Assessing and enhancing ecosystem services provided by diadromous fish in a climate change context

Deliverable title: DiadESland a tool for developing management policy; stakeholder perceptions of a serious game

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1. Introduction

1.1. Project background

This research forms part of the task carried out by the University of Plymouth and European partners in the DiadES project – a project which aims to assess and enhance ecosystem services provided by diadromous species (migratory between salt and fresh water) in a climate change context. The DiadES project is funded by the European Programme Interreg Atlantic Area and relies on an interdisciplinary partnership including partners and stakeholders from across the Atlantic Area.

One of the main outputs of the project is a serious game, of a role-playing form, entitled DiadESland. This innovative tool is a learning experience to foster discussions on managing diadromous species in the long term and on a large scale, including the effect of global climate change on the diadromous fish populations. The serious games method has been successfully applied in various subjects and has increased in popularity in supporting behaviour change and policy and management development. By participating in a DiadESland workshop, where both game play and group discussion took place, the aim is to help stakeholders envision alternative management scenarios in a globally changing environment.

To improve our understanding of the value of the serious game technique, the aim of the research is to gain the perspectives of stakeholders who participated in DiadESland game play workshops. The objectives of the research are: i) to assess game players' perceptions of the DiadESland game, ii) to develop further understanding of the use of serious games in management and policy development, and ii) to add to the wider knowledge exchange component of the DiadES project. The method for gathering data was using a post-game questionnaire (Annex A) where both qualitative and quantitative question formats were included. Descriptive statistical analysis was undertaken on the Likert scores to determine if there was a tendency to agree or disagree with statements relating to participant learning and development from the serious game. A content analysis was undertaken on open-ended questions to establish key themes emerging from the participants answers.

1.2. Serious games

3.1.1. An introduction to serious games

The term serious game gained popularity in the late 1990s and refers to a game or interactive experience that is designed for a primary purpose other than entertainment, such as education, training, or simulation (Wilkinson, 2016). The key distinguishing factor of a serious game is its intended purpose, which goes beyond entertainment. Serious games are designed with the objective of imparting knowledge, developing skills, fostering understanding, promoting behaviour change, or addressing real-world challenges (Laamarti et al., 2014). They are used for a wide range of purposes across various domains. The Serious Games Initiative was launched in 2002 by Ben Sawyer, aiming to explore the potential of games for education, health, and public policy (Wilkinson, 2016). Some current common applications of serious games are within education and training (Zhonggen, 2019), skills development (Checa & Bustillo, 2020), behaviour change (Chow et al., 2020), policy development (Stanitsas et al., 2019), and social impact and awareness (Flood et al., 2018). The advancement of technology, particularly in mobile devices and virtual reality, has provided new opportunities for serious games (Laamarti et al., 2014). The popularity of gamification, which involves applying game elements and mechanics to non-game contexts, further contributed to the growth of serious games across industries (Almeida & Simoes, 2019).

3.1.2. Serious game examples

Assessing the effectiveness of serious games in achieving desired learning outcomes can be challenging. Evaluation methods are necessary to measure the impact of serious games to establish their effectiveness and value (Den Haan & Van der Voort, 2018; Mozier et al., 2019). However, several studies have demonstrated how serious games are versatile tools that leverage the power of play, interactivity, and immersion to achieve specific objectives in an effective manner (Khowaja & Salim, 2019; Neset et al., 2020).

Serious games have been utilised in urban planning processes to engage stakeholders and develop sustainable city policies. Games like "SimCity" and "Cities: Skylines" allow players to design and manage virtual cities, making

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decisions related to zoning, transportation, energy, and public services (Robinson et al., 2021). By experimenting with different urban planning scenarios, policymakers and stakeholders can explore innovative approaches and assess their potential impacts (Sousa et al., 2022). Along a similar line, serious games have been used to develop policies and strategies related to energy and climate change, such as the game "Energy City". This game enables players to make decisions about energy generation, distribution, and consumption, aiming to balance economic growth and environmental sustainability (Sušnik et al., 2012). This type of game helps policymakers understand the complexities of energy systems and explore different pathways for transitioning to renewable energy sources (Stanitsas et al., 2019).

Serious games have been used to train and develop policies for crisis management situations and to facilitate conflict resolution and peacebuilding efforts. A serious game that is very apt for the current global health crisis is "Pandemic: The Board Game", which simulates the spread of infectious diseases and challenges players to contain outbreaks, allocate resources, and make critical decisions. This type of game can assist policymakers in understanding the complexities of crisis response and refining their strategies (Smith et al., 2020; Solinska-Nowak et al., 2018). Games like "PeaceMaker" and "A Force More Powerful" simulate political and social conflicts, allowing players to take on different roles and explore negotiation, dialogue, and policy development (Di Loreto et al., 2012). These games provide a safe space for experimenting with conflict resolution strategies and fostering empathy among participants (Solinska-Nowak et al., 2018).

Additionally, serious games have been employed to address complex environmental policy challenges (Edwards et al., 2019). An example aligned with the serious game in discussion, is the game "Fishbanks", which simulates the dynamics of managing a virtual fishery. Players make decisions about fishing quotas, conservation measures, and economic factors, aiming to maintain a sustainable fishery. This game helps policymakers explore different management strategies and understand the consequences of their policy decisions (Meadows, 2007).

The examples discussed demonstrate how serious games can be utilised to support policy development and management in various domains. By providing a dynamic and interactive platform, games enable policymakers and stakeholders to explore different scenarios, test strategies, and gain insights into the complexities of management and policy challenges. The game environment can foster a collaborative and participatory approach to policy development, allowing for experimentation, learning, and informed decision-making (Edwards et al., 2019; Madani et al., 2017; Solinska-Nowak et al., 2018).

3.1.3. Serious games within management and policy development

As discussed with the examples above, serious games can engage policymakers, stakeholders, and citizens in the management and policy development process. By providing interactive and immersive experiences, games can encourage active participation, foster collaboration, and promote dialogue among participants (Solinska-Nowak et al., 2018). Serious games can simulate complex policy challenges and help policymakers explore different scenarios and their potential outcomes. They provide a platform for testing management strategies and policies, understanding the consequences of decisions, and gaining insights into the complexities of real-world problems (Edwards et al., 2019; Madani et al., 2017). Games can facilitate experiential learning, allowing managers and policymakers to develop a deeper understanding of the issues (Checa & Bustillo, 2020; Madani et al., 2017). Through gameplay, managers and policymakers can grasp the implications of their decisions, experience trade-offs, and gain first-hand experience of management and policy implementation challenges (Stanitsas et al., 2019). Serious games can be utilised to engage diverse stakeholders in the management and policy development process. By providing a shared platform, games can facilitate communication, build consensus, and bridge gaps between different perspectives, fostering more inclusive and informed management and policy decisions (Flood et al., 2018).

Serious games can have their challenges, they can involve simplifying complex management and policy issues to fit within the limitations of the game mechanics and gameplay. This abstraction can lead to oversimplification or missing important nuances of real-world policy challenges, potentially impacting the accuracy and effectiveness of management and policy development (Laamarti et al., 2014). The transferability of skills and knowledge gained from serious games to real-world management and policy development may be limited. Games provide controlled

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environments with predefined rules, which may not fully capture the complexity and dynamics of actual policy contexts (Solinska-Nowak et al., 2018). Serious games need to be designed and developed with care to ensure the validity and accuracy of management and policy related information and scenarios (Mitgutsch & Alvarado, 2012). Incorrect or biased information within the game can lead to misconceptions or misguided management and policy decisions (Edwards et al., 2019). Serious games may face challenges in adequately representing the diverse perspectives and interests of stakeholders, therefore, it is crucial to ensure that the game captures the complexity of stakeholder interactions and avoids favouring certain perspectives over others (Solinska-Nowak et al., 2018; Sušnik et al., 2018). It can be challenging to evaluate the effectiveness of serious games in informing evidence-based management and policy decisions and robust evaluation methods are necessary to assess the impact of serious games on policy understanding, decision-making, and stakeholder engagement (Westera, 2019).

In summary, serious games can offer valuable contributions to management and policy development by engaging stakeholders, facilitating collaboration, and exploring complex policy challenges. However, challenges related to simplification, transferability, accuracy, stakeholder representation, evaluation, ethics, and evidence-based decision-making need to be carefully addressed to maximise the benefits of using serious games in the management and policy development processes. Within this research, we are using a serious game developed as part of an EU funded project as a tool for policy development and to help stakeholders who participate in game play to envision alternative management scenarios in a globally changing environment. To better understand the role of serious games in aiding management and policy development, we undertook quantitative and qualitative research following organised gaming sessions with the intention of gathering player insights, user preferences and learning attained.

2. Methods

2.1. Participant recruitment

DiadESland is a role-playing game targeting a diverse audience of stakeholders involved in the management of diadromous fish. Several game sessions took place across Europe in 2022 and 2023 hosted by the partners of the DiadES project, however, initially this research has focussed on workshops held within the UK. Four DiadESland workshops were organised between December 2022 and March 2023 within the UK (England and Ireland). Stakeholders from fisheries management sectors including non-governmental organisations and charities, government agencies, management organisations, and education and research were invited to take part in playing the DiadESland game within a half-day workshop setting.

2.2. Questionnaire structure

The questionnaire in Annex A was developed to gather data regarding game players perceptions of the serious game as a training and development tool. Participants were asked to complete a questionnaire directly after completing game play to establish how the game has been received from a UK perspective. The questionnaire was available in both a digital and paper version and participants were given a set amount of time to complete it (no more than 20 minutes). A combination of both quantitative (Likert scale) and qualitative (open ended free text) question formats was included. One set of questions required participants to recall their current knowledge regarding the main challenges associated with sustainably managing stocks of diadromous fish pre- and post-game play. To support this, participants were asked to note down their initial thoughts prior to game play to be able to include in the questionnaire once game play was completed.

2.3. Data analysis

Quantitative data analysis of the Likert scale questions was undertaken using Microsoft Excel. A point system of 2 to -2 was assigned to the Likert scale of strongly agree (2), agree (1), neither agree nor disagree (0), disagree (1) and strongly disagree (-2). Descriptive statistical analysis was undertaken on the Likert scores to establish mean values and variability of responses for each statement and so determine if there was a tendency to agree or disagree with the statement. Due to the short answers given to open-ended questions, qualitative data analysis was also undertaken in Microsoft Excel. A content analysis using inductive data coding was undertaken on open-

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ended questions to establish key themes emerging from the participants answers. Themes were ranked in order of percentage of participants stating key themes within their responses.

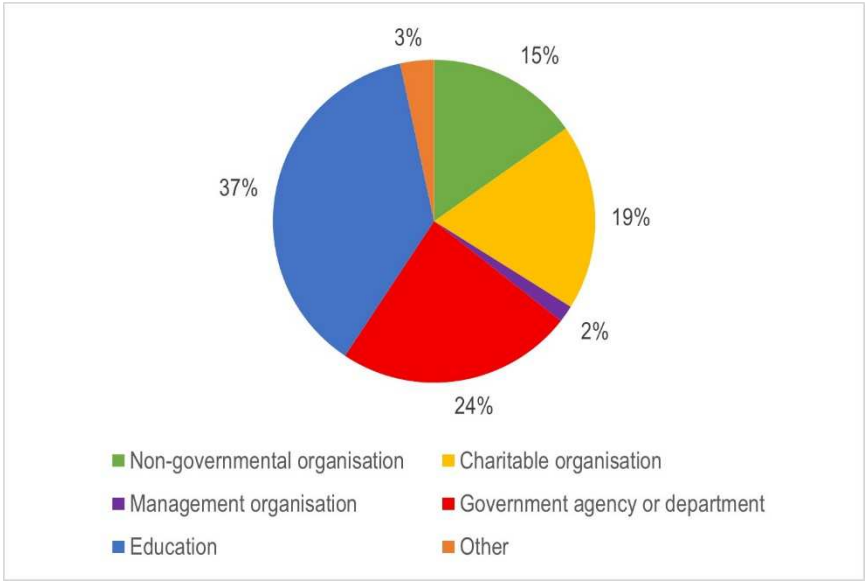
3. Results

3.1. Participant demographics

59 participants who took part in a DiadESland workshop within the UK and Ireland between December 2022 and March 2023 completed the 'DiadESland and knowledge exchange perception questionnaire'. 81% (n. 48) were based within the UK and 19% (n. 11) within Ireland. There was almost an equal contribution from participants who identified as men and women, 47% (n. 28) and 53% (n. 31) respectively.

Game play participants were from a diverse audience of stakeholders involved in the management of diadromous fish and who have already showed an interest in the DiadES project. The highest percentage of participants operated in the educational sector (37%, n. 22), with postgraduate students contributing to the highest proportion at 32% (n.19). 3% (n. 2) identified as an academic or scientist and 2% (n. 1) as a NGO or trust officer. 24% (n. 14) of participants came from a government agency or department with a variety of job roles (7% (n. 4) academic or scientist, 8% (n. 5) policy or decision makers, 3% (n. 2) consultant, 2% (n. 1) manager and 3% (n. 2) other). 19% (n. 11) of participants worked within charitable organisations (8% (n. 5) NGO or trust officer, 3% (n. 2) volunteer, 3% (n. 2) academic or scientist, 2% (n. 1) manager, 2% (n. 1) commercial fisher) and 15% (n.9) within NGOs (8% (n. 5) NGO or trust officer, 3% (n. 2) student, 3% (n. 2) academic or scientist). One participant (2%) worked within a management organisation as a commercial fisher and two (3%) participants identified with multiple roles (e.g., academic or scientist for a consultancy and angler, academic or scientist and NGO or trust officer for both an NGO and government organisation).

a.



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b.

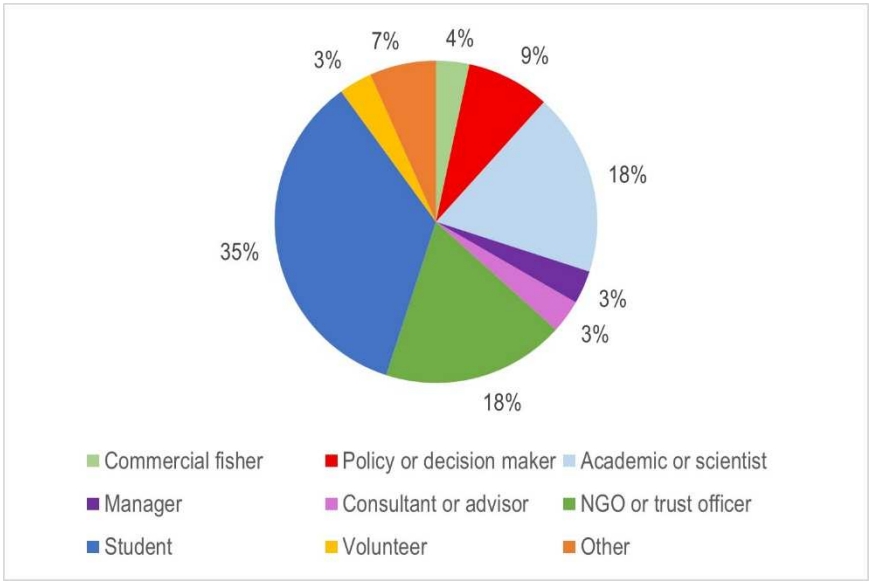

Figure 1. Composition of game play participants who completed the questionnaire by a. sector and b. job role.

3.2. Participant responses to Likert scale questions

Out of 59 participants, only one reported a negative total score on the Likert scale questions, indicating that 98% (n. 58) of participants had a positive perception of the game. As can be seen in figure 2 and 3, there was a tendency to agree with all statements and to strongly agree with statements *e. I would recommend this game to other stakeholders for knowledge exchange purposes* and *k. I enjoyed playing the game*. 59% (n. 35) of participants strongly agreed with statement *e that they would recommend the game to other stakeholders for knowledge exchange purposes*, with 36% (n. 21) agreeing and only 5% (n. 3) neutral. 73% (n. 43) of participants strongly agree with statement *k* regarding enjoying the game (24% (n. 14) agreed) with one (2%) participant disagreeing and no participants strongly disagreeing.

Statements *b. I have a greater understanding of other stakeholders' points of view from playing the game*, *h. I will discuss what I have learnt from the game with colleagues/other stakeholders* and *i. This game can help to guide policy development for the sustainable management of diadromous fish*, all have average Likert scores of 1 or above, indicating that the majority of participants agreed with the statements. 27% (n. 16) of participants strongly agreed with the statement regarding improved understanding of stakeholder viewpoints post-game play, with 64% (n. 38) of participants agreeing. 5% (n. 3) of participants had a neutral response with only 3% (n.2) of participants disagreeing with statement *b*. 30% (n. 18) of participants strongly agreed with statement *h* regarding discussion of what they have learnt from the game with colleagues or other stakeholders, with 59% (n. 35) of participants selecting they agreed with the statement. No participants selected a negative response to statement *h;* however, 10% (n. 6) of participants selected that they neither agreed nor disagreed. 68% (n. 40) of participants agreed with the statement *i* regarding the potential of the game supporting policy development, with 19% (n. 11) of participants strongly agreeing. 12% (n. 7) of participants neither agreed not disagreed with statement *i* and one (2%) participant strongly disagreed.

Statements *c. I have a greater understanding of the ecosystem services (benefits to humankind) of diadromous fish from playing the game*, *d. My perception of the challenges of sustainably managing diadromous fish species has changed since playing the game* and *g. I will apply what I have learnt from playing the game to my job role*, all had average Likert scores around 0.8 (0.83, 0.85 and 0.78 respectively) highlighting a neutral to positive response to these statements. Responses to statement *c* regarding improved understanding of ecosystem services post-game play had a varied response (SD +/- 0.91), with 22% (n. 13) of participants strongly agreeing, 49% (n. 29) agreeing, 20% (n. 12) neither agreeing nor disagreeing, 7% (n. 4) disagreeing and 2% (n. 1) strongly disagreeing. 17% (n. 10) of participants strongly agreed with statement *d* regarding changed perceptions of the challenges of sustainably managing diadromous fish post-game play, with 56% (n. 33) of participants agreeing with the statement.

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22% (n. 13) of participants had a neutral response to statement *d* and 5% (n. 3) of participants disagreed. 17% (n. 10) of participants strongly agreed with statement *g* regarding applying what they have learnt to their job role, with 51% (n. 30) of participants agreeing with the statement. 25% (n. 15) of participants had a neutral response to statement *g* with 7% (n. 4) of participants disagreeing.

Statements *a. I have a greater understanding of how climate change may affect diadromous fish species from playing the game*, *f. I will use the game in my workplace/with other stakeholders* and *j. The game is a good representation of reality - ecologically and socially connected* have the lowest average scores (figure 3) although still represent a neutral rather than negative response. 58% (n. 34) of participants agreed with statement *a* regarding improved understanding of climate change impacts on diadromous fish after game play and 14% (n. 8) of participants strongly agreed. However, 14% (n. 8) of participants disagreed with statement *a* with one (2%) participant strongly disagreeing. The remaining participants had a neutral response (14%, n. 8). 27% (n. 16) of participants had a neutral response to statement *f* regarding use of the game in their workplace, however, 17 % (n. 10) and 46% (n. 27) strongly agreed and agreed respectively. 10% (n. 6) of participants disagreed with statement *f*. 10% (n. 6) of participants strongly agreed with statement *j* regarding the game being a good representation of reality, with 32% (n. 19) agreeing. 17% (n. 10) of participants had a neutral response with 5% (n. 3) disagreeing and strongly disagreeing (3% (n. 2) and 2% (n. 1) respectively) that the game was a good representation of reality.

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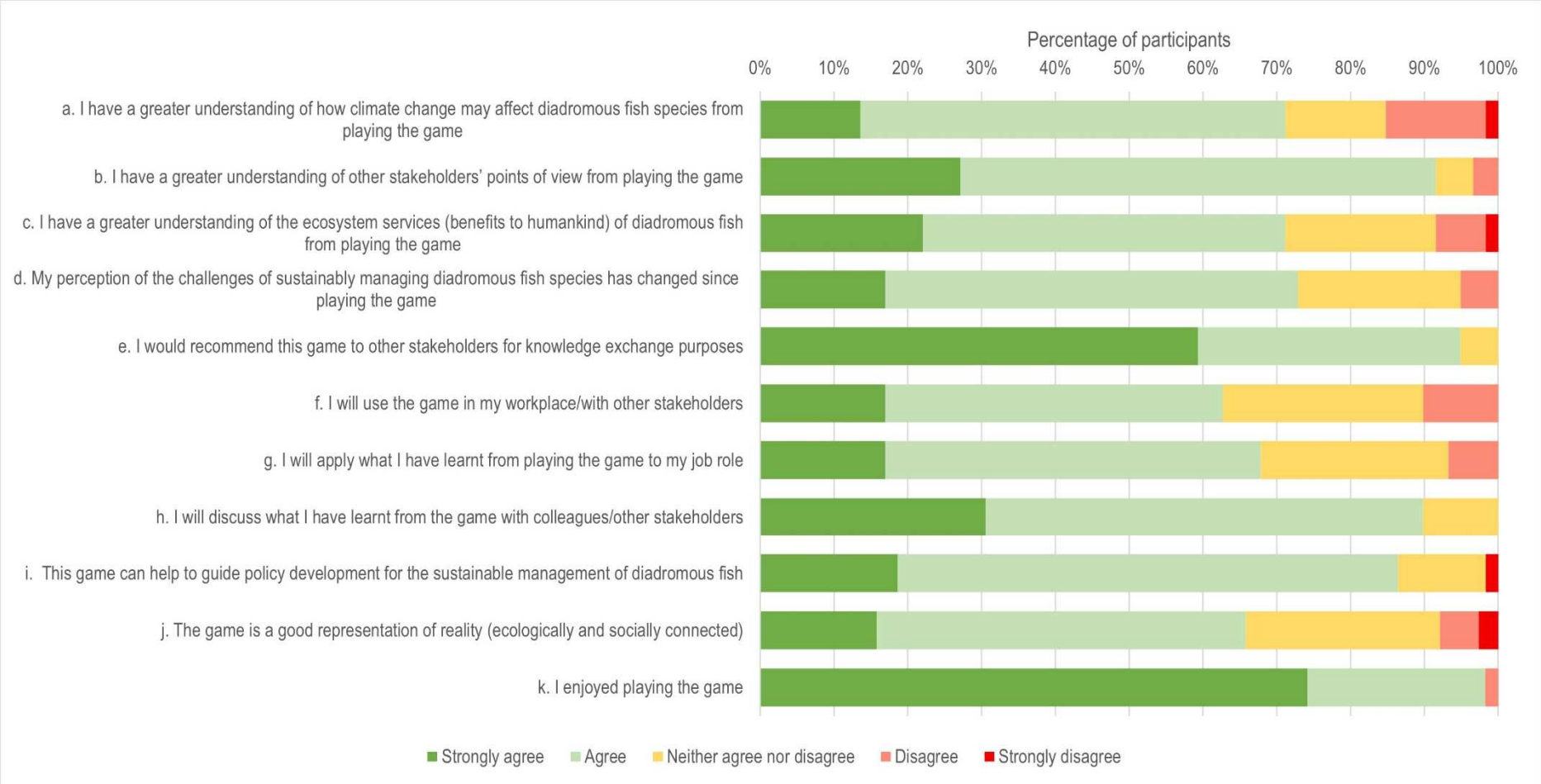

Figure 2. Bar chart illustrating mean response for the eleven Likert-style questions relating to statements regarding the playing and use of serious games, specifically DiadESland.

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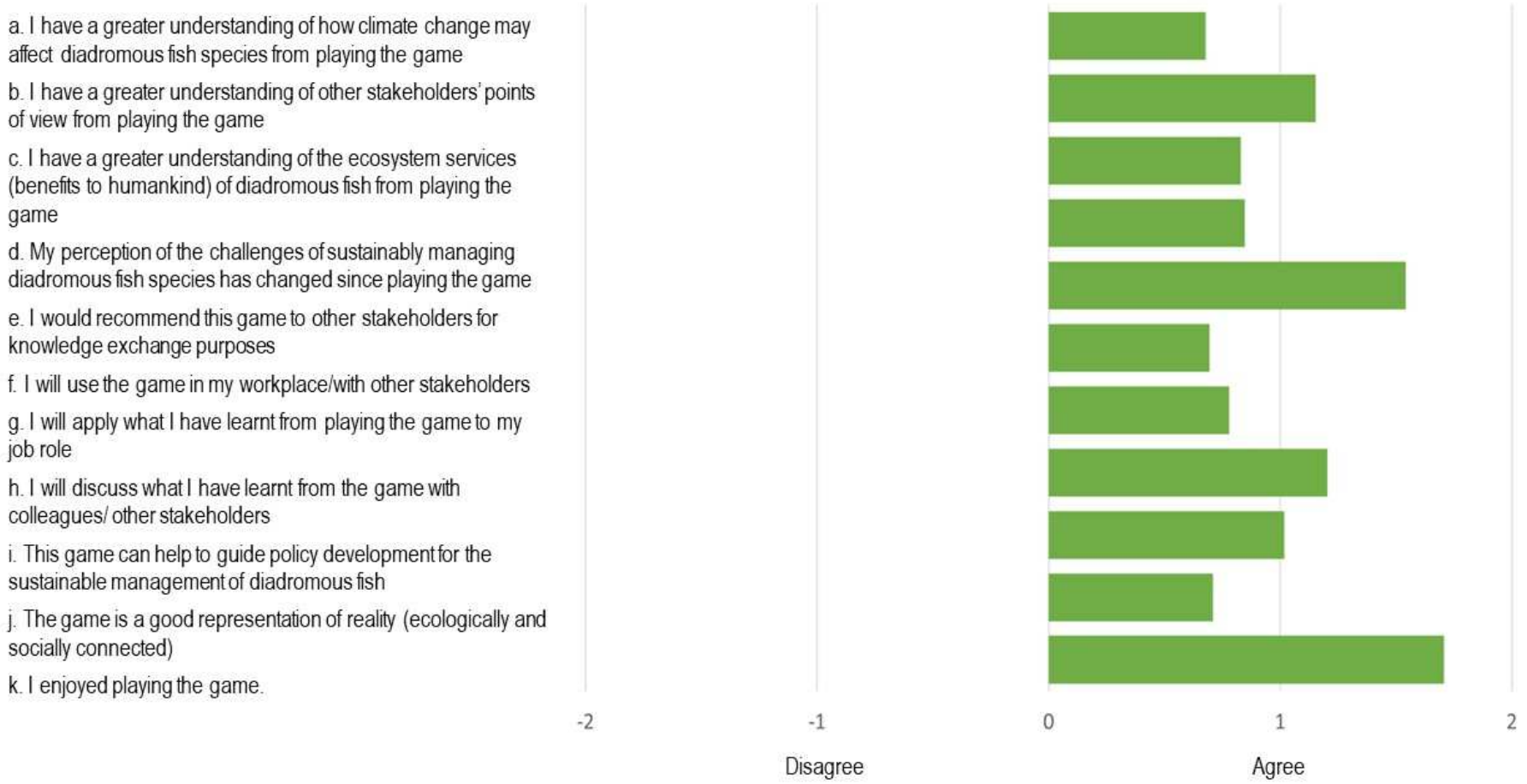

Figure 3. Bar chart illustrating mean response for the eleven Likert-style questions relating to statements regarding the playing and use of serious games, specifically DiadESland.

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3.3. Content analysis of free text questions

Eight key themes (table 1) were identified from the content analysis of questions four and five relating to participant perceptions of the main challenges in sustainably managing stocks of diadromous fish pre- and post-game play (figure 4).

Table 1. Theme descriptions for questions four and five relating to participant perceptions of the main challenges in sustainably managing stocks of diadromous fish pre- and post-game play established from content analysis.

Theme	Description
Management measures	Topics in relation to various management approaches came under this theme, such as decision-making processes, difficulties with management of species and ecosystems, management of connectivity between migration routes, differences between catchments.
Anthropogenic pressures	Participants either used the exact phrase 'anthropogenic/human pressures' or gave more specific examples such as: exploitation of fish stocks, habitat loss, pollution water quality decline and agricultural runoff.
Collaboration/communication between stakeholders	This theme was initially a subheading under management measures, however, became a distinct theme due to frequency of use of these specific terms.
Climate change	Where participants specifically mentioned climate change as a main challenge of managing diadromous fish stocks.
Biological/ecological factors	This theme encompasses the biological or ecological requirements and thresholds of diadromous fish.
Knowledge/scientific understanding	This theme included statements regarding a lack of knowledge or research of diadromous fish species was a main challenge in sustainably managing stocks of diadromous fish.
Regulation/enforcement	This theme was initially a subheading under management measures; however, participants were using the exact phrases of enforcement and regulation separate to their discussion around management measures.
Unpredictability	This theme was initially labelled as 'other' however, all statements used synonyms of unpredictability, although did not give further explanation.

The theme that was stated most frequently both pre- and post-game play (80% (n. 47) and 78% (n. 46) respectively) related to improvement of management strategies of diadromous fish. Pre-game play, anthropogenic pressures were the next highest theme discussed with 61% (n. 36) of participants mentioning it however, post-game play this dropped to 17% (n. 10). Post-game play both collaboration and/or communication between stakeholders and climate change were more frequently mentioned in response to main challenges of sustainable diadromous fish management (66% (n. 39) and 58% (n. 34) respectively). Pre- game play both these themes were only mentioned by 37% (n. 22) of participants.

> *"In addition to my previous knowledge, I now have a better understanding of the importance of Cultural and Provisional activities to stakeholders. Formerly I mostly considered the ecological impact of human activities and conditions on species"*
>
> Participant ID 4

> *"Same as before the game but now more focussed, it's still challenging but now I know what the challenges are e.g. management of people, conflicting demands, unpredictable circumstances"*
>
> Participant ID 8

> *"Understanding other points of view, trying to be unbiased in your approach"*
>
> Participant ID 29

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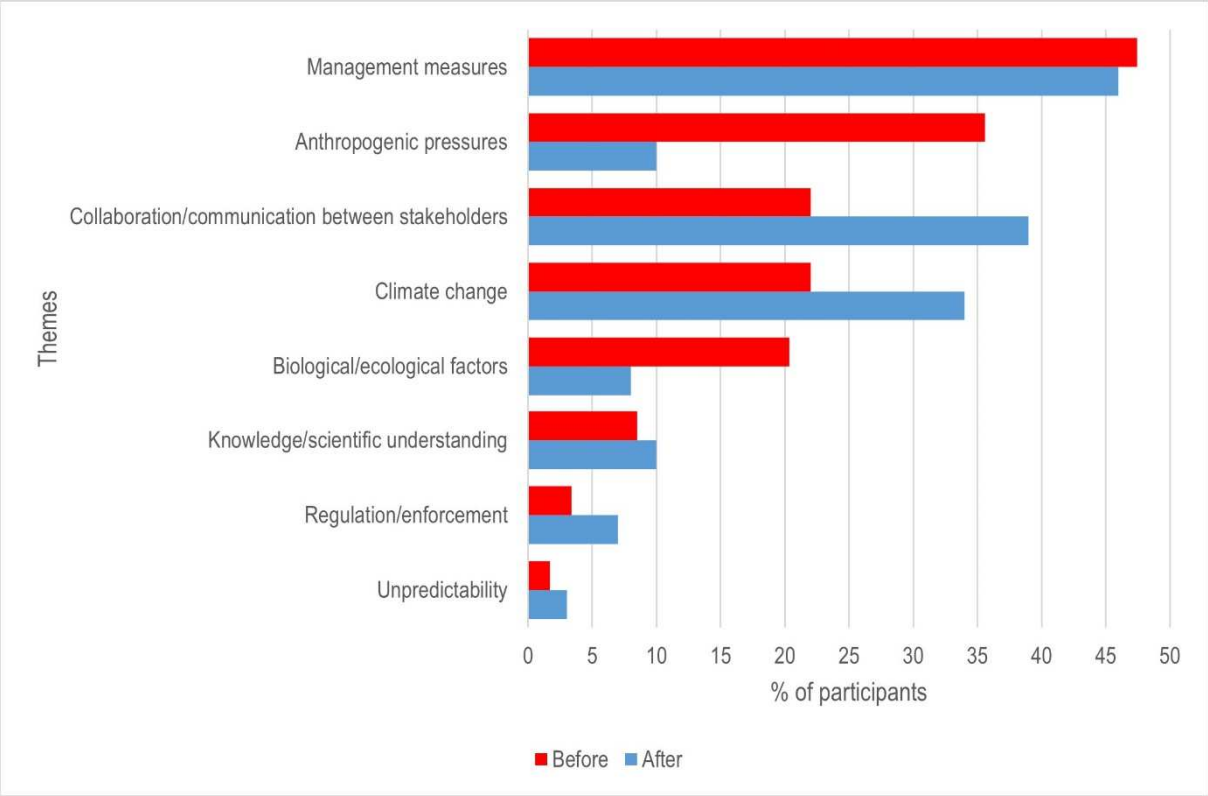

Figure 4. Bar chart representing key themes from participant responses to free text question "What key words or phrases summarise your perception of the main challenges associated with sustainably managing stocks of diadromous fish?" both before and after game play.

Two key themes emerged from question six (figure 5) as most frequently stated regarding specific actions participants could take to ensure the sustainable management of diadromous fish after post-game play were collaboration and/or communication between stakeholders (36%, n. 21) and management measures (25%, n. 15).

> *"Ensuring policies and planning applications relating to the statutory marine plans consider the intersection between marine and freshwater habitats"*
>
> Participant ID 8

> *"Don't make management plans to benefit a species only, as it would probably be detrimental for another one. Ecosystem based approaches are much more successful"*
>
> Participant ID 12

> *"Communicate aligned objectives despite different aims"*
>
> Participant ID 14

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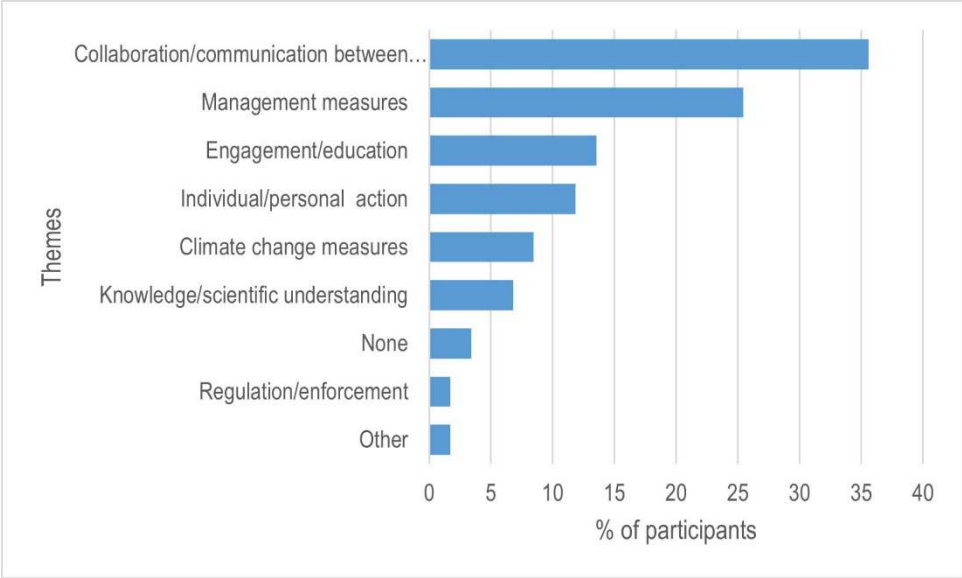

Figure 5. Bar chart representing key themes from participant responses to free text question "Are there any other specific actions you could take to ensure the sustainable management of diadromous fish after playing this game?"

Two key themes were frequently stated as the most important messages for participants to come out of playing the game and were consistent with previous questions (figure 6). The two key themes were in relation to collaboration and/or communication between stakeholders (78%, n. 46) and management measures (76%, n. 45).

> *"Hard to play fictionally if [it] conflicts with your core values. Collaboration is best when explaining benefits to others. Management can have wider unintended benefits"*
>
> Participant ID 7

> *"Even the most thought-out and evidence-backed approaches are not completely robust, circumstances can change and dramatically impact outcomes beyond what you thought; everyone collaborating is not always the best approach, regional collabs can reduce conflict over national; an asteroid will probably kill us all anyway so do the best you can with the resources you have but you can only do so much and it's not worth killing yourself over"*
>
> Participant ID 8

> *"All sectors should be included. Traditional fishermen are being wiped out and with them the knowledge"*
>
> Participant ID 36

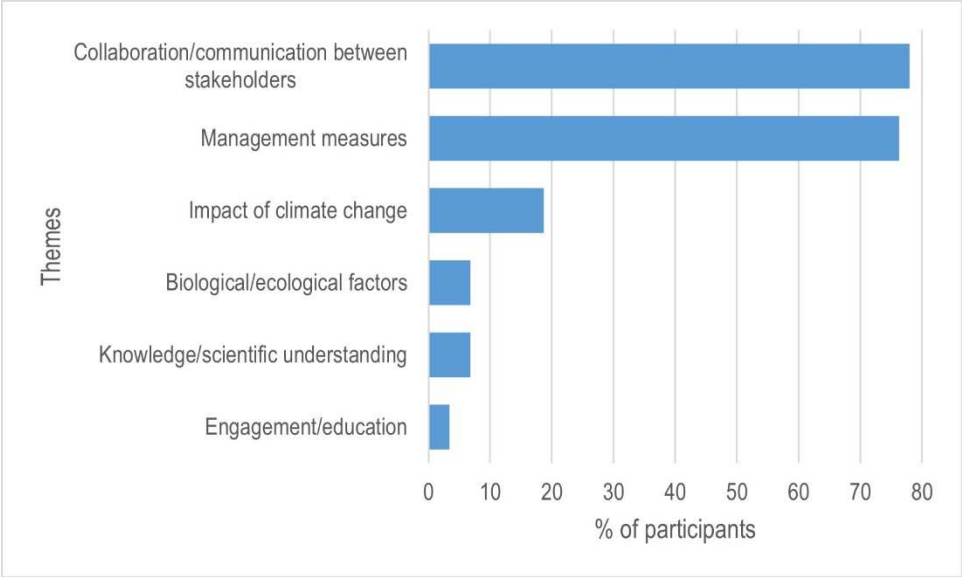

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Figure 6. Bar chart representing key themes from participant responses to free text question "What are the three most important messages for you to come out of playing this game?"

When answering question eight (figure 7) participants gave 'game development' suggestions (27%, n. 16) and 'widening the scope of the workshop audience' (20%, n. 12) as specific actions the project could take to implement and/or convey the important messages they had identified in question seven.

> *"A clear summary of research to engage greater range of stakeholders, not just complex scientific reports"*
>
> Participant ID 2

> *"Widen the game players to outside the usual suspects, what about a general public game to widen the understanding outside of practitioners? Don't be afraid to play the game with decision makers"*
>
> Participant ID 10

> *"Get bigger stakeholders like governmental people to play the game"*
>
> Participant ID 28

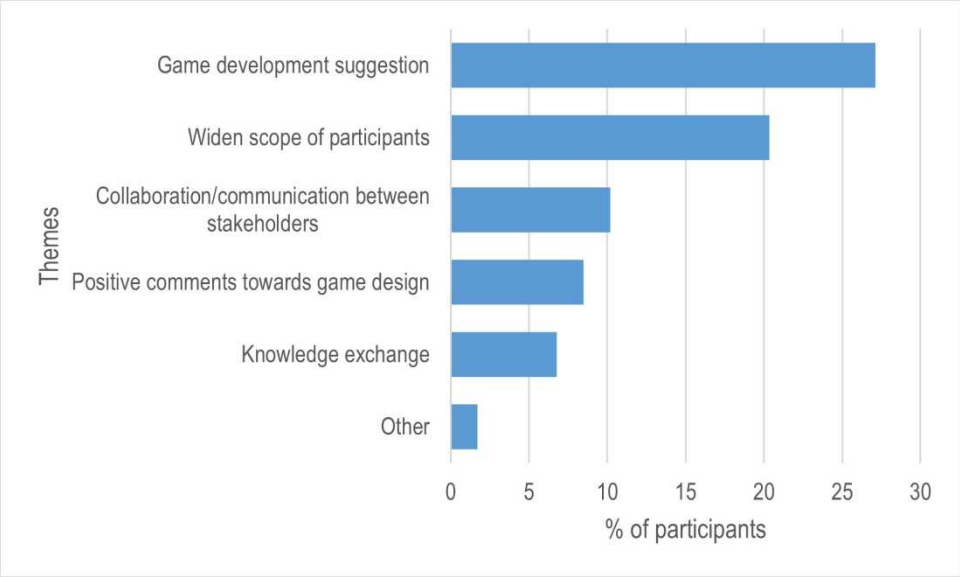

Figure 7. Bar chart representing key themes from participant responses to free text question "Are there any other specific actions the project can take to implement and/or convey the three important messages that you mention above?"

The final question (figure 8) asked participants to provide any additional comments regarding game play and design. 85% (n. 50) of participants chose to answer this question, with 37% (n. 22) providing positive comments towards the game and 24% (n. 14) providing game development suggestions.

> *"I have really enjoyed it! [I] was a little nervous as I have no fish ecology knowledge but this didn't hinder game play, would love the concept to be widened to a catchment management application so that for instance you play fish restoration, against water company activity, against tidal lagoon, i.e. take an actual catchment with a real problem and use a large group of stakeholders in the catchment to see if you can influence people to consider others perspectives!"*
>
> Participant ID 10

> *"The mortality rates for tropics should better reflect their tolerance to warmer water...i.e. their mortality should reduce as temperatures increase, at least initially"*
>
> Participant ID 11

> *"Lots of workshops claim to have fun activities which turn out to be not that fun. This game is actually fun and replicates real world scenario. I think it is genius"*

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Participant ID 16

"Really got me thinking beyond my area of expertise"

Participant ID 18

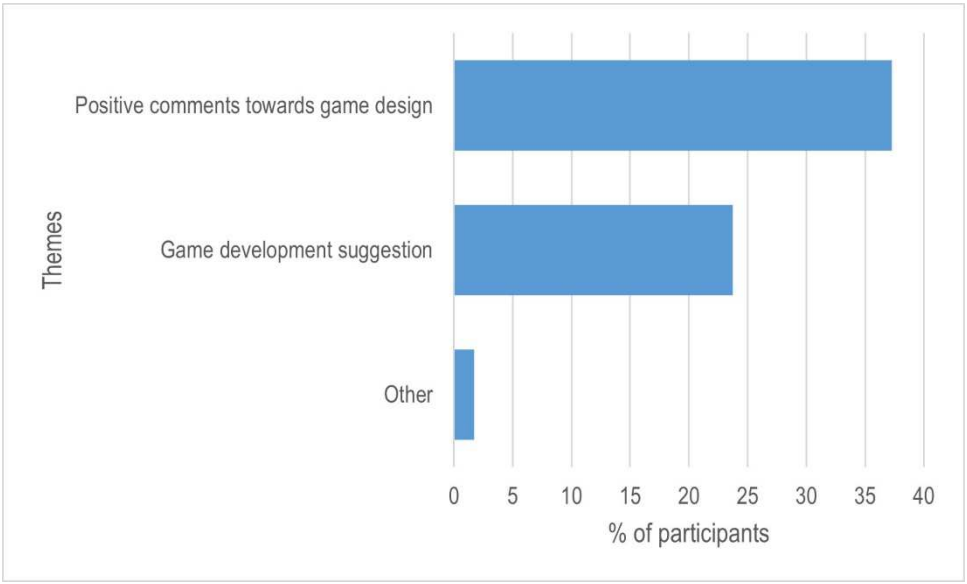

Figure 8. Bar chart representing key themes from participant responses to free text question "Please provide us with any other comments you have about playing the game."

4. Discussion

4.1. Perceptions and experience

Overall, DiadESland was exceptionally well received by game participants with 96% (n. 57) stating they either agreed or strongly agreed with enjoying their game experience. The enjoyment factor was highlighted further by 90% (n. 53) of the participants stating that they strongly agreed or agreed with sharing their experience with colleagues. Additionally, 98% (n. 58) of participants scored a positive total score for the Likert scale statements further indicating a positive perception of the game. In general, there was a tendency to agree with all Likert scale statements and to strongly agree with statements relating to game enjoyment and recommending the game to other stakeholders. Enjoyment is a key element to participants learning and engaging with the subject matter to be able to take things forward in their own practice (Ab Jalil et al., 2020; Barbosa et al., 2014; Laamarti et al., 2014).

The percentage of participants willing to play the game with colleagues or other stakeholders was positive overall although reduced, with 63% (n. 37) either agreeing or strongly agreeing. There could be many reasons why serious games may not be repeated or shared extensively including: lack of awareness, accessibility issues, promotion and marketing, lack of engagement or incentives, effort of game play, context-specific content, limited reply value and cultural and language barriers (Krath et al., 2021; Laamarti et al., 2014; Merilampi et al., 2018). The game designers of DiadESland took many of these elements into consideration when designing the game, specifically with regards to producing an engaging experience for game players that can be repeated due to the quantity and variety of action cards which allows for different options and decisions to be made each game. Additionally, DiadESland has a very specific target audience therefore awareness, promotion and marketing and context-specific content were not issues with regards to sharing of the game. Some elements which may contribute to participants not wishing to replay DiadESland with colleagues could be linked to incentives and game play effort. Incentives play a crucial role in encouraging users to repeat or share serious games. If there are no compelling rewards, recognition, or benefits associated with replaying or sharing the game, users may not find enough motivation to do so (Connolly et al., 2012). Additionally, DiadESland requires at least five players plus, a games master and possible games observer. Organising an event where a minimum of seven participants are present could be seen as a limiting factor within busy industry settings.

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4.2. Learning and outcomes

A fundamental outcome of all serious games is that of learning and development of understanding around a subject matter (Barbosa et al., 2014). In the questionnaire, two key areas of learning were of focus: improved understanding and the application of learning. Unfortunately, it can be difficult to assess learning in a one-off scenario (Serrano-Laguna et al., 2018), however, key questions were used to establish participants perceptions of their learning and what take away messages and actions, if any, they are wanting to take forward.

Four statements relating to the development of understanding around various aspects of climate change and sustainable management of diadromous fish were put forward, with one including follow up open free text questions for participants to demonstrate knowledge before and after game play. Between 71% (n. 42) and 91% (n. 54) of participants either agreed or strongly agreed with each of the four statements regarding improved understanding of various topics post- game play (climate change effects on affect diadromous fish species: 71%, n. 42; stakeholder viewpoints: 91%, n. 54; ecosystem services of diadromous fish: 71%, n. 42; and challenges of sustainably managing diadromous fish: 73%, n. 43). As demonstrated here, serious games support knowledge development by actively engaging participants, providing experiential and contextual learning opportunities (Laamarti et al., 2014).

DiadESland is a collaborative and discussion-based serious game. Many serious games incorporate this element of multiplayer or collaboration, allowing participants to work together towards a common goal (Tran & Biddle, 2008). Collaboration and/or communication between stakeholders was the top theme to emerge from two questions within the DiadESland questionnaire relating to i) the most important messages for participants to come out of the game (78%, n. 46) and ii) specific actions participants could take to ensure the sustainable management of diadromous fish (36%, n. 21). Reasoning behind this was not solely on promoting collaboration post-game play but also the importance of it during game play and the learning that developed by varying stakeholders coming together and communicating. A diverse range of stakeholders involved in the management of diadromous fish or who had an interest in the DiadES project participated in the four UK based DiadESland workshops. However, as stated by 20% (n. 12) of the participants, the game would benefit from being shared more widely by inviting stakeholders from the public to high-level policy advisors. By promoting collaboration, communication, and teamwork, serious games encourage social learning and the exchange of knowledge among stakeholders (Tran & Biddle, 2008). Improving the knowledge of stakeholders initially supports informed decision making however, research has shown that the benefits can have a wider impact by improving communication, participation, risk management, trust, empowerment, and adaptability. It contributes to the success and effectiveness of organisations, projects, and initiatives, fostering a culture of continuous learning and improvement (Medema et al., 2016). When stakeholders have a good understanding of the issues at hand, they are more likely to actively participate in discussions, planning, and implementation processes. Their active involvement leads to more comprehensive and well-rounded decision-making and implementation (Tran & Biddle, 2008).

With regard to the game supporting the development of fishery management policy, 86% (n. 51) of participants either agreed or strongly agreed with the statement. Additionally, policy and management strategies was a top theme in three of the free text questions, specifically in relation to actions participants could take to ensure the sustainable management of diadromous fish (25%, n. 15), the most important messages to come out of playing the game (76%, n. 45) and the main challenges in sustainably managing stocks of diadromous fish pre- and post-game play (80%,n. 47 and 78%, n. 46, respectively). Key terms that were frequently used related to resilience, sustainable and adaptive management. Serious games can be a valuable tool for the development of management strategies and policy by simulating complex and realistic scenarios that stakeholders might encounter in their various roles. By engaging in these simulated scenarios, stakeholders can develop their critical thinking skills, improve their ability to analyse situations, and practice making strategic decisions to apply to real life scenarios (Medema et al., 2016; Souchère et al., 2010).

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4.3. Next steps

When given the opportunity to provide additional comments, 85% (n. 50) of participants chose to do so, with 37% (n. 22) providing positive comments towards the game and 24% (n. 14) providing game development suggestions. The main themes in the feedback regarding game development were suggestions for more time and space to discuss game strategies and decisions, further explanations during the game with regards to game mechanics, and a desk organiser for the catchment's tokens and action cards. Due to the demand from organisations, another 150 DiadESland game boxes are being printed. This 2.0 paper version has addressed comments from participants and includes new designs to support understanding of game mechanics (graphs representing the thermal preferences of each species for example). Additionally, a tutorial for playing the physical game was put online on the DiadES YouTube Channel to allow more Game Masters and Observers to be trained. One participant did suggest an online version of DiadESland, which is in development and will be launched before the end of 2023. The online version will further support some of the suggestions for games development which participants put forward within the questionnaire. The online version will allow for participants from across the world to play the game together and support the development of collaboration opportunities, shared knowledge, and improved communication between stakeholders. However, as presented above, participants valued the collaboration and interactivity opportunities between game players the in-person game allowed for. A key element of the online game will be preserving the ability to interact and discuss with all game players, via online chat functions.

Finally, with regards to development of this research, it would be beneficial to develop the questionnaire further to include free text questions to ascertain reasoning for scoring statements. Thematic analysis of perception statements would support a deeper analysis of participant decision making and behaviour.

5. Conclusion

Serious games continue to evolve and find applications in diverse fields, including education, healthcare, government, environmental management, and social impact. They are recognised as valuable tools for learning, behaviour change, and management and policy development. Serious games provide a dynamic and interactive approach to support policy development by promoting engagement, collaboration, experimentation, and systems thinking. By harnessing the power of gamification, policymakers can enhance their decision-making processes, improve policy outcomes, and increase public participation in shaping the policies that affect their lives.

DiadESland has been successful in supporting stakeholder engagement, communication and learning with regards to diadromous fish. It has supported the development of policy by providing insights into stakeholder's requirements and needs and creating a shared interest and discussion around the management of diadromous fish at the large-scale and on the long-term. There is now a cohort of stakeholders familiar and engaged with the serious game DiadESland who are keen for it to be shared with a wider audience. The organisations, from which many of the stakeholders originate, have been provided with or can request a copy of the DiadESland serious game. Additionally, with the launch of the new online version, this can happen more widely and support the discussion around diadromous fish management further.

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7. Annexes

7.1. Annex A - Questionnaire

DiadESland and Knowledge Exchange Perception questionnaire

What was the date and location of the DiadESland workshop you attended?

Perceptions

1. Please read the statements in the table below and tick the options that you most agree with.

	Strongly agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
a. I have a greater understanding of how climate change may affect diadromous fish species from playing the game.					
b. I have a greater understanding of other stakeholders' points of view from playing the game.					
c. I have a greater understanding of the ecosystem services (benefits to humankind) of diadromous fish from playing the game.					
d. My perception of the challenges of sustainably managing diadromous fish species has changed since playing the game.					
e. I would recommend this game to other stakeholders for knowledge exchange purposes.					
f. I will use the game in my workplace/with other stakeholders.					
g. I will apply what I have learnt from playing the game to my job role.					
h. I will discuss what I have learnt from the game with colleagues/other stakeholders.					
i. This game can help to guide policy development for the sustainable management of diadromous fish.					
j. The game is a good representation of reality (ecologically and socially connected).					
k. I enjoyed playing the game.					

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1. What key words or phrases summarise your perception of the main challenges associated with sustainably managing stocks of diadromous fish **before playing the game?** **See your reflection notes prior to playing the game**

2. What key words or phrases summarise your perception of the main challenges associated with sustainably managing stocks of diadromous fish **now that you have played the game**?

3. Are there any other **specific actions you could** take to ensure the sustainable management of diadromous fish after playing this game?

4. What are the **three most important messages** for you to come out of playing this game?

5. Are there any other **specific actions the project** can take to implement and/or convey the **three important messages** that you mention above?

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6. Please provide us with any **other comments** you have about playing the game.

Participant demographics

Please complete the following information to aid the analysis of the questionnaire data:

8. In which country do you live and work?

€ United Kingdom
€ Ireland
€ France
€ Spain
€ Portugal
€ Other _____

9. What is your current role?

€ Commercial fisher
€ Angler
€ Policy or decision maker
€ Academic or scientist
€ Manager
€ Consultant or advisor
€ NGO or trust officer
€ Student
€ Other_____

8. Which type of organisation or sector do you work in?

€ Non-governmental
€ Charitable
€ Management
€ Government agency or department
€ Education
€ Other_____

9. Gender (please circle): Male Female Other

10. Age (please circle): 18-30 31-45 46-55 56-65 65+

Follow up communication

This project is co-financed by the Interreg Atlantic Area Programme through the European Regional Development Fund.

To assess the impact of knowledge exchange from DiadES it is important for us to be able to follow up with further communication with participants. If you are willing to be contacted again please provide your contact details below (your data will remain anonymous):

Name:_____

Phone number:_____

Email address:_____

☐ I would like to receive the final report related to this research

Thank you very much for your participation

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