A WEB-BASED SYSTEM FOR MARINE FISHES MAPPING AND ASSESSMENT

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ABSTRACT: Estimating the abundance of fishes through underwater visual census (UVC) using the transect method contributes to the development of coastal resources management in the Philippines. The manual method of performing data administration and management of numerous marine fishes is time-consuming and arduous to researchers. Aside from that, it is also likely to human errors and may result in data inconsistency and redundancy if not done properly. Thus, a Web-based System for Marine Fishes Mapping and Assessment is developed using the Yii 2.0 Framework and Rapid Application Development to present a solution to those difficulties encountered. The system was implemented using MySQL for manipulating data, functions and queries were written using the PHP Hypertext Processor programming language, the user interface was designed and enhanced using Hypertext Markup Language (HTML), Cascading Style Sheets (CSS), and Bootstrap Materialize, while the mapping feature was accomplished using Google Maps API. Furthermore, the system allows the administrator to manage fish species information, transect locations, and make an inventory of marine fish species. The administrator could also filter data using the search bars provided and could export data into files such as text CSV, PDF, and HTML. With this system, the data gathered can be visualized geographically through an interactive map. Moreover, map markers shown on the map could also be refined by the name of species, marine site, and environment using the filters provided. The system was populated and tested with data collected by the researcher. The system was also evaluated using System Usability Scale (SUS). The results show above average scores suggesting that users are satisfied with the system. Hence, with this system, marine fishes data can be handled by marine researchers effectively. The system is also a GIS-assisted resource mapping tool that is a fast and reliable technique for decision-making and data assessment.

I. INTRODUCTION

Marine protected area (MPA) establishment is one of the most achievable modes of protection in relation to coastal resource management particularly in the Philippines (White et al., 2002). International Union for Conservation of Nature (IUCN, 1999) has defined an MPA as any area of intertidal or subtidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment. With its evidently successful results, the National Integrated Protected Areas System (NIPAS) Act (RA 7586) and the Fisheries Code of 1998 both make provision for the implementation of MPAs through the means of marine reserves and fish sanctuaries (White et al., 2002).

In spite of the fact that MPAs cannot resolve all problems in the marine resources, especially overexploitation, they help reduce some anthropogenic-related problems like destructive fishing, forest deforestation, unregulated mining activities, and many others (Burke et al., 2012). Since 1950s, community developers concerned with agricultural resources began to use community-based resource management in the Philippines. Later on, in the mid-1970s, the same approach was applied to coastal resources management. Few factors helped in this development and one of which is the gathering of underwater information through SCUBA diving done by marine scientists and other professional groups (Alcala, 1998).

A study conducted by Samoilis and Carlos (2000) suggests that estimating abundance of fishes through underwater visual census (UVC) can be done in different methods. One of these is the transect method. The transect method refers to the counting of fishes within a rectangular strip of reef. This requires an observer who will record the numbers of fish species, within each transect, that are included in the checklist. Mid-range transect sizes are of 50 and 75 m lengths, and 10 m and 5 m widths (Samoilis and Carlos, 2000).

Many fish species can already be found within one transect. Each species and each MPA are associated with important attributes and can be of different data types (e.g. scientific names, date, fish size, and etc.) (Cabral et al., 2014). Considering these, the large amount of data involved requires management. Currently, researchers use multiple spreadsheets and manual methods to generate information for marine fishes. Furthermore, there is no existing database and interactive map for marine fish resources management specialized for Philippine species yet.

One way of helping address this problem is through the use of technology in creating a database and a map. Geographical information systems (GIS) has become an increasingly vital tool for mapping and assessment in natural

resource management activities in most countries. A GIS is a database management system that facilitates the storage, retrieval, manipulation and analysis of spatial and temporal data and its display in the form of maps, tables, and figures (Wright, 1997). Today, GIS is widely used by the public such as Google Maps and Google Earth (Jiang and Yao, 2010).

Hence, this study aimed to develop a web-based system for fish mapping and assessment. It was designed to make a system that would map out fishes on different marine environments in the Philippines including those within and outside MPAs. The system contains existing data of marine reef fishes collected by different individual researchers and organizes the large data collected into one repository system. The data gathered and stored are shown in a map. In particular, this study intended to develop a database and mapping system for marine fishes and marine sites.

Fish-Visual Censuses

Researchers conduct censuses to monitor fish species present in MPAs and fished reefs. These fish-visual censuses are conducted along 50 by 10 m belt transects. At each sampling site, at least one transect line are set along the reef tract both within the MPA and in fished reefs adjacent to the MPA. The observer swims along the transect line and records all fishes that fall within both sides of the transect. Fishes observed in each transect are counted and classified to its species and family level. Repeated censuses conducted at each site (Nañola et al., 2010).

Geographic Information System

A Geographic Information System (GIS) is a versatile computer-based system used to handle georeferenced data (Wright, 1997). With a GIS, a user can expect support from the system to enter georeferenced data, analyze it in various ways, and produce presentations including maps and other types. This helps users to understand relationships, patterns, and trends among the data gathered (Huisman and de By, 2009).

GIS has become the go-to technology for decision making, record keeping, and managing geographically. It benefits organizations of all sizes and in almost every industry (Esri, 2015). With its undeniable contributions to humankind, GIS has now become popular on the web and even applied in resource mapping.

GIS is a database management system that manipulates, analyzes, interprets, manages, and stores data (Wright, 1997). Once stored, GIS may retrieve, display, and present these data into usable digital information such as digital maps and image maps, tables, statistical results, graphs, and charts. The output may be processed further into other desired forms of spatial and non-spatial data (Tongco and Japos, 2011). The analytical capabilities of a GIS may be used to answer questions about what exists now or existed at some point in the past. In addition, they can be used to predict what will happen at a future point in time (Wright, 1997). Examples of GIS software are MapWindow, ArcGIS, Manifold GIS, and Quantum GIS.

Nowadays, GIS has been a widely used tool in mapping and assessment. In fact, GIS technology has developed rapidly and has become an essential tool for land management or conservation, resource management, emergency services or disaster response, medical and health, transportation, military, and etc. in most countries (Wright, 1997). In India, specifically Chennai City, a study has been made to understand the seismic hazards of the city using GIS (Ganapathy and Manoharan, 2015). GIS database was constructed on the exact location of the residential areas to explore the spatial distribution of settlements in flash-flood prone areas from a topographical perspective in Ulaanbaatar, the capital city in Mongolia, (Saizen et al., 2015).

Another recent study used remote sensing and GIS for change detection in the coastal zone of Amu Darya at Emam Sahep district of Kunduz in North of Afghanistan (Erener and Shirzad, 2015). A case study of malaria and dengue mapping in Ly Son Island, Quang Ngai Province, Vietnam (Binh, 2015). Philippines has also been familiar with the use of GIS. In the island of Bohol, GIS was utilized to identify areas that are prone to earthquake-triggered landslide hazards (Ramos et al., 2015).

Recent GIS analysis by Jadap, Santillan and Santillan (2015) in Mainit, Surigao Del Norte, showed that the snails carrying of schistosomiasis are found in the canal, lake, rice field, creek, and irrigation canal.

DREAM Program

The Disaster Risk and Exposure Assessment for Mitigation (DREAM) Program is a research project that introduced the use of LiDAR technology in generating high resolution 3D maps for hazard assessment and flood modeling (DOST, 2016). The Department of Science and Technology (DOST) invested in DREAM Program to produce the

information needed to prepare planners and proper agencies of the impending and potential flood hazards (Andaya et al., 2015).

Under DREAM Program is Phil-LiDAR, a research project which utilizes LiDAR or Light Detection and Ranging (UP DREAM Program, 2014). Phil-LiDAR is divided into Phil-LiDAR 1 and Phil-LiDAR 2. The Phil-LiDAR 2 program aims to utilize LiDAR datasets and other remotely sensed data to develop methodologies in extracting resource features for various applications like production of high value crops, irrigation assessment, coastal resource conservation, aquaculture production, forest protection, and discovery of renewable energy sources. One of the specific goals of Phil-LiDAR 2 is to produce high-resolution coastal resources database and map (Japitana and Bonotan, 2015). Resource mapping is to be implemented by the use of GIS.

II. MATERIALS AND METHODS

The model that was used for the software development of the web-based system in this study is shown in Figure 1. This follows the James Martin approach to Rapid Application Development (RAD) structure of System Development Life Cycle (SDLC). RAD had guided the proponent of this study for faster design and implementation of the system. RAD consists of four phases, namely: (1) Requirements Planning, (2) User Design, (3) Rapid Construction, and (4) Cutover.

As Figure 1 shows, the same phases followed in the traditional SDLC are also followed in RAD, but the phases are combined to produce a more streamlined development technique. RAD uses a set of management techniques that are optimized for speed. Among these are prototyping, iteration, and timeboxing.
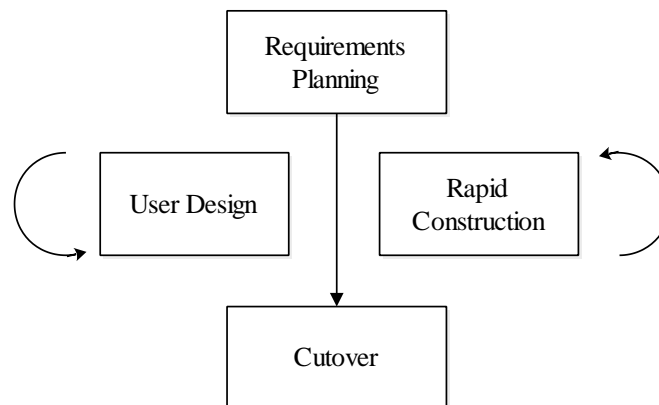

Figure 1. James Martin approach to Rapid Application Development (Lifted from www.ftms.edu.my, 2015).

Prototyping is an approach based on creating a demonstrable result as early as possible and refining that result; refinement is based on feedback from the users of the system. Iteration is a commitment to incremental development based on refinement. Prototyping and iteration go hand in hand. Timeboxing is a management technique that focuses attention on delivery above all else. Under a timebox, the scope can change but the delivery cannot.

In the first phase, Requirements Planning, the user and the developer agreed upon the software and hardware requirements. The next phase, User Design, includes the detailed analysis of functional and non-functional requirements of the system. Then comes the Construction, where the actual coding and initial testing took place. Lastly, Cutover phase involved the final testing, installation of the system and identification of potential future enhancement.

Requirements Planning

The Requirements Planning is the first stage in RAD. The objectives of this stage are to establish a general understanding of the system, and to become familiar with the related existing systems. An outline and a definition of the system scope was developed. Through a series of meetings between the developer and the adviser. These meetings had initiated the development process by establishing a mutual understanding of the objectives of the project in general and the system in particular. Also, interview and short meetings were conducted with the researcher. Only a short period of time was alloted in this stage to determine the initial requirements, namely: the user requirements, and the hardware and software requirements.

User Requirements

Philippine coral reef sites were surveyed by researchers through scuba diving. Transects were established randomly in upper slope of reef crests with depths ranging from 6 to 12 meters. The underwater surveys were conducted along 50 m × 10 m belt transects. At each reef site, 8 to 12 transects were surveyed; half of which were established inside MPAs and the other half outside MPAs. Fishes observed in each transect using a non-destructive fish visual census (FVC) technique were counted and classified to the family level. Repeated censuses were conducted at each site.

Many fish species were found within each transect. Each species are associated with attributes of different data types such as scientific name, family, group, trophic group, food items, and remarks. Each survey also involves attributes such as the date it was conducted, the name of the observer, the size estimate and actual count of fishes, and the categorization whether the fish is juvenile or not. Moreover, for the data analyses, the distribution of species across each site and the fish density need to be identified. Fish densities refer to the number of fish occupying the census area.

For this particular system, the focus was on the management of the marine fishes database and mapping of surveyed marine sites. Furthermore, the data gathered by researchers that were used as a database structure guide, were also used for system testing only for the purposes of this study.

Hardware and Software Requirements

For the hardware requirements, the developer of this system had used a computer with the following system specifications: Intel® Core™ i5-5200U CPU @ 2.20GHz processor, 4.00 GB installed memory (RAM), 64-bit operating system, and x64-based processor.

For the software requirements of this system, WAMP, an open-source and cross-platform software should be the primary tool to be used as it provides a web-server package including Apache HTTP Server and MySQL database. The developer also used Yii 2.0 as Hypertext Preprocessor (PHP) framework. The user interface had involved different scripting and styling languages such as Hypertext Markup Language (HTML), Cascading Style Sheet (CSS), and JavaScript. Bootstrap Materialize was used for the CSS. Finally, Google Maps API library for Yii 2.0, an open source mapping platform providing tools to design and publish custom maps was also used for the interactive map feature.

User Design

The User Design is the second stage in RAD. Its objectives include a detailed analysis of the data and the modules associated with the proposed system. This stage encapsulates the Control Flow Diagram (CFD), Data Flow Diagram (DFD), and Entity Relationship Diagram (ERD) of the system. As shown in Figure 2, the system was developed for two types of users: (1) public user and (2) system administrator.

The developer of this system and researchers were considered to belong in the category of the system administrator. The system administrator is the only authorized individual to perform basic features such as: add, update, view, and delete. The previously mentioned features were developed to allow the users to manage the database for the following: user accounts; fish species; marine sites; transect sites; inventory; and map markers.

The public user could be anyone who may access the system not required to log in. The public user, however, is only allowed to perform lesser functions compared to the system administrator. The public user is also allowed to view the map.
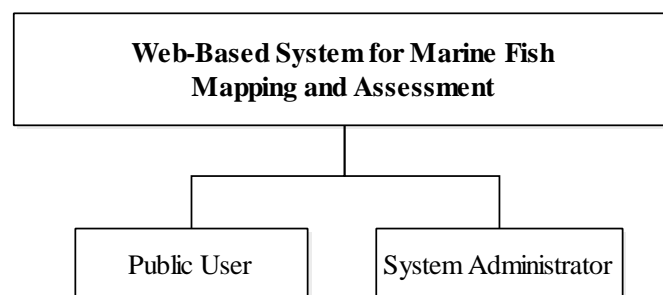
Figure 2. Types of Users in Web-Based System for Marine Fish Mapping and Assessment (MFMA).

Rapid Construction

The Rapid Construction is where the user design was implemented for development and testing. It is where the actual programming began. Its main objectives are to create and test the software that implements the proposed system; generate a system that operates at an acceptable level of performance; design, develop and test the required transition software; and perform necessary modifications to prepare for the conversion of the system to production status.

Cutover

The last phase in RAD is the Cutover. This includes the system installation, final user testing, and final system evaluation. The evaluation followed after the approval of testing phase of the system. The user would utilize the system for detection analysis, correction of software faults, interface modifications, or performance improvement as customer requested change after initial delivery and installation. This is needed to evaluate if the system is ready for release and deployment to the intended end users. Upon the completion of the final prototype, the system was put through usability testing to ensure that each component of the system performs according to the user requirements. Usability testing was performed by five representatives evaluated using the System Usability Scale (SUS). The SUS included 10 questions, which the users ranked from 1 to 5 based on how much they should agree with the statement they are reading specifically: 5 means they agree completely and 1 means they disagree vehemently.

III. RESULTS AND DISCUSSION

System Overview

The Database Management System used in implementing the system is MySQL. The entire database consisted of seven tables which includes the system users (*Users*), data collected of fish species (*Fishspecies*), family of the fish species (*Family*), necessary information for every survey conducted (*Inventory*), information in the marine site location (*Marinesite*), necessary information about the transect site location (*Transect*), and the marine environments where the inventory was conducted (*Environment*). Moreover, the online mapping feature of the system was implemented using Google Maps.

Types of Users

The system has two types of users: public and administrator. The system administrator is required to login the system using its username and password. After logging in, the system administrator is now authorized to manage information about the fish species and family, marine sites and environments, transect, and inventory. The system administrator can also add map markers through adding transect location on the map and can view the resulting markers through navigating to the interactive map. The public user, on the other hand, can only view the map and view some information through clicking the map markers. Clicking the other tabs on the navigation bar would result to prompting the user to log in.

Homepage

Upon logging in, the homepage is displayed. The homepage of the system features the primary module of the system which is the map. For security and data integrity, only the map feature can be accessed by all types of users. Information, including the date of inventory, name of observer, transect name, marine site, fish species' scientific and family name, type of marine environment, marine site location, and estimated count of fish species can be viewed by clicking the map markers in the map as shown in Figure 3.

Clicking the *Show All* checkbox on the left side portion of the page would show all the markers in the map and disable the map filters. Unchecking it, however, would allow the user to use the drop-down text fields to filter the markers that are to be shown on the map. Markers can be filtered by scientific name, marine site name, and environment type.
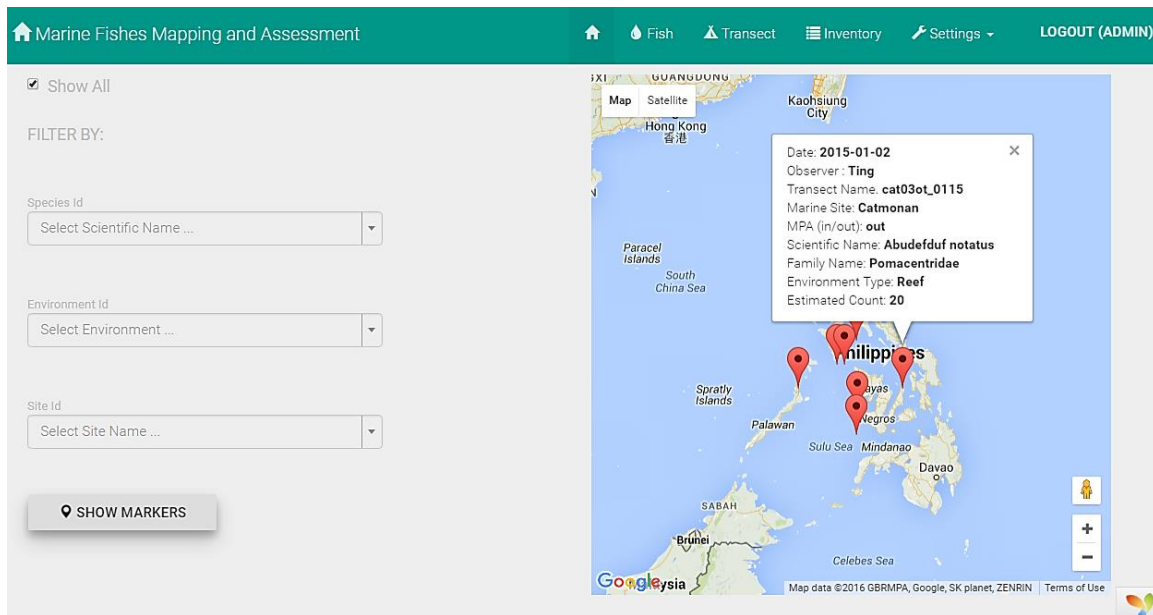
Figure 3. Homepage of MFMA.

Fish Species Module

As stated in the objectives, the system has a module where the system administrator can manage the database of fish species. This module allows the system administrator to view the list of all fish species, add new fish species, view an individual record of fish species, update the individual record of fish species, and delete a single record of fish species. The administrator can also search and refine the search using the data filters by scientific name, family, group or trophic group.

To retrieve data from the database, an additional feature that allows the system administrator to export the files of the user's choice has been added to the web-based system. It can be of the following data type: HTML, CSV, Text, PDF, and Excel. Also, the user can choose which columns to include before export (Figure 4).
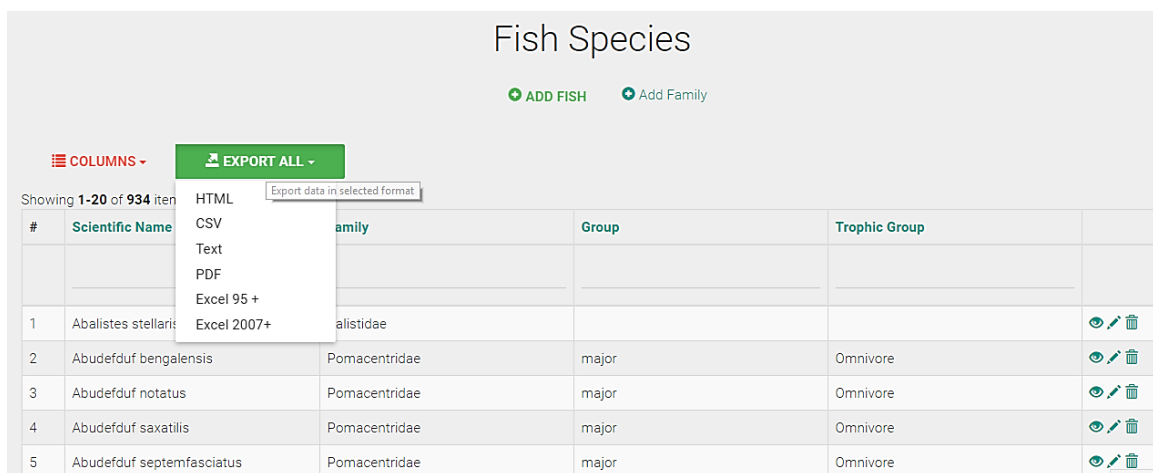

Figure 4. Fish species module of MFMA.

In the same module, the system administrator is also allowed to add a new fish family by clicking the "Add Family" button below the navigation bar. Clicking the button would result in a redirected page in the same way. The user would then be redirected to the Fish Family Page where all families in the database are listed. The user may also add new updates or delete fish family records individually.

Transect Site Module

Another module in the system is the Transect Site Module. This module enables the system administrator to manage the transect site information. As shown in Figure 5, this allows the system administrator to view the list of all transect

sites, add new transect sites, view the individual record of transect information, update a single record of transect sites, and delete the individual record of transect sites. The administrator can also search and filter data by marine site, MPA or transect side.

In this module, the system administrator is also allowed to add new transect location to be used on the map and add a new marine site by clicking the buttons on the top portion of the interface. There is also a button for updating, deleting and viewing transect details. Figure 6 shows the page after clicking the add site button.
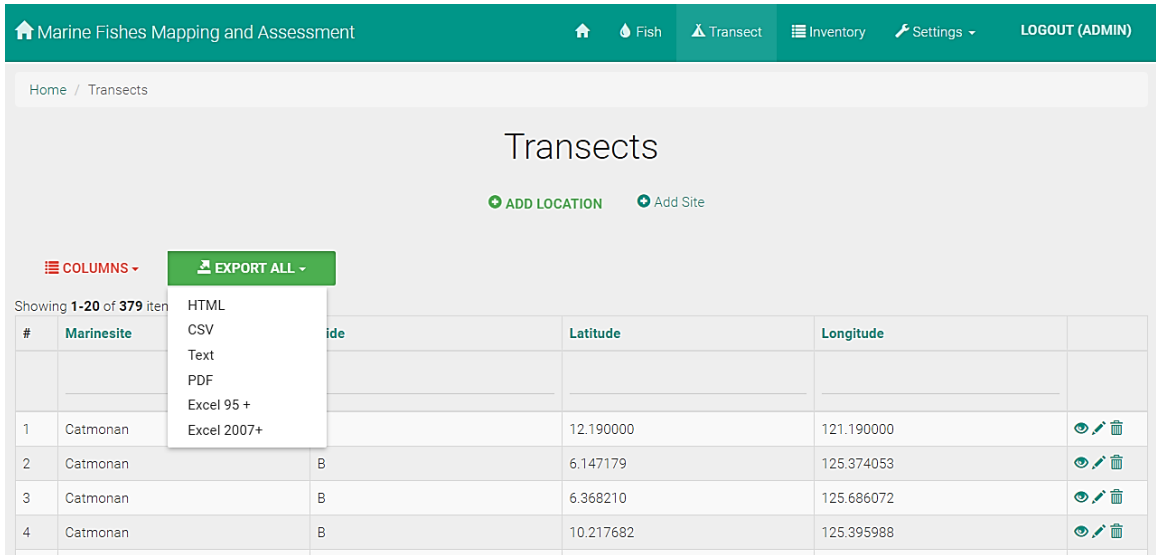

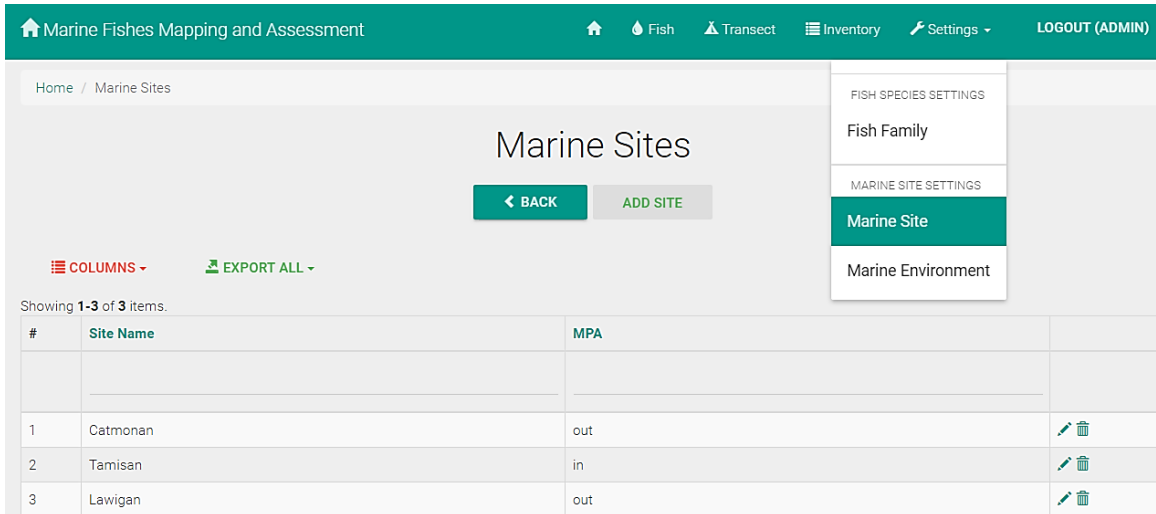Figure 5. Transect site information module of MFMA.

Figure 6. Add new marine site feature in transect site information module of MFMA.

Inventory Module

After adding fish species and transect location, the system administrator can now add new inventory. In the inventory module, the user can view the list of all surveys conducted. This module enables the system administrator to manage the inventory information. As shown in Figure 7, this allows the system administrator to view the list of all inventories made, search and filter search by fish species, marine environment, observer and count, add new inventory, view individual inventory information, update the individual record of inventory, and delete an individual record of inventory.

In this module, the system administrator is also allowed to add new marine environment where the inventory was made. Features for updating and deleting marine environment are available on this module as shown in Figure 8.

Figure 7. Inventory module of MFMA.

Figure 8. Marine Environment feature in inventory module of MFMA.

System Testing

Based on the acquired results in Table 1, most of the users would like to use the system frequently and strongly agreed that the system was easy to use, simple, and well-integrated. In addition, most of them highly disagreed with the need of assistance from a technical person to be able to use the system. The users also agreed there was a consistency of data between modules and functions, and agreed that the modules and functions were well connected or coordinated with each other. Most users would imagine that most people would learn to use this system very quickly. Finally, all of them felt very confident using the system and agreed that the system would be of great use for marine researchers. The average SUS score is 68 and the resulting SUS score in the system usability testing is 93 which indicates above average results for all the users.

Table 1. System Usability Scale (SUS) results of MRMA.

Questions	Average	SUS Score
1. I think that I would like to use this system frequently.	4.6	3.6
2. I found the system unnecessarily complex.	1.4	3.6
3. I thought the system was easy to use.	4.6	3.6
4. I think that I would need assistance to be able to use this system.	1.4	3.6
5. I thought there was too much inconsistency in this system.	1.4	3.6
6. I found the various functions in this system were well integrated.	4.8	3.6
7. I found the system very difficult to use.	1.2	3.8

8. I would imagine that most people would learn to use this system very quickly.	4.8	3.8
9. I felt very confident using the system.	5	4
10. I felt like this system will be of great use for marine researchers.	5	4
		37.2
Total SUS Score:		93

In addition, the system also enables the users to access their data wherever they go since the system is web-based and can be accessed online. Transactions done online could help them save time and effort in managing their data. The mapping tool feature would assist them in visualizing the data encoded. Hence, this system could help improve the data handling and assessment of researchers regarding marine fishes.

Moreover, this study only focused on the creation of database management system with a mapping feature that stores the data of fishes particularly in marine environments including both MPAs and fished reefs. The system was aimed to provide a user-friendly interface, and an efficient and interactive map. The system also aimed to manage marine fish species but would only demonstrate fish species on reef areas for evaluation and testing. Finally, Philippines was considered as the geographical scope of this study.

IV. SUMMARY AND CONCLUSION

The marine fish mapping tool was developed to help provide a more efficient and effective way of organizing and managing data for researchers. This web-based system is particularly aimed for those involved in marine fishes mapping and data management. One of the greatest concern among researchers is the handling of massive data related to fish species. Despite the significant amount of data, data analysis can become easier with the help of visualization through resource mapping.

The system enables the researchers to manage data related to fish species, add transect location and necessary details, and manage inventory to be viewed on the map. However, not everyone should be allowed to enter data in this system. Therefore, the system administrator is required to log in using the username and password provided. On the other hand, the public user can still view the map and view some information by clicking the map markers.
The system also enables the system administrator to filter data by name of species, group, the name of the marine site, the name of the environment, the name of observer, trophic group, date, and the estimated count of fish species through the search bars provided. Lastly, for the matters which involves flexibility and adaptability of the fish mapping web-based system, additional functions such as management of fish family, marine environment, and the marine site is made available for the system administrator.

A series of black-box testing has been done to check the functionalities of the system. Usability test used in this study was System Usability Scale (SUS). SUS is a usability scale invented which has proven itself to be a dependable method for evaluating the usability of systems which is at par with that of industry standards. The primary objectives defined for the system were the marine fishes database and mapping. These objectives have been met given that all functionalities are working correctly. In addition, the SUS scores indicate above average results which means a positive indication that the users are satisfied with the system. For better representation, the database was populated with actual data gathered by the researchers.

Through this system, it would be easier and more efficient for researchers to filter data summary according to species, site, or date taken. The resulting system is also intended as a tool for researchers in the assessment of MPA management through monitoring the increase or decrease of species and other important factors that concern MPAs. The effectivity of MPA management in every MPA site could be observed to a greater extent. Furthermore, this GIS-assisted resource mapping tool is also a fast and reliable technique that can improve decision-making and data handling.

For the system to be more efficient and more useful to the users, there are still functions that can be improved. One recommendation for the interested developers who would intend to continue this project is to enable the administrator to add up data through importing excel files into the system. This additional feature allows the administrator to set dynamically the information needed for fish species, and is a more interactive feature of adding transect locations on the map which in turn will create a more user-friendly interface. An additional module such as statistical data analysis by returning outputs that are not limited to graphs and measures of central tendency is recommended as well.

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