DM

Design of Interactive Touchpoint Interface for Reporting Marine Biodiversity using Recreational SCUBA Divers

MASTER DISSERTATION

Francisco Filipe Sousa da Silva

INTERNATIONAL MASTER OF INTERACTIVE MEDIA DESIGN

UNIVERSIDADE da MADEIRA

A Nossa Universidade

www.uma.pt

September | 2023

Cofinanciado por:

MADEIRA 14-20 · REGIÃO AUTÓNOMA DA MADEIRA · PORTUGAL 2020 · UNIÃO EUROPEIA Fundo Social Europeu · arditi · LARSyS Laboratory of Robotics and Engineering Systems · Interactive Technologies Institute LARSyS

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Faculdade de Ciências Exatas e da Engenharia

Master of Interactive Media Design

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Wednesday 20th December, 2023

Resumo

Examinar informações sobre biodiversidade marinha pode ajudar a determinar o estado de saúde dos nossos oceanos. Mudanças drásticas recentes na ocorrência de avistamentos de certa biodiversidade marinha são parcialmente causadas por mudanças antropogênicas que podem afetar todos os seres vivos e criar um efeito dominó que pode levar a mais sérias consequências, incluindo a extinção. Para recolher informação sobre biodiversidade marinha são tipicamente utilizados métodos que requerem trabalho e custos elevados, com uma grande quantidade de combustível a ser utilizado tal como tecnologia avançada (ex. ROV, AUV). Isto leva a que nem todas as áreas marinhas tenham o mesmo nível de programas de monitorização. Esta dissertação foca-se na recolha de informação de biodiversidade marinha através do uso de mergulhadores recreativos e da identificação visual, explorando o papel de ciência cidadã interativa na monitorização de biodiversidade in-situ. Este trabalho fornece uma ferramenta para a recolha de informação na forma de uma aplicação tablet, permitindo aos mergulhadores reportar espécies marinhas depois do mergulho. Num esforço para facilitar a monitorização a longo prazo, também analisa a usabilidade do sistema, o valor científico adicionado tendo em conta que os avistamentos são introduzidos por mergulhadores não especialistas e também o nível geral de compromisso pela comunidade de mergulhadores. O trabalho presente nesta dissertação foi utilizado para um artigo já publicado em Ecological Informatics com nome: "Crowdsourcing biodiversity data from recreational SCUBA divers using Dive Reporter" [1].

Keywords: Citizen Science, Monitoramento de Biodiversidade Marinha, Interface Sensível ao Toque, Mergulho SCUBA

Abstract

Examining biodiversity data can provide overal health status of our oceans. Recent drastic changes in their occurrence patterns are partially caused by anthropogenic impacts, which can affect all living species and create a domino effect leading to severe consequences, including possible extinctions. The collection of biodiversity data is typically laborious and expensive as it is performed with a high amount of fuel and logistics to reach the survey area and with the use of advanced technology (e.g. ROV, AUV). This provides that the monitoring of aquatic areas is not performed uniformly worldwide.

This dissertation focuses on the collection of biodiversity data using recreational SCUBA divers and visual surveys, exploring the role of interactive means used in citizen science for biodiversity monitoring performed in-situ. This work provides the tool for data gathering in the form of a tablet-based application inside of the physical structure, serving as a touchpoint interface, allowing recreational SCUBA divers to report the spotted marine species in the aftermath of diving activity. In an effort to facilitate long-term monitoring, it further analyses the usability of such system and the overall level of engagement by the diving community.

The work presented in this dissertation was used for an already published article in Ecological Informatics under title: "Crowdsourcing biodiversity data from recreational SCUBA divers using Dive Reporter" [1].

Keywords: Citizen Science, Marine Biodiversity Monitoring, Touch-Point Interface, Interaction Design, Recreational SCUBA diving

Acknowledgements

I would like to express my deepest appreciation for my thesis advisor Prof. Dr. Marko Radeta, not only did he help me with this work but also motivated me to keep going and expanding my academic curriculum and knowledge in different fields, and for that I will always be grateful. I would also like to acknowledge my co-advisor Dr. João Monteiro who helped me with the marine biology aspects of the dissertation, a field I knew very little about.

I am extremely grateful to my family, especially my mother who always pushed me to keep going through my whole academic life, from very early on and showed interest in understanding my concerns and how she could help me in any way. I will always be grateful for her support which I know I can keep counting on. *Obrigado mãe*. This thanks also goes to my brother, sister and father for their support and understanding.

I would also extend my thanks to the Wave Labs members that were present and helped me through the process of this thesis. Pedro Abreu, João Pestana and Rúben Freitas thank you for your contributions and the good moments that we spent together since I had the pleasure to join this great team. I also had the pleasure to work with some members of the MARE Madeira team which helped me further understand their field and how I could contribute to it. A special thank you to Victor Azevedo from Arditi's workshop who always found the time to help with the machines needed for the physical part of this thesis.

Lastly, I would like to mention Prof. Sandra Baptista who in a tougher moment in my life did not give up on me but instead helped me continue until I eventually reached this point.

This dissertation is part of the following projects: **CLIMAREST: Coastal Climate Resilience and Marine Restoration Tools for the Arctic Atlantic basin**, Grant ID 101093865 by EU (DOI: 10.3030/101093865); **INTERWHALE** - Advancing Interactive Technology for Responsible Whale-Watching, with grant no. PTDC/CCI-COM/0450/2020 by FCT; **MARE** - Associate Laboratory, with grant no. UIDB/04292/2020; **ARNET** - Associate Laboratory, with grant no. LA/P/0069/2020. Project has been conducted with the support of the Wave Labs[1] - interactive technologies for depicting the anthropogenic impact on the marine biosphere.

Francisco Filipe Sousa da Silva

[1] `https://wave-labs.org`

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List of Acronyms

3D Three-Dimensional

API Application Programming Interface

AUV Autonomous Underwater Vehicle

CLIMAREST Coastal Climate Resilience and Marine Restoration Tools for the Arctic Atlantic basin

CNC Computer Numerical Control

CRUD Create, Read, Update, Delete

JS JavaScript

MDF Medium-Density Fibreboard

MVC Model-View-Controller

PHP Hypertext Preprocessor

REST Representational State Transfer

ROV Remotely Operated Vehicle

RQ Research Question

SCUBA Self-Contained Underwater Breathing Apparatus

SDK Software Development Kit

SQL Structured Query Language

SUS System Usability Scale

UI User Interface

UML Unified Modeling Language

WCAG Web Content Accessibility Guidelines

1 Introduction

Here the dissertation describes the problem and current pitfalls when performing large-scale aquatic monitoring, proposing the usage of interactive technologies for biodiversity mapping. The main research questions and the overall thesis structure are described.

1.1 Problem Statement: Large-scale marine monitoring remains challenging

Aquatic conditions remain dire due to the anthropogenic impact on marine ecosystems, resulting in a reduction in marine biodiversity from corals to large predatory species, which have declined in their abundances to 10% in the last 50 years [2]. The collection of marine biodiversity data and its analysis is important as it allows domain experts such as marine ecologists to be able to detect changes early on and provide recommendations of solutions to help mitigate their further impact [3], as well as to be able to determine if efforts for restoration are being successful. Assessing marine biodiversity requires laborious and expensive tools (e.g. Remotely operated vehicle (ROV), Autonomous underwater vehicle (AUV) [4]), which typically provide a high level of detail in one specific area. However, these technologies have a high cost and require specialized training to operate them. In addition to the already high cost of the equipment and the time-consuming process, the data also requires additional time for analysis by domain experts in the aftermath of the performed collection.

1.2 Pitfalls of current low-cost approaches

Current alternatives for low-cost marine biodiversity monitoring remain on professional Self-Contained Underwater Breathing Apparatus (hereinafter SCUBA) diving surveys, typically performed by the domain experts and along previously established transects. However, recreational SCUBA diving, when used to assess the underwater marine biodiversity, is prone to the aggregation of noise in data [5] [6]. Contrary to scientific SCUBA diving, which is performed for fish counting and uses plates and pens underwater to record the data, data inquiry in recreational scuba diving is typically performed in the aftermath of the diving activities and using a paper-based form or by the usage of mobile applications (hereinafter apps) [7]. The latter provides cost-effective means and may cover larger sampling areas for marine biodiversity monitoring. However, due to the lack of an expert to validate such data, they are also prone to noise gathering as it is not performed by the domain experts.

1.3 Proposed approach and contributions

This dissertation explores the role of an interactive digital tool as a means to assess underwater marine biodiversity, leveraging the input from recreational SCUBA divers in the aftermath of their diving. Three types of interfaces were developed with the goal of understanding the effect that different properties that a physical structure can cause on the user perception and which interface is more robust to ease the data input.

The interfaces developed are a tablet interface, an interactive touch point interface, and two (2) web interfaces. The tablet interface is a mobile application used for data gathering made available in a tablet UI. The interactive touch point interface (hereinafter, kiosk interface) is a physical structure where the tablet interface can be introduced and made fixed. The web interface is an interface which can be used on web through a computer. The overall hypothesis is that such interfaces can motivate the data gathering of marine species from SCUBA diving centers, storing them and leaving them for future analysis by expert ecologists.

The tablet interface was developed following the previous work [8], conducted at Wave Labs [2] in Madeira island. The work on this dissertation expands on that previous work by developing a novel user interface, testing its usability and creating other interfaces for comparison and all their functionalities[3]. One research paper was made which provides the ecological evaluation of the mobile application itself [1] where the contribution was in the implementation of the system used to gather the biodiversity data presented throughout this dissertation.

1.4 Evaluation stages

To determine the usability of the interfaces and if they are according to traditional software development standards. Usability is first tested in a controlled environment with non-SCUBA diving audience, for the purpose of better understanding the performance of the interfaces with no additional external constraints (e.g. carried diving gear, direct sun exposure). The use of non-SCUBA divers is due to constraints of finding a considerable number (at least 15) of SCUBA divers to perform usability tests in a controlled environment. This would require to either get permission from a dive center to occupy their space for some usability testing or require the SCUBA diver audience to move to a controlled environment, which could be out of their way. The use of a non-SCUBA audience makes it more manageable to find a higher number of testers, and the lack of diving experience should not affect the overall results since they are usability-related and not diving-related. Further evaluations are then conducted in-situ with experienced SCUBA divers, being the dive center staff. Additional observations were reported in this thesis as well, allowing the creation of the design guidelines for facilitating the monitoring of biodiversity using SCUBA divers. All these evaluations allow to determine which interface is preferred by the diving audience, serving as the robust backbone of a reliable monitoring program, which is out of the scope of this thesis. In summary, the two evaluation stages were:

(I) usability tests conducted in a controlled environment (with no diving audience) - to understand if the interfaces have a high usability score and if the app is up to the standards to be used as a final product;

(II) tests conducted in-situ (with experienced SCUBA divers) - to study if the interface fits the stakeholder needs;

The final evaluation stage together with the initial surveys performed with the dive center staff centers during this dissertation provided results based on three different perceptual elements: (i) **hearing** - when the dive center staff initially heard the idea and before the interfaces were developed - hereinafter called Pre Design Intervention; (ii) **sight** - when the users saw the interfaces which appealed to their vision - hereinafter named Post Design Intervention; and (iii) **touch** - when users tested the interfaces which added the tactile component, hereinafter called Post Experience Intervention.

[2] `https://wave-labs.org`
[3] `https://play.google.com/store/apps/details?id=com.tigerwhale.divereporter`

1.5 Research questions

The two evaluation stages, as well as the literature review described in this thesis, were conducted with the purpose of answering the following research questions:

- **Research Question 1 (RQ1):** Which obstacles can an interface solve to ease the data input through its physical and digital properties?
- **Research Question 2 (RQ2):** Which interface should be pursued for a reliable monitoring program?
- **Research Question 3 (RQ3):** Will the data obtained through the app be reliable for scientific purposes?
- **Research Question 4 (RQ4):** Can a mobile application be used by non-scientists for marine biodiversity monitoring?

Research question 1 (RQ1) will be answered based on the obtained information through questionnaires and field observations, while research question 2 (RQ2) will be answered by the first and second evaluation stages. Research question 3 (RQ3) will be answered by already available scientific literature where the dissertation has been used for the evaluation. Research question 4 (RQ4) will be answered based on the determined results from RQ2 and RQ3.

1.6 Structure of the document

In the forthcoming, the dissertation will present the work related to the topic of the dissertation from already available applications and existing databases. Several gaps will also be presented in Section Related Work. Further on, Section Methodology will present how the dissertation plans on addressing the gaps, depicting the process of developing the new system and the main rationale of such decisions. It will showcase the procedures for conducting evaluation, motivating the need for each study to be relevant. Section Results will present the data related to the three implemented interfaces (being mobile, tablet, or kiosk) obtained through observation and questionnaires during the two evaluation stages. An example of obtained marine biodiversity data is showcased. Based on the results, Section Discussion will go in-depth evaluating said results and how these answer the proposed research questions, outlining the limitations and future work that can be built upon this dissertation with the goal of both improving the data collection as well as how the data is treated after being collected. Finally, Section Conclusion will address the mentioned Research Questions, explain the overall impact of the system, serving for the initial step in low-cost monitoring using SCUBA divers.

2 Related Work

This section showcases some of the existing methods, databases and technologies typically used for marine biodiversity monitoring. The gap is identified, paving the way for the proposed dissertation system.

2.1 Existing Methods for Reporting Underwater Marine Biodiversity

When assessing some of the most common methods for marine biodiversity exploration, one of the big setbacks is the price tag of the equipment and training needed to handle such [9]. However, there are other methods, as mentioned previously, also used to explore marine biodiversity that do not require such a high investment [10]. These ones allow for obtaining data at a lower cost, although the amount of data also tends to be much less. They also require a bigger time investment to get to the level of the more expensive methods. Some of these low-cost methods are the ones that are based on acoustics [11] or visual [12] census. Most of the methods that require a lower budget will still require some equipment, it also requires experts to spend valuable time in data gathering and data analysis. Where citizen scientists can help is with the collection of data itself and making it available to experts [13] [14], allowing for a long-term monitoring program that regularly records sightings of indicator species, making it possible for experts to quickly identify trends or changes that might occur in different areas.

2.2 Prior Research using Technology for Opportunistic Data Gathering

Visual censuses are not specific to marine biodiversity [12], and they have been used and proven beneficial in the collection of biodiversity data in other environments. There are apps and web-based approaches that allow for the reporting of data and the aggregation of such by area or specific species. The following technologies are the most widely used ones and have been proven to be useful for data gathering iNaturalist [4] [15] [16], NestWatch [5] [17], eBird [6] [18]. These technologies allow users to create reports and specify what species they consider to have observed and have it approved by an expert or not categorize it at all and leave that task to someone with more knowledge in that area. Said technologies allowed to increase the data collected while maintaining the quality of it [19] [20], they are also open access which means that not only can users report but they can also have access to data and learn from it which may motivate further involvement in future projects.

Apps and web-based technologies are also available for the collection of data in marine environments. However, marine biodiversity data tends to be skewed to species visible from the surface [21], due to most of these technologies requiring photo evidence of the sighting, which makes it not accessible for most users since underwater photos are not as widely available to all users due to equipment restrictions [22]. The data collected from such technologies focus mostly on marine birds, large mammals, and other marine species that are clearly visible on the surface. Some of these technologies are also only focused on a smaller group of species, for example, algae or mammals [23].

Table 1 shows some of the technologies that allow reporting underwater marine biodiversity using SCUBA divers and the characteristics of mentioned technologies. From the table it is possible

[4] `https://www.inaturalist.org/`
[5] `https://nestwatch.org/`
[6] `https://ebird.org/home`

conclude that most technologies require photos when reporting a sighting. This is useful to help classify the species in the cases of a user not being able to classify it correctly. Further more it also helps to identify reports that were misclassified, allowing for a higher standard to be implemented. The ones that do not require photos either require prior experience in protocols for surveying (e.g. Reef Life Survey) [24] to act as a filter or because the species are limited and easily distinguishable (e.g. GelAvista). The other approaches such as iNaturalist [25] allow the publication of observations without photo, however, due to neither requiring prior experience nor the photo it creates the possibility for those reported occurrences to have a negative effect in the data used for studies [26]. However, factors such as prior experience or photo evidence result in additional limitations for the users. Such requires that the user need explicit training or require necessary equipment leading to a loss in traction of users that would initially participate in such activities as reporting biodiversity in a more recreational way.

Table 1: Existing mobile and web apps that allow marine biodiversity monitoring using SCUBA divers.

Name	**App type**	**Species**	**Location**	**Photo**	**A-priori knowledge**
iNaturalist	Mobile	All	Worldwide		
Reef Life Survey	Web	Fish and algae	Worldwide		✓
Observadores del Mar	Web	Marine	Worldwide	✓	
Black Sea Watch	Mobile / Web	Marine	Black Sea	✓	
GelAvista	Mobile	Jellyfish	Portugal		
iSpot	Web	All	Worldwide	✓	
Dive Reporter	Mobile / Web	Custom	Worldwide		

From the apps mentioned on Table 1, iNaturalist is most likely the more widely known by biologists and even by the general public, having 3.2 million users. One of the big advantages of iNaturalist is that it covers all species worldwide and does not require a photo to be able to create a report. However, for the reports that researchers are most interested in, a photo is required. This is due to the iNaturalist form of classification for reports, reports that have a photo/sound, coordinates, and date can be turned into "research grade" records. To become a research grade record, the report has to be reviewed by at least two users, who both need to identify the species in the photo and agree to be the same species. This process allows for the reduction of misinformation. However, reports without photos can not achieve high trusted classification, leading to the reiteration that photos in an underwater environment have other requirements than the photos out of the water, requiring expensive equipment.

Reef Life Survey, compared to iNaturalist no longer requires photos or sounds to obtain a research grade records, as such obtained by Reef Life Survey are all considered to be the same level. This allows for researchers to be more confident of all the available information [27, 28]. However, it also limits the number of records since it limits the users to already be experienced divers. The users are also required to apply an approved survey method, which means that the dive where a user wants to collect information has to be done specifically to perform a transect (i.e. follow a line for a determined length and count the number of fishes seen on each side of the line at a specified distance from the line) and not as a typical recreational dive since a transect dive requires the divers to bring underwater pencils, paper and line, among others.

Observadores del Mar requires photos which limit the users. Their way of classifying the species, however, is different. After a picture is taken and introduced, it has to be connected to a project, and the species can then be chosen from the list available on the project. This not only makes it easier for users to navigate projects that might be of interest, but also makes it so users who have knowledge of species in that project can contribute to fixing species miss classification issues. This way of classification requires more work from the part of experts since there is a need for a team of experts to validate every data entry, and also makes the data more reliable.

Black Sea Watch is one of the technologies that is also limited to an area. This limitation, as well as the photo requirement, are limitations for user participation. It is not widely used, being the one on the list with the least data available. It uses a system similar to Observadores del Mar. However, on Black Sea Watch, there is no need to identify which species it is, and that classification can just be done by the team behind the project.

GelAVista is the other technology mentioned, which is limited to an area. This one, however, does not require a photo. Not requiring a photo allows for a higher number of participants but limits the quality of the data since the reports without a photo can not be reviewed. The data obtained from users also seems to be on a request basis since it is not made available through their website.

Another technology that is very similar to iNaturalist is iSpot [29, 30]. iSpot requires underwater photos. It also uses a similar system for classification where different users can discuss an identification, however it implements a reputation system. A reputation system allows one to be more confident when using data from a user if this has a higher reputation.

2.3 Existing Marine Biodiversity Databases

The previously referred technologies and methods for gathering marine biodiversity aid the databases for researchers worldwide. Indeed, with this approach, the researchers interested in surveying marine biodiversity have access to data that otherwise would have a high cost if done individually as well as a with great amount of time (such as the case with making AUV or ROV transects). These types of databases not only allow the merge of data from different studies but also allow that data to be organized in a standardized way while making it available on a bigger scale and in the same place [31]. This standardization not only makes the data more easily graspable but also allows for the aggregation of data in a raw form allowing for the creation and analysis of trends that are happening in our oceans.

For instance, the databases such as Ocean Biodiversity Information System (hereinafter OBIS[7]) and Global Biodiversity Information Facility (hereinafter GBIF[8]) are some of the ones that have a higher number of reports and that clearly have an impact on the marine biodiversity community as a whole. Still, despite their individual contributions, the databases like these create the problem of data replication [32], since different databases have different providers, it creates the risk of data to be in both databases as separate entries. Such can cause the influence on the results when figuring out the trends [33]. Moreover, the lack of a standard when registering reports can influence the analysis of said data due to a lack of precision when creating a record (e.g. rounding coordinates) [32]. Indeed, this is a risk that may be eliminated to a certain degree if the databases used have the same type of data stored and can be compared to eliminate what

[7] `https://obis.org/`
[8] `https://www.gbif.org/`

would be false positives. Such as the case with the standardization proposed by the Darwin Core[9]. However, even if standardization may be solved, there are other problems that may skew the data and create false trends such as when considering the provider credibility.

2.4 Identified Gaps for Opportunistic Marine Biodiversity Monitoring

Most of the current state-of-the-art developed technologies for assessing biodiversity using citizen scientists are too broad. Indeed, allowing the input of all types of biodiversity to be reported without focusing on a specific environment may bring cognitive load. The ones that focus on a specific environment end up not having as much relevant data as it could be obtained from such means due to limitations or requirements imposed by the technologies themselves (i.e. requiring photos or previous experience). These factors make it so recreational SCUBA divers are not leveraged as much as they could.

There is also a lack of an "attractor", which is to be used to raise attention to the users, further questioning the user motivation for data input. For instance, the individual person may be motivated to study a specific animal, but may not be of interest of the other members of the groups [10].

The Dive Reporter app is among all the ones outlined in Table 1 which provides the opportunity for customization, allowing monitoring of specific species which are to be found only in those specific diving spots which are managed by the diving centers. Such reduces the need for users to scroll in the mobile application and find the specific species. Moreover, Dive Reporter may be used to reach the SCUBA divers worldwide as a part of briefing[11] and provides a three-fold opportunity for the creation of a biodiversity monitoring program:

1. cost effective - using the same mobile application for reporting spotted marine biodiversity;
2. worldwide coverage - multiple dive centers across the planet can participate in monitoring;
3. data control - using the dive master during the part of briefing to ask the SCUBA divers and averaging reported results.

This thesis explores the type of interface which may be leveraged by the dive centers and introduces the new functionalities described further on.

[9] `https://dwc.tdwg.org/`

[10] `https://www.audubon.org/conservation/join-christmas-bird-count`

[11] SCUBA divers typically perform two briefings: (i) one when they decide about who is the dive master to lead the group, security signalization, what attractions are going to be visited and which species will be seen, etc; and (ii) second, when they gather back the rented equipment from the dive such as tanks, belts, snorkeling masks, rinsing. Typical monitoring program of marine litter is already part of the briefing is mentioned in some diving centers - `https://www.padi.com/aware`.

3 Methodology

This section showcases the prior study, where SCUBA divers were interviewed regarding the willingness in participating the monitoring program and as well as by their preference in potential interface. The context of dive center and physical constraints are also depicted. The design of the three interfaces and the technology used in each is also described below. System architecture describes all components for the design of the interface. Backend dashboard which stores the data is also depicted and the procedure for evaluating all the interfaces is shown.

3.1 Challenge

Recreational SCUBA divers are the focus of the dissertation since they are a large number of divers who currently provide very little marine biodiversity data. Moreover, being able to gather the data seen by them will greatly increase the monitoring of an area. However, recreational SCUBA divers may potentially introduce noise to the obtained data [34]. However, previous research has shown that such data despite the risk of noise is still valuable [35] [1]. Due to this, the possibility of noise is an imposed constraint for this dissertation. The dissertation uses a divemaster who has experience in species identification to help in reduction in the amount of noise[12].

While professional transect surveys are typically based on experts who annotate directly while being underwater (using plastic plate and wooden pen) [36], in this dissertation the counting will be performed in the aftermath of the dive. On the sea surface, a dive master serves not only to guarantee the safety of divers but also to play a crucial role in data filtering. Since the number of species for underwater annotation is limited, we take the same approach by limiting the number of species in this dissertation ($N = 24$). Such is used with the purpose of being easily distinguishable and to facilitate the identification of the species seen during the dive. The selection of species was made following the marine ecology experts, being interested for monitoring of such species using diving spots. In this case, the overall hypothesis is that the obtained data from recreational SCUBA divers may be used as an opportunistic "data gathering tool" as in the case of cetaceans [37], allowing the experts to further perform detailed analysis in the aftermath of a dive [1].

3.2 Stakeholders

Stakeholders of the proposed system based on Dive Reporter hence involve:

(i) *diving center staff*, being interested in obtaining more insights into the local biodiversity in their house reefs and used diving spots either for conservation or business reasons;

(ii) *recreational SCUBA divers*, users who facilitate the data collection, motivated by the dive center and interfaces;

(iii) *dive masters*, typically employed by the diving centers, serving to filter and average the collected data;

[12]Dive master typically goes and leads the groups of divers during diving activity. At the end of the dive, the dive master may ask all participants how many individuals of individual species the divers have seen. The obtained number from the group is then averaged per number of participants (i.e. 1,3 and 2 octopus results in 2 octopus).

(iv) *marine ecology experts*, who capitalize and obtain novel insights from the obtained data with the goal of pushing monitoring and restoration programs.

Conversely, these stakeholders have their own interests in mind to participate in the monitoring program for different reasons. One of the objectives of this dissertation is to bridge these interests and showcase that it is possible to obtain relevant data for all of them, and further motivate the continuation of a mutual partnership [38].

3.3 Understanding Motivation of Dive Centers to Participate in Biodiversity Monitoring

To bridge between different types of stakeholders, some meetings/workshops were conducted to help better understand their needs regarding their willingness to participate in the monitoring program, as well as, on the interface design preference and which type of information should be available.

User Study. Three meetings were conducted with the help of the MARE-Madeira[13] team of marine ecologists and with the dive centers around the island of Madeira as well as Porto Santo (North East Atlantic). Not all of the meetings included all participants from the dive centers staff due to schedule conflicts, however from all the meetings that took place, it was possible to involve 11 different dive centers, represented by 18 people, as well as an additional 8 scientists from MARE, with a mix of marine biologists and ecologists.

One of the key takeaways from these meetings was that the dive centers staff were interested in participating in a monitoring program and that they had a preference for the interface. All questions were asked to the participants in the closed room, where the questions were showcased on a big projection screen. Every participant anonymously used the web survey to respond to the question. These questions were made with Mentimeter [14], which allowed to display what other users were sharing in real-time while still keeping user input data anonymous.

Results. The results to the question "Would you participate in a monitoring program with this app?" had positive results, with 16 participants out of 18 saying "yes" and one (1) saying "I don't know". These showed the gap that the systems of this dissertation could fill and that there was an intrinsic need by the diving centers to participate in it. This question was missed by one of the dive centers members and it was not possible to identify who since the questionnaires were made anonymously.

The results for the question "Which interface would be better for you?" had mixed results, with 11 participants mentioning they would prefer the tablet interface, six replied that they would prefer a web interface, and only one participant mentioned the preference for a kiosk.

These results can be explained by the fact that the previously developed tablet interface was already available[15], and the web was a more commonly known interface. At the same time, a kiosk was a bigger question mark for the dive center. However, all these answers were relevant since they allowed for an open discussion about why they would prefer each interface and better understand what would need to happen for a certain interface to be chosen over another.

[13] https://mare-madeira.pt
[14] `https://www.mentimeter.com`
[15] Dive Reporter app has been updated for the purpose of this thesis.

This user study also included additional talks with marine biology experts, who had already worked directly with the dive centers and already knew how their modus operandi. From these talks, it was possible to find out that the state of the art studied was correct and that the dive centers were still paper-based during debriefing.

Participant Feedback. In addition to the question, an open discussion was also started to further understand stakeholder concerns. Some of the comments deemed more relevant for the system were the following:

– "Our diving center is very busy on high season, we see the value that the Kiosk would reduce the time needed to participate."

– "We don't believe a foreigner would download a mobile app just to use it once or twice when diving on vacation."

– "We think that the kiosk would be attractive and call to the attention of divers."

– "We believe that the diving community and regular divers would easily adhere to using the app regularly independently of the platform used."

– "The kiosk may show some problems due to dimensions/space constraints."

– "Making the outcome/maps/graphs visible to the clients could create expectations and drive clients (i.e. the stakeholder recreational SCUBA divers) to other dive centers/locations."

– "Some more common species need to be included. It looks bad for the business if they go over the list and no species available were actually seen."

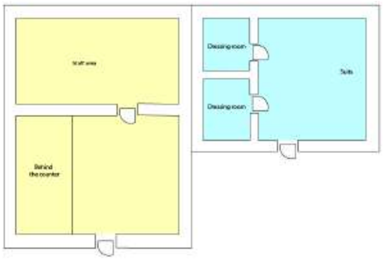
– "We have a high interest in the output of the app for dive spots data."

– "We are concerned that integrating it into debriefing might not be feasible due to usually being short and done while wet."

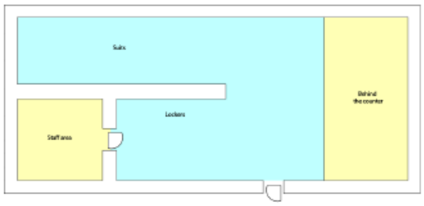
3.4 The Context - Dive Center

All of the prior obtained comments were taken into account in the design and functionalities integrated into the Dive Reporter interface and had contributed to some of the decisions taken further in the dissertation. Another aspect that was very important was the question that the interface should be made available in the limited physical space of each dive center and its conditions. These conditions can make the usage of an interface as a data gathering tool very difficult to use (e.g. not enough space for a kiosk). This thesis strives to create some guidelines to help choose which interface should be made available, not only for the continuation of the CLIMAREST project but also for other projects of citizen science.

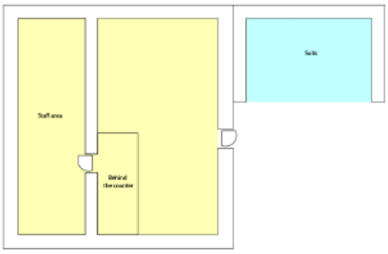
Figure 1 represents roughly the wet and dry areas of each interviewed dive center (i.e. wet areas in blue and dry areas in yellow). Having knowledge of these areas was important since these allowed to understand the space limitations which could constraint the interface. The author of this dissertation has visited all dive centers to inspect the possibility of location where the interface should be available. The Figure is not made to scale, but it serves to connect to the obtained results of the initial analysis and understand which factors impact the chosen interface. The diveCentreID is the same used on the Results and Discussion sections. One of the dive centers which is present in the results does not have its layout available as it was not possible to add it due to the author not being able to visit that space.



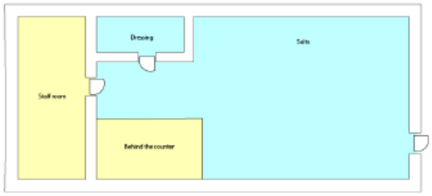
(a) diveCentreID 1



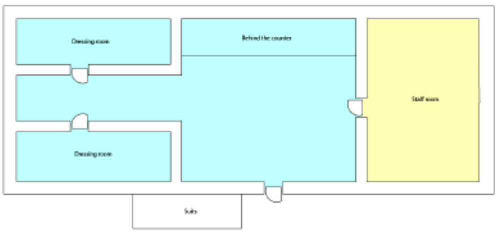
(b) diveCentreID 2



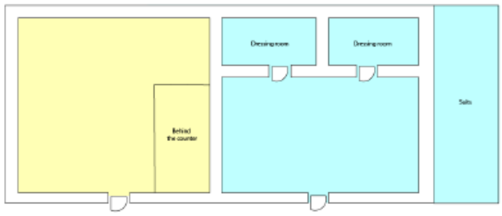
(c) diveCentreID 3



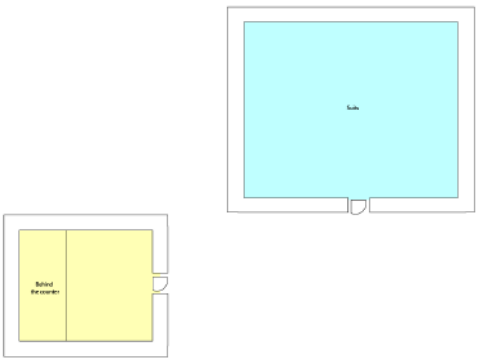
(d) diveCentreID 4



(e) diveCentreID 5



(f) diveCentreID 6



(g) diveCentreID 8

Fig. 1: Typical layout of the dive centers from bird perspective, indicating wet and dry areas, analyzed for this dissertation.

Being able to identify if a dive center presents some dry area and how the space of the dive center is organized helped to decide which interface should be pursued for each one of them. It is important to note that the conditions of a dive center are quite rough for technology and these dry areas are important since they are the areas where a physical structure could most likely be placed without damaging the tablet.

3.5 Species Preference

The other takeaway from the meetings with the diving center staff was what species should be present in the app with the specific reason, this is, why each species were chosen (i.e. value that it brings). These reasons can be for commercial interest, if they are vulnerable species in the area, if they are not native species, or if they are iconic (iconic species are important to be present for dive centers as they help attract the clients' attention). For the species, two questions were asked (i.e. What do you consider to be the most important species to monitor in Madeira?; What are the species more exciting for divers in Madeira?). The first question was used since some of the dive center staff also have conservation in mind to know what they see in their house reefs as changing and lead to a discussion on why maybe this changes occur. The second questions brings the financial or business aspect of marine biodiversity for the dive centers as some of the species which are important for the ecosystem may not be of interest for recreational SCUBA divers. The answers to these questions led to further discussion about what should be present, which in turn helped to collect a large number of species that the dive centers considered important from business and conservation standpoints.

From a conservation standpoint, the species mentioned are the ones depicted in Table 2.

Table 2: Answers for dive centres staff to "What do you consider to be the most important species to monitor in Madeira?"

Algaes	Island grouper	Yellowmouth barracuda	Atlantic Bonito	Shrimp
Crab	Mediterranean slipper lobster	Seahorse	Cuttlefish	Coral
Black coral	Blackpoint Sculling Crab	Gilt-head bream	Starfish	Jack
Monk seal	Squid	Jellyfish	Grouper	Sea urchin
Hogfish	Triggerfish	Octopus	Butterfly ray	Sardine
Scorpion fish	Turtle	Atlantic Trumpetfish		

From a touristic interest or business standpoint, the species mentioned are the ones listed in Table 3.

Table 3: Answers for dive centres staff to "What are the species more exciting for divers in Madeira?"

Seahorse	Grouper	Rays	Octopus	Yellowmouth barracuda
Greater amberjack	Shark	Monk seal	Turtle	Slipper lobster
Triggerfish	Amberjack	Almaco Jack	White trevally	Barracuda
Island grouper	Atlantic bonito	Seaslug		

From the data gathered in the meetings, it was then for the experts to decide the final list of species ($N = 24$, which will be displayed as 4×6 per page in the UI) that should be displayed (e.g. seagrass, monk seal), what units should the reports from certain species be in (i.e. abundance, e.g. number of individuals, size of the prairie) as well as what ranges for such abundances should be used (e.g. seagrass, $< 1m^2$, $1m^2 - 5m^2$, $5m^2 - 10m^2$ and $> 10m^2$), seen in Table 4. Each species has its own units of abundance as well as its own ranges. Both these units and ranges were provided by marine experts (e.g. a report with one (1) almaco jack or three (3) have the same scientific value).

Table 4: Final list of species chosen and reason why it was chosen

Common name	**Scientific name**	**Abundance levels**	**Reason**
Seagrass	Cymodocea nodosa	<1m^2, 1-5m^2, 5-10m^2, >10m^2	Vulnerable
Harpon Weed	Asparagopsis sp.	1-15, 16-30, 31-50, >50	Not Native Species
Leafy Flat-blade Algae	Stypopodium sp.	1-15, 16-30, 31-50, >50	Iconic
Pen Shell	Pinna sp.	1, 2, 3, >3	Iconic
Bushy Encrusting Anemone	Antipathozoanthus sp.	1, 1-2, 4-5, >5	Iconic
Club-tipped Anemone	Temlatactis cricoides	1, 1-2, 4-5, >5	Iconic
Fire Coral	Millepora alcicornis	1, 2, 3, >3	Not Native Species
Maybe Stinger	Pelagia noctiluca	1, 2-3, 4-5, >5	Iconic
Button Tunicate	Distaplia corolla	1, 2-3, 4-7, >7	Not Native Species
Octopus	Octopus vulgaris	1, 2-3, 4-5, >5	Commercial Interest
Common Cuttlefish	Sepia officinalis	1, 2-3, 4-5, >5	Commercial interest
Blackpoint Sculling Crab	Cronius ruber	1, 2-3, 4-5, >5	Not Native Species
Umbrella Slug	Umbraculum umbraculum	1, 2-3, 4-5, >5	Iconic
Atlantic Trumpetfish	Aulostomus strigosus	1-3, 4-6, 7-10, >10	Iconic
Fangtooth Moray	Enchelycore anatina	1, 2-3, 4-5, >5	Iconic
Almaco Jack	Seriola rivoliana	1-3, 4-6, 7-10, >10	Commercial Interest
Gilthead Seabream	Sparus aurata	1-3, 4-6, 7-10, >10	Not Native Species
Barred Hogfish	Bodianus scrofa	1-3, 4-6, 7-10, >10	Vulnerable
Island Grouper	Mycteroperca fusca	1-3, 4-6, 7-10, >10	Vulnerable
Dusky Grouper	Epinephelus marginatus	1-3, 4-6, 7-10, >10	Vulnerable
Seahorse	Hippocampus sp.	1, 2, 3, 4	Iconic
Common Stingray	Dasyatis pastinaca	1, 2-3, 4-5, >5	Vulnerable
Loggerhead Turtle	Caretta caretta	1, 2, 3, >3	Vulnerable
Monk seal	Monachus Monachus	1, 2, 3, >3	Vulnerable

The scientific names are the ones used according to WoRMS categorization [39] used in most available databases. Marine ecologists as domain experts also indicated what information should be available to the users for curiosity and education (e.g. size of the monk seal). The photos of all the species were also supplied by the experts.

3.6 System Architecture

The architecture includes a mobile app based on Dive Reporter, the web database, the backend and the application programming interface (hereinafter API)[16], as seen in the system architecture diagram (Figure 2) [40] [41]. The way each interface was developed, from low-fi to high-fi prototypes were developed, is explained in their respective sections (i.e. subsections Dive Reporter - Initial UI of the Mobile App, Dive Reporter - Kiosk interface and Dive Reporter Dashboard).

DB. Used database was a relational database, in this case, a MySQL, where the needed tables were created with their respective information and relations between them with different one-to-one and one-to-many relations. The Unified Modeling Language (hereinafter UML) diagram of the database can be seen in section A.

[16] https://wave-labs.org

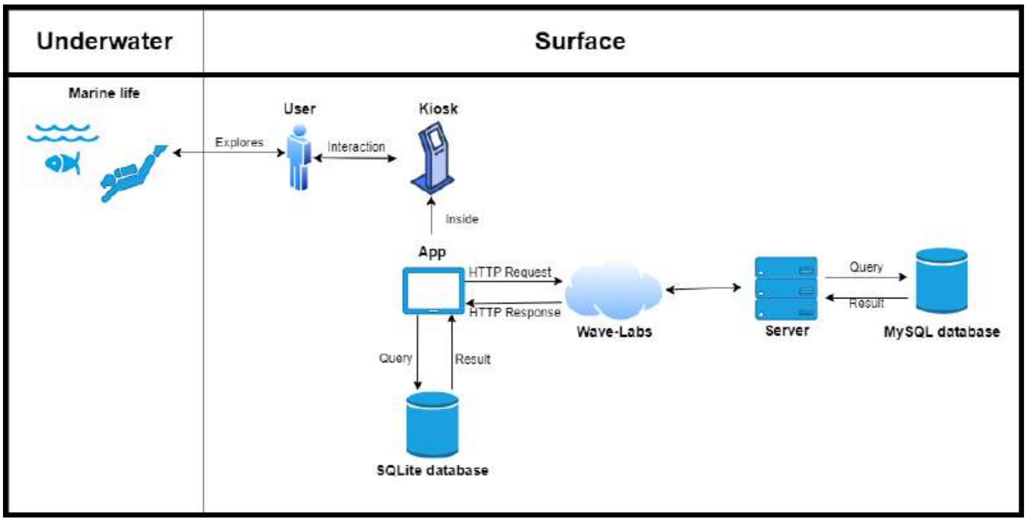


Fig. 2: System architecture UML

The database has a *users* table, which has all the information commonly gathered from users like email and password as well as some other customizable fields like photo and descriptions. This table also has a field which allows for the identification of the users as normal users or dive centres, which was later used to distinguish what information they should have access to. One of the other main tables is table *diving_ spots*, this table is a table that groups all the information about the diving spots. In turn, it has a relation with the table *diving_ spot_ has_ substracts* since a diving spot can have more than one substrate, and MySQL does not support array data type. The table *diving_ spot_ substracts* is populated with the options a diving spot can have as substrates.

Very importantly, from feedback gathered in the previously mentioned meetings, it was pointed to the importance that not all dive centres dive everywhere. As such, the diving spots shown for a specific user should be the ones they dive on. This was accomplished by having a table *user_ has_ diving_ spots*, which has the id from a user and from a dive spot when that user dives in that dive spot.

The information from the dives is saved in the table *dives*. This table saves the general information from the dives, such as the number of divers, dive time, dive spot and the user who reported that dive. This table has a relation with table *dive_ has_ litters* since one of the functionalities is that if litter is found during the dive, it can also be reported together with the species seen. The table *dive_ pivots* then creates a relation between the creatures and the dives where that creature was seen as well as the abundance seen, which is predefined from values available on the table *abundances*, each species has four different levels of abundances.

The table *creatures* still has another relation with the table *creature_ photos*, this table saves the id of each species and the path to where on the server the photo of that creature is saved. Although phpMyAdmin was used to administrate the database, the tables and relations between them were created in Laravel as the rest of the backend.

API. The API, in this case, a Representational State Transfer (hereinafter RESTful) API, was created in PHP with the Laravel framework. This is the same framework used to create the database with the use of migrations and models. Laravel allowed the creation of the whole database and the development of the API, where the apps (i.e. Tablet, Kiosk, Web) would make their requests. The API deals with the authentification of users with the use of tokens. This token is then passed to the apps to authenticate the user and if the user has permission. The API is mostly used for GET, POST and PUT requests which are used to fetch data from the server, send new information to the server and update information on the server, respectively.

Although an API is available with the restrictions from internet connectivity from where the dive centres are located, there had to be other alternatives and fallbacks. One fallback was using SQLite as a cache. Such allowed to hold the database tables that would be queried more often and that could be made available without creating any data breach, thus reducing the number of calls to the API and increasing the performance of the app [42]. Some of these queries are, for example, the images for each species as well as diving spots. This SQLite database is downloaded on user login since it is known that the user has an internet connection at that moment. The rest of the data that had to be more secure such as account credentials or that should be saved to the server after a report was made, was handled through the API. Since, in the moment of a report, it is possible for an internet connection not to be available, one of the other fallbacks is having a property that saves the reports until a user can get such a connection.

Laravel models were used to interact with the database. These allowed defining what attributes should be present on each model and facilitated inserting new records into tables and querying said tables. Laravel filters were also used, mostly because the dashboard allowed tables and graphs to be updated only with data the user wants at a given moment. Laravel controllers were used for the API calls, a request is made by the user from one of the interfaces, and this request is then received by the server, which sends a response. The routes were defined in an api.php file making calls to the methods in a specific controller. All such allowed CRUD operations (Create, Read, Update, Delete), functions or other methods with more specific applications (e.g. returning diving spots of a user). In the following sections, where each interface is explained, the requests and responses are further elaborated and explained.

3.7 Dive Reporter - Initial UI of the Mobile App

This application was based on a previously developed application [8](Figure 3). The application had minor in-situ testing and its stakeholders were not well identified. The identification of the stakeholders for the system was part of the work conducted during this dissertation. The whole interface was redesigned from the previous layout and some functionalities were added or changed. For example, the diving spots accessible for the users were only the ones needed by that specific user. During this dissertation, the newly redesigned application was also made available on the App Store market [17] where it was not previously available. This expansion makes it possible to expand the monitoring program to other areas and projects without hardware limitations (i.e Android or iOS) can be used. The goal when re-designing the app was to maintain simplicity and focus on rapid data inquiry since SCUBA divers will do such reports after completing a physically demanding activity like SCUBA diving and they may be in a rush for leaving. An example of how the previous interface looked can be seen in Figure 3.

The app itself was developed with the use of the Alloy framework, Model-View-Controller (hereinafter MVC) paradigm, from Titanium SDK, which allows the development of

[17]https://apps.apple.com/br/app/dive-reporter/id1636665151

Fig. 3: Dive Reporter (initial version)

cross-platform mobile applications with the programming language JavaScript (hereinafter JS). Like many others, this framework allows access to native User Interface (hereinafter UI) components and networking. Both of these are very useful to the app's development since having access to the UI native components allows the app to feel more like previous apps that the users might have used. The networking allows communication between the app and the server to transmit the data. Since the framework is cross-platform, it allowed the creation of the app for both Android and iOS with just one code base. This means that a bigger target audience is reached with the app. Figure 4 shows the intended design on low level prototype (wireframe).

A login window was needed to let the users get into their accounts, allowing the information to be associated with what dive center made each report. This allows the experts to be confident that the information is reliable as well as making it available for the dive center that made those reports. The layout for the login window can be seen in Figure 4a, which includes two (2) fields, the email and the password fields, which are needed to authenticate each account, as well as the login button that sends the information to the API, there is also a connection to send the user to the register window.

Since a login window is present, a register window was also deemed needed. However, this was changed since it was later deemed better for the users to register through the website as it would allow the users to know what the app is for and get more integrated into the CLIMAREST project. This window was planned to have, similarly to the login window, four (4) input fields, which the user would feel with its email, name and password, the password field would be present twice to confirm that the password is the one intended by the user, Figure 4b.

After a user logins into his account, the window where he would be sent is the one where the user will start reporting about his dive since this is the application's main goal. For that, there is an initial window where the information about the dive itself should be introduced like the location where the dive occurred, the amount of time spent on the dive and the number of divers on such dive, seen in Figure 4c. The bottom part of the screen was thought to be used as the call for action in all windows and is where all the elements to continue with a report are placed. This bottom bar has a button which is a bit upper on the bottom bar when compared to the other elements to make it more distinguishable from the navigation elements, which are also present in the bottom bar, can be seen in most windows of Figure 4 in the bottom part of the screens.

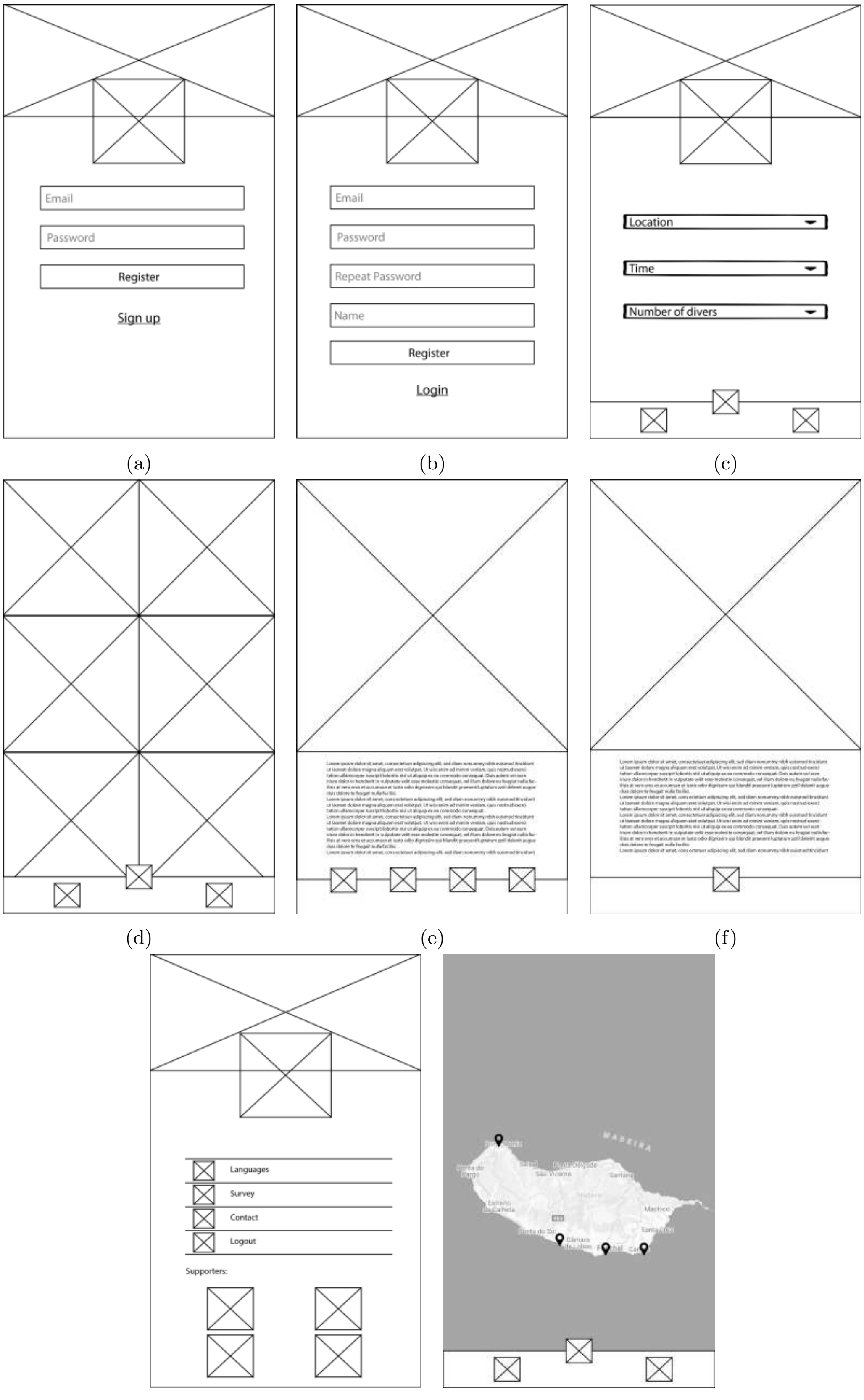


Fig. 4: Wireframe for the application: (a) window for login, (b) window for register, (c) window to choose the location, time spent and size of the group, (d) window with the species available in the app to report, (e) window of specific species with a photo of it and information with the options to choose at the bottom, (f) window with the summary of a report, (g) window for the profile of the user and (h) window of the map with diving spots

After all the dive information is filled in, the button on the bottom of the screen should be clicked to go to the next step. The next step is showing all the available species and their abundances already presented in Table 4. The moment when the species are shown and when the abundances are introduced are separated, the divemaster shows all the species to the divers quickly and only bothers with the abundance of the species identified by someone present on the dive. The initial window to show all the species would show all the species side by side from top to bottom as a catalog, for this, only a picture would be shown since it is the best way a non-expert diver would be able to recognize a species, seen in Figure 4d. After pressing a species image, a new window would open, which would have specific information about that species (e.g. photo, name, conservation status) and the abundance intervals that it should be reported in, here again, the bottom bar has four (4) buttons which are the four (4) levels of abundances that the species can be reported in and acts as a call to action from the user, seen in Figure 4e.

After choosing the abundance interval, the user would be again redirected to the window where all the species were chosen. After selecting all the species that were seen, the user would press the bottom button to go to the next page, which would be a summary of all the information that was inputted, from dive information to species seen. After ensuring all the information is the one intended, the user once again presses the call to action in the bottom bar to submit the report, as seen in Figure 4f. All this process fulfills the app's main functionality: collecting information from the users to experts.

Another window thought to be important is a profile window, which would have a profile image, where the user would change the application's language, complete surveys the experts wanted, contact or report problems found in the app, and log out. This window is also where the project and funders' information should be included, seen in Figure 4g.

The final window, which is relevant for the app, is a window where the diving spots are shown, this is mostly for the curiosity of users since the divemaster themselves will know where the dive was done but can be used to show the divers to help explain, the wireframe of this window can be seen in Figure 4h.

3.7.1 Dive Reporter - Redesign for Tablet UI

The redesigned app can be seen in Figure 5. It maintained the initially planned design, adding to the windows a header that indicates what page the user is on as well as a back button. This was added to make the app more user-friendly to a bigger diversity of users since the initial idea of swiping right to back out of a page may not widely used by every user and dedicated buttons to back were not available in all devices (Figure 5e and Figure 5f), having this back button brings redundancy and it ensures that all users will be able to go back in the app.

The predominant color in the app was blue on a white background, this was chosen since the app will be in an environment with direct sun exposure, and a higher contrast in UI helps make the UI elements more clear to the user's eyes and also more accessible to a wider group of people that might have color blindness problems [43]. Two tones of blue were used for different elements; the darker blue was used for the non-interactive part of the UI (e.g. headers), while the lighter blue was used for the buttons in the bottom component of the app, indicating the call for action. The icons further used a white colour over the dark blue background (Figure 5h). The colors used were checked to make sure that their contrast was high enough for accessibility purposes. For the color accessibility testing, an online resource that allows for grading and checking compliance

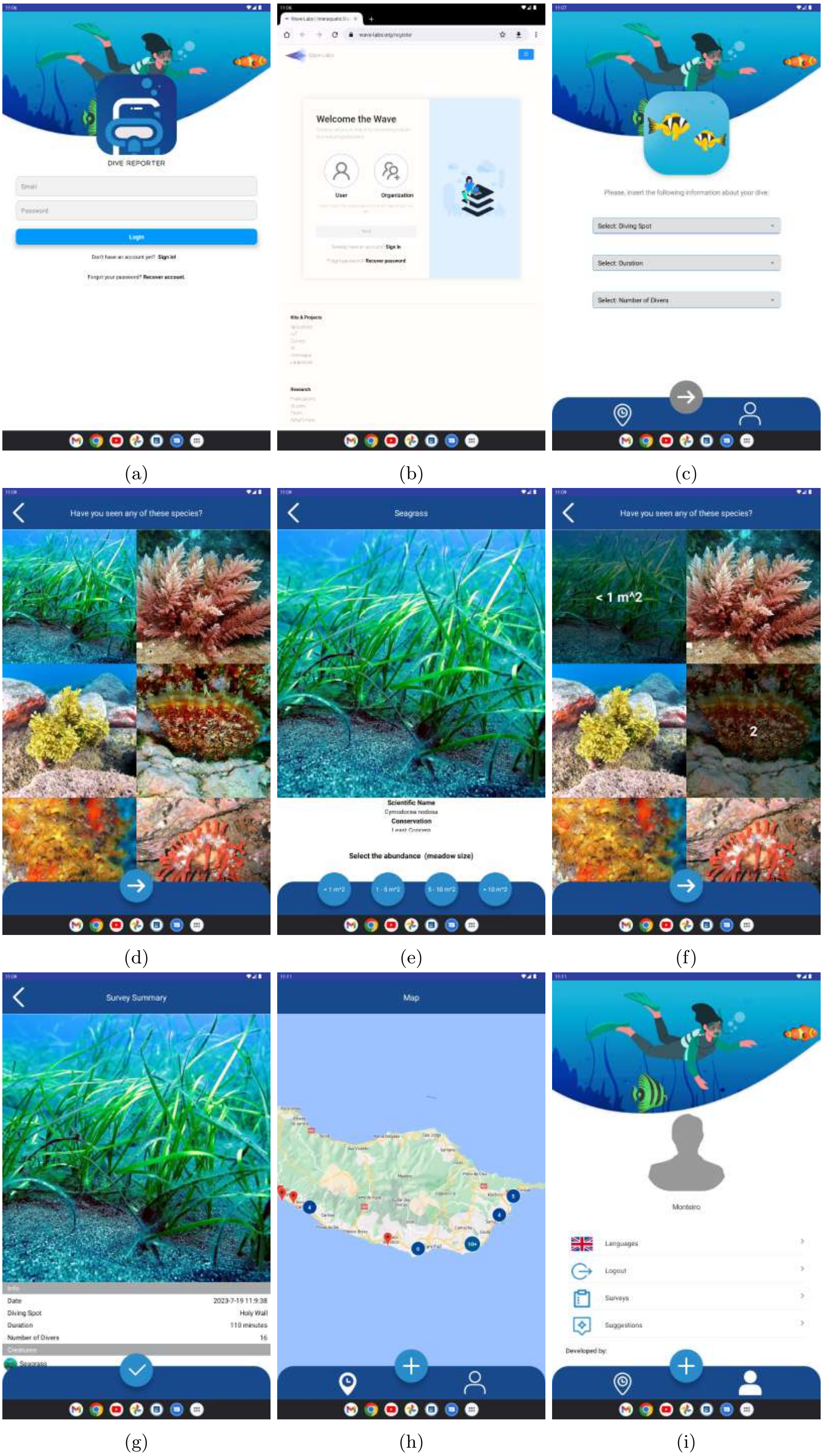


Fig. 5: (a) Login window, (b) register web page, (c) Initial dive information window, (d) list of available species window, (e) specific species window with its abundance, (f) list of species with feedback of the species already chosen, (g) summary of the report, (h) map with diving spots and (i) profile window

with Web Content Accessibility Guidelines (WCAG) (i.e. `https://webaim.org/resources/`) was used to check the colors used on all app windows. The interface maintained the position of the button to navigate to the next step of a report on the bottom.

The first window the user sees when opening the app depends on whether the user is already authenticated. If the user is not authenticated, the window shown is the login, seen in Figure 5a. This window practically had no changes to it from what was planned in the wireframe stage, with the only addition being a "Recover password" feature that sends the user to the recover password page of wave-labs.org. On the login window, when the user fills in the information required and presses the "Login" button, a Post request is sent to the API with the email and password introduced. This request then queries the table *users* to check if the account with this email exists, and in case it does exist, it then checks if the password saved in the database is the same as the one introduced in the app. If both the email exists and the password matches the one for that account, then the response is "success", and the user can log into the app. After logging into the app for the first time, the SQLite database is downloaded, which contains the species' information and also downloads the images of the species, which are saved to the AppData folder. If this database is updated, when the user opens the app, it will automatically log out to make the user have to log in once again and allow the database to update. This is done this way to ensure the user has an internet connection to download the database since, to log in, the user also needs internet.

The register window, as mentioned previously, was scrapped, and the register is done on `https://wave-labs.org/register`, this was not done as part of this dissertation as it was already implemented, Figure 5b.

If the user is authenticated when the app is open, the first window seen is the one seen in Figure 5c. At the bottom of this window, there is a bar used for navigation. Here there are two icons, the left one with a marker icon and the right one with a user icon that, when pressed, send the user to the map window and the profile window, respectively. This is the window where the initial information about the dive is inserted by the user, the duration and the divers are fixed values for all users, the dive time values are in increments of ten (10) minutes and the value of the number of divers in increments of 1 diver. The values that can be chosen for the diving spot depend on what the user associated to his account, this allows for personalizing what diving spots are seen since not all dive centres dive in all diving spots, this association is done in the Dashboard interface and can be seen on the section 3.10. The diving spots associated to that user are obtained by querying the table *user_has_diving_spots* by the foreign key *user_id* using the *id* saved in the app when the user logs in.

After all the information is filled, the grey button at the bottom of Figure 5c will turn blue, the same color as the other buttons, to show that it can now be clicked to continue with a report. From that window, the user is sent to the page with the species, seen in Figure 5d, on this window, the species list is shown in sets of two per row. The order they are shown is based on the type of species, from algae to fishes to more diverse species. These images are fetched from the AppData folder since they were downloaded to the user's device during the previously mentioned moment of download.

From the window where the species are shown, there are two different actions the user can take. It can either click the image of a species to open a more detailed view where the abundance is also chosen or the bottom button with the arrow to the right can be pressed, leading to the next page of the report, this is because even an empty report can be relevant since it shows the absence of the species on that specific diving spot.

If the user decides to click on one of the species, the window seen in Figure 5e is opened, containing the information for the species that were pressed. This is done by passing the id of the view, which is the same as the id of the species in the database. A SQL query is called on the database to grab all the information from the *creatures* table and the path to where the image is saved on the device from the table *creature_photo*. It also queries the table *abundances* by its foreign key *creature_id* to find the intervals that should be shown for that species.

After the user chooses what abundance he saw, the image of that species in the all the available species window will be darker with an overlay of the chosen abundance, seen in Figure 5f. From there, the user again has the choice to go ahead and finish the report, keep choosing other species or edit the ones already present in the report. When he chooses to go ahead and finish he will be sent to the summary window, seen in Figure 5g, where a summary of the dive information as well as the species and abundances chosen for the report. The images scrolling on the top part of the window are the species that were chosen by the user, beneath those images a summary is also shown with the name of the species and the respective abundance chosen for each. The bottom navigation bar is shown with a final button to submit the report. By pressing the submit button, two things can happen, if the user has an internet connection, the report is sent and saved on the table *dive* and *dive_pivot* where the dive information is saved in the first and the dive species saved on the latter. If the user does not have an internet connection, the report is saved in the device's memory, and a new button on the report page is added that can be pressed to send all the saved reports. This is an important functionality due to not all dive centers having a good internet connection, and this way it allows the users to keep submitting reports that can be sent later on.

The profile window, seen in Figure 5i, is just used to change the language and complete some surveys or report some problems. It shows what should be the profile image of the user, however, this was not implemented, so an avatar image is the one always shown, underneath the image, it shows the username of the user who is logged in.

The map window, seen in Figure 5h, shows all the diving spots available around the island, and when pressed, a small popup with the name and substrates of that diving spot is shown.

3.8 Dive Reporter - Kiosk interface

Contrary from the obtained feedback, where the diving participants mentioned that they do not find the kiosk to be adequate, it was selected to proceed with the idea to prototype the touch point interface, with the hypothesis that verbal spoken word of "kiosk" may not adequately present the possible physical touch point interface. Hypothesis was based on the fact that the role of the design cause an effect due to involvement of other types of senses (and not only hearing about it [44]). Indeed, this was the interface that was wanted the least on the initial questionnaires. However, the idea was that having a physical prototype would change people's perceptions and that it would change their minds to prefer a stationary interface.

Hence, the idea of a Kiosk, a physical structure where a tablet with the Dive Reporter app would be installed, was thought to help increase the motivation and overall usage of the app. This kiosk would act as a point of interest to the users [45] and would be placed in an area which would be a debriefing area for the divem asters and its clients (SCUBA divers). The digital interface of the application is the same as explained in Section 3.7 and the way it behaves as well. The only difference is how a physical interface could help catch users' attention and influence the app's number of uses.

3.8.1 Kiosk Prototyping - Initial stage

Here the dissertation explains the process from the planning to the prototype stages. This content includes the materials used, the rationale on why they were chosen, the multiple designs that were thought, and how the final version one was chosen.

Since dive centres are normally very wet environments, the divers themselves may be wet when making a report on the kiosk. However, since the goal of the dissertation was to produce a prototype only to understand how the kiosk could be useful for the monitoring program, a low-cost material was preferred. The initial idea was to recycle Medium-Density Fibreboard pieces (also known as MDF) previously used on the geodesic structure projects at Wave Labs. The pieces to be recycled can be seen in Figure 6.

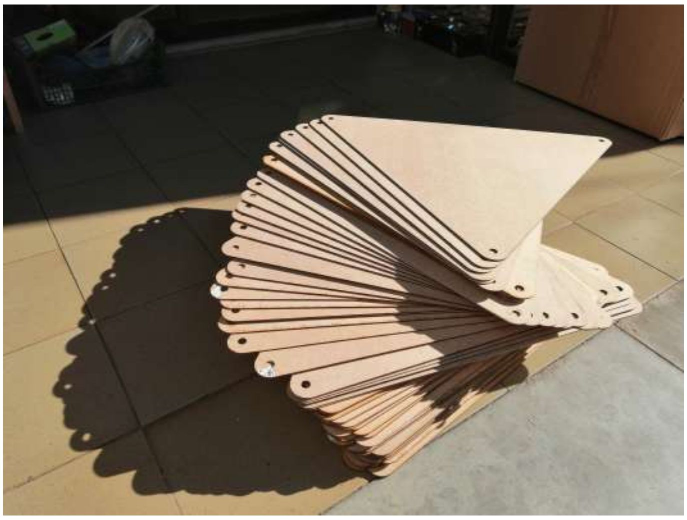


Fig. 6

These pieces would be glued together and then cut into smaller triangles. The structure would then be built similarly to what a 3D printer does, each small triangle would be a 1.5cm slice of the whole kiosk. These slices would be done in a laser cutter that would cut each layer of the structure that would need to be glued again. The triangles already glued and the cut ones can be seen in Figure 7a and Figure 7b, respectively. Figure 8a, which is from a project that used the same technique to reproduce a smaller structure. Figure indicates an example of how the final result would look, but instead of gluing the pieces of MDF vertically, they would be glued horizontally. With the number of pieces of MDF available, it would be possible to make a structure of at least 120cm tall since each triangle is a 1.5cm layer which is enough to reach the size of how tall a kiosk can be for accessibility purposes [46].

(a) (b)

Fig. 7: (a) three initial triangles glued together and (b) big triangle cut in three equal triangles and glued together again

The design of how the initial proposal would look can be seen in Figure 8b, however, this design was changed since during internal discussion a more iconic or charismatic marine species would be more appropriate and relevant to what the app is about as well as a more interesting structure would be more effective to grab the attention of users.

(a) (b)

Fig. 8: (a) process for the initial model and (b) initial model front view and side view

3.8.2 Kiosk Prototyping - Final Design

After discussion of the idea with the other team members within CLIMAREST project dealing with marine restoration, it was decided that for a more recognizable and more charismatic kiosk, a more iconic species would be a better option. When looking at the species available, the monk seal, octopus and seahorse were the more interesting ones (as indicated by the dive centers staff).

The seahorse was chosen for this prototype. However, since there are multiple dive centres on the island, different designs could also be made available for each dive center.

The idea of recycling the triangles was also scrapped for this new design since it would be very challenging to cut the pieces of triangles into the required shapes due to the number of curves and small details. The model can be seen in Figure 9, the model is an adaptation of a model from Sketchfab [18] from the account Rigsters. It was adapted to a more low poly model since the technique that was going be used for the kiosk, the texture and detail that it had would not be applicable.

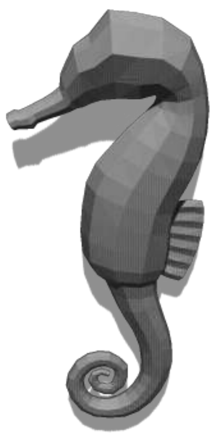


Fig. 9: 3D model of the seahorse used for the kiosk

For this model, it was thought to be modular, allowing different pieces to be mounted together and which could be easily disassembled. The pieces would fit together almost like a puzzle without glue or nails. The model shown above was sliced in the "Slicer for Fusion 360" with the construction technique of "Interlocked Slices", the result of this process is seen in Figure 10 and the mounting in Figure 11.

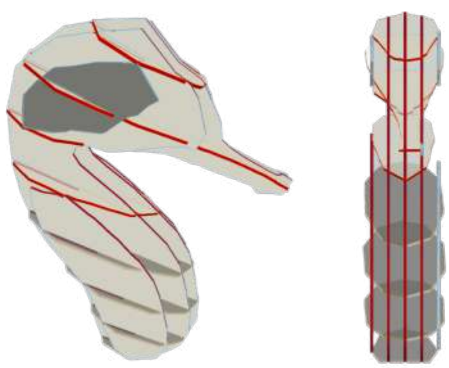


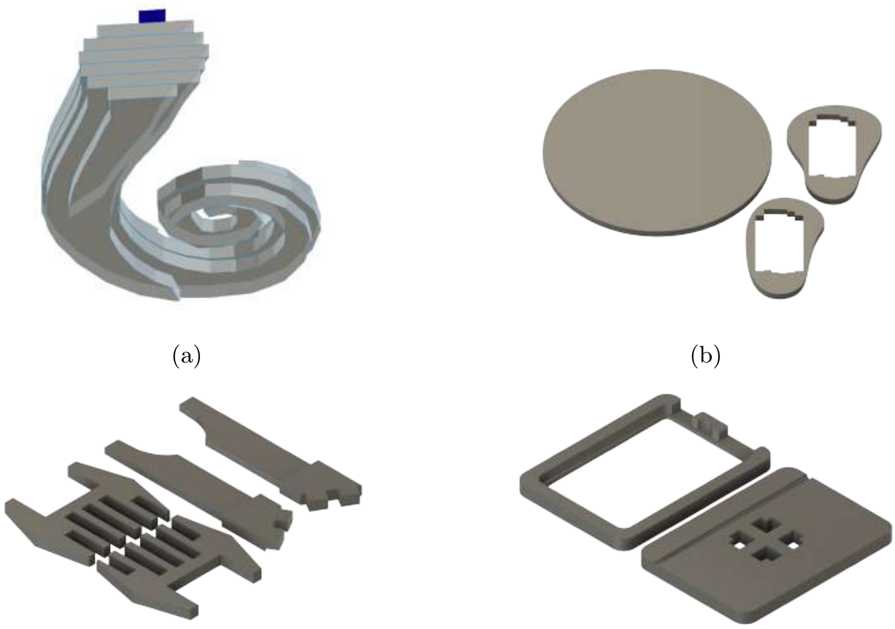
Fig. 10: Top part of the seahorse after being sliced with Interlocked Slices

[18]https://sketchfab.com/3d-models/seahorse-2651aa6a55944f34abdd12f29dcf99a2

Fig. 11: Slicer for Fusion 360 mounting of the pieces

To ensure the kiosk was strong enough not to fall, the tail was done through a different process where the pieces would all be glued together, providing a stronger base, as seen in Figure 12a. Since the tail was round and had a small contact point with the ground, a base where the tail would be inserted was also created, seen in Figure 12b. The tail and the top part of the seahorse where then joined by the join seen on the left of Figure 12c.

The tablet would then be placed on the support seen open on Figure 12d, which is closed with the tablet in-between the two pieces shown. The two other pieces seen on the right of Figure 12c are then inserted into the holes of the tablet holder and slide in between the MDF pieces of the seahorse top part.



(a) (b) (c) (d)

Fig. 12: (a) 3D model of the tail after slicing, (b) base of the Kiosk, (c) joints for the top and tail of the seahorse and connectors of tablet holder to Kiosk and (d) tablet holder

The Slicer for Fusion 360 also gave the plans for cutting the pieces. A CNC machine cut these pieces from a $180cm \times 80cm \times 2cm$ MDF slab. The plans for the cuts can be seen in Figure 13 and Figure 14.

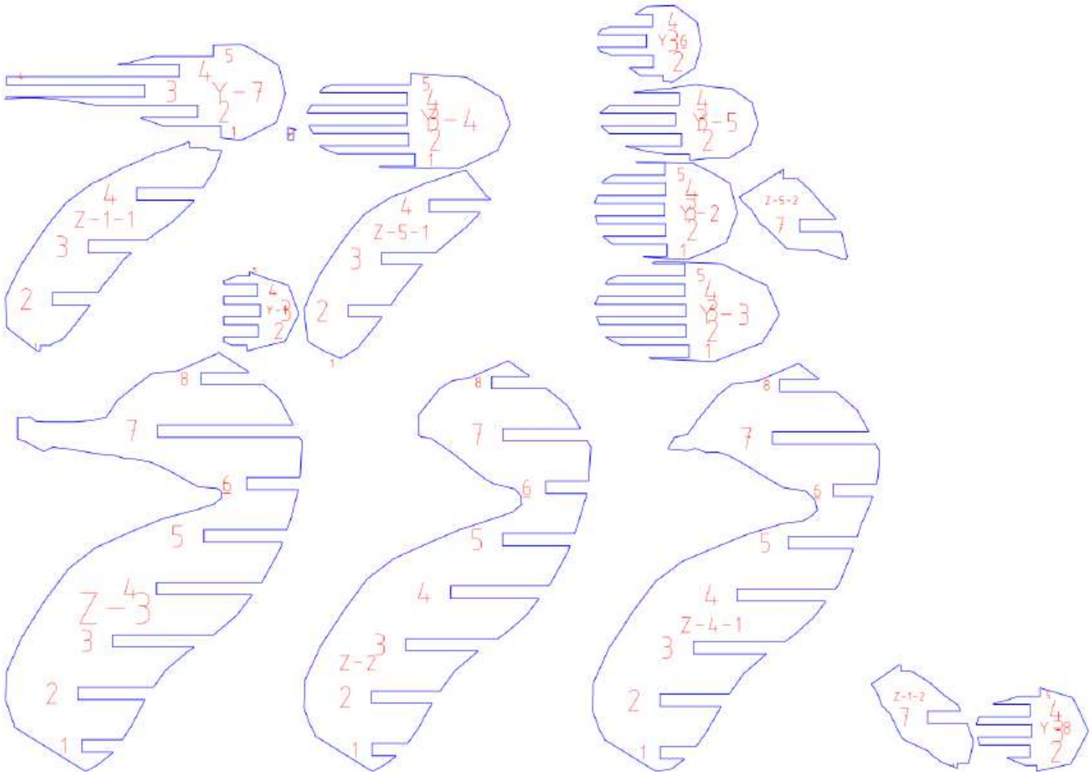


Fig. 13: Cut plans for seahorse top

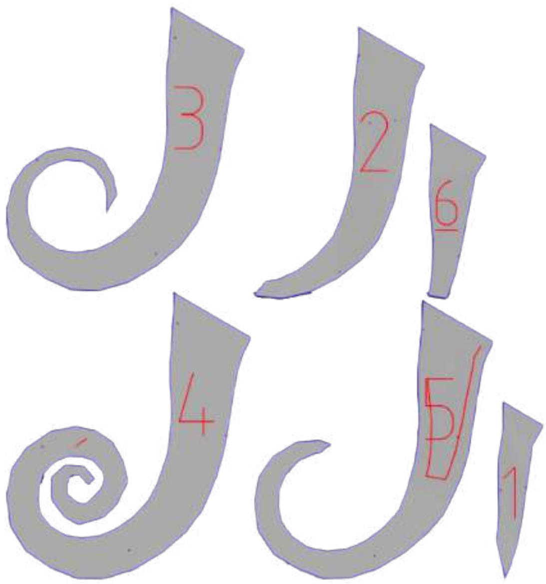
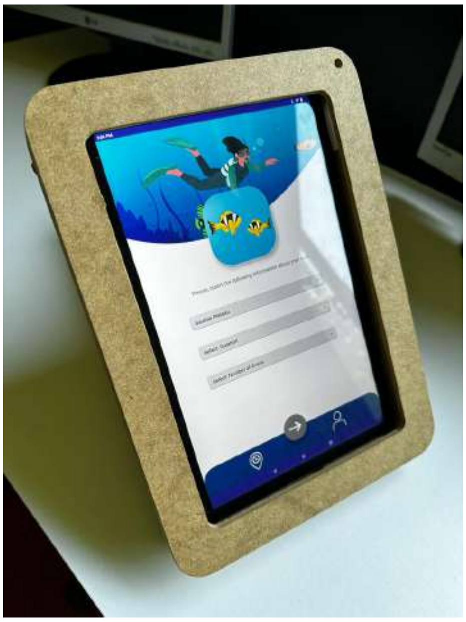


Fig. 14: Cut plans for seahorse tail

The mounting process can be seen in Appendix Section E. The top part of the kiosk was assembled as per the slicer instructions. The tail pieces were glued and left to dry while clamped. Having the two parts mounted then, the tail was placed into the base, being held by some joints and some wood dowels inserted in the connections of the base and the tail. After the tail was secured, the top part of the kiosk was placed into the joint from Figure 12c that connected the tail and the top once again, inserting some dowels to make it secure. The last step was to place the tablet support, which was closed with a tablet and inserted into the seahorse. The final prototype of the tablet holder and the fully mounted prototype can be seen in Figure 15.



(a)

(b)

Fig. 15: (a) Tablet holder and (b) Final kiosk prototype

3.9 Web Interface

The last interface that was created for reporting was the web one. This interface was created so that on the testing, it would be possible to understand if the three interfaces would still rank in the same order of preference as initially seen in the sessions with the SCUBA divers. This interface was developed in React.JS, and it uses the same API calls that the tablet interface uses. The interface itself was made to look the closest possible to the app interface, allowing it possible for comparisons.

The flow of the interface is still the same as well, having the moment when the user introduces the group information (seen in Figure 16a), followed by the list of species (seen in Figure 16b). If the user selects the species, a new page with just that species details and its abundances are shown as in Figure 16c. Such is similar to both the mobile and the tablet interface. After the abundance is selected, a layout will cover the image with the values chosen showcased the visual feedback to the user. To finalize, the user would submit the report and be greeted with a "Thank you" page, as seen in Figure 16d.

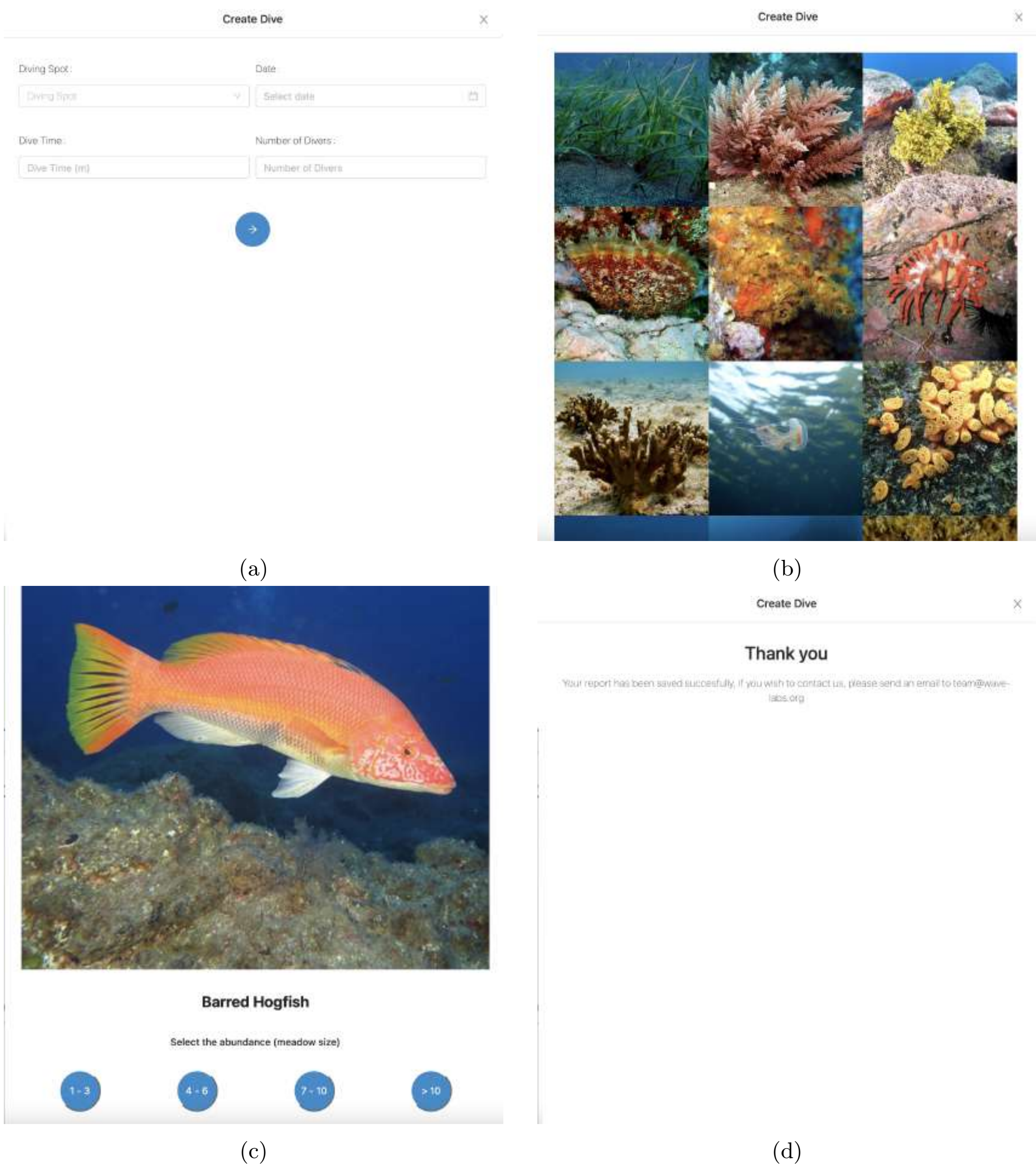


Fig. 16: (a) window to introduce information about the dive, (b) window with the list of species available to report, (c) window of a specific species and the abundances that can be chosen and (d) window with the thank you message

3.10 Dive Reporter Dashboard

The dashboard is an interface common to all the other interfaces and part of the Wave Labs apps. Independently of whatever interface the users would prefer to report the species, the dashboard will always be the interface that the user has to access to get details of the collected information.

The dive center staff may use it to access their accounts and is where they associate the diving spots that they normally dive to their accounts. This is also the interface used by marine ecologists experts to have access to all the data collected by the monitoring program. Since some dive centers were reluctant to share their information with other dive centers, it was important to consider this and not allow information to be widely available to everyone (e.g. showcase only dives from the single dive center). This reluctance to share the data with other dive centers can be attributed to the dive centers being a business, and sharing what is seen in their own diving spots could make them lose clients to other dive centers. For the monitoring program it is not relevant the sharing of information between dive centers and as such the opinion to not make the data shared only brings a positive influence for the project.

The functionalities that would need to be available in the dashboard are editing account details, access to statistics of the reports, access to all the reports made, filtering of those reports, filtering the diving spots available and the possibility to add those spots to their accounts. The dashboard's design followed already developed products of Wave Labs. For consistency reasons, the interface was not be too different from what users would already be used to using. Also, because it was to be integrated into the Wave Labs website, the technologies used were the same as the ones used to develop the rest of the website. In this case, this technology was React, a JavaScript framework for Web Development.

Initially, the pages were developed separately depending on their functionalities, however to help reduce the need for a lot of navigation through pages, all the pages were consolidated into one, which the user would see as soon as he logged into the website. The first part of the dashboard shows some overall information about the reports. It indicates how many reports have been submitted per month in the last 12 months and the most reported species, both use graphs to showcase these statistics, see Figure 17. However, the number of monthly dives uses a line graph since it is useful to show the user if the number of reports has increased or decreased through the months. In contrast, the most reported species are shown with a bar graph since the values are independent of each other.

Two API requests are sent to the server, one for each statistic. Both requests send which user is logged in (for authentication) to the server to identify which reports belong to that user. For the monthly reports, all the reports by that user are fetched from the database table *dives*, they are then separated by date, more specifically per month. For the most reported species, the table *dive_pivot* of the database is queried by the *dive_id*, which was previously queried with the user *id*, with the use of COUNT in descending order with a limit of five records since the goal was to only display the five most reported species by that user.

The next part of the dashboard is the one with a more detailed showcase of the reports submitted. Here three different elements are shown that complement each other. The table on the left side shows all the reports of that user with a pagination of ten, a heat map on the right side shows the frequency of reports in each diving spot, and on top filters that can be applied simultaneously to the table and map, see Figure 18.

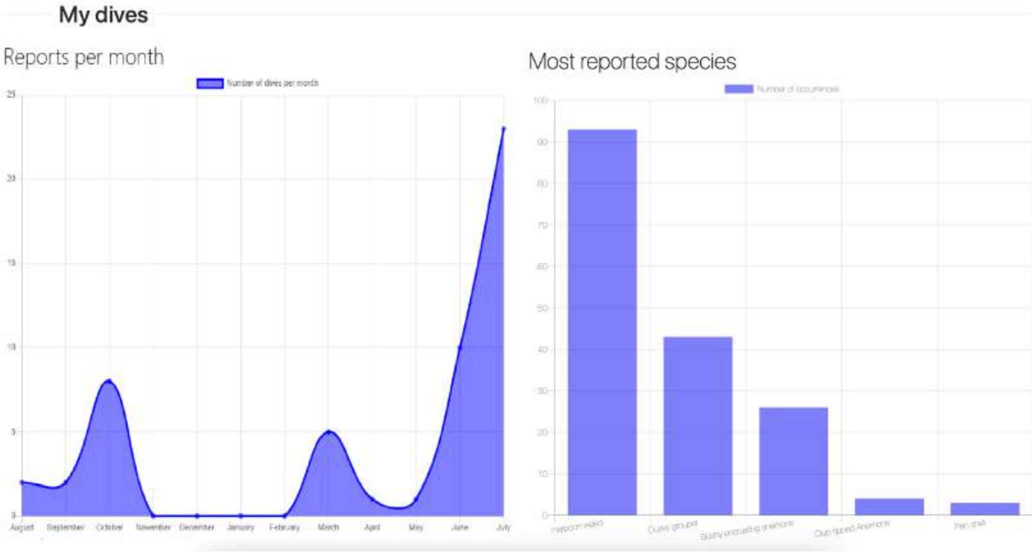


Fig. 17: Statistics shown on the dashboard

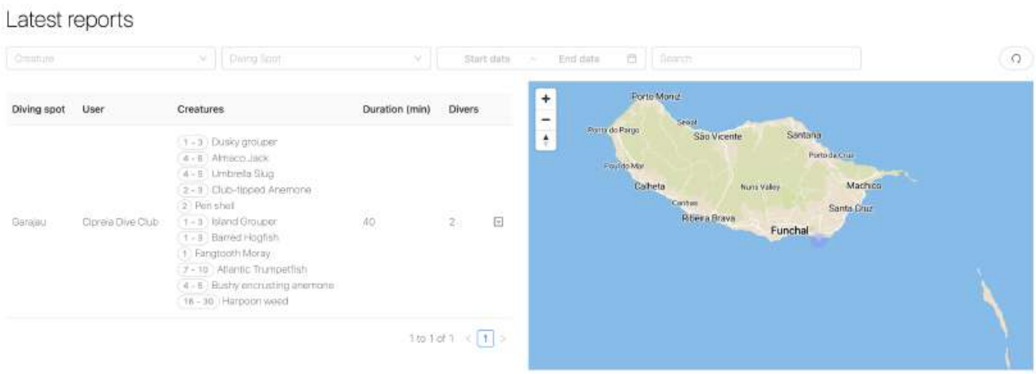


Fig. 18: Reports shown in the dashboard

The table of reports has the information introduced in each report done through the app, the diving spot, the number of divers, the time of dive and the species and their abundances. A request is sent to the server with the user *id*, which queries the *dives* table, after having all the dives of the user, it then queries the table *dives_pivot* to get what species those dives have. Similarly, the heat map also uses the result of the query done to the *dives* table, but instead of querying the *dives_pivot* tablet, it queries the *diving_spots* table to get the coordinates of the diving spots where those dives occurred.

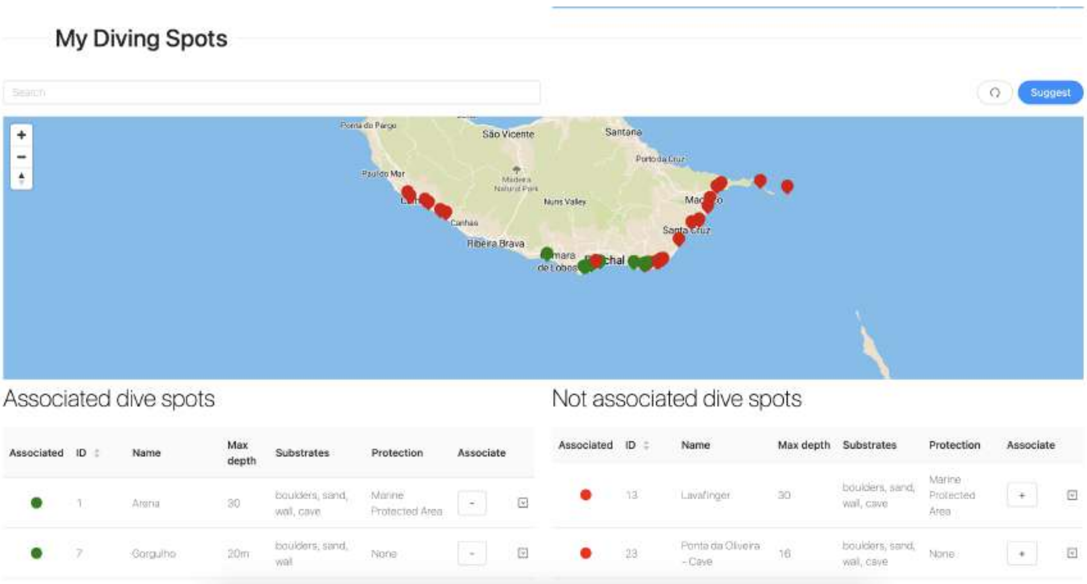
Since the table and map show all the reports from an account, it was important that the users could have some filters only to visualize what is relevant for them. The main aspects that should be of interest to the users to filter would be by specie since this would allow the user to see how many reports have been done of a specific species and where this specie is more likely to appear. Filter diving spots since the user might be interested in what species show up in a specific dive spot, this can be important for dive centres since it would allow them to decide on where to dive for certain clients who are more interested in some species than others, however, it is also important for experts as well since normally an expert specializes in one determinate species or group of them and this filters can be used to have access only to the ones relevant for each expert. The date filter can be used to check the reports made in a date interval since species are not present year-round in Madeira, it can be used to understand when those species start showing up and when they leave. The search field can then be used for any extra filter, for example, search for scientific names or diving spots in marine protected areas.

The final part of the dashboard specific to this dissertation is the section where the diving spots are shown to the users. This part has two sides depending if the user is a dive center or if it is an admin account. The dive center accounts are the ones provided to dive centers and which are further restricted to their own reports, while on the other hand, an admin account is an account with access to all the information and are the ones used by experts to analyze the data gathered by the dive centers.

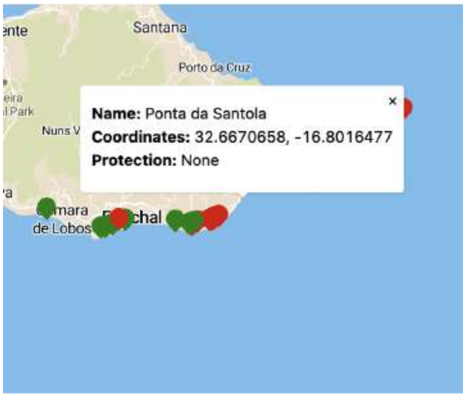
In case the account logged in is a dive centre, what is shown is a map and two tables, see Figure 19a. This map shows all the markers in two different colours, green and red, if the diving spot is already associated to that user's account or not respectively, these markers can be hovered to show some information about the diving spot (Figure 19b which can help a user identify a diving spot by its location and then add it through the tables. The two tables are also used to show associated and not associated diving spots, the main information about the diving spot is shown, like name, max depth, substrates and protection. The two other fields are used for the association, the "Associated" column shown at the beginning of the row is to help the user make the connection between the colour of the markers on the map with the colour of associated and not associated status. The "Associate" column at the end of the row is the call to action for the user to associate or remove an association with a diving spot. When the user does one of those actions, the row passes to the other table, and its status icon changes from green to red when the association is removed or from red to green when the diving spot is associated. If the user presses the row itself, a small slider from the right will show up with more detailed information about the diving spot of that row, seen in Figure 19c.

One of the other functionalities that non-admin users have is suggesting adding new diving spots. This is done through a form that appears when the user presses the "Suggest" button seen on top of Figure 19a. This form can be seen in Figure 20a, which asks for the main information about a diving spot. The name and max depth fields are open to what the user decides to input, with validation, for example, for max depth it has to be a number value. For the latitude and longitude fields, there are two ways of filling, this was done this way due to the talks with dive centres and experts, some dive centres do not have the right coordinates of the diving spots they go to, they only base themselves of a map and with experience are able to know if they are on the right spot. However, some other dive centres have specific coordinates. To help accommodate both types of users, a map and input fields were added, the user can either click on the map and choose the location based on visual perception or add it from coordinates. The "Substrates" field was a multiple choice field since the substrates are already predefined by experts (i.e. Boulders, Sand, Wall, Cave, or Wreck), and the user only has to choose which ones apply to the new diving spot, same with the "Protection" field, the choices are predefined by experts and the user only has to choose what applies (i.e. Natural Reserve, Marine Protected Area, or None). After all the information is filled in, the user can submit and receive the popup message seen in Figure 20b.

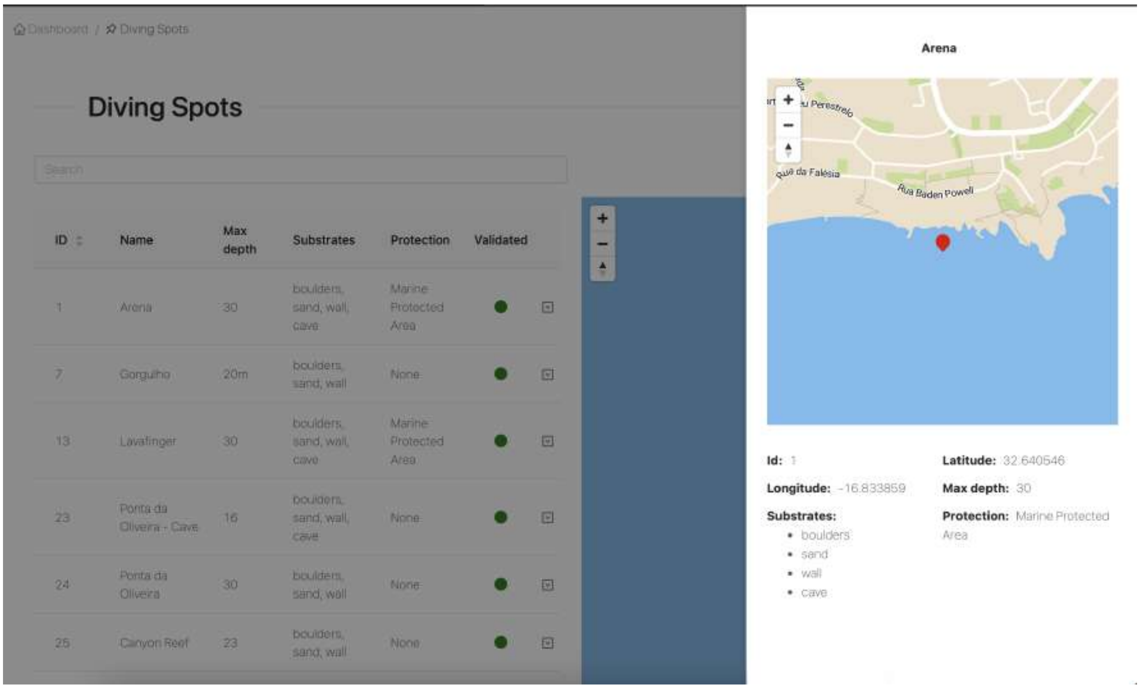
The "admin will approve it shortly" message refers to the other side of this section of the interface. If the user logged in is an admin user, then the interface will not be the one mentioned previously, but it will be replaced by the interface seen in Figure 20c. Here the admin will



(a)



(b)



(c)

Fig. 19: (a) diving spots shown to a dive centre user with the associated and not associated spots to that account, (b) information shown when a user hovers a diving spot marker on the map and (c) detailed information of a diving spot

approve new suggestions for diving spots. This allows for experts to make sure the diving spot inserted is correct, if not, the admin can decide to delete it or to change it with the correct information. The section still has a map and a table, the map once again uses red and green, red for the not validated diving spots and green for the validated ones. The table shows a "Validated" column instead of the "Associated" one present on the dive centres accounts, the admin can press the status icon of each diving spot to change it to the opposite. This will update both the colour of the status on the table and on the map.

Only the diving spots validated by an admin show up for other accounts. If the diving spot was suggested by an account, as soon as the admin validates it, that diving spot will also be associated to the account that suggested it. The admin can also add diving spots himself, not suggested by other users, by pressing the "+ Add" button on the top of Figure 20c. This will lead the admin to fill out the same form as other users, but it will be immediately validated.

3.11 Evaluation Procedure

For the evaluation phase, there were 15 participants in the mobile app usability test and the same 15 participants in the dashboard usability test. It was asked for these participants to perform the app usability test followed by the dashboard usability test in one single session. There were 21 participants on the in-situ testing. These 21 participants were different participants from the controlled environment, with none of the in-situ participants being the same as in the controlled environment.

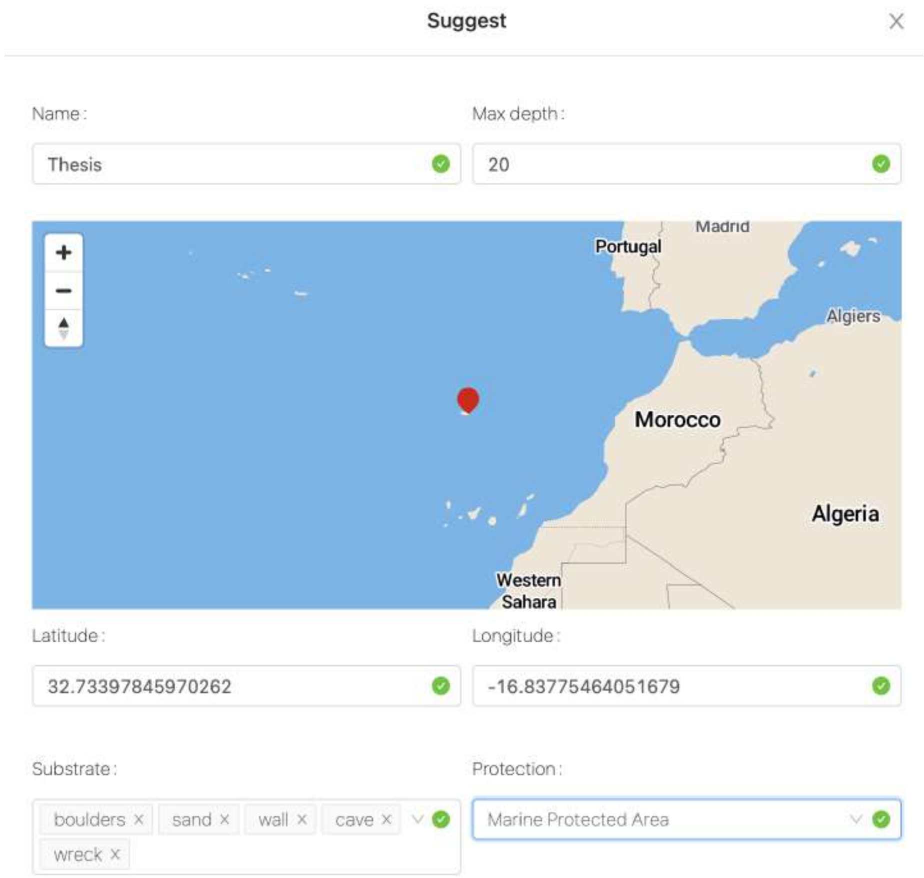
Controlled environment. The first stage of the evaluation was to test the system in a controlled environment to help identify interface usability problems. Any problem that would show up here would be fixed before going to the final user at the dive centres. This was important because the tests at the dive centre were done in the summer when the dive centres are busy and taking time out of their day for usability testing and having to go more than once to be able to test the interactions of the system would not be possible. For this initial stage of testing, a group of N=15 users were tested. This number was chosen based on research that shows that most usability problems can be found by a group of 15 users [47].

A full session of a test followed the following steps:

1. User reads and signs the consent form, seen in Appendix B
2. User is asked to perform some tasks on the app
3. User performs the tasks
4. User answers the usability questionnaire
5. User is asked to perform some tasks on the dashboard
6. User performs the tasks
7. User answers the usability questionnaire

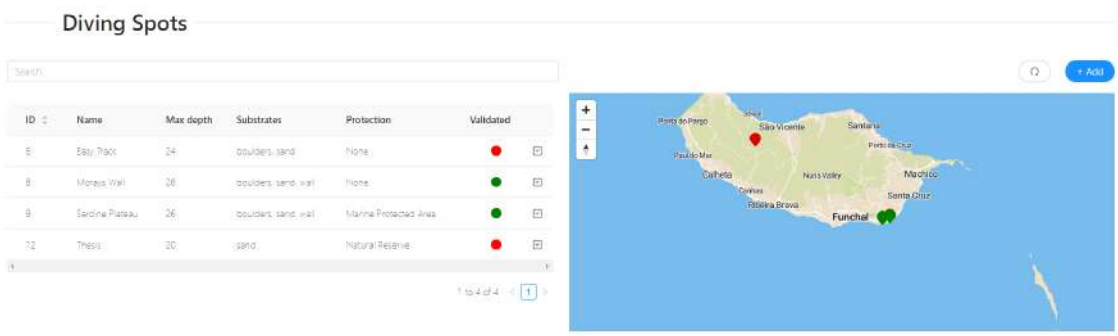
The test included tasks from different interfaces, some tasks were related to the App, while others were related to the Dashboard. All the tasks asked of the users tested were in the following order:

1. Make a report, on the app
2. Check the diving spots, on the app



(a)

(b)



(c)

Fig. 20: (a) form to suggest a new diving spot to be added (b) popup notification shown to the user after suggesting a new diving spot and (c) diving spots shown to an admin and their validated status

3. Logout, on the app
4. Find reports with Monk Seal, on the dashboard
5. Find reports in Arena, on the dashboard
6. Suggest a new diving spot, on the dashboard
7. Associate a diving spot to your account, on the dashboard

These tasks were chosen to be able to understand usability problems that could be present on the interfaces. The task to report on the app allows to understand if the introduction of the information is clear and easy to follow. The tasks to check the diving spots and the logout have more than one purpose: first, to understand if the functionalities are understandable, but they also allow to understand if the navigation menu is easy to follow or if the icons or positioning of the navigation are a problem. The tasks to find reports on the dashboard interface were chosen to understand if the user would clear the previously applied filters from task four (4) to task five (5), while the tasks for the dive spots were chosen to determine if the way that was chosen to suggest a new diving spot and associate a new one or remove the association were easy to follow. All the tasks allow to test all the tasks that can be done in both interfaces.

During the performance of the tasks, notes were taken from comments that the users would say and from what was observed. Some of the notes that were noted for the dashboard were if the user would use the filters or the search bar, if the user would clear the previous filters before the new ones while for the app the notes that were taken were if the user would go to the right section for the map and for the logout.

The final questionnaires the user answered were two equal questionnaires for usability but one related to the app and one related to the dashboard. The questionnaire can be seen in appendix C. The questionnaire itself is the System Usability Scale (SUS) that, despite its criticism, is still seen as a good tool to gather information about the usability of a system [48], it consists of ten questions, these questions are shown intercalated, first one positive statement followed by a negative which is then followed by a positive again, this continues for all the ten questions. The questions are then answered on a scale of one (strongly disagree) to five (strongly agree).

In-situ. For the tests in diving centers, due to time limitations, the tests had to be quick but still useful to understand what the users thought about the interfaces and what they would prefer. This phase of testing also did not focus on the usability of the interfaces themselves since they were made to be the most similar as possible, with the tablet and kiosk being the same. This phase, in turn, had the goal to explore which hardware was the most favored by the dive centers to be able to determine which interface should be made available to each for the long term monitoring program.

To compare questions from the initial workshops of what interface they preferred, this time, all the interfaces were tested being brought to the dive centers. The users were asked which interface they would rather have available to them before starting to use any of the interfaces. Following this question, they were asked to perform a report on all the interfaces and to rate their experience from one to five, one (1) being very bad and five (5) very good.

To then make sure the preferred interface would be possible to identify, they were also asked to order the three (3) interfaces in order of preference, one (1) being preferred and three (3) the least preferred, the questionnaire can be seen on Appendix D.

The dashboard was also shown, and comments were noted on how the functionalities were integrated indicating if something was missing.

4 Results

This section refers to the results obtained in the two stages of evaluation mentioned in the previous section. The first two subsections explain the results obtained on the controlled usability testing, for the app and dashboard, while the last subsection refers to the in-situ testing. While the first two focus on the usability of the system, the last section will explain the scores on the questionnaires filled by the dive center staff and how the system has been used.

To be able to maintain the anonymity of the participants on all the tests, each participant will be referred with an ID. The users of the dive centers will also be referred to by an ID, and each dive center will be referred by a unique ID as well. Individual users will be referred by userID, while dive centers will be referred by diveCentreID.

It is important to make clear that the userID of the app usability and the dashboard usability are the same for the same users, however, the same ID will be used for in-situ testing, but it will refer to a different user since the users of the controlled testing were all different of the ones from in-situ testing (e.g. controlled testing userID $= 1 \neq$ in-situ testing userID $= 1$).

4.1 Controlled Environment Testing

These tests followed the instructions explained previously in subsection Evaluation Procedure. The answer of each user to the system usability scale used after completing the required tasks in the evaluation can be seen in Table 5.

Table 5: Results of all users of the app usability tests

userID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS Score
1	5	1	5	1	5	1	5	1	4	1	97.5
2	4	1	5	2	5	1	5	1	4	1	92.5
3	3	1	5	1	1	1	4	1	5	1	82.5
4	5	1	5	1	4	1	5	1	5	1	97.5
5	5	1	5	1	5	1	5	1	5	1	100
6	4	1	5	1	4	1	5	1	5	1	95
7	5	1	5	1	5	1	5	1	5	1	100
8	2	2	4	1	3	3	5	2	5	1	75
9	4	1	4	4	4	1	4	1	3	1	77.5
10	5	1	5	1	5	1	5	1	5	1	100
11	4	1	4	1	5	2	4	4	5	1	82.5
12	5	1	5	2	5	1	5	1	5	1	97.5
13	4	2	3	4	4	2	3	3	3	4	55
14	4	1	4	1	5	2	5	1	4	1	90
15	3	2	4	2	5	1	4	1	4	2	80

The first column (column name *userID*) is used to identify the user, and columns two to column 11 (column names *Q1* to *Q10*) refer to the answer given to each question. The answers in each column answer the following questions:

- Question 1 (Q1): I think that I would like to use this system frequently.
- Question 2 (Q2): I found the system unnecessarily complex.
- Question 3 (Q3): I thought the system was easy to use.

- Question 4 (Q4): I think that I would need the support of a technical person to be able to use this system.
- Question 5 (Q5): I found the various functions in this system were well integrated.
- Question 6 (Q6): I thought there was too much inconsistency in this system.
- Question 7 (Q7): I would imagine that most people would learn to use this system very quickly.
- Question 8 (Q8): I found the system very cumbersome to use.
- Question 9 (Q9): I felt very confident using the system.
- Question 10 (Q10): I needed to learn a lot of things before I could get going with this system.

The final column (column name *SUS Score*) refers to the system usability scale score (hereinafter, SUS score) calculated through the following equation:

$$X = (Q1 + Q3 + Q5 + Q7 + Q9) - 5 \tag{1a}$$

$$Y = 25 - (Q2 + Q4 + Q6 + Q8) \tag{1b}$$

$$SUSscore = (X + Y) * 2.5 \tag{1c}$$

The results of these tests can be further visualized in Figure 21. For each question, the box of the plot shows the values from quartile one to quartile 3, the vertical line down from the box shows the values from quartile 0 to quartile one, and the vertical line up from the box shows the values from quartile three to quartile four. The solid horizontal line on the box shows the median value, while the dashed horizontal line shows the average score. The circles are outliers in the dataset.

These results show for Q1 an average score of ≈ 4.13, with the most common score (hereinafter, mode) appearing being a score of 5, with one outlier with the score of 2 being shown. The median for this question is 4. Question 2 shows an average score of 1.2 with a mode and median of 1. It shows outliers with a score of 3. For Q3, the average is ≈ 4.53 with a mode and median of 5. It does not show the presence of any outliers in the dataset. The average for Q4 is 1.6, both the median and mode are 1 for this question, with two outliers with a score of 4. For Q5, the average is of ≈ 4.33 with a mode and median of 5 with one outlier on the score of 1. Questions 6, 7, 8, 9 and 10 show an average score of ≈ 1.33, 4.6, 1.4, ≈ 4.47 and ≈ 1.27, respectively. Question 6 has a median and mode of 1, with one outlier with a score of 3. Question 7 shows a median and mode of 5 with no outliers. Question 8 shows a mode and median of 1 with three outliers, one at the score of 2, one at the score of 3 and the last one at a score of 4. Question 9 does not show any outliers and has a median of 5 as well as a mode of 5. Finally, question 10 shows a median and mode of 1, with one outlier at a score of 2 and another outlier at a score of 4.

The SUS score, calculated with equation 1, has an average value of ≈ 88.17. The lowest score was 55, which is considered an outlier on the dataset, and the highest score was 100. This average score is considered "Excellent" grade for the usability of the interface [49].

Notes were also taken about comments done by the users or things that were observed during the tests that can help further understand any usability problems. Table 6 shows the notes taken for

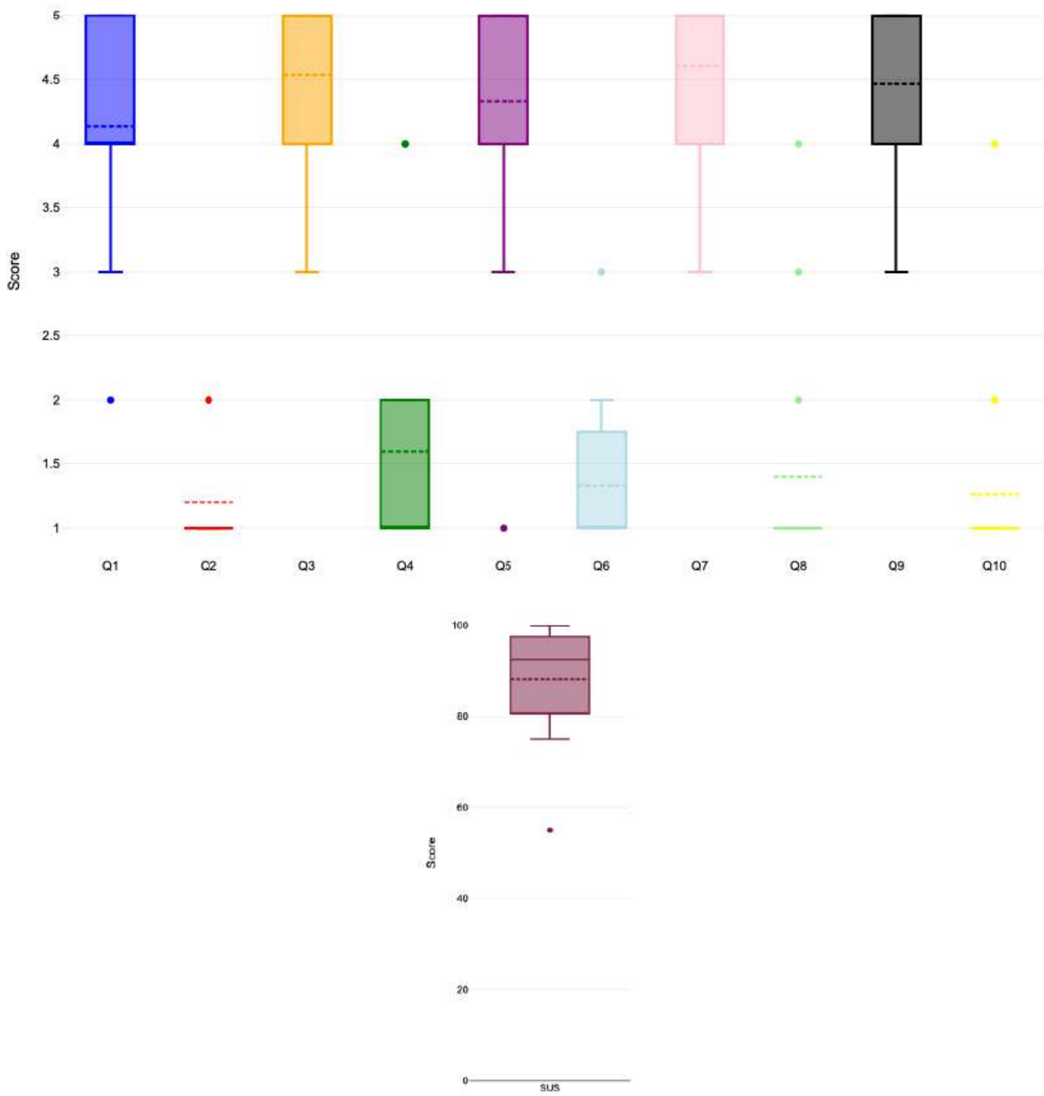


Fig. 21: Box plot of the app usability results

each user on the app usability tests. These notes help validate the results obtained from the questionnaires.

4.2 Dashboard Usability Testing

This interface, as mentioned previously, is the one used by the dive center staff and not by the clients (i.e. recreational SCUBA divers directly). The goal is to make the statistics, reports and the diving spots of each dive center available to them. The results shown are from the usability testing described previously and were conducted with the same users of the app usability testing and in the same session right after the app usability testing.

It will follow the same procedure as the results from the app usability testing, showing the raw results of the questionnaires and the SUS score for the interface calculated from those results.

Table 7, which shows all the results from the dashboard usability testing, follows the same structure as the one shown previously in the app usability testing. The first column is the ID of

Table 6: Notes taken during the app usability testing

userID	Notes
1	Able to do the report without problems Went to the profile page before going to the map page when asked to check the diving spots
2	Commented that the icon for logout was not the one he expected
3	Said he could not understand which were the various functions of the system
4	No problems observed, no comments by the user
5	No problems observed, no comments by the user
6	Asked why that specific specie showed up in the summary Said there was no indication that the species in the summary could be scrolled
7	No problems observed, no comments by the user
8	Did not like that the images of the species were glued together
9	Expecting the door icon to logout Expected the logout to be at the bottom of the page
10	No problems observed, no comments by the user
11	Was not expecting the scrolling of the images on some species since not all have them
12	No problems observed, no comments by the user
13	Logout button another icon Keep information when going back to the pre-survey from the survey page Was not sure if there was a limit of how many species could be introduced for each report
14	No problems observed, no comments by the user
15	Could not find the logout button, thought it should be in the first page and not on the profile one

the user, which are the same users of the app testing. Columns two to 11 refer to the answers given to the system usability scale questions. The final column is the system usability scale score calculated through equation 1.

Table 7: Results of all users of the dashboard usability tests

userID	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	SUS Score
1	5	1	4	1	5	1	5	1	5	1	97.5
2	4	2	4	3	4	1	5	2	4	4	72.5
3	4	3	3	5	4	2	4	2	4	2	62.5
4	5	2	5	3	4	1	5	1	5	1	90
5	2	5	1	5	2	4	1	5	3	4	15
6	4	1	2	1	4	1	5	1	5	1	87.5
7	5	2	4	4	5	2	4	1	4	3	75
8	2	4	2	1	3	3	4	1	2	2	55
9	3	2	3	4	4	2	3	2	3	4	55
10	5	1	5	1	5	1	5	1	5	1	100
11	4	2	2	4	4	1	4	4	2	4	52.5
12	5	3	3	2	4	1	4	3	3	2	70
13	4	2	4	2	4	1	5	1	4	2	82.5
14	3	3	3	2	4	3	4	3	3	3	57.5
15	4	2	4	1	5	2	4	2	4	2	80

The results can be further visualized in Figure 22. The rules of the box plot shown are the same as the ones in the app usability box plot. For each question, the box of the plot shows the values from quartile one to quartile 3, the vertical line down from the box shows the values from quartile 0 to quartile one, and the vertical line up from the box shows the values from quartile three to quartile four. The solid horizontal line on the box shows the median value, while the dashed horizontal line shows the average score. The circles are outliers in the dataset.

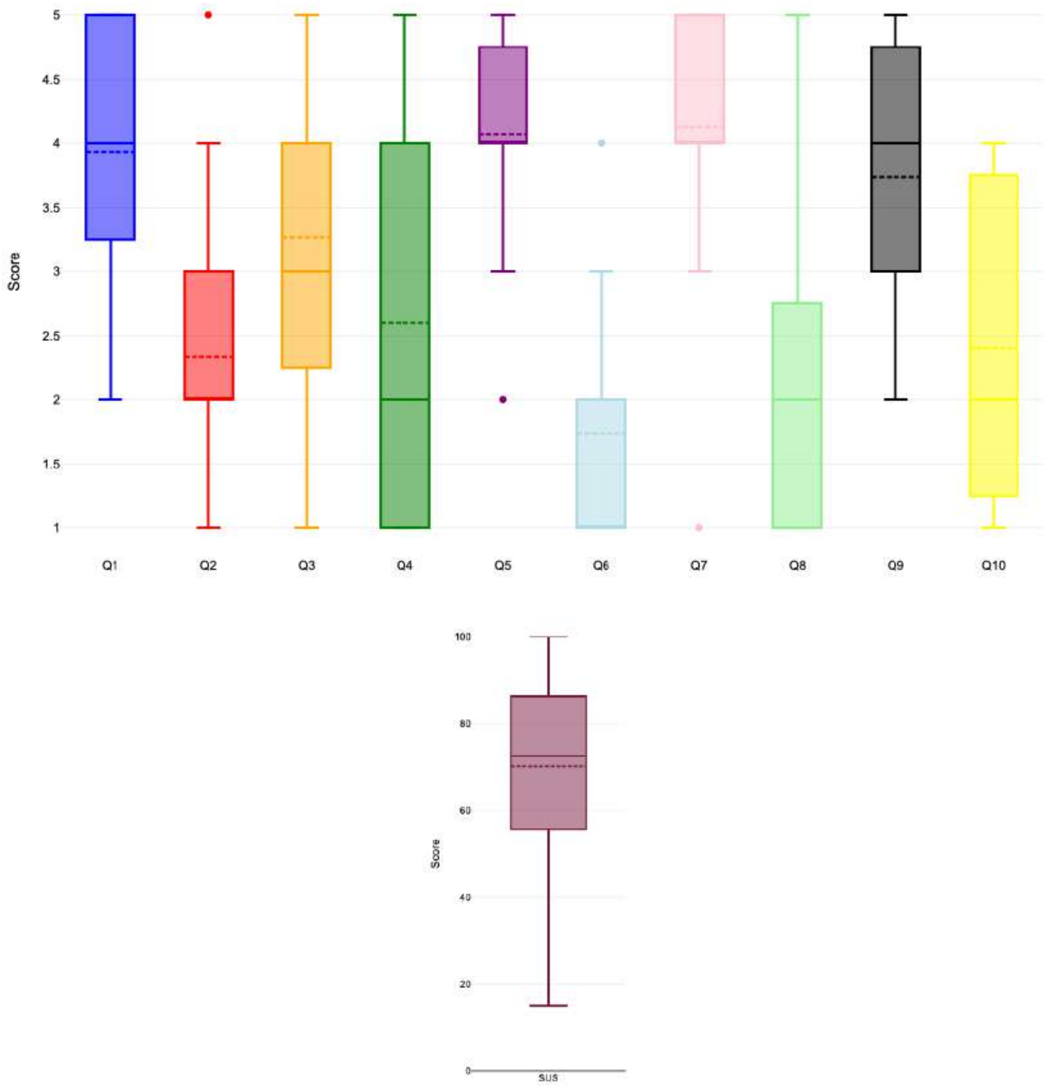


Fig. 22: Box plot of the dashboard usability results

Looking at both the table with the results and the box plot, it is possible to visualize the following results for each question:

- Question 1 has an average score of ≈ 3.93, with a median and mode of 4, it does not show any outliers. The lowest score obtained was 2 and the highest one was 5.
- Question 2 shows an average score of ≈ 2.33, it shows a median of 2 as well as a mode of 2. It shows a single outlier with a score of 5. This outlier was the highest score obtained, with the lowest score being of 1
- Question 3 shows an average, median and mode of ≈ 3.27, 3 and 4, respectively. The dataset for this question varies greatly on the whole scale, from 1 to 5, which were the lowest and highest scores obtained, respectively, there are no outliers.
- For question 4, the average was 2.6, with a median of 2 and a mode of 1. There are no outliers, the scores obtained vary greatly, with the lowest one being of 1 and the highest one being 5.

- Question 5 shows an average of ≈ 4.07. Both the median and mode are of 4. It shows a single outlier, which gave a score of 2, which is also the lowest score obtained. The highest score was 5.
- Questions 6 shows an average, median and mode of ≈ 1.73, 1 and 1, respectively. It shows one outlier with a score of 4, which was the highest score for this question. The lowest score for this question was 1.
- Question 7 shows an average of ≈ 4.13, a mode of 4 and a median of 4. It shows an outlier with a score of 1, very far from the other scores, which vary from 3 to 5
- Question 8 shows an average, median and mode of 2, 1 and 2, respectively. It does not show any outliers, and its scores varied from 1 to 5.
- Question 9 shows an average of ≈ 3.73, and both a median and mode of 4, it does not show any outliers. The lowest score obtained was 2, with the highest one being 5.
- Finally, question 10 shows an average of 2.4 with a median and mode of 2. It shows no outliers, with the values varying from 1 to 4.

The lowest SUS score obtained was 15 (obtained from userID 5). This user showed a lot of problems in performing the task and was able to identify various usability problems mentioned in Table 8. The educational/career background of this user most likely had an effect on the expectations for the interface. The highest score was 100, and the user showed no problems performing the tasks. The scores are drastically different, with a big variation. There are no outliers. The median is very close to the average score of 72.5 and ≈ 70.17, respectively. With this score, it falls into the category of "Good" [49] but by a very small margin.

For the dashboard usability tests, notes were taken just like what was done on the app usability testing. These notes will help better understand the justifications for the answers obtained in the questionnaires, and they will also help discuss what should be changed for better usability.

All the notes taken can be seen in Table 8. These notes are from observations made of actions taken by the users, or comments made by the same users.

4.3 In-situ Testing

This section will show the results obtained in those tests, the answers to the questionnaire seen in Figure 28 as well as comments noted during the tests.

This subsection will also show how long the app has been made available for each dive center and how many reports they have made in the time that it was available. This allows to understand if the app had a successful initial launch and helps gauge the level of interest in participating in the monitoring program.

For the in-situ testing, eight (8) different dive centers were visited, with a total of 21 individual participants. The number of participants in each dive center variated greatly due to the tests being done during the downtime when some of the dive center staff was available, which meant that not all dive masters of each center were available. This meant that some users were represented by a lot more members than other centers, however, the results will show that the opinion of the users did not vary much when compared with other users of the same dive center.

Table 8: Notes taken during the dashboard usability testing

userID	Notes
1	Used filter for species but search bar for diving spot search
2	Used search bar for all Was not able to find the suggest new diving spot button, was looking below the map
3	Could not associate a new diving spot Said that could not see which diving spots were associated
4	Was not able to find how to suggest a new diving spot
5	Said species should be ordered in alphabetic order Said the filters should be more clear, passed by without noticing those were filters Could not find the suggest button
6	Was confused on how to remove the filters
7	Could not find the associate diving spot button Said the color of the titles of associated and not associated diving spots should match the color of the map pins
8	Said the dashboard should be divided in different tabs
9	Expected filters to be in alphabetic order Used the write function in the filters
10	Expected the filters to be in alphabetic order
11	Tried to drag from one table to the other to associate a new diving spot before trying the button
12	Tried to apply filters by clicking in the specie in the table
13	Got lost in the filters because it was not ordered
14	Could not find the suggest new diving spot button Could not associate a diving spot
15	Filters should be in alphabetic order

This means that the results can be grouped by dive center and compared by the whole group instead of individual users. All the users tested have the divemasters certification, which means that they are the target users of the system and are the ones who will push it with the clients.

The answers of each user can be seen in Table 9. The first two columns are the identification of the user and what dive center it belongs to, the other columns are the questions from the questionnaire previously mentioned. The answers in each column answer the following questions:

- Question 1 (Q1): What interface would you prefer to use?
- Question 2 (Q2): Rate your experience with the **tablet** interface.
- Question 3 (Q3): Rate your experience with the **kiosk** interface.
- Question 4 (Q4): Rate your experience with the **web** interface.
- Question 5 (Q5): Order the interfaces in order of your preference.

As can be seen in Table 9, the results for each diving center are very similar, with only the dive center with diveCentreID = 2 having different preferences on the interface by the users tested in that center, with one preferring the Kiosk and another preferring the Tablet. The average score for Q2, Q3 and Q4 refers to the experience with the tablet interface, kiosk interface, and web interface are ≈ 4.66, ≈ 4.8 and ≈ 3.42, respectively.

Table 10 shows the average results for the questions about the experience and helps corroborate which interface is the preferred one for each diving center, it also shows the comments noted from each diving center. The data, when grouped by the dive center, can be further explored in Figure 23, which shows the variation of the results for each question.

Grouping by dive center the results for Q1 and Q5 is the best way to visualize which interface is preferred. The tablet interface has the highest average score per dive center of five (5) from dive centers with the ID of two (2), five (5), six (6) and eight (8), the lowest score for this interface came from the dive center with the ID of seven (7), which gave it a score of four (4).

Table 9: Results of all users of the in-situ testing

userID	diveCentreID	Q1	Q2	Q3	Q4	Q5
1	1	Kiosk	5	5	5	Kiosk / Tablet / Web
2	1	Kiosk	5	5	4	Kiosk / Tablet / Web
3	1	Kiosk	5	5	4	Kiosk / Tablet / Web
4	1	Kiosk	4	5	3	Kiosk / Tablet / Web
5	1	Kiosk	5	5	3	Kiosk / Tablet / Web
6	2	Kiosk	5	5	1	Kiosk / Tablet / Web
7	2	Tablet	5	4	3	Tablet / Kiosk / Web
8	3	Kiosk	5	5	3	Kiosk / Tablet / Web
9	3	Kiosk	4	5	3	Kiosk / Tablet / Web
10	3	Kiosk	5	5	3	Kiosk / Tablet / Web
11	3	Kiosk	4	5	3	Kiosk / Tablet / Web
12	4	Tablet	5	4	4	Tablet / Web / Kiosk
13	4	Tablet	4	4	3	Tablet / Kiosk / Web
14	4	Tablet	4	4	3	Tablet / Kiosk / Web
15	5	Kiosk	5	5	5	Kiosk / Tablet / Web
16	5	Kiosk	5	5	5	Kiosk / Tablet / Web
17	6	Kiosk	5	5	5	Kiosk / Tablet / Web
18	7	Kiosk	4	5	3	Kiosk / Tablet / Web
19	7	Kiosk	4	5	2	Kiosk / Tablet / Web
20	8	Kiosk	5	5	3	Kiosk / Tablet / Web
21	8	Kiosk	5	5	4	Kiosk / Tablet / Web

Table 10: Average results by dive center of in-situ testing with comments made by the dive centers

diveCentreID	Q2	Q3	Q4	Comments
1	4.8	5	3.8	The kiosk is good to attract the clients to participate Interfaces "move themselves", very straightforward
2	5	4.5	2	Tablet gives more freedom Not realistic for them, they are very busy Willing to try Afraid they will damage the hardware because of the saltwater Web is not doable
3	4.5	5	3	Kiosk is a good attraction Kiosk will make it so they won't lose the tablet Kiosk is more secure not to damage the tablet Want to be able to show species without making a report, to be able to show the species before the dive
4	4.33	4	3.33	Afraid the Kiosk is not resistant to the dive center conditions, very wet Don't dive in many places so the information they get is not very relevant
5	5	5	5	Willing to participate Afraid they wont have much space to fit the Kiosk Like that the interface is fast to make a report Think that the species have to be changed for some more common ones
6	5	5	5	Like that the Kiosk can also represent their brand by using the species that represents them Think the kiosk will attract the clients to participate Have a dry area where the clients always pass by
7	4	5	2.5	Kiosk is safer for tablet Good activity to do with clients Facilitates debrifing
8	5	5	3.5	Have a dry place to place the kiosk Facilitates debrifing Interested in expanding to their other dive centers

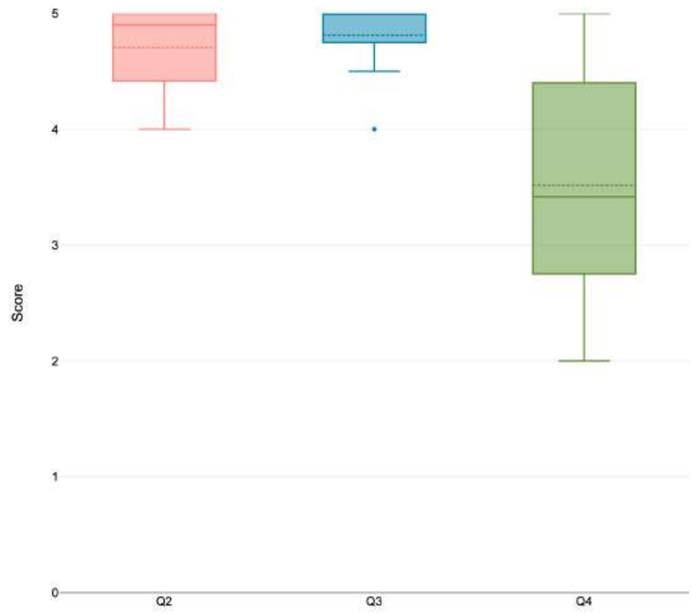


Fig. 23: Box plot with the average of each dive center of in-situ testing

The kiosk interface obtained its highest average score per dive center of five (5) from dive centers with the ID one (1), three (3), five (5), six (6), seven (7) and eight (8). The lowest average score came from the dive center with an ID of four (4) which scored it as four (4).

The web interface obtained its highest average score from dive centers with the id of five (5) and six (6), which gave it a score of five (5), and it obtained its lowest score from dive centers with the ID of two (2) which gave the interface an average score of two (2).

These results show that the web interface is never the favourite one, the tablet is the preferred one in only one dive center, diveCentreID of four (4), as well as the preferred one by one member of the dive center with diveCentreID = 2. The kiosk one is the preferred one by six dive centers and by the other member of the dive center with diveCentreID = 2. However, when considering the results for the questions about the experience, the diveCentreID = 2 can be said to prefer the tablet since it shows a higher average than the kiosk and web.

The results can also be seen individually by users to better compare with the initial results obtained from the workshops conducted at the beginning of the dissertation work. The results can be divided into three different moments where the users were presented with some aspect of the system. The moment when they first heard about the app and the monitoring program, this moment was named "Before Design Intervention", since, at this moment, the users only heard about how it would work and got a verbal explanation of what the interfaces would become.

The second moment was when the users were presented with the interfaces and had to decide just by look what would fit their needs better. This moment was called "Post Design Intervention" since, at this time, they were able to view what the interfaces looked like.

The third and last moment is the "Post Experience Intervention". This is the moment where the users had already tested the interfaces and had to choose not only based on the physical aspect but also consider how the digital interface itself fitted their needs.

Fig. 24: Different senses used in the different moments

Figure 25 shows the results obtained in those three moments. For the Post Experience Intervention results, the value that was considered preferred was the one classified as the first preference for the Q5 of the in-situ questionnaire. It is important to note that the number of participants changed from the workshops initially done to the in-situ test done by the end. This is due to not all staff of the dive centers being able to attend the workshop, however, it was still important to get their perspective by the end since they are also to take part in the program, and their input would still be of value.

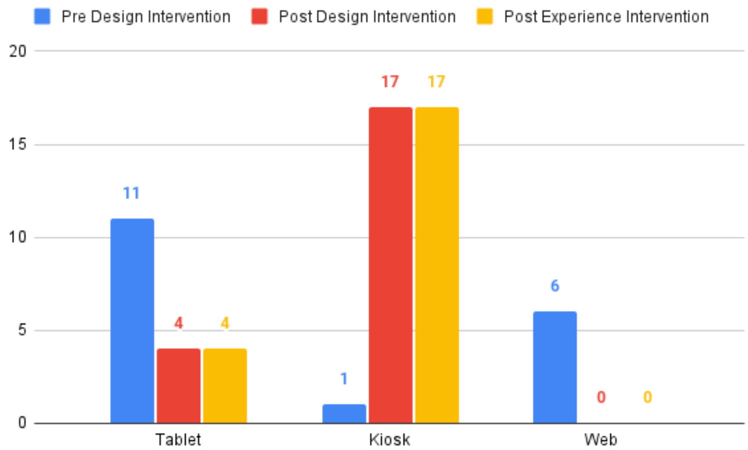


Fig. 25: Preference of each interface at the various moments of presentation to the users

When comparing the *Pre Design Intervention* results with the *Post Design Intervention* it is clear that there is a drastic change in preference. The web goes from six users preferring it to zero. The tablet preference also lowered from 11 to 4. The kiosk is the one which shows the clear change in user perspective, it goes from a single user preferring it to 17. The results from *Post Design Intervention* to *Post Experience Intervention* don't show any difference in results, the total number of preferences of each interface stays the same, with not a single user changing his mind after trying the interfaces.

The comments of the dive center staff, which are present in Table 10, can also be grouped by categories. All the comments done by the users were grouped into categories, which possibilitates to better understand why those comments were made and how they could be addressed. The categories they ended up being grouped by were attractiveness, usability, barriers, state of mind, hardware, customization, and enablers. Which comment belongs to each category can be seen in Table 11.

Table 11: Notes from in-situ testing categorized

Category	Notes
Attractiveness	Kiosk is good to attract the clients to participate Kiosk is a good attraction
Usability	Interfaces "move themself", very straight forward Like that the interface is fast to make a report Like that the Kiosk can also represent their brand by using the species that represents them Think the kiosk will attract the clients to participate Tablet gives more freedom
Barriers	Not realistic for them, very busy Web is not doable Don't dive in many places so the information they get is not very relevant
State of Mind	Willing to try Willing to participate
Hardware	Affraid they will damage the hardware because of the salt water Kiosk will make it so they wont lose the tablet Kiosk is more secure to not damage the tablet Afraid the Kiosk is not resistant to the dive center conditionsKiosk is safer for tablet Afraid they wont have much space to fit the Kiosk
Customization	Want to be able to show species without making a report, to be able to show the species before the dive Think that the species have to be changed for some more common ones Interested in expanding to their other dive centers
Enablers	Have a dry area where the clients always pass by Facilitates debrifing Facilitates debrifing Good activity to do with clients Have a dry place to place the kiosk

The app was made available to the dive centers during the summer in the form of a tablet since it was the preferred version after the kiosk and since the kiosk could not be made available due to only having a single prototype, Table 12 shows for how long the app has been made available to each dive center and how many reports have been gathered from them.

Table 12: Number of reports made by each dive center since getting the app

diveCentreID	Days since made available	Number of reports
1	44	7
2	27	1
3	41	62
4	32	18
5	14	4
6	29	21
7	23	1
8	23	3

5 Discussion

This section focuses on the interpretations of the results obtained from the two evaluation stages shown in the previous section. It will mention why those results are thought to have been obtained and the changes that should come from them. Relating the results obtained with the stakeholder analysis of the dive centers, the section provides further foundations for the proposed guidelines and methods to help choose what type of interface should be chosen for a diving center when using SCUBA divers to perform biodiversity monitoring.

5.1 App Usability

The SUS score for the app interface was considered "Excellent" based on the score obtained with literature already available. However, some of the notes taken from user comments indicate that some choices could have been made differently to help the user perceive what a certain feature does. These comments were mostly focused on the scrolling of the species that have more than one image available to them, as well as the logout feature. To address these comments, an indication of the number of images a species has should be added. This should be added on the window that shows specific species information as well as on the summary page since it was also referred to that there was no indication of scrolling there. This indication can be similar to the one used on other photo-sharing apps (e.g. Instagram), where the number of photos is shown in a corner of the image or could be made by simply having a number of small dots at the bottom of the scrollable view which shows one dot for every image available and where in the position of images the user is.

The logout feature seemed to be a bigger problem than initially thought. The icon change should be considered to be made a door with an arrow icon since it seems to be the expected icon when talking with the users who showed problems or commented on it. The position of the logout seems to be debatable based on user comments, while some seemed to not have a problem finding it, others seemed to think the placing for it should be changed either to what is considered the main window (i.e. report window) or to the bottom of the profile page. For now, this position has not changed since making it to the bottom of the profile page when there are multiple logos that also have to be shown there due to grant requirements, and placing it into the first window can be unexpected as well.

The other notes taken were not considered needed to be addressed for now since they were only mentioned by at most one of the users testing and seemed to be referring to personal preference (e.g. does not like the images together).

This part of the usability testing seemed to give a partial answer to Research Question 1 - Which obstacles can an interface solve to ease the data input through its physical and virtual properties? -, for this case, a very simple and fast to run through interface does seem to make it very intuitive for users who had no experience with the app to still be able to introduce a report with any problem, easing the data input since no problems were noted in the part of the usability that focused on the introduction of data.

5.2 Dashboard Usability

The SUS score for this interface at the end of the usability testing was considered "Good", however, it fell into this classification by a very small margin, so clearly, changes have to be made to make it possible for users to quickly learn how to use the interface and be able to consistently use the interface without the need to second guess themselves.

Based on the notes taken, it is possible to see what changes should be made at first and, from there, perform more usability testing to confirm if the usability of the system has improved.

The notes about the filters and search being used do not influence the usability of the system but do give an idea of what type of features the users were using. It was not specified in the usability testing if the user should clear the filters already applied before applying a new one for the first two tasks, this was an error in the usability test planning. However, some users did ask if the filter should be cleared before applying a new one, when this question did come up, it was asked the user how they would clear said filters and the clear button filter was only used by one of the users. The other users went to the filter list and scrolled up, looking for an empty field that would clear the filter. Based on this, it was considered that the best option would be to add an empty field on the top of the filters that would clear the filters. This creates redundancy, allowing for more than one way of performing the same action, this allows to cover a bigger portion of users independently of how they think the filters should be cleared. Still related to filters, the order of filters was based on the ID of the database, which is also a clear error when the filters should be ordered by a more expected order like alphabetic.

The problem found with the associated and not associated diving spots seems that it could be fixed by following the recommendation of one of the testers. Making the title more noticeable and related to the colors used for the map pins and status icons shown on the tables. This would also probably solve the issue of users missing what which table refers to since it would make the titles more apparent. Making this distinction clearer may have an impact on the users being able to associate the diving spot to the account and remove said association as well. Again, as per the filters feature, creating redundancy and making it possible to also associate a diving spot by dragging it from one table to the other, as one of the users tried, can be beneficial in the long run.

Although suggesting a new diving spot seemed to be a common problem among some users, it is not clear what position would be better fitted for the button. The button is next to the filters and on the top of the map, making it under the map would split the features of the diving spots into more "sections", creating the filters, then the map, then suggesting new diving spots and then associating. This placement may suffer changes in the future based on user feedback if deemed necessary.

The results obtained on the evaluation stage led to the changes in the filters' order which were changed to be in alphabetic order. The empty field for the filters was also added giving the user another way to clear the filters while still leaving the reset filters button previously available. The suggestion button was left to be the same since there was no other position deemed better for it.

5.3 The Role of Interaction Design

The in-situ testing revealed interesting findings. The results show that the kiosk is the favorite interface independently of which results are looked at, both the individual results and grouped by dive center show this preference. The tablet follows the kiosk with a very similar score for the experience as the kiosk, when looking at the order of the interfaces, it once again shows that the tablet is the second one preferred since it does come in at second place most of the time. The web only appears out of the third position once.

These results for preference of interface are very interesting because, when compared with the initial workshops, these show a clear shift from Tablet/Web to Kiosk/Tablet. This shift happened after the final interfaces were shown, and it was kept even after experiencing the interfaces. Looking at the results of the different moments shows that in the workshops, just explaining what the interfaces would consist of is not enough to make the users visualize and make a final decision.

The explanation for the results is that visualizing the final versions of the interfaces changed the perception of the users of what each interface could bring, and this is what caused the users to change their choices.

The preference on *Post Design Intervention* seems to be tied to the conditions of each dive center. These conditions are the physical ones present in subsection 3.3 but also the way that they conduct their work. Dive centers that do not have a dry area, like dive center with diveCentreId 2 and dive center with diveCentreId 4, tend to prefer the tablet since a bigger physical structure would require them to either change the way they wash the dive center, normally wash with a hose, or move the structure every time they intend to wash the center which would influence the effort they have to put into the system. Another physical limitation is the available space, diveCentreId 2 has a very limited space, and placing the structure in it would affect the space available for the clients when preparing for diving. One of the dive centers, which was expected to not have the conditions to accommodate the kiosk, also said they could expand their area outside and have the kiosk, outside, close to the entrance, this is important to note since it will affect the guidelines to follow when choosing the interface which should be made available.

Another influence the system itself can have in the day-to-day of the dive centers is that if a dive center does not normally conduct debriefing, asking them to start performing debriefing would change the amount of time spent with clients and the effort needed on both the client's and dive center staff part.

The number of reports from each dive center, seen in Table 12, could be explained as the dive centers that had the higher number of reports are the dive centers with a connection already to the research team behind the project, or those who had shown interest in the past in participating in research activities.

These results help answer Research Question 1 - Which obstacles can an interface solve to ease the data input through its physical and virtual properties? - and Research Question 2 - Which interface should be pursued for a reliable monitoring program?. For the focus of Research Question 1 on the virtual interface and how it can ease the data input, it is clear that due to time constraints, it is important that the interface allows the introduction of the information as quickly as possible but also having more detailed information which can be used for when time is not as much of a problem is important. The physical part of Research Question 1 and Research Question 2 can be answered by creating guidelines of which interface should be picked based on the conditions of each dive center since there is not a "one interface fits all" in this case.

Moreover, the Research Question 3 - Will the data obtained through the app be reliable for scientific purposes? - is confirmed partially with the recent published study [1], where the ecological and data validation have been addressed. That study evaluated the usage of the mobile interface with time series analysis of reported species. From the point of view of interaction design, further analysis are required to provide more insights to which extent the kiosk as well may be used for adequate data gathering. Studies should address the usability when the divers de-facto use the kiosk in the aftermath of their dives. Also, additional studies are needed to analyze how the kiosk may be used during the briefing by the dive master. Such were out of scope for this dissertation. Regarding Research Question 4 - Can a mobile application be used by non-scientists for marine biodiversity monitoring? - this dissertation confirms that indeed the mobile application may be used by non-scientists for marine biodiversity monitoring and that future studies can explore to which extent such may be applied for large-scale monitoring.

Comparing the work conducted in this dissertation with the technologies indicated in the Related Work section is cumbersome since the program has been running for a short time. However, some of the gaps identified in that section have been addressed. Dive Reporter allows for reporting without the need for photos/sounds, which was one of the problems identified as limiting users from using some of the technologies. It also does not require a big team in the background to review all reports for their quality since the dive master already acts as a filter when the report is being made, which also makes it so the divers themselves don't need to have previous training or to follow an established protocol. For now, it still has the same limitation as some other programs like GelAvista and Black Sea Watch that are limited to a certain area, however, expansion is possible.

5.4 Design Guidelines

Based on the initial stakeholder analysis of the dive centers who participated in the in-situ testing and the result obtained from them, it is possible to develop guidelines to help choose which interface is more appropriate based on the conditions of the dive center. For these guidelines, the web report will not be included since, based on the results, it is never the most appropriate interface to be made available. If the dive center has an area which is normally kept dry (i.e. dry area) and the divers post dive pass by that area, the better interface is the kiosk one. If there is a dry area but limited space, depending on the availability of each dive center, both the tablet and kiosk interface are appropriate. In case there are no dry areas, the best option is the tablet. Based on the comments of dive center diveCentreID 2, the tablet interface may be a better interface if the dive centers are reluctant to participate since it seems to be a "smaller investment". This explanation which is summarized in table **??**, answers Research Question 2 on what interface should be pursued.

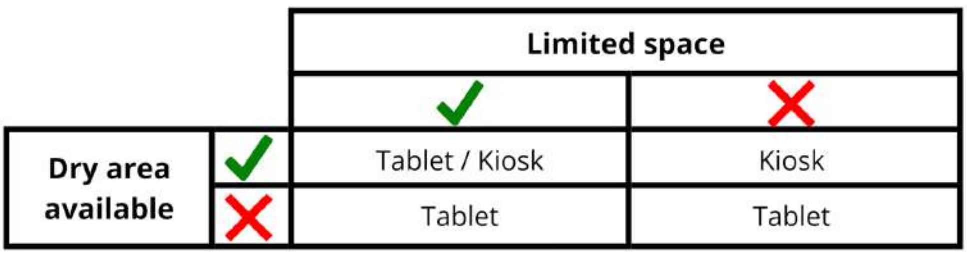


Fig. 26: Matrix rule for the interface that should be made available based on constraints

These guidelines, however, are limited to the information gathered from the in-situ testing. To further explore and expand them, the amount of data used should increase, and dive centers outside of the restricted area of Madeira should also be presented with the system.

Relatively to the data obtained with the system, it shows a good amount of reports by only a couple of dive centers, more notably diveCentreID 3 and diveCentreID 6. DiveCentreID 3 shows more than a report per day since it has been made available, while diveCentreID 6 shows almost a report per day when considering the days that they have been closed since then due to weekends and holidays.

Based on the related work found, it is possible to conclude that the data obtained can be used for scientific purposes [1], which answers RQ3 - Will the data obtained through the app be reliable for scientific purposes?. Experts could then analyze this data to know which areas they should focus on exploring and validating the findings from the system. For RQ4 - Can a mobile application be used by non-scientists for marine biodiversity monitoring?, based on the same work used for research question 3 (i.e. used to understand the reliability of the data) and based on the results obtained from the dive centers tests and number of reports from centers, it is concluded that a mobile application can be used by non-scientists to monitor marine biodiversity even without the need for expensive equipment for photography. However, motivation is a big factor that will influence the level of success of a monitoring program. As can be seen in the uses of the system, only a few of the dive centers that participated actually maintained regular use of the app.

5.5 Lessons Learned

The work conducted during this dissertation led to some lessons that can be used future considerations.

The usability of the tablet interface had excellent results which proved that going for a Human-centered design provided an adequate workflow. Also, the results of the dashboard interface were deemed good by a small margin, where most of the found errors were based on things that were not aligned with what the user was expecting (e.g unordered filters). This showed that the details are the make-or-break of an interface and that having an outside perspective can improve the work as a designer and developer. Indeed, the visual aspect and being visually appealing to a user can have a great effect on what the user prefers to use, using a physical structure as an attractor can be an adequate idea if the location where it is to be placed provides such conditions.

Being visually appealing however can not be the only factor, as usability and being able to integrate it with an already-established workflow is important when providing a digital solution for something that was previously conducted on paper. This is because it is hard for a user to adapt to a new technologies if it feels that it will be losing the time using it.

5.6 Limitations

The project developed during the dissertation shows some limitations, some of which can be directly addressed in the future without the need for more studies and some others that require further studies.

The limitations found which can be easily addressed in the future (without the need for user research or studies) are the material type of the kiosk. The MDF is not a material suitable for long-term exposure to the dive center conditions, and the size of the kiosk was also not appropriate for all dive centers.

Some of the other limitations that still require further studies such as the dashboard interface which had a considerably low score on the usability tests. Also it would be interesting to explore which other shapes could be used for dive centers and if they would have a bigger effect on the users, underpinning the overall motivation of the users to participate on the program and what could be achieved to motivate them. There are also some limitations on the software part, where if the program is to be expanded the software has to be rewritten to be able to be used in multiple different locations where species are different from the ones in Madeira.

The time limitations for further testing were also an imposed limitation for this dissertation, dive centers are more active during the summer season, however, it was not possible to complete all the work during those summer months. This means that the dive center staff will become more busy during the next summer season and that can influence the use of the app. Due to a bigger affluence of clients, the number of reports may increase, or, the number of reports may diminish if the workload becomes too heavy and the dive centers consider cutting the app out of their work.

5.7 Future Work

This work is to be continued in the following years through the CLIMAREST project. Here, the dissertation outlines the necessary work to be performed to improve the monitoring program as well as steps that should be taken into consideration to ensure the success of a long-term program.

As mentioned initially in this dissertation, it is important to make the value of the monitoring program appealing to all stakeholders. The value for the experts is very clear to capitalize upon collected data. The value for the dive centers, for now, is mostly focused on their will and their interest in participating in something that is dear to them, like conservation. However, this may not be enough to be able to stimulate their interest for long term. The continuous intervention and sharing of information between the experts' analysis and the dive centers can be an extra motivation to show to the dive centers that their work is becoming something large and that it has an impact on science.

After conducting the studies with the dive centers, it was noted that the diving community in Madeira is quite strong, and they have a clear interest not only in conservation but also a passion for learning more about the monitoring program. This applies to the dive centers and some recurrent divers. However, it might not apply to all divers, which should be a point of interest in finding a way to motivate the divers who are getting into diving or might not show that much interest in the monitoring program. The kiosk was referred to many times as an adequate attractor for the clients to aspire curiosity and make them want to participate, but it was never tested. The passive observation that was initially planned but not conducted due to time constraints should be executed to better understand the effect of the kiosk.

A different interface for the app can also be explored since some centers mentioned that allowing to show the species and information about them outside of a report could be useful to the process of reporting and captivating their client's attention.

For the kiosk, other materials will need to be used. The prototype was made of MDF to allow for quick prototyping, and was made possible with the tools available and at a low price. One material that can be used is acrylic (polymethyl methacrylate) which is resistant to water and strong enough to survive the harsh conditions of some dive centres [50]. This will, however, increase the price and might be more difficult to work with other than MDF. Another option that will be cheaper but will most likely be less resistant is marine grade plywood. These materials need to be studied and tested to understand better their durability and price/quality.

The design of the kiosk can also change, having multiple designs available can make it more popular with certain diving centers that may have a bigger chance of finding a specific species underwater. Ideally, these species would still be easily recognizable, for example, octopus, monk seal, turtles, etc.

The dashboard interface showed some usability problems, which, although they were changed to make it easier to use, were not tested again. Further usability tests should be conducted to ensure those changes were enough to bring the usability up to standards and what may still need changes.

After determining if the monitoring program is successful in Madeira Island, it can be expanded to other locations and integrated as part of other projects. For this to happen, the backend will need to be changed in order to accommodate the needs of different projects. There are two options that can be made available, however, depending on how the expansion is planned, one might be more appealing than the other.

If the monitoring program is to be expanded based on projects, there has to be a need to identify which project each account belongs to, this can be done with two new database tables. A table for projects and a table to associate each user to a project. A pivot table to connect the projects and the species that are being monitored in that project.

If the monitoring program is to be expanded just based on the location, the GPS of the mobile device can be used. This would require the app to get the location of the device and query the database based on that location and which species are being monitored in that location.

An interesting study that can be conducted is also based on the information collected with a dive master and scientists is to create an AI model that would fulfil the role of the dive master of reducing the noise. This would allow the system to be made available directly to the divers without the need for an expert to be present when using it.

6 Conclusion

Monitoring the oceans indeed requires a considerable amount of resources, and the availability of those resources, such as time and money, will vary greatly from area to area. This dissertation proposed a system based on recreational SCUBA divers for data gathering, and the use of dive centers to create foundations for a low-cost, large-scale and customizable monitoring program. It studied the role of a mobile and touch-point interface for data gathering, and how it can motivate the data gathering and be used by the SCUBA divers of different expertise. It shows the comparisons of the interfaces being both digital and physical, where the latter resulted in a higher attraction of the participants.

The dissertation provided a pre-study, where through an interview with the diving centers staff it was possible to conclude the preferences for species, interface and overall willingness to participate in the monitoring program. A system based on an existing mobile application Dive Reporter was redesigned for tablet screens and was developed and made available through a tablet, kiosk and web interface. The role of the design intervention was showcased, where the participants, after seeing the touch-point interface actually changed their preference from mobile to it. Indeed, in another round of interviews, this was demonstrated, and the participants expressed a high level of interest in taking part in the initial steps for low-cost monitoring.

Design guidelines, although initial, should serve as the foundation step, indicating what type of interface should be chosen for each dive center. Since not all diving centers have the same interior and exterior, there are further opportunities for interaction designers to address. As the usage of dive master may provide the filter for the data, the proposed system seems plausible to be used for ecological monitoring. Finally, the proposed dissertation provides initial steps to facilitate marine monitoring, using low-cost, worldwide SCUBA diving centers and the integration of the mobile application into the briefing procedure. It provides the backdrop for a successful long-term monitoring program, leveraging both citizen science and SCUBA diving.

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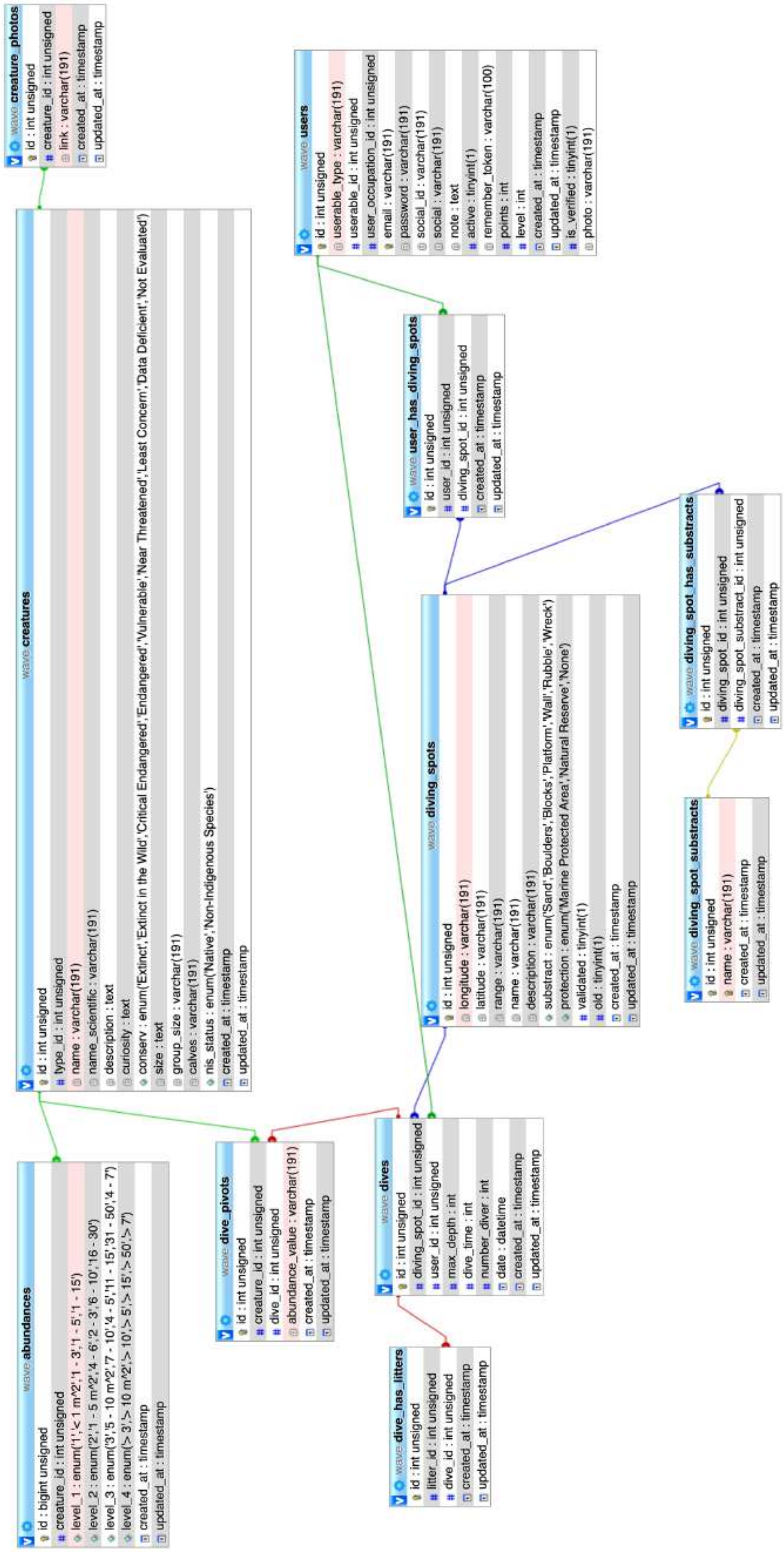
Appendices

A Database UML



B Consent form

Informed consent for participation

Title of study: Design of Interactive TouchPoint Interface for Reporting Marine Biodiversity using Recreational SCUBA Divers

Master's student: Francisco Filipe Sousa da Silva, University of Madeira, francisco.silva@mare.arditi.pt

Supervisor: Prof. Dr. Marko Radeta, University of Madeira

Goal of the study

This study is part of the thesis being developed by the master's student Francisco Silva for the Master's in Interactive Media Design on University of Madeira named "Design of Interactive TouchPoint Interface for Reporting Marine Biodiversity using Recreational SCUBA Divers". The goal of this study is evaluate the interfaces developed by the master's student during its thesis period.

Procedure

For this study its asked of the participant to complete some tasks and its performance to be observed as well as answering some questions about the tested interfaces. The tasks that will be asked of the participant are based in the usage of the interfaces, after it will be asked of the participant to fill some surveys about them.

Risks

The study does not show any associated risks out of the normal ones present in the usage of a digital interface.

Benefits

There will be no benefits for the participant.

Compensation and cost

There is no monetary compensation involved. There are no costs involved.

Confidentiality

Confidentiality of data gathered will be kept the following way: The identity of the participant will not be public, including the name, age nor the date that the activity was performed. Only the researchers involved in the study that appear as mentioned in the first page of the consent form will have access to this information.

Rights

Your participation is voluntary. You are free to discontinue your participation at any time. Refusal to participate or interruption of participation will not result in any penalty. The researchers may decide, in a reasoned manner, to discontinue their participation in this study.

Informed consent for participation

Funding

The master's student and its turn the study is financed by the project Coastal Climate Resilience and Marine Restoration Tools for the Arctic Atlantic basin (Climarest), financed by Horizon Europe (Grant agreement ID: 101093865).

Doubts and additional information

Any question can be asked before the study in person or after the study through email (francisco.silva@mare.arditi.pt).

Voluntary consent form

By signing this document, you confirm that you have read the above information about this study and that all of your questions have been answered. Likewise, you can ask additional questions at any time during the study, and even after it has ended. By signing this document, you agree to participate in this research study. You will receive a copy of this signed and dated informed consent document.

______________________________ _______________

Signature of participant Date

Research that gets the consent

As a member of the research team, I confirm that I have explained to the above participant the nature and purpose of this research study and that I have clarified the potential benefits and possible risks of participating in the study. All questions have been answered and I am available to clarify any doubts that may arise during the study.

______________________________ _______________

Signature of researcher Date

C Controlled environment usability questionnaire

In a scale of 1 (strongly disagree) to 5 (strongly agree) rate the following affirmations

I think that I would like to use this system frequently.	1	2	3	4	5
I found the system unnecessarily complex.	1	2	3	4	5
I thought the system was easy to use.	1	2	3	4	5
I think that I would need the support of a technical person to be able to use this system.	1	2	3	4	5
I found the various functions in this system were well integrated.	1	2	3	4	5
I thought there was too much inconsistency in this system.	1	2	3	4	5
I would imagine that most people would learn to use this system very quickly.	1	2	3	4	5
I found the system very cumbersome to use.	1	2	3	4	5
I felt very confident using the system.	1	2	3	4	5
I needed to learn a lot of things before I could get going with this system.	1	2	3	4	5

UNIVERSIDADE da MADEIRA   MDMi Master of Interactive Media Design   CLIMAREST   Age ______

Fig. 27: Usability questionnaire used

D In-situ questionnaire

Dive centre dive reporter questionnaire

What interface would you prefer to use? ______________________________

	Very bad				Very good
Rate your experience with the **tablet** interface.	1	2	3	4	5
Rate your experience with the **kiosk** interface.	1	2	3	4	5
Rate your experience with the **web** interface.	1	2	3	4	5

Order the interfaces in order of your preference. Web ____ Kiosk ____ Tablet ____

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Fig. 28: Questionnaire used for the dive centres

E Kiosk mounting

Fig. 29: (a) CNC cutting the pieces of the kiosk, (b) glueing the pieces of the tail, (c) glueing the support of the kiosk to the tail, (d) connector of the tail to the top part inserted, (e) top part of the kiosk and (f) connection of the top and bottom part together with the wooden dowels