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Aqua: Leveraging Citizen Science to Enhance Whale-Watching Activities and Promote Marine-Biodiversity Awareness

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Abstract: Life-supporting ecosystems are facing impending destruction. The human–computer interaction (HCI) community must rethink how to design technological interventions that reconcile concepts and theories for ecological computing. Proponents of sustainable HCI have pushed for tools and systems that aim to decenter the human in a shift toward posthuman design—a theoretical approach that challenges the assumption that only humans are stakeholders of technology as it increasingly shapes the future. Building on the iconic value of whales and the economic impact of whale watching as a form of ecotourism, we developed Aqua, a digital tool that leverages the potential of citizen science to engage tourists in marine-biodiversity awareness and conservation. This manuscript is advancing the field of sustainable HCI and tourism applications in two ways: first, we deliver an artifact contribution by designing and implementing a digital tool to enhance whale-watching activities. Second, we offer an empirical research contribution through observation and data gathering while comparing participants' experiences of a whale-watching trip with and without the digital tool. Finally, preliminary insights are provided to inform the design of future digital tools aimed at promoting environmental conservation and citizen-science approaches among tourists. This work presents progression in understanding and informs the design of digital tools to engage tourists in novel and sustainable experiences.

Keywords: sustainable HCI; citizen science; tourism experience; design; marine ecosystem; user experience

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1. Introduction

> *"for there is no folly of the beast of the earth which is not infinitely outdone by the madness of men"* Herman Melville, Moby Dick

One of the most iconic novels in modern literature, *Moby Dick*, describes an intrinsic and irresistible inter-dependency between humans and nature [1]. Recent years have seen a rise in human-computer interaction (HCI) research aimed at improving our understanding of the interactions between nature and humans to support more sustainable interactions with our environment [2,3]. The concept of non-anthropocentrism in HCI [4–6] encourages alternate design paradigms that can respond to the environmental crisis and sustain both human and non-human life. Lawrence and Philips [7] propose that whale watching is a crucial example of economic activity emerging from the radical changes in the societal understanding of nature and animals [8]. Humans have been hunting whales since the

beginning of history. However, it was not until the 1930s that international regulations were developed to manage oversupply and, later, over-exploitation. Bruno Latour argues that human–whale entanglements are a demonstration of a more general transformation of society referred to as "ecoligisation" [8] (a hybrid world in which the co-production of humans and non-humans is constantly renegotiated) [9]. Whales are, thus, prime examples of non-human actors, individualized in their "actor-hood" and acquiring "personalities," which have become increasingly plausible [10]. Indeed, whales are probably one of the prime examples of non-human "actants" in the fabric of contemporary western societies [8]. Interactions with cetaceans have been the stage of major socio-economic, cultural, and historical transformation. This transformation can be said to characterise new epochs (see Figure 1) [11].

The whale-watching industry is now reaching 13 million people worldwide (and is conducted in more than 119 countries) and accounting for more than USD 2 billion in revenue [12]. Whale-watching activities are today known to engage people with nature and cetaceans. In particular whale-watching operators can play a vital role in transmitting ocean conservation messages to tourists [13–15]. However, it is an activity remains costly for participants. These often do not even see the full size of the cetacean during the whale-watching trip, resulting in the observation of only dorsal fins and some frustration. In an attempt to satisfy their clients, vessels sometimes linger in the proximity of the animals and approach them. At the same time, the proximity of the sea vessels stresses the cetaceans and damages their habitat [16]. However, it has been demonstrated that ecotourists can play a crucial role in motivating tour operators to comply with the High Quality Whale Watching label and the Code of Good Conduct to "see animals in a respectful manner" [17]. One of the underlying motivations that inspired this work is the need to support a change in the whale-watching paradigm [16]. We want to help forge a new type of whale watcher who knows what species will be encountered and has realistic expectations about what they are likely to see. Participation in informative whale-watching tours can raise tourists' environmental awareness and render them more willing to play an active role in conservation efforts [18]. The other motivation is how non-traditional data sources, such as citizen-science data, can be a solution to producing relatively accurate estimates of cetacean abundance and distribution. These can be used to implement new protection and conservation measures [19–22].

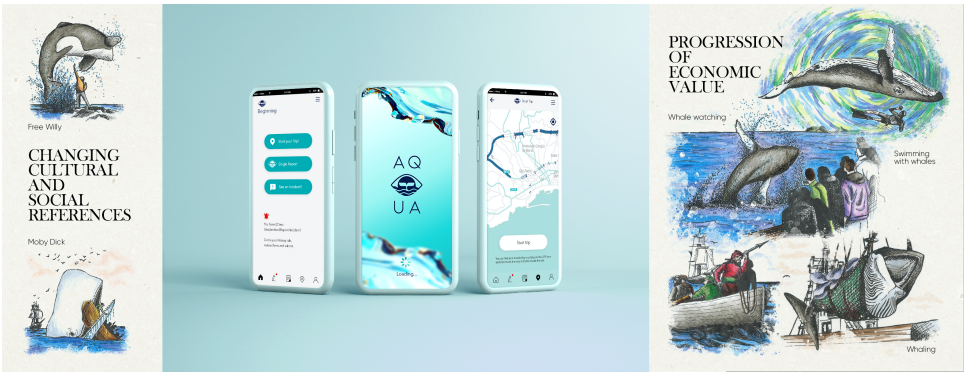

Figure 1. Aqua mobile application at the center of the social and cultural and economic evolution of whales in modern societies.

Research Questions and Contributions

In HCI research, sustainability and ecological concerns are typically framed as: "a psychological problem of bad habits" where the usual solution is to motivate and inform people to act pro-environmentally [23]. Instead, we propose using technology to enhance whale watching and promote the active participation of the observers, increasing their engagement with nature and opportunistically leveraging citizen science. This work leverages the fact that mobile devices are an indispensable tool for tourists to plan their

activities and collect memories of their trips. One of the most natural things tourists do during whale-watching trips is to use their mobile phones to take pictures of the cetaceans.

The mobile application Aqua supports a wide variety of users, providing: (i) tourists and whale-watching enthusiasts with additional information and scientific curiosities about species that can be sighted; (ii) whale-watching staff and marine biologists an effective digital tool to collect data on sightings, and (iii) opportunities for both groups to contribute as citizen scientists in collecting and reporting scientific data about the animals and their positions and learn characteristics of the encountered species. While, in this manuscript, we focus on an evaluation of Aqua during touristic whale-watching activities, the app can be used to support marine biologists and local recreational boat riders in reporting cetacean sightings that otherwise would have been carried out on paper. Consequently, we posited that Aqua serves multiple goals: (1) Supports data collection from experts and non-expert whale-watching-tour participants and staff; (2) Improves participants' sense of agency and satisfaction even when a sighting is partial or very distant, minimizing the need for the vessel's approach as a way to please the clients. [11].

Following this approach, the research described here addresses the following research questions:

- **Research Question 1 (RQ1):** Can we enhance the whale-watching experience with a digital tool that supports reporting of sightings and opportunistic citizen science?
- **Research Question 2 (RQ2)**: To what extent can a digital tool enhance the nature connectedness of those who engage in ecotourism activities?
- **Research Question 3 (RQ3)**: Can a whale-watching digital tool influence the marine-biodiversity awareness of ecotourists?

As interest within the HCI community expands beyond urban settings, novel tools and devices are being developed to support more sustainable interactions with natural environments and inform conservation action. Yet, little is known about the users' experience and how their requirements and priorities might affect the usability or operationalization of these tools in the real world [24]. Filling this gap, the contributions [25] of this paper are threefold. First, we deliver an artifact contribution by designing and implementing a digital tool to enhance whale-watching activities. The artifact is described in a detailed way so that future researchers can learn from it, not only in terms of what works but also in terms of what did not work. Second, we offer an empirical research contribution through observation and data gathering while comparing participants' experiences of a whale watching-trip with and without the digital tool. Thirdly, we provide a methodological contribution by simultaneously evaluating the Aqua technology-enabled experience and nature engagement. The evaluation produced new knowledge in the field of HCI and citizen science applied to the tourism industry. We believe this is the first step in understanding and informing the design of digital tools that promote nature engagement in real-world settings.

2. Related Work

Environmental sustainability is one of the fastest growing areas of activity in technology-related research. As HCI research engages with computing technologies to promote environmental conservation and ecological consciousness [23], research on technology usage in aquatic settings remains scarce in the HCI literature. The main efforts can be found in the visualizations of ocean-related phenomena [26–28], interactive installations [29,30], or games [31]. The following sections provide a comprehensive review of the main HCI concepts and studies related to ecotourism and environmental protection, citizen science, and applications to ecocentric design.

2.1. Ecotourism and Citizen Science

Ecotourism means visiting natural destinations responsibly and sustainably [32]. Its purpose is to educate tourists about conservation efforts while also providing opportunities for them to enjoy nature [33]. The current literature stresses the importance of considering

the tourism experience and tourist motivations, which include hedonistic pleasure, learning, escape, relaxation, and purposeful engagement [34]. Tourist expectations and needs must feature in participant design with extrinsic and intrinsic motivational factors incorporated into recruitment strategies [35].

Citizen science (CS) can be described as a type of collaborative research involving the gathering of data, where there is the engagement of expert researchers, amateur researchers, and non-experts such as the local community or visitors [36] who voluntarily collect, categorize, transcribe and analyze scientific data [37]. The purposes of citizen science can be very diverse, as they depend on the goal of the project, but they are often related to environmental concerns [38,39]. These can include observing and counting the number of species in some locations, listening and classifying the sounds of animal species [40], and gathering data to better understand a specific phenomenon [41]. Other projects such as Nature Watch produce digital content to promote awareness of the natural environment [42]. Research shows that citizen scientists involved in biodiversity monitoring and other nature-related activities tend to have higher connectedness to nature than the average citizen [43–45]. Hence, one way to provide novelty to ecotourism is to involve visitors in citizen-science projects. Nowadays, interest and resources are increasingly directed towards this approach [46]. On the other hand, the literature debates the effectiveness and negative impacts of citizen science [47]. Despite the usefulness, scalability, and low cost of citizen science, some scientists have contested the accuracy of the collected data for several reasons: specifically, when the level of complexity of the problem is high [48]; the knowledge to complete the data, by the citizens, does not match the user expertise [49]; there is a lack of training instructions [50]; technology exclusion; and length of time to obtain results or lack of impact [47]. However, the evaluation of marine and coastal citizen-science programs shows that citizen-science results are an underused tool [51], as citizen scientists often provide insights that can go unnoticed by professional field researchers [52,53]. Furthermore, it has emerged that there is potential in engaging tourists–scientists, as this is a heterogeneous group that seeks experiences ranging from superficial to profound [54]. Citizen-science projects must encourage and support this diversity [55] by including different levels of participation [54]. Furthermore, since training and education are essential for citizen science [56,57], tourists need to understand research objectives, collect accurate data and understand the intended outcomes. For these reasons, well-designed protocols are crucial to facilitate participation and engagement. As we were reviewing the literature and guidelines for overcoming CS challenges, it was important to remain critical, as one of the prevalent themes is the current lack of evaluation of the system's impact on the communities who used them in the context of environmental, digital citizen science [58–60]. Evaluating this impact can provide helpful information for the HCI community regarding system design [60] and nature connectedness. Part of our contribution lies here, as we assess our citizen-science approach from the perspective of the target users.

2.2. Sustainable HCI

The trend of decentering the human and including non-humans, such as plants, animals, and the environment in collaborative design, is being discussed among HCI researchers, designers and philosophers [4,61]. From human–computer biosphere interaction (HCBI) [62] to more than human concerns [4,63,64] and ecocentric design [65], the basis for a new conception of design to support a more sustainable future society is being laid. Yet, how such approaches translate into practice remains an open research question [66]. Dourish highlighted that it is necessary to "recognize the potential contradictions between the goals of our intervention and the forces that shape their deployment" to assess the potential for HCI interventions in environmental practice [23]. One recurrent guideline among sustainable HCI (SHCI) researchers is that, in order for the HCI community to understand the broader ecological, economic, and historical context of SHCI technologies, it needs to be open to collaboration with researchers, practitioners, and sustainability allies from other disciplines [67,68]. Our work aims to advance this goal by involving domain

experts, managers, and real-world users of conservation technologies in discussions about the design of novel tools for restoration.

Digital Tools for Environmental Conservation

Environmental conservation focuses on maintaining and restoring habitats and protecting species from extinction while enhancing ecosystem services. When studying species in dynamic habitats, opportunistic surveys (and citizen science) can have many advantages over traditional methods [20–22,69]. Formal and dedicated surveys provide poor temporal coverage because of financial and logistic constraints, meaning that they cannot capture long-term variation in species distributions and occurrence. Following this approach, we found many mobile platforms to report sightings and track marine species and plants following a citizen-science approach. iNaturalist [70] is one of the most popular online communities for naturalists consisting of a website and a mobile application. It allows users to document and identify observations of plants and animals by adding photographs. In this way, its participants contribute to monitoring biodiversity around the globe. One of the most interesting features is the automated species identification using a pre-set of trained data in a computer vision algorithm. Another notable example is AudioMoth [40], a low-cost, small-sized and low-energy acoustic detector. The device is open-source and programmable, with diverse applications for recording animal calls or human activity. AudioMoth is deployed globally, reaching in 2019 more than 700 projects worldwide [71]. The device also facilitated public engagement, including citizen-science projects for bat surveys [72], biodiversity distribution assessments [73–75] and engagement of the general public in wildlife monitoring programs [40]. Several other projects focus on different species such as insects [76,77] or birds [78] where the users of those projects also reported increased awareness about the local nature and animals. In particular, to monitor marine biodiversity, mobile applications have made progress in engaging marine-activity enthusiasts in species identification—e.g., there is Whale Report [79], a mobile application belonging to the "Sightings Network," where thousands of observers across British Columbia report their sightings of cetaceans (whales, dolphins, and sea turtles, for example). With this app, the "Sightings Network," can gather and review data filled by users on the occurrence and distribution of sea animals. Another similar approach is the application, "Wild about whales" [80], the official whale-watching application of New South Wales. Similarly, users can submit sightings and be alerted when whales are spotted near their location. Furthermore, participants can take and share photos in the social gallery, learn about many whale species and receive suggestions for spotting locations from shore. Finally, POSEIDON [81] deploys a low-cost passive acoustic monitoring system for citizen science in nautical/marine settings, enhancing whale-watching experiences with whale listening. Moreover, information collected opportunistically on board whale-watching boats can be used as base tools for better resource management and biodiversity monitoring. First, Fernandez et al. [19] used data collected on board commercial touristic boats to build distributional estimates of cetaceans, which could be used to implement new protection measures. Secondly, Sambolino et al. [82] used photos collected during touristic trips to study the whale-watching pressure on island-associated cetaceans populations.

The body of work presented in these sections highlights non-anthropocentric perspectives on interaction design; SHCI defines a space of possibility for technological interventions that support symbiotic encounters between humans and the natural environment for mutually beneficial ends [83]. With Aqua, we expand this body of work and focus on strengthening the impact of conservation technologies by opening new areas that could benefit from technological interventions, such as the marine ecosystem.

3. Design Materials

In this section, we describe Aqua, a whale-watching enhancement tool implemented as a mobile application in Madeira Island, as the regional government introduces guidelines and regulations to reduce disturbance to whales and dolphins. Among these regulations,

there are limits on the number of tour operators, vessels, times of day, or the number of tours conducted in a specific area. These regulations also include strict approach guidelines, limiting vessel speeds, and specifying the distances boats must maintain from groups of whales or dolphins. Finally, companies must submit a detailed report of the species encountered during the trip, which is currently performed by filling out a paper form. Aqua was developed to support the whale-watching experience of visitors to the Island by providing scientific information about the local marine species, tracking the vessel's journey and sighting of animals, reporting the sighting of species, as well as accidents that might be spotted during the trip (e.g., pollution spots or injured animals). The Aqua design followed an iterative process that was informed by HCI design methods (e.g., contextual inquiries) and expert interviews and feedback (in particular, from marine biologists and whale-watching companies). Initial results shaped the design decision to support two different types of users (See screenshot 1 of Figure 2) corresponding to different levels of expertise and frequency of participation in whale-watching activities: (1) Non-experts (tourist and local whale-watcher enthusiasts) who might not be proficient in identifying marine species; (2) Experts (marine biologists, skippers, and crew members of whale-watching boats) who can quickly identify marine animals and are generally busy supervising other on-boat activities.

The user experience with the application is distinct depending on the profile selected. For example, for the non-experts, the homepage presents a summary of the top spotted species and one-click-away scientific descriptions, as well as an interactive map showing the locations where most species were spotted (see screenshot 3 of Figure 2). Upon one click, the non-expert will be able to quickly access information about the local ecosystem and details on how to identify the local species (see screenshot 4 and 5 of Figure 2). Expert biologists designed the app's scientific content. On the other hand, the application's home screen for the experts offers shortcuts to add sighting information and spotted accidents (see screenshot 2 of Figure 2). Furthermore, the application offers three main features common to both profiles: (1) Add and edit Sight reports; (2) Track the vessel's journey in the ocean; (3) Add and edit an incident report. In the following subsections, we will explain the design rationale and experience flow for each user profile.

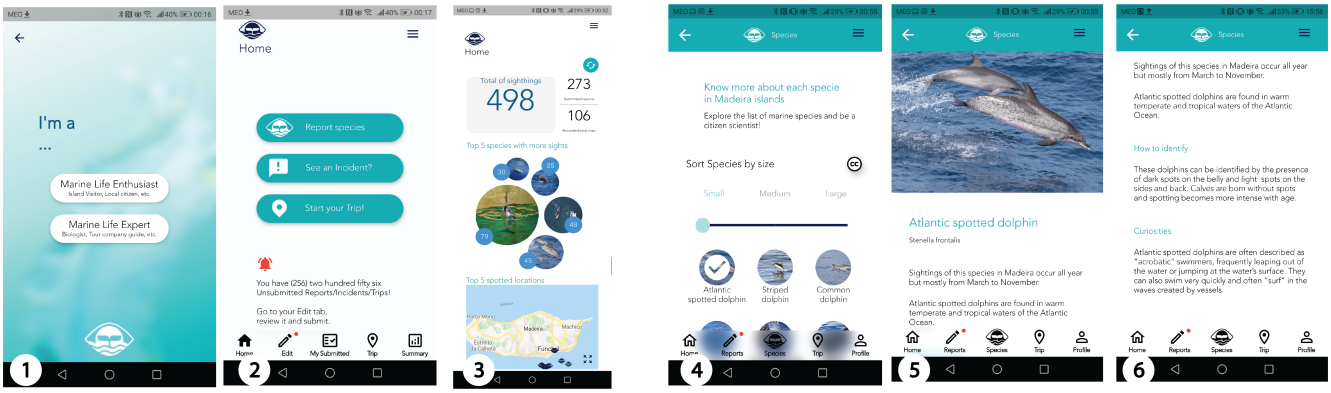

Figure 2. (1) Aqua screenshots for profile selection: Marine Life Enthusiast (Non-experts) or Marine Life Expert (Experts). (2) Home screen for the Experts. (3) Home screen for the Non-Experts. (4,5,6) Series of screens showcasing the information about the species for the Non-Experts.

3.1. Reporting a Sighting

Non-Experts are encouraged to add the sight report for the species encountered during the trip. The report screen starts by displaying the top five most reported species; all the species are organized by size, with the possibility to search for the species name (see screenshot 1 of Figure 3. Each species has a dedicated button identified by name and picture. Upon clicking, a reporting tab opens (see screenshot 2 and 3 of Figure 3), where the user fills in the number of individuals (marine animals), the behavior, comments, and can

upload recently taken photographs. The app automatically completes some information, such as time (which can be updated as there is a refresh button next to the timestamp), date, and location. To allow the quick addition of a species, experts can use the search field to type the species name.

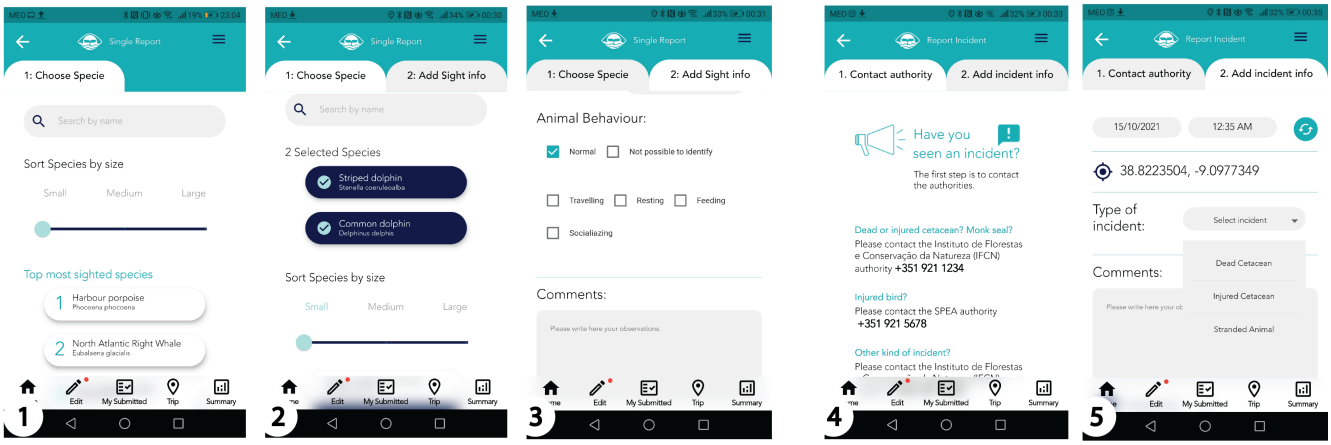

Figure 3. (1–3) Aqua sequence of screenshots showcasing the steps and required fields to add the report of a sight. (4–5) Aqua sequence of screenshots for reporting an incident: (4) contact information of local authorities; (5) required fields to add the report an incident (common for both Experts and Non-experts).

3.2. Reporting an Incident

During whale-watching trips, it is not unusual to encounter incidents (e.g., dead/sick cetaceans, trapped turtles, or vast portions of marine litter), so the app can be used to report them. Depending on the type of incident, the app presents the phone numbers of the local marine authorities and a form to report the details (see screenshots 4 and 5 of Figure 3).

3.3. Recording a Trip

Non-Experts and Experts can use a dynamic map that tracks the boat's path to record their trip and register sighting or incident positions (see screenshot 1 of Figure 4). This feature allows the user to (1) add a report, (2) start and pause the trip recording, and (3) end the trip. When the trip ends, a summary is presented with information such as time, distance, sightings, and incidents reported, which the expert can save to edit later or submit immediately (see screenshot 2 of Figure 4). This feature has different goals and values depending on the profile. Non-Experts are able to save a souvenir of their trip and the species they sighted. In this way, they can recall (and share) their route with peers or scientists, helping the environment. For whale-watching companies, the Experts can generate summaries for each trip which can be collated into Monthly or Annual Reports (see screenshot 3 of Figure 4). These can be used for internal statistics, advertising their success in spotting certain species, or sharing with the local entities that regulate the whale watching practice. This feature is also valuable for expert biologists, as Aqua can support their field trips and keep an interactive log of encountering marine species. Furthermore, the data collected will allow mapping of the ocean areas where these trips are made, study stress areas, and impacts on local biodiversity.

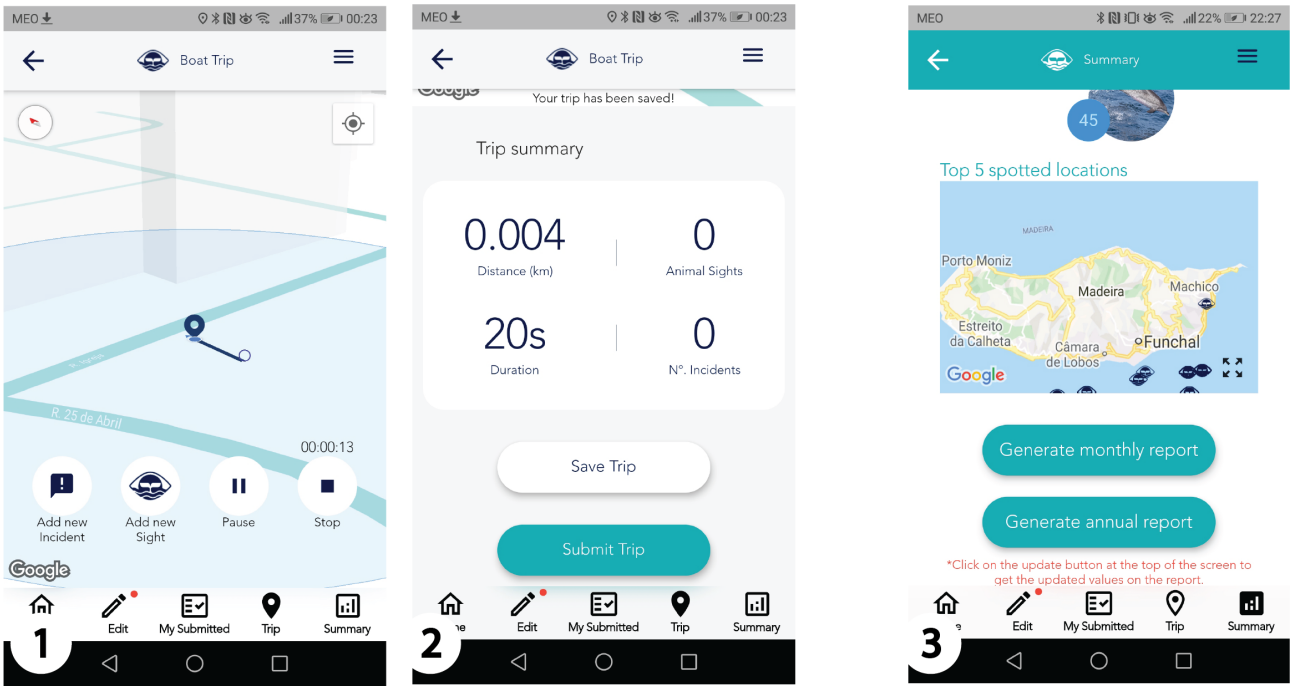

Figure 4. (1–2) Aqua sequence of screenshots for recording trip, common for both Experts and Non-experts; and (3) Aqua sequence of screenshots to generate a summary of the previously added reports. Feature only available for Experts.

The Aqua mobile application was developed using the Flutter framework with Dart [84]. To store all the authentication, information, and pictures the Firebase tools from Google [85] was used.

4. Methods

Although the Aqua application supports two different target audiences, this evaluation assesses the tourists' engagement and motivation while interacting with Aqua. It is essential to highlight that this evaluation represents one step further in defining methodologies to understand tourists' experiences with digital tools. Currently, there are very few studies of digital tools in the tourism industry carried out with tourists due to the difficulties in recruiting tourists in the wild, as they are on holiday and their main goal is to enjoy the holiday and relax [86,87]. Therefore, it is crucial to focus on the touristic experience to assess how Aqua can impact the tourists' marine-biodiversity awareness and connectedness with nature. This section describes the goals and measures used in the evaluation and explains the evaluation context and the protocol used to investigate the research questions. Finally, we detail the data analysis.

4.1. Measurements

The study employed an independent measures design to compare participants' experience of the whale-watching trip with and without interacting with Aqua. Participants who agreed to the study were randomly assigned to one group/condition: (1) Group A: Aqua group, participants using the application during the whale-watching trip; (2) Group B: Control group, participants taking a typical whale-watching trip without interacting with the mobile app Aqua during the whale watching. For both groups, the data was collected in two moments: before the trip, with a pre-questionnaire, and after the trip, with a post-questionnaire and a semi-structured interview. The pre-questionnaire was the same for both groups. However, there were two versions of the post-questionnaire, one for Group A—Aqua: Post-questionnaire A, and one for Group B—Control: Post-Questionnaire

B. Table 1 offers a summarized overview of evaluation measures used in each of these moments; for a detailed explanation, please refer to the materials in Appendix A.2.

These measures were carefully chosen to address each of the research questions. Collecting data using the connectedness to nature scale (CNS) [88] in both groups and at different times will allow us to understand if engaging with Aqua increased the connection with nature or not, therefore addressing RQ2.

The User Engagement Short Scale (UESS) [89] and the Memorable Tourism Experience (MTE) scale [90] will allow the assessment of how Aqua impacted the tourist experience during the whale-watching experience, addressing, in this way, RQ1. The Intrinsic Motivation Inventory (IMI) scale [91] will help us to understand if they were intrinsically motivated to contribute to reporting the sights. Finally, the interview and the Likert items will help us understand if Aqua influenced the users' marine-biodiversity awareness, addressing, in this way, RQ3.

Table 1. Summary of the measurements.

Conditions	**Evaluation Stages**		
	Pre-Questionnaire	**Post-Questionnaire**	**Interview**
Condition A: Aqua	Demographics CNS	CNS MTE UESS IMI	10 Questions
Condition B: Control	Demographics CNS	CNS MTE	N/A

4.2. Context and Study Protocol

Participants were recruited in Madeira Island in partnership with VMT, a local whale-watching company. In this company, a typical whale-watching trip lasts three hours. The sea vessel (a catamaran type of boat) carries around 100 passengers (however, capacity was reduced due to COVID-19 restrictions). Details on the flow of a typical whale-watching excursion are provided in Appendix A.1.

Participants were recruited at the beginning of the boat trip as they were waiting in line to go aboard (they must be there half an hour before the trip started). There were two researchers recruiting participants. These briefly introduced themselves, explained the study objective and asked tourists whether they were willing to participate in the study. As a small incentive to participate in the study, we offered a personalized cotton bag. The researchers were identified with a t-shirt from the local research center. The recruitment of the (60 participants) occurred during one week (involving a total of seven boat trips).

Participants in the Aqua group (A) were handed a smartphone with the application installed, and on which they filled out the consent form and pre-questionnaire. After this, they were encouraged to open the application and familiarise themselves. We also mentioned that the researchers would be on-board in case any question/problem arose. For the control group (B), participants were asked to give their consent form and complete a pre-questionnaire on paper. For each participant, a bracelet with an ID was given. Researchers did not interfere with participants during the trip but observed from afar, noting how many times and when they would use the application. Towards the end of the boat trip, participants completed the final questionnaire. We also asked participants in the Aqua group if they would be willing to attend semi-structured interviews. Finally, participants delivered the bracelets and smartphones, and researchers offered the cotton bag.

4.3. Data Analysis

All statistical analyses described were performed using SPSS version 26. The reliability of the scales and sub-dimensions were checked to ensure their consistency in the context of this sample. The scoring guidelines for each of the scales (CNS, IMI, MTE subscales) were

followed to obtain the scores. After confirming the normality of the data with the Shapiro–Wilk test, the data was confirmed to be normal. Therefore, parametric statistical tests were applied to check the differences between the two groups, and mean scores with respective standard deviation were reported. The resulting data from the semi-structured interviews and answers given in the comments section of the post-questionnaire were analyzed using thematic analysis [92] and analyzed with the support of Nvivo software [93]. Two researchers conducted a bottom-up data analysis review and iterative process in three stages. Firstly, researchers used open coding, where each researcher selected quotes and created high-level categories, reviewed and merged or divided into new nodes. Secondly, affinity diagrams were used to explain the relationships between categories. Thirdly, researchers organized the most frequent concepts and insights found, followed by the descriptions and illustrative quotes users gave in the interviews.

4.4. Participants Sample Demographics and Characterization

A total of 60 non-expert users agreed to participate in our evaluation (31 participants in Group A: Aqua and 29 in Group B: Control). Table 2 summarizes the main demographics or our sample of participants.

Table 2. Characteristics of Participants.

Demographic	Group	Frequency	Percentage
Gender	Female	31	52%
	Male	23	38%
	Not Reported	6	10%
Age	<18	3	5%
	18–24	13	22%
	25–34	27	45%
	35–44	7	12%
	45–54	8	13%
	55–74	2	4%
Nationality	Portuguese (PT)	17	28%
	United Kingdom (UK)	9	15%
	France (FR)	5	8%
	German (DE)	4	7%
	Netherlands (NL)	4	7%
	Italian (IT)	3	5%
	Spanish (ES)	3	5%
	Czech Rep. (CZ)	3	5%
	NR	12	20%
Familiarity with smartphones	Average experience	18	30%
	Expert users	42	70%

5. Results

This section presents the results from the study, divided into two subsections. The first reports the overall results of participants using Aqua and the comparison between participants who were in the whale watching trips using Aqua and participants not using the application (control group). The second section presents the qualitative results from the thematic analysis of the interviews.

5.1. Quantitative Results

User engagement: The participants' overall engagement with Aqua was positive, with most participants agreeing that it was an engaging experience, with most items scoring above average mean values for the total User Engagement Short Scale (UESS) (M = 3.35, SD = 0.36) (see Figure 5). Looking in detail at the different dimensions of the engagement scale, most participants reported that Aqua was rewarding (M = 3.54, SD = 0.36), usable

(M = 3.55, SD = 0.60), and they enjoyed the aesthetics of its graphics (M = 3.66, SD = 0.56). Looking in detail at the Focused Attention item sub-scale, we can see that the mean values are quite low (M = 2.65, SD = 0.58). This is a good indicator that the application was not too demanding or distracting, so that they could enjoy the whale-watching trip.

Intrinsic motivation: As we can see in Figure 6 by the high mean scores, participants were intrinsically motivated to use Aqua. Using Aqua was perceived as valuable and useful (M = 5.35, SD = 0.94). Similarly, the perceived choice and perceived competence also scored high mean scores (M = 5.38, SD = 0.84; M = 4.50, SD = 0.89, respectively). On the other hand, Pressure/tension has low mean scores (M = 2.69, SD = 1.08). While the first four dimensions are positive predictors of both self-report and behavioral measures of intrinsic motivation, pressure/tension is a negative predictor of intrinsic motivation. Hence, participants enjoyed Aqua and were satisfied.

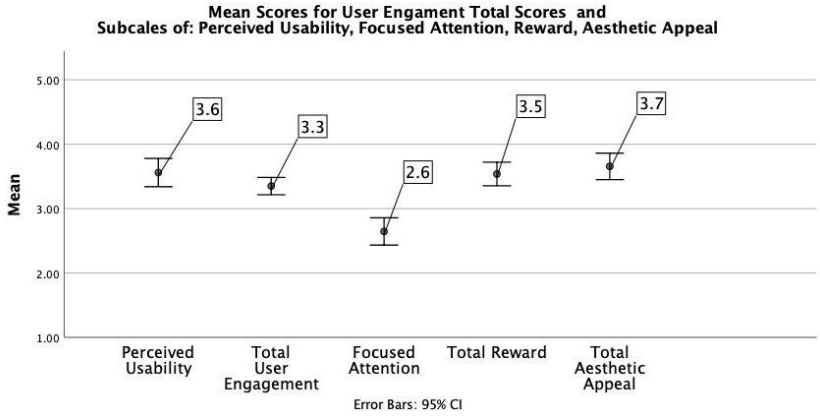

Figure 5. User Engagement Scale (UE) results for usability, attention, reward, aesthetic and appeal.

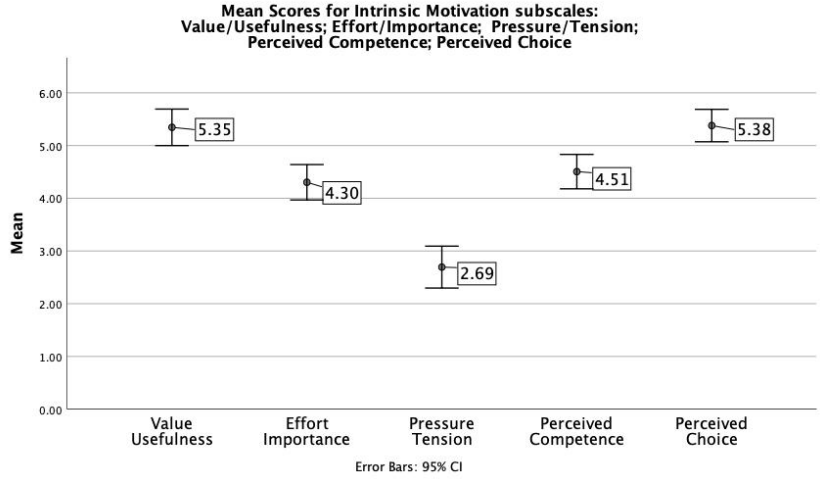

Figure 6. Intrinsic Motivation (IMI) results for Value/Usefulness, Effort/Importance, Pressure/Tension , Perceived competence and Perceived choice.

Tourism experience: Regarding the individual Likert items (Figure 7, the bar chart at the top right shows that most participants had a good scientific overview of the local marine biodiversity; 12 of the 31 participants somewhat agree that they gained information on the marine ecosystem. Furthermore, most participants felt like they did something meaningful while using Aqua (3—Strongly agree, 7—Agree, 13—Somewhat Agree). For most participants, the content of Aqua incited their curiosity (2—Strongly Agree, 9—Agree, and 12—Somewhat Agree). Similarly, the features offered by Aqua were interesting to the participants (4—strongly agreed, 13—Agree, and 6—Somewhat Agree). Most participants would recommend their friends and family use Aqua on a whale-watching trip (3—Strongly Agree, 9—Agree, and 7—Somewhat Agree).

Aqua vs Control Group: An independent-samples t-test was conducted to compare the CNS scores before and after the boat trip between participants who interacted with Aqua and those who did not—Control Group; see left graph in Figure 8. There was no significant difference in scores for Aqua participants after the boat trip (M = 54.38, SD = 6.45) and the Control Group (M = 55.31, SD = 7.69); t(58) = −0.50, p = 0.05]. Using Aqua has not negatively impacted the ability to enjoy and connect with the natural environment. A paired sample t-test was conducted to compare all participants before and after the boat trip, and the results show that there is a significant increase in the CNS score before (M = 50.83, SD = 0.78) and after (M = 54.83, SD = 7.03) (t (59) = 65.40, p = 0.0005) the whale-watching trip.

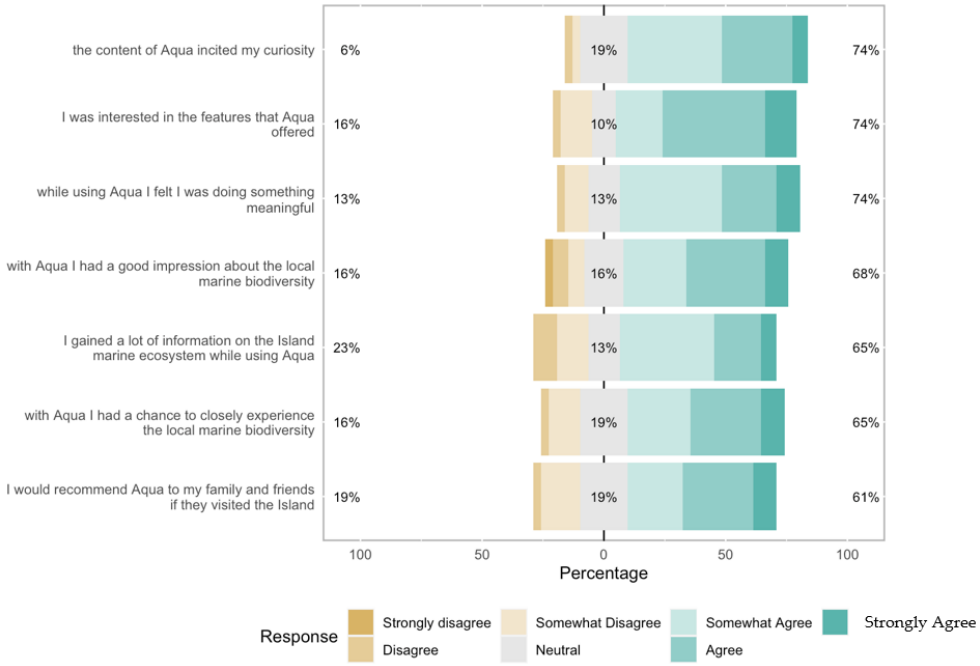

Figure 7. Results of the Likert items questions.

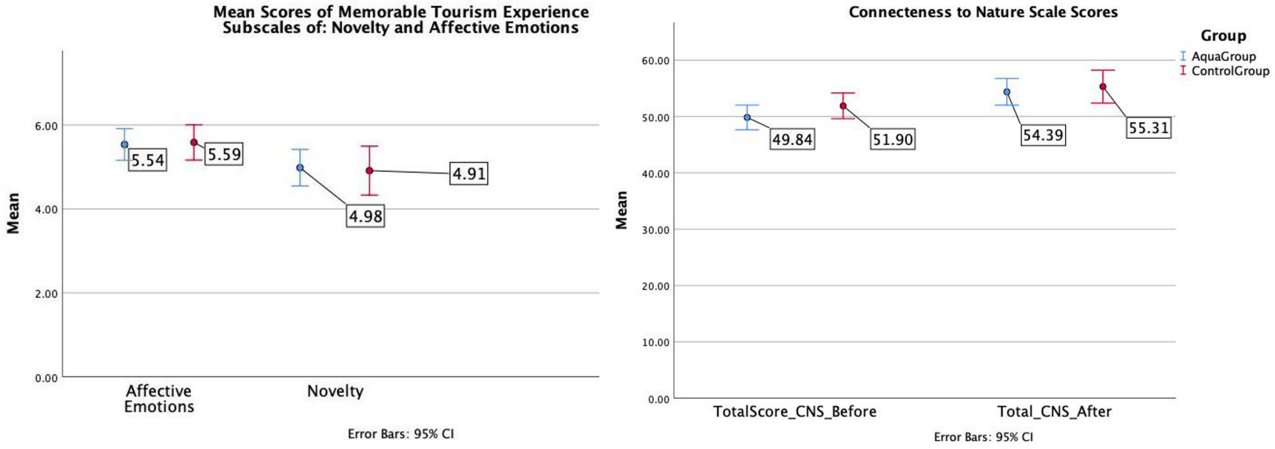

Figure 8. Connectedness to Nature (CNS) results before and after the trip with and without the digital tool and Memorable Tourism Experience scale (MTE) results for novelty and affective emotions.

Furthermore, we found no significant differences in terms of Novelty and Affective Emotions (sub-scales of the Memorable tourism experience) between participants who used the Aqua mobile application and the Control Group, see right graph in Figure 8, (Novelty

Scores Aqua: M = 4.98, SD = 1.18, N = 31; Novelty Scores Control: M = 4.91, SD = 1.53, N = 29; t(58) = 0.19, $p = 0.05$]), (Affective Scores Aqua: M = 5.53, SD = 1.02, N = 31; Affective Scores Control: M = 5.58, SD = 1.10, N = 29; t(58) = −0.18, $p = 0.05$).

5.2. Qualitative Results

In this subsection, we present the data from the qualitative analysis of the six non-expert Aqua testers who participated in the semi-structured interviews combined with the data collected from the blank field of the post-questionnaire. Seven main topics clusters emerged from the analysis: (1) user engagement with Aqua; (2) using Aqua incited a combination of excitement and frustration; (3) enhancing the whale watching boat trip; (4) when did participants interact with Aqua; (5) Aqua's impact on the whale-watching experience; (6) Aqua as a citizen-science application; and (7) opportunities to improve Aqua. To illustrate the findings, quotes from the participants are reported along the text. Quotes follow format U<userID>_<quoteID> so that the full extent of the quotes can be consulted in Appendix B.

User engagement with Aqua: In general, participants were positively engaged by Aqua; they appreciated its visual design, ease of use (U27_1). Consulting information and reporting sights were among the most used features of Aqua. All of the six participants mentioned that they used these two features the most. Participants appreciated the fact that Aqua enabled them to report valuable data, and they felt empowered to contribute to science in a meaningful way (U12_2). Three participants mentioned that the most exciting and engaging feature was adding a sight report because it gave them "something to do". They felt it was an important task to help monitor and preserve the local biodiversity (U3_3,U27_6). However, tracking the boat trip was also a cherished feature (U16_4,U18_5). Two users also mentioned that reporting incidents is an exciting and helpful feature for monitoring sea pollution (U45_7). Two users said they enjoyed looking at the previous reports to see what species were more commonly sighted, preparing themselves for what they would likely see during the trip (U18_9,U16_4). However, participants also mentioned several opportunities to increase/sustain the engagement with Aqua, which are discussed further below in the dedicated topic's section. User quotes are in Appendix B.1.

Using Aqua incited a combination of excitement and frustration: When asked what kind of feelings Aqua promoted, three users mentioned that Aqua provoked excitement. They were excited to add their report to the app database, and it felt good to help nature conservation through scientific reporting (U3_10). They mention that it was exciting to "gather" different species through the application as if it was a sort of "treasure hunt" to find them. Moreover, it was fun to share the information that they gathered with others (U25_11). On the other hand, all participants also mentioned feeling a certain degree of frustration and disappointment. These feelings emerged mostly when and if the application crashed, if the internet connection failed, losing the recorded data about the sightings and the recording of the trip. This last issue was mentioned as one of the most important causes of disappointment since participants felt like they were losing their own private memories and takeaways from the trip (U3_10,U9_12,U12_14). User quotes are in Appendix B.2.

Enhancing the whale-watching boat trip: Five participants highlighted that Aqua enhances the whale-watching trip by providing extra information that they would not have otherwise had access to (U23 and U25_17, U9_18). However, one participant mentioned that it could be messy using the mobile phone during the boat trip as the smartphone could fall into the water (U3_15). The other two users mentioned that using the application could be a concurrent activity to enjoying the trip (U16_16). Afraid of getting sea sickness, one participant did not consult the information about the species. Another two participants mentioned that there could be further unexploited opportunities for the mobile application to enhance the trip. Opportunities such as adding some gamification elements such as badges and points to the sighting reporting make the contributors form a large community of whale watchers that could consult, compete, or compare with (this topic will be further developed in the following subsection). User quotes are in Appendix B.3.

When did participants interact with Aqua: The mobile application was primarily used at the beginning of the trip, then during the sight moment, and then just a few minutes after the sight moment (U3_21, U27_25, U12_26). In the beginning, participants mentioned that they used the application as expected to register and set up their accounts, and then they explored the application's features. Four users mentioned that they started recording the trip. Two participants also mentioned looking for previous sight reports and information about the local cetacean species. Five participants mentioned using the report feature during the sighting moment, which lasted for around 10/15 min. Three participants mentioned that they were looking for a way to take photographs within the application as a quick way to report the species (U25_22). After the sighting moment, four participants mentioned that they started adding the sighting information to the report but also consulted the digital tool for more information about the species (U23_23). Only one participant checked the mobile application towards the end of the boat trip. User quotes are in Appendix B.4.

Aqua's impact on the whale-watching experience: Most interviewed participants felt like their overall experience in the boat trip differed from others who did not use the application (U12_28). Since they had access to extra information, they felt like they learned more than others (U16_33, U23 and U25_29). Three participants mentioned that by using Aqua they were more aware of the existing marine species. Two participants mentioned that using Aqua added an extra level of responsibility/commitment as they were more attentive to the sighting species to report and contribute to science (U3_27). Two participants mentioned that an application of this sort could impact the enjoyment of the natural environment (U16_31). While one of these participants mentioned that he might have been more disconnected from the natural environment, another participant mentioned the exact opposite; the participant felt like the time interacting with the application did not impact the connection with the natural environment (U18_32). User quotes are in Appendix B.5.

Aqua as a citizen-science application: For most participants, this was their first experience with what could be considered a citizen-science application. Generally, participants mentioned this was exciting (U12_41). However, two participants mentioned that adding the sighting reports was demanding, especially for a touristic activity. In addition, four participants highlighted some difficulties, first in recognizing the species they were seeing; this was then easily overcome since the boat crew would announce the species (U9_35). They also mentioned difficulties in adding the sighting information, as they felt they were not knowledgeable enough to fill in some of the information fields requested (U3_38,U18_40). One participant suggested having a shared report with the participants of the boat trip. In this case, one person could initiate the report, and others can confirm the data and further contribute to the report with pictures or additional information (U18_34). User quotes are in Appendix B.6.

Opportunities to improve Aqua: It was agreed among all participants that the application would need further refinements to the existing features, interface, and robustness, to avoid frustrating moments (U16_39). Several participants (10) suggested that the application should allow for an offline mode so that the experience with Aqua is not affected when the connection and reception at sea are not the best. In this way, all data is stored locally (phone memory) and accessible when the boat is at sea. Furthermore, three participants mentioned that the application could provide more scientific information, curiosities, and pictures of the species to help participants learn about and identify them (U16_36). Another suggestion was to provide fast access to the camera within the app. To enable users to add photographs to the report (U3_43), but also to capture moments of the trip itself (landscape pictures, group pictures, for example). One user mentioned that this feature could add some extra rewards to the participants' experience (U9_45). Two participants also suggested adding a social layer to the application, where participants of the same whale-watching trip could share reports and pictures, contributing to a shared report and photo album (U3_46). Several participants pointed to gamification to foster user engagement by

(1) unlocking information bonuses at certain moments of the trip, (2) allowing competition between participants of different whale-watching trips, and 3) adding quizzes and leader boards to test the participants' acquired knowledge (U18_48,U9_49). User quotes are in Appendix B.7

6. Discussion

In this study, we evaluated the whale-watching experience of non-expert whale watchers when using Aqua, a digital tool designed to support users in reporting and learning about cetaceans' scientific information during a whale-watching trip. Below, we discuss the quantitative and qualitative data-analysis findings alongside the proposed research questions, synthesize the lessons learned, and reflect on the limitations and future work.

6.1. Research Questions Analysis

RQ1. Can we enhance the whale-watching experience with a digital tool that supports reporting of sightings and opportunistic citizen science?

Aqua was engaging, mainly because it gave tourists something to do and a sense of responsibility towards the natural resources of the location they were visiting. Aqua provided the opportunity to be helpful and impact the local nature conservation cause in their touristic destination, something that the literature on the tourism experience mentions as something desired by visitors [94]. Users reported Aqua as non-intrusive or requesting too much effort, this is important because tourists' engage and pay for whale-watching trips to enjoy the time out in the sea and the connection with nature, so Aqua should be unobtrusive. Participants were intrinsically motivated to contribute with Aqua. The IMI scores are encouraging, with high mean scores in all dimensions representing good indicators for intrinsic motivation. These results highlight the potential of Aqua as a citizen-science application. Previous work has identified that high intrinsic motivators are significant predictors of success in citizen-science projects [95]. Looking at the IMI sub-dimensions, using Aqua was perceived as a high-value activity, with participants voicing feelings of accomplishment in contributing to science through their reporting. Participants were frustrated when the application crashed for two reasons: losing their trip mementos (photos, tack of the journey), and the second was related to "missing their opportunity to contribute to science" since their efforts in reporting the sights and animal behavior were not recorded.

RQ2. To what extent can a digital tool enhance the nature connectedness of those who engage in ecotourism activities?

One of the goals of this research was to understand how Aqua could affect participants' connectedness with nature. We found no significant differences in CNS scores between participants who used Aqua during the whale-watching trip and those who did not, suggesting that using Aqua did not increase the connection with nature. While, in the literature, we can find evidence that participating in nature-based citizen science can increase emotional and cognitive connections to nature [96], we could not verify this among tourists. In the work of Koss et al., volunteers reported positive feelings, emotionally and mentally, stemming from a sense of achievement from preserving and improving their local marine protected area [97]; similarly, in the work of Haywood et al., volunteers developed a deepened sense of place from regular participation, which led to a strong sense of belonging and ownership of the site [98]. In both examples, participants had a long-term involvement with the citizen-science approach. We posit that since the interaction with Aqua was a one-time interaction, it might not suffice to see a change in CNS score as there was no time to develop this more profound relationship with the place. Therefore, it might be that participants' connectedness with nature might significantly increase after a more extended period of contribution. Therefore, to see a significant increment in the CNS scores, Aqua should be used more times, possibly keeping track of participants' whale-watching trips over time or other nature-relevant activities. Moreover, there were no significant differences between participants who used Aqua and those who did not in terms of novelty and

affective feelings, the two sub-dimensions of the memorable tourism experience. While we posited that Aqua would enhance the tourism experience (by introducing a novelty aspect and evoking an emotive response by engaging participants' in biodiversity monitoring), the limited interaction time and the early evaluation did not confirm our idea. This echoes Preece: "due to the dilemma of Wicked Problems, it is extremely challenging to statistically verify whether the interactive system truly empowers communities and causes attitude or behavior changes" [59] as it becomes difficult to track and control confounding factors that may influence their behaviors and attitudes, such as the effect of news, social media, and the use of other mobile applications [59]. Further and longitudinal studies will be necessary to delve deeper into the question posed by RQ2. This study might function as a primer to start the investigation and illuminate the possibility of designing applications that can keep track of activities and behaviors or participants engaging with nature over more extended periods and diverse kinds of nature-centered activities.

RQ3. Can a whale-watching digital tool influence the marine biodiversity awareness of ecotourists?

Generally, Aqua successfully increased participants' awareness of the richness of the local marine biodiversity. The quantitative results show that most participants felt like Aqua gave them a good overview of the local biodiversity, as they felt like they gained information on the marine ecosystem. This is consistent with the results of the semi-structured interviews, with participants saying that Aqua complemented the boat trip by providing extra information about the species and the number of existing species. However, the average values for curiosity reveal that there is room to improve participants' curiosity further. Some users suggested that Aqua could provide more scientific information, as they were eager to know more curiosities and scientific facts about the species. They wanted more information about the different animals of the local fauna. Moreover, participants wanted more information on conservation measures and more details on the impact of boat trips on the marine ecosystem. Perhaps, in the future, very factual and scientific information can be combined with storytelling, leveraging narrative persuasion and character identification to deliver specific facts intertwined in a more playful and relaxed approach, leading participants to engage with **Aqua's** information section during but also after the completion of the trip.

6.2. Preliminary Insights for HCI Designers to Engage Non-Experts with Citizen Science for Marine Conservation

(1) Marine context: Designing mobile applications to be used in the marine context can be pretty challenging, in particular, to be used during boat trips. Consider designing content mindful of seasickness while using the application. For example, although Aqua makes extensive use of images and illustrative icons, most of the information about the species is text-based, and, as a result, we had one participant complaining about feeling seasick. Hence, information could be delivered using audio as a complementary approach. In this way, participants can listen to the content while enjoying the surroundings;

(2) Social experience: Applications with an underlying citizen-science approach should report sightings as a social activity. Once posted to the community, the sight report of a species could be completed by a community of citizen scientists, which could enrich it with more accurate, detailed information, including group photos, videos, and notes. Supporting group sightseeing activities, such as whale-watching trips, scuba-diving excursions, or mountain hikes could generate networks of citizen scientists that could eventually engage in community-friendly dynamics and maybe get to know each other across different trips and locations. Eventually, as mentioned in the interviews, an application such as Aqua could even cover different locations and connect with more companies that organize whale-watching trips in more parts of the world, building, in this way, a network of whale-watching journeys through boats, animals, and people.

(3) Citizen-science gamification: Participants considered that Aqua could be enhanced with gamification features. They highlighted gamification as a strategy to increase engage-

ment and add extra motivation. Results from the study hint that gamification for citizen science for tourists might require a different approach from the classic badges or points. Instead, designers should think about something that adds value to the tourism experience to make it more memorable, for example, unlocking more knowledge or something specific to the locality. For example, some secret pieces of information could be released during the boat trip or coordinates to a new location unlocked, allowing tourists to keep exploring different aspects of the marine ecosystem.

(4) Lower the barrier to engaging with citizen science: Participants truly enjoyed the citizen-science activity and feeling of accomplishment afterward. A designer should foresee ways to decrease the barrier to citizen science, especially when the target audience is tourists who do not have time to go through much scientific information or tutorials to start engaging. For example, adding sight reports should be as simple as taking a photograph. Sight reports could be already pre-filled with some information based on the most common thing to observe in those species. Wherever possible, computer vision algorithms could help citizen scientists to recognize different species.

(5) Sustained engagement: The design of applications such as Aqua should leverage the moments before and after an actual sightseeing trip to increase engagement. For example, before the trip at the planning stage, the application could prepare users for the trip by providing tips and curiosities, showing what to expect; ideally, this could be co-designed with the experts and crew members following a participatory design approach; after the trip, the app should continue the relationship with the users, build a diary of future engagements with nature, and connect with more information, for example, alerts when someone else sees the same species in different locations around the globe. As our results show, a single trip interaction is not enough to increase nature connection among tourists, so the design should aim at a sustained engagement.

6.3. Limitations

In this section, we report the emerging limitations of Aqua design and evaluation. The research conducted could benefit from a larger sample of participants. In particular, the sample size for the quantitative section of our study was limited. Recruiting tourists is challenging as their participation in our evaluation competes with their leisure time. Tourists pay a significant amount for a whale-watching trip, so participating in a research study is not a priority as they want to enjoy the trip as much as possible without being disturbed to perform specific tasks and answer questionnaires. Pressure to get through the questionnaires was often an issue; therefore, many tourists did not agree to participate in the semi-structured interview. Furthermore, the recruitment process was hampered by the COVID-19 pandemic measures. There were also limitations in terms of the evaluation methodology. Since engaging tourists in the evaluation was going to be hard, we had to keep it as short as possible. For example, we could not use the total length and dimensions of the scales. Using full-scale dimensions would have allowed more reliable results. Furthermore, we realize there was a short time between the pre and post-questionnaire, especially to measure complex dimensions such as biodiversity awareness and connectedness to nature. Such dimensions might require long-term evaluations in order to be adequately analyzed.

6.4. Future Work

Future work will involve the continuous improvement of the application, especially to make it more robust and usable. The next step will be to evaluate the application with the experts (biologists and members of the whale-watching crew). It would also be interesting to study a whale-watching trip where experts and non-experts use the Aqua application simultaneously to see if any dynamics arise from this. It would also be relevant to evaluate Aqua in the context of different whale-watching companies as the experience might differ depending on their internal protocols, crew members, and types of vessels. Furthermore, we plan to evaluate the application with local non-experts, as their social capital connected

with the island might offer some interesting insights. These possible users are vessel owners who go into the sea for recreational purposes such as fishing or sailing. Another exciting aspect of continuing this investigation is how we could re-design Aqua to incorporate and validate our preliminary insights by adding a more prominent social aspect to the citizen-science reporting feature and the gamification opportunities.

7. Conclusions

Marine environments attract millions of visitors, and the desire to encounter wildlife in natural settings provides opportunities to enlist tourists to record observations, sightings, and emotions. Tourists who engage in ecotourism activities, such as whale watching, take photographs as mementos to ensure the moment is not lost. Not only are these photos precious for them but also for marine biologists, as they can support the identification and monitoring of marine species [69].

Inspired by the potential value of citizen science, particularly in the context of marine ecotourism, this manuscript described the design and evaluation results of Aqua, a mobile application to actively engage tourists in monitoring local marine biodiversity. The work delivers an artifact contribution by describing the designing and implementation of a digital tool to enhance whale-watching activities. An empirical research contribution is present through the quantitative and qualitative evaluation of the participants' experience with and without the digital tool. The lessons learned from the research process and evaluation culminate into five preliminary insights for HCI designers to engage tourists with citizen science for marine conservation and awareness.

Sustainable HCI aims at developing and testing technology solutions for biodiversity and climate actions, nature awareness, and conservation. Aqua is a first step in understanding how digital technology can focus on more than humans and re-balance our relationships with nature and depleting biodiversity. We hope our work inspires future designers seeking new project ideas in this design space.

Author Contributions: All authors were involved in the initial conceptualization, discussed the results, and commented on the manuscript. M.D. and M.M. were involved in the concept development and implementation, M.D. was responsible for the user experience and M.M. for the software development. M.D. was responsible for the methodology, data analysis, and original draft preparation. M.F., V.N. and N.N. were responsible for the project supervision and administration as well as funding acquisition. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: Ethical review and approval were waived for this study since there were minimal risks involved for the participants of this study; furthermore, all the data were properly anonymized and informed consent was obtained at the time of original data collection.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data that support the findings of this study are available in https://doi.org/10.6084/m9.figshare.21370911.v1, (accessed on 25 July 2022).

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A. Methodology Details

Appendix A.1. Details on the Boat Excursion

The excursion starts with a crew member introducing the boat members to the trip participants and outlining the security requirements using a microphone. Usually, thirty to forty minutes after the trip starts, the skipper will spot an area where cetaceans are present. Once near this location, the boat slows down and continues slower until the site and the species are spotted. The crew member updates the participants, indicating the location

(left, right, back, or front of the boat), name, and scientific information. Tourists are also informed that only two ships are permitted to approach the species and are only allowed to do so for ten minutes to protect the species. After the encounter, the trip then continues to a specific scenic point of Cabo Girão, where passengers are invited to swim for around 20 min. As the boat heads straight back to the harbor, the crew member provides some sightseeing information describing the coastal landmarks spotted from the boat.

Appendix A.2. Detailed Description of the Evaluation Measurements

- **Pre-questionnaire:** gathered information about the participants' demographics; their experience with mobile devices and whale-watching trips; and measured how connected they felt with nature by using the connectedness with nature scale (CNS) [88]. Mayer and Frantz proposed the connectedness to nature scale (CNS), which measures an individual's affective, experiential connection to nature [88]. Unlike previous scales measuring environmental/nature awareness and attitudes, such as NEP and INS [99,100], the CNS scale focuses on the relationship between humans and the natural world through a short and multi-item artifact. The scale was successfully used to predict behavior and test the effects of situational factors and personality characteristics on connection to nature [101].
- **Post-questionnaire A - Aqua Group:** (1) Measured human connectedness with nature by replicating the CNS [88]; and (2) how memorable their experience was using the novelty and affective subscales of the Memorable Tourism Experience (MTE) [90]. The MTE scale consists of seven dimensions to evaluate how memorable a tourism experience is: hedonism, refreshment, local culture, meaningfulness, knowledge, involvement, and novelty dimensions. Due to the time constraints, we decided to evaluate only three dimensions: hedonism which refers to experiences associated with emotions such as pleasure, excitement, and enjoyment; the involvement dimension, which represents the travelers' active participation in memorable tourism experiences; and the novelty dimension, which denotes unique experiences encountered by travelers during MTEs. (3) We also measured user engagement with the User Engagement Short Scale (UESS) [89] comprised of 12 items covering four dimensions of engagement: focused attention (FA); perceived usability (PU); aesthetics appeal (AE); and reward factor (RW). (4) Intrinsic motivation was measured with the subscales of the Intrinsic Motivation Inventory (IMI) scale [91], namely: perceived choice, perceived competence, pressure/tension, effort, and value/usefulness. Intrinsic motivation refers to the act of performing an activity because it is satisfying or enjoyable [91] and the Intrinsic Motivation Inventory (IMI) is a multidimensional measurement grounded in self-determination theory (SDT) [102] used in assessing the subjective experiences of participants when developing an activity. Previous works show that one of the most common forms of motivation to participate in volunteering initiatives was enjoyment-based intrinsic motivation [103]. Perceived choice and perceived competence concepts are theorized to be positive predictors of both self-report and behavioral measures of intrinsic motivation. In contrast, pressure/tension is theorized to be a negative predictor of intrinsic motivation; effort is a separate variable that is relevant to some motivation questions, so it is only used if relevant [104]. (5) Furthermore, we also used seven Likert-scale items to measure (a) the increased awareness of local marine biodiversity; (b) how meaningful using Aqua was; (c) how interesting the Aqua features were; (d) how much information they obtained; (e) how much the content sparked participants curiosity; (f) if they would recommend Aqua to others; and finally, (g) a blank field was dedicated to gathering qualitative comments and suggestions from the participants.
- **Post-questionnaire B—Control Group:** was a shorter version of Post-questionnaire A, made of the CNS scale and the subscales of MTE.
- **Semi-structured Interview:** only participants who engaged with Aqua were interviewed to assess the overall experience. The audio of the interviews was recorded

and later transcribed. Ten questions prompted participants to share their thoughts: (1) What Aqua features you used during this boat trip? (2) Which ones were more interesting to you? (3) Can you remember in what moments you used Aqua? Please match the features that you used with the different moments of the trip; (4) In what way did Aqua engaged you? (If not) How could it engage you more? How do you think of this symbiosis between a boat trip and Aqua mobile application? (5) How do you think the mobile application, Aqua, could be further improved to complement the boat trip experience? (6) Compared to the other visitors on this boat trip do you think your experience was different? If so, how? (7) Did you discover something about the Madeira marine ecosystem by using Aqua? If so what? (8) Do you think that by participating in a Citizen Science project, like Aqua you are now more likely to support marine conservation than before? Why do you think so? (9) In what ways do you think that Aqua as a citizen science project of this sort could inform participants more about marine conservation? and (10) Any suggestions or any other comments that you would like to leave?

Appendix B. User Quotes Derived from the Interviews

Quotes follow format U<userID>_<quoteID>

Appendix B.1. User Engagement with Aqua

U27_1: The app was really easy to use.

U12_2: Overall, I think that, it's a fun app to use in these types of trips. I think it adds to the experience because at least I felt like I was kind of contributing to something.

U3_3: As was trying to report the dolphins I was feeling that I was helping science. I was like I really want to count how many dolphins we are seeing to make a better report ...

U16_4: I use the report species once for spotted dolphins and I also used the trip tracker to track the trip. I found it useful and interesting. I also checked previous spotted species. I think checking previous reports of species was the most interesting feature.

U18_5: I used the start trip thing (..) that was like one of my favorite features, (...). Just to see like the route of the trip.

U27_6: The reporting for all the users because you are helping biodiversity monitoring.

U45_7: (...) the report accident feature, you could like report trash or something like that, and then it would give us information about, like the amount of trash and pollution in the sea.

U18_9: I also liked the information thing because I got to see, like, all the species that could be in the tour. And it was kind of disappointed because the tour is only on the species that you encounter and not the species that exists.

Appendix B.2. Using Aqua Incited a Combination of Excitement and Frustration

U3_10: (...) it was the excitement of doing the report and somehow a bit of frustration because I was trying to see if my trip was being saved and I had no idea if it was or not so I was getting frustrated to see if the work that I have been doing had an outcome.

U25_11: I felt excited at one point that I was able to gather the species and to share it. I think that was the best moment when I used the application - to try to share that information with people.

U9_12: It was kind of... Exciting in a way, because it felt like a sort of a treasure hunt, this idea of collecting things. But then when I realized I couldn't retrieve

my input was a bit like... disappointed. Yeah, the beginning i was kind of excited, I felt good also because I know what citizen science is so it's cool...

U12_14: At first, I was interested in the app because I hadn't done anything like this and it seemed like an interesting experience. But I think after using it, I started to be slightly frustrated because it was slow to respond, and then there were some small details that I didn't quite get at first. (...)So even though it was a bit frustrating, I think, in overall, the concept is fun.

Appendix B.3. Enhancing the Whale Watching Boat Trip

U23&U25_17: It complements the trip because it gives more information (about the species) and to see where we are going around, because I would not have access to it in a normal trip and the sharing U25 (daughter of U23): I like to learn about the species and also that I could like look at the pictures of the animal and the curiosities. That was really fun. U23: Also I like to contribute. I think that it is very nice that we can record the species.

U3_15: I think it gets a bit messy because of the water and the ocean and the mobile phone… I was getting scared if the phone would slip through my fingers and get into the ocean. But I think we only need the phone in the bag and then when we spot the specie … in this case we only had one specie we did not interact with other species …

U16_16: Again, it could be a bit more integrated within the ecosystem. It has a lot of potential. It complements the trip because you can be even more engaged (with the whale watching experience) because there's an interface. However, it can be a bit distracting and bothersome because it can distract you from the main goal which is to enjoy the trip...

U9_18: Also this way, you can, you know, for the species you have to look for to get more information. So, I think it's just a perfect combination. On the other hand, I'm a tourist here and I want to enjoy the trip, maybe in a demanding way. But I believe that some kind of people might still be willing to use it.

Appendix B.4. When Did Participants Interact with Aqua

U3_21: In the beginning, I was exploring the app, ...looking at the photos of the species. And then I tried the start the trip to see if it was working and then I left the app…. I mean I let the trip recording and then I forgot about the app itself. (…) Then we started to see the dolphins.. I was listen to the girl on the microphone to see what was the specie that we were seeing then to try to report. ...I was trying to take a picture but didn't know where the camera was on the application ... I think these were the two main moments of the trip were I used the app.

U25_22: When I saw the dolphins I wanted to use the application, because I wanted to take the pictures and to record the moment but because of the network I was not able to. But that was something that I really wanted to use.

U23_23: It was after I saw the species, I wanted to find out more about it.

U27_25: When the dolphins were there I had the phone in my hand because I knew it was the perfect moment, but I was more interested in looking at the dolphins, so I reported after.

U12_26: I was just checking what the app did and then I noticed the register trip and as soon as we were leaving the port, I started recording the trip. And then, yeah, I guess at the moment we saw the dolphins... I didn't do it right away, but I was mostly enjoying myself. And then after I couldn't see the dolphins anymore, so then I went to the part where you add the sighting. And then a bit after that, I checked the part where you have the different species description.

Appendix B.5. Aqua Impact in the Whale Watching Experience

U3_27: I was trying to get the scientific part, not only the leisure, I was committed .. I was trying to see more species and to know the name of the specie and looking at the scientific name of the species... So I remember that when I saw the dolphins I went back to the app to see what was the scientific name...

U23&U25_29: I got more information about that I watched, that probably they did not have; U25: I could see the locations of the species and I would see many more that are found in these oceans and we were not able to see.

U16_31: It was certainly different. I learned a bit more than the others, but I was also distracted with the app, so other people might have profited more from the trip as they had a experience more connected with the environment that I had.

U18_32: I didn't feel like It took so much time using the app to kind of endanger the tourism experience of the tour.

U16_33: There's a lot of species that I discover using the app but only saw 1 in the trip, a dolphin.

Appendix B.6. Aqua as a Citizen Science Application

U12_41: (...) the citizen science, I think it engaged me in that sense (...) ...adding the sightings and stuff like that, I think it's nice.

U9_35: the issue is, for me, I don't know anything about marine species. So we so the dolphins, I was OK, I have to report... which dolphin? I have no idea. But they say it is the spotted dolphin. Also this way, you can, you know, for the species you have to look for to get more information.

U18_34: do you need 10 people saying that they saw a dolphin? Or do you need one person saying that they saw a dolphin and then nine people saying that they also saw it? So in that case, if it was just a matter of confirming or amending something in the report (...), then people could add photos to that and they, they shared like a full, a common photo album or something.

U3_37: Yeah. I think my first instinct was like trying to take a picture to see what type of, uh, animal was. And then afterwards, I would check like the scientific name and how many species it was. But like, first of all, like take a picture and have, have it like the, the report, like the visual reports. And then like the additional information I could add it afterwards.

U3_38: I think that I only saw, like, three or four dolphins, but at a certain point, I think, I don't know if it was twenty?

U18_40: And then the behavior [referring to fill in the specie behavior], I don't know what the normal behavior is. I thought it was normal behavior, but then I didn't know. And it's like it's a type of information that I couldn't report.

Appendix B.7. Opportunities to Improve Aqua

U16_39: It was positive. It could engage more by being more polished, even more intuitive, simple and it should also have a hot key to take photographs on the go ... it could be more integrated, the whole experience, not just the reporting of species but also taking photographs. U16_36: I was actually thinking about like some type of verification with, um, the camera some kind of AI to help recognizing the specie.

U3_43: I think the feature are pretty fine. I think that it was what I was looking for but I wish that there was a easier way to report the specie and for me it would be to take the picture of the specie and then to look for what it was ... try to to find the name and then add all the other information. So take the picture and report afterwards.

U9_45: Something on the Aqua website, you can log in and then have a map with all your trips. And perhaps access the pictures that other people took. But I think that in general, it would be good to add something that is more touristic in a way. Because citizen science is you providing, because you're feeling good because you're providing information or doing something good. But thinking about the specific context it would be nice also to give us more reward. Which is really just saving your trip.

U3_46: I don't know.... I was actually thinking if my colleagues were already reporting ... if I could see already the pictures that were already uploading and if there was a way that we could put the species together like a merged [report]. ...Because were are in groups, if the information could be shared .... We could all be doing the same report and we could be like counting together ...

U18_48: Exactly, the gamification, (should) be internal to each tour. And that's something that is like trophies or(...) along the tour, like finding stuff or something like that. (...) Uh, if you had a quiz, you get points.

U9_49: I guess at the end that all of us, we'll add more or less, the same spotted (specie). - Yeah. So another thing could be competing like is a team. - Yup. And then at the end, you see it compared to the other boats.

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