This would ensure better success in their recruitment and retention throughout  
455 volunteer projects. Our recommendations for future research are to:

- 456 ● Design survey methods that build upon previous research on motivations, behavior and  
457 knowledge from different research disciplines.
- 458 ● Include demographic information in the study for possible segmentation of the sample into  
459 different groups with different motivations, e.g. nationality, gender, age, income, level of  
460 education, ethnicity, disability status and employment status.
- 461 ● Comply with transparency and FAIR data policies, e.g. publish survey questions, results  
462 and other relevant methodological information as standard practice.
- 463 ● Use comparative study designs for measuring the types and strengths of motivations in  
464 different kinds of projects or comparing between different groups.
- 465 ● Test whether self-reported motivations align with observed behavior and whether these  
466 change over time (longitudinal and explanatory studies)

467

#### 468 *Recommendations for project managers*

469

470 Most papers provided concrete recommendations for designing projects that consider the diverse  
471 motivations of participants to maximize their recruitment and retention. For example, having clear  
472 aims and objectives is important to be inclusive of diverse groups of people and tailor to their  
473 interests (MacLeod and Scott 2020; Pateman et al. 2021). To this end, providing clear information  
474 on what is required from the volunteers, how much time would they need to invest and what  
475 support they can expect from the project is important. Also, projects should consider active  
476 recruitment strategies based on information from potential participants regarding their preferences  
477 for reporting data or contributing to IAS management. Some concrete recommendations for  
478 designing IAS volunteer projects based on the information reviewed in our work are:

- 479 ● Document and report participant demographics (age, gender, participant profile, etc.) to  
480 monitor diversity in citizen science, evaluate engagement and devise strategies to improve  
481 inclusiveness
- 482 ● Consider whether volunteers can have a larger role in co-designing or collaboratively  
483 developing the project. Asking (potential) volunteers about their needs and wishes before  
484 and during a project enables the targeting of specific audiences and adapting to their needs.
- 485 ● Organize activities that provide volunteers with unique opportunities, exciting experiences,  
486 and fun and enjoyment.
- 487 ● Visit locations where (potential) volunteers can see and experience the negative impacts of  
488 IAS first-hand. Such an experience can trigger a desire to help or to continue volunteer  
489 activities. In case of control projects, clearly state the management objectives of projects  
490 to avoid disillusionment.
- 491 ● Carefully consider ethical and legal aspects around the involvement of volunteers,  
492 particularly in control projects. Provide adequate support to volunteer work that involves  
493 high risk activities (e.g. insurance)
- 494 ● If possible, partner up with existing projects and initiatives to ease volunteer recruitment  
495 and avoid ‘competition’ between projects.
- 496 ● Promote long-term projects that allow for continuity and for “knowing and recognizing the  
497 brand”.

498

## 499 **Conclusions**

500

501 Knowledge of volunteer motivations is important for developing and improving project design,  
502 communication, and evaluation of IAS projects. Despite increasing public involvement in  
503 monitoring and control of IAS, our synthesis found that only a limited number of studies have  
504 investigated volunteer motivations to participate in such activities. Our conceptual framework  
505 identified 15 motivations of which three were unique to the IAS context: supporting IAS  
506 management, protecting native species and habitats, and livelihood/food/income protection or  
507 opportunities. This framework, including environmental, social and personal motivations,  
508 provides a clear starting point for developing survey instruments, though the selection and number  
509 of survey items will depend on the target audience. We encourage researchers and project

510 managers to amplify their efforts in systematically gathering and reporting data on participant  
511 motivations in IAS projects, to allow for comparative studies and quantitative assessments of the  
512 importance of certain motivations. Collaboration with social scientists is strongly recommended  
513 to ensure the use of appropriate methodologies and consideration of relevant theoretical  
514 frameworks.

515

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524

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### 880 **List of figure and table legends**

881 **Figure 1.** Conceptual framework for understanding volunteer motivations for participating in  
882 monitoring and control of invasive alien species along three main themes. Newly identified  
883 motivations unique to the IAS context (compared to existing literature) are marked with an asterisk

884 **Table 1.** Questions and categories used for describing study contexts

885 **Table 2.** Questions and categories used for describing study methodologies for measuring  
886 motivations

887 **Table 3.** Motivations of volunteers participating in invasive alien species monitoring and  
888 management projects (categories unique/specific for IAS contexts are given in bold)

889

### 890 **List of supplementary files**

891 **Supplementary file 1** List of the studies used in the analysis.

892 **Supplementary file 2** Overview of the study characteristics and methodological approaches of the  
893 selected papers.