

Coral Reef Management Information System (CRMIS) for the Sustainable Management of Coral Reef in Indonesia

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Abstract—The Coral Reef Rehabilitation and Management Program (COREMAP), a program in the Research Center for Oceanography of the Indonesian Institute of Sciences has the task of collecting data on coral cover and its related ecosystems, such as seagrass and mangrove. Collected data comes from baseline surveys and regular monitoring in various sites of Indonesian marine waters. The collected data are grouped into three parts, such as coral reefs, seagrasses, and mangroves. Managing these data was very challenging due to the state of the former data management process, which was manual, scattered, non-centralized, and non-standardized. Integrated information system is needed in order to reduce data redundancy, and allows simple data access and linking. To meet this need, the Coral Reef Management Information System (CRMIS) was introduced. The CRMIS is an easy-to-use information system that has made the coral reef management integrated and practical. CRMIS enables the stakeholders to easily obtain the right information for making better report, research-planning and decision-making on the condition of coral reefs, seagrasses and mangroves in areas of concern.

Keywords—coral reef, COREMAP, mangrove, CRMIS

I. INTRODUCTION

Being located along the equatorial line, Indonesia is blessed with the most extensive coral reefs in the world. These coral reefs are distributed from Aceh to Papua. Indonesia has a population of around 200 million people, with around 60% living in coastal areas. It is no wonder that coral reefs have become an important resource, helping people living in coastal areas to earn a living. Apart from being fisheries, coral reefs are also an income source for traditional fishers through tourism activities as well as ornamental fish. Indonesia is facing a concerning degradation of coral reefs. Degradation affects the amount of fish caught by the fishermen directly. Catches are smaller, the fish caught are smaller, and it takes a longer time to catch the same amount of fish. The other important and effective function of coral reefs, mangroves and seagrasses is the protection of coasts under waves and storms [1]. The economic value produced by coral reefs, which

includes fisheries, tourism and coastal protection are reached \$30 billion per year [2]. Only 6.56% of Indonesian coral reefs were in excellent condition, 22.96% good, 34.3% fair, and 36.18% poor [3]. In 1998, the Indonesian government initiated a long term program known as Coral Reef Rehabilitation and Management Program (COREMAP), managed by the Research Center for Oceanography (RCO/Pusat Penelitian Oseanografi=P2O) of the Indonesian Institute of Sciences (Lembaga Ilmu Pengetahuan Indonesia - LIPI). COREMAP is an Indonesian national program which aims at promoting the management and rehabilitation of damaged coral reefs. In line with the above objective, Coral Reef Management Information System (CRMIS) was performed. CRMIS is one of the COREMAP programs with the purpose of providing integrated, practical, easy to use and useful computer based system that support sustainable management of coral reefs in Indonesia.

A. Problem Description

Indonesian sea waters have a vast extent of coral reef cover. An immense quantity of coral reef data can be collected from baseline studies and routine monitoring surveys. Besides collecting data on coral reef covers, COREMAP also conducted surveys to collect data on mangrove cover and its density, as well as seagrass cover. The data that has been collected from field surveys by COREMAP in various regions of Indonesian marine waters are then grouped into three main parts:

1. Coral reef health.
2. Mangrove cover and its density.
3. Seagrass cover.

At the beginning of COREMAP activity, the data obtained was not stored in one place but tended to be scattered in different locations and storage areas. This has become a serious problem, since these data are needed for reports and analysis on the condition of coral reefs and its related ecosystems in a certain site. Each site of the coral reef that is being studied can actually be determined by each geographical position correctly. In additions with this sampling point, geographic information

regarding the location of the coral reef being studied is also important to be recorded and documented well. It is no doubt that each ecosystem studied must be referred by its geographical position so that all can be linked to each other. Furthermore, it is well known that each data has its own codification so that when the codification used is unclear, it can cause confusion and inconsistency.

II. SOLUTION PROPOSAL

To create ideal conditions where data is no longer scattered and codification is well structured, it is necessary to establish a globally standardized data center. If these ideal conditions can be achieved, it will be easier for stakeholders to access data for various purposes. This can be achieved if we are able to create a web-based data distribution system which is accompanied by detailed geographical information. The development of Coral Reef Management Information System (CRMIS), a web-based data distribution system which stores the data alongside its geographical information, will hopefully enable the stakeholders to obtain the right information easily. This will enable better reports, research planning, and decision-making on the condition of coral reefs, seagrasses, and mangroves in areas of concern.

III. METHODS

The development of CRMIS is carried out by the Software Development Life Cycle (SDLC), which consists of two types of models: the waterfall model and the iterative incremental development models.

The first type of model has many disadvantages compared to the second model. For example, the waterfall model is only suitable for those who need fixed requirement only, whereas in reality as we may face it every day, the needs always change from time to time. Based on this fact, it is not surprising that only iterative and incremental models are more widely accepted and used.

Many new models of iterative and incremental models have been developed in the past 20 years. Three of the most widely used are Extreme Programming (XP), Scrum, and Rational Unified Process (RUP). Scrum and XP are not suitable for CRMIS since they need the developers to fully dedicate their time and resources throughout the development process. RUP on the other hand, is suitable due to these reasons:

- RUP has four major phases which are clearly defined, thus making it easy for the developers and stakeholders to see if the development targets have been met and whether to continue to the next development phase.
- Each RUP phase has one or more iteration, allowing the developer to focus on a particular aspect of the system to be developed.
- RUP allows incremental release of product over time, which in this case, after one iteration of a phase.

- RUP has a proven workable methodology formalized by the Rational Software Corporation, a division of IBM.

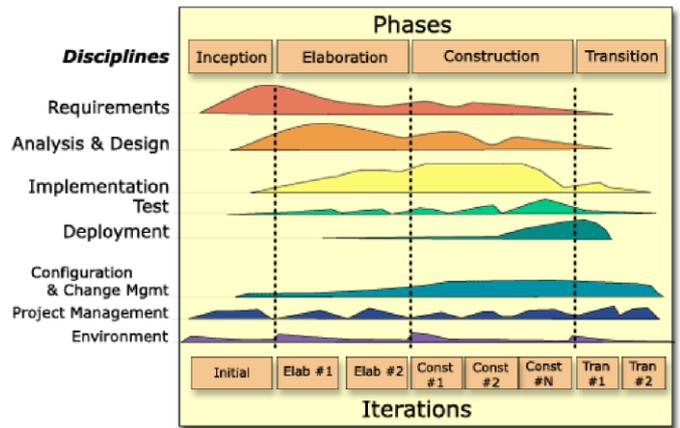


Fig. 1. RUP phases and disciplines [4].

- Inception: In this step, the focus is on the area scope identification, schedule estimation, risk identification and architecture identification.
- Elaboration: This phase explains system requirements and architecture proof in detail. The architecture proof can be done in one testing cycle against one use case/menu in the system.
- Construction: The focus on this phase is to design the components and features which are ready to be deployed.
- Transition: In this phase, transition from development to production took place. In addition, the system test, User Acceptance Test (UAT), user training, and maintenance are also conducted.

IV. RESULTS AND DISCUSSION

A. System Integration and Architecture

To compile a centralized data collection from multiple resources, we agreed to the convention on which a coding system is applied to codes that are shared. We have two kinds of codes that are shared between Geographic Information System and Reef Health Monitoring modules, which are the station code and the geo-position code. The station code represents a station, where the geo-position codes represents the longitude and latitude. The centralized data collection will be stored in Relational Database Management System format in MySQL for non-spatial data and PostgreSQL for spatial data. MySQL and PostgreSQL are free open-source database management systems which are well-tested and used widely. After the database infrastructure is established, the spatial and non-spatial data will be made accessible online using Apache web server and Geo server.

CRMIS is developed using several programming languages. The web application is developed using PHP in the Laravel framework for the back end, and a JavaScript/CSS combination for the front end. The ICT high-level architecture of CRMIS server has accessibility both through the internet and intranet (Figure 2). The external access can be done through the CRMIS web page at <http://oceanografi.lipi.go.id/crmis>.

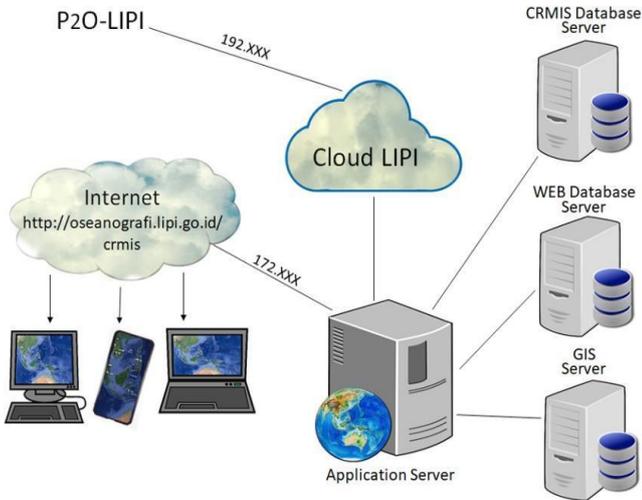


Fig. 2. CRMIS ICT high level architecture.

B. The Developed CRMIS Application

This section showcases some features of CRMIS that have been developed. Figure 3 is a screenshot of the CRMIS home page. This page is available in English.

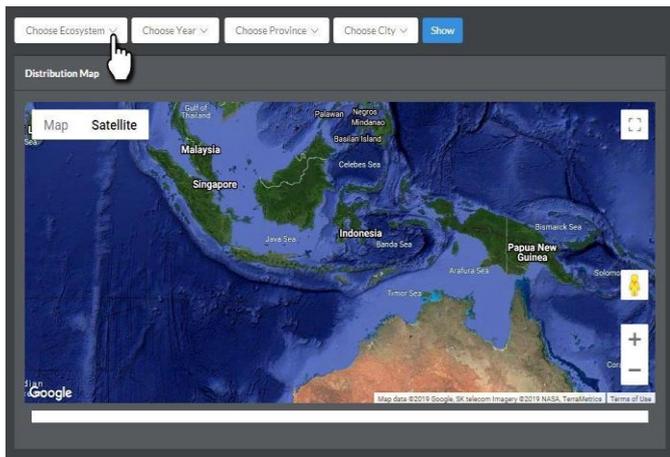


Fig. 3. Main page of CRMIS.

To facilitate different data searching, an ad hoc query features were created in order allowing the users to retrieve data with customized searches which suit their needs, such as its ecosystem, year, province and the respective of its sub-district. Figure 4 and figure 5 demonstrates how a query can be made with this feature.

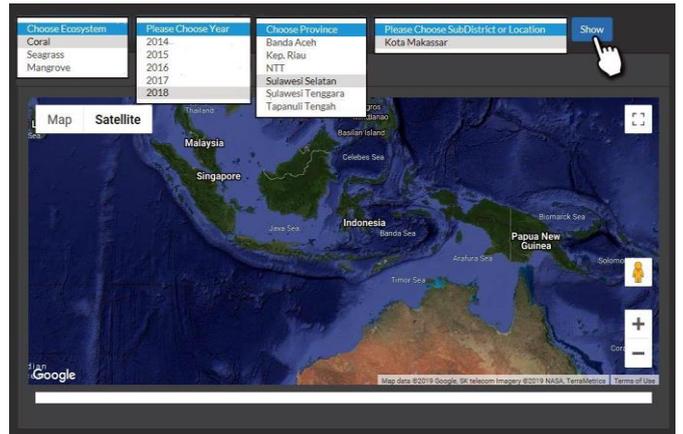


Fig. 4. Users can click on the needed ecosystem, year, and location as shown on the screen.

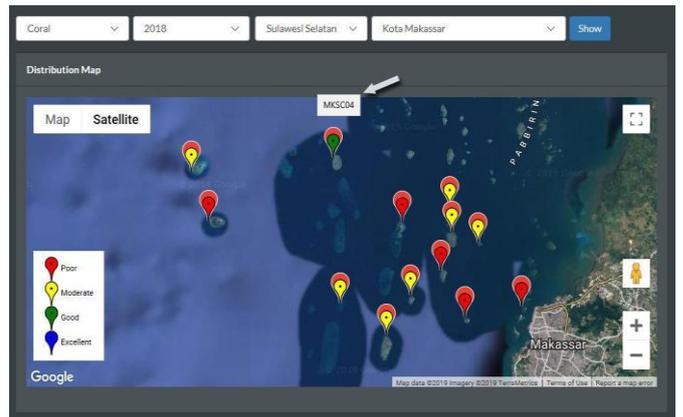


Fig. 5. This ad hoc query shown that Site MKSC04 (see arrow) has better coral reef condition compared to other sites.

Another feature provided this application is time series analysis. This feature allows a user to see coral reef health trend over a certain time period at a similar location, as presented on Figures 6 and Figure 7 (see the following page).

Condition of Coral Reefs in monitoring sites (number of stations)

Year	Bad	Enough	Good	Very Good
2014	31	20	10	0
2015	114	130	56	0
2016	127	102	28	0
2017	76	73	18	2
2018	18	44	5	0

Bad (Bad (0-24.99% cover of coral))
 Enough (Enough (25-49.99% cover of coral))
 Good (Good (50-74.99% cover of coral))
 Very Good (Very Good (75-100% cover of coral))

Fig. 6. Shows number of stations and its coral reef health conditions in Sub-District Kota Makassar waters from 2014 – 2018.

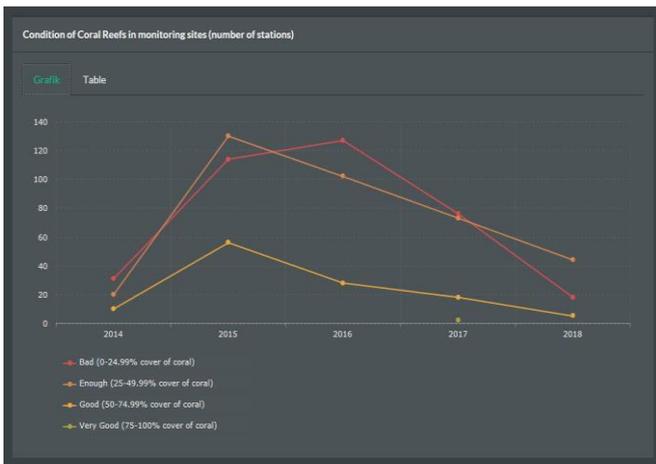


Fig. 7. Time series analysis on the coral reef health of Sub-District Kota Makassar waters during 2014 till 2018.

More detailed information regarding the condition of the coral reefs ecosystem, both biological and physical environment at Kota Makassar waters can also be displayed clearly. The biological condition of coral reefs is indicated by the composition of hard coral (HC), dead coral (DC), and algal overgrown on the dead corals (DCA) (Figure 8). Further, Figure 9 shows a spatial analysis of the percentage of coral cover and its components found in this waters.

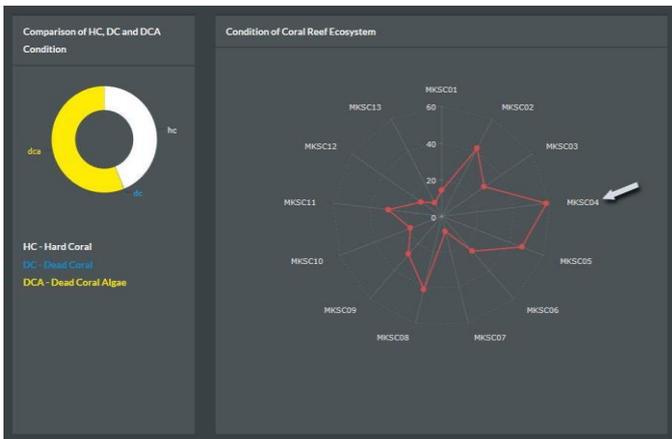


Fig. 8. Composition of HC, DC and DCA, and condition of coral reef ecosystem in Kota Makassar waters.

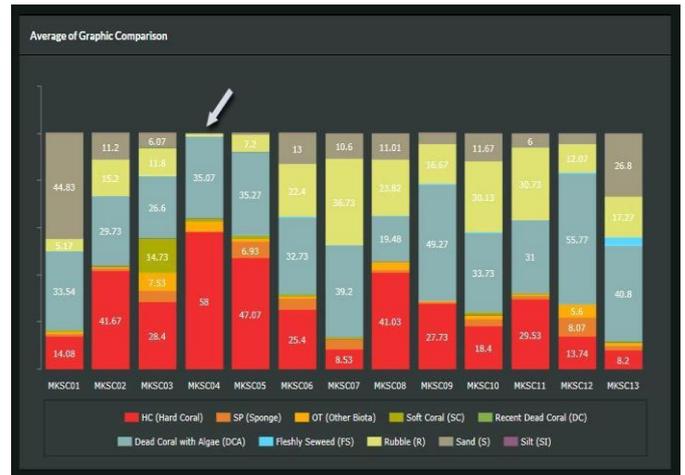


Fig. 9. Percentage of coral covers and its components in Kota Makassar waters, 2018.

V. CONCLUSION

CRMIS provides an integrated, user-friendly online information system that supports the management of data surrounding coral reefs. An online application available in English, CRMIS supports Web GIS (Geographic Information System), searches by users, time series analysis and reports. Web GIS also provides online interactive thematic maps detailing the conditions of reefs. CRMIS therefore allows stakeholders to obtain easily customized information for better research of reef conditions, reporting results, and making future plans.

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