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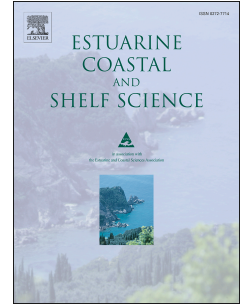
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Uses and management of saltmarshes: A global survey

E. McKinley, J.F. Pagès, M. Alexander, D. Burdon, S. Martino



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Author Statement

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Emma McKinley: Conceptualization; Methodology; Formal Analysis; Writing - Original Draft; Writing - Review & Editing. **Jordi F. Pagès:** Conceptualization; Methodology; Writing - Original Draft; Writing - Review & Editing. **Meghan Alexander:** Conceptualization; Methodology; Formal Analysis; Writing - Original Draft; Writing - Review & Editing. **Daryl Burdon:** Conceptualization; Methodology; Formal Analysis; Writing - Original Draft; Writing - Review & Editing. **Simone Martino:** Conceptualization; Methodology; Formal Analysis; Writing - Original Draft; Writing - Review & Editing.

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Uses and Management of Saltmarshes: A Global Survey

McKinley, E.^{1*}, Pagès, J.F.^{2,3}, Alexander, M.⁴, Burdon, D.^{5,6}, and Martino, S.⁷

*Corresponding author: mckinley1@cardiff.ac.uk

¹School of Earth and Oceans Sciences, Cardiff University, Main Building, Park Place, Cardiff, CF10 3AT, United Kingdom.

²Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Institut de Recerca de la Biodiversitat (IRBIO), Universitat de Barcelona, Av. Diagonal, 643, 08028 Barcelona, Spain

³Centre d'Estudis Avançats de Blanes (CEAB-CSIC), Accés a la cala Sant Francesc 14, 17300 Blanes, Spain

⁴School of Politics, Philosophy and Language and Communication Studies, University of East Anglia, NR4 7TJ

⁵Institute of Estuarine & Coastal Studies, University of Hull, Hull, United Kingdom, HU6 7RX

⁶Daryl Burdon Ltd., Marine Research, Teaching and Consultancy, Willerby, HU10 6LL, UK.

⁷Department of Environment and Geography, University of York, YO10 5NG, UK

Uses and Management of Saltmarshes: A Global Survey

Abstract

Saltmarshes are important coastal fringe ecosystems supporting a myriad of coastal uses and users. However, saltmarshes have undergone a significant period of global decline, losing 25%- 50% of their coverage due to a range of drivers, but mainly as a result of anthropogenic pressures and land-use change. While the value of these coastal systems to society is recognised, global data are fragmented, patchy, and often restricted to local case studies. There is currently no comprehensive understanding of the global variation of ecosystem services, benefits and management practices available. This pioneering study addresses this by investigating the socio-ecological dimension of global variation in ecosystem service provision, and how this is being managed by and for different saltmarsh users. Through a global online questionnaire survey (n=438) targeting professional saltmarsh researchers and practitioners representing 40 countries across 5 continents, this paper presents an overview of saltmarsh ecosystem services, key drivers influencing management and the variation in factors that influence them. Analysis indicates considerable variation, with geographical location ('continent') being the most common moderator, influencing perceptions of saltmarshes, the prioritisation of ecosystem services and management perceptions. Finally, the paper presents a series of recommendations, including the development of an interdisciplinary, international research programme to support restoration and conservation of saltmarshes worldwide.

Key words: ecosystem management; wetlands; global change; ecosystem services; saltmarsh management

1. Introduction

Coastal ecosystems support some of the most productive and highly valuable natural resources across the globe. These include coastal protection, carbon storage, nutrient cycling, habitat for biodiversity and protected/vulnerable species, nursery habitats for fish, tranquil environments that support societal health and wellbeing, tourism and recreation (Himes-Cornell, et al., 2018; Moser et al., 2012; Barbier, 2011; MEA, 2005), in addition to supporting various livelihoods, particularly within developing contexts (Rebours et al., 2014; Arkema et al., 2015). Understanding stakeholder values and views towards ecosystem services and benefits, and how these might vary across spatial and temporal scales, is essential for effective conservation, management and policy development. The historical exclusion of cultural dimensions from coastal ecosystem decision-making has been shown to hamper conservation goals, produce unaccounted negative impacts to communities (Poe et al., 2014), misidentification of potential conflicts and undermine the operationalisation of integrated management plans (de Jaun et al., 2017). Weak policy and/or poor policy implementation can exacerbate the current trend of unprecedented loss and deterioration impacting coastal systems globally, driven by climate change and anthropogenic pressures (Gedan et al., 2009; Neubauer, 2009; Moser et al., 2012), both contributing to habitat change, biodiversity loss and alteration of ecological functions (IPBES, 2019).

Saltmarshes are not extraneous to this dynamic. Although extremely valuable in contributing to livelihoods locally and globally, saltmarshes are often overlooked ecosystems (Barbier et al., 2011). The database provided by Mcowen et al. (2017), presents the first global estimate of saltmarsh extent, and can help track progress towards global conservation targets set by the Aichi Biodiversity

44 Targets (2011), the United Nations Sustainable Development Goals (2015) and the Ramsar
45 Convention (1971). However, to achieve the goals established by these international agreements,
46 there is a real need to develop a more comprehensive understanding of the social-ecological
47 dimension of these fringe systems worldwide. In June 2017, at the UN Ocean Conference, 193
48 countries expressed their commitment to coastal systems by setting out a guidance to mitigate
49 against the impacts of climate change, encompassing global saltmarshes. Recognition of the
50 importance of protecting and restoring coastal systems, such as saltmarshes, is clearly growing.
51 However, this endeavour requires better awareness of the drivers influencing decision-making and
52 management, including, the inherent variation in protection and differences in prioritisation of
53 saltmarsh ecosystem function and services exhibited by different countries globally.

54 Through a global online questionnaire survey, this research targeted respondents representing
55 professional stakeholders working on/ with or researching saltmarshes in some manner, with
56 responses received across 40 countries, all populated continents and including 12 countries that
57 have yet to be the subject of any peer-reviewed saltmarsh publication. This paper examines three
58 pivotal research questions:

- 59 1) How does the perceived importance of saltmarshes and their ecosystem services vary
60 globally?
- 61 2) What are the main threats and challenges facing saltmarsh environments?
- 62 3) What is the perceived effectiveness of current saltmarsh management and how does this
63 vary globally?

64 This study provides a significant contribution to the ongoing development of the global knowledge
65 base about the management of ecosystem services associated with saltmarsh environments, the
66 priorities for different professional stakeholder groups, current gaps in research and understanding,
67 as well as insight into the perceived challenges to effective saltmarsh management. This paper
68 presents a review of the current literature relating to saltmarshes, their ecosystem services and their
69 management, before outlining the methodological approach taken to survey a self-selected
70 community of international and interdisciplinary saltmarsh researchers and practitioners. The paper
71 draws on the data collected and highlights key trends and drivers influencing global variation in
72 prioritisation and management of saltmarshes and their ecosystem services. Finally, a series of
73 recommendations for future work are presented to support ongoing management of global
74 saltmarshes.

75 **2. Global uses and management of saltmarshes**

76 When compared with other coastal habitats, such as seagrass and mangroves, saltmarshes have
77 received limited research attention with respect to understanding the ecosystem services and
78 benefits that they deliver (Duarte et al., 2008; Mcowen et al. 2017). However, as seen in other
79 coastal fringe environments, saltmarshes are highly valuable and productive, contributing a diverse
80 range of ecosystem services from which society derives numerous benefits in terms of provisioning
81 (Luisetti et al., 2014), regulating (e.g. Sousa et al., 2010; Beaumont et al., 2014; Himes-Cornell et al.,
82 2018), and supporting services (e.g. Colclough et al., 2005). Among the regulating services, research
83 has focused on the quantification and valuation of carbon sequestration (e.g. Macreadie et al., 2017;
84 Muenzel and Martino, 2018) and flood defence capacity (e.g. Möller et al., 2014; McDonald et al.,
85 2017). In contrast, cultural ecosystem services have received comparatively less attention. Although
86 limited, this literature shows that stakeholders tend to attribute high rankings to tourism and

87 recreation (Hutchinson et al., 2012; Sousa et al., 2013; Clemente et al., 2014; Cabral et al. 2014), but
 88 rarely consider sense of experience (Fletcher et al., 2011; Christie and Raymant, 2012; Carollo et al.,
 89 2013; da Silva et al., 2014) and spiritual and inspirational benefits (Church et al., 2014). Although
 90 aspects of wellbeing such as physical and mental health provided by coastal habitats, or “blue
 91 infrastructure” more generally, have been studied (White et al., 2013; Gascon et al., 2017), and
 92 although there are some examples of this type of work (see for example, Rendon et al., 2019),
 93 similar human benefits provided by saltmarshes have not yet been widely reported. A summary of
 94 the relative importance of saltmarshes in providing intermediate ecosystem services and benefits is
 95 provided in Figure 1 (after Potts et al., 2014). This figure illustrates the range and relative importance
 96 of ecosystem services and benefits that saltmarsh provides when compared with other marine and
 97 coastal habitats in the UK.

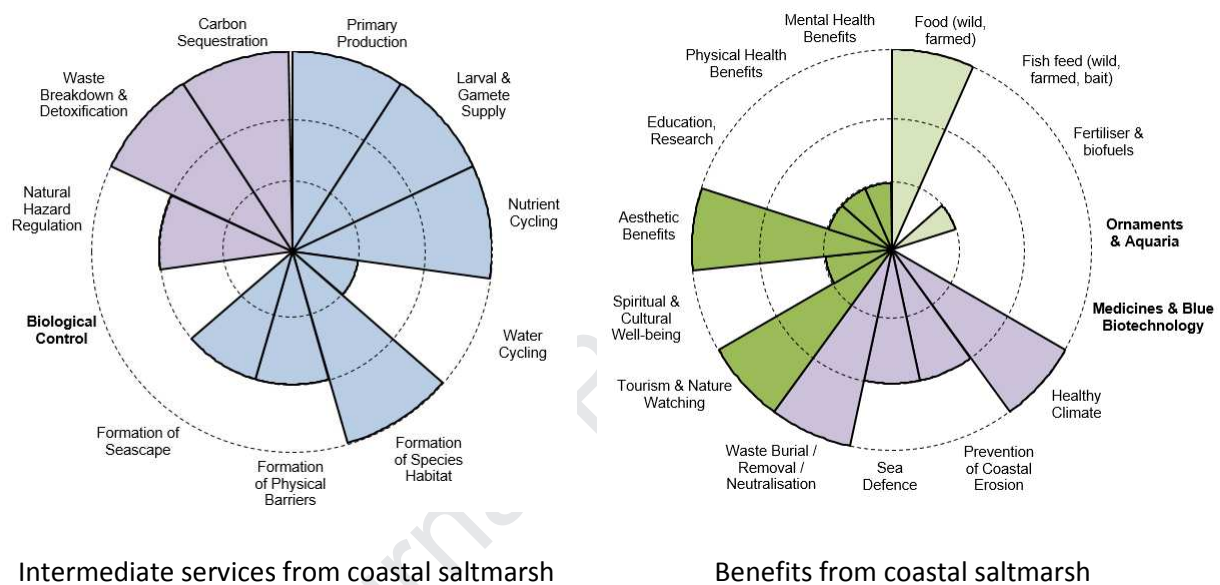


Figure 1. Relative importance (low (inner ring), medium (middle ring), high (outer ring)) of ecosystem services and benefits provided by coastal saltmarsh. Blue = supporting services, Purple = regulating services, Light green =provisioning services, Dark green = cultural services. Services and benefits in bold were not assessed (after Potts et al., 2014).

98 Globally, saltmarshes, like other coastal systems, have undergone a significant period of decline,
 99 with between 25% and 50% of their historical coverage lost as a result of anthropogenic pressures
 100 and changes in land use (Duarte et al., 2008; Gedan et al., 2009; Mcowen et al., 2017). Socio-
 101 economic drivers such as land reclamation (Rodrigues et al., 2017) and eutrophication (Deegan et al.,
 102 2012) are among the drivers found to negatively affect saltmarshes, as well as the ongoing impacts
 103 of climate change (Rocha et al., 2015).

104 Given that pressures on these systems show no sign of abating, there is a growing call to maintain
 105 and improve (i.e. through restoration) current levels of saltmarsh coverage (Shepard et al., 2011). To
 106 achieve these goals in a way that is sustainable and effectively managed, it is necessary to inform
 107 our understanding of the relative role that a range of factors play in the formation of management
 108 strategies for coastal habitats (Martino et al., 2019). In addition, more efforts to bridge the historic
 109 gaps between research, policy and practice are necessary (McKinley et al., 2018); therefore, this is
 110 not just a case of developing new policy – the impact and effectiveness of these new policies must
 111 also be understood (McKinley and Ballinger, 2018). Despite a growth in participatory approaches in
 112 saltmarsh management (Burdon et al., 2019), and calls for greater inclusion of research in policy,

113 legislation and practice (Jarvis et al., 2015; Drakou et al., 2017), to date this has had limited impact
114 on ground-level management of saltmarshes and other coastal environments (Foster et al., 2014).
115 Reducing the gap between ground-level management and research is a requisite to delivering
116 effective ecosystem-based management that supports benefits to communities across the globe
117 (Baulcomb et al., 2015; Hattam et al., 2015a; Bryce et al., 2016; Broszeit et al., 2017).

118 Although there has historically been a greater focus on ecological aspects of management (de Juan
119 et al., 2017), social factors are increasingly represented in the literature. These are most commonly
120 accounted for as socio-economic valuation and tend to be dominated by monetary valuation
121 (Barbier, 2013; Le Gentil and Mongrue, 2015). However, there is a growing recognition that
122 stakeholders (including communities) and decision-makers may be motivated by non-monetary
123 drivers; indeed, social and institutional values for many marine ecosystem services often conflict
124 with economic priorities (Martino et al., 2019). The current challenge is, therefore, to effectively
125 integrate biophysical, ecological and the socio-economic information (Bennett et al., 201) and to
126 explore how preferences for different management scenarios are related to drivers of change, and
127 efficacy of results (benefits) (Fulton et al., 2011). Through an analysis of drivers and impact on
128 ecosystem services, Rocha et al. (2015) found that many marine regime shifts are caused by multiple
129 drivers, have multiple consequences and need concerted local, national and international
130 management action.

131 To date, research into drivers of saltmarsh change, priorities, needs, management strategies,
132 stakeholder perceptions and values of saltmarsh ecosystem services is fragmented in terms of the
133 representation of geographies, types of services and stakeholders. A search carried out in “Scopus”
134 in March 2019 (www.scopus.com) using the keywords “saltmarshes” and “management” for all
135 countries characterised by the presence of saltmarshes showed that the majority of studies consider
136 biological and ecological aspects of saltmarsh management, but that only a fraction (1%) examine
137 the socio-ecological dimensions of saltmarsh ecosystems. In terms of number, 20 papers dealing
138 with saltmarsh management (be it from an ecological or socioecological point of view) have been
139 produced in Africa (principally from South Africa), 53 in Asia (mainly from China), 213 in Europe
140 (mainly from the UK), 234 in the Americas (with particular focus on the USA), and 77 in Oceania
141 (mainly Australia). Although this finding might, in part, reflect the geographical areas with higher
142 saltmarsh abundance, it should be noted that the literature is also biased towards those countries
143 with stronger academic influence.

144 This paper seeks to address these knowledge gaps, providing insights into the current priorities for
145 saltmarsh management, how priorities vary globally, and will support the development of
146 recommendations for future work that will continue to address existing gaps in the literature and
147 evidence base.

148

149 **3. Methodology**

150

151 **3.1. Questionnaire Development and Sampling**

152 To obtain global responses, a multi-lingual online questionnaire (English, Spanish, Italian, Chinese,
153 Welsh, French, German and Portuguese) was developed comprising four sections (See SM1). The
154 questionnaire included a mix of both open and closed questions, providing both quantitative and
155 qualitative data. Section 1 asked background questions about the respondent, their experience in
156 saltmarsh management and/or research, and the main geographical location for their work. Section

157 2 posed questions regarding saltmarsh management, drivers influencing management decisions, the
158 perceived effectiveness of management and key challenges facing saltmarsh management in the
159 future. Section 3 required respondents to consider the benefits derived from saltmarshes, and to
160 gauge the importance of these benefits to society. Finally, Section 4 gave respondents an
161 opportunity to attribute values to ecosystem services provided by saltmarshes through a series of
162 pairwise comparison-based questions adopted from the Analytical Hierarchy Process (AHP)
163 approach.

164 The questionnaire was piloted through the RESILCOAST¹ and CoastWEB² project consortia, in
165 addition to colleagues in academic institutions and key local stakeholders who have experience in
166 interdisciplinary saltmarsh research. Once translated, each version of the questionnaire was checked
167 by a native speaker. Respondents were recruited through a self-selection process based on their
168 access to the online questionnaire. To maximise the geographical reach, the questionnaire was
169 disseminated between September and November 2018, using Survey Monkey, through the recently
170 established SaltMarshNet network³, the Communication for Sustainability and Management (CMS)
171 Network⁴, the Marine Social Science Network⁵, and through the research team's own professional
172 networks. These networks were selected for their diverse membership, comprising both research
173 and practitioner audiences spanning across geographical regions. The survey intended to target
174 professional practitioners working on/ with or researching saltmarshes in some way (for example,
175 this could include a protected area manager, a local authority officer responsible for a saltmarsh site
176 or a researcher working on any aspect of saltmarshes) and other key beneficiaries using saltmarshes
177 in some way (e.g. wildfowlers).

178 **3.2. Data Analysis**

179 **3.2.1. Quantitative data analysis**

181 Initially, a range of different data visualisation methods were used to explore overall trends in the
182 data set. To statistically examine respondent perceptions towards saltmarsh management and
183 saltmarsh benefits, one-sample Wilcoxon tests were used to determine if the responses differed
184 from the mid-point (i.e. 'neither agree nor disagree'; 'somewhat beneficial' or 'important' depending
185 on the question). Given the non-normal distribution of responses, Wilcoxon tests were the most
186 appropriate. Further analyses examined the influence of respondents' characteristics in moderating
187 their answers, using ordinal regression models.

188 Ordinal regressions were used to examine the influence of several moderators on respondents'
189 perceived importance/level of agreement towards the questions/statements presented. The
190 moderators included: respondents' place of work (i.e. continent), type of organisation, primary role
191 within the organisation, duration of respondents' work experience in the area, proportion of their
192 work that was related to saltmarshes and educational attainment. In all cases, model selection
193 started with a full model including one response variable and the above-cited moderator variables.

¹ <http://www.nrn-lcee.ac.uk/resilcoast/>

² <https://www.pml.ac.uk/Research/Projects/CoastWEB>

³ SaltMarshNet is an international, interdisciplinary network of researchers, representing a range of both natural and social science related academic disciplines from saltmarsh ecology, to sediment process, to ecosystem services assessment, to coastal governance and policy.

⁴ CMS is a network of 6,000 researchers and practitioners engaging in marine and coastal issues.

⁵ www.marsocsci.net

194 Akaike Information Criterion (AIC) and Log-likelihood ratio tests were then used to eliminate non-
195 significant variables one by one until no more variables could be removed (Zuur et al., 2009).
196 Assumptions of proportional odds and scale effects were tested, and care was taken to discard any
197 ordinal regression with a Hessian number $> 10,000$, which is a sign of non-identifiable models
198 (Christensen, 2019). Finally, Chi-squared tests were applied to examine geographical variation in the
199 responses, whenever the response variable was nominal.

200 All analyses were run in R (R Development Core 2018). Additionally, the package Ordinal was used to
201 run ordinal regressions (Christensen, 2019). The R scripts used to run all of the analyses reported are
202 available as a GitHub repository ([https://github.com/jordipages-](https://github.com/jordipages-repo/smnet_globalQ_data_analysis)
203 [repo/smnet_globalQ_data_analysis](https://github.com/jordipages-repo/smnet_globalQ_data_analysis)).

204 Further analysis was carried out on the pairwise comparisons. Originally developed by Saaty (1980),
205 Analytical Hierarchy Process (AHP) is a flexible multi-criteria analysis method that encourages
206 respondents to consider trade-offs between different 'attributes' or elements – in the case of this
207 work, these attributes were six categories of ecosystem services provided by saltmarshes (as
208 outlined in McKinley et al., 2018). Although initially designed for one individual respondent, the AHP
209 process has been used in a range of studies to elucidate non-monetary values relating to
210 environmental issues within group settings (Duke and Aull-Hyde, 2002; and see Huang et al., 2011
211 for examples). For a detailed description of the methodology, see Innes and Pascoe (2010) and Duke
212 and Aull-Hyde (2002).

213 Respondents were asked to indicate their preferences across six categories of saltmarsh derived
214 ecosystem services, namely: 'Coastal Protection', 'Carbon Storage', 'Food Production' (including
215 agricultural and foraging uses), 'Fisheries', 'Human Connection to the Marsh' (a broad category
216 taking account of cultural ecosystem services), and 'Biodiversity and Natural Landscape'. The
217 descriptions of ecosystem services provided to respondents is presented in SM2.

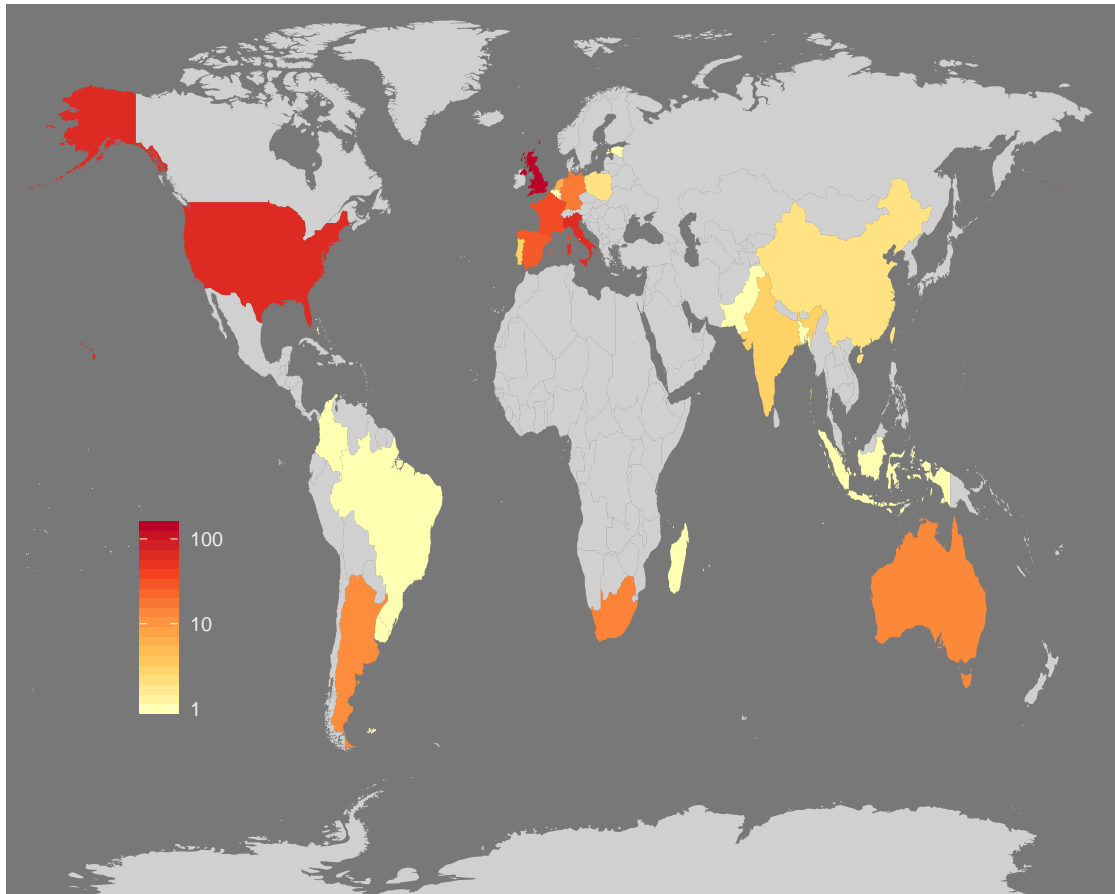
218 **3.2.2. Qualitative data analysis**

219 The open-ended questions allowed respondents to articulate their views on the priorities and
220 perceived effectiveness of saltmarsh management, as well as the threats and/or challenges to the
221 sustainable use of saltmarshes. To identify key priorities, the survey asked respondents to list their
222 top three priorities for saltmarsh management in their region. Based on the responses received,
223 themes were identified and used to transform the qualitative data into categorical data, thereby
224 enabling further statistical exploration of the dataset. In contrast, questions relating to management
225 effectiveness and threats and challenges to sustainable saltmarsh use often inspired more detailed
226 responses, therefore the qualitative integrity and richness of the dataset was maintained and was
227 not transformed into categorical data. These data were analysed inductively using the qualitative
228 data analysis computer software, NVivo (QSR International), and were subject to thematic coding to
229 identify recurring themes through iterative first and second cycle coding (Bryman, 2016).

230 **4. Results**

231 **4.1. Respondent Profile**

232 A total of 438 questionnaires were completed, representing individuals working on saltmarsh in 40
233 different countries across 5 continents. Most respondents worked in European countries (71%),
234 followed by America (20%), Africa (4%), Australia (3%) and Asia (2%). With respect to individual
235 countries, respondents working on UK saltmarshes (32%), USA saltmarshes (15%) and Italian
236 saltmarshes (14%) dominated the sample (Figure 2 and in Table SM3).



237

238 Figure 2. Map showing the distribution of respondents per country.

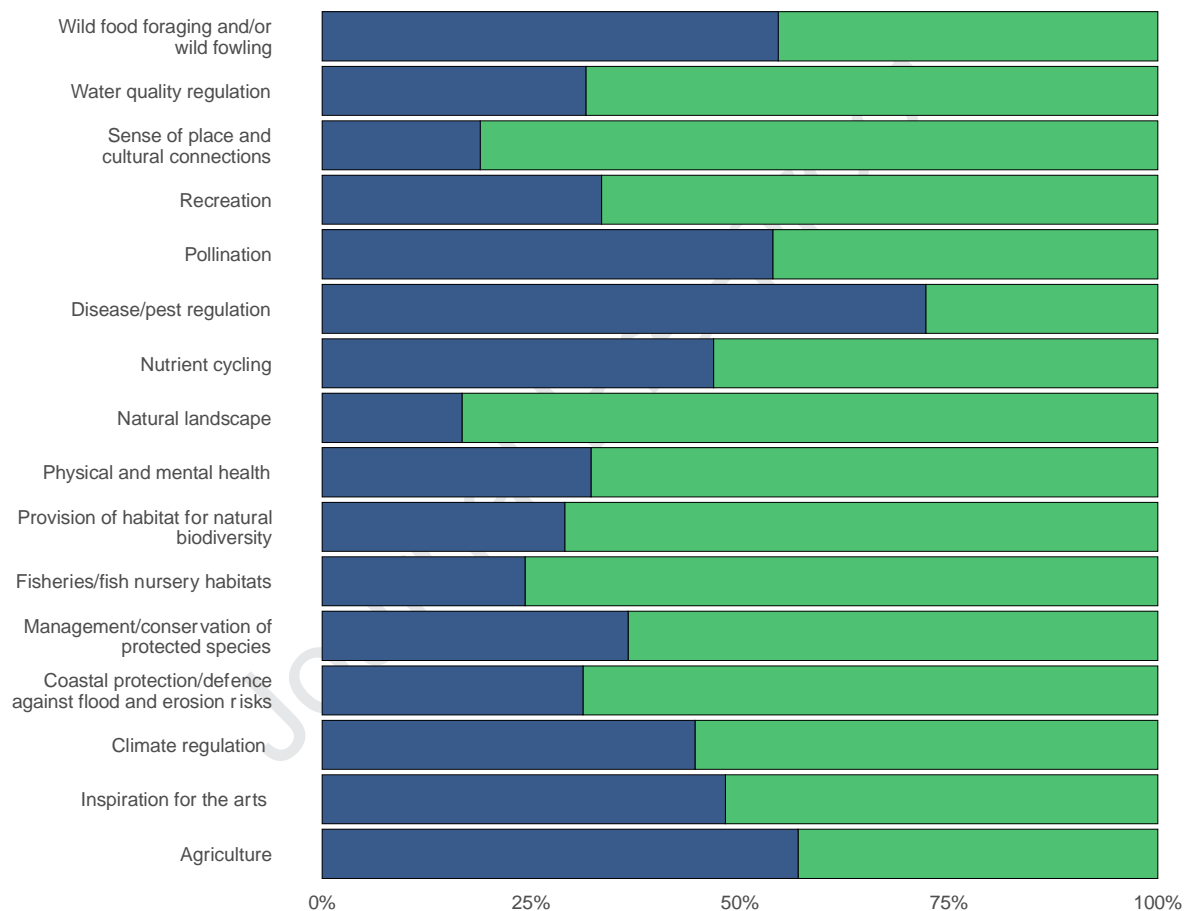
239 The questionnaire was completed by representatives of a range of organisations, including
 240 academics (27%) and civil servants (24%) but also included responses from research Institutions
 241 (11%), non-profit organisations (10%), local government (7%), Non-Governmental Organisations
 242 (6%), private sector (5%) and wildfowling (4%). The majority of respondents (65%) had been working
 243 on saltmarshes for over 5 years (41% over ten years) with their main focus on conservation (20%),
 244 research (18%), habitat restoration (13%), natural resource management (10%), and public
 245 engagement, education and outreach (9%).

246 **4.2. How does the perceived importance of saltmarshes and their ecosystem** 247 **services vary globally?**

248 Using the AHP methodology, the research examined how potential differences in prioritisation or
 249 preference towards different ecosystem services might influence management decisions globally.
 250 AHP data provided 183 valid responses (i.e. individuals who provided a response to every pairwise
 251 comparison set), representing 42% of the total respondent sample. Analysis of this data found that,
 252 overall, these respondents rated 'Natural diversity' and 'Landscape and Coastal protection' as the
 253 top two priorities (with 26% and 25% respectively); this was followed by 'Fisheries' (18%) and
 254 'Carbon Storage' (15%), with the lowest levels of priority allocated to 'Human connection to the
 255 marsh' (10%) and 'Food Production' (6%). Further analysis will be conducted on these variations
 256 within this data set for a later publication and have therefore not been included in this paper.

257 These trends of preferences were further examined through a series of statement-based questions,
 258 whereby respondents were required to indicate the level of importance of a range of ecosystem

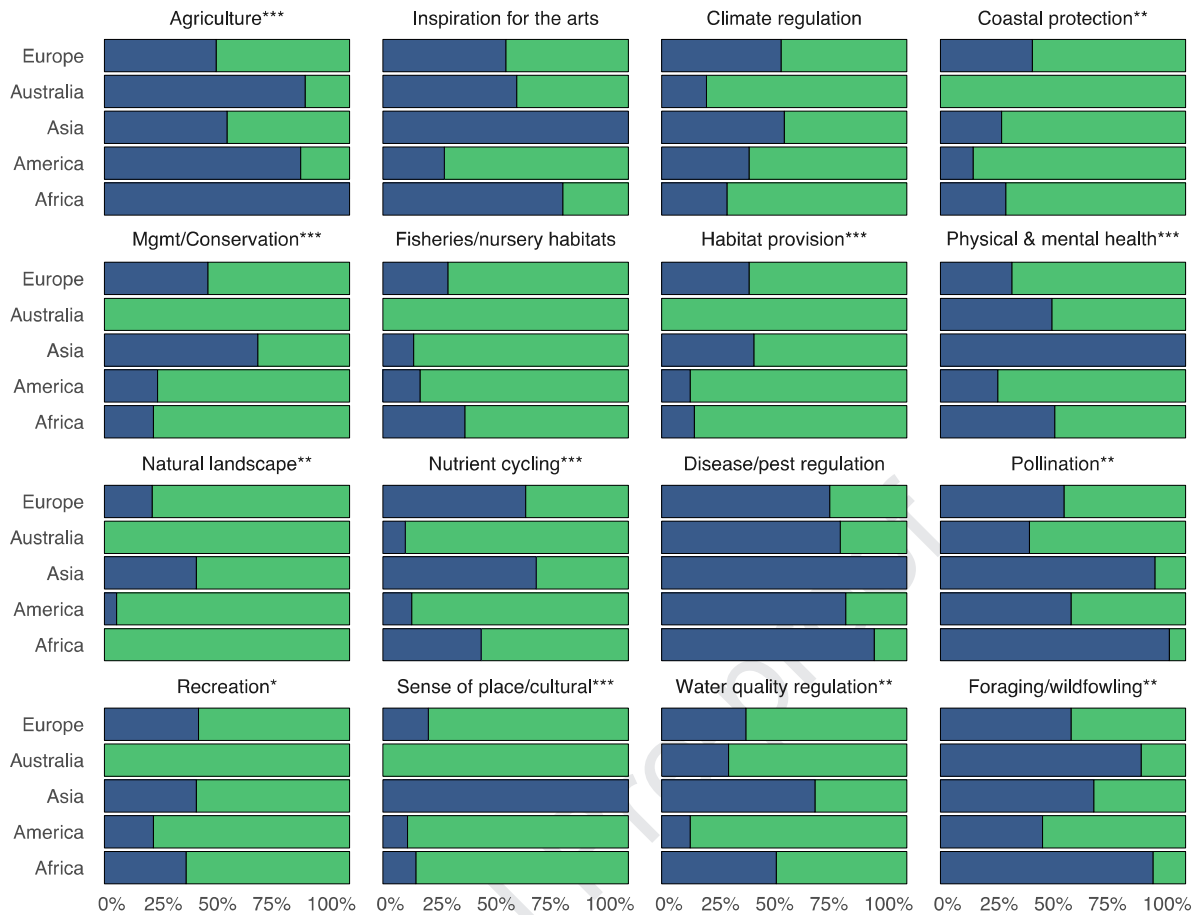
259 services and benefits derived from saltmarshes (framework taken from McKinley et al., 2018).
 260 Interestingly, there were some differences in the data collected from these questions to the views
 261 collected through the AHP. For example, the benefits most widely identified included a 'sense of
 262 place and cultural connections' – represented by the 'human connection to the marsh' which
 263 received the second lowest rating in the AHP. Conversely, the second most commonly identified
 264 benefit was being a 'natural landscape', which was rated as one of the top two priorities in the
 265 pairwise comparisons. Other widely acknowledged benefits were 'Fisheries/fish nursery habitats',
 266 'Provision of habitat for natural biodiversity', 'Physical and mental health', 'Water quality regulation',
 267 'Recreation', followed by 'coastal protection'. Conversely, 'disease/pest regulation', 'Agriculture',
 268 'Pollination' and 'Wild food foraging and/or wild fowling' (as mirrored in the pairwise comparison
 269 findings) were the least frequently identified benefits (Figure 3).



270

271 Figure 3: Relative frequency (%) of perceived benefits and services provided by saltmarsh in the
 272 regions respondents are working in. Colour codes: blue = no, green = yes.

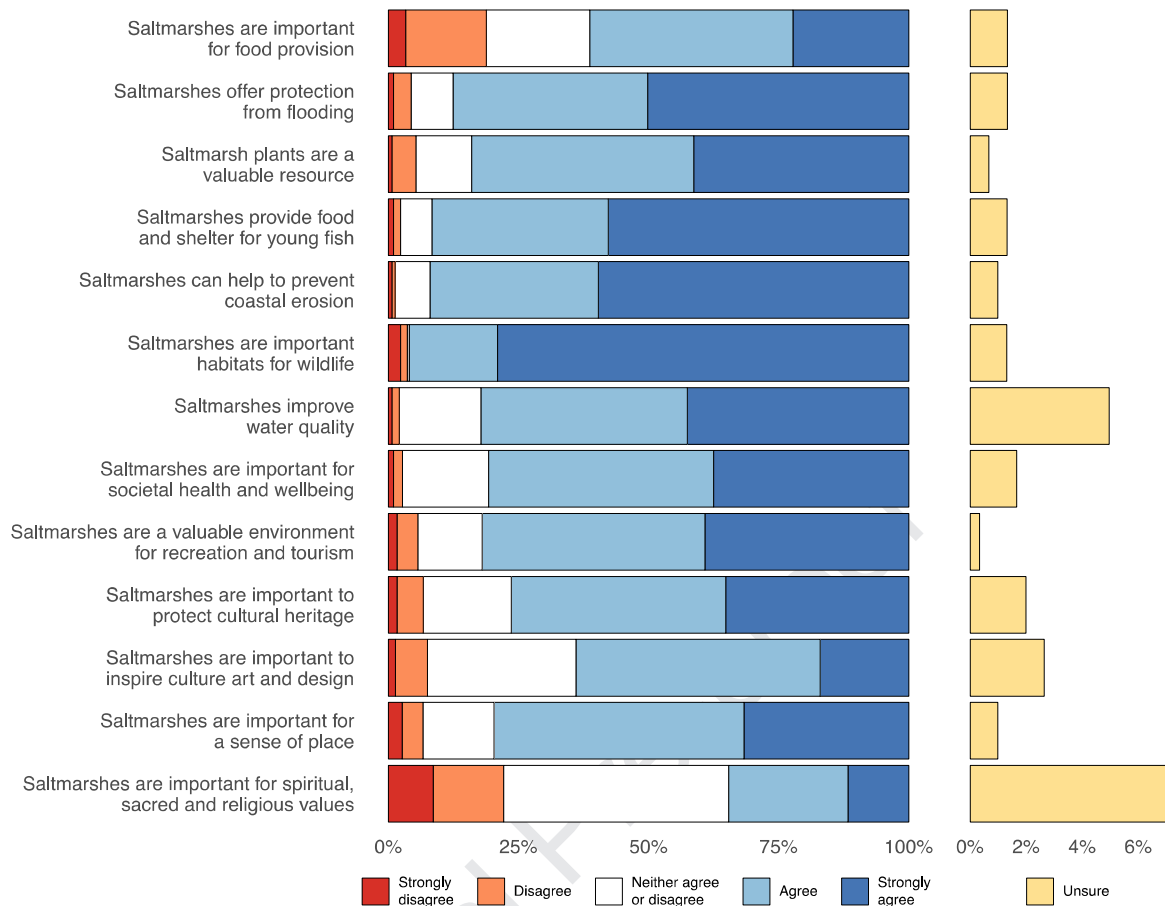
273 Chi-squared tests were used to identify geographical differences in the perceived benefits provided
 274 by saltmarshes (Figure 4). From the 16 benefits assessed, 12 of them were influenced by the
 275 continent respondents worked on, except 'inspiration for the arts', 'climate regulation',
 276 'fisheries/fish nursery habitats' and 'disease/pest regulation' (Figure 4). As an example, agriculture
 277 was widely identified as a benefit provided by saltmarshes in Europe and Asia, but less so in America,
 278 Australia or Africa. It is interesting to note that not a single respondent from Asia identified
 279 saltmarshes as contributing to 'sense of place/cultural' and 'physical & mental health'.



280

281 Figure 4: Influence of continent on respondents' perceptions of saltmarsh ecosystem services and
 282 benefits. Asterisks indicate a significant effect of continent on the associated saltmarsh benefit,
 283 according to a chi-squared test. Significance codes $p < 0.001$ '***', $p < 0.01$ '**', $p < 0.05$ '*'. Colour
 284 codes: blue = no, green = yes.

285 Regarding the contributions of saltmarshes to society, respondents tended to agree with all of the
 286 statements provided (all significantly different from the midpoint according to Wilcoxon tests
 287 [midpoint being neither agree or disagree], presented in Figure SM4), and for most statements less
 288 than 2 % of respondents were unsure. Respondents indicated lower levels of certainty to statements
 289 related to the spiritual, sacred and religious values and on whether saltmarshes improve water
 290 quality.



291
 292 Figure 5: Respondents' agreement to the perceived contribution of saltmarshes to society (left
 293 panel). Right panel indicates the % of respondents that answered "unsure" for each of the
 294 statements. We tested if these perceptions differed from the midpoint ("Neither agree or disagree")
 295 with a Wilcoxon test (see Figure SM4).

296 The geographic variable (i.e. continent) was shown to moderate participants' perceptions regarding
 297 the contribution of saltmarshes to society (Table 1). In particular, respondents working in Europe
 298 were less likely to agree to some of the statements. Overall, levels of agreement to these statements
 299 were very high, meaning that the effect of working in Europe was more likely a moderation of very
 300 high ratings rather than these respondents giving negative ratings. This may be due to the majority
 301 of respondents being from Europe, which might make this group more buffered against extremes.
 302 Level of education was also found to be an important moderator of the levels of agreement to
 303 saltmarsh contributions to society (Table 1). In general, lower levels of education decreased the
 304 likelihood of agreeing to the statements, and having a PhD increased the likelihood of agreeing more
 305 to the statements. Finally, the type of organisation for which the respondents worked influenced
 306 their levels of agreement as well; respondents affiliated in research institutions or private companies
 307 were less likely to give high ratings of agreement to the statements.

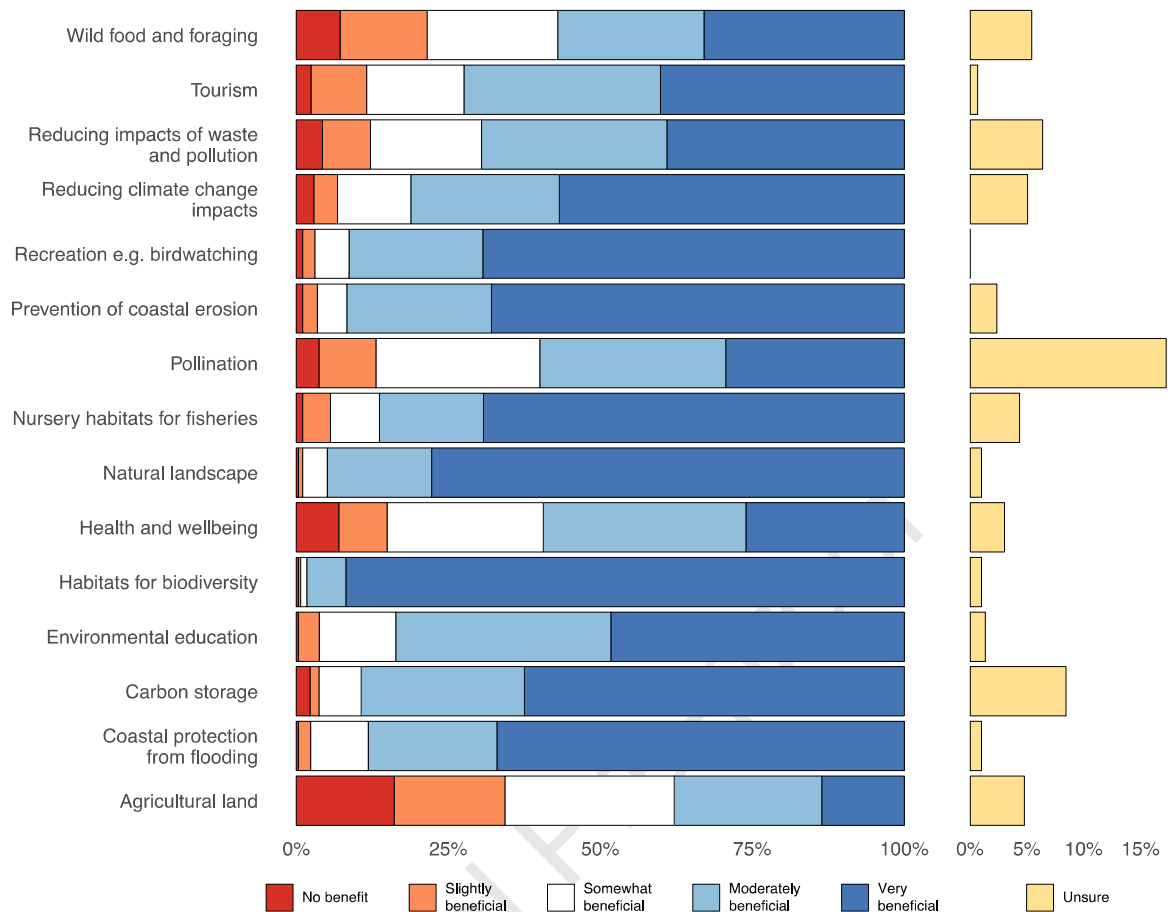
308

309 Table 1: Influence of respondent characteristics on perceptions of the contribution of saltmarshes to
 310 society in respondents' regions. Green cells indicate those levels from the different predictor
 311 variables that increased the odds of giving high ratings to the statements. Red cells indicate those
 312 levels from the different predictor variables that decreased the odds of giving high ratings to the
 313 statements. Grey cells indicate predictor variables that were dropped during ordinal model selection
 314 for each statement.

Question/statements to rate (response variables)	Respondents' characteristics that moderated the responses (predictor variables)					
	Organisation	Primary role within organisation	Duration of your work in this area	% of your work related to marshes	Continent	Highest level of education
Please indicate how much you agree with the following statements about saltmarshes in your region and their contribution to society:						
Saltmarshes are important for food provision						
Saltmarshes offer protection from flooding	Research Private					Diploma, secondary or lower
Saltmarsh plants are a valuable resource					Europe	
Saltmarshes provide food and shelter for young fish					Europe	Masters
Saltmarshes can help to prevent coastal erosion						
Saltmarshes are important habitats for wildlife including birds, mammals and invertebrates.	Private Research					Diploma, secondary or lower
Saltmarshes improve water quality	Private Research				Europe	PhD
Saltmarshes are important for societal health and wellbeing					Europe	
Saltmarshes are a valuable environment for recreation and tourism					Europe	Other
Saltmarshes are important to protect cultural heritage	Private Research					PhD
Saltmarshes are important to inspire culture art and design						
Saltmarshes are important for a sense of place						
Saltmarshes are important for spiritual sacred and religious values					Europe	

315
 316 Respondents considered all of the saltmarsh benefits and services presented to be beneficial
 317 (significantly different from the midpoint [somewhat beneficial], according to a Wilcoxon test; Figure
 318 SM5), with the exception of '[being] agricultural land', which was the service with the lowest level of
 319 importance, according to respondents (i.e. not significantly different than somewhat beneficial). In
 320 contrast, respondents identified [being] habitats for biodiversity, natural landscapes, and nursery
 321 habitats as the most beneficial services provided by saltmarshes. Respondents also perceived
 322 recreation as a very important service provided by saltmarshes, and with a high level of confidence.
 323 Services related to coastal protection were also considered very beneficial. Interestingly, there was
 324 higher level of uncertainty around pollination as a service provided by saltmarshes, despite being
 325 considered moderately beneficial (17 % selected unsure).

326



327
 328 Figure 6: Perceived value attributed to the benefits and services provided by saltmarshes (left panel).
 329 Right panel indicates the % of respondents that answered “unsure” for each of the
 330 benefits/services. Each statement was analysed with a Wilcoxon test (see Figure SM5)

331 By subjecting the data to ordinal regression, the continent where respondents worked was again
 332 found to be an important moderator (Table 2). Specifically, the likelihood of attributing high levels of
 333 importance to the benefits of tourism, ‘reducing the impacts of waste production’, and ‘health and
 334 wellbeing’ was seen to be lower for respondents working in Australia and Europe. Similar results
 335 were also observed for respondents working in Australia and services relating to ‘environmental
 336 education’ and ‘reducing climate change impacts’. In contrast, the likelihood of assigning high ratings
 337 towards agricultural land was greatest amongst those working in Europe and Asia, while those
 338 working in America rated ‘wild food and foraging’ more highly. Respondents’ highest level of
 339 education, percentage of their worktime devoted to saltmarshes, their primary role in their
 340 organisation and organisation type were also found to influence respondents’ views towards some
 341 of the ecosystem services presented (Table 2).

342

343 Table 2: Summary of respondent characteristics and their moderating effect on perceptions of
 344 saltmarsh services and benefits. Legend as in Table 1.

Question/statements to rate (response variables)	Respondents' characteristics that moderated the responses (predictor variables)					
	Organisation	Primary role within organisation	Duration of your work in this area	% of your work related to marshes	Continent	Highest level of education
Please indicate the level of importance of the benefits and services provided by saltmarshes to society:						
Recreation e.g. birdwatching						
Tourism					Australia Europe	
Coastal protection from flooding				50-75%		
Habitats for biodiversity	The model is overidentified (Hessian > 10 000)					
Reducing impacts of waste and pollution					Australia Europe	Diploma, secondary or lower
Health and Wellbeing					Australia Europe	Masters PhD Other
Agricultural land					Asia Europe	
Natural landscape	The model is overidentified (Hessian > 10 000)					
Nursery habitats for fisheries	The model is overidentified (Hessian > 10 000)					
Pollination	The model is overidentified (Hessian > 10 000)					
Environmental Education					Australia	
Carbon Storage						
Prevention of coastal erosion						
Reducing climate change impacts		Policy/strategic planning Researcher		25-50% 50-75%	Australia	
Wild food and foraging	Other				America	

345

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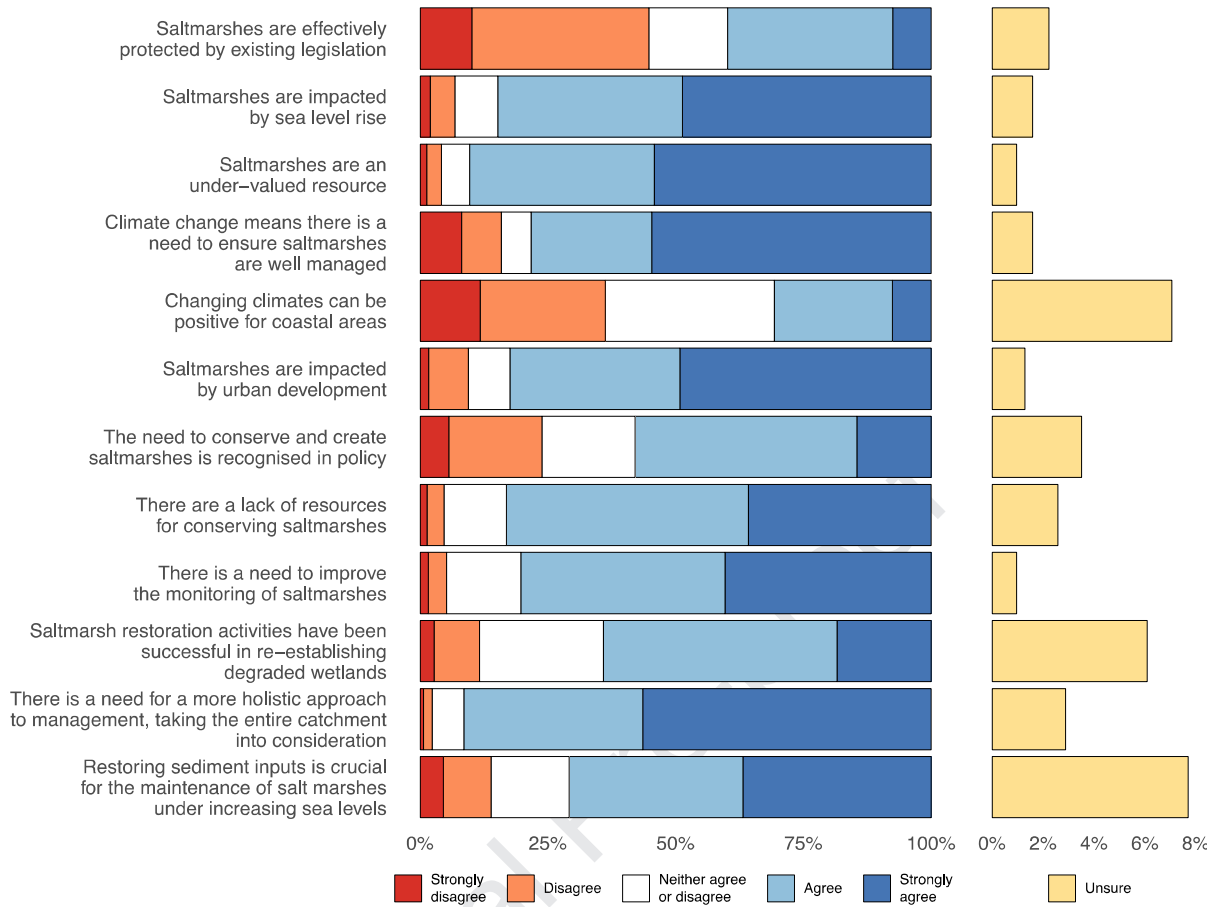
347 4.3. What are the main threats and challenges facing saltmarsh 348 environments?

349 Respondents were asked to give an indication of their views on the global status of saltmarsh
 350 management, drivers of impacts, level of protection and benefits – this is summarised in Figure 7.
 351 This information provided valuable insight into the perceived threats and challenges facing
 352 saltmarshes globally. Respondents agreed or even strongly agreed with most of the statements
 353 about saltmarshes, the threats they face and their management (scores were significantly different
 354 than the midpoint [neither agree nor disagree], according to a Wilcoxon test, see Figure SM6). The
 355 highest levels of agreement are seen for factors pertaining to wider views towards management
 356 (e.g. resourcing), and threats from sea level rise and climate change. In contrast, respondents' views
 357 were split for the statements 'Saltmarshes are effectively protected by existing legislation' and
 358 'Changing climates can be positive for coastal areas' (overall views did not differ from the midpoint
 359 [neither agree or disagree] for these statements, according to Wilcoxon tests; see Figure SM6)
 360 Continent, type of organisation and education were also identified as important moderators (Table
 361 3).

362

363

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 368
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Figure 7: Respondent agreement to statements on saltmarsh management and future threats (left panel). Right panel indicates the % of respondents that answered “unsure” for each of the benefits/services. Each statement was analysed with a Wilcoxon test (see Figure SM6).

370 Table 3: Summary of respondent characteristics and their moderating effect on perceptions of the
 371 management of saltmarshes and the threats they face. Legend as in Table 1.

Question/statements to rate (response variables)	Respondents' characteristics that moderated the responses (predictor variables)					
	Organisation	Primary role within organisation	Duration of your work in this area	% of your work related to marshes	Continent	Highest level of education
Please indicate your level of agreement with the following statements about saltmarshes, the threats they face and their management:						
Saltmarshes are effectively protected by existing legislation					Europe	
Saltmarshes are impacted by sea level rise	Private Research					
Saltmarshes are an under-valued resource					Asia	
Climate change means there is a need to ensure saltmarshes are well managed				10-25% >75%	Europe	Masters PhD Other
Changing climates can be positive for coastal areas						
Saltmarshes are impacted by urban development					Europe	PhD
						Diploma, secondary or lower
The need to conserve and create saltmarshes is recognised in policy						
There are a lack of resources for conserving saltmarshes	Private					
There is a need to improve the monitoring of saltmarshes					Europe	Diploma, secondary or lower
Saltmarsh restoration activities have been successful in re-establishing degraded wetlands						
There is a need for a more holistic approach to management, taking the entire catchment into consideration.						PhD
Restoring sediment inputs is crucial for the maintenance of salt marshes under increasing sea levels	Other					

372

373 Further insights into the perceived threats and challenges facing the sustainability of saltmarshes
 374 and their usage, were furnished through qualitative analysis. Using a process of thematic coding and
 375 categorisation, a total of 36 different themes were identified, with the top ten themes outlined in
 376 Table 4. The results show that the biggest threat or challenge to sustainable saltmarsh use is
 377 attributed to sea level rise, followed by anthropogenic pressures related to development and
 378 different uses/users of saltmarshes and neighbouring spaces. Interestingly the themes reflect a
 379 combination of physical/natural driven processes and anthropogenic pressures. Issues related to
 380 management practices and governance were also found to be embedded in numerous themes (see
 381 more detailed codebook in Table SM7), with issues related to resource constraints, societal and
 382 political interest, implementation and enforcement of policies/legislation and managing conflicting
 383 priorities. It is noteworthy that concerns related to societal interest and attitudes towards
 384 saltmarshes appear fairly high on the list, with one respondent commenting that '*saltmarshes are a*
 385 *forgotten habitat*', suggesting the need to raise awareness of the different values and benefits on
 386 saltmarsh ecosystems within society.

387

388 Table 4: Top ten themes identified as threats or challenges facing the sustainable use of saltmarshes
 389 (N=288). Note: This analysis looked at responses on a country level to provide a more nuanced
 390 understanding of the responses.

Code (theme)	Example	No. of mentions	Countries
Sea level rise	<i>SLR; coastal squeeze and lack of landward migration zones</i>	75	France, Germany, Italy, Netherlands, Portugal, South Africa, Spain, Taiwan, U.K., U.S., multiple regions
Development pressures, urbanisation and hardened shorelines (Main theme)	<i>...The dynamic system being constrained by hardening of shoreline is a major threat.</i>	54	Argentina, Australia, Bahamas, East and West Asia, France, Indonesia, Italy, Pakistan, Poland, South Africa, Spain, U.K., U.S., Uruguay, multiple regions
Impact & management of different users/uses or anthropogenic impacts more broadly	<i>Over-exploitation by the daily use of these areas as a playground for mountain bikers, joggers and dog walkers.</i>	40	Australia, China, France, Italy, Netherlands, Portugal, Spain, U.K., U.S., multiple regions
Climate change	<i>Climate Change, sea level rise and lack of management measures</i>	38	Argentina, Australia, France, Germany, Italy, Netherlands, Pakistan, Spain, Taiwan, U.K., U.S.
Management measures, approaches and spatial scale (sub-theme of "Governance matters")	<i>Saltmarsh should not be considered something we can USE; it passively provides its services best when left alone and allowed to migrate landward at its own pace. Doing so will allow us to move communities away from flood effected areas as put simply saltmarsh represents the maximal extent that seawater can reach</i> <i>Money available to manage, protect and re-create the habitat. Better knowledge of success of creation sites as well as an understanding of what is taking place across a whole estuary</i>	30	France, Germany, India, Italy, Netherlands, South Africa, Spain, Taiwan, UK
Nutrients, water quality and pollution	<i>Chemical, plastic and nutrient pollution</i> <i>Pollution run off from farm land</i> <i>Invasive species, urbanization and discharge of pollutants</i>	30	Argentina, France, Germany, Italy, Netherlands, Poland, South Africa, Spain, Uruguay, U.S., U.K.
Physical processes and factors influencing saltmarshes	<i>Biophysical variability and influence on biogeochemical cycles</i> <i>in Venice: imbalance of sediment budget, focus on technical solutions</i>	26	Belgium, Germany, Italy, Netherlands, South Africa, Spain, U.K., U.S.

Code (theme)	Example	No. of mentions	Countries
	<i>for flood prevention (MOSE project), hydrological changes of the entire lagoon (shipping channels, relocation of rivers)</i>		
Societal interest, attitudes & awareness of saltmarshes and their different values	<i>Ignorance; saltmarshes are the forgotten habitat, with little public appreciation or appeal.</i> <i>Public sentiments towards marshes, which affects politicians and therefore policy implementation / conservation</i>	25	Australia, Brazil, France, India, Italy, U.S., Poland, Senegal, Spain, U.K., multiple regions
Resource & capacity constraints	<i>lack of resources for management at required levels</i> <i>Financial restrictions and limitations</i>	21	Australia, South Africa, U.S., U.K.
Coastal Squeeze (Main theme)	<i>Coastal squeeze is impacting on saltmarshes by limiting the ability to roll back and preventing natural coastal processes</i>	18	Australia, Netherlands, South Africa, U.S., U.K.

391 *Note that entries may have been coded at more than one code accordingly

392 * 'multiple regions' refers to participants that have listed multiple locations within which their work is situated.

393 * Countries are listed in alphabetical order.

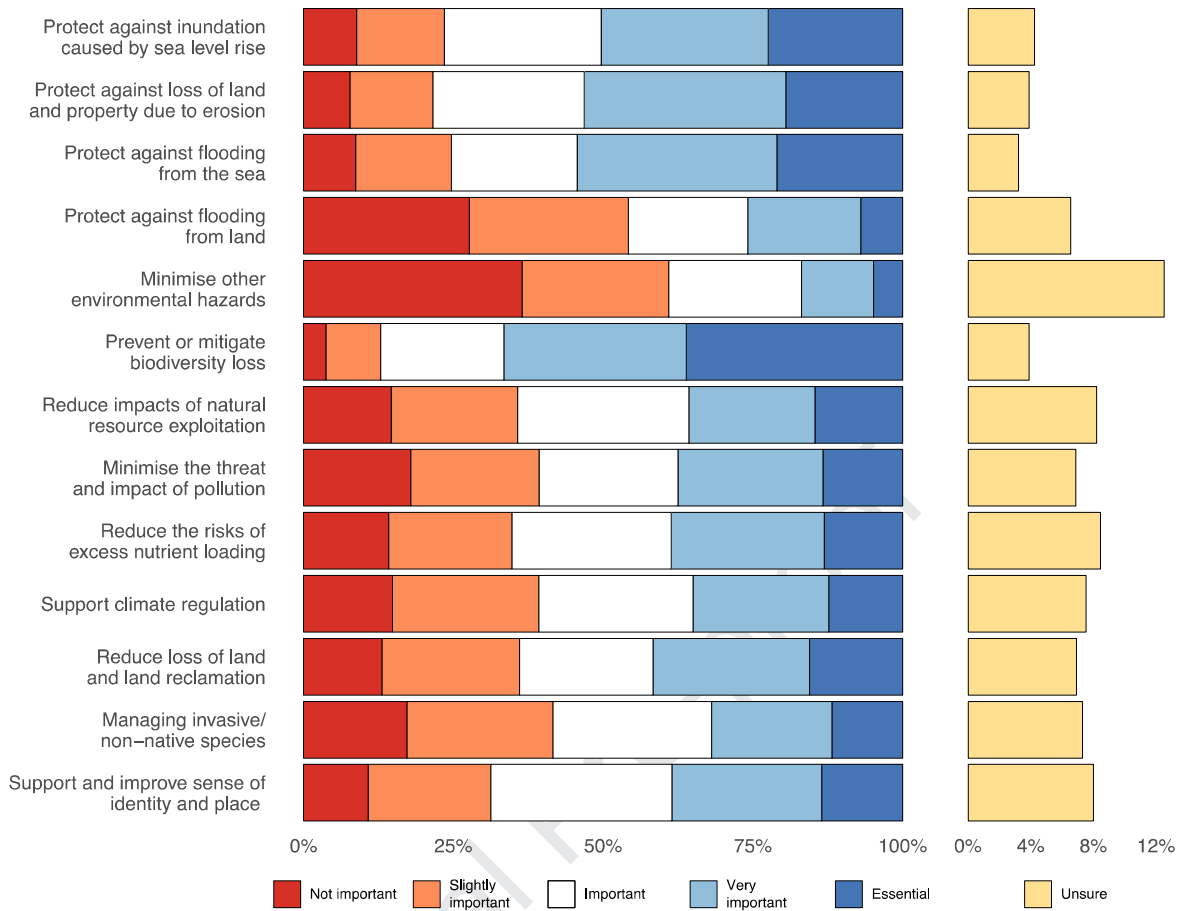
394

395 **4.4. What is the perceived effectiveness of current saltmarsh** 396 **management and how does this vary globally?**

397 To address the third research question, the survey elicited views on the perceived priorities and
398 drivers influencing saltmarsh management, drawing insight as to how these might influence
399 management decisions and their effectiveness, as well as the perceived effectiveness of saltmarsh
400 management overall.

401 Analysis found that respondents regarded the majority of priorities presented as important for
402 saltmarsh management in their region, particularly coastal protection, flooding from sea and
403 prevention/mitigation of biodiversity loss (scores significantly higher than 'important' according to
404 the Wilcoxon test, Figure SM8). Conversely, managing invasive species, protection against flooding
405 from land and minimising other environmental hazards were perceived as the least important
406 (Figure 8, Figure SM8 and Table 5). It should be noted that 3-12% of the respondents answered
407 unsure depending on the statement.

408



409
 410 Figure 8: Level of importance attributed to priorities of saltmarsh management (left panel). Right
 411 panel indicates the % of respondents that answered “unsure” for each of the priorities. Each
 412 statement was analysed with a Wilcoxon test (see Figure SM8).

413 Further ordinal regression analysis was conducted to identify potential moderating factors of the
 414 perceived importance of the management priorities presented (Table 5). Again, differences were
 415 observed in relation to continent, percentage of work time devoted to saltmarshes and educational
 416 attainment. For example, respondents working in Europe, America and Australia were more likely to
 417 give high ratings to the priority of coastal protection, while respondents working in Australia
 418 perceived the priority of ‘managing invasive/non-native species’ as more important than other
 419 respondents.

420

421 Table 5: Influence of respondent characteristics on saltmarsh management priorities. Legend as in
 422 Table 1.

Question/statements to rate (response variables)	Respondents' characteristics that moderated the responses (predictor variables)					
	Organisation	Primary role within organisation	Duration of your work in this area	% of your work related to marshes	Continent	Highest level of education
What are the main priorities influencing saltmarsh management in your region? For this question we are interested in the priorities that have been set by policymakers.						
Protect against inundation caused by sea level rise						
Protect against loss of land and property due to erosion				>75%	America Australia Europe	
Protect against flooding from the sea (e.g., tidal, storm surge)						
Protect against flooding from land (e.g., flash floods, river/estuarine floods)						
Minimise other environmental hazards (e.g., disease)				10-25% 25-50%		Masters PhD
Prevent or mitigate biodiversity loss					America	
Reduce impacts of natural resource exploitation	Non-profit Research					
Minimise the threat and impact of pollution (e.g. heavy metals and contaminants)				10-25% 25-50% 50-75%		
Reduce the risks of excess nutrient loading				25-50%		
Support climate regulation e.g. carbon storage						Diploma, secondary or lower
Reduce loss of land and land reclamation			5-10 years >10 years			Diploma, secondary or lower
Managing invasive/ non-native species				>75% 10-25%	Australia	
Support and improve sense of identity and place						

423

424 Rather than restricting respondents to specific options, a further question was included in the survey
 425 to directly ask respondents to identify the top three priorities for saltmarsh management in their
 426 region (Figure SM9). On the basis of this analysis, 33 distinct themes were identified, thus
 427 demonstrating the considerable diversity of priorities that concern saltmarsh management
 428 worldwide. In particular, the reduction, maintenance, enhancement and conservation of
 429 biodiversity, habitats and specific species was found to be a prominent management concern across
 430 all regions. This was followed by i) erosion prevention and management (both in terms of the
 431 shoreline and saltmarshes themselves, ii) matters around flood risk management and iii) responding
 432 to sea level rise. General management concerns were expressed around coastal protection, defence
 433 and adaptation, as well as restoring or allowing saltmarshes to migrate landward in response to sea
 434 level rise and coastal squeeze. A range of issues were further raised relating to ecosystem functions
 435 and processes underpinning healthy functioning saltmarshes (e.g. geomorphological, hydrological,
 436 sediment supply).

437

438 In terms of the factors driving management globally, respondents perceived national/federal policy
 439 and legislation, state/regional policies and the availability of financial and monitoring resources as
 440 key drivers influencing saltmarsh management in their region (all significantly higher than the
 441 midpoint [important] according to the Wilcoxon test, see Figure SM10). Local policies were also

442 perceived as being very important to management. The drivers with lower ratings in influencing
 443 saltmarsh management were cultural myths and traditions, international policy, and local champions
 444 and/or community action groups – although all of them were still considered important. Note there
 445 was some variability on the amount of uncertainty for each driver, with 5-10% of respondents
 446 leaving the ratings as ‘unsure’. Again, trends were moderated by respondents’ characteristics,
 447 particularly by their geographical area of expertise (Table 6). For example, respondents who
 448 indicated they worked in America were less likely to perceive international policy as a key driver of
 449 saltmarsh management, while Europeans were less likely to perceive national policy legislation as an
 450 important driver.

451 Table 6: Influence of respondent characteristics on drivers of saltmarsh management. Legend as in
 452 Table 1.

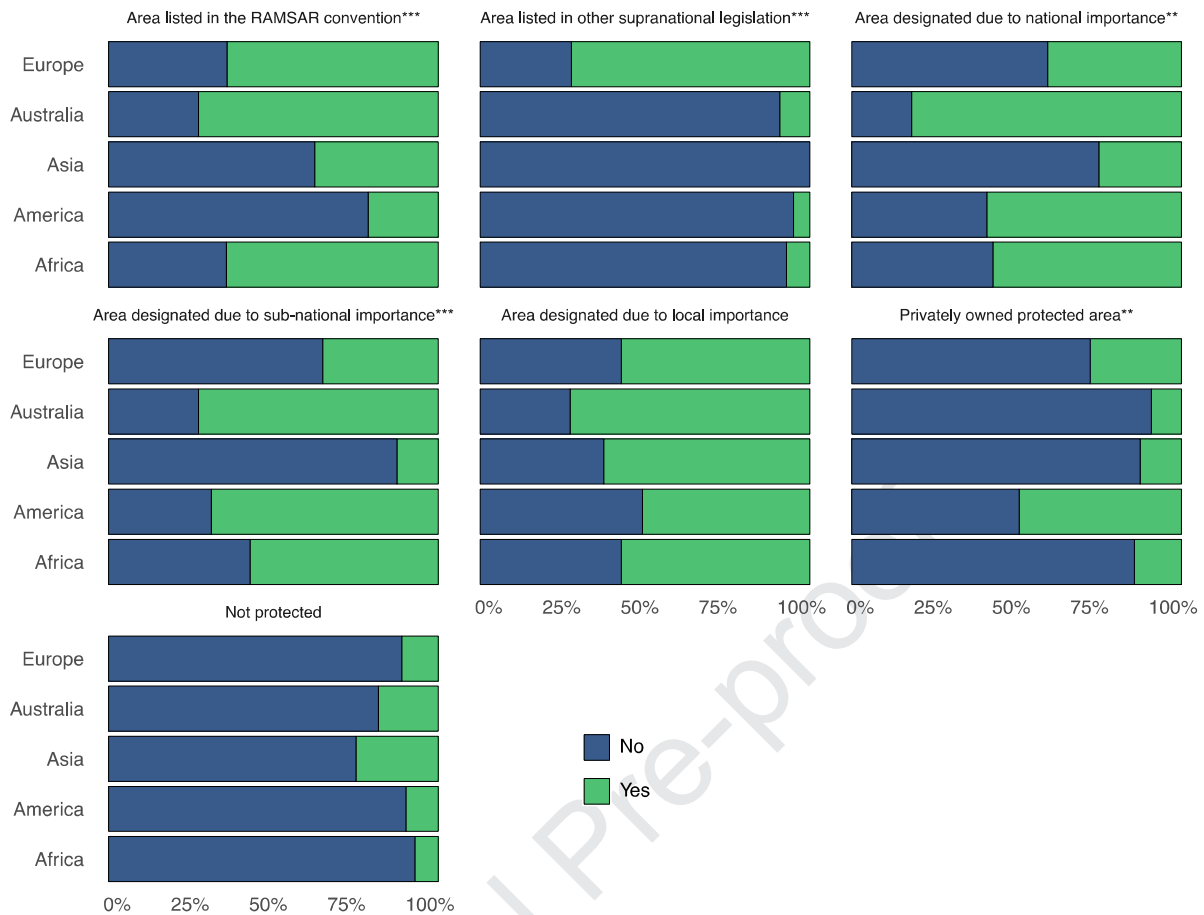
Question/statements to rate (response variables)	Respondents' characteristics that moderated the responses (predictor variables)					
	Organisation	Primary role within organisation	Duration of your work in this area	% of your work related to marshes	Continent	Highest level of education
What are the main drivers influencing saltmarsh management in your region?						
International policy (e.g., IPCC)					America	
National/federal policy and legislation					Europe	
Policies of your state/region		Field/Park Ranger or Warden				
Local policies (specific to village, council, national park, etc)					Australia	Diploma, secondary or lower Masters
Cultural myths and traditions			1-5 years 5-10 years >10 years			Diploma, secondary or lower Masters
Local champions and/or community action groups			5-10 years		Europe	
Availability of financial resources						
Availability of resources (equipment/ personnel) to carry out monitoring for management					Europe	

453

454 Only 11% of the respondents said there was no form of land protection for the areas they were
 455 working in, whereas 55% and 52% of respondents worked within sites listed within the RAMSAR
 456 convention or other supranational legislation respectively, or within areas designated for their
 457 national (46%) or local importance (56%). 30% of respondents acknowledged the existence of
 458 privately-owned protected areas in their areas of work.

459 These results were moderated by continent (Figure 9). Specifically, national protection was widely
 460 perceived as a driver influencing saltmarsh management in Australia more than any other region,
 461 private protection was mainly considered in America and Europe, areas designated under the
 462 RAMSAR Convention were least considered in America, subnational protection was least considered
 463 in Asia, and supranational protection was highly considered in Europe but not in the rest of regions.

464



465
 466 Figure 9: Influence of geographical location (continent) on saltmarsh protection. Asterisks indicate a
 467 significant effect of continent on the associated form of land protection, according to a Chi-squared
 468 test. Significance codes $p < 0.001$ '***', $p < 0.01$ '**', $p < 0.05$ '*'.

469 Further analysis found that 75% of respondents acknowledged that the protection measures
 470 examined above led to some limitation in the uses of saltmarshes. This again differed according to
 471 the continent, with only half of the respondents in Asia acknowledging some limitations in their
 472 areas of work (supplementary Figure SM11).

473

474 4.4.1. Factors influencing the perceived effectiveness of saltmarsh management

475

476 Respondents were asked to rate the perceived effectiveness of saltmarsh management in their
 477 region, based on a Likert 1 to 5 scale (where 1 is not effective and 5 is very effective). The results are
 478 illustrated in Figure 10. Only 27% of respondents regard current management to be effective or
 479 highly effective, compared to 57% who feel that saltmarsh management is either not, or only
 480 somewhat, effective. Interestingly, the only moderator of perceived effectiveness of saltmarsh
 481 management, identified in the ordinal regressions, was the primary role of the respondents within
 482 their organisation: with policy/strategic planners more likely to perceive saltmarsh management as
 483 more effective.



484 Figure 10: The perceived effectiveness of saltmarsh management (N=313)

485
486
487 Respondents were invited to explain the reason for their answer. This was an optional question that
488 received 133 responses. Responses were split between those who regarded saltmarsh management
489 to be effective/very effective (N=83), ineffective/somewhat effective (N=178) and neither effective
490 or ineffective responses (N=52) and coded within these categories (and organised thematically
491 therein).

492
493 Perceived effectiveness was largely attributed to strong arrangements of '*governance, regulation*
494 *and legislation*', this included references to strong partnerships between key actors and protections
495 mandated through legislation (see quote below and Table 7). Another recurring theme centred on
496 the '*active management, restoration, maintenance and monitoring*' of saltmarsh environments, as
497 well as effective '*protection, conservation and restoration*'. Signs of '*visible success*' were also
498 mentioned, while one respondent also commented on the importance of awareness – "*its benefits*
499 *are well known, so taking care and protection is common practice*".

500
501 *All Dutch saltmarshes are being mapped each 6 yrs. Each 6 yrs. the monitoring*
502 *results are being reported for WFD, N2000, TMAP and PAS (national nitrogen vs*
503 *habitat types program). If the results are negative within the aims there has to*
504 *be managing solutions (protection groins, grazing, mowing etc.).*

505
506 Despite regarding saltmarsh management to be (highly) effective, this group of respondents still
507 offered some negative reflections and considered ongoing threats or pressures (such as urban
508 development or sea level rise), or calls for improvement, such as the need for further research or
509 more consistent practices. These issues were reflected upon in greater depth by those respondents
510 who regarded current management to be ineffective. A central theme was around the 'lack of
511 requirement, regulation, legislation or enforcement' (N=13), such as enforcement of certain
512 activities or public access, or absence of specific protections for saltmarshes. The second most
513 frequent theme focused on the 'limited success or visible failure' of current management
514 approaches, followed by 'resource constraints', particularly in terms of financial resources. Despite
515 perceiving saltmarsh management to be ineffective, certain respondents offered some positive
516 reflections on current management practices and remarked on the growing interest from
517 government agencies or good monitoring, to name a few. Other topics included poor management
518 or governance, inconsistency, conflicting priorities and the narrow focus of saltmarsh management
519 (Table 7).

520
521

522
 523 Table 7: Top ten codes identified regarding perceived effectiveness of saltmarsh management. Listed
 524 in descending order.
 525

Perceived effectiveness (respondents gave a score of 4 or 5)	Neither effective nor ineffective (respondent gave a score of 3)	Perceived ineffectiveness (respondents gave a score of 1 or 2)
<ul style="list-style-type: none"> ▪ Negative reflections – ongoing threats, pressures or caveats; ▪ Good governance, regulation and legislation; ▪ Active management, restoration, maintenance and monitoring; ▪ Protection, conservation and restoration; ▪ Visible success; ▪ Awareness of saltmarsh benefits and value. 	<ul style="list-style-type: none"> ▪ Ongoing pressures; ▪ Social acceptability & interest; ▪ Limited management; ▪ Limited improvement, continued deterioration or loss; ▪ Inconsistency; ▪ <i>{All other categories thereafter tied N =1}</i> 	<ul style="list-style-type: none"> ▪ Lack of requirement, regulation, legislation or enforcement; ▪ Limited success or visible failure; ▪ Resource constraints; ▪ Poor management or governance; ▪ Inconsistency; ▪ Positive reflections; ▪ Ongoing threats and pressures; ▪ Conflicting priorities; ▪ Narrow focus; ▪ <i>{10th place tied between}</i> – <ul style="list-style-type: none"> ▪ Gaps in knowledge and understanding; ▪ Lack of awareness of saltmarsh benefits and value; ▪ Limited effectiveness of approaches & monitoring; ▪ Scale misalignment.

526

527 5. Discussion

528 Coastal environments are under increasing threats, not least from climate change, increased coastal
 529 populations and environmental degradation. Despite these seemingly unsurmountable challenges,
 530 there are efforts underway to address these ‘wicked’ problems and deliver management and policy
 531 that is sustainable and future-proofed to protect coastal environments. The implementation and
 532 delivery of international conservation policy (including, for example, the RAMSAR Declaration (1971)
 533 and the more recent Aichi Biodiversity Targets (2011) and UN Sustainable Development Goals
 534 (2015), requires an holistic and interdisciplinary understanding of saltmarsh ecosystems and their
 535 management; yet to date, saltmarshes have typically represented an under-studied coastal fringe
 536 system and the subject of predominantly natural science-based research. While efforts have been
 537 made to document the global distribution of saltmarsh environments (Mcowen et al., 2017), there
 538 has been no attempt to complement these data with additional information on the global
 539 distribution of ecosystem services/benefits or crucially the perceived threats, challenges, priorities
 540 and effectiveness of saltmarsh management.

541 In order to deliver on international goals, understanding global variation is crucial, particularly given
 542 that timeframes, priorities and scales of work and interest across the science-policy-practice
 543 interface vary, and that mismatches often occur between researchers and practitioners (Jarvis et al.,
 544 2015). This paper provides the first global overview of these issues, drawing from the perspective of
 545 professional stakeholders and provides insight into the similarities and differences of saltmarsh-
 546 related ecosystem services, threats/challenges and the perceived effectiveness and priorities for
 547 saltmarsh management. Reflecting on the three research questions presented in the introduction,

548 the next section discusses the key observations, taking account the limitations of the research and
549 implications for future research needs and saltmarsh management.

550 *How does the importance of saltmarshes and their ecosystem services vary globally?*

551 Firstly, it is important to note that the overall perception of the importance of ecosystem services
552 and benefits derived from saltmarshes varied across respondents. The benefits most commonly
553 positively identified by respondents spanned a diverse range of ecosystem services and benefits –
554 for example supporting ‘fisheries and providing fish nursery habitats’, ‘provision of habitat for
555 natural biodiversity’, supporting ‘Physical and mental health’, supporting ‘Water quality regulation’,
556 ‘Recreation’ and ‘coastal protection’. Although, ‘Agriculture’, and ‘food production’ more generally,
557 were seen as less beneficial by the overall sample of respondents, it should be noted that the role of
558 saltmarsh environments in agriculture and other artisanal processes of food production is well
559 documented in certain places (Gedan et al., 2009; Barr and Bell, 2016; Davidson et al., 2017).

560 In addition to understanding overall trends, socio-demographic factors were used to further
561 interrogate the data and provide insight into the potential influence of the socio-cultural-political-
562 environmental context of each region. While all socio-demographic factors were found to influence
563 at least some of the responses to the questions presented, overall, geographic location (i.e.
564 continent) was found to be the most frequent moderator influencing perceptions and attitudes
565 towards saltmarshes, their ecosystem services and benefits, and even perceptions of management.
566 For example, while the agricultural role of saltmarshes was not perceived as very beneficial overall,
567 respondents working in European and Asian saltmarshes were more likely to perceive this service as
568 very beneficial, concurrent with previous observations (Davidson et al., 2017). Australian
569 respondents were most likely to attribute higher levels of importance to management of invasive
570 species, which may be expected given the pressure on endemic species in Australia (Adam, 2009).
571 This, and similar trends, clearly evidence the presence of variation in global attitudes. Other
572 examples from the data further support this. For example, tourism and health and wellbeing, two
573 factors more commonly linked to the category of cultural ecosystem services, were less likely to be
574 seen to be important by respondents working in Europe or Australia, while American respondents
575 were more likely to value “wild food and foraging” benefits compared to respondents working in
576 other geographic locations.

577 Increasingly, there is a growing understanding of the role of perceptions and related values (both
578 monetary and non-monetary) attributed to natural resources in both development and
579 implementation of effective management and governance (Stefanski and Villasante, 2015; Arkema
580 et al., 2015; Cavanagh et al., 2016; Börger et al., 2014; Ainsworth et al., 2019). Building an
581 understanding of the human dimensions of saltmarshes and how they are perceived across different
582 user groups and audiences would contribute to a more integrated understanding of their true value
583 to society (Foster et al., 2013; Josephs and Humphries, 2018), and support development of more
584 socially acceptable management strategies delivering on multiple management goals and objectives.

585 *What are the main threats and challenges facing saltmarsh environments?*

586 Through this study, the range and varying scales of challenges facing saltmarshes are evident. At a
587 global scale, it is clear, for example, that saltmarsh management faces significant global challenges
588 e.g. sea level rise and climate change; but equally, there is also evidence of challenges which may be
589 more easily addressed at a local or regional scale (namely around management practices and
590 resourcing). While the number and diversity of challenges identified by respondents may appear
591 daunting, it is important to recognise the potential for ‘quick wins’ and the role of collaboration and

592 interdisciplinary working. In terms of quick wins, there is an opportunity to continue to build the
593 active and growing saltmarsh research community, and to use the challenges identified here as the
594 building blocks for an international and interdisciplinary research agenda. Some of the more
595 commonly identified challenges (e.g. climate change and sea level rise) are not specific to
596 saltmarshes, and there is a role for whole system and cross-sectoral thinking to identify and
597 implement solutions. For example, how can a better understanding of the coastal protection
598 provided by saltmarshes be used to support development of more effective coastal flood risk
599 management? Or developing the understanding of the carbon storage capacity to support
600 conservation and restoration programmes, which in turn can support climate change mitigation
601 schemes. Furthermore, given their position at the land-sea interface, saltmarshes provide a valuable
602 opportunity to adopt 'catchment to coast' based thinking (Nelson and Zavaleta 2012) – for example,
603 understanding the interaction between land use and coastal environments such as agricultural land
604 use practices (Muenzel and Martino, 2018; Dokter et al., 2018), or the impact of plastic pollution on
605 saltmarsh environments and their role as plastic sinks (Browne et al. 2010; Ball et al., 2016), and how
606 this might need to be taken account of within management.

607 It should also be noted that while there are ongoing calls to raise public awareness of the role and
608 value of saltmarsh environments, this is not without its own challenges. A recent study found public
609 awareness of saltmarshes in Wales to be quite low, with a high level of uncertainty around
610 understanding of ecosystem benefits (McKinley et al., 2020). When compared with the results from
611 this study, the difference between public and practitioner or expert perceptions is evident (low
612 uncertainty in most responses, in this study). From public perspective, saltmarshes are complex,
613 dynamic systems and their tidal nature can make them dangerous and difficult to access. If
614 saltmarshes are to be safeguarded for the future, it is necessary that there are efforts to raise public
615 awareness; however, these will need to take advantage of innovative communication approaches
616 and technologies to reduce risk to both saltmarshes and the people using them. At the domestic
617 scale, recent years has seen funding cuts for many organisations involved in natural resource
618 management across the world (Borja and Elliott, 2013; 2018); this trend must be reversed to provide
619 adequate resources to support management (e.g. developing a knowledge base about the social
620 values attributed to saltmarshes or implementing longitudinal monitoring programmes) and fund
621 restoration schemes.

622 *What is the perceived effectiveness of current saltmarsh management and how does this vary*
623 *globally?*

624 While there was some variation across the data collected, continent was not seen to influence views
625 on management effectiveness; instead, the only moderator was related to respondents' job role,
626 with those involved in policy development more likely to consider current management to be
627 effective. The 27% of respondents who indicated management to be effective cited the presence of
628 good governance and active management approaches as being key to that effectiveness. However,
629 overall, there was a feeling that saltmarsh management faces a number of challenges, including a
630 lack of effective regulation or inclusion at a legislative level. This is supported by recent work by
631 McKinley et al. (2018) who found ecosystem services derived by saltmarshes to be inadequately
632 considered in key legislation in Wales, UK. The presence of conflicting needs and priorities across
633 user groups and scales and the challenge these pose to delivery of management was also highlighted
634 by respondents. Again, this diversity of views and its influence on prioritisation within management
635 was a common theme. In terms of providing context for management, there was a call for evidence
636 of success, drawing on best practice and where things have worked well to develop positive case
637 studies included as examples within management guidance. Respondents were also asked about the

638 drivers influencing saltmarsh management – here, the influence of different policy and management
639 drivers was seen to vary with location, although local policies were found to be important across the
640 board. This lack of consistency regarding the role of different drivers (e.g. international policy goals)
641 may have contributed to the variation in management approaches, and indeed the perceived
642 effectiveness of these, seen in saltmarsh management globally. Furthermore, the emphasis placed
643 on local policy may pose a challenge to the development of a strategic, global approach to
644 restoration and management. Overall, the research suggests there is significant scope for
645 management of saltmarshes, and perhaps of wetlands more broadly, to be improved globally. This
646 paper provides insights into areas which may need improvement, including, use of effective
647 stakeholder engagement techniques (such as participatory mapping; Rova et al., 2015; Burdon et al.,
648 2019; Lillebø et al., 2019) and using interdisciplinary projects to add depth and breadth to current
649 understanding of saltmarshes across a range of scales (e.g. the RESILCOAST [[http://www.nrn-](http://www.nrn-lcee.ac.uk/resilcoast/)
650 [lcee.ac.uk/resilcoast/](http://www.nrn-lcee.ac.uk/resilcoast/)] and CoastWEB [<https://valuing-nature.net/coastweb>] projects).

651 *Implications and next steps*

652 This paper presents an overview of existing knowledge and data gaps associated with saltmarsh
653 ecosystems and provides valuable insights into the variation in the perceived importance of different
654 services and benefits from saltmarshes. The data collected through this study contributes to the
655 knowledge base and understanding around global saltmarsh management and provides a baseline
656 for developing a future research agenda. A key strength of this work has been having access to a
657 global network of saltmarsh experts through the SaltMarshNet community; however, gaps remain in
658 terms of achieving a truly global coverage of saltmarsh management. Despite utilising a multi-lingual
659 approach to data collection, responses were dominated by English speakers and those working in
660 America and Europe. While this work has broadened the knowledge base for these areas, it must be
661 recognised that some areas remain understudied. Future work seeking to add to the baseline
662 provided by this paper should consider a more targeted approach, perhaps linking up with
663 universities and research institutions in harder to reach countries, recognising their role as gate
664 keepers to key stakeholders and actions. There is, perhaps, an opportunity for the SaltMarshNet
665 community to support this with individual researchers acting as multiple contact points within
666 countries of interest.

667 Moving forward, some of the key threats facing saltmarshes, particularly climate change and sea
668 level rise, will require development and implementation of effective forms of governance and skilful
669 negotiations around sometimes conflicting priorities. For instance, in some places difficult decisions
670 will need to be made about coastal communities and making space for saltmarshes to migrate
671 landward. Taking a whole system approach to developing collaborative governance mechanisms that
672 deliver integrated and joined up thinking to address these issues will be key. The findings from this
673 study provide valuable insights into the regional variations in ecosystem services and benefits
674 provided by saltmarshes. In addition, the results could be used to inform design and implementation
675 of a range of interventions, including raising public and political awareness of saltmarsh systems and
676 their contribution to society more broadly. When compared with other environments, saltmarshes
677 and their ecosystem services are poorly understood (Curado et al., 2014; McKinley et al., 2020) and
678 have been perceived as sites of disease and danger in some cultures (Barbier et al., 1997). Having a
679 better spatio-temporal understanding of the importance of ecosystem services, could help inform an
680 appropriate suite of interventions, which are socially acceptable, contribute to social, economic and
681 cultural wellbeing, as well as protecting ecological integrity. For this to be achieved, there is a need
682 for more explicit recognition of saltmarshes and other coastal fringe systems (McKinley et al., 2018),
683 particularly given the growing emphasis on nature-based solutions as a component of climate

684 change adaptations (Möller, 2019; Powell et al., 2019). Alongside there is a need for stronger global
685 leadership and development of tangible commitments to support improved management of
686 saltmarsh environments (for example through managed realignment), and indeed other coastal
687 fringe systems. This can be achieved through achieving stakeholder consensus to reduce the risk of
688 policy failure and potential conflicts among parties. This aspect has been recently recognised in the
689 literature that considers mainly the economic monetary values of the ecosystem services as an
690 instrument to achieve saltmarsh sustainability. However, relying solely on monetary valuation can be
691 limited by institutional and social aspects, as already documented in the realignment schemes
692 adopted for the Somerset saltmarshes (UK) (da Silva et al., 2014; Martino et al., 2019) or in France by
693 coastal flooding policies allowing the reopening of polders to the sea (Goeldner-Gianella et al.,
694 2015).

695 **6. Concluding comments and recommendations**

696 This study has provided valuable insights into the global variation in how saltmarshes and their
697 ecosystem services are perceived by different stakeholders, and how this and other factors can drive
698 management and decision making. As efforts to improve, maintain and restore saltmarshes and
699 other wetlands systems grow in a bid to mitigate against climate change and other environmental
700 issues, understanding global variation in these systems and how they are managed has a valuable
701 role to play. Drawing on the results from this study, and the existing evidence base, the following are
702 set out as a series of future recommendations for saltmarsh management:

- 703 ○ **Development of a truly global, interdisciplinary research agenda.** Building on the efforts of
704 SaltMarshNet, continuing to develop a research agenda and community which encompasses
705 sciences traditionally associated with saltmarsh systems (e.g. ecologists, geographers,
706 biophysical modellers, geomorphologists, etc.) with under-utilised research disciplines (e.g.
707 marine social sciences) will add depth and breadth. Furthermore, this agenda and the
708 underpinning community must actively ensure that research is geographically representative.
709 As outlined in Table SM12, 12 countries included in this paper had previously not been
710 represented with saltmarsh-related research in the peer-reviewed literature. However, there
711 are 16 remaining countries where saltmarshes have been the subject of studies but that are
712 not covered by our survey, as well as others not covered by this work that have not yet
713 received attention in the literature (6 in the Americas, 12 in Africa and Middle East, 8 in
714 Europe, 6 in Oceania, and 2 in Asia). For a truly global approach to maintenance and
715 improvement of global saltmarsh systems, there is first a need to understand the baseline
716 context globally.
- 717 ○ **Take account of multiple values when developing management strategies.** This work has
718 shown there to be a significant variation in the perceived importance, and consequently in
719 the level of priority assigned to saltmarsh ecosystem services and benefits by managers and
720 stakeholders globally. This paper presents insights into this, but the dataset is incomplete.
721 Further work is required to better understand the multiplicity of values and priorities that can
722 be associated with saltmarshes across the globe. It is also important to note that there was
723 some degree of variation between the two methods of prioritisation in this study i.e. the AHP
724 pairwise comparisons and the simple ranking/ prioritisation exercises. Approaching
725 ecosystem services values from multiple perspectives, using multiple methods (e.g. Hattam et
726 al., 2015b), and encompassing these differences in a global approach to restoration and
727 management is a challenge and will require flexibility within any future management
728

729 guidance to allow for different interpretations of management in response to local, regional
730 and national needs and priorities.

731

732 ○ **Utilise alternative and innovative methods of research and engagement for further**
733 **knowledge development.** Although this paper draws on data from work conducted in 40
734 countries, it is by no means exhaustive. It is also important to recognise that due to self-
735 selection biases, the research findings reflect the dominant interests of the countries best
736 represented in the data set (particularly the UK and Europe). Care has been taken to
737 contextualise the findings in order to highlight where gaps in the knowledge base persist. It is
738 therefore recommended that the work presented here is recognised as a baseline, and that
739 further research is carried out to continue to develop the database, increase the depth and
740 breadth of the geographical scope and ensure there is representation across sectors and
741 disciplines. By better understanding global variation in priorities, and also the factors
742 influencing and driving saltmarsh management globally, there is an opportunity to use this
743 study to develop the existing dataset, which includes primarily ecological and economic data
744 (Mcowen, 2017). Furthermore, it is recommended that future work looks to other disciplines
745 and draws on the more qualitative approaches of the social sciences where appropriate. For
746 example, the data collected in this study could be used to identify “hot spot” locations which
747 could identify sites for in-depth, qualitative research at a case study level.

748

749 ○ **Adopt an ecosystem, “catchment-to-coast” approach to management.** There is a need to
750 understand the interlinkages between upland and coastal ecosystems, so as to deliver
751 effective management and mitigate for impacts across the entire catchment to coast
752 system. Moser et al. (2012) highlight this as a contributing factor towards the ‘wicked’
753 problems facing global coastal ecosystems, recognising that all coastal zones will be
754 influenced by activities happening further in- and upland, in places resulting in degradation,
755 habitat and biodiversity loss and deterioration in ecosystem service provision. Recent
756 interest in the role of coastal fringe systems, such as saltmarshes, as sinks for plastic
757 pollution reiterates the need to better understand this connectivity across the entire
758 ecosystem. This research contributes to this by adding to the global understanding of
759 saltmarsh management and the variation in ecosystem service priorities in different
760 locations.

761

762 ○ **Embracing opportunities to conserve and restore saltmarsh.** Although outside the scope of
763 the current study, there is an opportunity to build on the success stories of saltmarsh
764 restoration projects across the globe. Sharing best practice and lessons learned from
765 management interventions to restore saltmarsh may be a crucial step to the delivery of
766 future interventions. There is an opportunity to build on the global SaltMarshNet Network
767 and the background evidence which has been gathered by the current questionnaire survey
768 to better understand where successes have happened, with a view to developing global best
769 practice. We fully advocate the integral role of active stakeholder engagement in co-
770 producing solutions/strategies for managing the threats/challenges identified in this study at
771 a local, regional and national scale.

772 Once considered by some as wasteland or non-productive, saltmarshes are now increasingly
773 recognised for their integral role in environmental resilience and as natural buffers against
774 environmental degradation and climate change. Conservation, restoration and management of
775 saltmarshes globally will take a comprehensive understanding of how their importance varies across

776 time and space; this paper provides a starting point for this discussion to feed into saltmarsh
777 management worldwide.

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Highlights

- A global study of saltmarsh stakeholders (n=438) examining global variation in importance of ecosystem services.
- Perceived importance of saltmarsh ecosystems services varies with geographical location.
- This variation has implications for efforts to restore, conserve and maintain saltmarshes.
- Recommend adoption of a catchment to coast approach to account for multiple values of saltmarshes.

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Declaration of interests

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

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: