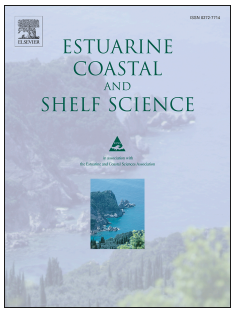

Uses and management of saltmarshes: A global survey

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

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Author Statement

Uses and Management of Saltmarshes: A Global Survey

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.

Uses and Management of Saltmarshes: A Global Survey

McKinley, E.[1*], Pagès, J.F.[2,3]Alexander, M.[4], Burdon, D.[56], and Martino, S.[7]

[*]Corresponding author: mckinleye1@cardiff.ac.uk

[1] School of Earth and Oceans Sciences, Cardiff University, Main Building, Park Place, Cardiff, CF10 3AT, United Kingdom.
[2]Departament de Biologia Evolutiva, Ecologia i Ciències Ambientals, Institut de Recerca de la Biodiversitat (IRBIO), Universitat de Barcelona, Av. Diagonal, 643, 08028 Barcelona, Spain
[3]Centre d'Estudis Avançats de Blanes (CEAB-CSIC), Accés a la cala Sant Francesc 14, 17300 Blanes, Spain
[4]School of Politics, Philosophy and Language and Communication Studies, University of East Anglia, NR4 7TJ
[5] Institute of Estuarine & Coastal Studies, University of Hull, Hull, United Kingdom, HU6 7RX
[6] Daryl Burdon Ltd., Marine Research, Teaching and Consultancy, Willerby, HU10 6LL, UK.

[7]Department 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

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

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

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

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

2. Global uses and management of saltmarshes

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

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

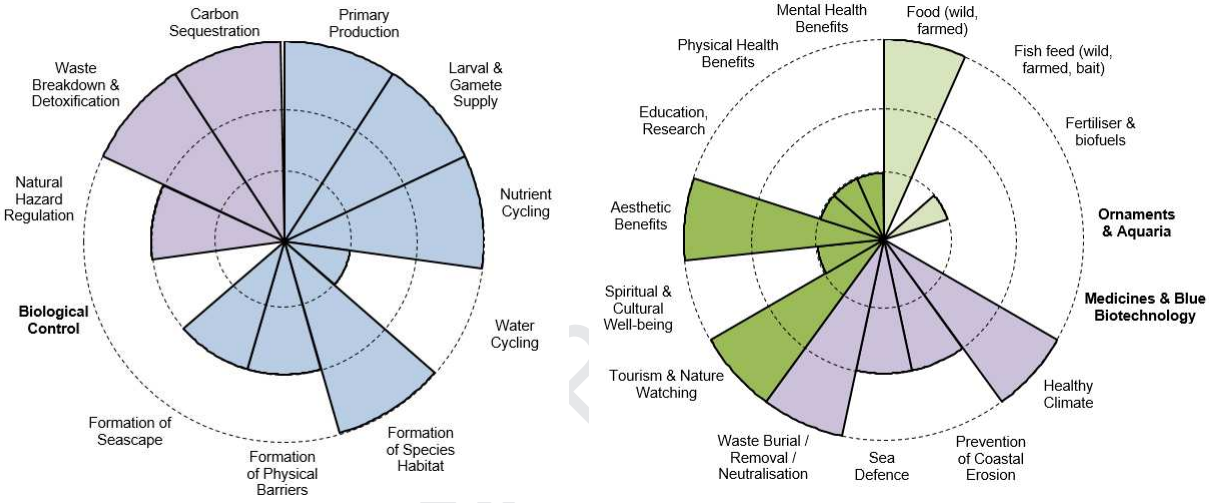

Figure 1. Relative importance (low (inner ring), medium (middle ring), high (outer ring)) of ecosystem services and benefits provided by coastal saltmarsh. Blue = supporting services, Purple = regulating services, Light green =provisioning services, Dark green = cultural services. Services and benefits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

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

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

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

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

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

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

3. Methodology

3.1. Questionnaire Development and Sampling

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

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

The questionnaire was piloted through the RESILCOAST[1] and CoastWEB[2] project consortia, in addition to colleagues in academic institutions and key local stakeholders who have experience in interdisciplinary saltmarsh research. Once translated, each version of the questionnaire was checked by a native speaker. Respondents were recruited through a self-selection process based on their access to the online questionnaire. To maximise the geographical reach, the questionnaire was disseminated between September and November 2018, using Survey Monkey, through the recently established SaltMarshNet network[3], the Communication for Sustainability and Management (CMS) Network[4] , the Marine Social Science Network[5], and through the research team's own professional networks. These networks were selected for their diverse membership, comprising both research and practitioner audiences spanning across geographical regions. The survey intended to target professional practitioners working on/ with or researching saltmarshes in some way (for example, this could include a protected area manager, a local authority officer responsible for a saltmarsh site or a researcher working on any aspect of saltmarshes) and other key beneficiaries using saltmarshes in some way (e.g. wildfowlers).

3.2. Data Analysis

3.2.1. Quantitative data analysis

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

Ordinal regressions were used to examine the influence of several moderators on respondents' perceived importance/level of agreement towards the questions/statements presented. The moderators included: respondents' place of work (i.e. continent), type of organisation, primary role within the organisation, duration of respondents' work experience in the area, proportion of their work that was related to saltmarshes and educational attainment. In all cases, model selection 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

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

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

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

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

3.2.2. Qualitative data analysis

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

4. Results

4.1. Respondent Profile

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

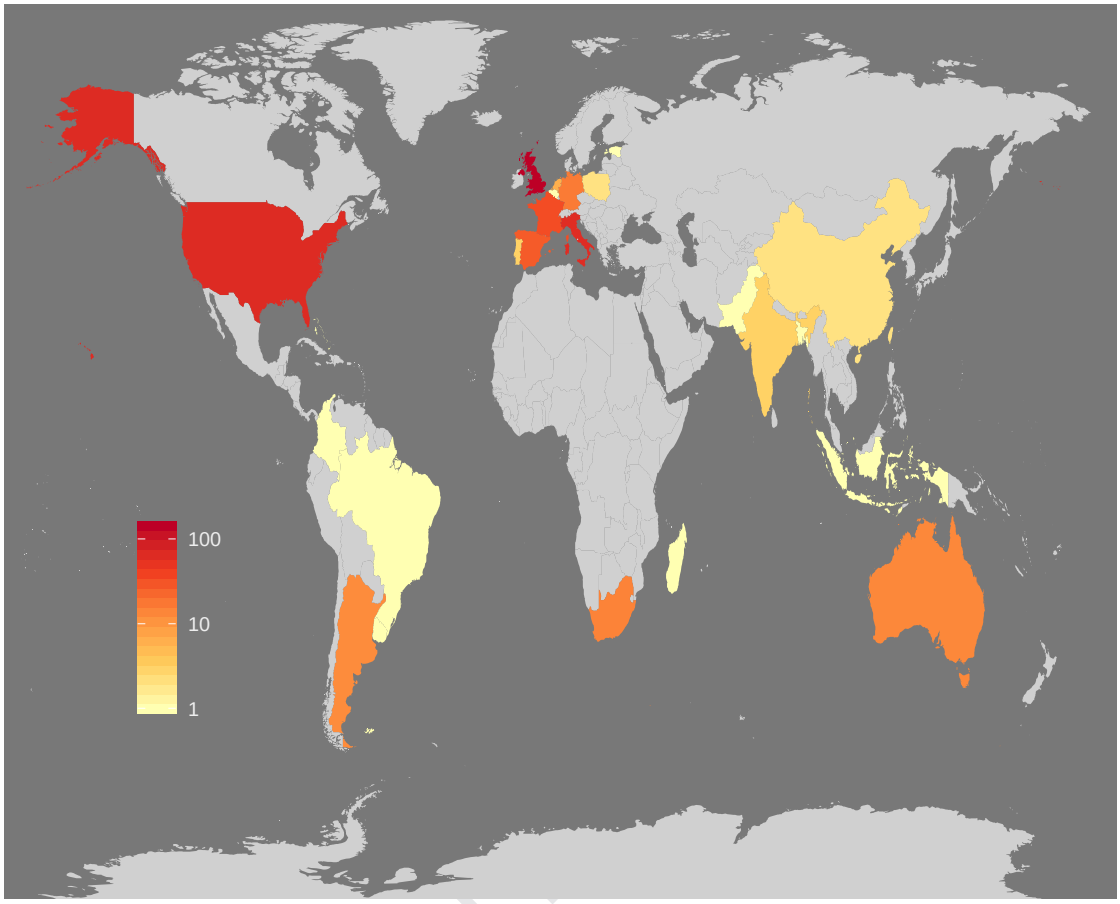

Figure 2. Map showing the distribution of respondents per country.

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

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

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

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

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

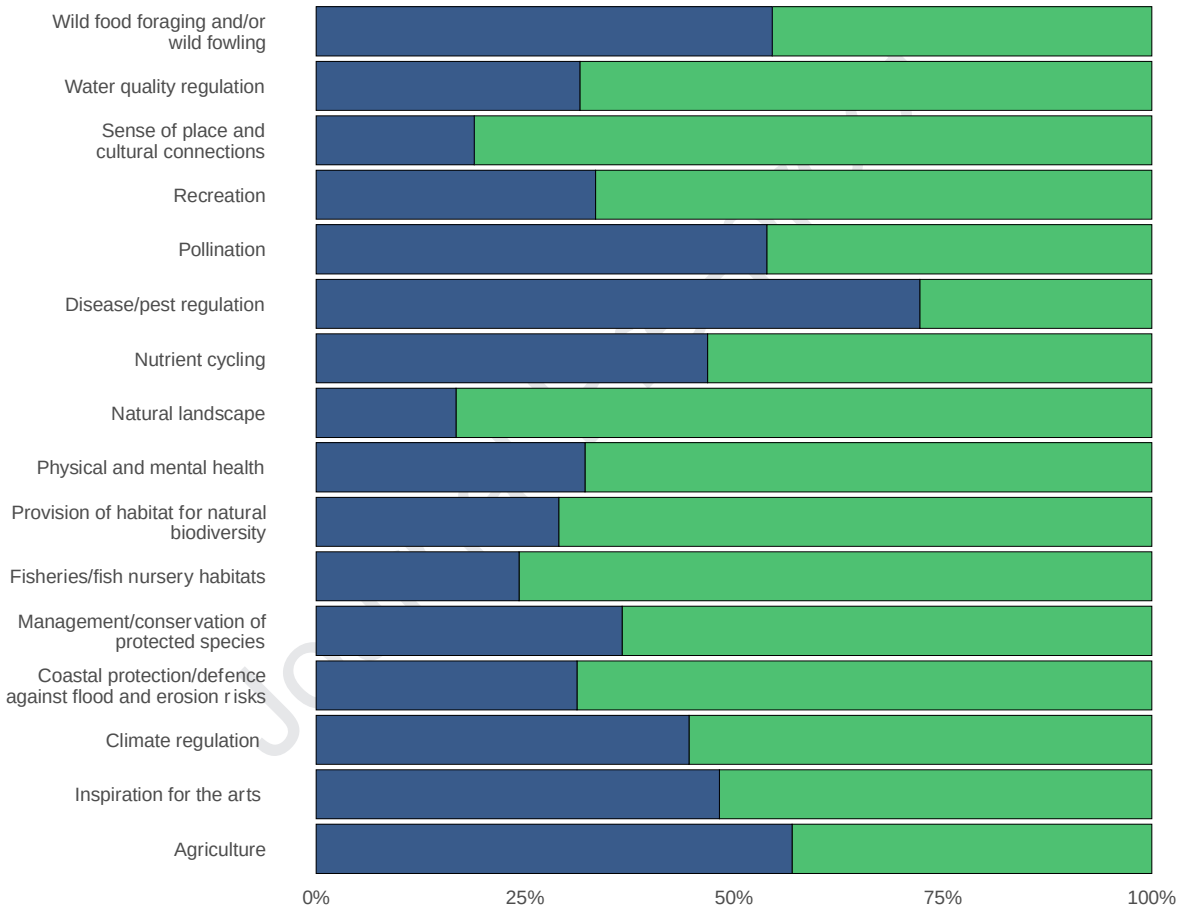

Figure 3: Relative frequency (%) of perceived benefits and services provided by saltmarsh in the regions respondents are working in. Colour codes: blue = no, green = yes.

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

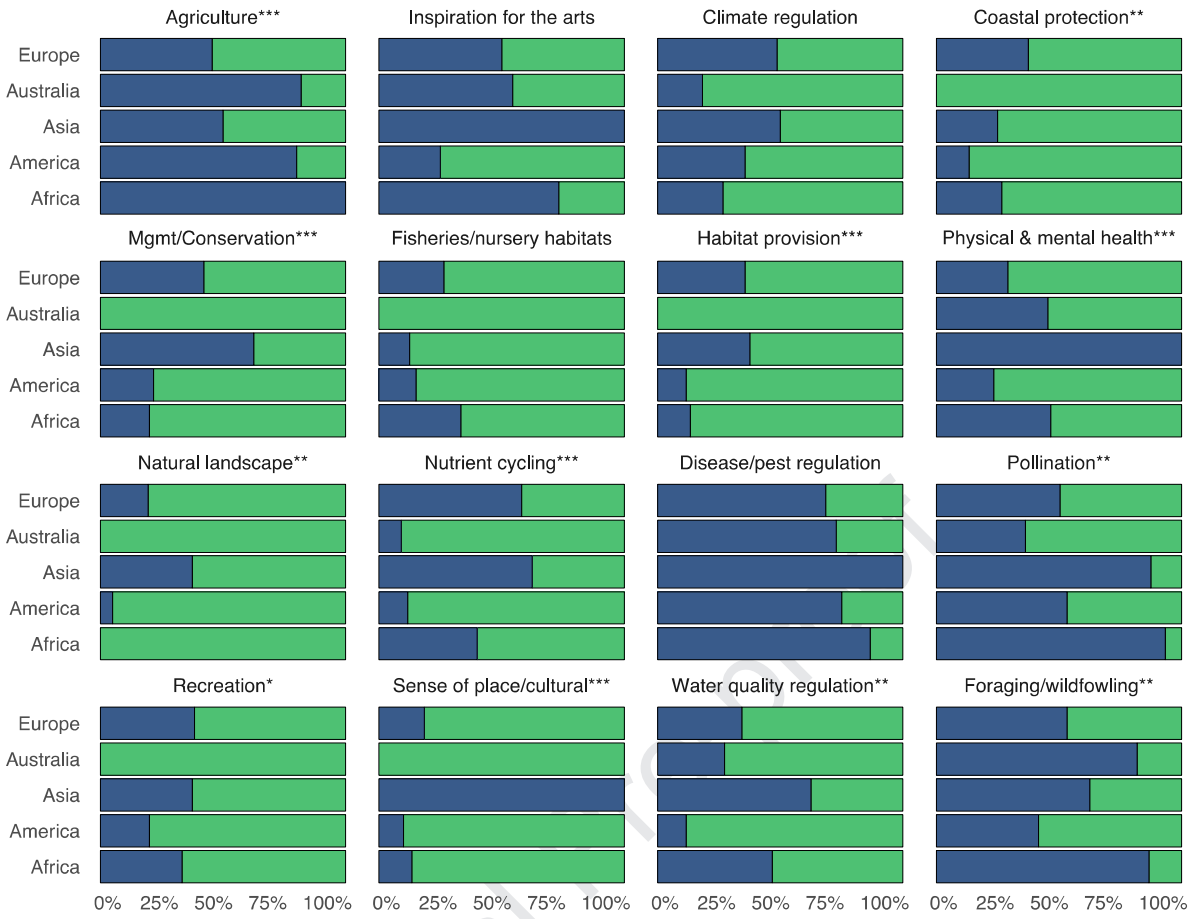

Figure 4: Influence of continent on respondents' perceptions of saltmarsh ecosystem services and benefits. Asterisks indicate a significant effect of continent on the associated saltmarsh benefit, according to a chi-squared test. Significance codes $p < 0.001$ '***', $p < 0.01$ '**', $p < 0.05$ '*'.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

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

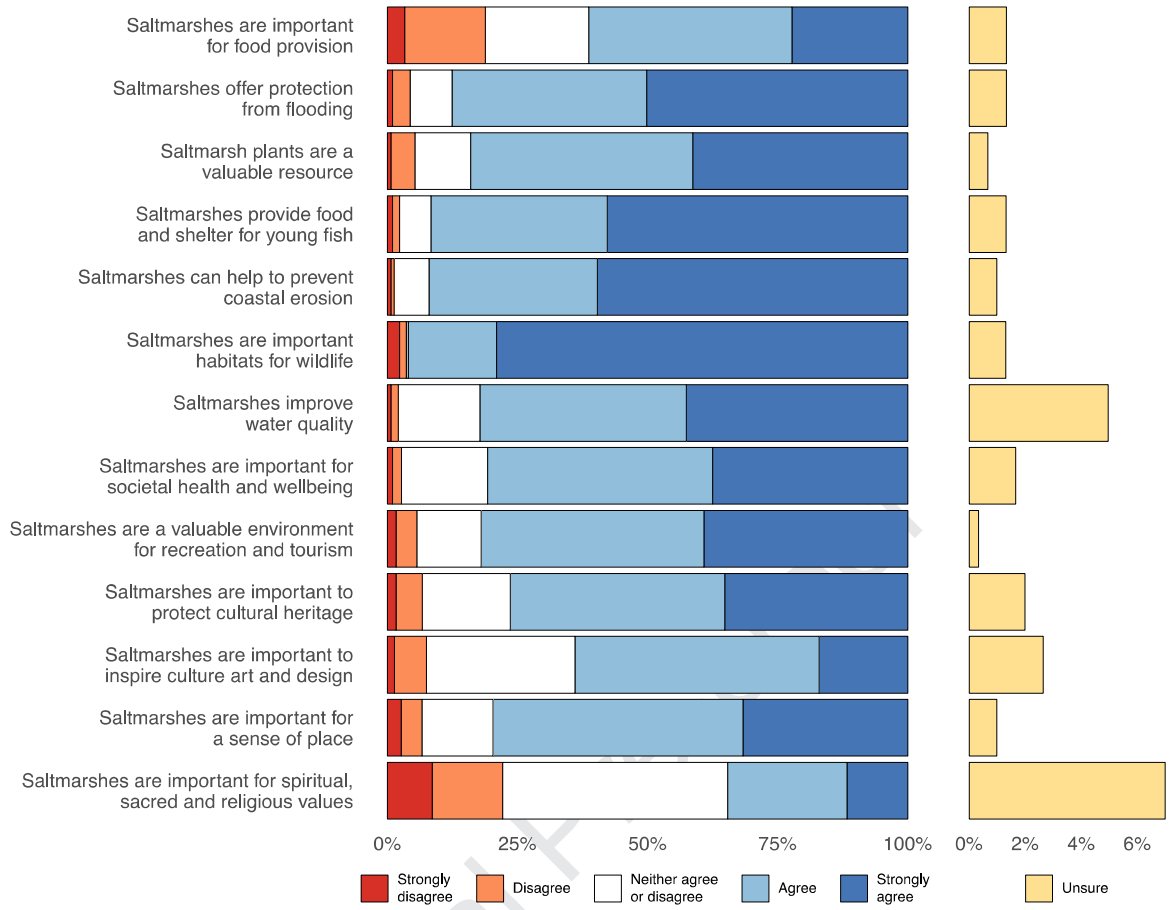

Figure 5: Respondents' agreement to the perceived contribution of saltmarshes to society (left panel). Right panel indicates the % of respondents that answered "unsure" for each of the statements. We tested if these perceptions differed from the midpoint ("Neither agree or disagree") with a Wilcoxon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

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

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

	Respondents' characteristics that moderated the responses (predictor variables)					
Question/statements to rate (response 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	

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

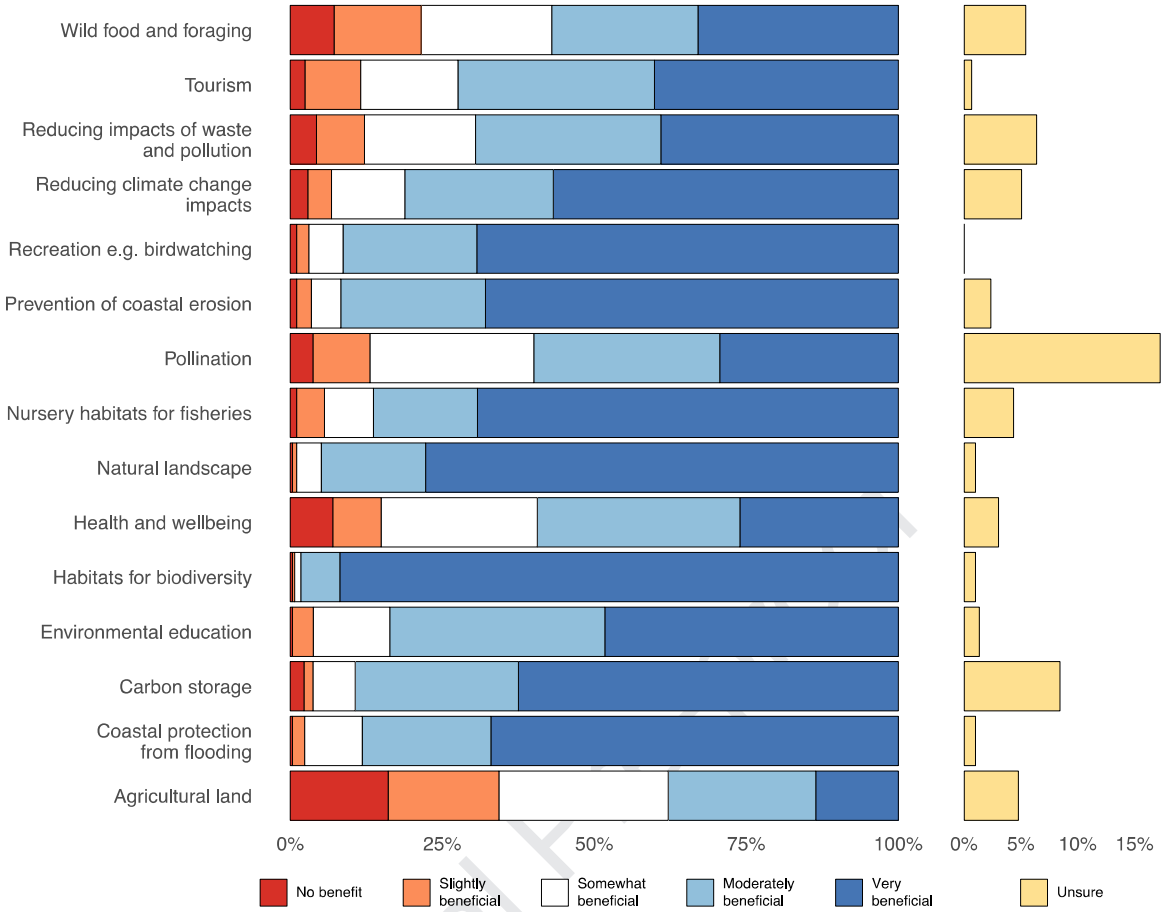

Figure 6: Perceived value attributed to the benefits and services provided by saltmarshes (left panel). Right panel indicates the % of respondents that answered "unsure" for each of the benefits/services. Each statement was analysed with a Wilcoxon test (see Figure SM5)

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

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

	Respondents' characteristics that moderated the responses (predictor variables)					
Question/statements to rate (response 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	

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

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

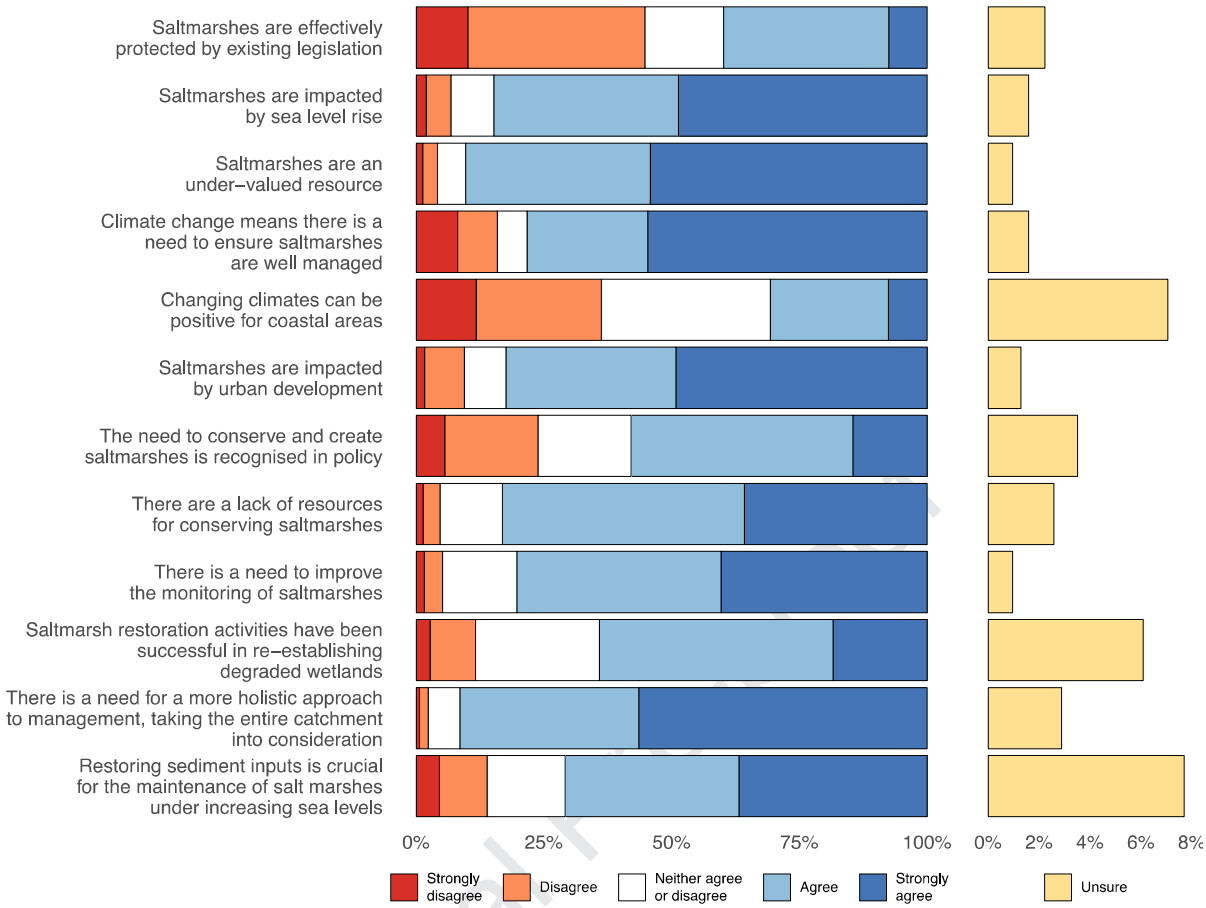

Figure 7: Respondent agreement to statements on saltmarsh management and future threats (left panel). Right panel indicates the % of respondents that answered "unsure" for each of the benefits/services. Each statement was analysed with a Wilcoxon test (see Figure SM6).

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.

	Respondents' characteristics that moderated the responses (predictor variables)					
Question/statements to rate (response 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	*SLR; coastal squeeze and lack of landward migration zones*	75	France, Germany, Italy, Netherlands, Portugal, South Africa, Spain, Taiwan, U.K., U.S., multiple regions
Development pressures, urbanisation and hardened shorelines (*Main theme*)	*…The dynamic system being constrained by hardening of shoreline is a major threat.*	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	*Over-exploitation by the daily use of these areas as a playground for mountain bikers, joggers and dog walkers.*	40	Australia, China, France, Italy, Netherlands, Portugal, Spain, U.K., U.S., multiple regions
Climate change	*Climate Change, sea level rise and lack of management measures*	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")*	*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* *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*	30	France, Germany, India, Italy, Netherlands, South Africa, Spain, Taiwan, UK
Nutrients, water quality and pollution	*Chemical, plastic and nutrient pollution* *Pollution run off from farm land* *Invasive species, urbanization and discharge of pollutants*	30	Argentina, France, Germany, Italy, Netherlands, Poland, South Africa, Spain, Uruguay, U.S., U.K.
Physical processes and factors influencing saltmarshes	*Biophysical variability and influence on biogeochemical cycles* *in Venice: imbalance of sediment budget, focus on technical solutions*	26	Belgium, Germany, Italy, Netherlands, South Africa, Spain, U.K., U.S.

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

*Note that entries may have been coded at more than one code accordingly
* 'multiple regions' refers to participants that have listed multiple locations within which their work is situated.
* Countries are listed in alphabetical order.

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

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

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

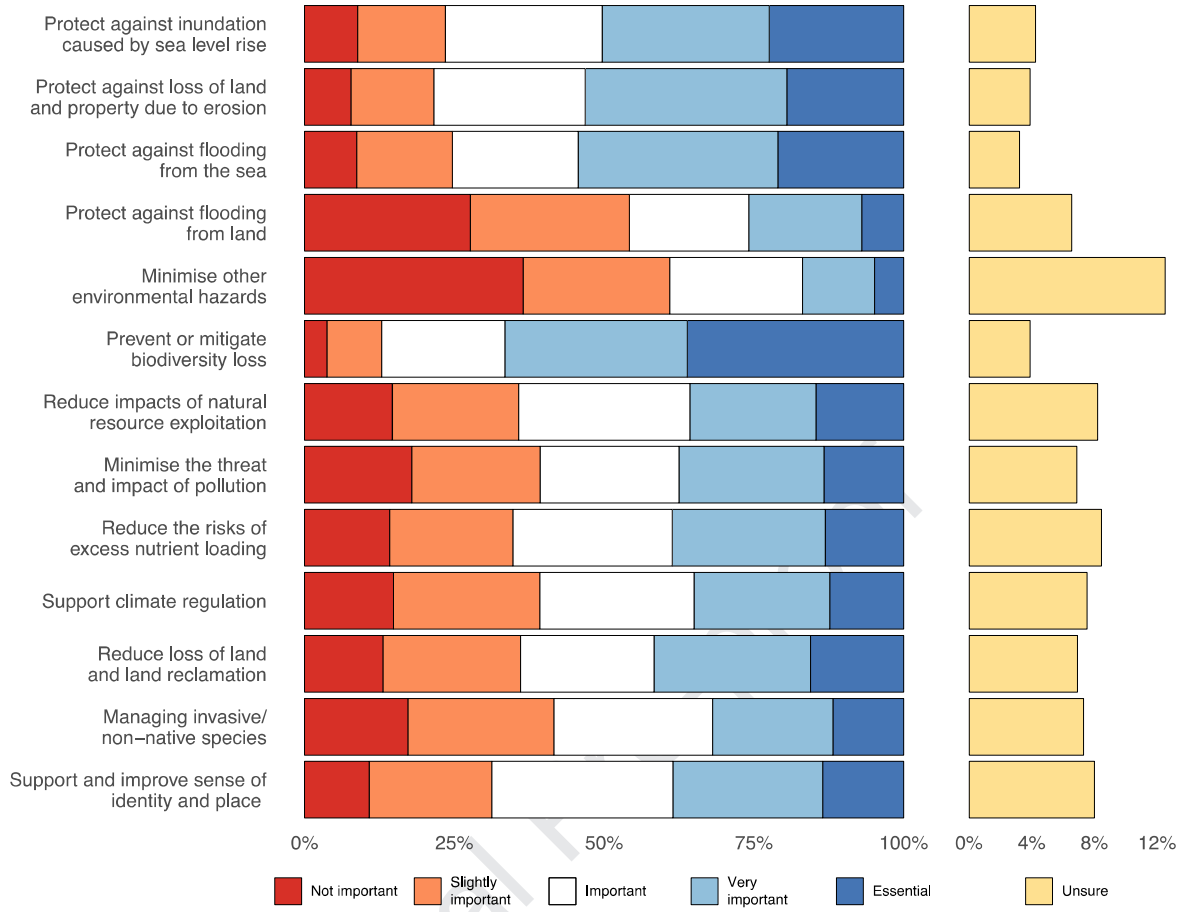

Figure 8: Level of importance attributed to priorities of saltmarsh management (left panel). Right panel indicates the % of respondents that answered "unsure" for each of the priorities. Each statement was analysed with a Wilcoxon test (see Figure SM8).

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

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

	Respondents' characteristics that moderated the responses (predictor variables)					
Question/statements to rate (response 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

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

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

	Respondents' characteristics that moderated the responses (predictor variables)					
Question/statements to rate (response 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	

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

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

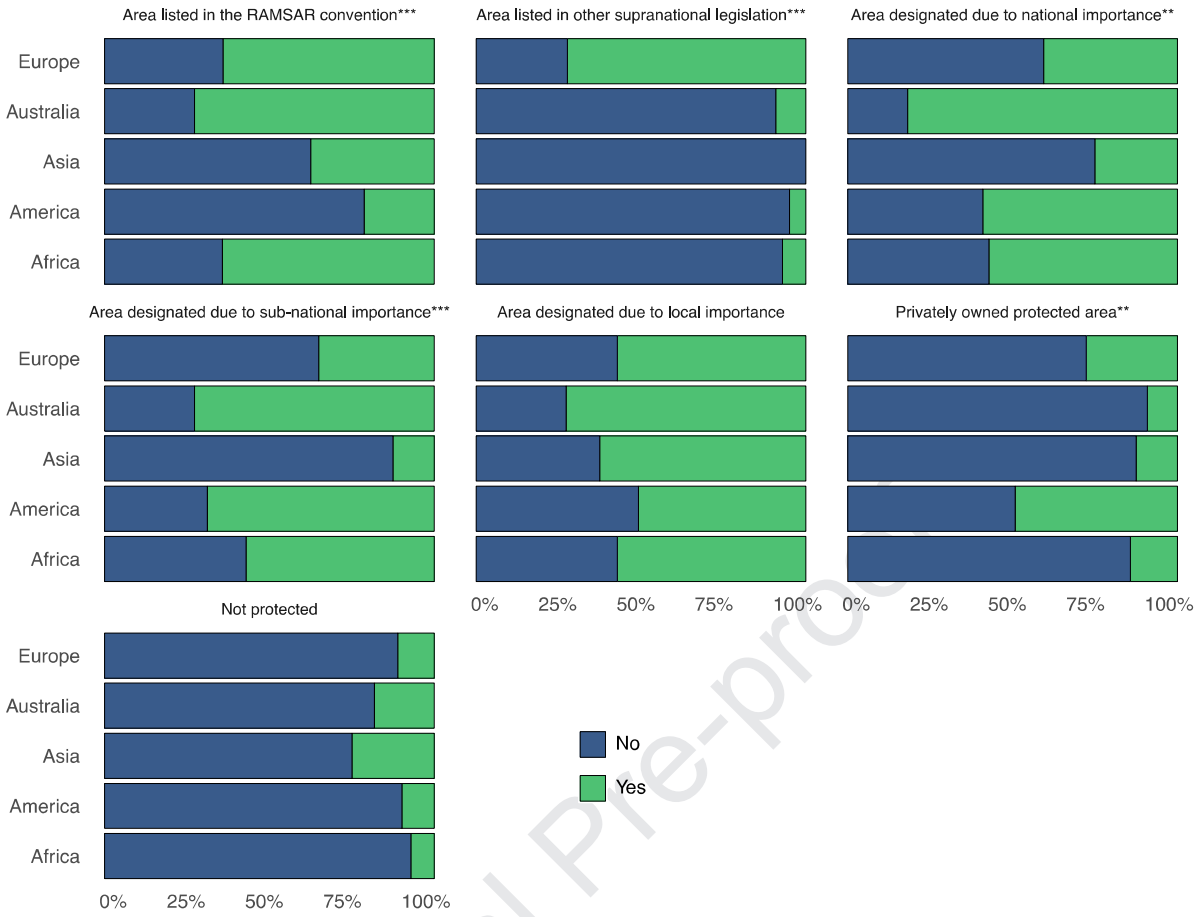

Figure 9: Influence of geographical location (continent) on saltmarsh protection. Asterisks indicate a significant effect of continent on the associated form of land protection, according to a Chi-squared test. Significance codes $p < 0.001$ '***', $p < 0.01$ '**', $p < 0.05$ '*'.

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

4.4.1. Factors influencing the perceived effectiveness of saltmarsh management

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

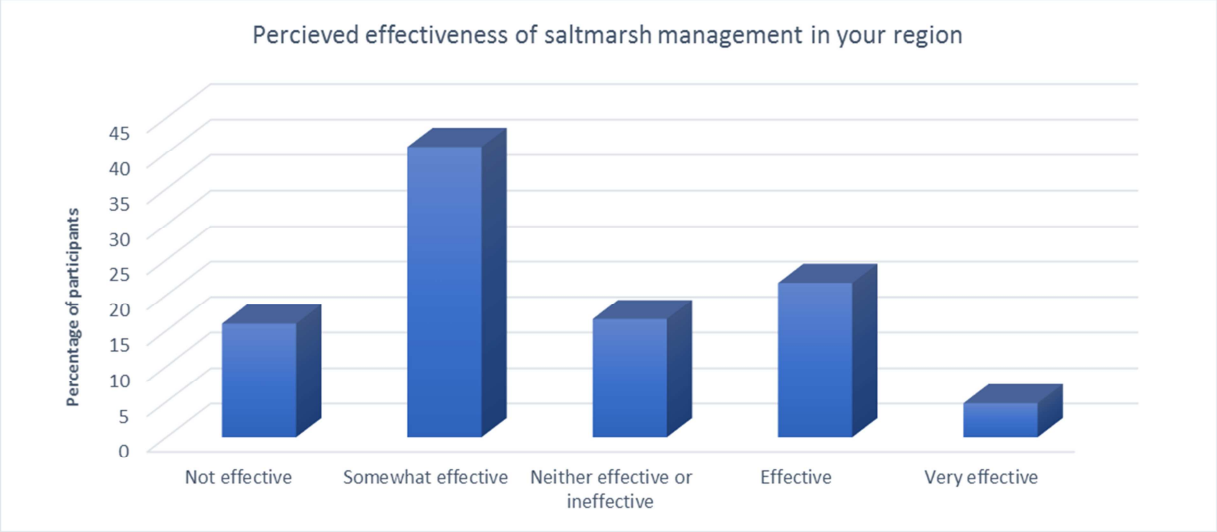

Figure 10: The perceived effectiveness of saltmarsh management (N=313)

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

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

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

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

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

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)

▪ 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.
	▪ Ongoing pressures;
	▪ Social acceptability & interest;
	▪ Limited management;
	▪ Limited improvement, continued deterioration or loss;
	▪ Inconsistency;
	▪ {*All other categories thereafter tied N =1*}
		▪ 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;
		▪ {*10th place tied between*} –
		  ▪ Gaps in knowledge and understanding;
		  ▪ Lack of awareness of saltmarsh benefits and value;
		  ▪ Limited effectiveness of approaches & monitoring;
		  ▪ Scale misalignment.

5. Discussion

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

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

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

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

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

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

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

What are the main threats and challenges facing saltmarsh environments?

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

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

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

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

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

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

Implications and next steps

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

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

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

6. Concluding comments and recommendations

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

- **Development of a truly global, interdisciplinary research agenda**. Building on the efforts of SaltMarshNet, continuing to develop a research agenda and community which encompasses sciences traditionally associated with saltmarsh systems (e.g. ecologists, geographers, biophysical modellers, geomorphologists, etc.) with under-utilised research disciplines (e.g. marine social sciences) will add depth and breadth. Furthermore, this agenda and the underpinning community must actively ensure that research is geographically representative. As outlined in Table SM12, 12 countries included in this paper had previously not been represented with saltmarsh-related research in the peer-reviewed literature. However, there are 16 remaining countries where saltmarshes have been the subject of studies but that are not covered by our survey, as well as others not covered by this work that have not yet received attention in the literature (6 in the Americas, 12 in Africa and Middle East, 8 in Europe, 6 in Oceania, and 2 in Asia). For a truly global approach to maintenance and improvement of global saltmarsh systems, there is first a need to understand the baseline context globally.

- **Take account of multiple values when developing management strategies**. This work has shown there to be a significant variation in the perceived importance, and consequently in the level of priority assigned to saltmarsh ecosystem services and benefits by managers and stakeholders globally. This paper presents insights into this, but the dataset is incomplete. Further work is required to better understand the multiplicity of values and priorities that can be associated with saltmarshes across the globe. It is also important to note that there was some degree of variation between the two methods of prioritisation in this study i.e. the AHP pairwise comparisons and the simple ranking/ prioritisation exercises. Approaching ecosystem services values from multiple perspectives, using multiple methods (e.g. Hattam et al., 2015b), and encompassing these differences in a global approach to restoration and management is a challenge and will require flexibility within any future management

729 guidance to allow for different interpretations of management in response to local, regional
730 and national needs and priorities.
731
732 o **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 o **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 o **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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794

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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.

Declaration of interests

☒ The authors declare that they have no known com_peting 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: