Improvement and Application of a Decision Support System for Sustainable Floating Net Cage Finfish Cultures Development in Indonesia

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Abstract

Indonesia has great potential for aquaculture development but its expansion still faces many constraints. Development is often insufficiently focused on environmentally sustainable practice with respect to coastal environment degradation, overlapping and conflicting utilization, and laws regarding marine and coastal management. For this reason, there is a need to improve aquaculture technology and management systems regarding an ecosystem approach to aquaculture (EAA).Eco-friendly production processes and food safety concerns in the sustainability of Indonesian aquaculture need to be addressed. The aim of this dissertation is to demonstrate the application of the SYSMAR Decision Support System (DSS) for sustainable management of floating net cage finfish cultures which provides a detailed and comprehensive overview in three selected regions in Indonesia: Talise Island (TI), Galang Island (GI), and Ekas Bay (EB).

This DSS utilizes high resolution hydrodynamic information concerning water depth, current velocities and wave heights obtained from hydrodynamic models, water quality information, and Integrated Coastal Zone Management (ICZM) in the surrounding area. Through GIS spatial planning tools, SYSMAR DSS is used to perform site selection for floating net cage finfish cultures, and assesses the dispersive character of each site to provide estimates of different sustainable carrying capacities with respect to the deposition of particulate carbon and the accumulation of dissolved nitrogen in the water column of a suitable area. Economic analysis provides vital information on 18 cases, focusing on the economic viability of Tiger Grouper (*Epinephelus fuscoguttatus*), Humpback Grouper (*Cromoliptes altivelis*), and Leopard Coral Grouper (*Plectropomeus leopardus*), the most common high value finfish species nurtured in Indonesia in floating net cage cultures. FNC farming utilizes various feed types and production scales, the prototype farms consisting of 10 cages and 600 cages at Galang Island with a cage size of 3 x 3 x 3 m.

SYSMAR DSS shows that only Galang Island provides a potential area for FNC finfish culture development with a suited area of about 12,940 ha. The estimated maximum production carrying capacity is 51 – 366 tons/farm. Estimated ecological carrying capacity for Galang Island is in the range 18,393 – 21,727 tons/year/suitable area. The economic evaluation highlighted that all of the FNC finfish culture developments are economically viable. After a 5-year projection period, positive cumulative cash flow and net present value (NPV) are generated, internal rates of return (IRR) are higher than bank discount rates, and payback periods (PP) are less than 1 year. These results confirm the SYSMAR DSS is able to determine potential sites for FNC grouper culture projects in three selected Indonesian coastal areas which comply with environmental, sustainability and socio-economic criteria.

Keywords: Decision Support System, SYSMAR, Carrying Capacity, Sustainability, Indonesia

Zusammenfassung

Indonesien hat großes Potenzial für die Entwicklung der Aquakultur, allerdings unterliegt die weitere Expansion zahlreichen Einschränkungen. Die Entwicklung fokussiert sich oftmals viel zu wenig auf eine ökologisch nachhaltige Vorgehensweise hinsichtlich der Umweltzerstörung in den Küstengebieten, der übergreifenden und kollidierenden Nutzung sowie der Gesetzgebung zum Meer- und Küstenmanagement. Aus diesem Grund ist es notwendig, sowohl die Aquakulturtechnologie als auch das Managementsystem in Bezug auf den Ökosystemansatz für Aquakultur (EEA) zu verbessern. Umweltverträgliche Produktionsmethoden und Lebensmittelsicherheitsbelange in der Nachhaltigkeit der indonesischen Aquakultur sind Punkte, die thematisiert werden müssen. Zielsetzung dieser Dissertation ist, die Anwendung des SYSMAR Decision Support Systems (DSS; deutsch: „System konkreter Entscheidungshilfen und Empfehlungen“) für den nachhaltigen Betrieb von Fischfarmen in schwimmenden Netzkäfigen darzustellen, das einen umfassenden Überblick über drei ausgewählte Regionen in Indonesien bietet: Talise Island (TI), Galang Island (GI) und Ekas Bay (EB).

Das DSS verwendet hoch auflösende hydrodynamische Informationen bezüglich der Wassertiefe, der Strömungsgeschwindigkeiten und der Wellenhöhe, die mithilfe hydrodynamischer Modelle gewonnen werden und darüber hinaus Informationen zur Wasserqualität und das integrierte Küstenzonenmanagement (ICZM)in der Umgebung. Unter Einsatz geographischer Raumplanungsinstrumentewird SYSMAR DDSbenutzt, um Standorte für die schwimmenden Netzkäfige auszuwählen. Des Weiteren misst SYSMAR die Dispersion an jedem Standort, um so Schätzungen der unterschiedlichen ökologischen Tragfähigkeiten in Bezug auf*partikulären*organischen *Kohlenstoff* und auf die Ansammlung von gelöstem Stickstoff in der Wassersäule eines geeigneten Gebiets abgeben zu können. Die wirtschaftliche Analyse liefert wichtige Informationen zu 18 Fällen, wobei sie sich auf die wirtschaftliche Rentabilität des Zackenbarsches (*Epinephelus fuscoguttatus*), des Pantherfisches (*Cromoliptes altivivelis*) sowie des Leopard-Forellenbarsches (*Plectropomeus leopardus*) fokussiert, da diese zu den hochwertigen Fischarten zählen, die in Indonesien am häufigsten auf Fischfarmen in schwimmenden Netzkäfigen gehalten werden. Bei der Bewirtschaftung werden unterschiedliche Futtersorten und Produktionsmaßstäbe eingesetzt: Prototypische Fischfarmen bestehen aus 10 Käfigen bis 600 Käfigen bei Galang, wobei die Käfiggröße 3x3x3m beträgt.

SYSMAR DSS zeigt, dass lediglich Galang als potenzielles Gebiet für die Entwicklung von Fischfarmen in schwimmenden Netzkäfigen geeignet ist. Das geeignete Gebiet umfasst ca. 12940 ha. Die geschätzte maximale Produktionstragfähigkeit beträgt 51-366 Tonnen/Fischfarm. Die geschätzte ökologische Tragfähigkeit der Insel Galang liegt im Bereich von 18393-21727 Tonnen/Jahr/geeignetes Gebiet. Die wirtschaftliche Auswertung zeigte, dass sich die Entwicklung von Fischfarmen in schwimmenden Netzkäfigen wirtschaftlich rentiert. Nach einem 5 jährigen *Prognosezeitraum wurde ein kumulativer Cash Flow sowie ein Kapitalwert erwirtschaftet. Die interne Rendite* ist höher als die Diskontraten und die Tilgungszeiträume betragen weniger als 1 Jahr. Diese Ergebnisse bestätigen, dass SYSMAR DSS dazu in der Lage ist, potenzielle Gebiete für die Entwicklung von Fischfarmen für Barscharten in drei ausgewählten indonesischen Küstengebieten, die die ökologischen, nachhaltigen und sozio-ökonomischen Kriterien erfüllen, zu ermitteln.

Schlüsselwörter: Entscheidungshilfe, SYSMAR, Traglast, Nachhaltigkeit, Indonesien

Contents

Notations

AMA	:	Aquaculture Management Area
ArcGIS	:	A geographic information system (GIS) for working with maps and geographic information.
a_t	:	The Net Cash Flow
AUTO DEPOMOD	:	A particle tracking model used for predicting the sinking and resuspension flux of particulate waste material (and special components such as medicines) from fish farms and the benthic community impact of that flux.
B/C	:	Benefit Cost
BCR	:	Benefit Cost Ratio
BOD	:	Biochemical Oxygen Demand
BODC	:	British Oceanographic Data Centre
BPP PSPL	:	Badan Penelitian dan Pengembangan Pengelolaan Sumberdaya Perairan dan Lingkungan (BPP-PSPL) Universitas Riau. Research and Development of Water Resources and Environment Riau University
BPS	:	Biro Pusat Statistik, Statistic Indonesian
C	:	Carbon
CADS-TOOL	:	Cage Aquaculture Decision Support Tool
CC	:	Carrying Capacity
CCMRS	:	The Center for Coastal and Marine Resources Studies
COD	:	Chemical Oxygen Demand
COREMAP	:	Coral Reef Rehabilitation and Management Program
COREMAP II	:	Coral Reef Rehabilitation and Management ProgramCoral Reef Information and Training Centers - Riau University II
CRITC	:	Coral Reef Information And Training Centers
CRITC-LIPI	:	Coral Reef Information And Training – Lembaga Ilmu Pengetahuan Indonesia (Indonesian Research Institute)
CRMP	:	Coastal Resources Management Project of North Sulawesi
$D_{advection}$	:	The Traveling Distance of Particles Through Advection in the Current Direction
DD	:	Domain Decomposition
$D_{diffusion}$	:	The radius of the diffusion area
DEPOMOD	:	A dispersion model designed for marine (salt-water) aquaculture that has recently been successfully employed in the marine environment.

DIN : Dissolved Inorganic Nitrogen

D_{max} : The Maximum Deposition

D_{mean} : The Mean Deposition per Unit Area

DSS : Decision Support System

D_{xfarm} : Farm Dimensions Parallel

D_{yfarm} : Farm Dimensions Perpendicular

E : The Approximation of Diffusion Coefficient

E : The effective tidal volume

EAA : Ecosystem Approach to Aquaculture

EB : Ekas Bay

Esri : International supplier of Geographic Information System (GIS) software, web GIS and geodatabase management applications. The company is headquartered in Rendlands, California.

ESRL : Earth System Research Laboratory

ESRLPSD : Earth System Research Laboratory Products Daily Sigma Level Data

E1-E6 : Observation Point in Ekas Bay 1 to 6

FAO : Food and Agriculture Organization

FCR : Food Conversion Ratio

FMA : Fisheries Management Area

FNC : Floating Net Cage

FRS : Fisheries Research Service

GEBCO : General Bathymetric Chart of the Oceans. British Oceanographic Data Centre, Liverpool, United Kingdom (U.K.)

GESAMP : Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection. Food and Agriculture Organization of The United Nations.

GI : Galang Island

GIS : Geographic Information System

GUI : Graphical User Interface

G1-G6 : Observation Point in Galang Island 1 to 6

h : The Temporal Mean Water Depth

HG : Humpback Grouper

i : The Discount Rate Per Period

ICZM : Integrated Coastal Zone Management

IHO : International Hydrographic Organization

IOC	:	Intergovernmental Oceanographic Commission
IPB	:	Institut Pertanian Bogor (Bogor Agricultural University)
IRR	:	Internal Rate of Return
ITB	:	Institut Teknologi Bandung, Bandung Technology Institute
ITI	:	Infaunal Trophic Index
I_o	:	Initial Investment at Point in Time 0
KKP	:	Kementrian Kelautan dan Perikanan (Marine Affairs and Fisheries)
K2	:	Lunisolar semidiurnal constituent
K1	:	Lunar diurnal constituent
LG	:	Leopard Coral Grouper
LIPI	:	Lembaga Ilmu Pengetahuan Indonesia (Indonesian Research Institute)
LPPM	:	Lembaga Penelitian and Pengabdian kepada Masyarakat (Research and Community Empowerment)
MATLAB	:	Matrix Laboratory, the language of technical computing.
MF	:	Lunisolar fortnightly constituent
MFADS	:	The Marine Finfish Aquaculture Decision Support System
MM	:	Lunar monthly constituent
MMAF	:	Ministry of marine affairs and fisheries Indonesia
MOM	:	Modelling Ongrowing fish farm-Monitoring system
MN4	:	Shallow water quarter diurnal constituent
MS4	:	Shallow water quarter diurnal constituent
M2	:	Principal lunar semidiurnal constituent
M4	:	Shallow water over tides of principal lunar constituent
n	:	The Number of Periods During Which The Project Operates and Generates Net Cash Flow
N	:	Nitrogen
NACA	:	The Network of Aquaculture Centers in Asia-Pacific
NCAR	:	National Center for Atmospheric Research
NCEP	:	National Centers for Atmospheric Prediction, Global Six Hourly Reanalysis Data With The Resolution 1.87 degrees (192 x 94 grid) for Wind And Sea Level Pressure.
NDPAa	:	National Development Planning Agency (NDPAa), Local Regulations no. 2 of Batam City., (2004). Regional Planning of Batam City 2004-2014.

NDPAb : National Development Planning Agency (NDPAb), Local Regulations no. 11 of Nusa Tenggara Barat Province. Regional Planning of Nusa Tenggara Barat Province.

NDPAc : National Development Planning Agency (NDPAc), Secretariat of National Regional Planning Agency. Regional Planning of North Sulawesi

Net B/C : Net benefit cost ratio

NH_4^+ : Ammonia

NOAA : National Oceanic & Atmospheric Administration

NODC : National Oceanographic Data Center

NO_3^- :Nitrate

NO_2^- :Nitrite

NPV : Net Present Value

NTB : Nusa Tenggara Barat Province of Indonesia

O1 : Lunar diurnal constituent

P : Phosphate

PEST : Parameter estimation

pH : A measure of the acidity

POC : Particulate Organic Carbon

POC_{farm} : The Total Farm Load

POM : Particulate Organic Matter

PP : Payback Period

PSU : Practical Salinity Unit

P1 : Solar diurnal constituent

Q1 : Larger lunar elliptic diurnal constituent

RDCOG : Research Development Centre of Ocean Geology Bandung

ROI : Return of Investment

R2010b : Release in 2010

SA : Sensitivity Analysis

SEPA : Scottish Environment Protection Agency

SPICE : Science for the Protection of Indonesian Coastal Marine Ecosystems

SWAN : Simulating Waves Nearshore is a third-generation wave model that computes random, short-crested wind-generated waves in coastal regions and inland waters

SYSMAR : System for the Sustainable Management of Floating Net Cage Grouper Cultures.

S2	:	Principal solar semidiurnal constituent
t	:	metric ton (1,000 kg)
T	:	The number of tidal cycles
TDN	:	Total Dissolved Nitrogen
TG	:	Tiger Grouper
TI	:	Talise Island
Ton	:	metric ton (1,000 kg)
TPXO 6.2	:	Current Version of a Global Model Of Ocean Tides, Astronomical Tides Derived from A Global Ocean Tide Model
TSS	:	Total Suspended Solid
T1-T4	:	Observation Point In Talise Island 1 to 4
UNEP	:	United Nations Environment Programme
USA	:	The United States of America
V	:	Total volume of the embayment
Win32	:	The Windows Application Programming Interfaces
WL|DELFT HYDRAULICS	:	Simulation of Multi-Dimensional Hydrodynamic Flows and Transport phenomena, including sediments. Delft Hydraulics, The Netherlands.
WOA	:	World Ocean Atlas
WOD	:	World Ocean Database
w_s	:	The Typical Period of Time a Particle Takes to Arrive at the Bottom by a Constant Settling Rate
X	:	Cartesian coordinate system at x direction (m)(the x-axis)
Y	:	Cartesian coordinate system at y direction (m)(the y-axis)
3D	:	three dimensional
α	:	An Adjustment From Mean to Maximum Deposition
ū	:	Depth Averaged Current Velocity

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Chapter 1

Introduction

1.1 Overview

As the stocks of wild fish decline worldwide and the human population increases, aquaculture is becoming one of the quickest increasing food production sectors and also important as protein food supplier to the world population (Rückert et al. 2009; FAO 2007; Staniford, 2002). On the other hand as a result of the increase in fish production and seafood mariculture, there is a growing concern about the impacts of such activities on the environment. However, up to now little attention has been given to environmentally sustainable practices. In particular, the degradation of coastal environments, overlapping and conflicting utilization of the coastal areas and enforcement of laws regarding the management of the marine and coastal environments are not being addressed properly.Therefore, it is vital to improve aquaculture technology and to develop management tools that address the need for an eco-friendly production process and the concerns regarding food safety (Hermawan et al. 2012).

According to the FAO (2007), Indonesia is the largest aquaculture producer of marine finfish in Southeast Asia (De Silva and Philips, 2007). Being the largest archipelagic state in the world with about 81,000 km of coastline, corresponding to approximately 14% of the world's coastlines, Indonesia has a great potential for developing the mariculture industry (Ministry of Marine Affairs and Fisheries, 2009). The expansion of the mariculture and fishery sector is expected to improve the country's welfare, especially for fishermen and fish farmers that are currently living under the poverty level (BPS, 2009). On other hand, the accomplishment of sustainable practices and management systems to preserve coastal environments is still in its infancy and more emphasis should be given to it.

In 2010, an ecosystem approach to aquaculture (EAA) was introduced by FAO to promote sustainable development, equity, and the resilience of interlinked socio-ecological systems.The challenge for coastal planners is to manage coastal and marine resources, balancing the economic benefit with coastal environmental needs to ensure a sustainable development. In Indonesia the sustainable development of floating net cage (FNC) finfish cultures is affected by constraints in policy, resources, institutions, socio-economic factors, technology and finance (Sugama, 2010). A good understanding of the needs of different fish species concerning site selection, carrying capacity, and economic viability, would provide the basis for overcoming a number of these constraints.

Farhan and Lim (2010) recommended the use of Decision Support Systems (DSSs) to meet the flexibility ofdynamic environments. Such systems can be used to cope with the complexity of coastal management issues, and support decision-makers in the integration of socio-economic and bio-geophysical properties of the environments and in political decisions. Several authors emphasize the need for the continuing development of planning tools for the management of mariculture activities using an integration of Geographic Information Systems (GIS), field measurements and results of the application of numerical models (Silvert, 1994, 2010; Hargrave, 2003; Mayerle& Windupranata, 2006, Mayerle et al. 2009; Martinez et al. 2008; Longdill et al. 2008; Boroushaki, 2008; Kapetsky, Manjarrez, Soto, 2007; Szutser, 2010; Van der Wulp et al. 2010; Mayerle et al. 2011; Hermawan et al. 2012).

In this study the application of a DSS under development at the Research and Technology Centre Westcoast of the University of Kiel for the sustainable environmental and socio-economic management of floating net cage is assessed. This system for the management of sustainable floating net cage finfish cultures (SYSMAR) was developed in the framework of the two first phases of the bilateral scientific and technological cooperation “Science for Protection of Indonesian Coastal Ecosystems” (SPICE) involving German and Indonesian experts and governmental authorities. In the first phase of the project from 2003 to 2007, emphasis was given to the conceptual development of the DSS and to methods for the selection of sites suited for the installation of floating net cages (Mayerle& Windupranata, 2006, Windupranata and Mayerle 2009, Mayerle et al., 2007).In the second phase of the project, the focus was on the selection and implementation of criteria for estimation of carrying capacities and on the set-up of a user-friendly interface to facilitate decision-making (van der Wulp et al., 2010, Mayerle et al. 2011).

SYSMAR integrates physical, chemical and biological properties as well as information on coastal uses. The system has been used to perform site selection for floating net cage finfish cultures, and to assess the dispersive character of each site. It allows estimates of different types of carrying capacities with respect to the deposition of particulate carbon and the enhancement of dissolved nitrogen in the water column to be adopted. The system has been successfully applied to several coastal areas in Indonesia. Applications were done to sites in the Seribu Islands in the Java Sea and in Batam in the Riau Archipelago, Pegametan Bay and Celukanbawang in Bali and Saleh Bay in Lombok. Extensive measurements and monitoring programs were done in the Pegametan Bay, Bali in cooperation with experts of the Gondol Research Institute for Mariculture, Indonesia (van der Wulp et al. 2010, Mayerle et al. 2011).

Along with recent developments in SYSMAR DSS, we have turned our attention to the need for substantial and user-friendly software. The lack of measurement data in remote areas has been identified as a major problem for many years and is addressed in this study. This will be complemented with an evaluation of the economic viabilities. The results obtained will support decision makers and the public with respect to the selection of best sites, assessment of the impacts and estimation of economic viabilities for the sites under investigation.

The investigations will be carried out at three priority sites in Indonesia namely Talise Island located in the northern most tip of Sulawesi; Galang Island which is part of the Riau Archipelago located opposite of Singapore and Ekas Bay located south of the Lombok Island. The development focuses on the most common high value finfish species nurtured in FNC in Indonesia (Heemstra and Randal, 1993; Sim et al. 2005; Sadovy et al. 2003, 2008). In this study Tiger grouper (*Epinephelus fuscoguttatus*), Humpback grouper (*Cromoliptes altivelis*), and Leopard Coral grouper (*Plectropomeus leopardus*) are considered.

1.2 Hypotheses

Regarding the code of conduct on responsible fisheries issued by the Food and Agriculture Organization of the United Nations (FAO, 2011), the new perspective goal of aquaculture development is to ensure ecological sustainability in conjunction with a rational use of the resources shared by aquaculture and other activities. This study applies this concept, therefore the hypothesis of this dissertation is that the application of a system for the management of sustainable floating net cage finfish cultures (SYSMAR DSS) could be a possibility as an instrument to achieve this aim. The DSS utilizes high resolution hydrodynamic information concerning water depth, current velocities and wave heights obtained from hydrodynamic models. Through GIS as spatial planning tools, SYSMAR DSS is able to assist in estimating site selection, determine different types of carrying capacities such as production, as well as ecological to guarantee sustainable environmental development. Furthermore, a method for the economic analysis of mariculture investment is proposed. Financial indicators to enable an adequate economic assessment will be identified. The output as a whole can be used as a precious instrument for decision makers and the public when evaluating the effect of development and expansion of sustainable aquaculture operations.

1.3 Objectives

The main objectives to be accomplished in this dissertation are listed below:

1. Determination of site selection as physical carrying capacity for FNC finfish cultures at three selected locations in Indonesia with respect to the results of hydrodynamic numerical models, water quality, and integrated coastal zone management (ICZM);
2. Estimation of the different types of sustainable carrying capacities in relation to the EAA concept including the local carrying capacity as production carrying capacity and the regional carrying capacity as ecological carrying capacity. The carrying capacities are determined with regard to sediment transport or particulate matter derived from FNC finfish cultures (local carrying capacities) and water quality in the sea water column in the vicinity of FNC finfish cultures based on dissolved nutrient fluxes (regional carrying capacities);
3. Profitability assessments for FNC grouper cultures investment adopted for economic analysis. In particular the adequacy of the financial indicators in the definition of a ranking of the analysed cases will be handled. The indicators of economic viability of an investment used in the study are the net present value (NPV), internal rate of return (IRR), and payback period (PP). A careful assessment of the method will be carried out and recommendations for improvements shall be proposed. The way the method should be embedded within SYSMAR shall also be discussed;
4. On the basis of the investigations provide recommendations for further studies aiming at the improvement of the effectiveness of the existing DSS.

Chapter 2

Scientific Background

This study focuses on the application of a decision support system and numerical models as well as economic viability criteria for the development of sustainable floating net cage (FNC) grouper cultures in Indonesia. Emphasis is given to the environmental and socio-economic management of FNC for the cultivation of grouper species. As a luxury live reef fish food, groupers bring high prices for local and export markets mainly to Hong Kong, Japan, Singapore, and Southern China (Sim et al. 2005). In the last decade there have been an increasing number of investigations of concepts related to the cultivation of FNC grouper culture in Indonesia. The main principles of environmental and ecological protection practiced at the production level of aquaculture activities are summarized in FAO (2011). To guarantee successful FNC grouper farming operations, the Network of Aquaculture Centers in Asia-Pacific (NACA) recommends key guidelines and improved management practices (Pahlevi et al. 2012).

Given that the literature on the subject is quite extensive, only the most relevant issues directly related to the current research will be reviewedin this chapter. This includes an overview of the methodologies adopted for the selection of suitable sites and the criteria used in the estimation of carrying capacities in FNC systems. Attention is also given to the scale of fish farms and to issues related to sustainable aquaculture feeding. Finally, a review of economic concepts governing mariculture investment in Indonesia and the current state of the art in the development of decision support systems for the management of FNC is provided.

2.1Site Selection

There is clear evidence that the deterioration of water and sediment quality caused by FNC affects the conditions of the surrounding environment and thus the farming operation. Inappropriate site selection is probably the most frequent reason for the failure of aquaculture projects and adverse environmental effects (Boyd and Clay, 2002). Proper site selection significantly reduces construction and operating costs, while enhancing fish growth and survival rates as well as the lifetime of FNC. The selection of suitable sites in a coastal environment should be based on extensive suitability and sustainability analyses. Suitability parameters are linked to the conditions required for the successful cultivation of the farmed species and associated with the operation of the farms in such a way that the buffering capacity of the ecosystem with respect to emissions is not exceeded. As already pointed out, environmental degradation will take place if the ecosystem cannot cope with the pollutant load from the farms. Sustainability therefore implies that a resource should be used in such a way that it is not depleted, so that future generations may still benefit from it.

To ensure adequate fish growth and to minimize the risk of diseases and large-scale mortality, a number of biophysical preferences or appropriate water quality parameters have been recommended for grouper species (FAO, 1989; Cross and Kingzett, 1992; Kapetsky and Aguilar-Manjarrez, 2007; Szuster and Albasri, 2010; Mayerle and Windupranata, 2006). Key physical and chemical parameters, sediment characteristics and coastal uses for Indonesian coastal waters were identified by Windupranata (2007). Table 3.1 lists the parameters adopted for working in Indonesia.

The FAO (2010) has addressed the potentials of spatial planning tools to support the ecosystem approach to aquaculture (EAA), proposing various tools and methodologies to adequately perform environmental impact and risk analysis. To enable practical implementation, essential elements in EAA such as the utilization of spatial planning tools including GIS, remote sensing techniques, mapping, data management and analysis, numerical models and decision making tools are required. Ferreira et al. (2012) demonstrated the relevance of using advanced technologies including GIS, satellite remote sensing, and dynamic models for the selection of suitable sites.

For many years GIS based models have been recognized as a standard methodology in the selection of suitable sites (Nath et al. 2000). Martinez (2002) reported on the application of GIS, remote sensing techniques and mapping in order to determine the potential suitability of a region for developing marine fish cage cultures. The most suitable areas were defined on the basis of the dispersive nature of the site in question. Assessing the environmental impacts facilitated the final decision and helped regulators to establish the maximum desirable production at a given site to support sustainable development. Model outputs were used as acost-effectivemeans of assisting in the prediction of the dispersive potential of a site by determining quantities of waste material (uneaten feed and faeces) and the distribution of wastes and discharges. An improved version of a predictive particulate waste distribution model for marine cage fish farming was used in combination with GIS and spreadsheets.

Windupranata (2007) integrated GIS tools with results of model simulations for the selection of suitable sites and identified key parameters for the selection of suitable sites of FNC in Indonesia (see Table 3.1). In the selection of suitable sites, the available information was reclassified into 'optimal', 'allowable', and 'unsuited'. Weighted grid overlays, leading to average suitability scores in conjunction with filter techniques to exclude unsuited scores are applied. The results provide a spatial representation of the suitable sites for FNC culture. Similarly, Longdill et al. (2008) used GIS in combination with model results to identify the most suitable and sustainable location for an offshore aquaculture management area within the Bay of Plenty, New Zealand. Focus was given to aquaculture operations and suspended mussel cultures (*Perna canaliculus*), and the existing natural conditions, coastal uses, and stakeholders were taken into account.

Rajitha et al. (2007) recommended the use of weighted overlay techniques in conjunction with different degrees of importance of the various factors, based for example on prior investigations or on subjective analysis.

Radiarta et al. (2010) integrated information from satellite remote sensing techniques within a GIS model. A multi-criteria evaluation approach to determine aquaculture site selection for Japanese Kelp culture (*Laminaria Japonica*) in Southern Hokkaido, Japan was adopted. Focus was given to physical parameters including sea surface temperature, suspended solids, and bathymetry. Multi-criteria evaluation procedures were adopted. The effectiveness of remote sensing techniques was also demonstrated by Silva et al. (2011). The results confirmed the potential benefit of remote sensing techniques to improve spatial and spectral resolution of the data and to enable the mapping of features based on band reflectance content only. Information on bathymetry, substrate types, classification of sea grass species, coastline changes, classification of water bodies, assessment of proxies for marine water pollution including chlorophyll and particulate organic carbon can thus be obtained quite effectively.

Strong relationships between site selection and sustainability have been reported in the literature, and the importance of site selection in the development of FNC grouper culture is emphasized. GIS can be applied for this purpose in different ways, taking into account a wide range of data sources to construct spatial models for the development of mariculture. The use of GIS facilitates the integration of criteria for locating aquaculture and other performance to classify suitable zones for different activities or combinations of activities, including aquaculture. The simple overlay of information is the most common technique, but weighted overlay is currently being used. GIS models thus provide efficient and effective tools for site selection and can, furthermore, provide an interface within structured analysis of the spatial data, and hence be used for the purposes of resource appraisal and management.

2.2 Carrying Capacity

The concept of carrying capacity is a significant factor for ecosystem based management in determining upper limits of aquaculture production given the environmental limits, social acceptability, the need to avoid unacceptable changes in the natural ecosystem, social functions and structures (Ross et al. 2013). The assessment of carrying capacity is not only based on environmental sustainability, which is limited by farm aquaculture or population size issues, but also applies at ecosystem, watershed and global scales. In general, carrying capacities for aquaculture are based solely on production; however, they have also been expanded further into more comprehensive categories on the basis of physical, production, ecological and social carrying capacity (Ross et al. 2013).

Inglis et al. (2002) and Mc Kindsey et al. (2006) identified four types of carrying capacities, i.e. physical, production, ecological, and social. “Physical Carrying Capacity” is the total suitable potential area for the development of fish farming in the ecosystem without causing conflicts with other uses (Mc Kindsey et al. 2006 and FAO, 2010). “Production Carrying Capacity” is defined as stocking density of production or the optimal level of production, which leads to the maximum aquaculture production restricted to the smaller areas or farm scale within a water basin (FAO, 2010). It is an indication of the total produced biomass of the water basin which does not exceed the ecological carrying capacity (Byron and Coasta-Pierce, 2010). “Ecological Carrying Capacity” is defined as the stocking or farm density above or the total production of biomass in the water basin with no improper ecological impacts (FAO, 2010). It gives an indication of the amount of aquaculture production that can be generated without leading to significant changes in ecological processes, species, populations, or communities in the environment (Byron and Coasta-Pierce, 2010; Gibbs, 2007 and FAO, 2010). The magnitude of farm development with respect to intensity, scale, production system and unacceptable social impacts accounting for the three other types of carrying capacities is defined as "Social Carrying Capacity" (Mc Kindsey et al., 2006 and FAO, 2010).

Carrying capacity is usually defined as the maximum amount of biomass of a farmed species that can be supported without violating the acceptable impacts on the farmed stock and its environment (Stigebrandt, 2011; Coasta-Pierce & Page, 2010; Byron & Coasta-Pierce, 2010; Legovic et al. 2008).

The main difficulty in the estimation of carrying capacities is the scarcity of reliable and objective methods for estimating the response of the farmed stock on the environment and vice-versa. A considerable amount of the research has been carried out on the ecology of the local benthic ecosystem, and it is well known that site-specific conditions affect waste accumulation and thus the management of FNC finfish cultures. For example, the enrichment of organic matter in the sediment stimulates microbial activity, which requires oxygen. This in turn can cause oxygen depletion in the water column and an increase in the release of inorganic nutrients such as nitrate, nitrite, ammonium, phosphate, and silica (Morrisey et al. 2000). Oxygen depletion in pore water of sediments has also been related to the bacterial degradation of organic matter. Both direct and indirect toxicity effects can alter the nature of the ecology of the local benthic ecosystem (Findlay and Watling, 1997).

The main reason for the deterioration of the water quality in coastal environments is probably the deposition of suspended solids on the seabed in the vicinity of FNC farms. Waste effluents contain high concentrations of organic matter, with remains of uneaten feed along with feces released into the surrounding waters. Generally, the effluents are characterized by increases in total suspended solids, biological oxygen demand, chemical oxygen demand, and carbon, nitrogen and phosphorus content. As a result, levels of organic carbon and other nutrients in the benthic environment are raised (Gilibrand et al. 2002; Kibria et al. 1996; Niederndorfer, 2006).

The transport of particles released from fish farms is controlled primarily by the acting current velocity and direction, wind and wave conditions, bathymetry and falling velocities. Currents and tides play a major role in the process of waste disposal and oxygen supply. Particles of organic matter usually settle in the vicinity of fish farms if the speed of particle deposition exceeds current speed. The extent of the area affected by waste releases from aquaculture activities is very much dependent on the flow dynamics and water depth. Furthermore, the characteristics of the culture produced also plays a role. All these factors determine the dispersion of organic inputs and particles and the redistribution of waste material on the ground (Cornel and Whoriskey, 1993; Stigebrandt, 2011, and Staniford, 2002).

Several studies have attempted to estimate carrying capacities on the basis of model simulations. Byron et al. (2011a) applied a mass balance model for the estimation of the ecological carrying capacity in the highly flushed lagoons of Rhode Island, USA. This remained balanced when one biomass of the higher trophic level consumer groups was halved and doubled. Exceeding ecological carrying capacity led to phytoplankton being overgrazed in the model, which resulted in an ecotrophic efficiency exceeding 1. The results showed that the current cultured oyster biomass could be increased by more than 62 times before the ecological carrying capacity is exceed. The high capacity of the system may allow managers to consider expansion of shellfish aquaculture.

Alongi et al. (2009) investigated the fate of organic matter in small-scale fish farms in the coastal waters of Sulawesi and Sumatera, Indonesia. Nutrient cycling, carbon processing in water, sediments, and water circulation were examined at two farms. Different types of feeding were considered, and a mass balance model of C, N, and P was developed to predict the pathway of waste utilization and dispersal. The rates of primary production and community respiration of the farms resulted equal to or greater than the flow matter from the cages. The small farms were found to have only marginal impact on the surroundings, with carbon deposition in sediments beneath the cages averaging about 0.26 – 0.27 g C $m^{-2}yr^{-1}$. At both farms, benthic enrichment accounted mostly for less than 25% of the total C flux, and denitrification / ammonium oxidation for only 4-17% lost from sediments. No traces of impacts at a distance from the cages were identified.

Gilibrand et al. (2002) developed a simple box model for the estimation of nutrient enhancement levels and benthic impact from the finfish cultivation in Sea Loch, Scotland in which nitrogen was treated as a conservative substance. A modified model of particulate dispersion (known as Gowen model) was applied to predict benthic impact, given the deposition of organic matter in the form of solid waste from finfish farms. The prediction of the area of the seabed was impacted by different levels of organic carbon deposition. Attention was given to the selection of settling velocities and the associated quantities of excreted carbon. Flushing rates, total consented biomass of the finfish farms and the nitrogen source rates were also taken into consideration. In the application of the model, the release of nitrogen at a rate of 48.2 kg N per ton of salmon produced per year was considered. The level of enhanced organic carbon deposition on the seabed of one of the lochs resulted higher than 0.70 kg C m^{-2} y^{-1}, which is equivalent to about 1.9 g c m^2 d^{-1}. In places in which the deposition rates exceeded this value, the seabed was found to be 'degraded' and faunal diversity of sediments was reduced.

Filgueira et al. (2010) developed a multi box ecosystem model within the visual simulation environment generated by Simile software. The system allows for explicit coupling between boxes to assist in the development of sustainable mussel culture in Lysefjord, Southwest Norway. Carrying capacity for mussel culture was determined with respect to the characteristics of the environment and food availability, and an optimization of various parameters for enhancing the management of mussel production regarding carrying capacity criteria was carried out.

Table 2.1 lists the main models used for the estimation of carrying capacities in an ecosystem approach, applied to sites worldwide. Most of the applications are based on the assessment of production carrying capacity with respect to the level of production of biomass / stocking density / holding capacity (Cromey et al. 2002, Halide et al. 2009 and Stigebrandt et al. 2011). Others consider physical carrying capacity regarding site selection and suitability along with the water quality (Cromey et al. 2005 and Sepa., 2005, Halide et al. 2009), while ecological carrying capacity was adopted by Cai and Sun (2007) and Rensel et al. (2007). They assessed the capacity using a water quality model and benthic ecosystem impact. As can be seen, the authors have all assessed and defined the carrying capacity with respect to an ecosystem aquaculture approach with different objectives and methods.

Table 2.1: Selection of important models for use in determinations of carrying capacities in an ecosystems approachon the cage aquaculture of fin fishes

Author / source	Model	Objectives of the model	Carrying Capacity (CC)
Cromey et al. (2002); SEPA (2005); www.Sepa.org.uk/aquaculture/modelling	DEPOMOD AND AUTODEPOMOD	Predictions of waste fecal and feed deposition and benthic	Site selection as physical cc, biomass level as production cc
Cai and Sun (2007)	Hydrodynamic and mass transport model	Water quality relation with water discharge and benthic environment impacts	Environmental cc as ecological cc
Rensel et al. (2007); www.aquamodel.org	AquaModel	Models determine fish cage biomass impacts on pelagic and benthic ecosystems	Total biomass in large scale farms as ecological cc
Szuster and Albasri (2009)(see page 6)	Framework of site selection	Site capability and site suitability analysis	Suitable area as physical cc
Halide et al. (2009); www.epa.org.uk/aquaculture/modelling	CADS_TOOL (Cage Aquaculture Decision Support Tool)	Based on MOM, SMOM model, Site selection, site classification, site economic appraisal	Holding capacity as production cc
Gaĉek and Legoviĉ (2010)	3D Finite Element Tidal Model	Site selection regarding to water quality model	Proposed Ecological cc
Stigebrandt et al. 2011	Norwegian MOM model	Max biomass assessed by water quality model and benthic ecosystem	Stocking capacities as production cc

In order to provide improved prediction of the effect from large maricultures on the benthos and better objectivity in the regulatory decision-making development, Cromey et al. (2002) developed DEPOMOD as a computer particle tracking model which describes the transport of particles from the surface to the sea floor. The objectives of this model were to achieve estimations of solids accumulation for six Scottish marine farms and to predict the solids accretion on the seabed occurrence and related changes in the benthic faunal community. The model was validated using sediment trap studies, and predicted flux (g/m^2/day) with an accuracy of $\pm$ 20% and $\pm$ 13% for a dispersive and depositional site respectively. Data from numerous Scottish fish farms was used to validate a resuspension model, predict solid accumulation (g/m^2/year), Infaunal Trophic Index (ITI) and total individual abundance. DEPOMOD may thus be used for determination the potential effect of a farm during a growing cycle and may also be utilized in the site selection procedure of a new farm to examine the future farm position and biomass levels.

Cai and Sun (2007) determined the ecological carrying capacity of a marine cage aquaculture, based on the dry feed conversion rate to analyze the nutrient loadings in Xiangshan Harbor, China. A hydrodynamic model coupled to a water quality model was used. Regarding nitrogen and phosphorus, which were considered in this study, the simulated outcomes show that the maximum nitrogen and phosphorus concentration were 0.216 mg/l and 0.039 mg/l respectively. The calculated environmental carrying capacities of nitrogen and phosphorus were 1,107 t/yr and 134 t/yr respectively**.**

Rensel et al. (2007) provided an overview of applicable hydrographic conditions and the potential water quality of salmonid finfish maricultures in the Strait of Juan de Fuca in the U.S. Pacific Northwest for commercial harvest or stock rehabilitation. They carried out circulation studies and current, wave, and phytoplankton assessments. Results were determined by a Aqua Model simulation that computes for growth and metabolic oxygen demands of cage fish and the response of phytoplankton to nutrients and grazing. The outcomes of model and field study confirmed that there were no probable undesirable effect of large scale fish mariculture, indicated by a lack of phytoplankton enrichment and thus no bloom, along with the reduction downstream of dissolved oxygen at less than 0.1 mg/L. This study showed that the high energy area close to the south shore of the Strait is suitable for finfish mariculture since adverse effects on benthic or plankton components are minimal or not even measurable. The authors thus concluded that effects of mariculture on benthic conditions and water quality would be insignificant and that fish culture was technically feasible in the Strait.

Szutser and Albasri (2010) determined the suitable sites of a floating net cage grouper culture at Kaledupa Island in Indonesia using a Geographic Information System (GIS). Data collection focused on 15 biophysical parameters addressing the suitability of a site, including bathymetry, pH, temperature, dissolved oxygen, salinity, nitrate, phosphate, wave height, water current, sediment, water clarity, red tide, parasites and diseases, pollution, low tide. In addition, another 7 site suitability parameters including coastal activities, transportation, diving sites, fishing grounds, harbors, protected areas, benthic species, and spawning ground determined through interviews with villagers along with local experts were considered. The outcomes of the site capability revealed that 4,511 ha capable of sustaining grouper maricultures within the 8,582 ha study area. Whilst, with respect to villager opinions, the suitability analysis identified 2,667 ha and 4,083 ha considering local expert opinions. Regarding villager opinions and resolution of fragmentation issues reduced the final area estimated suitable to 2,423 ha.

To assist cage aquaculture managers, Halide et al. (2009) developed a decision support system, with performed essential tasks including site selection, holding capacity, and economic appraisal of an aquaculture at a given site. The best site was evaluated by an analytical hierarchy processing tool and classified into three categories of poor, medium, and good. In order to assess carrying capacity, a simplified version of the modelling on growing monitoring (SMOM) was applied. The calculated holding density was HD = 0.002 water flow at surface – 0.018 critical oxygen concentration in the cage + 0.004 flow variance – 0.012 number of cage rows – 0.081 ammonium concentration in the cage + 0.075 critical ammonium concentration in the cage – 0.008 food conversion ratio + 0.008 critical oxygen concentration at the seabed + 0.096 cage length. Economic appraisal was calculated by determining break-even point price and return on investment (ROI) with respect to stocking density and volume, mean fish weight at harvest, feed conversion ratio, survival rate, feed cost, fry, investment of cages, the interest rate on borrowed funds along with the fish price.

Geĉek and Legović (2010) proposed the assessment of carrying capacity by the quantification of the process responsible for (a) water quality within the units, (b) impacts to the seabed and (c) water quality in the surroundings. A 3D tidal flow model was applied to Balino Bay in the

Philippines, which showed that water quality within the cages was strongly influenced by the local water exchange.

Stigebrandt (2011) set up a model for the estimation of sustainable marine aquaculture based on the Norwegian MOM Model (Aure & Stigebrandt, 1990; Stigebrandt & Aure, 1995).The carrying capacity was estimated on the basis of a relationship between the biomass of the farms and their environmental impact. First the impact of the load on the water quality was assessed. Then for a given farm the relationship between loading and biomass was determined. The holding capacity of a location is determined by maximum potential fish production which doesn't lead to extinction of the benthic infauna and the minimum value of the concentration of ammonium and oxygen. The main difficulty in the estimations turned out to be the uncertainty in the current conditions during very calm weather conditions.

Production Carrying Capacity

Comparing the literature above, in this study, production carrying capacities have also been defined by the destination of particulate carbon governed by the amount of waste and physical characteristics, and deposited beneath FNC farms. The deposition rate of particulate organic matter resulting from faecal and waste feed is influenced by the hydrodynamics of the site (Gowen et al. 1989). A simplified footprint approach considers particle settling velocities, carbon flux, current velocities, water depth and dispersion constants to provide an approximation of the carbon deposition footprint and derived deposition rates around the farm as described in Van der Wulp et al. (2010) and Gilibrand et al. (2002). According to Angel et al. (1995) and Findlay and Watling (1997), the rate of carbon on the seabed should not exceed approximately 1 to 5 gC/m^2d^{-1}. Whilst, Morrisey et al. (2000) made model predicted rates of mineralization of organic carbon in the sediments of 3.3 g - 10.8 g C m^{-2} d^{-1}. Gilibrand et al. (2002) identified a breakdown rate of 0.7 kg C $m^{-2}y^{-1}$, which is equivalent to 1.9 g C m^{-2} $d^{-1}$and adopted by Rachmansyah (2004), while Krost (2007) proposed a slightly more conservative threshold value of about 0.5 to 2 gC m^{-2} d^{-1}on the basis of measurements carried out in fish farms in Indonesia. Thus in order to ensure practical sustainability in Indonesia, this study adopts the threshold value criteria of 1 - 2 g C m^{-2} d^{-1} for determining local/production carrying capacity.

Ecological Carrying Capacity

Although there is a good understanding of the process leading to the deterioration of the water and sediment quality due to fish farming, the definition of limiting criteria to guarantee sustainability remains a major difficulty. If we now turn to ecological carrying capacity, in this thesis it is assessed by regional carrying capacity which is determined based on total load of dissolved nitrogen. Furthermore, it was also calculated by multiplying the entire water inflow with respect to concentration of total dissolved nitrogen. Soluble fractions of the particulate waste from FNC finfish culture are transported over greater distances, which is dissimilar to the local carrying capacity. Accumulative effects may occur in poorly flushed areas, potentially leading to unacceptable nutrient levels. Hence, carrying capacities on a regional scale should consider natural nutrient levels, flushing rates and a definition of assimilative capacities for soluble nutrients.

Criteria based on the levels of water quality in the surroundings of the farms have been proposed. Weston (1986) suggested criteria based on the tolerable increase in the flux of nitrogen into the embayment area, along with Gesamp (2001) and Rosentahal (2006), who suggested that the flux of nitrogen emitted by the fish farms should be lower than 1% of the nitrogen flux into the domain**.** This was then adopted by van der Wulp (2010). Therefore in this study, the ecological carrying capacity for FNC finfish farms within a domain is set to be equivalent to the production rates of total dissolved nitrogen (TDN) not more than 1% of the TDN flux of the domain.

2.3 Aquaculture Feed

The FAO (2011) has proposed a code of conduct for responsible fisheries, with technical guidelines on the use of wild fish as feed in aquaculture which includes information for the improvement of aquaculture activities and sustainable utilization of feed-fish stocks. The relevant issues of the utilization of wild fish in aquaculture feeds are covered, including ecosystem and environmental impacts, ethical consideration on the responsible use of fish as feed, aquaculture technology and development, as well as statistics and information needs for managing the development of aquaculture.

The main types of fish feed used in grouper cultures are moist feeds, trash fish, and dry pelletized feeds. Dry feeds generally contain a large fraction of trash fish and other marine animals such as shrimp and squid. The use of unprocessed trash fish is still widespread in South East Asia, mainly because it is cheaper than pellets. Its use was discouraged on the grounds of unreliable supply, inconsistency of fish feed quality, high risks of infecting pathogens and an increase in pollution. The use of formulated feeds, such as dry pellet diets, should be encouraged given their greater efficiency. Groupers have high protein requirements and pellets should therefore contain more than 50% of crude protein (The International Standard for the Trade in Live Reef Food Fish; http://www.livefoodfishtrade.org).

Blyth and Dodd (2002) revealed that feed management was a significant factor in several farming mariculture operations in Asia, contributing about 50 – 70% to overall production cost in intensive aquaculture. However, the widespread utilization of trash fish imposed severe problems for mariculture industry, since trash fish as an untreated feed ingredient was a potential vector for disease transmission.

In Indonesia, the development of FNC grouper culture started in the late 1980s and has been consistently intensified since grouper species secure high prices in local markets and for export. However, grouper cultures were repeatedly lost due to inappropriate feeding strategies, leading to fish diseases, mass mortalities, and reduced commercial market values (Rückert et al. 2009 and Sim et al. 2005). Rückert et al. (2009) identified the potential risk of parasite transfer through the feed into grouper mariculture in Lampung Bay, Indonesia. The results showed that replacing trash fish with manufactured pellets could improve control of helminth parasite transmission, and additionally prevents overfishing of trash fish species for the steadily growing mariculture industry. Talbot and Hole (1994) in turn highlighted that feed manufacturers should ensure that feed is both nutritionally correct for the intended farming production system and also properly managed by the farmer.

Huntington and Hasan (2009) carried out a global synthesis of practices, sustainability, and implication of fish as feed input of aquaculture. The function of feed fisheries in fish and animal farming was examined, as well as direct human consumption of these sources on environmental, food security and livelihood grounds. They analyzed case studies in several countries around the world and found that there are marked differences among regions with respect to the source and utilization of fish based protein for feeds. In Asia the consumption of trash fish for aquaculture is utilized by small-scale fish farms, which cannot afford pellets. Thus it is a significant factor in maintaining the farmers' livelihood and from an economic point of view, the use of trash fish was found to make sense for small-scale enterprises.

The controversy regarding scientific evidence for sustainable aquaculture feed is widely recognized. In Europe, the intensification and feed management of aquaculture production is regarded as one of the leading polluters of the aquatic environment (Staniford, 2002). However, the aquaculture industry and developments have already been responding to the challenge of sustainable feeds, but there is still much to be done. Serious weaknesses with all arguments revealed that sustainable feed management for the development of FNC is still uncertain. Thus in this study feed management is addressed to a limited extent only, in the context of diverse feeding strategies.

2.4 Farm Scale and Spacing

So far there is no clear definition of the scale of farms in aquaculture. Farm scale is commonly related to production technology, particularly feed, and stock density (FAO, 1987; FAO, 1997 and Beveridge, 2004). Culture systems are usually classified into extensive, semi-intensive and intensive. *Extensive culture systems* adopt traditional techniques of aquaculture and receive no international nutritional inputs. *Semi-intensive culture systems* adopt mid-level technology and rely largely on natural food, which is increased over baseline levels by fertilization and/or use of supplementary feed to complement natural food. *Intensive culture systems* adopt a full complement of culture techniques and rely on nutritionally complete diets. They include scientific pond design, fertilization, supplemental feeding or only feeding without fertilization, full measure of stock manipulation, disease control, scientific harvesting, high level inputs and high rate of production.

According to the total number of cages, fish farms are classified into small (less than 10-20), medium (10 to 100) and large (over 100). In China and Indonesia, grow-out operations are mainly medium scale (Kangkeo et al. 2010). In this study, semi-intensive FNC finfish culture systems along with medium and large, fish farms will be considered.

In the estimation of carrying capacity, the spacing between farms is also of great relevance. The spacing was usually related to the size of the farms. For larger cage farms, the FAO (1997) recommends minimum distances of about 500m, while for smaller farms this distance could be reduced. Wong et al. (1999) found that the diversity of fauna is significantly higher away from (>500 m) than near (< 500m) farm sites. In the colder waters of Denmark, adverse effects caused by emissions due to FNC finfish were noticed at distances up to about 1.2 km (Holmer, 1991)while in Indonesia, Ladwig and Hesse (2007) found that the emissions from medium size farms are not detectable in the water column at distances of more than 200 m from the farms. Syadiah (2010) and Adibrata (2012) have shown that the local extent of altered benthic community structure and biomass is limited to less than 150 m.

2.5 Economic Analysis of Mariculture Investments

Economic decision tools in mariculture aim to assist farmers, potential investors, and decision makers (stakeholders) in understanding the economic requirements, costs and benefits, and risks involved in production. For further development, the stakeholders can develop farm models based on experience, and apply them to decision-making and management. Through the development of economic decision tools they can assess impacts such as diseases, climate and market prices (known as externalities) that may influence profitability. They can also determine changes in profitability caused by changes in the cost of feed, labor, electricity, packaging and transport. Additionally, the decision tools can evaluate the economic effects of improvements in yield, future development plans, or a change in production efficiency. Economic sustainability is maintained when environmentally sustainable production rates remain profitable (Johston and Pickering, 2003). In this thesis an economic analysis is used to determine economic sustainability for FNC grouper cultures.

The need for guidelines for conducting economic valuations with respect to coastal ecosystem goods and services is highlighted in UNEP (2007). In decision making, there is increasing concern to provide critical ecological, economic, and social services which maintain the existence of valuable ecosystems and human communities. Thus, besides evaluating development plans, cost benefit analysis is widely used by many aquaculture economists. In this study, cost benefit analysis is used for the development of FNC grouper cultures in selected areas in Indonesia.

Further analysis shows that the cost benefit analysis methodologies facilitate the justification of an investment in cases in which the net present value (NPV) is greater than 0, the benefit cost ratio (BCR) greater than 1 and the internal rate of return (IRR) greater than each benefit cost value. Numerous studies have attempted to evaluate the economic viability of existing and planned grouper net cages projects (Afero et al. 2010; Utama, 2008; Astuti, 2005; Herlina, 2006; Sulaiman, 2010).

Afero et al. (2010) conducted an economic study of grouper cultures including tiger and humpback grouper for different scale farms (small 15 cages, medium 28 cages, large 48 cages) in Indonesia. The results indicated the small scale farm were not feasible. On the other hand, the medium scale farms of humpback grouper at different production scales showed a positive cumulative cash and net present value (NPV), benefit cost ration (BCR) over 2, internal rate of return (IRR) over 300%, payback period (PP) < 1 year. The results of a sensitivity analysis of humpback grouper indicated economic viability with positive NPV in all the three production scales.

O'Rourke (1996) reviewed some of the basic budgeting tools and analytical methods to assess the potential economic viability of an existing or planned Walleye aquaculture enterprise. He showed that the volume of business relative to expenses had a significant influence on economic and financial viability, and that understanding the correlation between volume and expenses played a key role in achieving profitability objectives. The estimation of annual depreciation rates for buildings, fixed equipment, and system components required information about expected economic life and salvage values, and a key variable in the estimation of operating cost was the selected level of technology. The general aim of the study was to improve economic viability of the commercial production of advanced 6 inch walleye fingerlings, reared intensively in a tank system. The net present value was calculated for the investment in a simulated Walleye fingerling system and assumed a weighted cost of capital of 15%. All permanent equipment as well as components were assumed to be sold for salvage value at the end of a 5 year period, while labor wages were a major cost factor (36.3% of total revenues), with the results showing positive net present value.

Utama (2008) performed a feasibility study of a *tiger grouper* aquaculture in a floating net cage development in Pagang Island, Seribu Island, DKI Jakarta. In his study, he considered financial aspects, technical aspects, and market analysis. The financial analysis was assessed by net present value (NPV), internal rate of return (IRR), net benefit cost ratio (Net B/C), and payback period (PP). A sensitivity analysis was also used to assure sustainability given a certain alteration in variable prices and costs and survival rate of groupers. The market analysis was conducted to assess potential demand in the grouper market. At that time, Hongkong imported about 30,000 tons of live groupers every year from many countries such as Australia, Malaysia, Philippines and Indonesia, with Indonesia contributing an average of 267 tons per year. Based on a floating net cage mariculture size of 4x4 meters for 2, 4, and 6 cages, the results proved feasible for the application of the *tiger grouper* culture development. Utama's research showed that FNC of 6 cages performed best, as indicated by the positive NPV of € 4,400, with € 4,160, and €1,920 for 4 and 2 cagesrespectively. The payback periods are 5.3 months, 5.5 months, 5.6 months respectively. Other parameters including IRR and BCR showed similar trends among the FNC grouper cultures.

In order to increase social prosperity on Sugi Island, in the Karimun Region of Riau Archipelago Province, a study has been conducted by Astuti (2005), which aimed to give guidance in integrated management and sustainable marine culture for grouper farming, shrimp farming, and seaweed farming, and was assessed by financial analysis and labor recruitment. The financial analysis was determined for a 5 year project lifetime by investment criteria including NPV, Net B/C, IRR, and payback period. The financial analysis showed that grouper was the best performing crop, more profitable than shrimp and seaweed. This is indicated by the highest positive value of NPV, while Net B/C was 3.26, IRR was 65%, and payback period was about 1.3 years.

A financial analysis for grow-out of tiger grouper culture and hatchery has been carried out by Herlina (2006) in Semak Daun Island, Seribu Island Region, Jakarta Province for a 10 year project estimation. She analyzed investment criteria such as NPV, which aimed to assess the benefit gain in relation to project duration, as well as Net benefit cost ratio (Net B/C) which intended to determine the comparison of input and output during the economic project duration. IRR was used to assess the level of profit gained, and PP was evaluated to verify return of investment. In order to determine the robustness of business development, a sensitivity analysis was also carried out. Regarding Tiger grouper cultures, her results showed positive values of NPV at €

25,920, IRR at 73%, BCR at 3.89 and a PP of 7 years 6 months. The study considered a sensitivity analysis using a 10% level of cost variation.

In a study on Seribu Island, Jakarta Province by Sulaiman (2010), the high value of capital investment was found to be the main obstacle faced by entrepreneurs of floating net cages (FNC) mariculture in developing the business. Financial institutions (banks) were uncertain about successful FNC mariculture development, which resulted in farmers experiencing problems when applying for bank loans. His study describes three grouper culturescenarios: hatchery, grow out, as well as combined hatchery and grow out. The results of the profitability assessments of the mariculture activities showed that they were all acceptable. Regarding sensitivity analysis, the grow-out scenario was very sensitive to decreasing market prices, while feed price was not seen to have any major influence.

When we consider fresh water fish farming, Okechi (2004) presented profitability rating tools to evaluate the viability of fish farm investments and operations in Lake Victoria basin, Kenya. The study created predictions with respect to secondary data on catfish (*Clarias gariepinus*) production of small scale farms. Indicators of returns on investment such as net present value (NPV), internal rate of return (IRR), payback period (PP), and debt service ratio were determined to evaluate the profitability of the venture. Okechi also conducted sensitivity analysis study including sales price, cost of fingerlings, stocking density, cost of feed and survival rates. The results showed a positive NPV, and acceptable IRR, as well as PP of less than five years, thus indicating that cash flow was sufficiently high. Sensitivity analysis highlighted that the project was extremely sensitive to stocking density, survival rates and sales price, on the other hand not as much of sensitive to the cost of fingerlings and the cost of feed used in production.

2.6 Decision Support Systems in FNC Finfish Culture

To date, various methodologies and tools have been developed and applied to support decision makers in the management of aquaculture activities. Schulstad (1997) was one of the first developers of the decision support system (DSS)concept. He designed a computerized DSS name “Ithink” for hatchery production management of young Atlantic salmon in Norway. The system was used to operate a simulation model with a biological component. An integrated DSS implementing a mechanistic approach was developed to describe the physical components and economics. The results showed good agreement with the results of theoretical models, thus proving the potential for a computerized decision support system.

Ernst et al. (2000) demonstrated the capabilities of the simulation and decision support system “AquaFarm” for aquaculture facility design and management of operations. AquaFarm implements several components, including physical, chemical, biological unit process, along with models of facility and fish culture management, for the collection of facility resource and enterprise budgets. The system comprises a graphical user interface and data management capabilities. AquaFarm can be applied for purposes of brood fish, maturation, egg incubation, grow out of finfish or crustaceans in cages, water recirculation, or solar algae pond systems. The methods and results obtained have shown that it provides useful and sufficiently accurate decision support functionality.

Doucette and Hargrave (2002) published guidelines which aim to provide structured scientific advice for decision making and in the assessment of environmental data in marine finfish cultures. To determine the state of environmental variables in the near vicinity and away from potential finfish aquaculture sites, a traffic light method is proposed. It supports managers in gathering and assessing physical, chemical, and biological information. It helps in the assessment of sets of potentially critical environmental variables that might not be perceived by the operator. The results can be used as a warning for potential problems. Hargrave (2002) extended the traffic light method, aiming to assess variables potentially affected by marine finfish aquaculture. It consist of twenty questions, which are ranked by a traffic light method and was tested using data from eight salmon farms. The results showed useful management capabilities and a systematic framework for regulations to store and analyze temporal data from environmental monitoring programs.

Windupranata (2007) developed a Decision Support System (DSS) to help in the determination of suitable FNC in Indonesia. Under GIS application, the DSS was developed by ESRI software ®ArcGIS ™ v8.3 using a weighted overlay method. A wide range of physical and chemical parameters, including sediment characteristics are taken into consideration. The DSS was applied to Seribu Island in the Java Sea and the Riau Archipelago, and the results obtained showed the adequacy of the system for supporting governmental system in the application, environmental controlling and prediction of overall carrying capacity for environmental sustainable marine fish farming.

Mayerle et al. (2009) developed a DSS for the selection of suitable sites and estimation of the carrying capacity of FNC. The system combines GIS technologies and open source numerical models for simulation of flow, waves, and water quality. Suitable sites are based on Windupranata (2007),whileissues related to coastal zone management are further considered by van der Wulp (2010). Carrying capacities are based on approaches taking into consideration water and sediment quality. The DSS ensures suitable production with respect to the environment by site selections and estimates two types of carrying capacities. The local/production carrying capacity is determined by particulate organic carbon (POC) loads which were estimated from farm emissions. Hydrodynamic aspects of nutrient flux of total dissolved nitrogen (TDN) estimated from nutrient background concentration were used to assess a regional carrying capacity / ecological carrying capacity (Weston, 1986). To facilitate decision making, a user-friendly interface has been implemented (van der Wulp, 2010).

A DSS model to assist the cage aquaculture manager has been presented by Halide et al (2009). The model integrated and implemented in Java is called cage aquaculture decision support tool (CADS_TOOL). It performs the four essential tasks of (i) site classification, (ii) site selection, (iii) holding capacity determination, and (iv) economic appraisal of an aquaculture farm at a specified site. Cage aquaculture with respect to criteria of water and substrate qualities, hydrometeorology, and socioeconomic aspects is classified as poor, medium, and good. The authors have developed a simplified version, called the Modeling-On growing-Monitoring (MOM) and applied it to verify how much fish can be grown on a site without harming the environment. The simplified model was calibrated, evaluated with other carrying capacity models and validated with farm data. Thus, the model used volume and holding density, feed conversion ratio (FCR), mean fish weight at harvest, survival rate, feed cost, seeds and cages, interest rates on borrowed funds and fish prices to calculate the break-even price and the return on investment.

Ferreira et al. (2012) has reviewed recent developments in DSS with regard to EAA for novel management in aquaculture using simulation models and information systems. In this study, emphasis was given to the identification of the main constraints in the applications of the DSS tools in developing countries. They pointed out that DSS tools would play an important role in addressing many elements in aquaculture, including a)remote sensing and ecosystem scale models through the use of GIS to determine site suitability and carrying capacities, b) farm scale tools for support licensing, c) sensors for data acquisition for monitoring and modelling.

In this thesis, the parameters of the DSS were analysed mainly for grouper species with respect to the EAA concept. SYSMAR DSS utilizes high resolution hydrodynamic information concerning water depth, current velocities and wave heights obtained from hydrodynamics models. The system has been developed for the selection of suitable sites and for the determination of different types of carrying capacities including production and ecological. The DSS has been amended with economic appraisal tools based on Jacob (1969), Weston and Birgham (1974) and United Nation Environment Programme (UNEP) cost benefit analysis (Unep, 2007).

Chapter 3

Decision Support System SYSMAR

3.1 Introduction

In this study, the Decision Support System SYSMAR was applied to the identification of suitable sites, the estimation of carrying capacities and the assessment of economic viability at three Fisheries Management Areas (FMA) in Indonesia. The system has been developed at the Research and Technology Centre Westcoast of the University Kiel since 2003. The design, set-up and first applications to real conditions were carried out during the 1st phase of the SPICE Project from 2003 to 2007. Emphasis was given to the conceptual development and to the selection of methods for the identification of suitable sites for the installation of floating net cages (Windupranata 2007, Windupranata and Mayerle 2009, Mayerle et al. 2009). In the 2nd phase of the SPICE project, from 2007 to 2010, the system was extended to enable estimations of different types of carrying capacities to ensure environmental sustainability. Emphasis was also given to approaches which ensure socio-economic sustainability and on the set-up of a user-friendly interface to facilitate decision-making (Mayerle et al. 2009, Wulp et al. 2010, Mayerle et al. 2011).

SYSMAR comprises primarily three modules embedded with a graphical user interface. Sites suited for fish farming activities are initially identified for a given coastal area on the basis of a wide range of parameters of the site required. Then production and ecological carrying capacities are determined. Finally, an assessment of economic viability are made. SYSMAR is integrated in a graphical user interface and the system has been successfully applied to a large number of coastal sites in Indonesia. In this chapter, the most important details of system for the present study are presented.

3.2 Identification of Suitable Sites

Appropriate site selection in terms of the surrounding conditions affecting the structures and the farmed stock reduce the potential risks to which FNC finfish farms are exposed. The selection of sites is usually based on spatial information of an array of parameters with respect to the suitability (biophysical parameters) and feasibility analysis (extrinsic aspects: coastal usage/Integrated Coastal Zone Management (ICZM)). In order to determine the suitability of a site, a number of parameters and criteria affecting FNC grouper culture for South East Asian farm practice were selected. The parameters considered in SYSMAR were taken from FAO (1989), Cross and Kingzett (1992), Kapetsky and Agullar-Manjarrez (2007) and Szuster and Albasri (2010). Table 3.1 lists the parameters adopted with the associated qualifications allowing for a ranking regarding the conditions of a predefined culture type and species.

3.2.1 Sources of Data

The required data for the application of the DSS is obtained from several sources. Bathymetric data along near shore areas in Indonesia is usually obtained from nautical charts issued by the Badan Koordinasi Survey dan Pemetaan Nasional (National Coordinating Agency for Survey and Mapping). GEBCO (General Bathymetric Chart of the Oceans) data, issued by the British Oceanographic Data Centre, U.K. (www.gebco.net/data_and_products/gebco_digital_atlas/) which is usually adopted to provide information in deeper areas. The data is provided on a horizontal grid with a resolution of 30 arc-second intervals or about 0.5 nautical miles. For tidal variations and wind characteristics for diving, the numerical models are extracted from *Total Modal Driver* (see Egbert and Erofeeva, 2002). The data is obtained from the NCEP/NCAR reanalysis database (NOAA/OAR/ESRLPSD, 2009). Water quality information is usually obtained from agencies and measurements taken in the vicinity of the selected areas. In many cases, it is supported by analysis of satellite data. The most critical parameters to be considered are water temperature, salinity, dissolved oxygen and ammonium.

Problems resulting from conflicts of coastal uses and adverse natural environmental conditions are also accounted for in the selection of suitable sites, and for this purpose geographic data is collected to identify the most relevant problems in the coastal zone. In this study, the analysis of ICZM aspects was done following the criteria implemented in SYSMAR. In this case, specific uses are assigned to identify a coastal area and the associated potential risks. The initial analysis is usually based on regional planning data, satellite imagery information along with other

parameters so as to provide comprehensive information. On the basis of this analysis, the most relevant information for the conditions under investigation are selected.
Due to the fact that information on current velocities and waves are seldom available, models for the simulation of flow and waves are usually set up for the coastal areas under investigation.

3.2.2 Analytical Framework

The data is assimilated in a Geographic Information System (GIS) and processed by an analytical framework proposed by Windupranata (2007). As a result, an overview of the degree of capability and suitability criteria for development of FNC finfish culture within the entire chosen domain is provided. The adopted GIS approaches rely on a simple overlay of processes. In this way, the areas considered suitable for supporting the use of the proposed resource are identified with suitability factors weighted equally across categories (Szuster and Albasri, 2010). As already mentioned, thematic grids are prepared using GIS tools and reclassified according to the suitable criteria (see Table 3.1). Three categories representing unsuitable (=0), allowable (=1), and optimal (=2) conditions are considered.

An example of a reclassification process of bathymetric information is presented in Figure 3.1a. The figure illustrates the approach adopted in the classification of the bathymetry on the basis of minimum water depth. Once a grid cell is unsuited due to the fact that it is outside the recommended range, the overall score is turned into unsuited (0) (red color). By overlapping the information from all the thematic map final scores are allocated, as shown in Figure 3.1b.

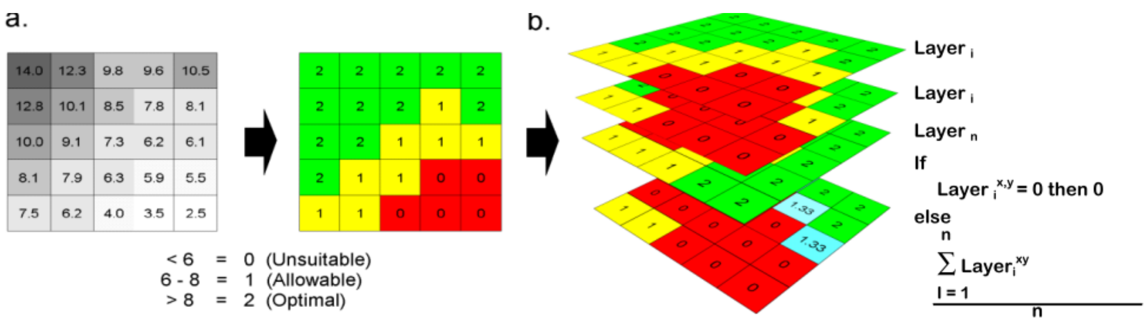


Figure 3.1: Scheme of the suitability assessment: a) reclassification of bathymetric information b) estimation of a final score using an overlay procedure (van der Wulp et al.2010)

Table 3.1: Site selection of groupers grown in floating net cages. (Windupranata, 2006; van der Wulp, 2010; Mayerle et al. 2011, modified)

Description	Parameters	Indicators	Units	Unsuitable	Allowable	Optimal
Physical Process	Min. water depth	water depth	m	< 6	> 6	> 8
	Max. mooring	water depth	m	> 25	< 25	< 20
	Flushing	mean current	m/s	<0.01	>0.01	0.2 – 0.5
	Currents	mean current	m/s	> 1	< 1	0.2 – 0.5
	Exposure to waves	significant wave	m	> 1	< 1	< 0.6
	Exposure to wind	max wind speed	m/s	> 15	< 15	< 10
Water Quality	Water temperature	water temperature	^{o}C	<20 or >35	20 – 35	27 – 31
	Salinity	salinity	ppm	<15 or >35	15 -35	26 – 31
	Dissolved oxygen	dissolved oxygen	mgO_2/l	< 4	> 4	> 5
	Acid-base balance	pH	$-log(H^+)$	<6 or >8.5	6 – 7.8	7.8 – 8.5
	Water transparency	Secchi depth	m	< 2	> 2	> 4
	Turbidity	suspended matter	mg/l	> 10	< 10	< 5
	Ammonium	ammonium	mg NH_4-N/l	> 1	< 1	< 0.5
	Nitrate	nitrate	mg NO_3-N/l	> 200	< 200	< 200
	Nitrite	nitrite	mg NO_2-N/l	> 4	< 4	< 4
	Phosphate	total phosphate	mg P/l	> 70	< 70	< 70
ICZM	Villages	thematic map	m	< 200	> 200	> 500
	Towns	thematic map	m	< 200	> 200	> 500
	Cities	thematic map	m	< 200	> 200	> 500
	Harbours	thematic map	m	< 200	> 200	> 500
	Industry	thematic map	m	< 200	> 200	> 500
	Tourism	thematic map	m	< 200	> 200	> 500
	Streams	thematic map	m	< 200	> 200	> 500
	Rivers	thematic map	m	< 200	> 200	> 500
	Erosive shoreline	thematic map	m	< 200	> 200	> 500
	Semi intensive hatcheries	thematic map	m	< 200	> 200	> 500
	Intensive hatcheries	thematic map	m	< 200	> 200	> 500
	Ponds	thematic map	m	< 200	> 200	> 500
	Sewage discharges	thematic map	m	< 200	> 200	> 500
	Traffic lanes	thematic map	m	< 200	> 200	> 500
	Coastal usage	thematic map	m	< 200	> 200	> 500
	Environmentally protected area	thematic map	m	< 200	> 200	> 500

3.3 Estimation of Carrying Capacity

Two entirely independent methods for the estimation of carrying capacities are adopted. The so-called production carrying capacity is defined in terms of the deterioration of the sediment quality under each individual farm. The ecological carrying capacity in turn is defined on the basis of the deterioration of the water quality due to the emissions from all the farms. A brief description follows.

3.3.1 Production Carrying Capacity

The production carrying capacity for a given farm is determined on the basis of a simplified deterministic method proposed by Gilibrand et al. (2002). The deposition of carbon under the farms is predicted. Threshold rules in terms of carbon deposition are defined in order to obtain the maximum threshold rates of particulate organic carbon per farm (POC_{farm}). The method accounts for advection and diffusion and takes the farm dimensions into consideration. A reoccurring tidal current along the main direction x, on which advective transport predominates, is assumed. Diffusion is multidirectional and hence is considered for both x and y direction.

The method assumes uniform water depths (h), time averaged current velocity ($\bar{u}$) and constant settling velocities (w_s). The following simplifications are made. The displacement of a particle due to advection ($D_{advection}$) in the main current direction x, is obtained as follows:

$$D_{advection} \approx \bar{u}.\frac{h}{w_s} \text{...... (3.1)}$$

The diffusion coefficient (E) is approximated as below:

$$E \approx \bar{u}^{0.8}.h^{1.2} + E_{background} \text{ ...... (3.2)}$$

The radius of the area influenced by diffusion, is expressed in terms of the diffusion coefficient resulting in the distance transported by diffusion ($D_{diffusion}$) as follows:

$$D_{diffusion} \approx \sqrt{\frac{E}{\pi}.\frac{h}{w_s}} \text{......(3.3)}$$

Fig. 3.2 shows the approximation of the deposition footprint under the fish farm due to farm emissions. The deposition area is considered as an ellipsoid around the farms.

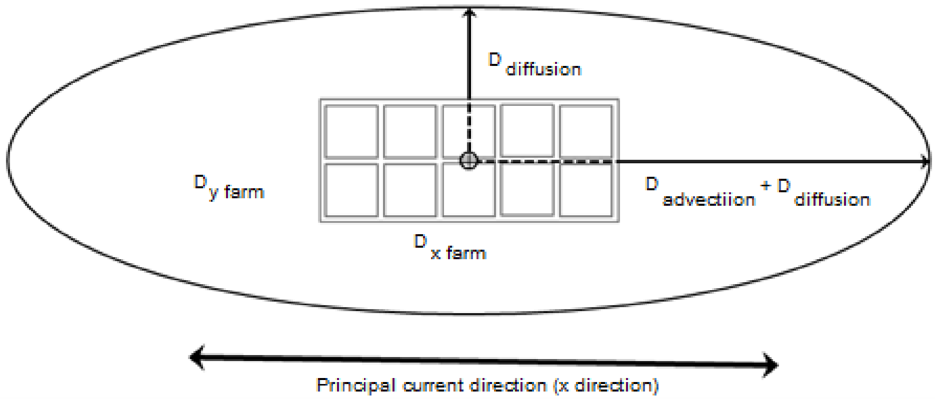


Figure 3.2: Footprint area based on farm dimension (Dx,y) and contribution due to advection and diffusion (Mayerle et al. 2011).

Particle wastes are considered to be distributed over the farm area. Farm dimensions parallel (D_{xfarm}) and perpendicular (D_{yfarm}) to the main current direction are added to the displacement of particulate waste leading to the area in which the total particulate carbon load is spread over the deposition footprint :

$$A_{footprint} \approx \pi.\left(1/_2 . D_{xfarm} + \bar{u}.\frac{h}{w_s} + \sqrt{\frac{E}{\pi}} . \frac{h}{w_s}\right).\left(1/_2 . D_{yfarm} + \sqrt{\frac{E}{\pi}} . \frac{h}{w_s}\right) \text{......(3.4)}$$

The mean deposition per unit area (D_{mean}) is the total farm load (POC_{farm}) divided by the footprint area.

$$D_{mean} \approx \frac{POC_{farm}}{A_{footprint}} \text{......(3.5)}$$

User-defined values in terms of the acceptable rates of carbon deposition on the seabed under the farms are considered. Based on the literature review summarized in Chapter 2, threshold values in terms of deposition rate of 2 g c m^{-2} $d^{-1}$is adopted.

3.3.2 Ecological Carrying Capacity

The ecological carrying capacity is estimated on the basis of the levels of nitrogen within the study area. According to Weston (1996), the total dissolved nitrogen (TDN) emissions from the farms in the area under consideration should not more than 1% of TDN flux inflowing the site under investigation (GESAMP, 2001). The nitrogen loads are obtained on the basis of background concentrations in the region. The mean flushing rates are estimated for the perimeter of the area on the basis of the effective intertidal volume which has been calculated by determining the number tidal cycles required to remove 50% of water per tide, where E represents the effective tidal volume, v is total volume of the embayment, T is the number of tidal cycles (Weston, 1986).

$$E = \frac{0.5\ V}{T} \text{.....(3.6)}$$

FNC finfish culture in Indonesia needs an environmental sustainability assessment to ensure the surrounding environment is not adversely affected by farming emissions. This is achieved by not exceeding the assimilative capacity as well as the degree of impact with respect to particulate carbon, which depends on the rate of emission (production carrying capacity) along with water quality in the sea water column in the vicinity of FNC finfish cultures, based on dissolved nutrient fluxes (ecological carrying capacity). Production carrying capacity calculates aquaculture production and is usually at the farm scale. However, production biomass estimated at production carrying capacity could be limited to smaller areas within a water basin so that the total production carrying capacity of the water basin does not exceed that of the ecological carrying capacity (Byron and Coasta-Pierce, 2010).

3.4 Economic Analysis

The development of Floating Net Cage (FNC) finfish culture in the Indonesian coastal zone is expected to be both environmentally and economically sustainable. Economic sustainability is achieved in those sites in which environmentally sustainable production rates turn out to be profitable. In order to achieve the objective of the economic analysis two steps are necessary. The first step deals with the estimation of the relevant financial indicators, the second step with a ranking of the analyzed cases according to the values of the indicators.

3.4.1 Financial Indicators

Profitability assessments for FNC grouper culture investment are carried out by applying three standard methods of financial analysis: (i) the net present value, (ii) the internal rate of return and (iii) the payback period.

The Net-Present-Value Method

The net present value (NPV) of a project indicates whether an investment in the development of floating net cage culture (FNC) is profitable. Annual variable costs as well as annual revenues during the project are estimated and then discounted to the point in time in which the decision is taken to supply capital for the initial investment (Jacob, 1969):

$$NPV = -I_0 + \frac{a_1}{1+i} + \frac{a_2}{(1+i)^2} + \ldots + \frac{a_n}{(1+i)^n} \qquad \text{.... (3.7)}$$

Under the assumption that *a* is constant over time, taking advantage of the properties of finite geometric series and multiplying eqn. 3.9 with

$$(1+i)^n = a(1+i)^{n-1} + a(1+i)^{n-2} + \cdots + a \qquad \text{....(3.8)}$$

the following equation is obtained:

$$NPV = -I_0 + a\frac{(1+i)^n - 1}{i(1+i)^n} \text{....(3.9)}$$

where

NPV	=	net present value
I_0	=	Initial investment at point in time 0
a_t	=	the net cash flow (surplus over variable cost) expected to be achieved each period t; since a_t= const. ∀ t, $a_t = a$
i	=	the discount rate per period; $i = 13\ \%$
n	=	the number of periods during which the project operates and generates net cash flow; $n = 5$.

For the project to be economically viable, the NPV should be positive (> 0). A positive NPV indicates that the capital invested earns a return that is higher than the benchmark i. For the purpose of this study, the current discount rate of 13% quoted by the central bank of Indonesia is applied.

Internal-Rate-of-Return (IRR) Method

The internal rate of return from FNC development constitutes the actual rate of return on capital earned by the initial investment under the assumption that the net cash flow *a* is realized each period. If the IRR (*r)* is found to be greater than the discount rate (i = 13 %), which is obvious if

NPV>0, then the project is also economically viable according to the IRR. The IRR substitutes r for i in equation 3.9 above, setting equation 3.10 equal to zero and solving for r. The IRR r can be found heuristically from equation 3.11 (Jacob, 1969; Weston and Brigham 1974):

$$0 = -Io + a\frac{(1+r)^n - 1}{r(1+r)^n} \; .... \; (3.10)$$

$$\frac{I_0}{a} = \frac{(1+r)^n - 1}{r(1+r)^n} \; ....(3.11)$$

The Payback Period

In order to assess the time needed to recover the initial capital invested, the following relation is used

$$PaybackPeriod = \frac{InitialInvestment}{PeriodicNetCashFlow} = \frac{I_0}{a} \; .... (3.12)$$

3.4.2 Ranking of the values of the Financial Indicators.

The ranking of the values of financial indicators is carried out with respect to types of grouper cultures, feed and number of cages which are assumed for a FNC farm. In order to understand how the values of financial indicators affect the ranking, the highest value of financial performance which is indicated by NPV, IRR and PP will be presented in chapter 05. Finally, the decision rules for financial analysis of fin fish farming projects will indicate viability if NPV >0 and IRR > 13% along with the shortest possible PP.

3.5 User-friendly Interface

SYSMAR DSS is integrated in a graphical user interface (GUI), which has been constructed in MATLAB by van der Wulp et al. (2010) and amended with additional features by Mayerle et al. (2011). These interfaces have several databases for quick access, and they are linked to a GIS to process and visualize spatial information (Mayerle et al. 2011). In this study the MATLAB version 7.11.0.584 (R2010b), 32 bit (win32), was used.

Input data from different sources is fed into the SYSMAR DSS through an interface and stored in the database component. The applications of SYSMAR DSS imply and show spatial distribution of input parameters. It gathers information from the essential data sources and provides a quick analysis along with an overview of the DSS results.

Practical information through the SYSMAR DSS is accessible by choosing buttons from the opening screen of the interface, as shown Figure 3.3. Under the database menu, new database entries can be added, modified or removed. The following windows are shown to illustrate the presentation of SYSMAR DSS. The next selection window is displayed for preparing a DSS input.

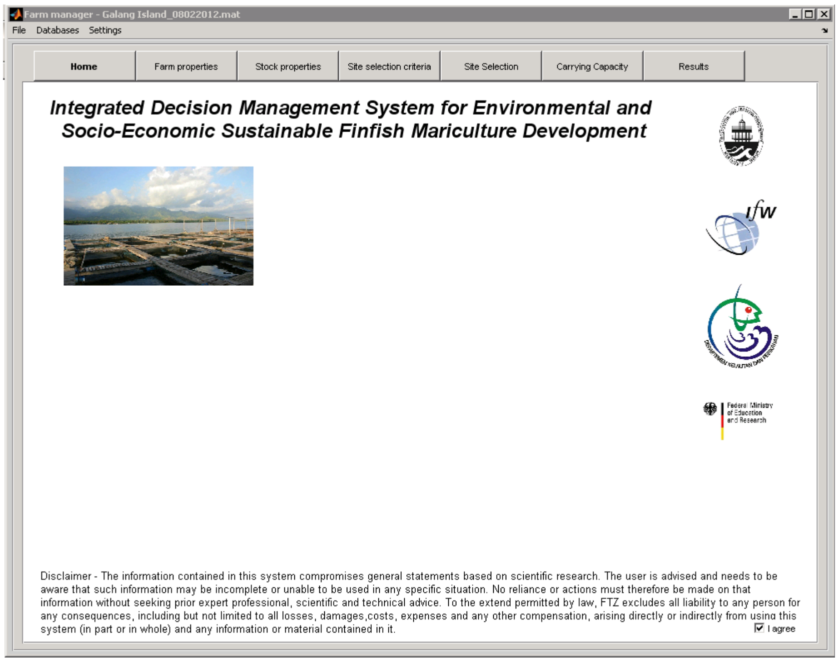


Figure 3.3: The opening screen of the SYSMAR DSS interface (Mayerle et al. 2011)

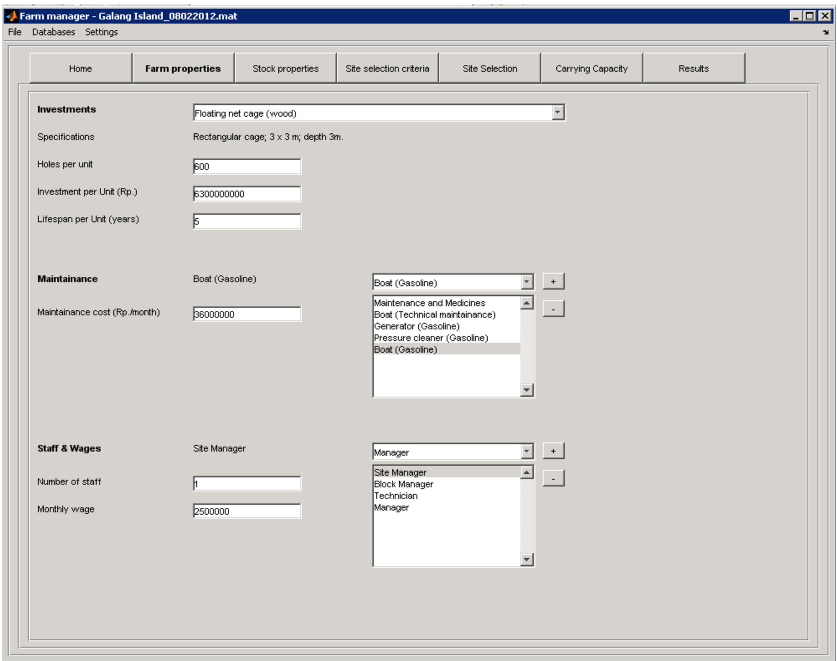


Figure 3.4: Farm properties interface (Mayerle et al. 2011)

Figure 3.4 shows how the window interface of farm properties allows the user to select the FNC grouper culture farm type for decision purposes. The tab allows a specification of farm type, dimensions, investment description, maintenance cost, and staff along with wages of a representative FNC grouper culture unit. It contains farm size, estimated investment cost, maintenance cost, as well as staff and technician wages, and anticipated farm lifespan. Prices given are valid for the local market.

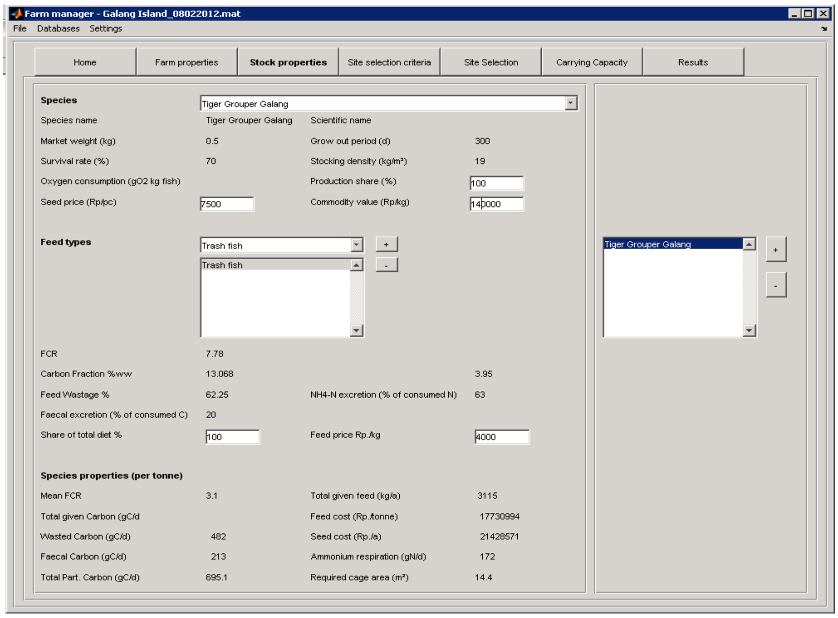
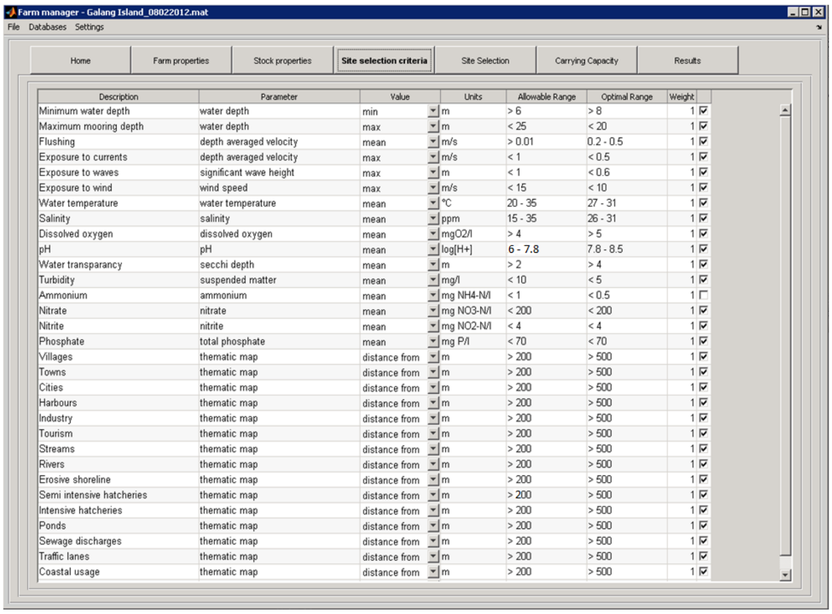


Figure 3.5: Stock properties interface (Mayerle et al. 2011)

In this study, SYSMAR DSS allowed the selection of a combination of one out of three types of grouper species with three feed types. For example: tiger grouper can be selected for species and then combined with feeding by trash fish, pellet, as well as a mix of 30% pellet and 70% trash fish. The selected combination of fish species and feed types allows the DSS to establish the production characteristics per ton of production. Site selectioncriteria are defined in the table shown in figure 3.5.



Description	Parameter	Value	Units	Allowable Range	Optimal Range	Weight
Minimum water depth	water depth	min	m	> 6	> 8	1
Maximum mooring depth	water depth	max	m	< 25	< 20	1
Flushing	depth averaged velocity	mean	m/s	> 0.01	0.2 - 0.5	1
Exposure to currents	depth averaged velocity	max	m/s	< 1	< 0.5	1
Exposure to waves	significant wave height	max	m	< 1	< 0.6	1
Exposure to wind	wind speed	max	m/s	< 15	< 10	1
Water temperature	water temperature	mean	°C	20 - 35	27 - 31	1
Salinity	salinity	mean	ppm	15 - 35	26 - 31	1
Dissolved oxygen	dissolved oxygen	mean	mgO2/l	> 4	> 5	1
pH	pH	mean	log[H+]	6 - 7.8	7.8 - 8.5	1
Water transparancy	secchi depth	mean	m	> 2	> 4	1
Turbidity	suspended matter	mean	mg/l	< 10	< 5	1
Ammonium	ammonium	mean	mg NH4-N/l	< 1	< 0.5	1
Nitrate	nitrate	mean	mg NO3-N/l	< 200	< 200	1
Nitrite	nitrite	mean	mg NO2-N/l	< 4	< 4	1
Phosphate	total phosphate	mean	mg P/l	< 70	< 70	1
Villages	thematic map	distance from	m	> 200	> 500	1
Towns	thematic map	distance from	m	> 200	> 500	1
Cities	thematic map	distance from	m	> 200	> 500	1
Harbours	thematic map	distance from	m	> 200	> 500	1
Industry	thematic map	distance from	m	> 200	> 500	1
Tourism	thematic map	distance from	m	> 200	> 500	1
Streams	thematic map	distance from	m	> 200	> 500	1
Rivers	thematic map	distance from	m	> 200	> 500	1
Erosive shoreline	thematic map	distance from	m	> 200	> 500	1
Semi intensive hatcheries	thematic map	distance from	m	> 200	> 500	1
Intensive hatcheries	thematic map	distance from	m	> 200	> 500	1
Ponds	thematic map	distance from	m	> 200	> 500	1
Sewage discharges	thematic map	distance from	m	> 200	> 500	1
Traffic lanes	thematic map	distance from	m	> 200	> 500	1
Coastal usage	thematic map	distance from	m	> 200	> 500	1

Figure 3.6: Site selection criteria interface (Mayerle et al. 2011)

Figure 3.6 presents the windows of site selection criteria, which allow the user to input data based on several parameters related to suitability and sustainability analysis. In this module, the user can define allowable ranges or optimal ranges with respect to the information data.

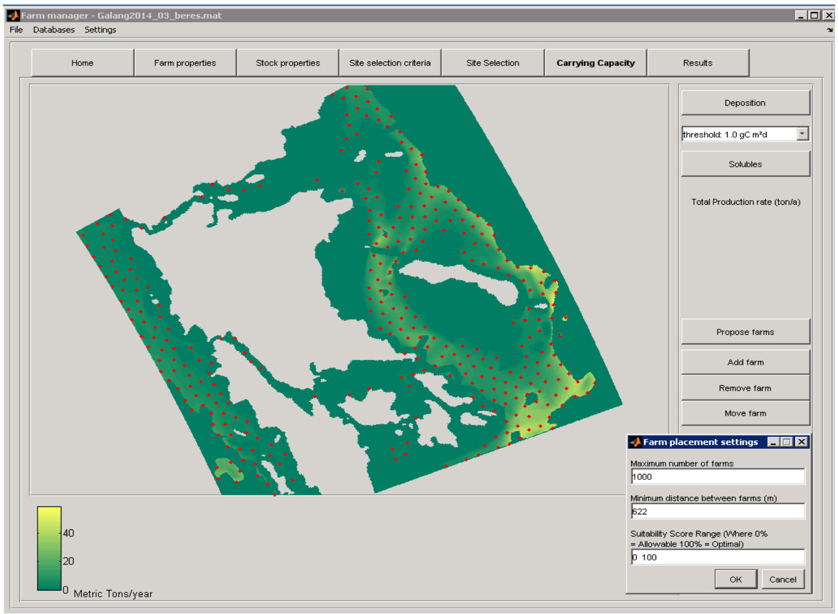


Figure 3.7 : GIS for processing and spatial planning data for carrying capacity (Hermawan et al. 2012)

Figure 3.7 shows how the carrying capacity tabs are used to determine carrying capacities with respect to particulate carbon. Locations can be selected by adding farms (manual or auto). For each farm, the suitability analysis and carrying capacity is summarized including needed farm area and economic analysis. This figure has been generated with a particulate carbon deposition threshold of 1 - 2 g cm^{-2} d^{-1}, as well as the settings of the tab for farm placement with the maximum number of farms being adjusted for farms located at a minimum between farm distance of 500 m.

It can be seen in Figure 3.8 below how an overview of the economic flow of development for a FNC tiger grouper culture fed with trash fish is executed under the SYSMAR DSS interface. The capital cost of 600 cages for a five year project is shown by the annual depreciation cost. The variable cost including maintenance, seed, and feed are also presented. As can be seen from this figure, the wage costs are defined by 1 manager, 1 site manager, 2 block managers as well as 25 technicians (compare Figure 3.4).

A.	Depreciation	Euro/Year
	Floating net cage (wood) (600 holes, 16200 m³)	100,800 €
	--	
		100,800 €
B.	Variable cost	
	Maintenance	
	Freshwater	5,760 €
	Boat (Gasoline)	5,280 €
	Boat (Technical maintenance)	2,880 €
	Generator (Gasoline)	3,840 €
	Maintenance and Medicines	14,400 €
	Seed	
	Tiger Grouper (438000 pcs)	262,800 €
	Feed	
	Pellet(~520 tons)	541,158 €
	--	
		836,118 €
C.	Wages	
	Site Manager	2,400 €
	Manager	4,800 €
	Technician	33,648 €
	Block Manager	3,840 €
	--	
		44,688 €
D.	Revenue	
	Tiger Grouper (~197.1 tonnes)	2,207,520 €
	--	
	Total Revenue	2,207,520 €
	Profit (D - (A + B + C)	1,225,914 €

Figure 3.8: Economic analysis interface of the SYSMAR DSS (Hermawan et al. 2012)

The thesis presents and applies economic models which have been developed as an amendment using SYSMAR DSS in conjunction with a Microsoft Excel spreadsheet program with respect to the cost-benefit analysis technique. All biological data, production cost and profit is obtained from personal communication and literature data from the development of FNC cultures in Indonesia. Data was obtained from many institutions, including Ismi, S (2012) Gondol Research Institute for Mariculture in Indonesia, Indonesian Bank, Act No. 17 in 2010 about progressive tax for domestic agency Indonesian, Ministry of Labor Indonesia, CRITC LIPI – Riau University, and Sugama (2012). The results of the economic studies will be presented in detail, with respect to standard economic analysis. This method has not been comprehensively reviewed and discussed in previous research with the application of DSS.

Chapter 4

Study Areas

4.1 Overview

The Indonesian government aims to expand fish farming activities, especially through small family owned businesses. For this purpose, the Ministry of Marine Affairs and Fisheries (KKP) has proposed a management plan comprising several priority areas. Details of the development plan are summarized in the Ministerial Decree Nr. PER. 01/MEN/2009 on Fisheries Management Area (FMA) of 21 January 2009 (MMAF, 2009). Altogether, eleven FMA were identified, the location of which is indicated in Fig. 4.1.

Figure 4.1: Location of the Fisheries Management Areas in Indonesia (MMAF, 2009)

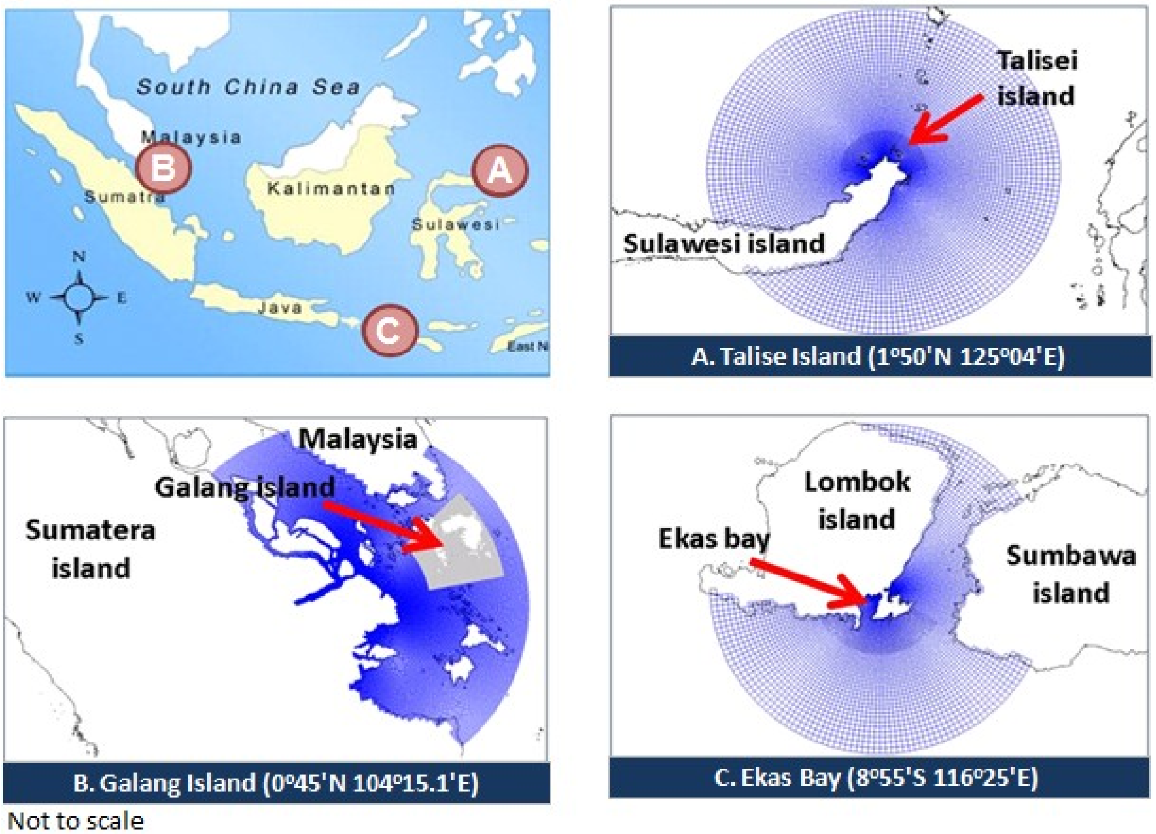


Figure 4.2: Study Areas

In this study, investigations will be carried out at the following three FMA areas identified by the Indonesian government: Talise Island (FMA 716: Sulawesi Sea – North of Halmahera), Galang Island (FMA 571: Malacca Strait – Andaman Sea) and Ekas Bay (FMA 573: Indian Ocean (South of Java) – South of Nusa Tenggara – Suwu Sea – West of Timor Sea). Figure 4.2 shows the location of the three areas, and general descriptions of the study areas are provided in this chapter.

4.2 Investigated Fisheries Management Areas

4.2.1 Talise Island (1^{o}50'N 125^{o}04E)

According to government administration, the village of Talise consists of Talise Island and the small island of Kinabohutan, located just east of Talise Island (Crawford et al. 1998). Talise Island region has hilly areas which are covered by tropical rainforest. The coastline has white sand bordered by mangroves and wild scrubland, as well as fringing reefs (CRMP Sulut, 2001). It is a small island of about 20 km^2, 6 kilometers in length from north to south and about 2 kilometers from east to west. Crawford et al. 1998 reported that Kinabohutan Island is a low lying island of roughly 60 hectares with a small hill on the eastern side. To the north, the shoreline is protected by a mangrove fringe. The western shoreline is a barrier spit that borders the mangroves and is connected to the southern section of the island. The small island of Kinabohutan shows several limestone formations. A small mangrove estuary is placed on the southern end of Talise Island, and the northern end is a rugged, rocky shoreline (see Figure 4.3).

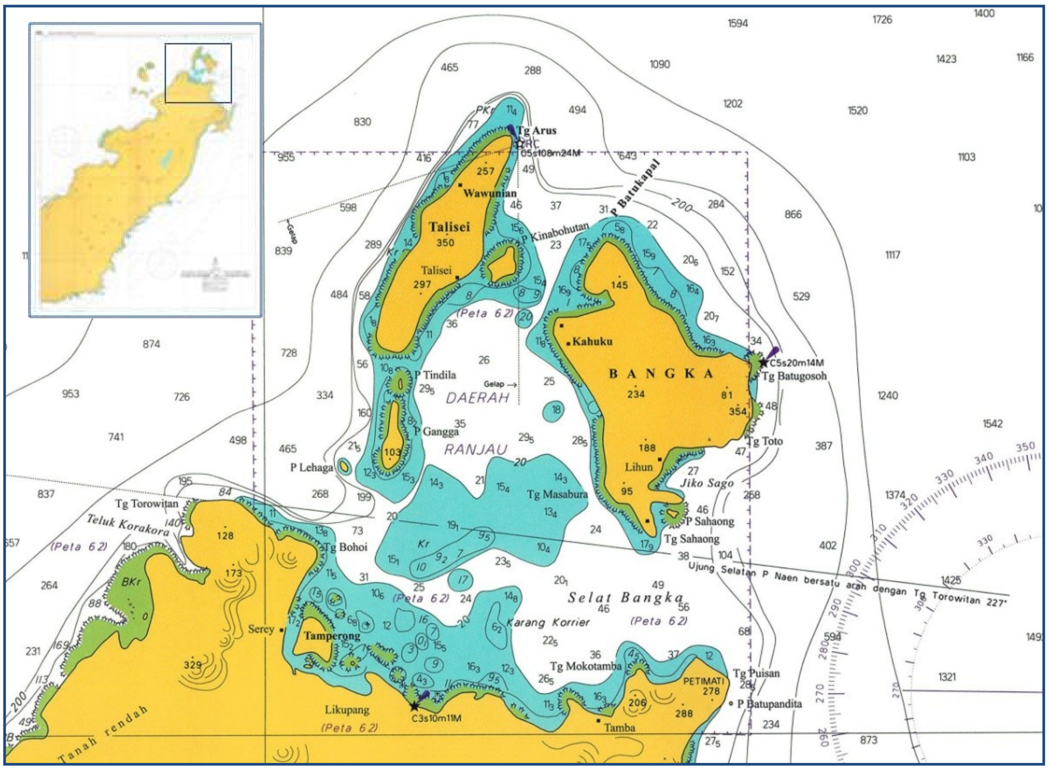


Figure 4.3: Talise Island bathymetry depth with respect to Indonesian Nautical chart no. 344

Concerning the bathymetry in this region, coral reefs surrounding Talise Island and Kinabohutan Island comprised about 198 hectares out of a total reef area (reef flat, seagrass beds and coral) of about 295 hectares (Kusen et al. 1999).This area has coral reefs at depths of around 15 - 20 meters along the coastline. As can be seen in Figure 4.3, the condition of coral reef, mangrove, seaweed at coastal zone area in the vicinity of Talise Island North Minahasa Regency - North Sulawesi Province has been surveyed by Faculty of Fisheries and Marine Sciences (FFMS), University of Sam Ratulangi Manado, 1999.

An examination of the bathymetry and topography made by Crawford et al. (1998) revealed that the area features a shallow trench between 50 to 100 meters in depth to the southeast of Talise. The sea bottom around the island is composed of sandstone and gravel. There are volcanic formations in the vicinity of Talise Island which may be an ancient caldera that exploded, leaving the majority of the present-day crater below sea-level (Wantansen, 2008). Given FNC grouper culture criteria of a maximum depth of 25 m, most of this region, with bathymetry depth above

30 m, as shown in dark brown is considered as inappropriate for the future development of this project (see Figure 4.4).

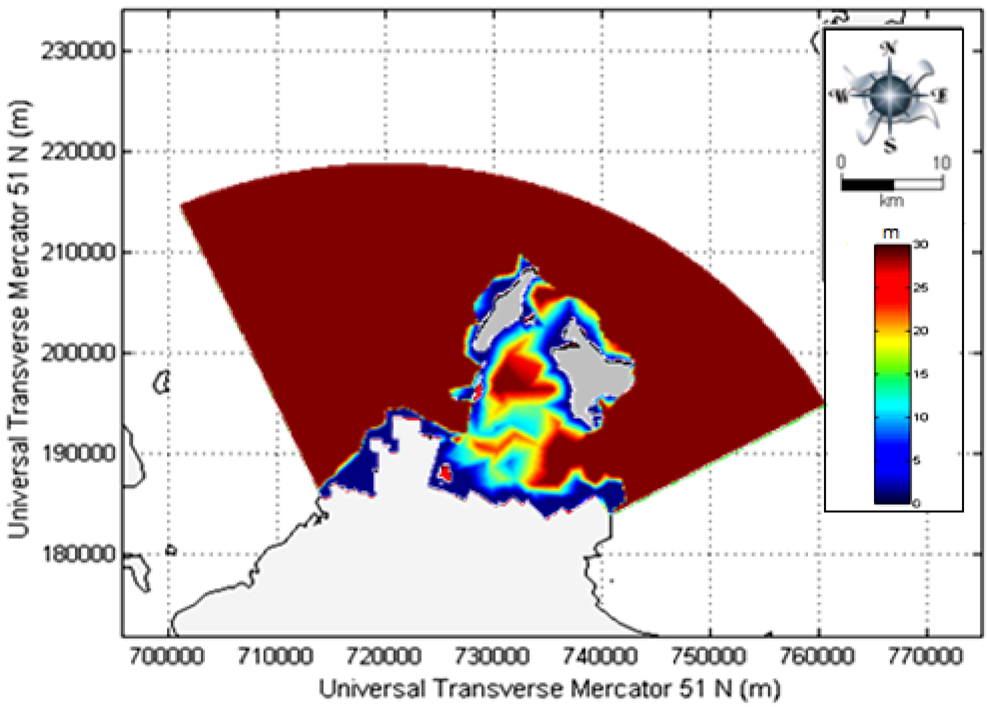


Figure 4.4: Talise Island – Local Model Bathymetry

According to Wantansen (2008), the seawater temperature around Talise Island lies in the range 28.5 °C - 29 °C. Characteristic pH values of 7.9 – 8.25 were observed. Water transparency in the location ranges from 15 to 20 m, and reaches 75 % of the water depth. Salinity ranges from 30.6 – 32.8 PSU. Schlitzer (2011, *Ocean Data View, http://odv.awi.de*) showed that the dissolved oxygen in the surroundings of Talise Island is in the range 4.1 - 4.3 mg/l. BOD_5 values range from 0.58 to 1.58 mg/l and COD values range from 12.7 to 20.8 mg/l. The concentrations of ammonia (NH_4^+) are in the range 0.01 – 0.02 mg/l. Nitrate (NO_3^-) concentration in the area is generally around 0.92 – 1.44 mg/l. The chlorophyll concentrations vary from 0.44 µg/l to 1.73 µg/l and phosphate concentration is in the range 0.015 – 0.05 mg/l. In general the water quality in the surrounding area of Talise Island meets the conditions required for FNC grouper culture (Wantansen, 2008). However, oxygen concentrations in particular required further evaluation.

Information available to account for the ICZM criteria is scarce. Wantansen (2008) reported on villages, tourism areas, streams, rivers, semi intensive hatcheries, coastal usage, and environmentally protected areas (mangrove). There are also pearl culture companies holding concessions from the North Minahasa district government to cultivate an area of about 10,200 ha. However, currently only around 422 ha are utilized.

The hydrodynamics are characterized by strong tidal currents which rip through the passages between these islands as well as between the island group and the mainland of Sulawesi. The flow pattern of the northern waters over the year generally moves from the southwest to the northeast (Wyrtki, 1961). The current magnitudes at the research area are still under 0.51 m/s, namely 0.13 – 0.30 m/s to 0.15 – 0.40 m/s (Wantansen, 2008). According to the Directorate General of Water (1996), the flow was predominantly eastward with a maximum speed of 0.46 m/s. Dishidros (2004) revealed that tides in the vicinity of Talise are predominantly semi-diurnal tides. In order to assess tide fields and make predictions in the vicinity of Talise Island, we extracted the appropriate data from Tide Model Driver TPXO6.2 which was written by Egbert and Erofeeva (2002) and shows that the fluctuation of surface water is of about 2 m. Weekly maximum wave heights in the Moluccas Sea between May 29th – June 05th 2013, provided by the Indonesian Agency for Meteorology, Climatology, and Geophysics, predicted the weekly maximum wave height to be in the range of 0.75 – 1.5 m. Furthermore, the possibility of occurrences of wave heights exceeding more than 3 m is estimated at about 5%.

Further information about hydrodynamics in North Sulawesi came from Sangari (2014), who reported that the potential of maximum tide flood at Mangadistik Minahasa North Sulawesi was about 207 cm. Meanwhile, at Inoboto coast North Sulawesi, Lolong and Masinambow (2011),the maximum wave height from October to March was computed in the range 2.3 m to 4.27 m, along with maximum and average current magnitude of 0.406 m/s and 0.237 m/s, respectively.

There was a large scale pearl farm company holding concessions at Talise North Minahasa district government since the late 1980s with a lease area of about 10,000 ha. However, currently only around 422 ha are utilized, including 77 ha to the north of Kinabohutan Island and a larger area to the south totaling an area of 345 ha (Kusen et al. 1998). While the corporation started as a joint venture with a local firm, since 1998 it has been wholly owned by the Japanese firm of Horiguchi Pearl Co. Ltd (Crawford et al. 1998). On the other hand, the statistical data of Directorate General Aquaculture of the Ministry of Marine Affairs and Fisheries (2013) at North Sulawesi province revealed that the production of grouper in 2008 to 2012 had declined. The volume of grouper culture production in 2008, 2009, 2010, 2011 and 2012 was 96 t, 212 t, 198 t, 163 t and 91 t, respectively. There is currently no fish farming activities in the waters surrounding Talise Island. However, the chairman of MMAF of Minahasa Utara regency (2012) reported that the production of grouper in this region was 10 t/a, which was cultured in the vicinity area of Kinabohutan Island (a small island east of Talise island) (Siwi, 2012a, 2012b).

According to the Ministry of Marine Affairs and Fisheries (MMAF, 2013), the North Minahasa Regency government will be developed into a center for seaweed production in Eastern Indonesia by 2015, with an estimated production of about 1.1 million t/a. To achieve these targets, the MMAF has launched a regional vision as the largest seaweed producer in 2015 and also encourages local governments and communities of this district to expand the cultivation area.

4.2.2 Galang Island (0^{o}45'N 104^{o}15.1E)

As a part of the Riau Archipelago, Galang Island has become the 32^{nd} Indonesian Province in accordance with the Act No. 25 in force since 2002. The island covers an area of about 80 km^2. It is located in the southern part of the Malacca Strait, in the southern part of the South China Sea, and about 40 km southeast of Kota Batam. The island is currently under the administration of Kecamatan Galang Kota Batam, Batam City, Riau Archipelago Province. The sub district Galang comprises 120 islands covering the total area of 14,610 km^2. Only 36 islands are populated. About 14,600 inhabitants live in Galang Island (http://skpd.batamkota.go.id/galang/).

The condition of the bathymetry with respect to Indonesian nautical chart no. 42 can be seen in Figure 4.5. Generally, the sea water in the vicinity of Galang is categorized as a shallow area which is surrounded by coral reef. Near Galang Island there is small island to the east, including Karas island and Karas kecil island. The depth of seawater in the vicinity Galang island is mostly less than 15 m, only the eastern area and a small area in the southwest have a depth of about 25 m (see Figure 4.6).

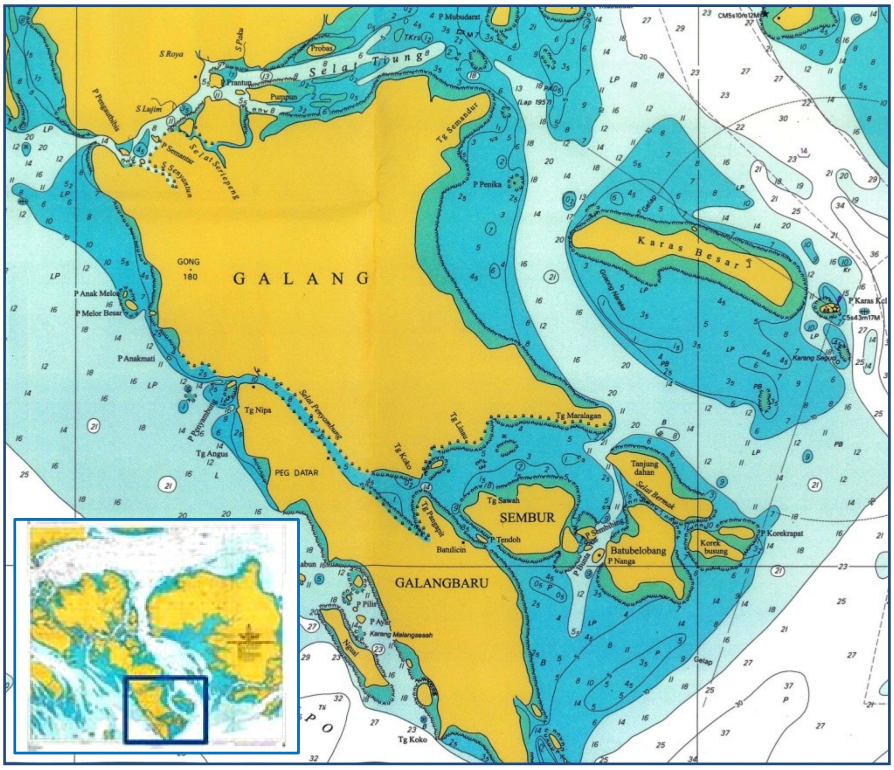


Figure 4.5: Bathymetry depth with respect to Indonesian nautical chart no. 42

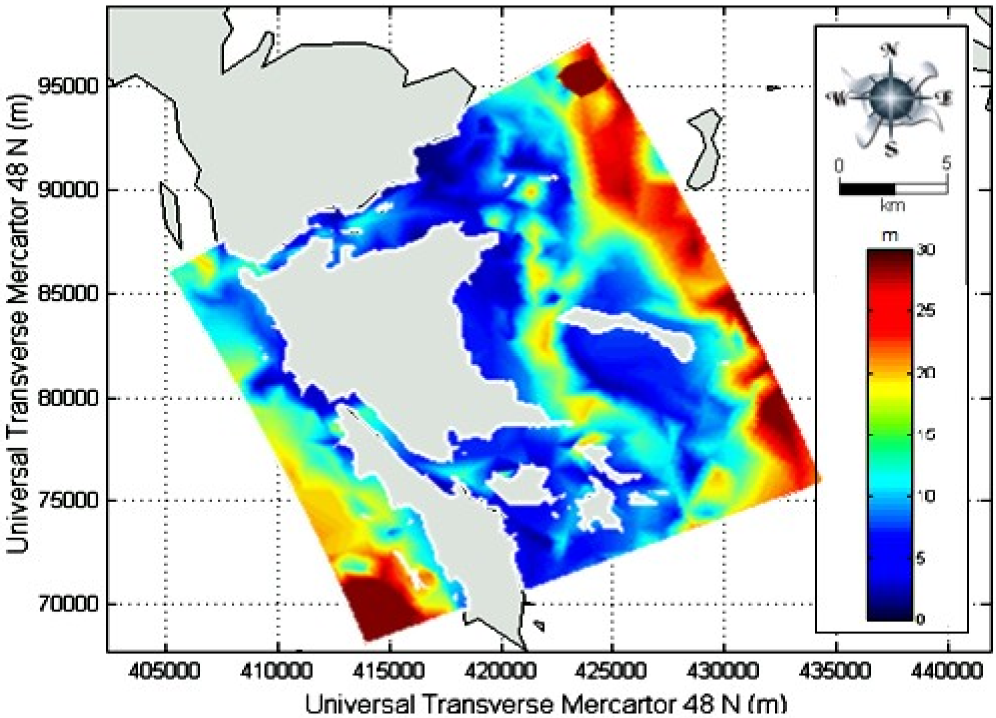


Figure 4.6: Galang Island-Local Model bathymetry

According to CRITC (2009), dissolved oxygen concentrations are in the range of 6.9 – 8.2 mg/l. Salinity ranges from 32 – 35 psu. The sea water temperatures vary between 26 - 29^{o}C.

Characteristic pH values of 8.20 – 8.80 were observed in the area. Secchi depth ranges from 2.5 to 10 m. The average current velocities ranges from 0.2 to 0.4 m/s. The Research Development Centre of Ocean Geology (2005) revealed that nitrate concentrations were in the range 0.002 - 0.078 mg/l, and nitrites were between 0.002 and 0.431 mg/l. Characteristic turbidity values are about 8 mg/l. According to Diansyah (2006), the phosphate concentration ranged from 0.001 to 0.006 mg P / l, water temperatures are in the range 28 – 29^oC, dissolved oxygen vary between 4.3 and 4.4 mgO_2/l. On the basis of the information available, the water quality in the surrounding area of Galang Island is acceptable for FNC grouper culture development. As with Talise Island, attention should be paid to oxygen concentrations.

The rainy season in the region is longer than the dry season, which affects the climate, in particular air temperature and precipitation (CRITC, 2009). In 2005, the minimum and maximum air pressure were respectively equal to 100.5 kPa and 101.8 kPa. The average humidity ranges from 77 to 86%. Maximum wind speed is reported in the order of 13.4 m/s. The amount of rainfall during 2005 was 2,171 mm within 220 days rainy days. Windupranata (2007) revealed that significant wave heights in the vicinity of Galang Island are in the range 0.6 – 1 m. The mixed semidiurnal tides have a tidal range varying between 0.6 and 2.8 m (Dasminto, 2007). Field measurements carried out at several locations in the Galang sub-district from May to November 2009 by the Coral Reef Information and Training Centers (CRITC), Indonesian Institute of Science (LIPI), resulted in recorded tide heights of around 1.2 – 1.5 m.

According to CRITC (2009), dissolved oxygen concentrations are in the range of 6.9 – 8.2 mg/l. Salinity ranges from 32 – 35 psu. The sea water temperatures vary between 26 - 29^oC. Characteristic pH values of 8.20 – 8.80 were observed in the area. Secchi depth ranges from 2.5 to 10 m. The average current velocities ranges from 0.2 to 0.4 m/s. The Research Development Centre of Ocean Geology (2005) revealed that nitrate concentrations were in the range 0.002 - 0.078 mg/l, and nitrites were between 0.002 and 0.431 mg/l. Characteristic turbidity values are about 8 mg/l. On the basis of the information available, the water quality in the surrounding area of Galang Island is acceptable for FNC grouper culture development. As with Talise Island, attention should be paid to oxygen concentrations.

Data from the National Development Planning Agency (NDPAa) was collected to assess the ICZM criteria near Galang Island. Information was gathered on villages, tourism, semi intensive hatcheries or mariculture areas, traffic lanes, coastal usage for strategic areas, as well as environmentally protected areas (coral reef region). The sea covers 96 % of the total area of the territory. This makes it very favorable for developing mariculture activities, including hatchery cultivation, and snapper fish farming, seaweed cultivation and floating net cage (FNC) farms cultivating groupers are in operation. However, current development is quite slow.

According to an assessment by the MMAF (2013) of the Riau Archipelago province, the potential for development of mariculture activities in the area is huge. Sustainable production has been estimated at more than 140 thousand tons per year for marine fish and 179 thousand tons per annum for seaweed (http://profilkp.kepulauanriau.info/#). On the other hand, CRITC (2009) revealed that the production of fish farming culture at Galang District was about 87 tons in 2007, and the statistical data of Directorate General Aquaculture of the MMAF (2013) at Riau Archipelago province showed that the production of grouper had declined from 2008 to 2012. Volume of grouper culture production in 2008, 2009, 2010, 2011 and 2012 was 906 t, 851 t, 3.200 t, 1.512 t and 1.202 t, respectively.

4.2.3 Ekas Bay (8^{o}55'N 116^{o}25E)

Ekas Bay is located south of Lombok Island, Southwest Kabupaten (Regency) Lombok Timur, Sub district Jerowaru. The total area of the bay was 5,640 hectares, but only 3,400 hectares with potential for mariculture (CCMRS-IPB, 2004; Wibowo, 2007). The remaining areas of about 1,900 hectares are shallow or dry during low tide (CCMRS-IPB, 2004; Wibowo, 2007). Ekas Bay has a tropical climate. The average amount of rainfall is 1,882 mm/year within 15 rainy days per month. This area is generally influenced by westerly and easterly winds. At peak strength between June and September the wind blows from the east with a maximum speed of 7.7 m/s. Daily air temperature in East Lombok Regency ranges between 19 and 33^{o}C with an average humidity of 74% - 85% (East Lombok Profile, 2002).

The bathymetry of coastal water of the Eastern Lombok Regency is categorized into near shore coastal areas and steep coastal ramps. This bay lies north to south with a narrow width at the southern part of the bay. This part is a barrier to protect energy which comes inside the bay (see Figure 4.7). According to measurements from CCMRS-IPB (2004), the water depth ranges between 0 and 70 m where shallow areas are mostly found in the northern part of the bay. As can be seen in Figure 4.8, the surrounding coastal areas in the vicinity of Ekas Bay mostly have depths of less than 10 m at the eastern, northern and western parts of Ekas Bay. Regarding the CCMRS-IPB (2004) survey, the depth at the northern part was about 0 – 37m. In the middle region, there was crevice/cranny between 26 to 37 m. Meanwhile, the west coast bathymetry was more slightly sloping than the east coast. At the narrow part of Ekas Bay, there were 3 troughs of about 43 m to 56 m.

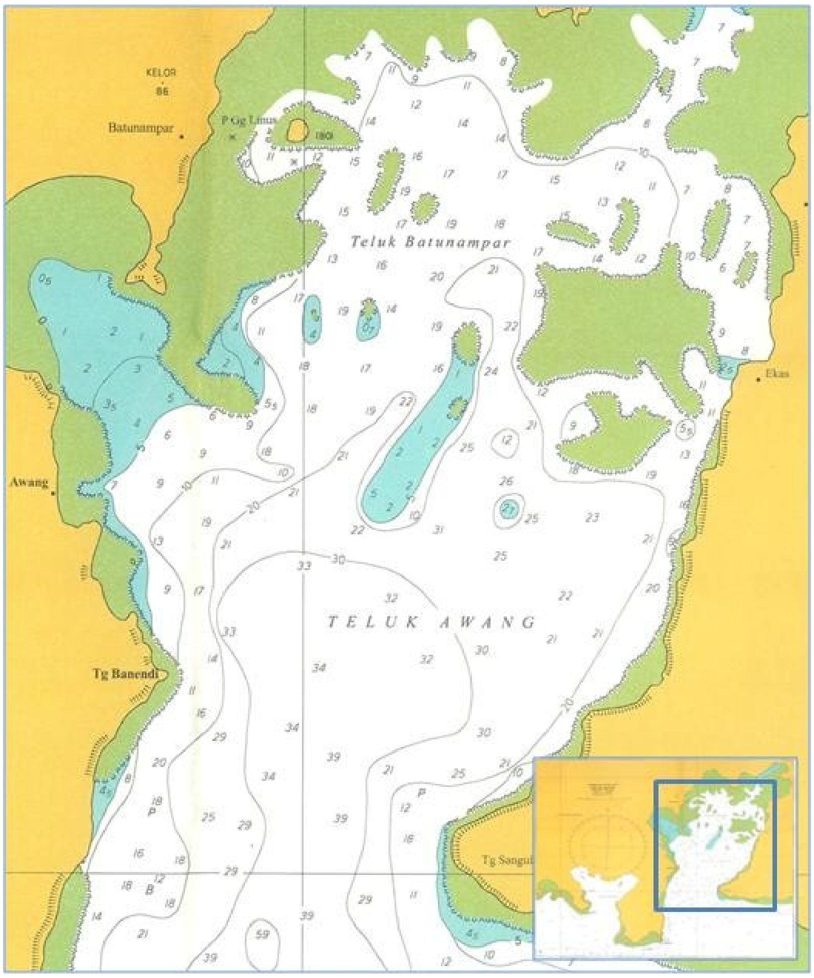


Figure 4.7: Ekas Bathymetry depth with respect to nautical chart no. 262

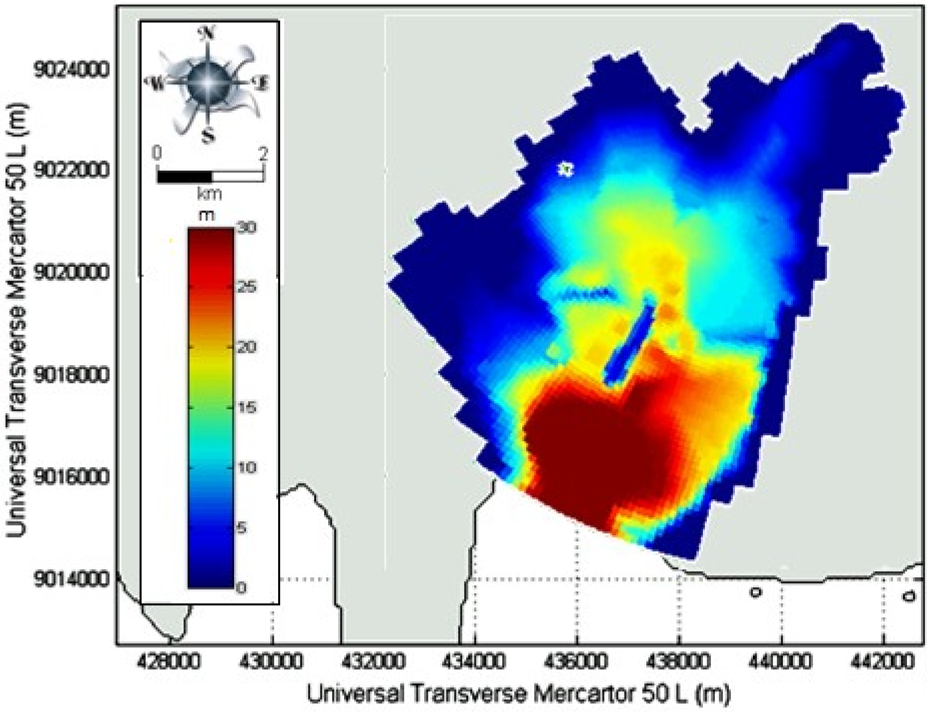


Figure 4.8: Ekas Bay – Local Model bathymetry

Krisanti and Zulhamsyah (2006) carried out investigations at four stations in Ekas Bay: at a location far away from FNC activities, on a site with numerous FNCs, on a site with a high concentration of FNC, and on a site very close to land. The results show that seawater temperatures range from 26 to 30°C. Salinity ranges from about 34 to 35 psu. Total suspended solids varied from 8 to 22 mg/l. PH values vary from 8.0 to 8.5. Dissolved oxygen concentrations were 5.9 – 8.4 mg/l. Ammonium (NH_4^+), Nitrite (NO_2) and nitrate (NO_3) concentrations were in the range of 0.05 – 0.33 mg/l, 0.001 – 0.010 mg/l, and 0.376 – 0.936 mg/l, respectively.
Regarding water quality, the evaluation showed that the chemical and physical conditions in the vicinity of Ekas Bay were viable for developing mariculture activities. However, particular care should be given to the oxygen concentrations. In general, the parameters qualified for sea life standard water quality.

Model simulations by CCMRS-IPB (2004) revealed that average current magnitudes from April to August are in the range 0.05 – 0.40 m/s. From September to December this is much lower, in the order of 0.10 m/s. The maximum measured wave heights outside and inside the bay were respectively equal to 2.6 m and 1 m. During a measurement campaign from May to November 2009, the current speed varied between 0.15 and 0.27 m/s (Wibowo, 2007). Wibowo (2007) measured pH values from 7.7 to 8.25 in August and 7.3 – 7.7 in December. The difference is caused by the highest temperature during August (dry season) when pH is higher than in December. Dissolved oxygen concentrations were around 3.2 to 8.5 ppm. The variances were attributed to different times of the measurement which were carried out at 08.00 am and 13.00 am.

Besides its potential for capture fisheries, the coastal waters of East Lombok also have potential for marine aquaculture activities (Aslianti et al. 2002). According to the statistical data of the Directorate General Aquaculture of the MMAF (2013) at Nusa Tenggara Barat province, the production of grouper in 2008, 2009, 2010, 2011 and 2012 was 169 t, 177 t, 207 t, 256 t and 279t, respectively. Concerning the study area in the vicinity of Ekas Bay, Sunoto (2014, 2012) presented that the potential area of grouper culture was 509 Ha alongside the existing area of 9 ha, and total production was 12.60 t in 2009. Further marine aquaculture production in 2009 was about 0.2 tons of pearls, 146 tons of lobster, and 118,975 tons of seaweed.

The information required for the development of the models and application of the DSS was collected from existing data, several projects, government agencies, published data, and from numerical model simulations. Besides data from previous measurements documented by several authors, agencies and internet were also used. Physical-chemical properties of seawater were taken from global model data (see Appendix 1). Current velocities and waves were taken from model simulations. ICZM data were extracted from maps of regional planning and published data. Chemical properties were obtained from agencies and measurement data from projects conducted in the vicinity of the selected areas.

Chapter 5

Flow and Wave Models

5.1. Overview

In this chapter, the development and application of flow and wave models for three selected Fisheries Management Area (FMA) sites is presented. A description of the model solvers and strategies adopted is followed by a summary of the development phases of the models and results of the application.

5.2 Flow Models

In this section, a description of the flow model solvers used for the simulation of flow and water levels, and the techniques adopted for providing open sea boundary conditions for the local model are presented. Details of how the flow models are set up for the local areas are also provided.

5.2.1 Model Solver

Flow models were developed to simulate water levels and current velocities in the three selected regions. Simulations were carried out with the two-dimensional depth integrated model developed by Delft Hydraulics in Netherlands (WL|DELFT HYDRAULICS, 2009). Delft3D-Flow forms the centre of the model for the simulation of water motion due to tidal and meteorological forcing by solving the unsteady shallow water equation for the primitive variables of velocity and water level. Staggered finite difference grids with a terrain-following sigma-coordinate system in the vertical as well as fixed vertical coordinate are used. The model solver has the capability to simulate flow conditions based either on a rectilinear or a curvilinear grid system in the horizontal plane. In this study sub-domain decomposition was used to avoid the inherent problems associated with the local refinement of structured grids and to reduce computing time. The model solver is based on the Alternating Direction Implicit method. In the generalized version, it poses no integration time step constrains with regard to the stability of numerical computation. Thus larger time steps are allowed and a reduction in the computation time is achieved. The only limitation to the integration time step is posed by the accuracy requirement. The method adopted enables simulation with courant numbers as high as 10 (Lesser et al. 2004; Roelvink and Banning, 1994).

5.2.2 Domain Decomposition

Domain decomposition was used in the development of the regional models. The approach implemented in Delft3D-Flow is based on a subdivision of the domain decomposition into non-overlapping domains, with the possibility for grid refinement in both the horizontal and vertical direction (WL|DELFT HYDRAULICS, 2009). This allows for a nearly optimal distribution of grid points. It should be noted that a domain decomposition approach is based on a subdivision of the model into non-overlapping domains, each one covering its own structure grid. Therefore, the numerical approach best meets the demands of efficiency, accuracy, and general applicability. Furthermore, tools have been developed to increase the user friendliness of the domain decomposition application. Data exchange and the algorithms for the coupling of sub domains and local grid refinement are handled in separate processes. The sub domains are computed as an individual process using a multi processor configuration which achieves considerably greater speeds. In this way, the modeling flexibility for the grid development technique increases considerably. The advantages of a multi domain modeling approach for flow and transport problems are an efficient iterative method which has been used for solving the discretised equations over the domains, modeling flexibility and accuracy.

5.2.3 Nesting Sequences and Local Models

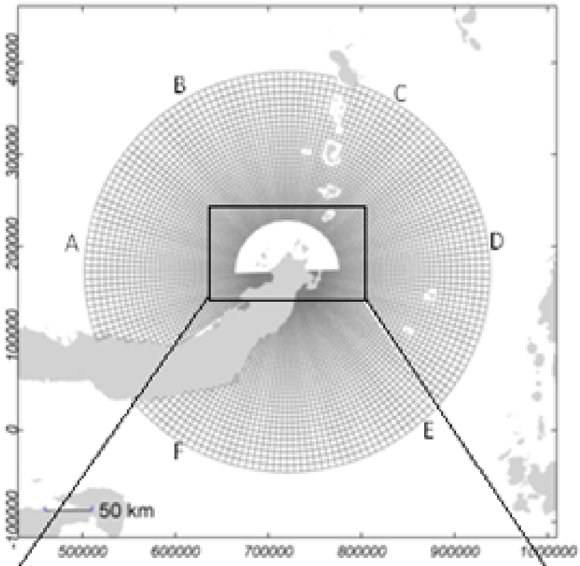
Nesting sequences were set up in order to provide adequate open sea boundary conditions for the three sites. The bathymetry of the models was obtained from several sources. In the near-shore area, nautical charts were digitized (bring the maps used for the other regions. Nr. 344: North Sulawesi and Northeast Coast, Tanjung Mamiri to Tanjung Tolu, scale 1: 200.000). In the deeper regions, depths were taken from GEBCO online database (See Appendix). Astronomical tides derived from the global ocean tide model TPXO 6.2. were imposed along the open sea boundaries of the large-scale models. In this study, thirteen harmonic components (M2, S2, N2, K2, K1, O1, P1, Q1, MF, MM, M4, MS4, and MN4) were used to drive the models. Due to the large extensions of the open sea boundaries, several segments were considered. In order to determine the appropriate set-up for local models, sensitivity investigations with respect to time steps and bed roughness were carried out. The resulting nesting sequences for the domains in questions are shown in Figure 5.1 to Figure 5.5.

The assessment of the grids (Talise Island, Galang Island, and Ekas Bay) served to carry out the next phase of model development. Sensitivity analysis with respect to numerical and physical parameters including time step, eddy viscosity, roughness coefficients and wind was carried out. A simulation period of one month (January 1st to January 30th 2009) was considered. In general, the influence of wind on the flow conditions was investigated by considering a constant maximum wind speed. In addition, two periods with maximum wind speed during the simulation period show the significance of wind drag in changing the model results concerning water level and current velocities of the regional models.

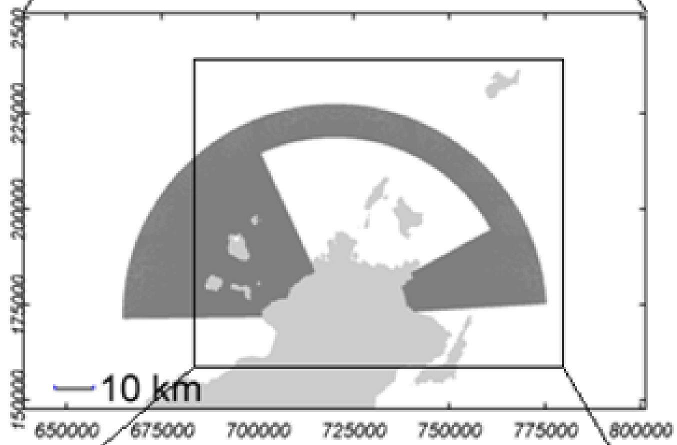
In general, it was found that satisfactory results can be obtained at boundary conditions for the local models. Regarding numerical parameters, acceleration due to gravity, water density, horizontal eddy viscosity, threshold depth, and marginal depth are set up as default values, wind input is according to Egbert and Erofeeva (2002) NCEP wind analysis, smoothing time is 60 minutes, and interval data is stored every 15 minutes. Simulation periods are set up to maximum wind condition for 2 weeks, time step is 0.01 minute for Talise Island, with 0.1 minute for Galang Island and Ekas Bay. Manning roughness are 0.025 $m^{1/2}/s$, 0.025 $m^{1/2}/s$, 0.030 $m^{1/2}/s$ respectively for Talise Island, Galang Island, and Ekas Bay.

Talise Island (1^{o}50'N 125^{o}04E)

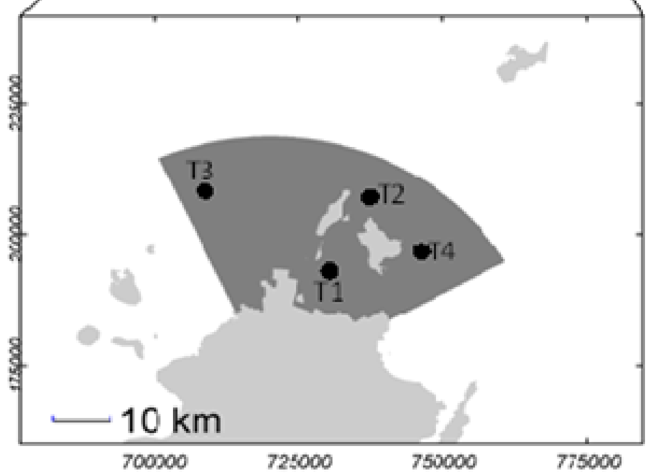
Figure 5.1 shows the grid sequence set-up using DD for Talise Island. The larger scale model grid shown in Fig. 5.1a comprises grid sizes ranging from 547 m to 7742 m. The total number of grid cells is 13,500 (76 cells x 181 cells). Figure 5.1b shows the intermediate grid model with a grid size between 146 m and 647 m resulting in 33,642 grid cells (127 cells x 268 cells). Figure 5.1c shows the grid of the local model with grid size ranging from 52 m to 191 m and 120,960 grid cells (316 cells x 385 cells). Four observation points (T1, T2, T3, and T4) were used to evaluate the results of the hydrodynamic flow model (see Fig. 5.1c). In the present study, emphasis was given to observation points T1 and T2 which are situated nearest to the area of interest.



a. Grid size 547 m to 7742 m, number of grid cells 13,500 (76 cells x 181 cells)



b. Grid size 146 m to 647 m, number of grid cells 33,642 (127 cells x 268 cells)



c. Grid size 52 m to 191 m, number of grid cells 120,960 (316 cells x 385 cells)

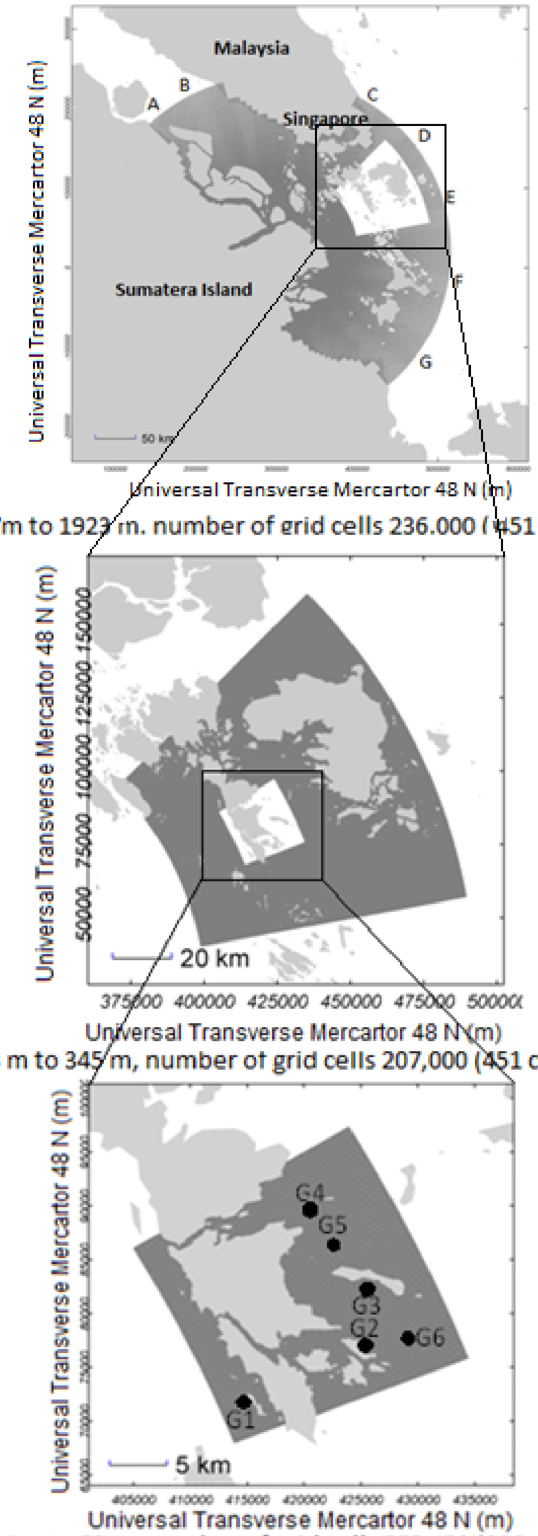
Figure 5.1: Talise Island Nesting Sequence: Large Scale, Intermediate and Regional Models

Galang Island ($0^o45'N$ $104^o15.1E$)

Figure 5.2 shows the nesting sequence developed for Galang Island. In Fig. 5.2a, the larger scale model with grid size ranging from 194 m to 1941 m and 136,240 grid cells (261 cells x 525 cells) is shown. Figure 5.2b shows the intermediate grid model with grid size from 185 m to 347 m and 122,475 grid cells (356 cells x 346 cells). Finally, in Figure 5.2c the local model of Galang Island with grid size varying from 44 m to 52 m, with 207,000 grid cells (451 cells x 461 cells) is shown. In this figure, six observation points (G1, G2, G3, G4, G5, and G6) are shown. Attention was given to the conditions at the observation points G1 and G2 respectively located on the west and east side of the island.

Ekas Bay ($8^o55'N$ 116^o25E)

The DD grid development in the Ekas Bay model is shown in Figure 5.3. Only two models were considered. The regional model of Ekas Bay comprises 14,352 grid cells (105 cells x 139 cells) with grid spacing ranging from 59 m to 2310 m. The grid of the local model is constructed with sizes varying between 17 m and 145 m, and 23,200 cells (181 cells x 130 cells). There are 6 observation points (E1, E2, E3, E4, E5, and E6) allocated to the local model. Attention was given to the conditions at observation points E1 and E3.

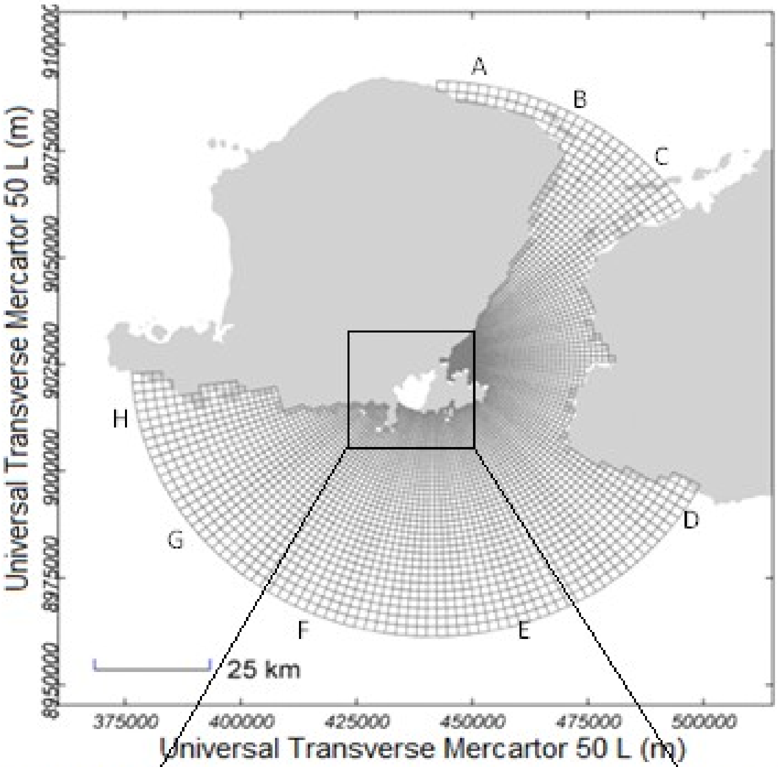


a. Grid size 477m to 1923 m. number of grid cells 236.000 (451 cells x 525 cells)

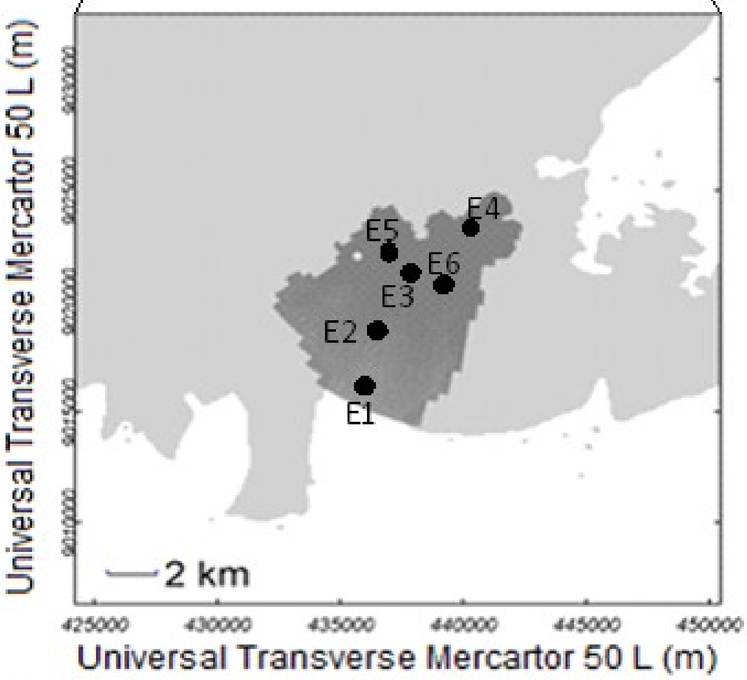
b. Grid size 183 m to 345 m, number of grid cells 207,000 (451 cells x 461 cells)

c. Grid size 44 m to 52 m, number of grid cells 555,450 (806 cells x 691 cells)

Figure 5.2: Galang Island Nesting Sequence: Large Scale, Intermediate and Regional Models



a. Grid size 59 m to 2310 m, number of grid cells 14,352 (105 cells x 139 cells)



b. Grid size 17 m to 145 m, number of grid cells 23,220 (181 cells x 130 cells)

Figure 5.3: Ekas Bay Nesting Sequence: Large Scale and Regional Models

5.3 Wave Models

Wave effects are integrated in the flow model simulation by the third generation SWAN wave processor developed at Delft University of Technology, Netherlands (Holthuijsen, 2007; Ris 1997). SWAN is based on a discrete spectral action of density that accounts for refractive propagation of random, short-crested waves over arbitrary bathymetry and current fields. Physical processes included are: generation of waves by wind, refraction, shoaling, wind-induced generation and dissipation due to white-capping, depth-induced wave breaking, bottom friction, and non-linear quadruplet and triad wave-wave interactions. The model is fully spectral, i.e. it solves the spectral action balance for a specified number of directional sectors and frequency intervals. The wave module also allows full coupling with the flow module of the Delft3D model suite. Both wave and flow processes can be simulated on curvilinear grid systems, which assign an accurate and very efficient representation of complex areas. The wave models developed in this study adopt grids which are coarser than the ones used in the flow model simulations.

5.3.1 Talise Island

To provide information about wave conditions in the vicinity of Talise Island, wave model simulations were carried out. The results of the flow were coupled to run the wave model. SYSMAR DSS wave criteria relates to maximum wave height, where the potential maximum wave height corresponded to the highest wind velocity. Wave model simulations were carried out for such conditions. Six-hourly wind analysis data from Egbert and Erofeeva (2002), NCEP data base was analyzed for a 5 year period (2005 – 2009) in order to identify extreme wind events.

The results obtained from the preliminary analysis of wind rose and wind class distribution in Talise Island are shown in Figure 5.4. Regarding statistical analysis, wind speeds are divided into 9 classes and wind directions into 32 sectors subdividing the typical 8 classes of wind directions for the sake of accuracy (north, northeast, east, southeast, south, southwest, west, and northwest). 55% of wind data are in the range of 0 – 8 m/s and the main wind directions are from east and southeast with 43.2% and 27.2% of the wind direction respectively. It shows that Talise Island area is in the category of fresh breeze (8.0 – 10.7 m/s on the Beaufort scale, because the dominant wind speed is above 8 m/s with 45% of total occurrences. Only 2% of wind data show a wind speed over 14 m/s. Maximum wind speed over this period is 19.6 m/s and direction 117^{o}.

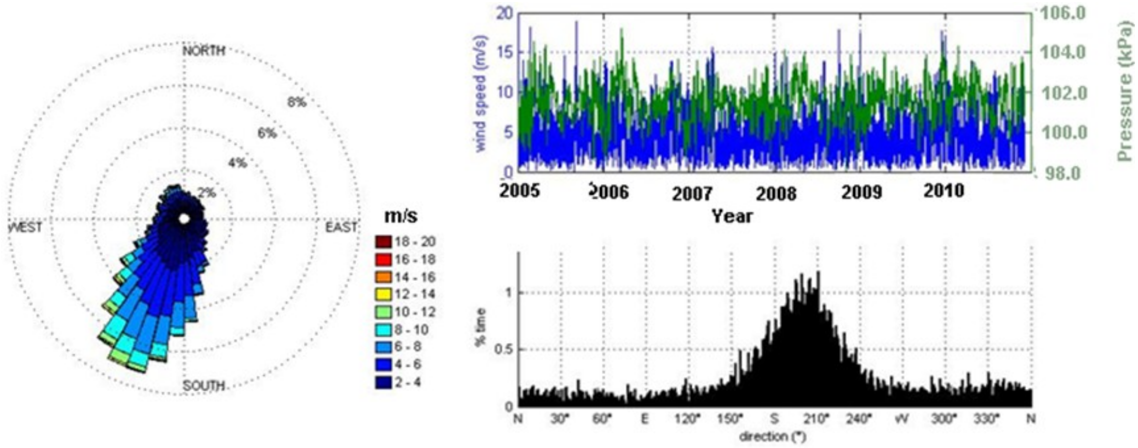


Figure 5.4: Wind rose and class frequency distribution at Talise Island Model from Egbert and Erofeeva (2002) NCEP wind data 2005 – 2009

5.3.2 Galang Island

For the purpose of information regarding wave conditions in the vicinity of Galang Island, wave model simulations were applied within the same period (2005 – 2009). On completion of wave modeling, the associated process of hydrodynamic results to run the wave model is carried out. Wind rose and wind class generation in Galang Island can be seen in Figure 5.5. 88% are in the range of 1 – 4 m/s, and the main wind directions are west and southwest (38.9% and 36.2% of the wind directions respectively). The region is characterized by relatively calm weather. Wind speeds exceeding 7 m/s are sporadic (about 0.04 % of time). Maximum wind speed over this period is 7.3 m/s and direction 244^{o}, i.e. wind blowing from the west.

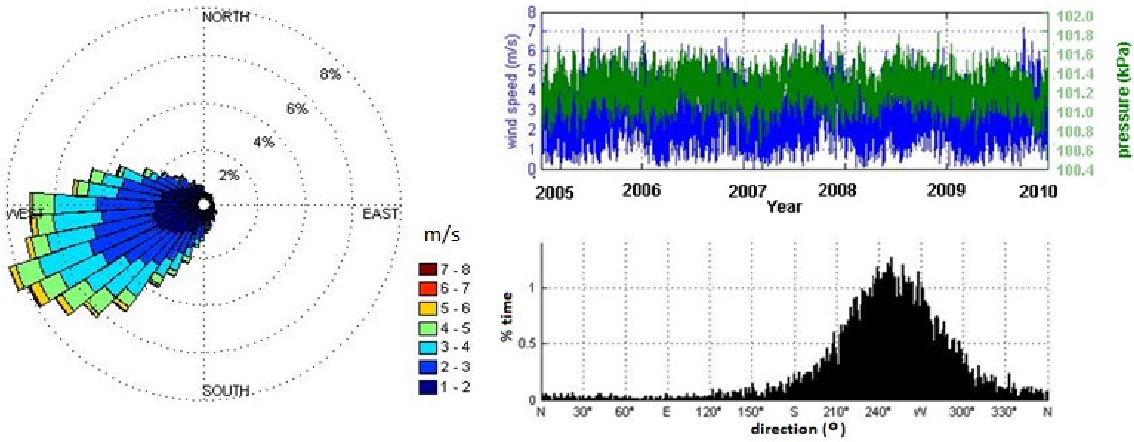


Figure 5.5: Wind rose and class frequency distribution at Galang Island Model from Egbert and Erofeeva (2002) NCEP wind data 2005 – 2009

5.3.3 Ekas Bay

Following the same procedure as for the Galang Island model, the wave models for Ekas Bay were developed. Wave model simulations were carried out for six-hourly wind analysis data from the NCEP database in the period 2005 – 2009. Thus, we identify wind events regarding wave model results in the Ekas Bay regional model as shown in Figure 5.6.

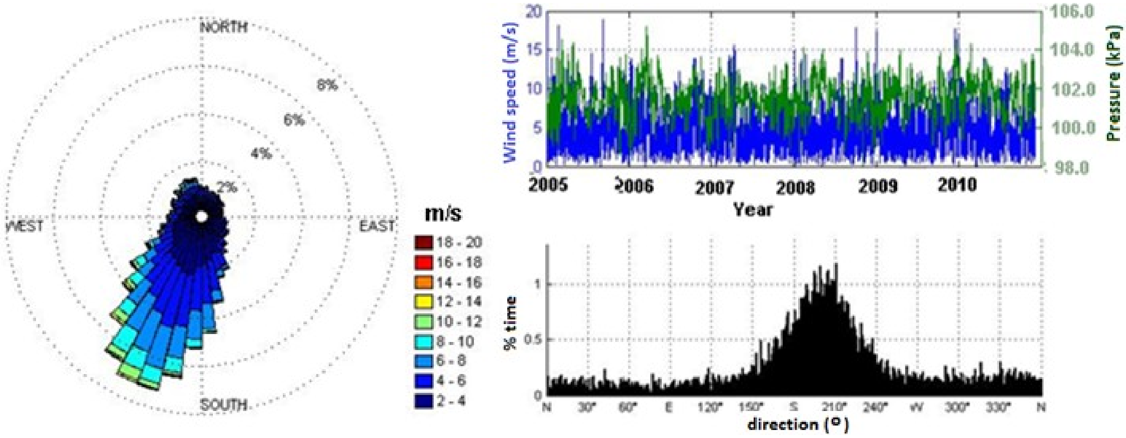


Figure 5.6: Wind rose and class frequency distribution at Ekas Bay Model from Egbert and Erofeeva (2002) NCEP wind data in 2005- 2009

Figure 5.6 visualizes wind rose and wind class generation in the sea surrounding Ekas Bay. It shows 64% are in the range of 1 – 6 m/s, and the major wind directions are south and southwest (38.3% and 32.1% of the wind directions respectively). It shows the Ekas Bay area is in the category of moderate breeze (5.5 – 7.9 m/s) with respect to the Beaufort scale, only 1.1 % of wind data shows wind speeds above 12 m/s. Maximum wind velocity over this period is 19.6 m/s and the direction 206^{o}.

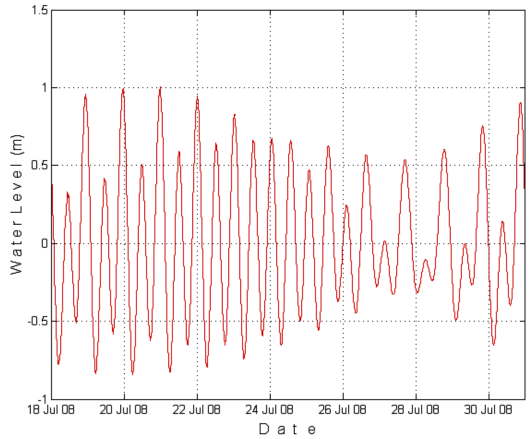
5.4 Results of Model Simulations

5.4.1 Talise Island

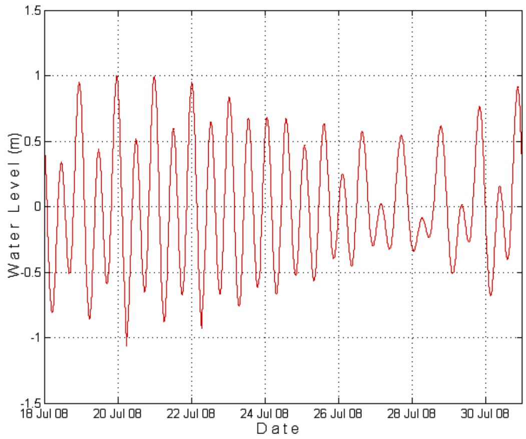
From Figure 5.7, we can see the final simulation of the Talise Island model comparing water level variations, current speed, and current directions at observation point T1 and T2. The results of the fluctuations of surface water level are of about 1.8 m to 2 m (see Figure 5.7a and Figure 5.7b), this finding supports previous predictions which were extracted from Tide Model Driver TPXO6.2 (Egbert and Erofeeva (2002).

To compare the current speed data in Talise Island during the simulation period, the literature study was implemented. These data must be interpreted with caution because the current speed and direction at the two observation points are different. As shown in Figure 5.7c, at observation point T1 the magnitudes are of about 0.15 – 0.25 m/s. These results seem to be consistent with other studies which found the current speed range 0.15 - 0.30 m/s (Wantansen, 2008). Further analysis showed that the current speed at observation T2 is higher than T1. From Figure 5.10d we can see that the magnitude ranges from 0.2 to 1.4 m/s. The unprotected open sea around the location of observation point T2 (see Figure 5.7e and Figure 5.7 f) is responsible for the variance in current magnitude and direction.

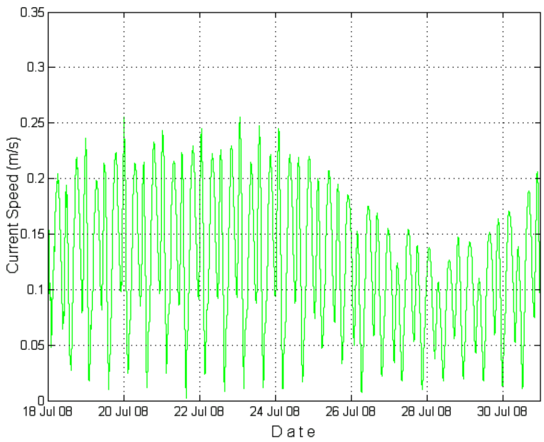
Figure 5.8 illustrates the results of 5 year (2005 - 2009) wave simulations using the NCEP wind data in the vicinity of Talise Island. From the visualization of the significant wave height in the vicinity of Talise Island at two observation points (T1 and T2), a maximum wave height of about 6 m has been identified. This result agrees with our earlier observations. The prediction of the Indonesian Agency for Meteorology, Climatology, and Geophysics showed that there was a 5% probability of an occurrence of wave heights exceeding more than 3 m. The present study is designed to determine the wave characteristics in the vicinity of the study area concerning the development of FNC grouper culture. The results indicate that wave heights at Talise Island exceed about 1 m quite frequently. Thus, it should be noted that from this view point this area is not considered appropriate for the development of FNC projects.



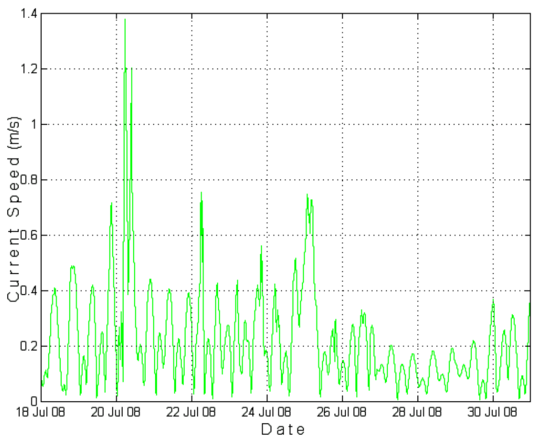
a. Water level at point T1



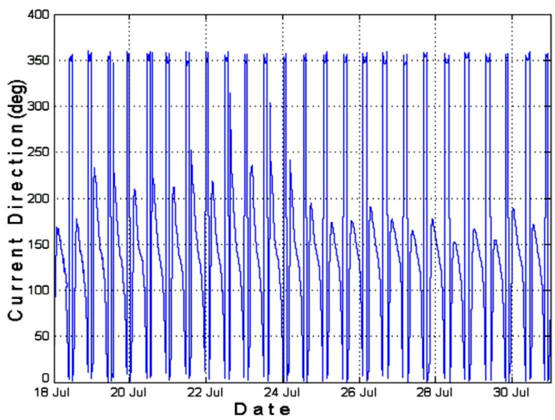
b. Water level at point T2



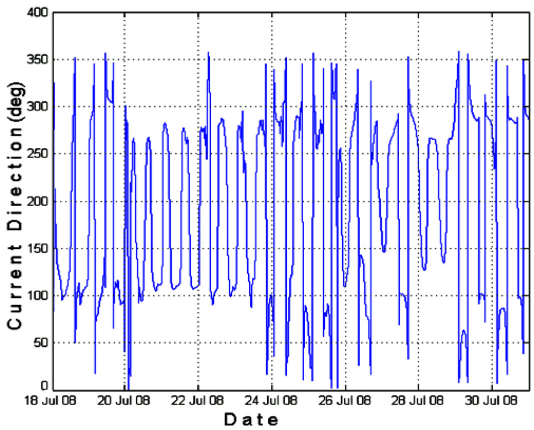
c. Current speed at point T1



d. Current speed at point T2

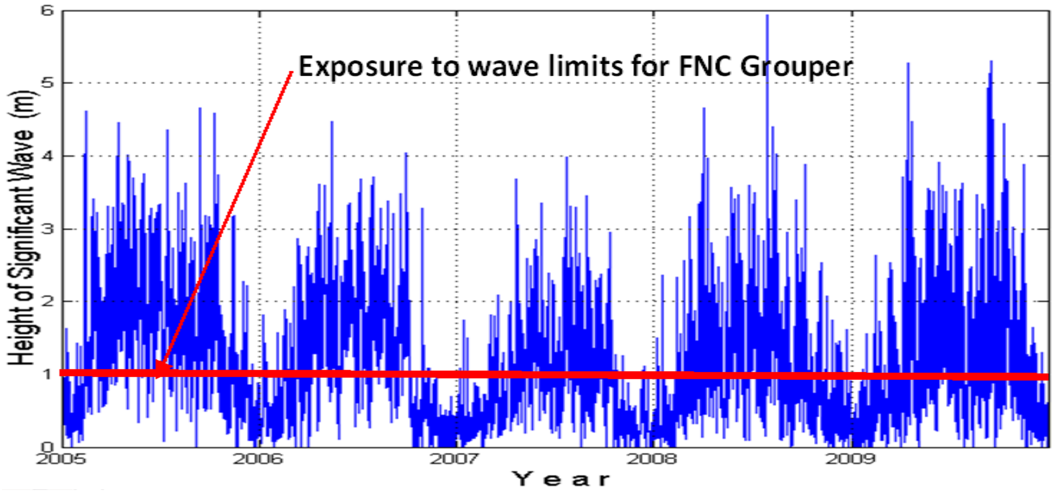


e. Current direction at point T1

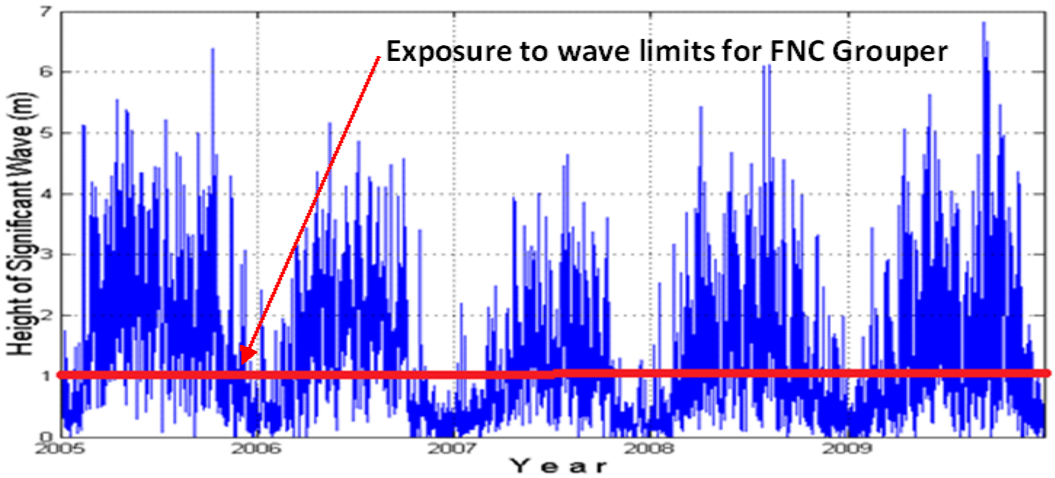


f. Current direction at point T2

Figure 5.7: Hydrodynamic model results at Talise Island Local Model



a. Height of wave at observation point T1



b. Height of wave at observation point T2

Figure 5.8: Wave model results in the vicinity of Talise Island

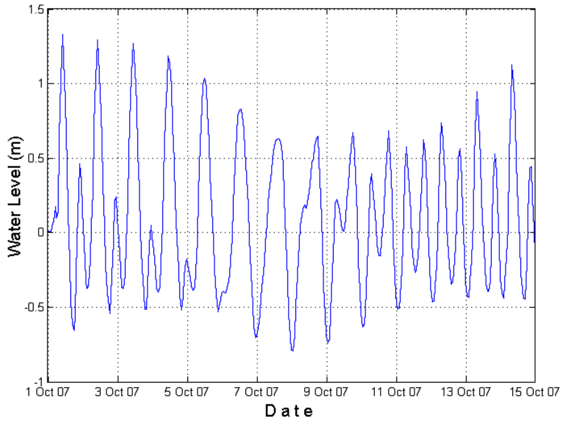
In the literature, no measured data were found in order to compare the physical ocean characteristics in the Talise Island area. However, according to the Indonesian Agency for Meteorology, Climatology, and Geophysics, the likelihood of wave heights exceeding 3 meters was estimated at about 5% and the weekly maximum wave heights (based on data recorded between May 29th and June 05th 2013) in the Moluccas Sea were in the range of 0.75 – 1.5 m. Regarding the assessment of hydrodynamic flow in the vicinity of Talise Island including water level fluctuations as well as current speed magnitude, the results show severe evidence for conditions which are suitable for FNC grouper culture development. However, the wave model simulation showed that these results are not physically appropriate for the development of this project (see Figure 5.8a and Figure 5.8b).

5.4.2 Galang Island

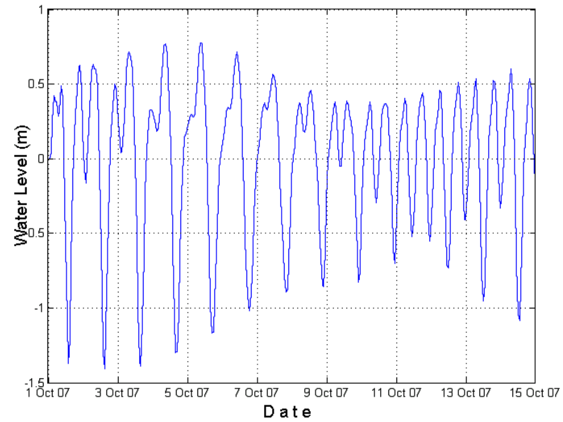
The hydrodynamic simulation for local model at Galang Island is executed using the domain decomposition module of Delft3d-Flow. The period of 14 days from 01/10/2007 until 14/10/2007 which covers spring flood and spring ebb conditions will be evaluated for its performance. From the visualization of water level fluctuations at observation point G1 and observation point G2, we can conclude that the variations of surface water levels at point G1 are of about 0.6 – 2m (see Figure 5.9a) and the type of tide is categorized as mixed diurnal tide. However, at point G2 the fluctuations range from 0.3 – 2 m. The present results are consistent with other studies and confirm that the type of tide around Galang Island is a mixed diurnal tide with an amplitude of 0.6 - 2.8 meters (CCMRS - IPB, 2001). These results are confirmed to a certain extent by CRITC (2009). Measured maximum height of tide in the vicinity Galang Island was of about 1.2 – 1.5 m.

Figure 5.9c and Figure 5.9d show the typical current speed prediction in the vicinity of Galang Island waters. Throughout this period, the current magnitude may reach the highest value and the distribution of their occurrences will be of interest for any decision making or for further research. From the Figure 5.9c we can see that the maximum current magnitude at observation point G1 is of about 0.22 m/s, and the maximum current speed prediction at observation point G2 is close to 0.4 m/s. These results are in agreement with CRITC (2009) findings which showed average current velocities ranging from 0.2 – 0.4 m/s. Comparison between two observation points concerning estimation of the current directions can be seen in Figure 5.9e and Figure 5.9f. Figure 5.9e shows that the current direction during high tide runs from the northwest (320^{o}) and during low tide it comes from the southeast (150^{o}).

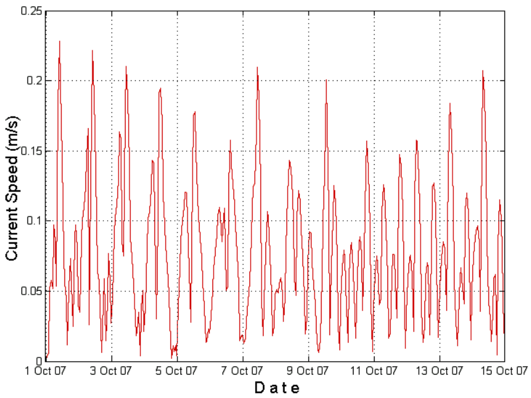
In order to assess the character of waves in the vicinity of the Galang Island seas, wave model simulations were used. Comparisons between the two observation points were made using Delft3D wave simulation module for a period of 5 years, as shown in Figure 5.10. It indicates that the maximum wave height is lower than 0.8 m. This study produced results which confirm the findings of Windupranata (2007), who revealed that significant wave heights surrounding Galang Island were in the range 0.6 – 1 m.



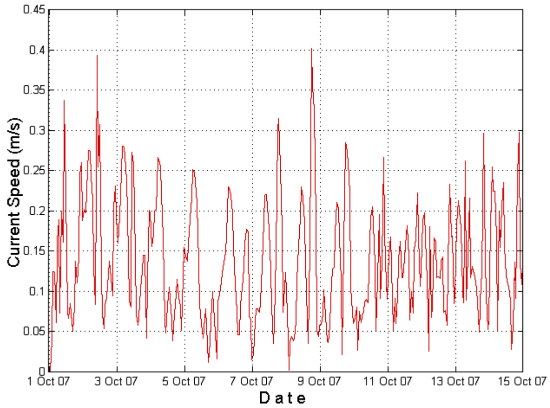
a. Water level at point G1



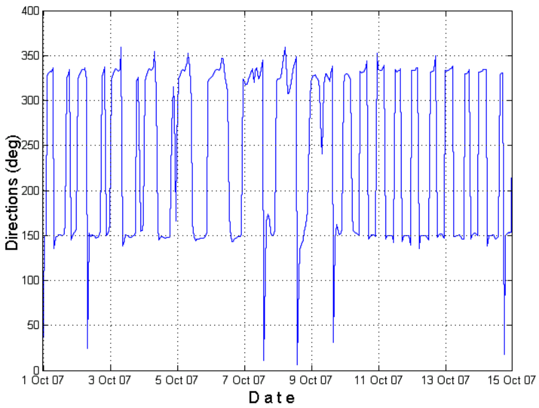
b. Water level at point G2



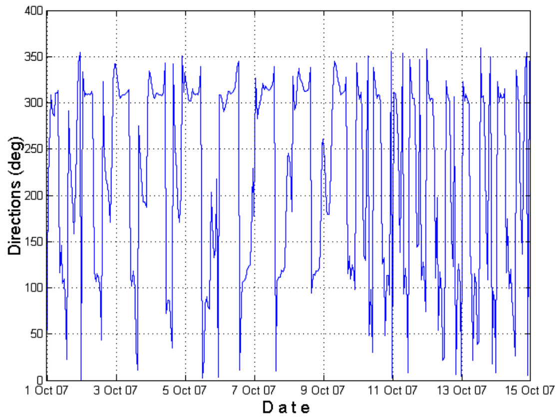
c. Current speed at point G1



d. Current speed at point G2

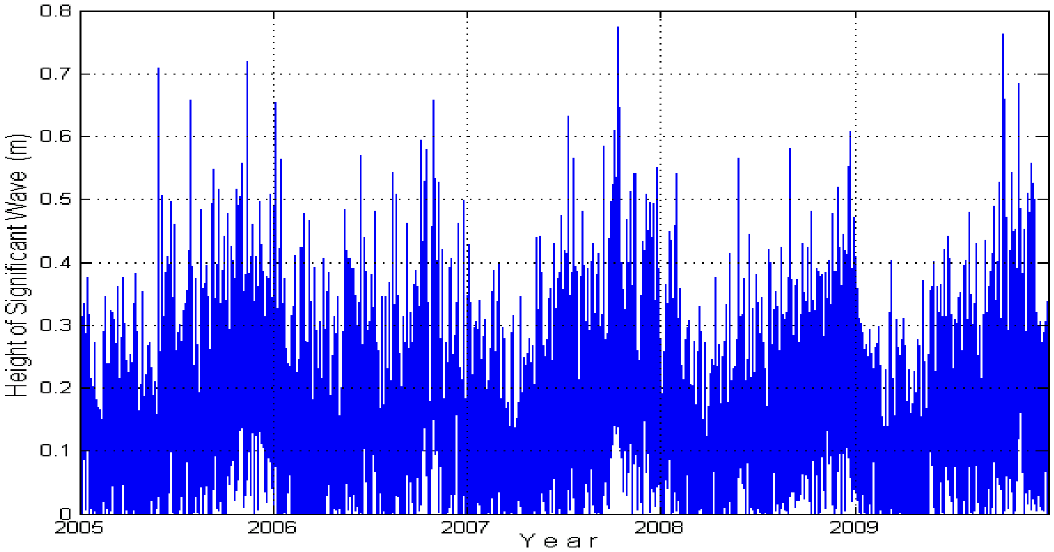


e. Current direction at point G1

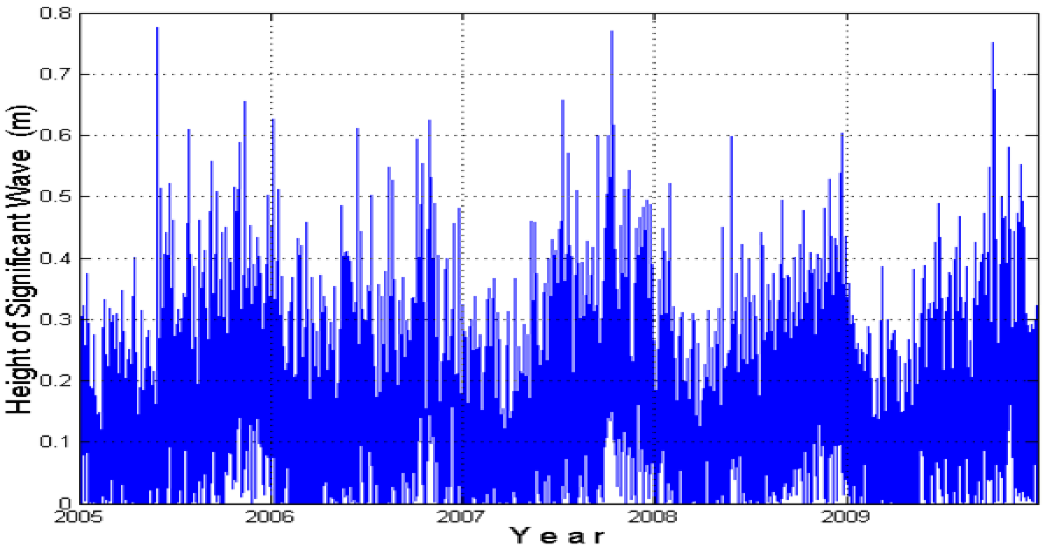


f. Current direction at point G2

Figure 5.9: Hydrodynamic model results at Galang Island local model



a. Height of wave at observation point G1



b. Height of wave at observation point G2

Figure 5.10: Wave model results in the vicinity of Galang Island

The findings of the current study support previous studies which were carried out by several Institutions and authors. The results are significant in at least three major aspects, including water level fluctuation, current magnitude, and wave height. Considering these parameters, we show that most of the area of the Galang Island regional model is defined as a suitable area for development of FNC grouper culture.

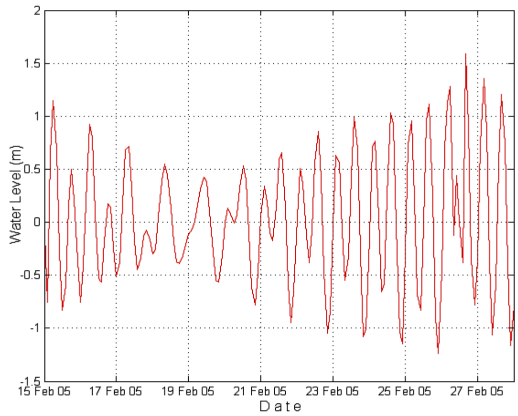
5.4.3 Ekas Bay

Finally, the results of numerical simulation in the Ekas Bay study area are provided in Figure 5.11 and Figure 5.12. Simulated oscillations of water levels at two observation points are in the range 0.2 – 2.6 m which covers neap to spring flood and ebb condition. The present findings seem to be consistent with results by CCMRS-IPB (2004) which found that the maximum fluctuation of water level in the vicinity Ekas Bay was 2.6 m.

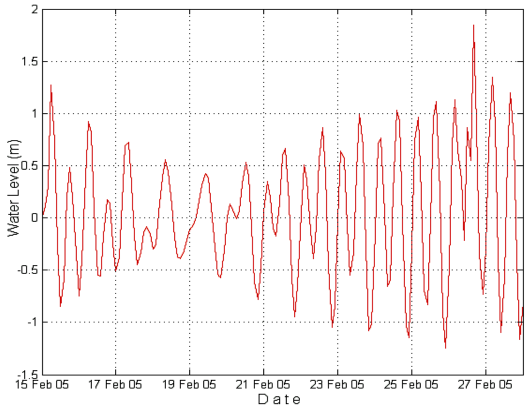
However, the current speed estimation at the two observation points shows that the current characteristics at E1 and E3 are different. We find an extreme current speed of 0.9 m/s and 1.1 m/s, respectively at E1 and E3 which coincides with maximum wind speed. In general, the current magnitude shows a discrepancy of between 0.08 – 0.1 m/s (see Figure 5.11c and Figure 5.11d). This result therefore needs to be interpreted with caution, because while it is in agreement with CCMRS-IPB (2004) which revealed that the current speed was about 0.10 m/s during September – December, from April to August the current velocities were in the range 0.05 – 0.40 m/s.

Simulated wave height results at Ekas Bay covering a period of five years show that the maximum value is higher than 2 m. The average of wave heights are in the range of 0.5 – 1 m (see Figure 5.12). This findings support previous literature by Wibowo (2007).

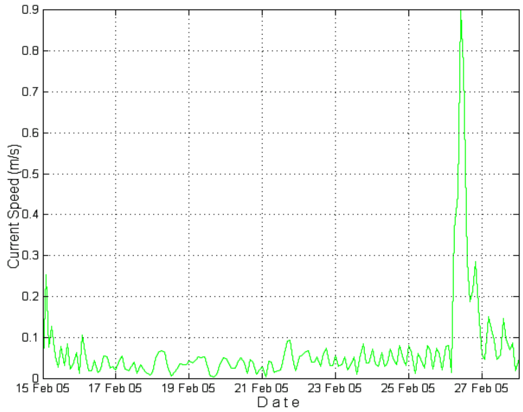
The significant results of this investigation with respect to physical characteristics of the marine environment of Ekas Bay show that the current magnitude can generally be categorized as weak. A current speed of less than 0.05 m/s is of course too weak to cover the minimum requirement for the flushing of a FNC farm, and provides a possible explanation for previous business failures in the region. In contrast, during extreme wind conditions it provides very high magnitudes. Maximum heights of wave and wind criteria do not suit the development of FNC grouper culture. These findings have significant implications for the future practice of FNC grouper culture development in this area.



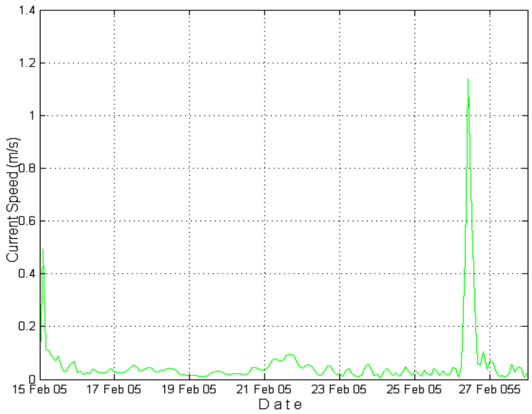
a. Water level at point E1



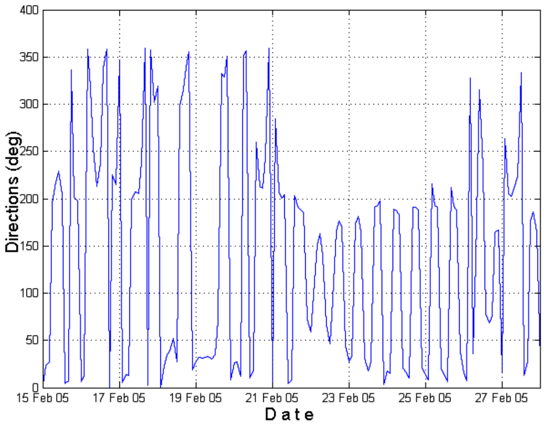
b. Water level at point E3



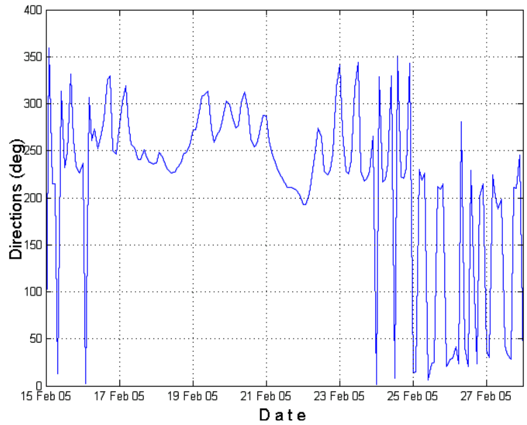
c. Current speed at point E1



d. Current speed at point E3

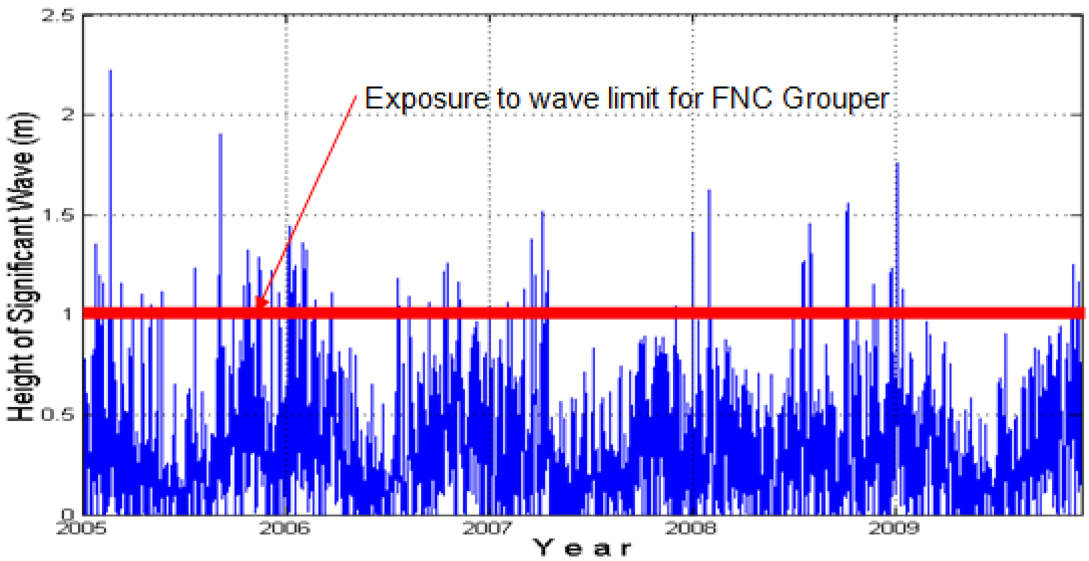


e. Current direction at point E1

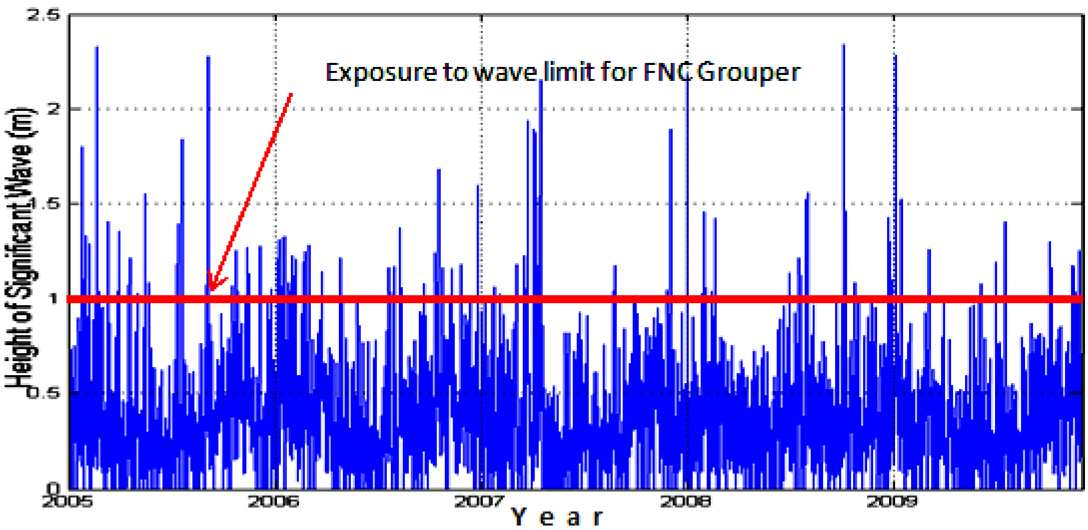


f. Current direction at point E3

Figure 5.11: Hydrodynamic model results at Ekas Bay local model



a. Height of wave at observation point E1



b. Height of wave at observation point E3

Figure 5.12: Wave model results in the vicinity of Ekas Bay

5.5 Summary

In order to assess the results of hydrodynamic flow and wave models with respect to the criteria of FNC finfish farming development, we conclude that Galang Island is a suitable location. Talise Island is assessed as not appropriate for reasons of wave height. Finally, at Ekas Bay the current magnitude is generally categorized as too weak, while maximum wave height and wind criteria do not meet the criteria for the development of FNC grouper culture.

Chapter 6

Application of SYSMAR DSS and Results

The performance of a system for the management of sustainable floating net cage finfish cultures, the (SYSMAR) Decision Support System (DSS), will be discussed in this chapter. Through the use of a geographic information system (GIS) as a spatial planning tool, SYSMAR DSS is able to assist in site selection, determining different types of carrying capacities and performing an economic assessment as has been shown by a number of previous authors (Windupranata, 2007, v.d. Wulp et al. 2010, Mayerle et al. 2011, Hermawan et al. 2012). The SYSMAR DSS results for almost uncharted areas of the Indonesian coast are presented in the form of maps, figures, and analysis reports.

6.1. SYSMAR DSS Site Selection

A comprehensive site suitability and capability map which integrates all of the selected criteria was edited using thirty two parameters identified in Table 3.1. In order to assess the relative impacts of each category of parameters (e.g. physical, chemical, and ICZM) on the DSS result, the suitability maps of the three applied categories are presented. Locations are selected based on the suitability and sustainability consideration of each weighted parameter. Thus, the inputs and results of the SYSMAR DSS are designed to investigate, estimate, and correlate the information from different sources available in the database. When using SYSMAR DSS, data input or analysis type are selected by the user through the interface that control the type of analysis to be made by the model components of the DSS.

6.1.1 Site Selection in the Vicinity of Talise Island

After classifying, the physical information from hydrodynamic and wave numerical models gives an insight into the spatial distribution of areas which are suited for the development of floating net cage mariculture. The first location for the application of SYSMAR DSS site selection is in the vicinity of Talise Island. All of the suitability maps are presented from Figure 6.1 to Figure 6.5. Figure 6.1 shows minimum water depth digitized from nautical charts. With respect to Table 3.1, with criteria for site selection for groupers grown in floating net cages, the allowable minimum water depth is not less than 6 m, and optimal water depth is above 8 m.

The initial setting of the SYSMAR DSS examined the impact of the bathymetric information to assess the water depth in the surrounding area. The preliminary analysis has found that the total area in the Talise Island domain is about 129,765 hectares. The deepest area has water depths up to about 6,000 m. The result obtained from the minimum water depth analysis of this DSS is presented in Figure 6.1. The minimum water depths in majority of seawater areas in Talise Island are defined as optimal locations with about 122,219 hectares (94.2%) of the total domain area. Only 5.3% of the area is considered as unsuited location.

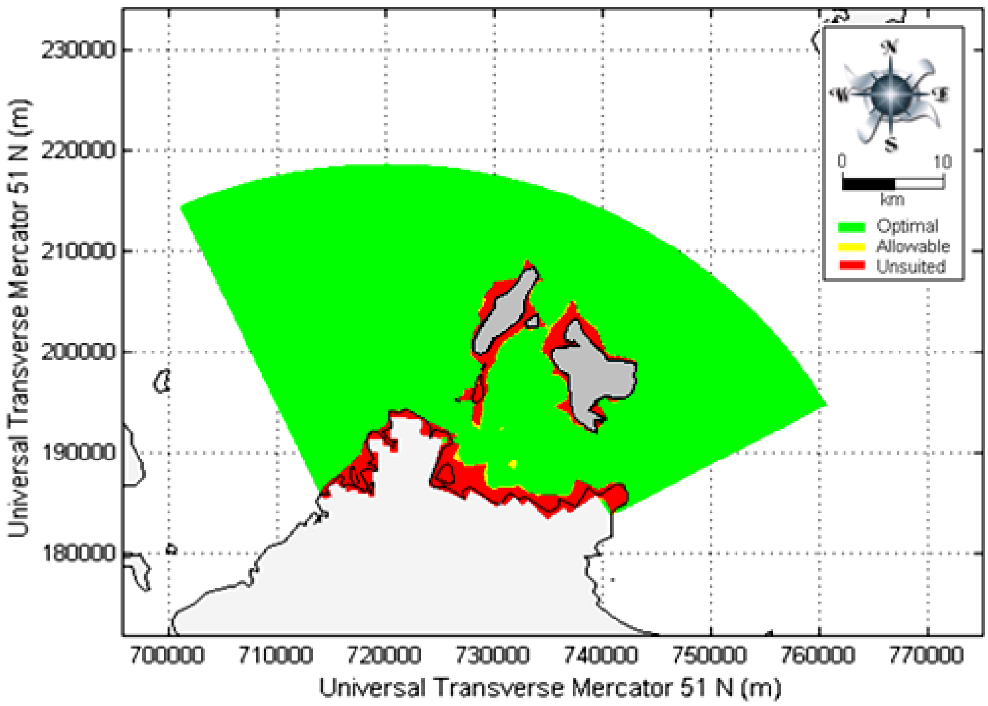


Figure 6.1: Suitability map in the vicinity of the Talise Island based on minimum water depth

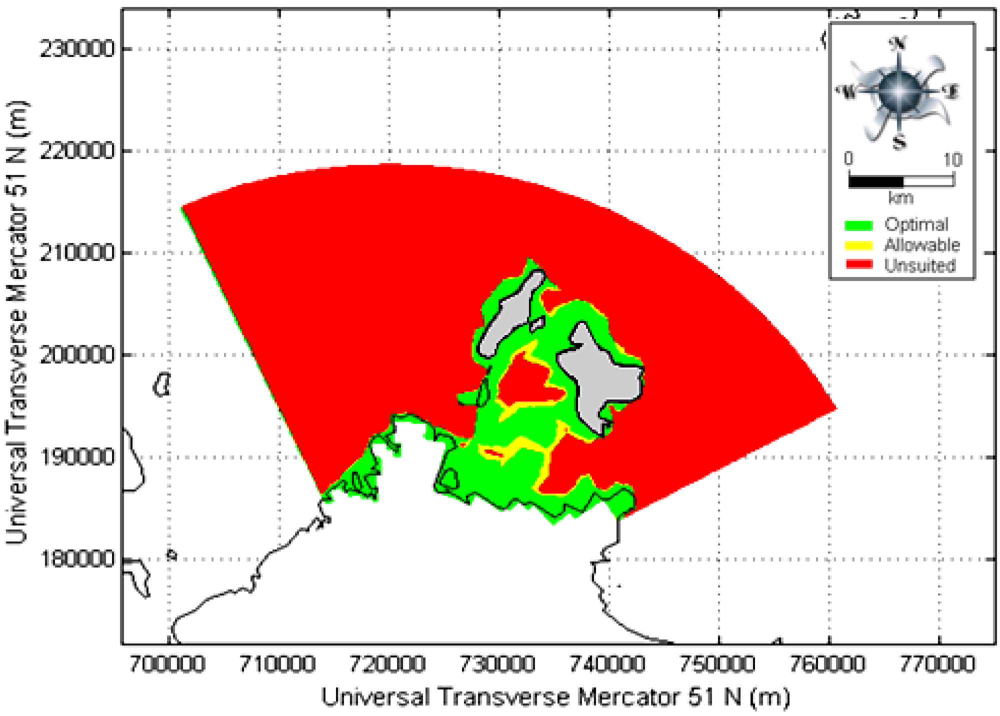


Figure 6.2: Suitability map in the vicinity of the Talise Island based on maximum water depth

However, looking at maximum water depths in Talise Island a different picture emerges because FNC grouper culture is allowable if water depth is less than 25 m, and optimal if it is less than 20 m. Hence Figure 6.2 indicates only 14.2% and 2.4% of the area can be interpreted as optimal and allowable, respectively. It is apparent from this figure that about 108,178 hectares (83.4%) sea water areas in the vicinity of Talise Island are considered as unsuited area. This is due to the particular geological situation of the islands next to a deep sea trench with very narrow shelf edges.

The suitabilty map based on flushing conditions in the vicinity of Talise Island can be seen in Figure 6.3. Data indicate that most parts of the location are considered as allowable area, namely about 74.2% or 96,325 hectares of the domain. Another part of about 22.2% are considered as optimal, with only 3.5% or 4,600 hectares are defined as unsuited area.

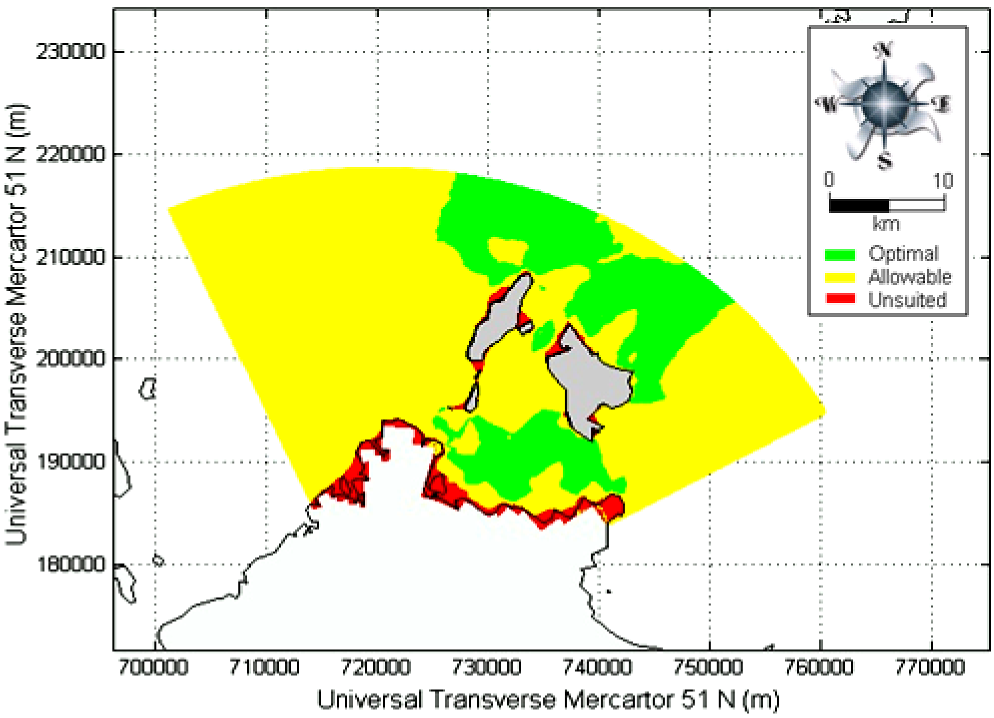


Figure 6.3: Suitability map in the vicinity of the Talise Island based on flushing

Figure 6.4 shows the suitablity map based on exposure to the current parameters in Talise Island. Most of the area, more precisely about 83,878 hectares (64,6%) are considered as suited area. When the current velocity is higher than 0.1 m/s, the areas are categorized as allowable, and between 0.2 - 0.5 m/s, the areas are categorized as optimal. Only 22.6% and 12.8% of the total area are defined as allowable and unsuited, respectively.

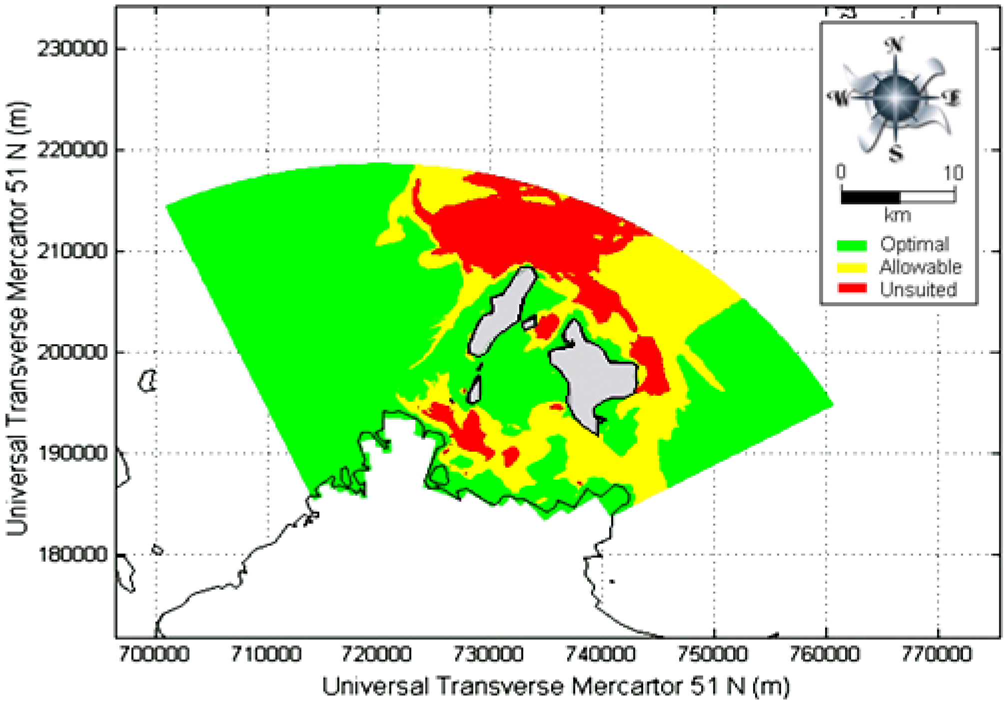


Figure 6.4: Suitability map in the vicinity of the Talise Island based on exposure to currents

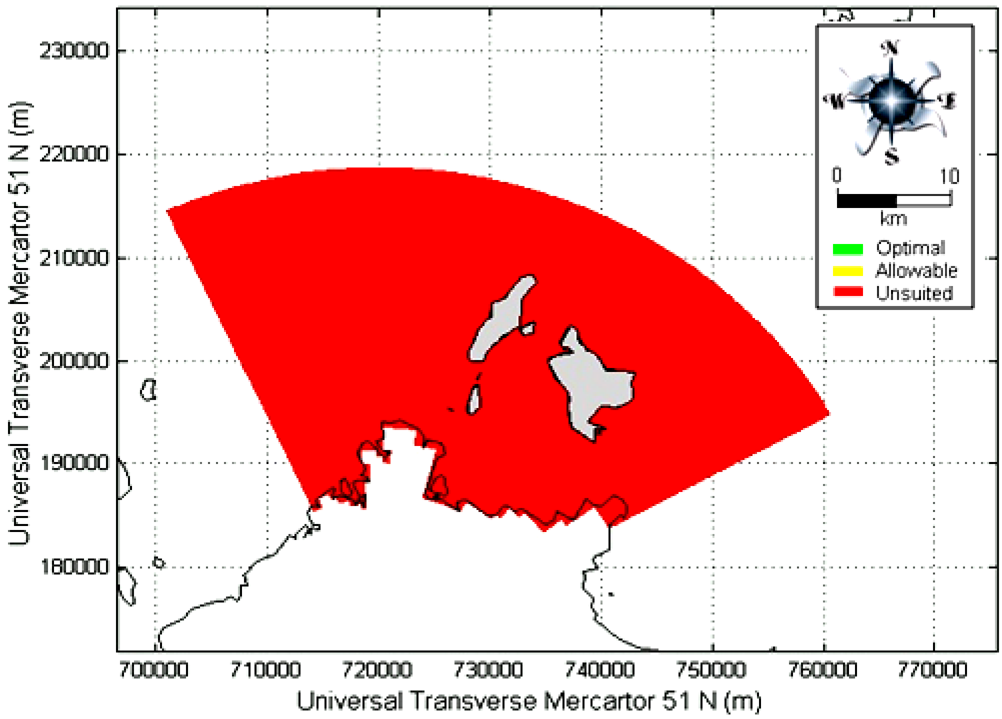


Figure 6.5: Suitability map in the vicinity of the Talise Island based on wave exposure

A suitability map based on exposure to wave parameters in Talise Island can be seen in Figure 6.5. The figure indicates that all of the area is interpreted as unsuited area. As shown in Figure 5.11,the average maximum wave height is above 3 m. Within a maximum wind speed of 19.6 m/s and fetches of approximately 300 km in length, the wind generates a maximum wave height of about 6 m. This condition obviously implies that the area is unsuitable with regard to the criteria. As a result of the exposure to strong wind fields and long fetches, the entire domain is considered a high energy marine environment, and thus perhaps more suitable for other usages rather than FNC culture, which needs a certain level of protection.

6.1.2 Site Selectionin the Vicinity of Galang Island

Data analyses by SYSMAR DSS site selections in the Galang Island area are presented in Figure 6.6 to Figure 6.15. Figure 6.6 presents 806 Ha or 2.5% where minimum water depth is allowable, whereas 67.4% (21,612 Ha) areas in the vicinity of Galang Island are optimal for FNC grouper culture. Figure 6.7 shows a suitability map in the vicinity of the Galang Island based on maximum water depth. It shows 80.6% (25,857 Ha) of the area was considered as optimal, and only 10.3% (3298 Ha) as unsuited area.

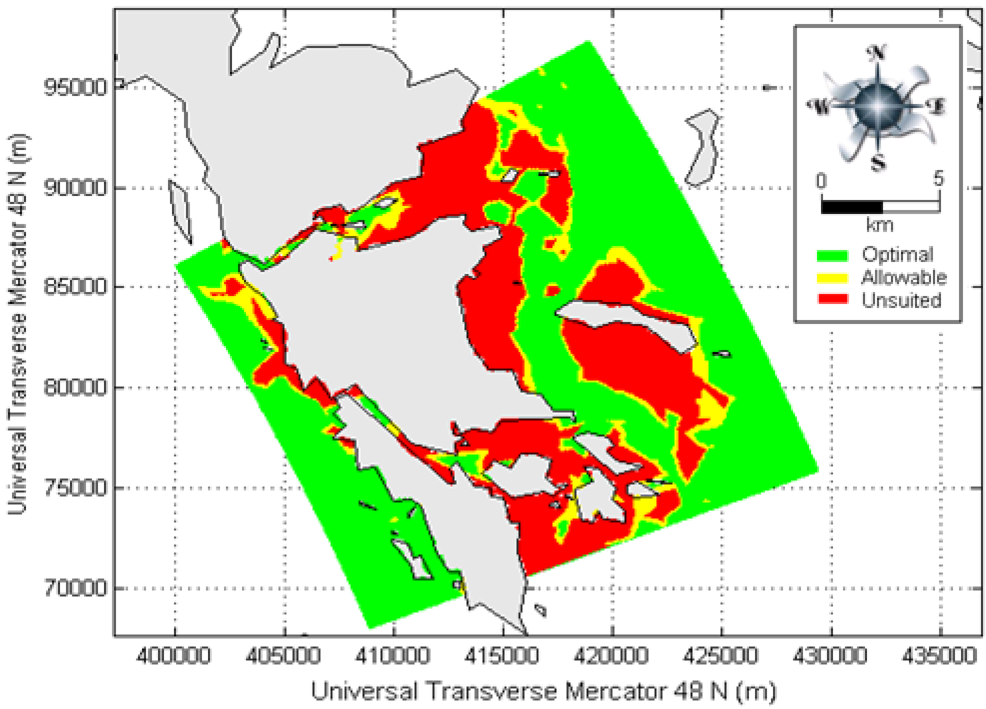


Figure 6.6: Suitability map in the vicinity of the Galang Island based on minimum water depth

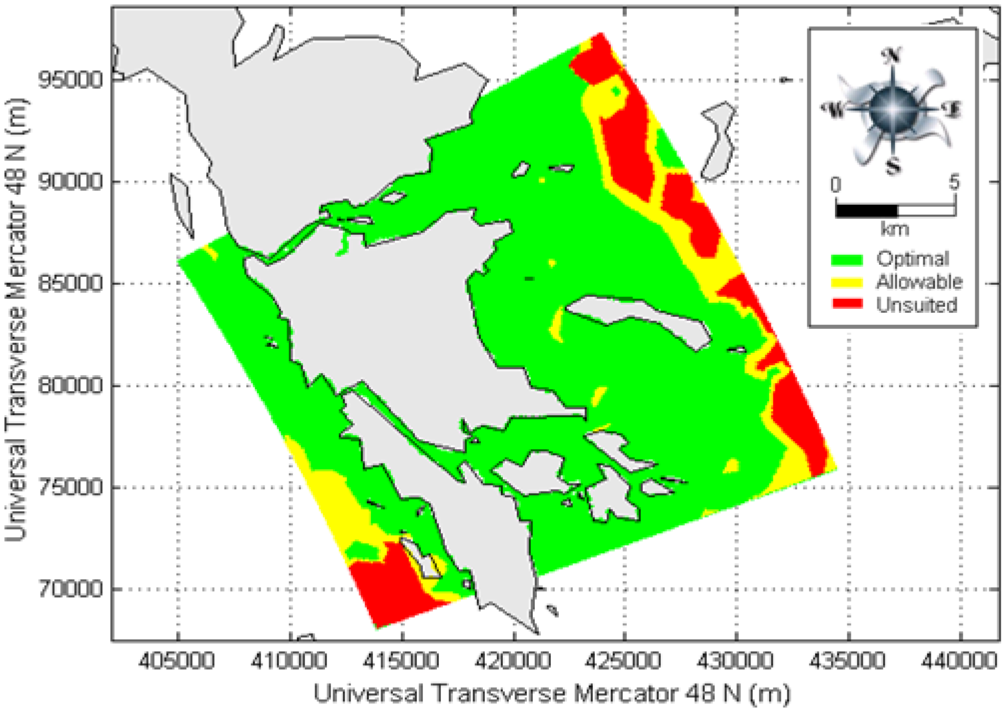


Figure 6.7: Suitability map in the vicinity of the Galang Island based on maximum water depth

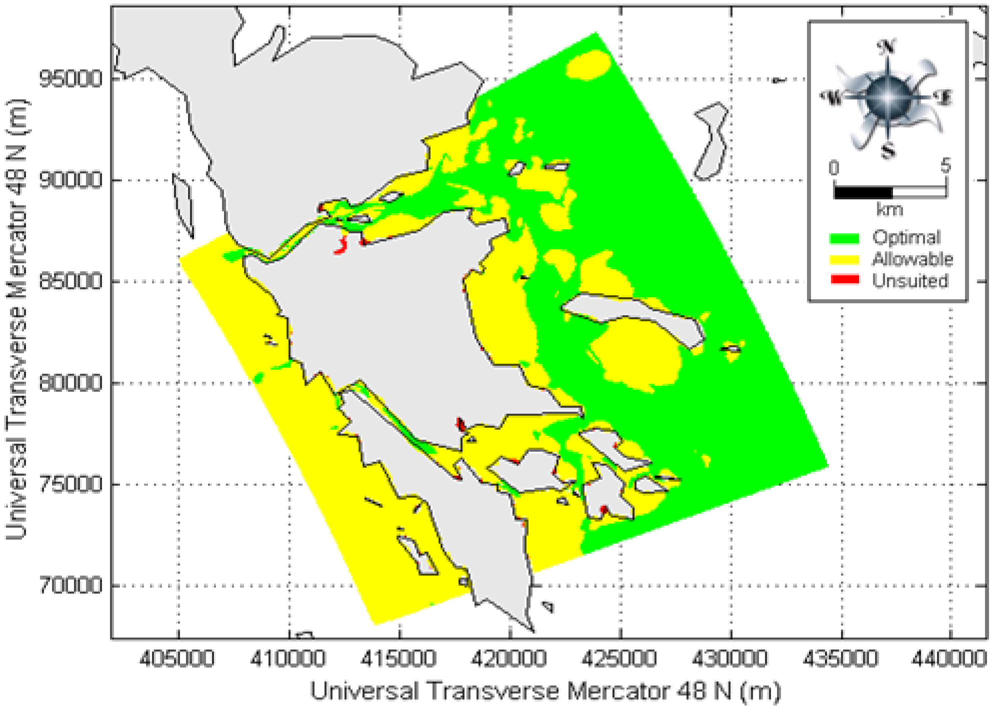


Figure 6.8: Suitability map in the vicinity of the Galang Island based on flushing

Considering the flushing rate, only 0.3 % (90 Ha) of the area in the vicinity of Galang Island area is identified as unsuited for mariculture activities (see Figure 6.8). Areas representing optimal and allowable conditions cover 54.5% and 45.3%, respectively. Figure 6.9 presents the suitability map based on exposure to currents, it shows about 11,859 Ha (37%) and 20,000 Ha (62.3%) exhibiting allowable and optimal current velocities, respectively. Only 0.7% (221 Ha) of the area is defined as unsuited.

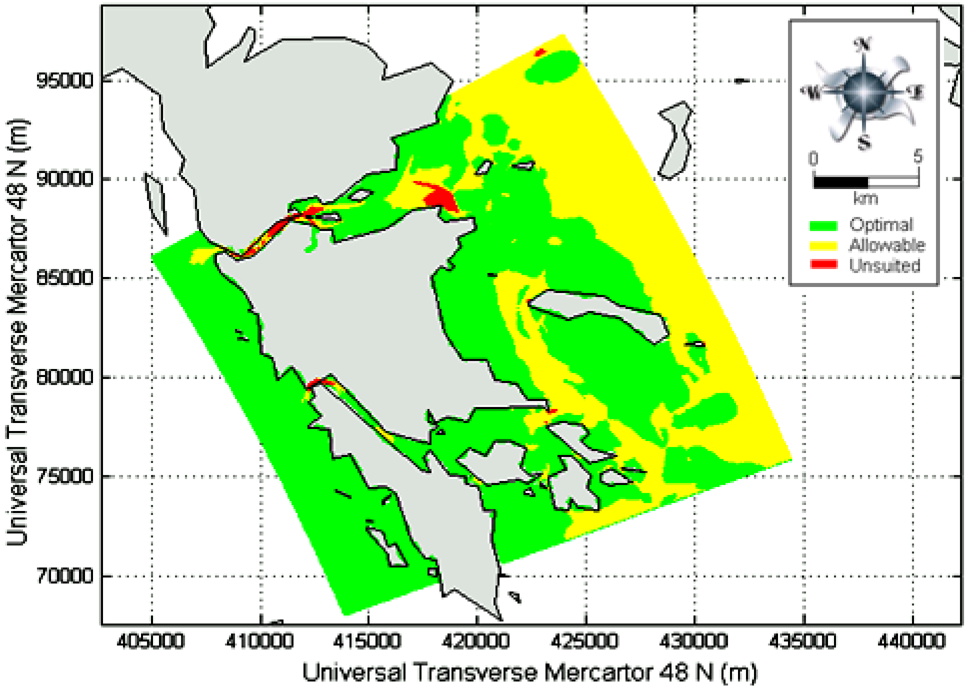


Figure 6.9: Suitability map in the vicinity of the Galang Island based on exposure to currents

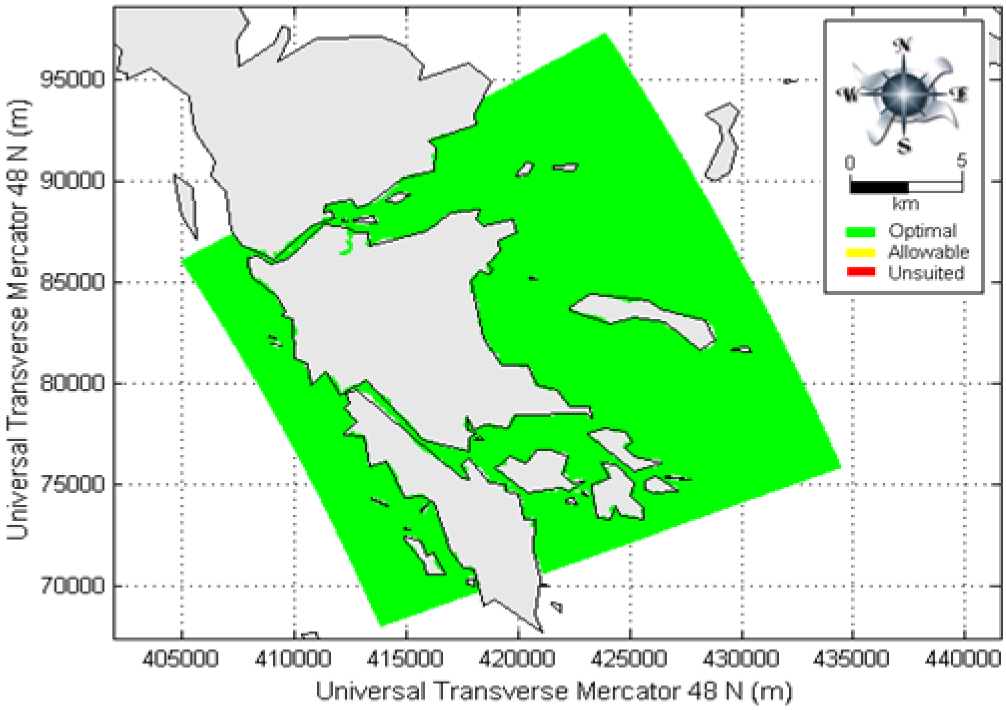


Figure 6.10: Suitability map in the vicinity of the Galang Island based on wave exposure

The maximum waves resulting from the simulations of the Galang Island model are displayed in the map of Figure 6.10. It shows that all of the area is defined as suitable location. Furthermore, the suitability map in the vicinity of the Galang Island based on exposure to wind clearly shows that the whole area is suitable for FNC finfish culture activities (see Figure 6.11). As shown in Figure 5.13, the maximum wave height is lower than 0.8 m. Within a maximum wind speed of less than 7.3 m/s and fetches not exceeding approximately 70 km length, the wind generates an average maximum wave height of about 0.4 m. This condition implies that the area is clearly suitable for FNC activities.

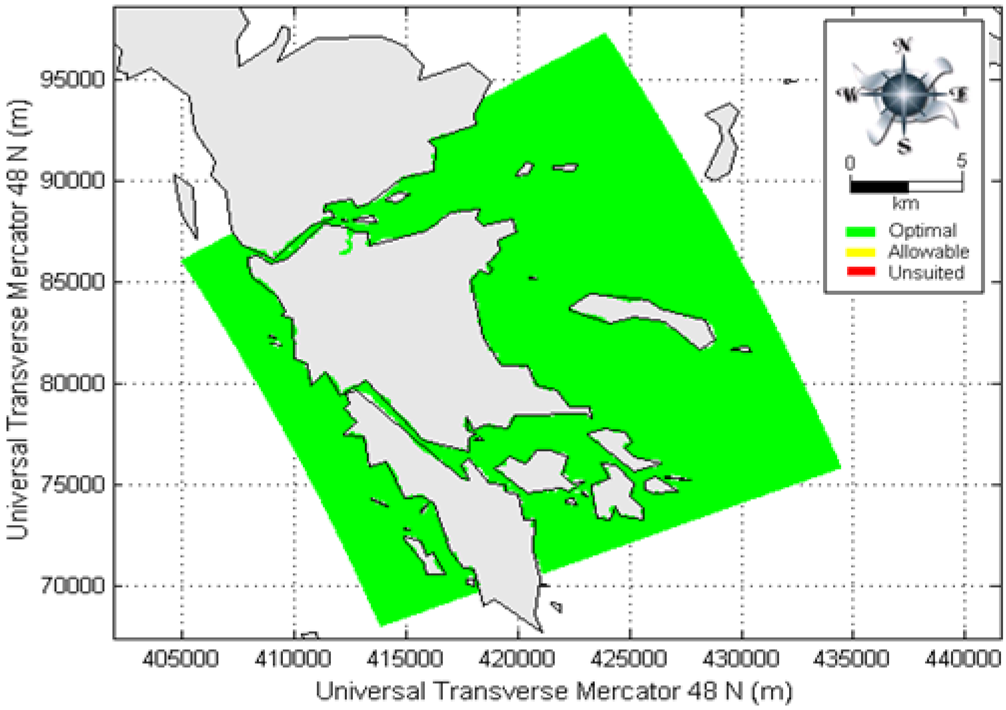


Figure 6.11: Suitability map in the vicinity of the Galang Island based on exposure to winds

As shown in Figure 6.12, to study chemical parameters such as water temperature, salinity, dissolved oxygen, pH, and water transparency, data of water quality were adopted from CRITC (Coral Reef Information And Training Centers)COREMAP-LIPI., (COREMAP II) CRITC LIPI, BPP-PSPL UNIVERSITAS RIAU, 2009). Other parameters, such as turbidity, ammonium, nitrate and nitrite were taken from the Research Development Centre of Ocean Geology Bandung (RDCOG Bandung, 2005). The phosphate map of the area is derived from Schlitzer (2011) and Diansyah (2004). The result of the suitability map based on water quality in the vicinity of Galang Island shows that the total area is suited for FNC finfish culture activities without restrictions.

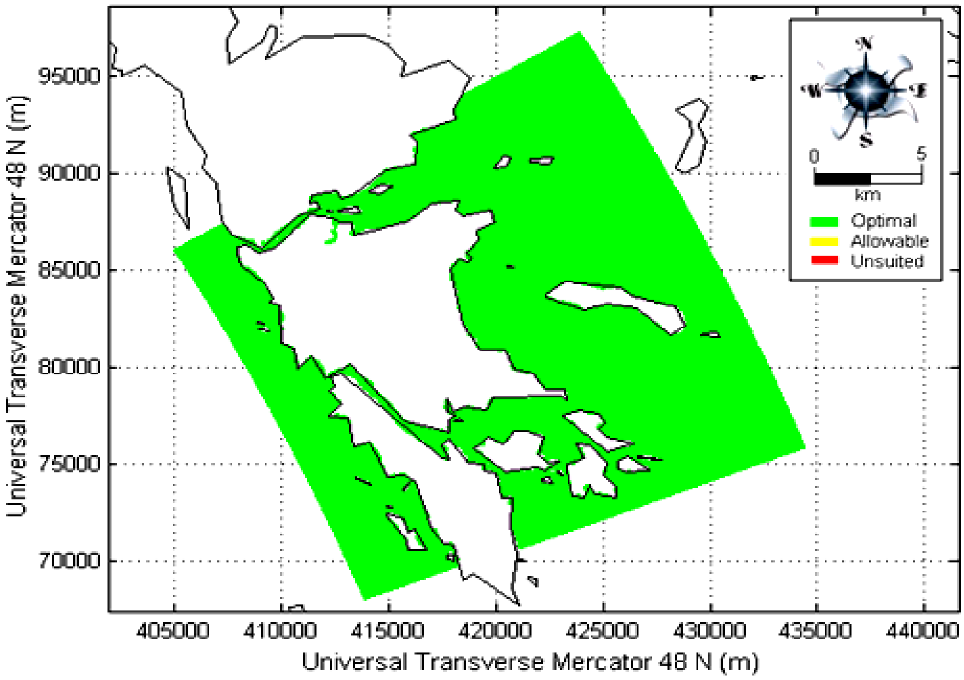


Figure 6.12: Suitability map in the vicinity of the Galang Island based on exposure to water quality

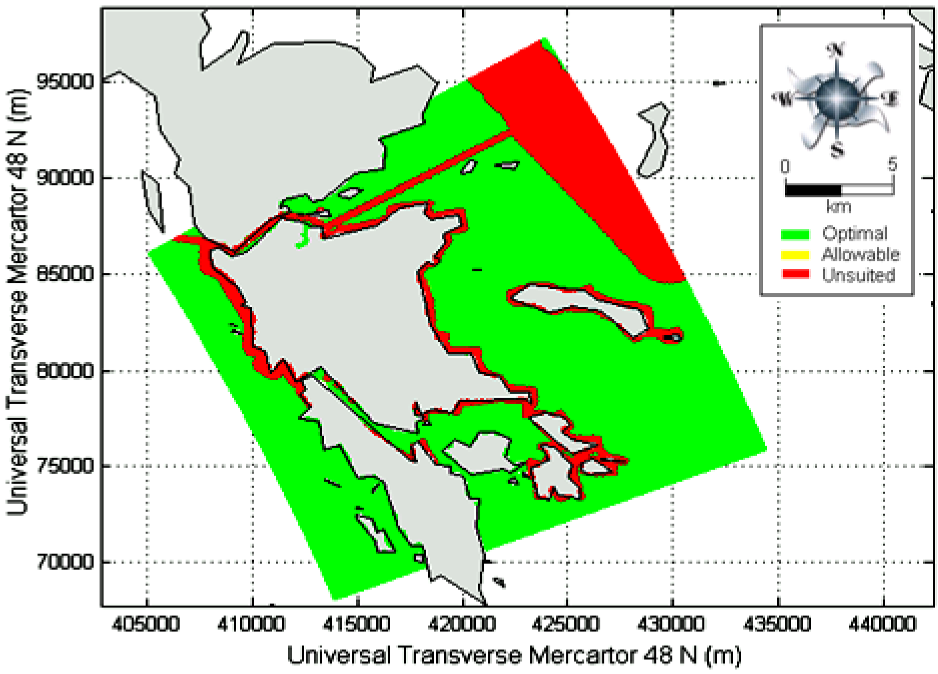


Figure 6.13: Suitability map in the vicinity of the Galang Island based on ICZM

A suitability map based on the integrated coastal zone management (ICZM) in Galang Island is indicated by sixteen thematic maps, covering buffer zones of more than 200 m to other coastal usage properties. The thematic maps are of villages, towns, cities, harbours, streams, rivers, erosive shoreline, semi intensive hatcheries, ponds, sewage discharges, traffic lanes, and coastal usage. In order to analyze land use for coastal utilization in Galang Island, we found a large quantity of data and applied it by using a graphic user interface of SYSMAR DSS. As can be seen in Figure 6.14, of 16 parameter criteria, only 8 main criteria are detected which imposed restrictions on FNC finfish development, such as villages (indicated by number 1), strategy or industry areas located in the north and south domain (shown by number 5), and tourism areas located on the west part of domain (see number 6). Rivers can also be found spread over the domain (see number 8), semi intensive hatcheries and pond areas which the government had planned to extend (number 10), traffic lanes (number 14) and the environmentally protected area including mangrove zone and coral reef areas (number 16). As a result of computing ICZM adopts data from Sahalo (2014),the master plan of Batam City for 2004 – 2014 from National Development Planning Agency (NDPAa, 2004) and Indonesian Land use Data Bank (ITB, 2006), the analysis of ICZM criteria is carried out. Figure 6.13 presents an area of 77.5% or about 24,856 Ha of seawater areas as being defined optimal, but only 22.5% of the area are categorized as unsuited.

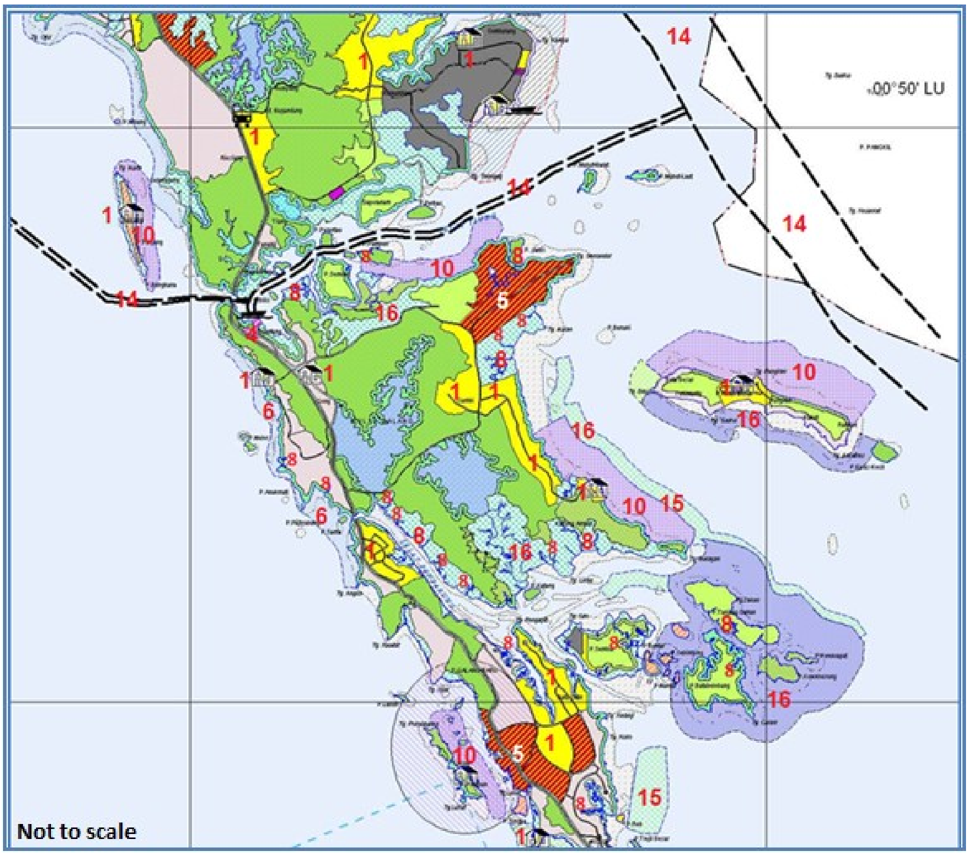


Figure 6.14: ICZM criteria in Galang Island (source: NDPAa)

Remarks: 1: villages, 5: industry, 6: tourism, 8: rivers, 10: semi intensive hatcheries, 14: traffic lanes, 15: coastal usage, 16: environment protected area.

This study applies the DSS for Integrated Coastal Zone Management (ICZM) and has the ability to integrate the multidisciplinary environment as a complex and variable system. However, the result must be interpreted with caution, because Ferrol-Schulte et al. (2013) revealed that the researchers and practitioners have been blurring the boundaries between conservation, development, poverty-alleviation and natural resource ecosystem management in Indonesia.

The final result of the suitability map from all parameters in the vicinity of the Galang Island can be seen in Figure 6.15. It shows about 12,940 Ha (40.3%) of the seawater area in Galang Island are interpreted as suited area. The areas are spread over the vicinity of the Galang Island.
The SYSMAR DSS is an approach to support decision making through the screening of data. The scoping of stakeholders and the scanning of development strategies are found to expand FNC finfish culture in the vicinity of Galang Island.

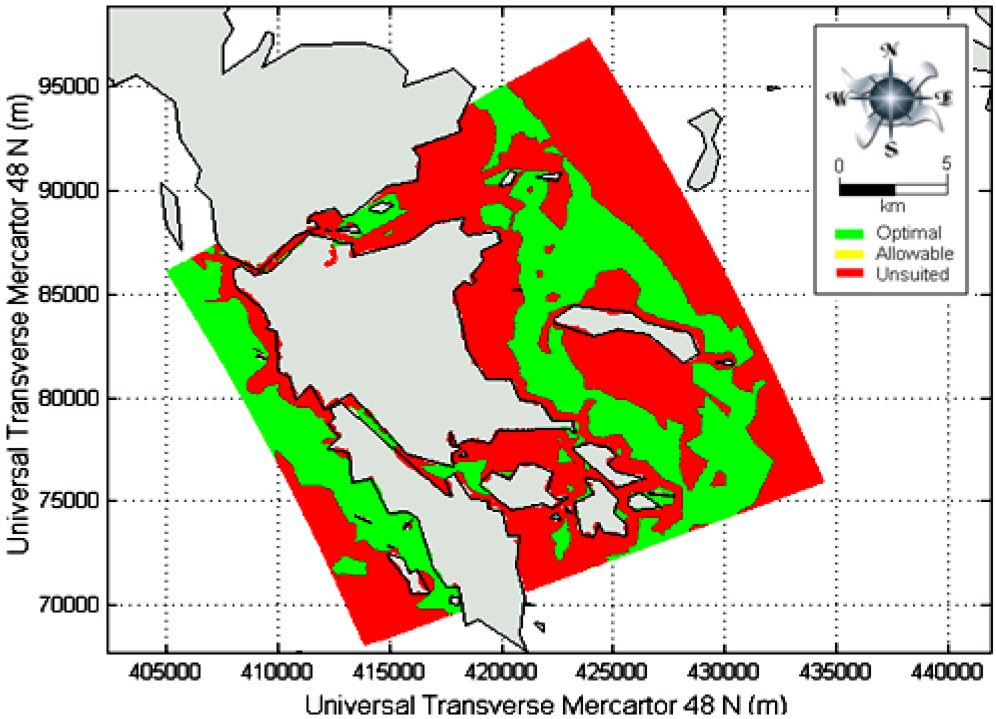


Figure 6.15: Final result of the suitability map from all paramaters in the vicinity of the Galang Island

6.1.3Site Selectionin the Vicinity of Ekas Bay

The results which were obtained from the analysis of SYSMAR DSS application for FNC grouper in the vicinity of Ekas Bay can be seen in Figure 6.16 to Figure 6.19. As shown in Figure 6.16 regarding the criteria of minimum water depth, the total suitable area of the seawater in Ekas Bay is about 3,009 Ha. This figure provides the result that the minimum water depth in Ekas Bay is exceeded in 50.6 % of the area. About 2673 hectares of the area are optimal, but an area of about 2875 hectares (49.4%) is considered unsuited due to shallow waters with a water depth of less than 8 m.

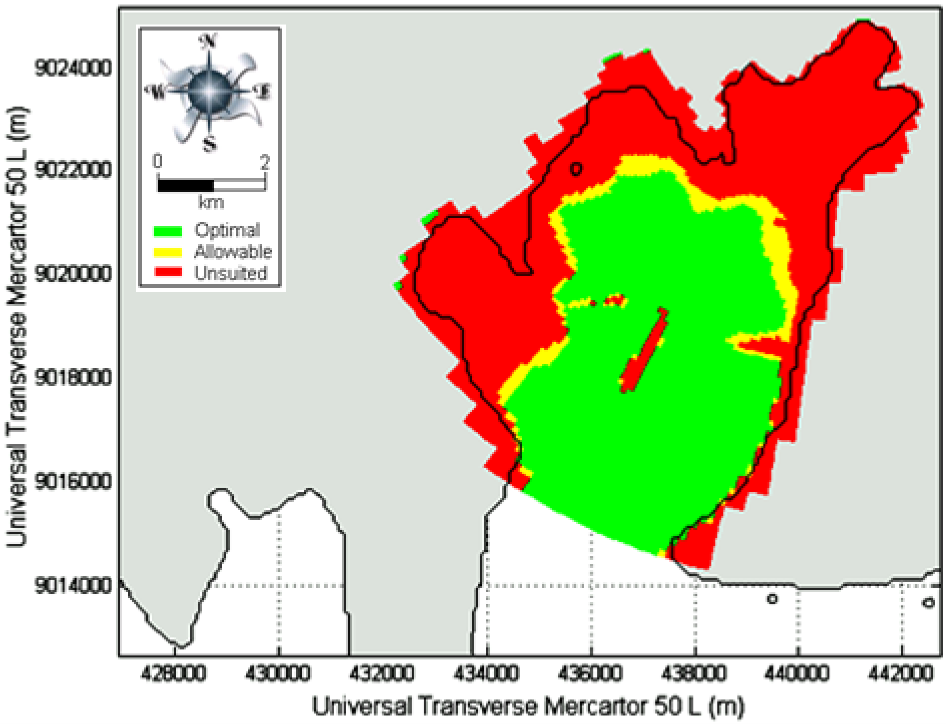


Figure 6.16: Suitability map in the vicinity of the Ekas Bay based on minimum water depth

Figure 6.17 presents a suitablity map based on maximum water depth in Ekas Bay. It shows about 914 hectares (15.9%) in the south of Ekas Bay sea water defined as unsuited location, because these areas have a depth exceeding 25 m. From the graph below,we can see that 60.3% of the locations in the northern part of Ekas Bay seawater area are considered optimal and 72.8% allowable with respect to the maximum mooring depth.

In order to assess the flushing parameter at Ekas Bay, repeated site selection of the SYSMAR DSS is carried out. As can be seen from the Figure 5.18, only 1.7% (96 Ha) of the area in Ekas Bay seawater is defined as unsuited location. About 5671 hectares (98.3%) of seawater area are considered allowable. In the entire area, there are no optimal sites based on flushing for FNC finfish cultures activities, a result that clearly suggests flushing in Ekas Bay needs to be considered when the potential development of FNC culture is estimated later on.

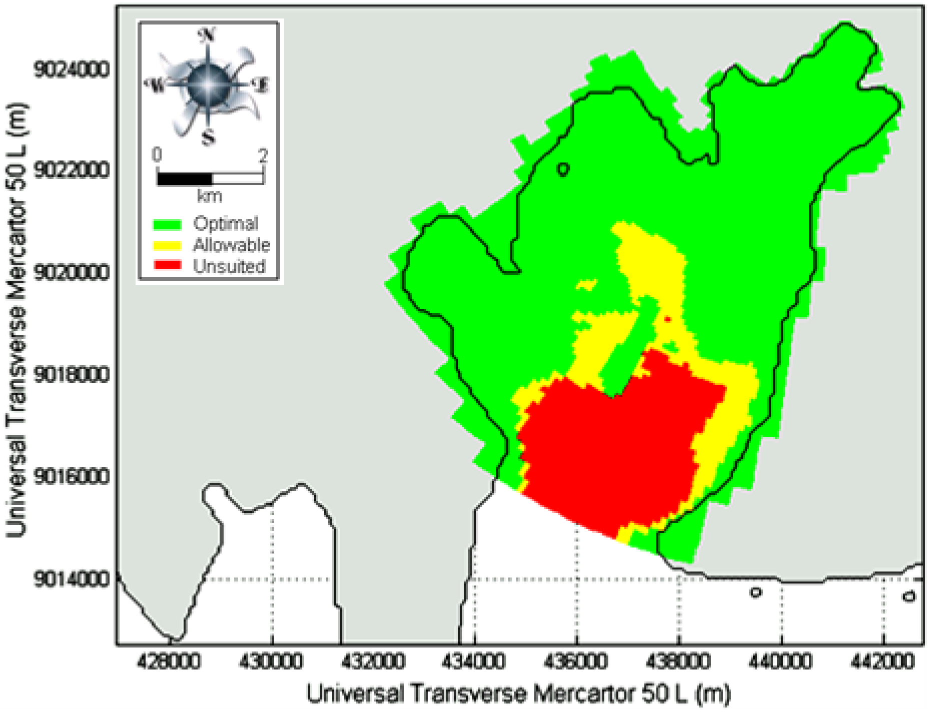


Figure 6.17: Suitability map in the vicinity of the Ekas Bay based on maximum water depth

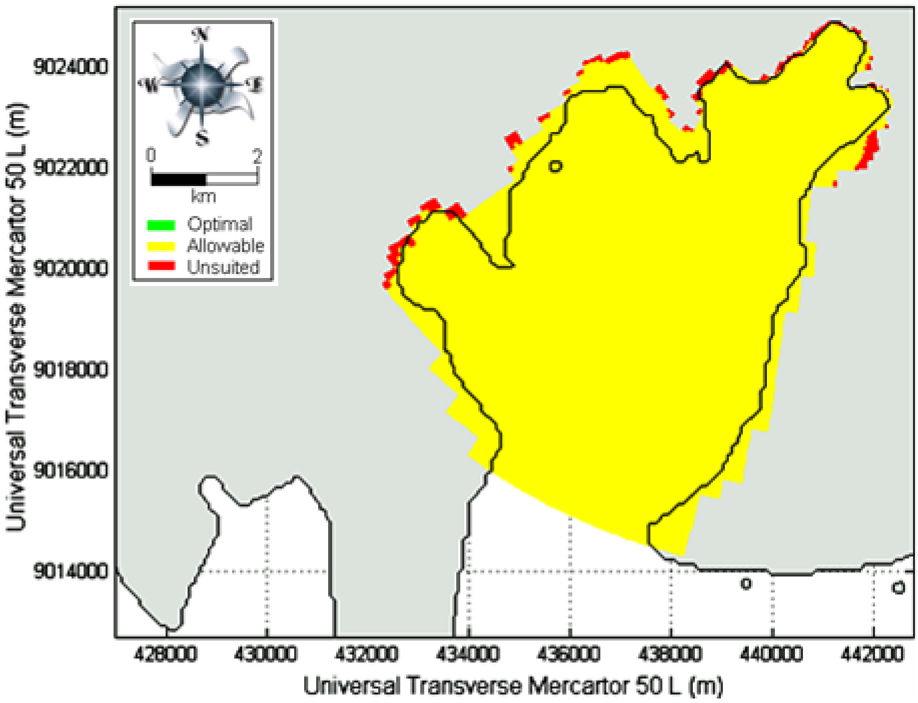


Figure 6.18: Suitability map in the vicinity of the Ekas Bay based on flushing

The result, as shown in Figure 6.19, indicates that the suitabiliy map in the vicinity of Ekas Bay based on exposure to currents presents the domain as unsuited area. The current speed characteristic in this area can be compared to Figure 5.14c, d.

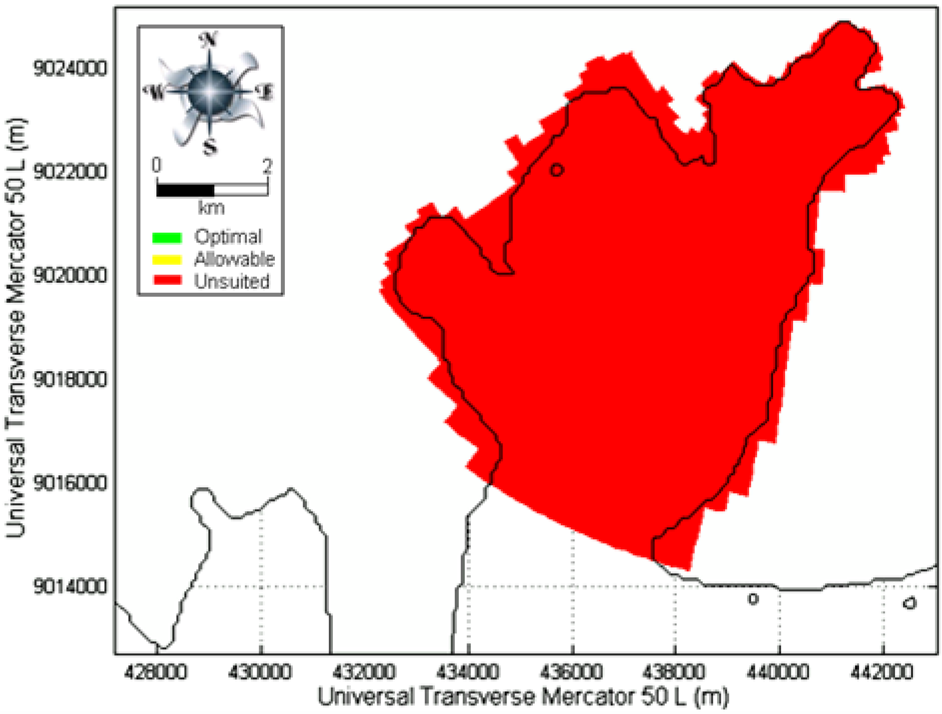


Figure 6.19: Suitability map in the vicinity of the Ekas Bay based on exposure to currents

The final result of site selection in Ekas Bay shows no potentially suitable area for development of FNC grouper culture. It is affected by current and flushing which are considered too weak or low for FNC activities. This finding agrees with Krisanti and Imran (2006), who revealed that the existing FNC culture activities in this region should be organized because they are not suited to the carrying capacity. Furthermore, the average maximum wave height is higher than 1 m (compare to Figure 5.15) which is also indicated as inappropriate for FNC development.

6.1.4 Concluding Remarks of Site Selection

Talise Island

From Figure 6.1 to Figure 6.5 , we can see the results of the application of SYSMAR DSS in the vicinity of Talise Island based on bathymetry, fluctuation of water level, flushing, current and wave. The result with respect to maximum water depth shows that about 6,877 ha (5.3%) of the area is considered unsuitable, including the areas surrounding Talise Island and Kinabohutan

Island where mangrove and coral reef exist (Crawford et al. 1998, Kusen et al. 1999, FFMS., 1999).On the other hand, when SYSMAR DSS considers maximum water depth, there is about 16.6% (21,540 ha) potential for future development on FNC grouper culture. This area is located surrounding the coastal coral reef zone at both Talise island and Sulawesi island, which are indicated as protected areas.

After applying SYSMAR DSS to analyze flushing and current in the vicinity of Talise Island, the results showed that most of the area is defined as a suitable location (96.4% or 125093 ha) and (86.8% or 112636 ha), respectively. However, with respect to flushing it was demonstrated that a small part of eastern, western, and southern Talise island is considered as an unsuitable location (see Figure 6.3). These findings support previous studies which found the suitable current magnitude for this culture of about 0.15 – 0.70 m/s (Wantansen, 2008).

The outcome of the wave parameter study showed that all the area is defined as unsuitable. The result seems to be consistent with other studies which found significant waves at Inoboto coast, North Sulawesi to be in the range of 2.3 m – 4.3 m (Lolong and Masinambow, 2011).

Although this condition obviously implied that the area is unsuitable, there is FNC grouper culture activities in the vicinity of Talise Island at the north of Kinabohutan Island (a small island east of Talise island). However, production was small (5 tons – 10 tons, Ministry of Marine Affairs and Fisheries, North Sulawesi, 2012).

Galang Island

Results of data analysis by SYSMAR DSS concerning minimum water depth indicated that 32.6% or 10,453 ha of the area is defined as unsuitable. This area surrounds Galang Island and Karas Island. Meanwhile, with respect to maximum water depth about 10.3% (3,298 ha) of the area is considered unsuitable, and this is mostly located on the east side.

The results of flushing and current showed that most of the locations are suitable for future development of FNC grouper culture. These results are confirmed by CRITC (2009), Adriman et al. (2012) and Sukmana (2007). Meanwhile, the outcomes of wave and wind analyses by SYMAR DSS present all the area as suitable, which is in agreement with Sukmana (2007), Windupranata (2007) and CRITC (2009).

The analysis of water quality with chemical parameters in seawater in the vicinity of Galang Island which is gained from CRITC (2009), RDOG (2005), WOD, NOD, WOA, Schlitzer (2011) and Diansyah (2006), including water temperature, salinity, dissolved oxygen, pH, water transparency, turbidity, ammonium, nitrate, nitrite and phosphate, showed that the whole area is defined as suitable. This result is in agreement with Adriman et al. (2012), Sari and Usman (2012).

Ekas Bay

The outcomes of SYSMAR DSS application around Ekas Bay with respect to minimum water depth showed that 2,875 ha (49%) is defined as an unsuitable location due to shallow waters of less than 6 m depth. This region is located in the near shore area of this bay lying from west to north and east, along with a small island which is located in the middle of the bay. On the other hand, considering maximum water depth (exceeding 25 m), the result revealed that 15% or 914 ha which is located in the south of Ekas Bay can be considered as a suitable location. Flushing analysis demonstrated that only about 96 ha of seawater area is considered unsuitable. Concerning current and wave exposure, applying SYSMAR DSS showed that the seawater in the vicinity of Ekas bay is defined as unsuitable. The result is in agreement with CCRMS, IPB (2004).

Regarding the results of site selection / physical carrying capacity carried out on three areas, we conclude that Galang Island is a suitable location for development of FNC grouper culture in Indonesia. Thus, for the next steps of the application of SYSMAR DSS, Talise Island and Ekas Bay will not be included further.

6.2 Evaluation of Production Potential Using SYSMAR DSS

According to the results of site selection, there is a large area available for the development of FNC grouper culture in Galang Island. The SYSMAR DSS is applied to recognize the best locations for a limited number of farms. The selection is carried out for all potential farms based on the production carrying capacity. Thus, suitable and potential locations for all farms with a minimum distance of 500 meters between individual farms were selected for each of the locations as shown in Figure 6.20. We consider large scale farms (over 100 cages) along with the size of single farm to be 3m x 3m x 3m, with a distance between cages of 1 m (Kangkeo et al. 2010, Wong et al. 1999).

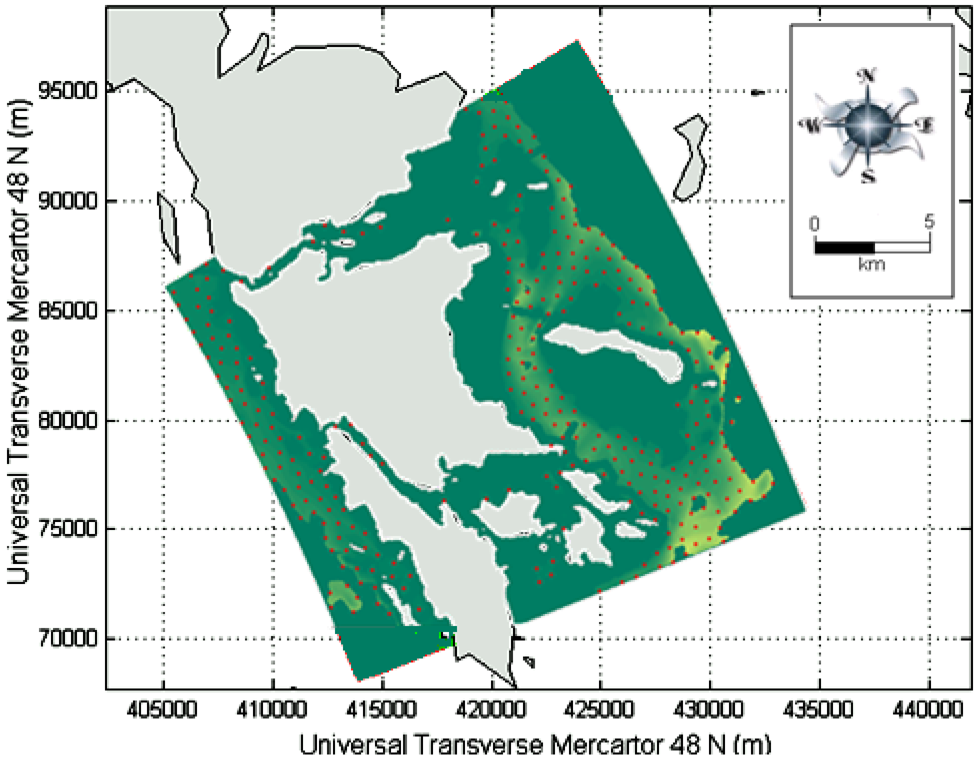


Figure 6.20: Production carrying capacities including proposed potential farmlocations in Galang Island, indicated by a small red dot

In Figure 6.20, showing the locations of potential FNC grouper culture, about 321 farms are presented which could produce an estimated total maximum production CC of about 23,795 t/a along with the total ecological CC of about 21,727 t/a. The locations are indicated by a small red dot. They are determined by SYSMAR DSS criteria which are applied in the vicinity of Galang Island.

6.2.1 Production Carrying Capacity

Table 6.1 illustrates some of the main characteristics of the production carrying capacities for different feeding patterns and carbon deposition thresholds. Among feed technologies, the utilization of pellet and trash fish and a combination of both are applied, which represents those most widely used by the Indonesian FNC business. The increase of carrying capacities due to lower wastage rates as specified in the methodology is approved. Increased assimilative capacities in the form of deposition rates of 1 and 2 g organic Carbon m^{-2} d^{-1} significantly enlarge individual FNC finfish culture sizes and production values.

As shown in Table 6.1, the maximum production of fish farms is determined by Leopard coral grouper (LG) feed with pellet, because LG presents the minimum estimated production between other cultures including Tiger grouper (TG) and Humpback grouper (HG). It means that there are no fish farms which can produce 1000 t/year. Meanwhile, pellets are used to ensure sustainable practice for future Indonesia aquaculture, since trash fish is regarded as a major factor of the environmental deterioration of Indonesia's coastal waters.

In Galang Island, prediction based on maximum deposition and feeding with trash fish indicated that about 51 – 125 tons/year/farm can be produced, but when feeding with mixed trash fish and pellet or feeding just pellet about 73 to 196 tons/year/farm and 115 to 366 tons/year/farm, respectively can be sustained. Discrepancies of the local/production carrying capacity are obtained by feeding type and also physical models which are influenced by currents and maximum water depth parameters as dominant factors and responsible for the indicated ranges (footprint area, compare chapter 3).

6.2.2 Ecological Carrying Capacity

The ecological carrying capacity for FNC finfish farms within a domain is proposed to be equivalent to emission rates of total dissolved nitrogen (TDN) not exceeding 1% of the TDN flux of the suitable domain. The maximum daily TDN load is calculated with respect to the flushing rate and TDN background concentration of the suited region, which is recorded in the order of 0.31 mg N l^{-1} (SPICE, 2006). The ecological carrying capacities is in the range of 18,393 - 21,727 tons per year in the vicinity of Galang Island.

Table 6.1: Results of the estimation of site selection and carrying capacity, A) Site Selection, B) Production CC based on the dissipation of particulate organic matter in the vicinity of a particular farm, C) Ecological CC based on the maximum POM load and TDN surplus, details in the text.

Type of Carrying Capacity	Feedstock	Grouper species TG	HG	LG
Site Selection ha			12,940	
Production Carrying Capacity: Deposition threshold 1g C $m^{-2}d^{-1}$				
t/a/fish farm	TF[a]	0.5-59	0.5-85	0.5-91
	P[b]	0.5-158	2-400	0.5-73.5
	M[c]	0.5-90	0.5-153	0.5-73.5
Deposition threshold 2g C $m^{-2}d^{-1}$				
t/a/fish farm	TF	0.5-155.5	1-277	0.5-125.5
	P	3-624	20-1000	2-366
	M	1-268	2.5-650	1-196
Ecological Carrying Capacity[d] based on a limitation by particulate organic matter:				
t/a/entire domain	TF	3,959-9,972	5,371-15,503	3,493-8,410
	P	10,478-35,993	22,162-128,071	7,942-23,795
	M	6,014-16,729	9,152-33,467	5,308-13,050
based on a limitation by Total Dissolved Nitrogen:				
t/a/entire domain	TF	18,393	18,393	18,393
	P	21,727	21,727	21,727
	M	20,116	20,116	20,166

Remarks:
[a] trash fish, [b] Pellet, [c] Mix 70%trash fish and 30% pellet
[d] The calculation considers an acceptable bed load of 1-2g organic carbon $m^{-2}d^{-1}$

6.2.3 Correlation between Farm Scale, Production Carrying Capacity and Ecological Carrying Capacity

As discussed in chapter 4, the aim of the Indonesian government is to expand fish farming activities, especially through small family owned businesses. Therefore, it is necessary to consider small scale farms (10 cages or less) and large scale farms (100 cages or more). Table 6.2 compares the maximum production obtained from the estimates regarding small scale and large scale farms which are mainly influenced by the grow out period among culture species. The grow out period of TG, HG, and LG are 300 days, 500 days and 180 days, respectively. The estimated production of small scale farms using 10 cages are 3.3 t/a, 1.4 t/a and 5.5 t/a respectively for TG, HG and LG. Meanwhile, this table illustrates that HG fish farms can produce about 13.8 t/a if the fish farm uses 100 cages, but leopard coral grouper and tiger grouper produce 54.7 t/a and 32.8 t/a, respectively. Thus, the estimated fish farm production of about 13.8 t/a is used as a limit to determine large farm scale, with 500 m as the minimum distance between farms.

Table 6.2 : Correlation between number of cages with maximum production of fish farm

Fish farm	Tiger Grouper (t/a)	Humpback Grouper (t/a)	Leopard coral Grouper (t/a)
10 cages	3.3	1.4	5.5
100 cages	32.8	13.8	54.7

Since the estimation of the total maximum production CC does not exceed the ecological carrying capacity (Byron and Coasta-Pierce, 2010), the estimation of the maximum allowable production in the vicinity of Galang Island is 21,727 t/a. Regarding the table of production carrying capacity in the vicinity of Galang Island, this total production is achieved by 206 fish farms with an estimated production CC in the range of 32.5 t/a/f to 366 t/a/f (See Table 6.3).

Table 6.3: Estimation of the Maximum Farm sizes and Total Production in Galang Island

No	Production indication (tonnes/year)	No	Production indication (tonnes/year)	No	Production indication (tonnes/year)
1	366	41	163	81	100
2	351.5	42	162.5	82	100
3	305	43	152	83	100
4	303.5	44	151	84	99
5	295	45	148	85	99
6	283	46	148	86	96
7	278	47	148	87	93.5
8	276.5	48	147	88	92.5
9	272.5	49	143	89	92.5
10	264	50	142	90	90
11	253	51	140	91	88
12	249	52	139	92	88
13	248	53	137.5	93	87.5
14	247.5	54	135.5	94	87
15	236	55	134.5	95	86
16	235.5	56	133	96	85.5
17	230.5	57	132.5	97	85.5
18	225.5	58	131	98	84.5
19	218	59	130.5	99	84
20	209.5	60	129.5	100	82.5
21	208.5	61	128.5	101	81.5
22	204.5	62	127.5	102	80.5
23	202.5	63	121	103	80
24	200.5	64	116.5	104	80
25	199	65	115.5	105	79.5
26	196	66	114.5	106	78
27	195.5	67	111.5	107	77.5
28	194	68	110.5	108	76
29	191	69	110	109	75.5
30	190	70	108.5	110	75
31	189.5	71	108	111	73.5
32	188.5	72	106.5	112	72.5
33	188.5	73	105	113	72
34	184.5	74	105	114	72
35	181.5	75	104	115	71.5
36	176.5	76	103.5	116	71
37	171.5	77	103	117	71
38	169.5	78	102	118	70.5
39	168.5	79	101	119	69.5
40	163.5	80	100	120	69

No	Production indication (tonnes/year)	No	Production indication (tonnes/year)	No	Production indication (tonnes/year)
121	68	161	49	201	34.5
122	68	162	48.5	202	34
123	68	163	48.5	203	35.5
124	66.5	164	48.5	204	33
125	66.5	165	48	205	33
126	66	166	47.5	206	32.5
127	65.5	167	47		
128	64.5	168	47	**TTL**	**21704**
129	64.5	169	46		
130	64.5	170	45.5		
131	63.5	171	45.5		
132	63.5	172	45.5		
133	63.5	173	45		
134	60.5	174	45		
135	60	175	44.5		
136	60	176	44		
137	59.5	177	44		
138	57.5	178	43		
139	57.5	179	42.5		
140	57.5	180	41.5		
141	57	181	41.5		
142	57	182	41		
143	56.5	183	40.5		
144	56.5	184	40.5		
145	56	185	40		
146	56	186	40		
147	55.5	187	40		
148	55	188	40		
149	55	189	40		
150	54	190	39.5		
151	53.5	191	39		
152	53	192	38.5		
153	52.5	193	38		
154	52	194	37.5		
155	51	195	36.5		
156	50.5	196	36.5		
157	50	197	36		
158	50	198	36		
159	49.5	199	36		
160	49.5	200	35.5		

Considering the type of species and various feeds, in order to produce 32.5 t/a/f as the minimum production of the production CC, it is necessary to develop big/large scale farms requiring more than 100 cages. Thus, for future fish farm development in the vicinity of Galang Island, large scale farms are recommended. Then, regarding the estimation of maximum production CC in the vicinity of Galang Island which projects potential production of 366 tons/year/farm, we assume that the required number of FNC to be 600 cages, 2250 cages, 950 cages for TG, HG, and LG, respectively. Thus, these are categorized as large farms because the number cages is above 100 cages (Kangkeo et al. 2010) along with the minimum distance between fish farm being 500 m (Wong et al. 1999).

6.2.4 Farm Arrangement

In order to give an interpretation of farm arrangements in the vicinity of Galang Island, the best potential locations for 5 farms of 600 cages with a minimum distance of 500 meters between individual farms were selected. This scenario is achieved by applying SYSMAR DSS which configures the best location and appropriate distance given the information collected. As can be seen in Table 6.4 below, the best 5 suitable locations are presented. The scenario of a 600 FNC farm arrangement will be drawn up to complement the overview taking into account bathymetry and hydrodynamics along with the SYSMAR DSS application.

Table 6.4: The 5 most suitable farm sizes in the vicinity of Galang Island

No	X	Y	Production indication (tons/year)
1	430814	83211	366
2	430725	81747	351.5
3	429525	83984	305
4	430854	82487	303.5
5	431393	81024	295

Bathymetry and Hydrodynamics

To give an analysis of the bathymetry information, as can be seen in Figure 6.21 below the bathymetry in the vicinity of Galang Island is categorized as shallow and favorable for grouper fish farm operation. Comparing the bathymetry informationwhich is presented by isoline, the model of current magnitude points out higher speed and a hydraulically more energetic environment on the eastern side in the vicinity of Galang Island. High current magnitude can be expected in the east and deeper part of Galang Island.

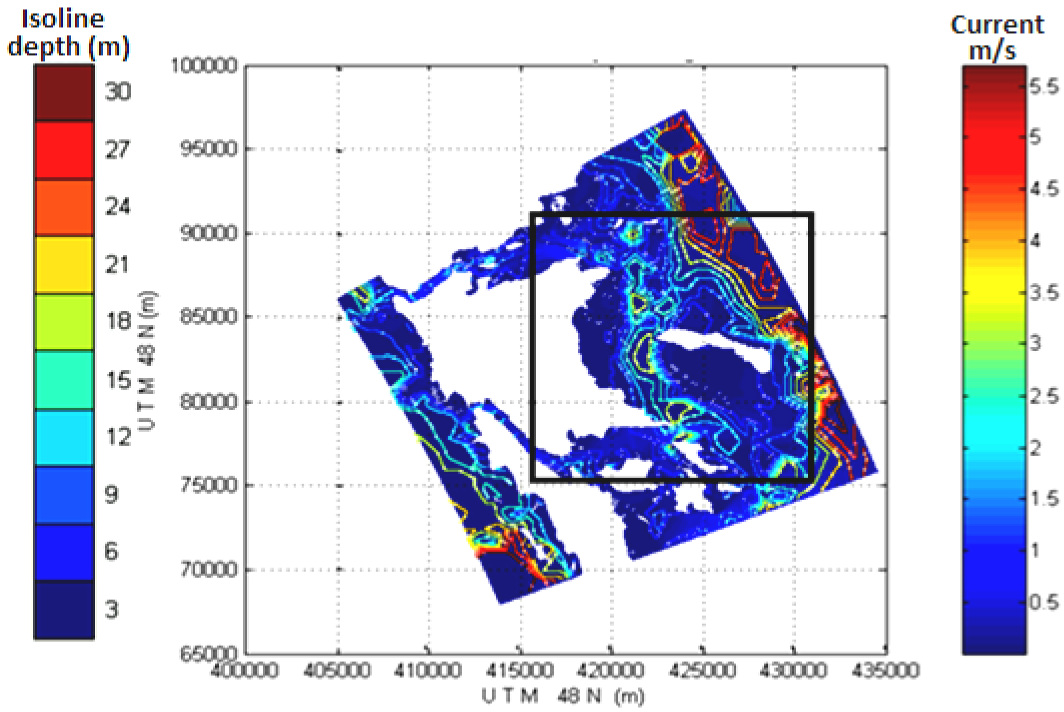


Figure 6.21: Bathymetry and Current Speed in the vicinity of Galang Island

The model results in the vicinity of Galang Island show that the current speed at Galang Island demonstrates the sequence of a semi-diurnal tide. The maximum current speeds at observation point G3 are higher during the ebb flow, at about 0.4 m/s and 0.35 m/s, than during the flood flow, at about 0.25 m/s (see Figure 6.22, Figure 6.23 and Figure 6.24). In general, the current velocities in the vicinity of Galang Island during flood flow are directed towards the north (north west / north east), the ebb flow on the other hand is south (south east and south west).

The current speed through the model simulation in the vicinity of Galang Island established that the flow characteristic is categorized as semidiurnal and diurnal tides (see Figure 6.24), the currents have strong ebb flow towards the south and weaker in flood flow directed northwards (this finding meets agreement with Niederndorfer, 2006).

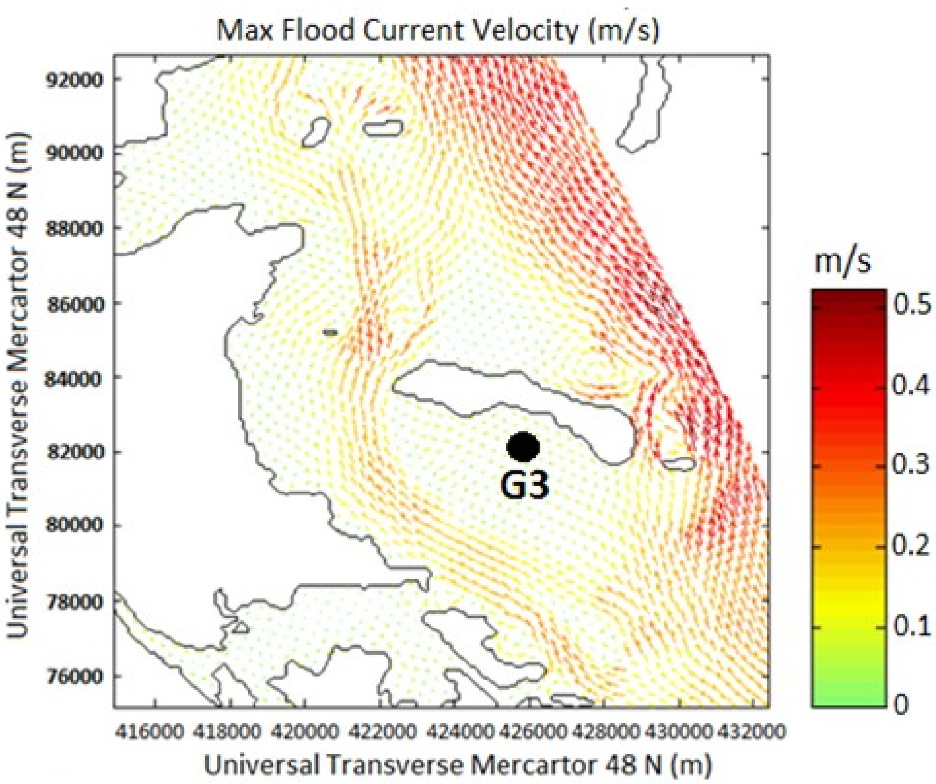


Figure 6.22: Max Flood Current Velocity in the vicinity of Galang Island

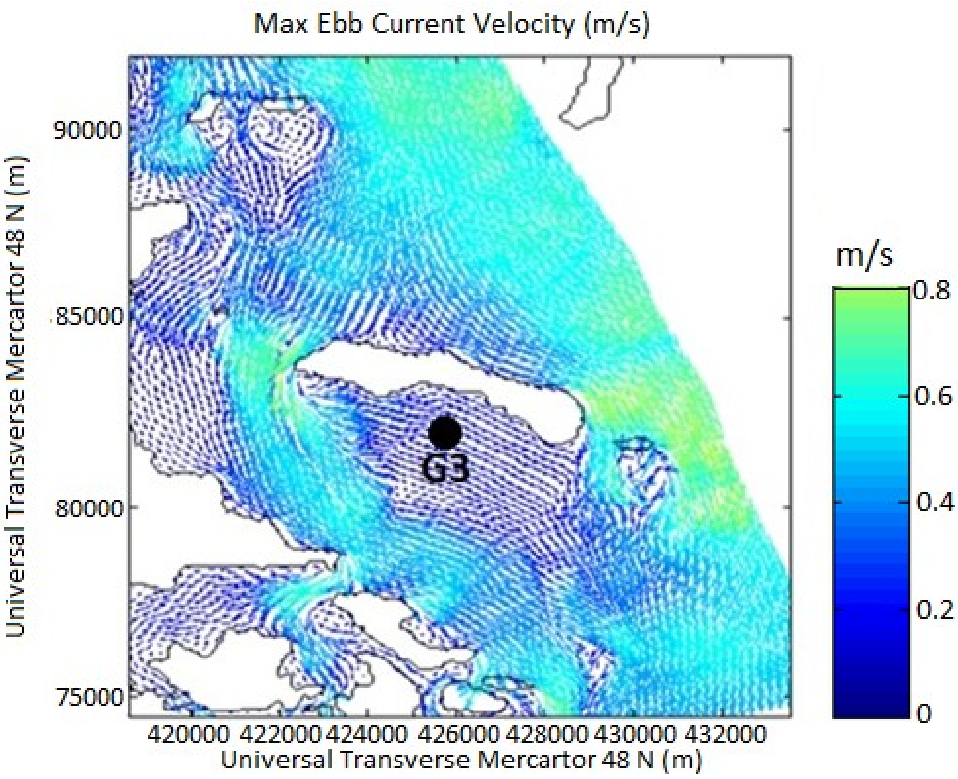


Figure 6.23: Max Ebb Current Velocity in the vicinity of Galang Island

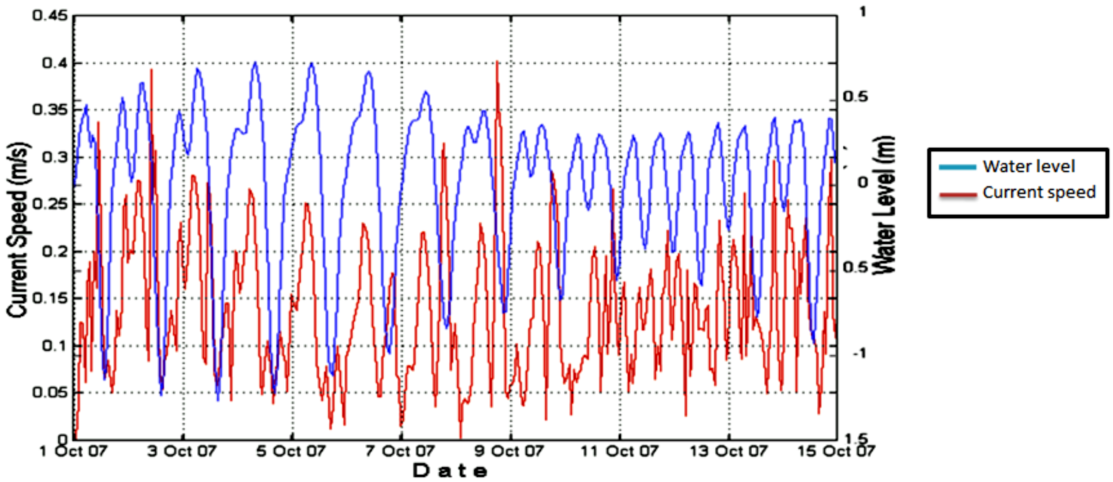


Figure 6.24: Water level and Current speed at observation point G3

As already explained before, the outcomes of the application of SYSMAR DSS show that the estimation of the maximum allowable production in the vicinity of Galang Island is 21,727 t/a which is produced in the range from 32.5 t/a/f to 366 t/a/f. Thus, in order to give a detailed interpretation, the 5 best suited locations have been selected. The production of each fish farm is in the range 295 t/a to 366 t/a, and they are located in the eastern part in the vicinity of Galang Island (compare Table 6.4 and Figure 6.21, 6.22, 6.23, 6.25 and 6.26). These proposed fish farms are marked by a red line along the suitable location. As can be seen in Figure 6.26, details of the 5 most suitable fish farms in the vicinity of Galang Island are presented. The suitable locations are found in the eastern part of Galang Island, including Karas Island and Karas Kecil Island.

The 5 Most Suitable Farm Arrangements in the vicinity of Galang Island

According to the results of the SYSMAR DSS application, the 5 suitable fish farms should be arranged by considering the direction of flood and ebb flow currents for reducing energy during maximum flow. Heavyweight anchors are placed in the dominating flow directions to keep the clusters in place (Wulp, 2006). Thus, the direction of the 600 FNC grouper cultures should be arranged by considering flow direction. Example fish farm no. 1 towards north west along with fish farm no.2 towards north east (see Figure 6.26 and 6.27).

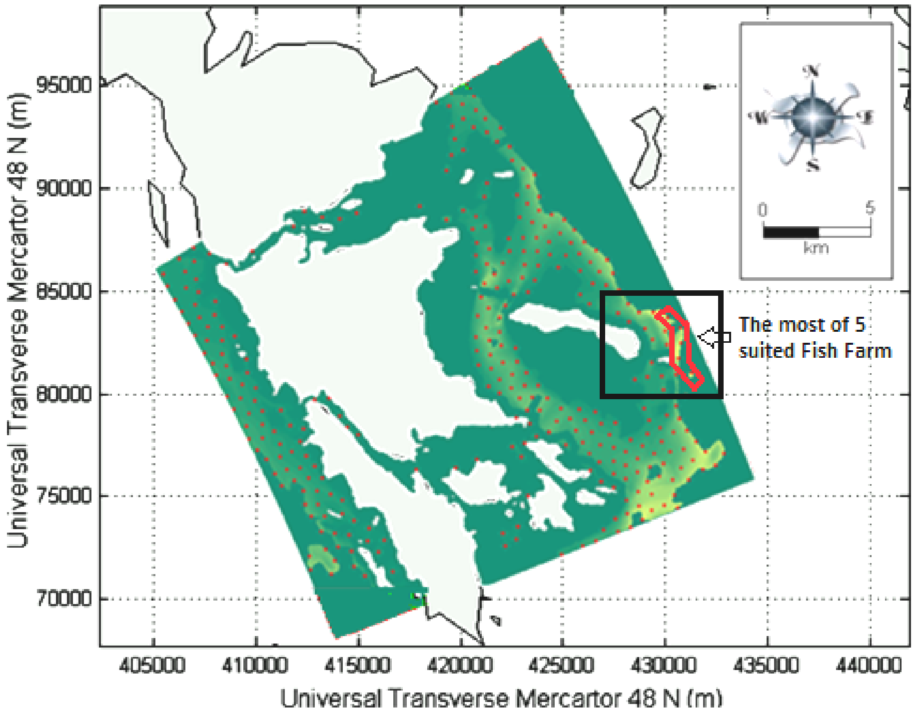


Figure 6.25: The 5 most suitable Fish Farms in the vicinity of Galang Island

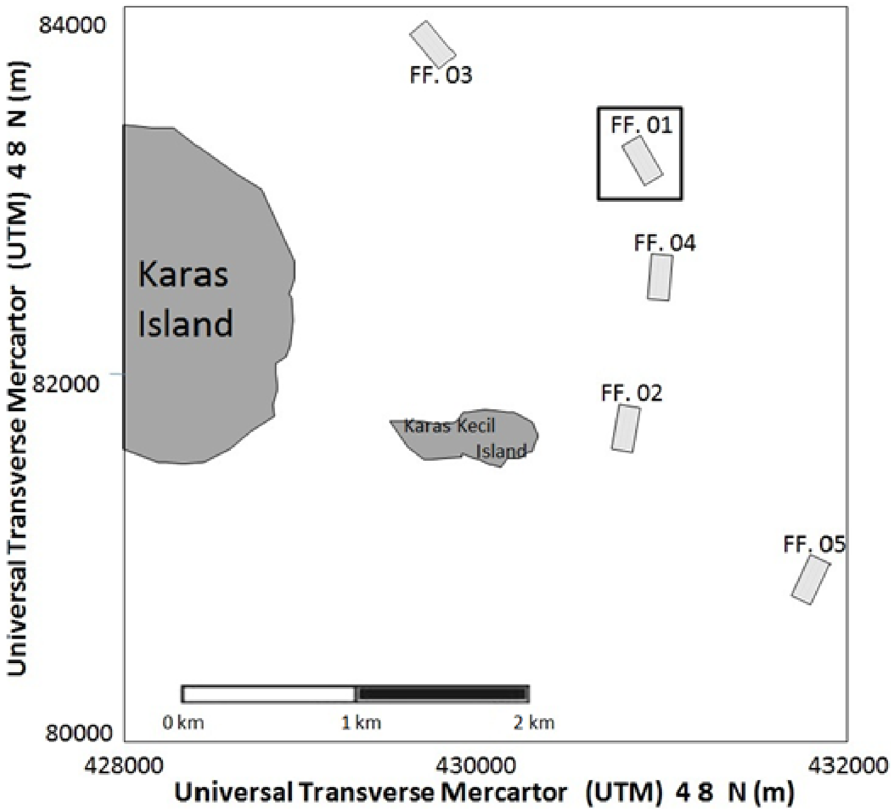


Figure 6.26: Detail of the 5 most suitable Fish Farms in the vicinity of Galang Island

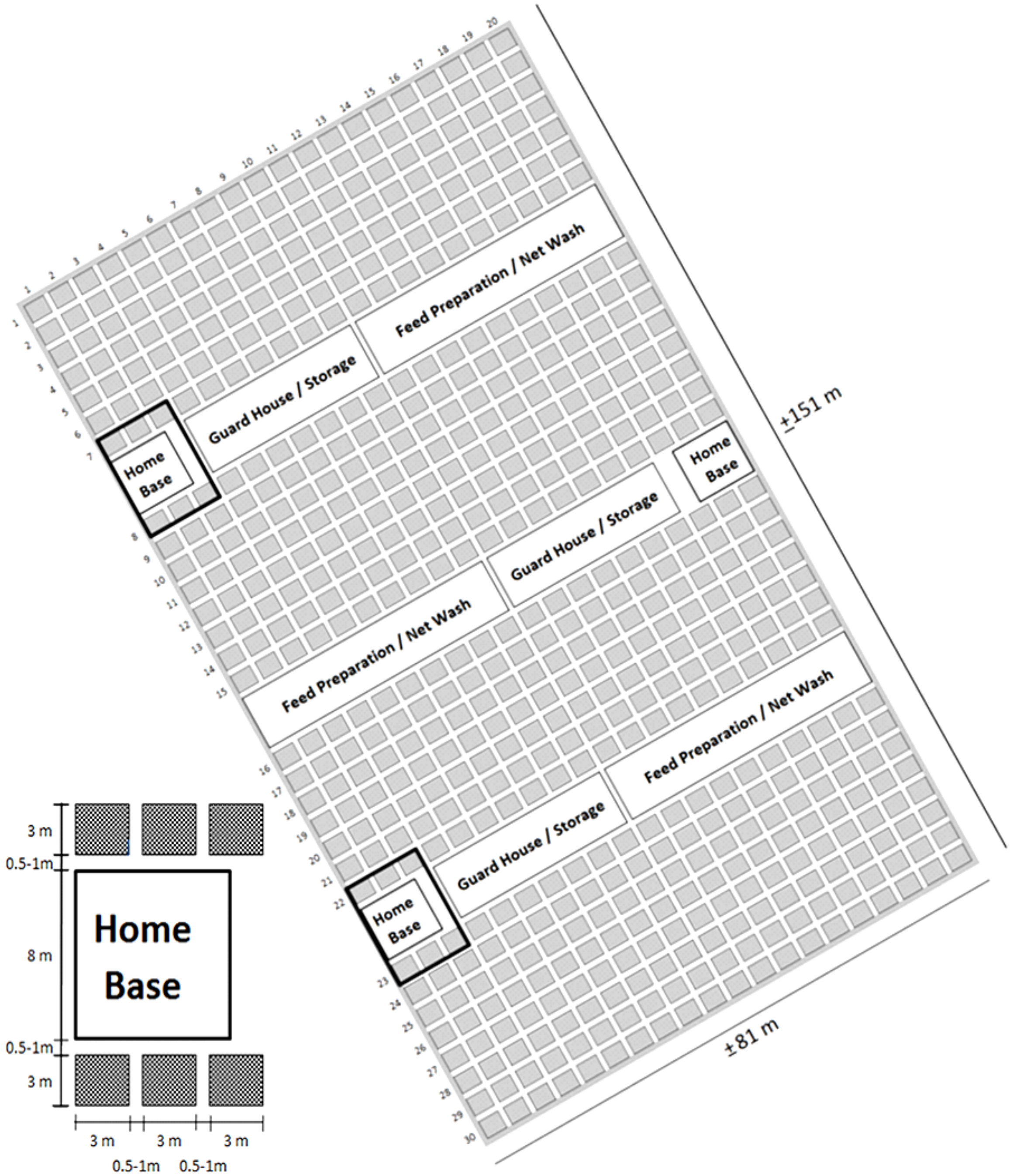


Figure 6.27: Farm Arrangement of the 600 FNC grouper culture

As already pointed out before, the development of the area FNC grouper culture affected by waste releases from aquaculture activities is very much dependent on the flow dynamics and water depth. The foremost reason for the deterioration of the water quality in coastal environments is probably the deposition of suspended solids on the seabed in the vicinity of FNC farms, which is contained high concentrations of organic matter, with remains of uneaten feed along with feces released into the surrounding waters. In this study, it is defined by the destination of particulate carbon governed by the amount of waste and physical characteristics, and deposited beneath FNC farms which adopt threshold value criteria of 1 - 2 g C m^{-2} d^{-1} , along with criteria based on the levels of water quality in the surroundings of the farms which is applied 1% of the nitrogen flux into the domain**.** Furthermore, the characteristics of the culture produced also plays a role. All these factors determine the dispersion of organic inputs and particles and the redistribution of waste material on the ground (Findlay and Watling, 1997;Cornel and Whoriskey, 1993; Stigebrandt, 2011, Staniford, 2002; Weston, 1986; Gesamp, 2001; van der Wulp, 2010; Gilibrandt et al. 2002; Krost, 2007; Hermawan, 2012; Angel et al. 1995; Gowen et al. 1989; Kibria et al. 1996; Niederndorfer, 2006).Thus, the farm of 600 cages which accommodate about 151 m x 81m along with the minimum distance between fish farm being 500 m could be recommended.

Furthermore, as already explained, this study also considers small scale fish farms consisting of 10 cages, and the farm arrangement of 10 FNC grouper culture is shown in Figure 6.28. Nevertheless, the finding of this study recommends large scale farms for future development of FNC grouper culture in the vicinity of Galang Island, but the goal of Indonesian government for poverty reduction by expanding these culture activities especially through small family owned businesses must also be taken into account. Then, for the next step concerning economic analysis to decide economic profitability, we will consider 600 cages as a large scale farm and 10 cages as small scale.

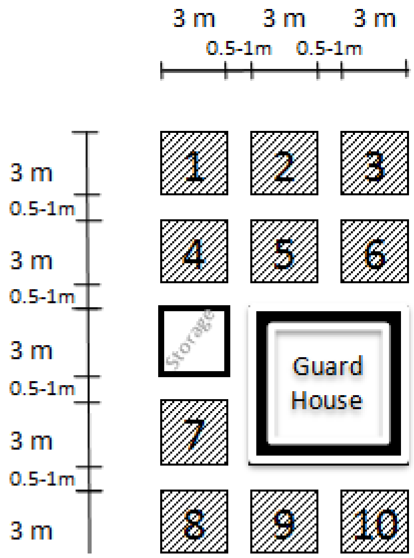


Figure 6.28: Farm Arrangement of the 10 FNC grouper culture

6.3 Economic Analysis of the SYSMAR DSS

The development of Floating Net Cages (FNC) finfish culture in the Indonesian coastal zone is expected to be both environmentally and economically sustainable. Economic sustainability is achieved in those sites in which environmentally sustainable production rates turn out to be profitable. Regarding SYSMAR DSS, the site selection analysis revealed that the Galang Island is the best location to further develop FNC finfish culture in Indonesia. In this study the economic viability of FNC finfish culture projects in the coastal zone of Galang Island is assessed. The economic viability is determined for 3 species (Tiger Grouper (TG), Humpback Grouper (HG) and Leopard Coral Grouper (LG)), 2 farm sizes (10 cages and 600 cages), 3 production levels for each farm size (10 cages: 3.3 t, 1.4 t, 5.5 t, respectively for TG, HG and LG; 600 cages: 197 t, 83 t, and 328 t respectively for TG, HG, and LG), and 3 types of feed (pellets, trash fish, and a mix of 30% pellets and 70% trash fish). Therefore, a total number of 18 cases are analyzed.

In order to achieve the objective of the economic analysis two steps are necessary. The first step deals with the estimation of the relevant financial indicators, the second step with a ranking of the analyzed cases according to the values of the indicators. Step 1: Profitability assessments for FNC grouper cultures investment are carried out resorting to three standard methods of financial analysis: (i) the net present value, (ii) the internal rate of return and (iii) the payback period. Step 2: Ranking of all 18 cases according to NPV, IRR, and PP.

It can be seen from the data in Table 6.5 that the assumed initial investment cost of FNC grouper culture in Galang Island for 10 cages and 600 cages amounts to about 11,980€ and 504,000€, respectively. The duration of the project is 5 years. It is apparent from this table that the discount rate with respect to Indonesian Bank is 13%, along with a local treasury tax rate of 25% which is applied progressively in accordance with Law No.17 of 2010. The food conversion ratio used for trash fish feed is 7.78 and for the pellet feed we used 2.64. The growout period of the groupers range from 180 days to 500 days. From the table we can see that the seed price at Galang Island for TG, HG, LG are 0.6€, 0.96€ and 2.72€, respectively, and the feed price of trash fish and pellet are 0.32 €/kg and 1.04 €/kg, respectively. This table assumes that the commodity values are 11.2 €, 28.0 €, 21.6 € respectively for tiger grouper, humpback grouper, and leopard coral grouper. These prices can be compared to exporter prices for humpback grouper which reach 36 - 40 € per kg (MMAF, 2013, i.e. PT. Bofa Marine NTB).

What is interesting in this data is that the total wage bill per year of a 10 FNC farm and a 600 FNC farm is 4,612 € and 44,688 €, respectively. We assume that 10 cages need 3 workers (2 technicians with wages of 112 €/month/person and a block manager with wages of 160 €/month) while 600 cages need 28 workers (25 technician at 112 €/month/person, a site manager at 200 €/month, a block manager at 160 €/month and a manager at 400 €/month).

In the general cost benefit economic analysis conducted here, a variety of assumptions must be made in order to simplify this study, along with maintaining the focus of the analysis on the proper areas. The assumptions used in this study include capital cost, initial investment, fixed cost, variable cost, sales price, tax rate, discount rate, and production volume. All of the assumptions are taken from actual data which were gathered from multiple sources in 2012. The difference of variable cost including seed price, feed price, and wages are estimated with regard to the variance of standard prices and salaries. However, in this study there are limits to variable cost including transportation, packaging, delayed implementation of project and salvage value which are regarded as insignificant.

In Table 6.6 and Table 6.7 a clear and comprehensive description of the capital cost for 10 cages and 600 cages are shown. Data were collected from many sources including CRITC ((Coral Reef Information And Training Centers) COREMAP-LIPI., (COREMAP II) CRITC LIPI, BPP-PSPL UNIVERSITAS RIAU, (2009)), the Center for coastal and marine resources studies, research and community empowerment at Bogor Agricultural University, 2002-2011, along with the marine and fisheries research center of Nusa Cendana University, 2006. Table 5.3 is quite revealing in several ways:
First, the expenditure of a home base (5 x 5 m), guard house, storage including wood log, window, cupboard, construction cost etc are assumed of about 1,640 €; second, the expenses of 10 floating net cages including wood log, wood plank, rope, net cage, drum, bolt and nut, special paint, as well as construction cost are 8,275 €; third, charges for operational equipment including scoop net, bucket, mechanical balance, search light rechargeable, glove, electricity are about 149 €; and the cost of general equipment such as generator and electricity installations, boat, kitchen equipments, cool box, aerator are assumed to be 1,277 €. Besides that there are contingency costs of about 5% of total investment which amount to about 567€. Thus, the total capital cost based on 10 cages at Galang Island is about 11,908€. The capital cost of the development of FNC grouper culture in Galang Island for 600 cages is presented in Table 6.5. The calculations were carried out with respect to the number of cages in a particular project along with other parameters including home base, operational equipment, etc., amounting to an estimated total capital cost of 503,248 €.

Table 6.5: Economic properties of grouper cultures at Galang Island

		Galang Island 10 cages		Galang 600 cages
Investments	Floating net cages 3×3×3m,	11,908 €		504,000 €
(see Table 5.3-5.4 for detailed				
Figures)	Lifespan (years)		5	
	Discount rate (%)[a]		13	
	Tax rate (%)[b]		25	
Food conversion ratio[e, f]	Trash fish		7.78	
	Pellets		2.64	
Grow out period (day)[f]	Tiger Grouper		300	
	Humpback Grouper		500	
	Leopard Coral Grouper		180	
Seed price (€/pc.)[c]	Tiger Grouper		0.6	
	Humpback Grouper		0.96	
	Leopard Coral Grouper		2.72	
Feed price (€/kg)[c]	Trash fish		0.32	
	Pellets[g]		1.04	
Production (kg)	Tiger Grouper	3,285		197,100
	Humpback Grouper	1,380		82,782
	Leopard Coral Grouper	5,475		328,500
Commodity value (€/kg)[c]	Tiger Grouper		11.20 €	
	Humpback Grouper		28.00 €	
	Leopard Coral Grouper		21.60 €	
Wages (€/year)[d]	Total wages	4,612 €		44,688 €

Remarks:

[a] Discount rate based on Indonesian Bank (2012)

[b] Progressive Tax for Domestic Agency based on UU No.17 year 2010

[c] Ismi, Gondol research institute for Mariculture Indonesia (2012) compare MMAF (2013)

[d] Labor salary based on Ministry of Labor Indonesia (2012)

[e] Alongi et al, (2010)

[f] Van der Wulp et al, (2010)

[g] Sugama (2012)

Table 6.6: Capital cost based on 10 cages at Galang Island

No.	Item	Spesications	Quantity	Unit	Price Cost	Sub-total Cost	Total Cost
1	Homebase, guard house, storage[a,b,c]	Size : 5x5 m, wood log, wood plank, zinc roof, door, window, cupboard	1 [d]	unit [a,b]	1,200.00 € [a,b]	1,200.00 €	1,640 €
2	Smooth net cage[a,b,c]	a. Plastic, Ø 5 mm, 30 unit	3 [d]	roll [a,b]	40.00 € [a,b]	120.00 €	
		b. construction costs	1 [d]	unit [a,b]	320.00 € [a,b]	320.00 €	
3	Floating Net Cages : 10 pcs [a,b,c]	2 cages, 3x3, wood, PE net 2					8,275 €
	Wood log[a,b,c]	10x6x400/500 cm, *Shorea spp. Or Araucaria spp.*	5 [d]	m3 [a,b]	408.00 € [a,b]	2,040.00 €	
	Wood plank[a,b,c]	20x3x400/500 cm	2 [d]	m3 [a,b]	408.00 € [a,b]	850.00 €	
	Rope[a,b,c]	a. FNC : PE, 10 mm	80 [d]	kg [a,b]	4.16 € [a,b]	332.80 €	
		b. Anchor : PE, 30 mm	160 [d]	kg [a,b]	4.16 € [a,b]	665.60 €	
		c. PE, 5 mm	160 [d]	kg [a,b]	4.16 € [a,b]	665.60 €	
	Net cage[a,b,c]	a. Polyethylene (PE), D21, Ø 0,5 inch 3,5x3,5 m	180 [d]	kg [a,b]	4.64 € [a,b]	835.20 €	
		b. PE, D21, Ø 1 inch	180 [d]	kg [a,b]	4.64 € [a,b]	835.20 €	
	Drum[a,b,c]	Hard Plastic, 200 l, blue	53 [d]	unit [a,b]	13.60 € [a,b]	720.80 €	
	Bolt and nut[a,b,c]	5x0,5 " & 10x0,5", steel	113 [d]	kg [a,b]	1.08 € [a,b]	122.04 €	
	Special paint[a,b,c]	antibiofouling and anticorrotion,	2 [d]	l [a,b]	4.00 € [a,b]	8.00 €	
	Construction coasts[a,b,c]	a. 1 Unit for 10 cages of wood	1 [d]	unit [a,b]	960.00 € [a,b]	960.00 €	
		b. 1 Unit for 10 cages of net cages	1 [d]	unit [a,b]	240.00 € [a,b]	240.00 €	
4	Operational equipment[a,b,c]	a. Scoop net (fine and large mesh)					
		- Long handle	2 [d]	unit [a,b]	10.00 € [a,b]	20.00 €	149 €
		- large mesh size	2 [d]	unit [a,b]	6.40 € [a,b]	12.80 €	
		- fine mesh size	2 [d]	unit [a,b]	6.00 € [a,b]	12.00 €	
		b. Bucket (small tanks)	1 [d]	unit [a,b]	4.00 € [a,b]	4.00 €	
		c. Mechanical balance	1 [d]	unit [a,b]	28.00 € [a,b]	28.00 €	
		d. Searchlight rechargeable	1 [d]	unit [a,b]	26.00 € [a,b]	26.00 €	
		e. Glove	3 [d]	unit [a,b]	2.00 € [a,b]	6.00 €	
		f. Electricity	1 [d]	unit [a,b]	40.00 € [a,b]	40.00 €	
5	Generator & electricity installations[a,b,c]	Diesel, 2 kw, 110-240 V	1 [d]	unit [a,b]	100.00 € [a,b]	100.00 €	1,277 €
6	Boat[a,b,c]	a. Body & accessory: Wood, 12,5 m long, 3 ton, wood roof	1 [d]	unit [a,b]	440.00 € [a,b]	440.00 €	
		b. Engine: Yanmar, 24 PK, diesel	1 [d]	unit [a,b]	600.00 € [a,b]	600.00 €	
7	Kitchen equipments[a,b,c]	Stove gas, gas tube, plate, pan, spoon, etc.	1 [d]	packet [a,b]	100.00 € [a,b]	100.00 €	
8	Cool box[a,b,c]	250 l, insulation	1 [d]	unit [a,b]	28.00 € [a,b]	28.00 €	
9	Aerator[a,b,c]	Portable, 15 watt	1 [d]	unit [a,b]	8.80 € [a,b]	8.80 €	
10	Overheads/Contingency[d]	5% of total investment					567 €
	Total						11,908 €

Remarks :

[a] CRITC LIPI – Coral Reef Information And Training Centers is a component of COREMAP-LIPI, (COREMAP II) CRITC LIPI, BPP-PSPL UNIVERSITAS RIAU, 2009

[b] Center for Coastal and Marine Resources Studies (CCMRS-IPB), Research and Community Empowerment (LPPM), 2011

[c] Marine and Fisheries Research Center of Nusa Cendana University, 2006

[d] Modified regarding to Engineering adjustment

Table 6.7: Capital cost based on 600 cages at Galang Island

No.	Item	Spesications	Quantity	Unit	Price Cost*	Price Cost	Sub-total Cost	Total Cost
1	Homebase, guard house, storage[a,b,c]	Size : 8x8 m, wood log, wood plank, zinc roof, door, window, cupboard	3 [d]	unit	30,000,000 [a,b]	2,400.00 € [a,b]	7,200.00 €	9,360.00 €
2	Smooth net cage[a,b,c]	a. Plastic, Ø 5 mm, 30 unit	30 [d]	roll	500,000 [a,b]	40.00 € [a,b]	1,200.00 €	
		b. construction costs	3 [d]	unit	4,000,000 [a,b]	320.00 € [a,b]	960.00 €	
3	Floating Net Cages : 600 pcs [a,b,c]	20 cages, 3x3, wood, PE net						465,170.00 €
	Wood log[a,b,c]	10x6x400/500 cm, *Shorea spp. or Araucaria spp.*	300 [d]	m3	5,100,000 [a,b]	408.00 € [a,b]	122,400.00 €	
	Wood plank[a,b,c]	20x3x400/500 cm	125 [d]	m3	5,100,000 [a,b]	408.00 € [a,b]	51,000.00 €	
	Rope[a,b,c]	a. FNC : PE, 10 mm	5,000 [d]	kg	52,000 [a,b]	4.16 € [a,b]	20,800.00 €	
		b. Anchor : PE, 30 mm	10,000 [d]	kg	52,000 [a,b]	4.16 € [a,b]	41,600.00 €	
		c. PE, 5 mm	10,000 [d]	kg	52,000 [a,b]	4.16 € [a,b]	41,600.00 €	
	Net cage[a,b,c]	a. Polyethylene (PE), D21, Ø 0,5 inch, 3,5x3,5 m	12,000 [d]	kg	58,000 [a,b]	4.64 € [a,b]	55,680.00 €	
		b. PE, D21, Ø 1 inch	4,500 [d]	kg	58,000 [a,b]	4.64 € [a,b]	20,880.00 €	
	Drum[a,b,c]	Hard Plastic, 200 l, blue	3,200 [d]	unit	170,000 [a,b]	13.60 € [a,b]	43,520.00 €	
	Bolt and nut[a,b,c]	5x0,5 " & 10x0,5", steel	6,750 [d]	kg	13,500 [a,b]	1.08 € [a,b]	7,290.00 €	
	Special paint[a,b,c]	antibiofouling and anticorrotion,	100 [d]	l	50,000 [a,b]	4.00 € [a,b]	400.00 €	
	Construction coasts[a,b,c]	a. 1 Unit for 12 cages of wood	50 [d]	unit	12,000,000 [a,b]	960.00 € [a,b]	48,000.00 €	
		b. 1 Unit for 12 cages of net cages	50 [d]	unit	3,000,000 [a,b]	240.00 € [a,b]	12,000.00 €	
4	Operational equipment[a,b,c]	a. Scoop net (fine and large mesh)						
		- Long handle	15 [d]	unit	125,000 [a,b]	10.00 € [a,b]	150.00 €	768.00 €
		- large mesh size	15 [d]	unit	80,000 [a,b]	6.40 € [a,b]	96.00 €	
		- fine mesh size	9 [d]	unit	75,000 [a,b]	6.00 € [a,b]	54.00 €	
		b. Bucket (small tanks)	9 [d]	unit	50,000 [a,b]	4.00 € [a,b]	36.00 €	
		c. Mechanical balance	3 [d]	unit	350,000 [a,b]	28.00 € [a,b]	84.00 €	
		d. Searchlight rechargeable	6 [d]	unit	325,000 [a,b]	26.00 € [a,b]	156.00 €	
		e. Glove	36 [d]	unit	25,000 [a,b]	2.00 € [a,b]	72.00 €	
		f. Electricity	3 [d]	unit	500,000 [a,b]	40.00 € [a,b]	120.00 €	
5	Generator & electricity installations[a,b,c]	Diesel, 2 kw, 110-240 V	6 [d]	unit	1,250,000 [a,b]	100.00 € [a,b]	600.00 €	4,156.80 €
6	Boat[a,b,c]	a. Body & accessory: Wood, 12,5 m long, 3 ton, wood roof	3 [d]	unit	5,500,000 [a,b]	440.00 € [a,b]	1,320.00 €	
		b. Engine: Yanmar, 24 PK, diesel	3 [d]	unit	7,500,000 [a,b]	600.00 € [a,b]	1,800.00 €	
7	Kitchen equipments[a,b,c]	Stove gas, gas tube, plate, pan, spoon, etc.	3 [d]	packet	1,250,000 [a,b]	100.00 € [a,b]	300.00 €	
8	Cool box[a,b,c]	250 l, insulation	3 [d]	unit	350,000 [a,b]	28.00 € [a,b]	84.00 €	
9	Aerator[a,b,c]	Portable, 15 watt	6 [d]	unit	110,000 [a,b]	8.80 € [a,b]	52.80 €	
10	Overheads/Contingency[d]	5% of total investment						23,972.74 €
		Total						503,427.54 €

Remarks :

[a] CRITC LIPI – Coral Reef Information And Training Centers is a component of COREMAP-LIPI, (COREMAP II) CRITC LIPI, BPP-PSPL UNIVERSITAS RIAU, 2009

[b] Center for Coastal and Marine Resources Studies (CCMRS-IPB), Research and Community Empowerment (LPPM), 2011

[c] Marine and Fisheries Research Center of Nusa Cendana University, 2006

[d] Modified regarding to Engineering adjustment

6.3.1 Profitability assessment

In order to carry out an economic analysis in Galang Island, profitability assessment can be illustrated briefly by one sample calculation. Table 6.8 provides the cash flow results which are obtained from a cost benefit analysis of the 5 year project of FNC Tiger grouper culture in Galang Island for 10 cages with respect to feeding with pellets. This shows the inflow and outflow of the project and a total revenue of 183,960€ for an estimated total production of 3,285 kg/year. In order to assess net present value, cost benefit analysis is used by applying a 13% discount rate. The result provides a positive NPV of 34,089 € which is obtained from Equation 3.7 and applied by using a Microsoft Excel table. Similarly, the NPV result is assessed by Equation 3.9 (see Chapter 3).

$$NPV = -I_0 + a\frac{(1+i)^n - 1}{i(1+i)^n} \ldots (3.9)$$

where

NPV	=	net present value
I_0	=	Initial investment at point in time 0
a_t	=	the net cash flow (surplus over variable cost) expected to be achieved each period t; since a_t= const. ∀ t, a_t = a
i	=	the discount rate per period;$i = 13\ \%$
n	=	the number of periods during which the project operates and generates net cash flow;$n = 5$.

Then:

$$NPV = -11908 + 13078\frac{(1+0.13)^5 - 1}{0.13(1+0.13)^5}$$
$$NPV = 34{,}090\ €$$

Strong evidence from different formulas was found to prove the calculation of the NPV of FNC finfish culture.

Table 6.8: Cash Flow of 10 FNC Tiger Grouper culture by production scale at Galang Island base on feeding with pellets

	Variable	YEAR						TOTAL
		0	1	2	3	4	5	
A	INFLOW							
	Production (kg)		3,285	3,285	3,285	3,285	3,285	
	Price (€/kg)		11.20 €	11.20 €	11.20 €	11.20 €	11.20 €	
	Total revenue		36,792 €	36,792 €	36,792 €	36,792 €	36,792 €	183,960 €
B	Initial investment	**11,908 €**						
C	Variable cost							
	Freshwater		192 €	192 €	192 €	192 €	192 €	
	Fry		4,380 €	4,380 €	4,380 €	4,380 €	4,380 €	
	Feed		9,019 €	9,019 €	9,019 €	9,019 €	9,019 €	
	Labor		4,612 €	4,612 €	4,612 €	4,612 €	4,612 €	
	Medication		288 €	288 €	288 €	288 €	288 €	
	Fuel and electricity		864 €	864 €	864 €	864 €	864 €	
	Total variable cost		19,355 €	19,355 €	19,355 €	19,355 €	19,355 €	96,776 €
	Variable cost per kg		**5.89 €**					
D	Gross surplus		17,437 €	17,437 €	17,437 €	17,437 €	17,437 €	87,184 €
E	Tax 25%		4,359 €	4,359 €	4,359 €	4,359 €	4,359 €	21,796 €
F	Net surplus		13,078 €	13,078 €	13,078 €	13,078 €	13,078 €	
G	Discount rate 13%		0.885	0.783	0.693	0.613	0.543	
H	Present value		11,573 €	10,242 €	9,063 €	8,021 €	7,098 €	
I	Net Present Value [a]	**34,089 €**						
	Net Present Value [b]	**34,089 €**						
J	Internal Rate of Return[c]	**106.9%**	6,321 €	3,055 €	1,477 €	714 €	345 €	**11,911 €**
	Internal Rate of Return[d]	**106.9%**						
K	Payback period	**0.91**	year					

Remarks : a = equation 3.8
b = equation 3.10
c = equation 3.11
d = equation 3.12

The internal rate of return (IRR) is one of the most effective parameters in economic analysis. In order to look for the internal rate of return, we carried out a calculation in two ways. First, by trial and error regarding Equation 3.10 which is implemented by a Microsoft Excel table, second, by applying the Equation of 3.11. Regarding case number 18 (cash flow of 10 FNC Tiger grouper culture by production scale at Galang Island feeding with pellets), the results revealed that both methods produce the same value, with the IRR of the project at 107 % which is greater than the 13% discount rate thus indicating that the project is also economically viable.

$$\frac{I_0}{a} = \frac{(1+r)^n - 1}{r(1+r)^n} \ldots .(3.11)$$

$$\frac{11908}{13078} = \frac{(1+r)^5 - 1}{r(1+r)^5}$$

$$0.91 = \frac{(1+r)^5 - 1}{r(1+r)^5}$$

r = 1.07

Table 6.8 proved that the different equation of Jacob (1969) is working properly to determine the NPV and the IRR for this project. In order to assess the time needed to recover the initial capital invested, the payback period is calculated. The result showed that this is 0.91 year or about 11 months, which is far below the duration of project. In comparison, the profitability assessment of 600 FNC tiger grouper culture feeding with pellets cultures is presented in Table 6.9.

Table 6.9: Cash Flow of 600 FNC Tiger Grouper culture by production scale at Galang Island base on feeding with pellets

	Variable	YEAR						TOTAL
		0	1	2	3	4	5	
A	INFLOW							
	Production (kg)		197,100	197,100	197,100	197,100	197,100	985,500.00
	Price (€/kg)		11.20 €	11.20 €	11.20 €	11.20 €	11.20 €	
	Total revenue		2,207,520 €	2,207,520 €	2,207,520 €	2,207,520 €	2,207,520 €	11,037,600 €
B	OUTFLOW							
	Production cost							
	Fixed cost							
	Initial investment	**504,000 €**						
C	Variable cost							
	Freshwater		5,280 €	5,280 €	5,280 €	5,280 €	5,280 €	26,400.00
	Fry		262,800 €	262,800 €	262,800 €	262,800 €	262,800 €	1,314,000.00
	Feed		541,158 €	541,158 €	541,158 €	541,158 €	541,158 €	2,705,788.80
	Labor		44,688 €	44,688 €	44,688 €	44,688 €	44,688 €	223,440.00
	Medication		14,400 €	14,400 €	14,400 €	14,400 €	14,400 €	72,000.00
	Fuel and electricity		12,480 €	12,480 €	12,480 €	12,480 €	12,480 €	62,400.00
	Total variable cost		880,806 €	880,806 €	880,806 €	880,806 €	880,806 €	4,404,029 €
	Variable cost per kg		**4.47 €**					
D	Gross surplus		1,326,714 €	1,326,714 €	1,326,714 €	1,326,714 €	1,326,714 €	6,633,571 €
E	Tax 25%		331,679 €	331,679 €	331,679 €	331,679 €	331,679 €	1,658,393 €
F	Net surplus		995,036 €	995,036 €	995,036 €	995,036 €	995,036 €	4,975,178 €
G	Discount rate 13%		0.885	0.783	0.693	0.613	0.543	
H	Present Value		880,563 €	779,259 €	689,610 €	610,274 €	540,066 €	
I	**Net Present Value**[a]	**2,995,771 €**						
	Net Present Value[b]	**2,995,771 €**						
J	Internal Rate of Return[c]	**196.6%**	335,515 €	113,132 €	38,147 €	12,863 €	4,337 €	**503,993 €**
	Internal Rate of Return[d]	196.57%						
K	Payback Period of capital	**0.51**						

Remarks : a = equation 3.8
b = equation 3.10
c = equation 3.11
d = equation 3.12

6.3.2 Ranking of economic analysis

Table 6.10 presents a ranking of the 18 cases studied according to the indicators of financial viability of FNC grouper culture projects in Galang Island. The project ranking shows that the highest net present value (NPV) amounts to 9,961 million Euros, that the highest internal rate of return (IRR) amounts to 590% and that the payback period is shorter than 1 year in the case of a large farm of 600 cages in which the variety Leopard Coral Grouper is fed trash fish. On the other hand, the lowest NPV is obtained from a small farm of 10 cages in which the variety Tiger Grouper is fed pellets (NPV: 34,089 €, IRR 107% and payback less than 1 year).

Surprisingly, the results for the 18 cases show strongly positive levels of NPV, very large values of internal rate of return (well above the discount rate value of 13%) and an extremely short payback period below one year. It is apparent that the economic analysis for the sites in Galang Island clearly indicates the economic feasibility of FNC grouper culture projects. The results pointing toward the profitability of all cases are influenced by the value of the initial investment (I_o) in relation to the value of the periodic net cash flow (a): generally, $I_0 < a$ and $a > 0$ implies a high NPV and a high IRR as well as a relatively short payback period. In such a situation, site selection may occur (i) on the basis of the analysis of the carrying capacity or environmental appraisal of the sites under consideration and (ii) taking into account the amount of capital available for investment in the selected sites. If no investor can be found, the projects cannot be developed even if they were viable from an environmental point of view.

Table 6.10: Ranking of economic analysis of the FNC finfish culture

No.	Type of Floating Net Cages Grouper	NPV (1.000 €)	IRR (%)	PP year
	600 Cages			
1	Leopard Coral Grouper feed with trash fishes	9,961	590	0.19
2	Leopard Coral Grouper feed with trash fishes and pellets	9,837	583	0.17
3	Leopard Coral Grouper feed with pellets	9,739	577	0.17
4	Humpback Grouper feed with pellets	4,062	257	0.39
5	Humpback Grouper feed with trash fishes	4,025	255	0.39
6	Humpback Grouper feed with trash fishes and pellets	3,994	253	0.39
7	Tiger Grouper feed with trash fishes	3,159	204	0.49
8	Tiger Grouper feed with trash fishes and pellets	3,054	200	0.50
9	Tiger Grouper 600 cages feed with pellets	2,996	197	0.51
	10 cages			
10	Leopard Coral Grouper feed with trash fishes	150	387	0.26
11	Leopard Coral Grouper feed with trash fishes and pellets	148	382	0.26
12	Leopard Coral Grouper feed with pellets	146	378	0.26
13	Humpback Grouper feed with trash fishes	51	149	0.66
14	Humpback Grouper feed with trash fishes and pellets	51	148	0.67
15	Humpback Grouper feed with pellets	50	147	0.67
16	Tiger Grouper feed with trash fishes	36	112	0.87
17	Tiger Grouper feed with trash fishes and pellets	35	109	0.89
18	Tiger Grouper feed with pellets	34	107	0.91

Chapter 7

Discussion and Conclusion

7.1 Discussion

7.1.1 Site Selectionand Carrying Capacities

The aim of this dissertation was to demonstrate the application of the SYSMAR Decision Support System (DSS) for the sustainable management of floating net cage finfish cultures. The work is focused on the improvement of SYSMAR DSS to incorporate the EAA concept of the carrying capacity (CC) for sustainable FNC finfish cultures in Indonesia. This concepts includes site selection (total area of mariculture that can be accepted in the offered physical expanse), production CC (the stocking density of cultures at which harvests are maximized) and ecological CC (the stocking or farm density which causes no unacceptable ecological impacts) (Inglis et al. 2002 and FAO, 2010). Although the lack of measurement data is recognized as a major problem for development of mariculture in Indonesia, it is also addressed in this study. Therefore, in order to run SYSMAR DSS, it is essential to get a great deal of data for site selection analysis by physical model simulation and secondary data including project, research, study, online data source as well as Indonesia government data. The SYSMAR DSS is able to determine potential sites for FNC grouper culture projects in three selected Indonesian coastal areas, namely Talise Island (TI), Galang Island (GI), and Ekas Bay (EB) that comply with environmental, sustainability and socio economic criteria.

The priority given to the different carrying capacity categories varies depending on location, national, regional along with environmental, cultural and social issues, which can be utilized as a complimentary standing conclusion making support tool for determining carrying capacity and a decision can be made based on the locally highest-priority category (Ross et al. 2013).

This study produced results which confirm the findings of a great deal of the previous work regarding carrying capacity in this field and presented the utilize of GIS to model site selection or physical carrying capacity for FNC finfish culture in Galang Island based on certain important criteria. Radiarta et al. (2010) reported that GIS is a particularly useful tool for facilitating the decision-making process for coastal planners. The benefit of GIS is the capability to renew, integrate and evaluate data in order to bring out new ratings without difficulty when new (up to date and high quality) data gets available Nath et al. (2000), Cross & Kingzett, (1992) and Radiarta et al. (2010) revealed that other environmental parameters have a notable influence on FNC finfish growth and survival and recognize them as significant in assuming the capability of a site to maintain production, including flow, wave height, dissolved oxygen, salinity, pH, fouling, disease, predators, pollution (or sewage) and seed availability.

The physical parameters including hydrodynamic and wave model resultsfor determining site selection has been reported in chapter 6. The findings are analyzed in the following section.

Talise Island

The findings of the application of SYSMAR DSS which considered that wave exposure in the surrounding area of Talise Island was unsuitable for future development of FNC grouper culture (higher than 1 m) must be interpreted with caution. This result is in agreement with Lolong and Masinambow (2011), who computed the maximum wave height at North Sulawesi province in October to March to be in the range 2.3 m to 4.27 m. This condition, however, obviously implied that this area is an appropriate place. There is no existing fish farming, but there were pearl farm activities which were started in 1980 by a Japanese company.

FNC grouper culture activities exist in the north of Kinabohutan Island (a small island east of Talise Island). However, production is small (5 tons – 10 tons, Siwi$_{a,b}$, Ministry of Marine Affairs and Fisheries, North Sulawesi, 2012). It should be noted that from a wave parameter viewpoint, this region is not appropriate for future FNC grouper culture development. Moreover, the suitable maximum depth is located at a coral reef / mangrove zone which is also indicated as a protected area.

Ekas Bay

In order to analyze Ekas Bay, the results of applying SYSMAR DSS showed that this area is not an appropriate location for future FNC grouper culture development considering its physical characteristics including current speed and wave height. This finding confirms bathymetry information taken from Indonesian nautical chart no. 262 which confirms that the location of fish farms there is inappropriate. Meanwhile, Krisanti and Imran (2006) revealed that there were 52 FNC located at Awang village (western part of Ekas Bay). Their analysis showed that the carrying capacity of these FNC culture was exceeded. They concluded that the number of cages (farm scales) in this region should be limited because this activity contributed to waste disposal into sea water in this region. This finding was anticipated by Aslianti (2002), who detected diseases in grouper cultures in Ekas bay. Thus, in order to provide other sources of income, other cultures including seaweed, which does not add waste, and increasing sustainability of aquaculture should be introduced and applied.

On the other hand, the suggestion to stop the activities of this culture means most fisherman would lose their income (Krisanti and Imran, 2006). There are two villages which contribute to grouper culture, lobster and pomfret fish in this area including Awang village on the west side and Ekas village on the east side. About 50% of fishing households in Awang village are now involved, part or fulltime in lobster and grouper culture (Pet et al. 2012) with the MMAF promotes East Lombok, including Ekas Bay, as a blue economy zone of marine industry towards a sustainable marine and fisheries development for the prosperity of the Indonesian citizens (Sunoto, 2014, 2012). However since 2009, there is no data about the extent of grouper production in this area except Sunoto (2014, 2012) who reported 12.6 tons. On the other hand, according to Directorate of Aquaculture Statistic MMAF (2013), the production of grouper in this province was increasing from 2008 to 2012.

Galang Island

The outcomes of site selection in the vicinity of Galang Island have been presented in a previous chapter. These results provide further support for the analysis that those physical parameters including water depth, flushing, current, wave and wind have important implications for estimations of suitable areas in Galang Island. The most interesting finding from Galang Island indicated that the main physical parameter which determined site selection was the water depth fluctuation, which was obtained from model results and bathymetry information. It showed that 21,612 Ha (67.4%) are optimal for FNC grouper culture development.

As mentioned in the literature review and results, this study shows that water quality parameters in Galang Island are suitable for development of FNC finfish culture. It is encouraging to compare this figure with that found by Coral Reef Information And Training Centers Indonesian Research Institute (CRITC-LIPI), (2009) who found that sea water quality in the area surrounding Galang Island sub district including Abang Island, Air Saga, Petong Island, Nguan Island, Sembur Island, Karas Island and Mubut Island were suitable for grouper culture activities. The present findings of SYSMAR DSS seem to be consistent with earlier observations which showed that water quality in the vicinity of Galang Island is suitable for the development of FNC finfish projects.

In order to analyze land use for aquaculture and coastal zone utilization, Stead et al. (2002) and Nurhidayah (2010) found complex problems, such as coastal environment degradation and resources depletion, land based marine pollution and overfishing, utilization conflicts of marine space (marine conservation, tourism, aquaculture, industry, ports, access for local people) and overlapping and conflicting laws regarding marine and coastal management. New perspectives on the sustainable use of coastal areas and natural resources were reported by Burnell et al. (2001). Farhan and Lim (2010) revealed that the DSS for Integrated Coastal Management can be used to solve the issues of multiple decision makers and has the ability to integrate multi-disciplinary studies of economic, social, and environmental sustainability in aquaculture. An implementation of the comprehensive ICZM is shown in this study. It is interesting to note that among all 16 parameters of ICZM SYSMAR DSS criteria, half of those parameters including villages, industry, tourism, rivers, pond/semi intensive hatcheries, traffic lanes, coastal usage and environment protected area are seen to affect the size of the area considered suitable for FNC development. The analysis shows that 77.5% of the area or about 24,856 Ha can be defined as an optimal area for FNC finfish culture with regard to ICZM criteria mentioned in Table 3.1.

However, as mentioned previously, this result must be interpreted with caution, as Ferrol-Schulte et al. (2013) and Farhan and Lim (2013) reported that in Indonesia the researchers and practitioners have been blurring the boundaries between conservation, development, poverty-alleviation and natural resource ecosystem management as well as the uncertainty and powerlessness of law enforcement which had caused damage to the environment to some extent.

Thus, the present study highlights that physical carrying capacity is obtained from the site selection of SYSMAR DSS implementation with respect to the results of the high resolution of the hydrodynamic and wave numerical model, water quality and integrated coastal zone management (ICZM). Finally, it demonstrates that about 40.3% (12,940 Ha) of the seawater area in the vicinity of Galang Island are estimated as suitable area.

Generally, the suitability of an area for culture of a certain species is determined by the carrying capacity, which is the maximum biomass of the cultured species that the area can support without exceeding maximum acceptable impact to farmed stock and its environment (Stigebrandt, 2011; Costa-Pierce and Page, 2010). In the present research, production carrying capacity is based on sediment transport or particulate matter derived from FNC finfish cultures. This study uses deposition thresholds ranging from 1 to 2 g organic carbon m^{-2} d^{-1}, compared to van der Wulp et al. (2010), who uses deposition thresholds ranging from 1 to 5 g C m^{-2} d^{-1}, along with Angel et al. (1995), Findlay and Watling (1997), while Gilibrand et al. (2002) used 0.70 kg C m^{-2} y^{-1} (equivalent to 2 g C m^{-2} d^{-1}) as the threshold.

Cai and Sun (2007) revealed that the hydrodynamic effect was the main process when determining the environmental or ecological carrying capacity. The tidal currents played an important role in the diffusion of pollutants and proved that numerical models were convenient tools to predict the environmental carrying capacity. Obviously, areas with the lowest speed currents may effect the most problems for the fish which is influenced by the major uncertainties in the determines of carrying capacity on the farm scale. The uncertainty in current speed conditions occurred during very calm weather (Stigebrandt, 2011). In this study, ecological carrying capacity is achieved with respect to water quality which was calculated by emission rates of total dissolved nitrogen (TDN) not exceeding 1% of the total dissolved nitrogen flux of the suitable domain (Weston, 1986; GESAMP, 2001; Rosenthal, 2006). This was determined based on the natural total dissolved nitrogen flux which had been identified as major contribution for sustainability of farming activities (Wibowo, 2007) in each considered region and yielded high production potentials. This information is considered as confirmation that it will most likely not become a limiting factor in the development of floating net cage farms. It is expected that ecological CC as considered in this study will however become more important when smaller regions are considered. Improved feed technologies i.e. pellet feed are characterized by higher feeding efficiency and lower health risks to the fish stock. Wastage rates are much lower resulting in higher local carrying capacities as shown by the results. Nonetheless, it is common practice in Indonesia to use substantial amounts of trash fish.

7.1.2 Economic analysis

It should be recalled here that the overall goal of this interdisciplinary research project is to develop and apply a decision support system for the implementation of marine fish farming along the Indonesian coast. Therefore, in the final section we carry out the economic analysis of data collected in Indonesia in order to establish whether FNC finfish culture projects comply with the criteria for socio economic viability.

CRITC-LIPI and Riau University (2009) carried out a study of mariculture development in the vicinity of Batam City. They reported that the economic analysis of small scale tiger grouper culture of a single floating cage was viable for development, with results showing a positive NPV of 1.8 thousand Euros, a ROI of 33.5% and a PP of of 1.5 years. The present study shows differences in profitability among grouper types but nevertheless indicates strong financial performances for farming of tiger grouper (TG), humpback grouper (HG) and leopard coral grouper (LG). For example in Galang Island, the results of the economic performance study of the 5 year project with 10 and 600 FNC TG culture feeding with pellets show a positive NPV value in Euro of 34 thousand and 3.0 million, respectively. These figures are 50 thousand and 4.1 million, respectively for HG, and 146 thousand and 9.7 million, respectively for LG. The internal rate of return on 10 cages is 107%, 147% and 378%, and on 600 cages is 197%, 257%, and 577%, respectively for TG, HG, and LG. Regarding payback period, the results showed that all the cultures will be able to gain a return on investment in under one year project lifetime. These findings agree with an economic analysis by Afero et al. (2010). Their economic analysis of tiger and humpback grouper in Indonesia revealed positive values for fish farming activity. They revealed that the large-scale grouper cage cultures with a projected 5-year lifetime are economically feasible, including cumulative cash of 56 thousand Euro, a NPV of 32 thousand Euro, a BCR of 1.33, an IRR of 157% and a payback period of 0.57 years. These results are consistent with a previous study by Utama (2008) who performed a feasibility study of the grouper mariculture in a FNC development in Pagang Island, Seribu Island DKI Jakarta. His results proved that the application of mariculture development was feasible. Furthermore, Sadi (2006) revealed the financial analysis of FNC cultures in Subang West Java showed the highest economic benefit.

An implementation of final decisions have to integrate socio-economic and cultural factors which will approve coastal planners to make better decision. Stead et al. (2002) showed that management of coastal resources such as mariculture has given little consideration to the outlook of stakeholders. Therefore, involving many stakeholders (communities) in the planning and decision-making practice is an essential step toward acceptability and accomplishment of the sustainability management of

FNC finfish culture in this region (Radiarta, 2010). It can thus be suggested that the stakeholders should be supported when establishing themselves. The Asian market is a region of countries with a relatively high level of fish consumption and promises to remain a good market for Indonesian exports. Even the domestic market with some 250 million consumers represents a great potential that should be tapped with high quality products (Foders, 2011).

7.1.3 Sustainable Feed Aquaculture

Aquaculture is a rapidly expanding sector which already accounts for almost half of global seafood production. Individuals involved in the trade are aware that overfishing has been occurring in wild populations and that future supplies of wild caught live reef fish will be more limited. They consequently see the aquaculture sector as providing future growth opportunities for the trade (Chan and Johston, 2007). There is still an urgent need for the development of high quality artificial feed and efficient culturing technology in trash fish areas in order to reduce waste generation (Cai and Sun, 2007). Furthermore, by reason trash fish is held liable for the transmission of parasites to mariculture fish (Rückert et al. 2009), the use of pellet food significantly decreases the transfer of endohelminths and the amount of parasites with a heteroxenous life sequence. Carnivorous finfish mariculture has been the topic of intensive criticism, since the process uses more fish biomass in the form of fishmeal and fish oil than it produces. The limited supply of fishmeal and fish oil from wild fisheries and the continued strong demand for these products have led to concerns about the long term sustainability of the fisheries and the level of responsive management of the fisheries (FAO, 2011). Carnivorous finfish mariculture caused a net loss of livelihood marine resources and is unsustainable given the continued development of the production (Welch et al. 2010).

As mentioned in the literature review, feed manufacturers have the important responsibility to ensure that the feed provided to farmers is nutritionally correct for the intended production system (Talbot and Hole, 1994). Sugama (2012) recently explained that Indonesia had 12 feed manufacturers to support Indonesian mariculture development. The future of fish farming lies in moving away from the intensive monoculture of finfish towards fish farming and integrated polyculture systems (Cai and Sun, 2007). Nevertheless, ensuring that the feeds used in aquaculture are obtained from sustainable fisheries has become a significant issue for the industry. This combination of findings provides some support for future Indonesia FNC finfish culture developments; it is indicated by gradually decreasing the usage of trash fish for feeding to promote sustainable aquaculture.

7.2 Conclusion

The use and implementation of a DSS for sustainable aquaculture development in Indonesia, with respect to the EAA concept of various carrying capacities which was introduced by FAO in 2010, is very complex and a number of concerns should be taken into account. We find that the dissimilarity of the definitions of carrying capacity in the different contexts, along with its development, is a complex problem. On the other hand, this DSS is able to present the integration of all key components of detailed site selection, determination of carrying capacity along with economic appraisal.

7.2.1 Site Selection and Carrying Capacities

Applying site selection of the SYSMAR DSS shows that Galang Island provides a bright potential for FNC finfish culture development which is indicated by a suitable area of about 12,940 hectares. The results of hydrodynamic and wave numerical models show that Ekas Bay and Talise Island are not suited for FNC finfish culture projects. This is why, in the future, the Indonesian government needs to select the locations for new farms in the coastal area very carefully, taking into account environmental, sustainability, and socio economic criteria.

Globally, site selection is helpful to quantify potential areas offered for aquaculture in the ecosystem, on the other hand it recommends little information for the determination of limitations in aquaculture at the water body or watershed level in Ecosystem Aquaculture Approach. Production carrying capacity predicts maximum aquaculture production and is characteristically considered at the farm scale. The production of biomass calculated as a production carrying capacity might be limited to smaller areas or a water basin, thus the amount production biomass of the local area does not go beyond the ecological CC. Ecological CC is interpreted as the amount of aquaculture production that can be sustained with no leading to significant change in ecological cultivate, species, populations, or communities in the environment. Social carrying capacity has been interpreted as the number of aquaculture which is proposed to be developed with no undesirable social impacts (Byron et al. 2011c). Gibbs et al. (2007) defined an economic carrying capacity as the number of money investors are ready to investand the monetary value connected with sellable products and ecosystems services. Not all concepts of Carrying Capacity were addressed in this study; however this study shows different types of carrying capacities by applying the SYSMAR DSS in response to the EAA concept as shown in Table 7.1.

As shown in Table 7.1 below, with respect to production carrying capacities, the marine environment in the vicinity in Galang Island obviously has large potential for the development of FNC grouper culture. The findings of this study indicate that the estimation of maximum and minimum production carrying capacity of all potential farms with distances of at least 500 m between farm sites are in the range of 51 - 366 tons per farm and 0.5 - 2 tons per farm, respectively. To estimate total production regarding ecological carrying capacity, Table 7.1 indicates that Galang Island (GI) could produce in the range of 18,393 - 21,727 tons/year/community area, respectively.

Table 7.1: Different types of carrying capacities based on EAA concept

Type of carrying capacities		Galang Island
Site Selection (Physical carrying capacity) (ha) / suitable area		12,940
Production carrying capacity (t/a/fish farm)	min[a]	0.5 – 2
	max[b]	51 – 366
Ecologicalcarrying capacity (t/a/community area)	POM[c]	3,493 – 23,795
	TDN[d]	18,393 – 21,727

Remarks:

[Amin]: minimum, [b]max: maximum, [c]POM : particulate organic matter, [d]TDN : total dissolved nitrogen

Considering the correlation between carrying capacity and economic analysis, it is interesting to modify SYSMAR DSS to find the appropriate scenario. According to Byron and Coasta-Pierce (2010), the production carrying capacity of the water basin does not exceed the ecological carrying capacity.Thus, we estimate that the ecologicalcarrying capacity in Galang Island of about 21,727tons/annual is achieved by 206 FNC grouper cultures, with a distance between farms of 500 m and the production CC in the range 32.5 – 366 tons/farm.

7.2.2 Economic Analysis

The results from the present study have provided vital information of about 18 cases regarding the economic viability of tiger, humpback, and leopard coral groupers FNC farming utilizing various feed types and production scales. Every prototype farm consists of 600 cages and 10 cages, respectively in Galang Island with a standard cage size of 3 x 3 x 3 m for width, length, and depth. Different types of feed are also considered, such as trash fish, pellet, as well as mixing 70% trash fish and 30 % pellet. The study shows that FNC finfish culture developments are economically viable as a whole, because after a 5-year projection period, positive cumulative cash flow and net present value (NPV), internal rate of return (IRR) at rates above the bank rates, and a payback period (PP) far below the 5 year projected lifetime of the project are evident.

The profitability difference among groupers indicates a stronger financial performance for the farming of Leopard Coral Grouper, as opposed to Humpback and Tiger grouper. As a result, FNC finfish farming offers high revenues and large-scale production and is the most profitable way for grouper farming. For example in Galang Island, the economic analysis of 600 FNC tiger grouper feed with pellets revealed positive results of 5–year cumulative yield cash flow of Euro 6.6 million, NPV of 3 million, with 8.6 million and 4.1 million for humpback grouper, and 19.4 million and 9.7 million leopard coral grouper. The internal rates of return are 197%, 257%, and 577%, respectively for TG, HG, and LG. Regarding payback period, the results showed that all the cultures will be able to gain return of investment within less than one year.

In aquaculture management, the attention to DSS is relatively new, and development of such a technology will play an increasingly important role in analyzing and planning potential aquaculture site selection and production, environmental impacts, and sustainability. SYSMAR DSS intends to help decision makers in Indonesia to collect useful information from a variety of information systems (GIS, remote sensing, online data, etc). A possible explanation for some of our results may be the lack of adequate raw data. These results therefore need to be interpreted with caution. However with model simulations, caution must be applied, as the findings might be utilized to identify tasks and make decisions. It is also a priority to develop a management system to ensure that the environmental impact from Indonesian mariculture does not exceed acceptable levels. These results advertise a strategy for the incorporation of aquaculture within the broader ecosystem in a way that supports sustainable development, equity, and the resilience of interlinked social and ecological systems. The application of an EAA requires the use of a range of methodologies and tools, such as environmental impact assessment systems, risk assessment analysis and decision support tools. For

Indonesia it is very important to develop sustainable mariculture based on the principles of the EAA. However, there have been only limited efforts to develop approaches for implementing a comprehensive and integrated management system, and limited research on the coupling of numerical models and GIS for decision support purposes.

7.3 Recommendations

It is absolutely essential to carry out marine surveys or field verification as part of model activity, organizing certain information sources as well as trying the SYSMAR DSS model. This work can be developed through data inputs, the model results and giving feedback for the modelling process itself by allowing a better understanding of the assumptions used. It should be remembered that a SYSMAR DSS created with participative input also has high acceptability to stakeholders or the full community. Implementing SYSMAR DSS appropriately will require a challenging coupling of management, science and policy, along with strengthened institutions including governments and associated management, with the intention that the future development of sustainable aquaculture in Indonesia can be applied. This implementation needs monitoring and evaluation, as well as an integrated system for assessment and adjustment in order to be developed into a process which shows the achievement of overall objectives.

More broadly, research is also needed to determine an ecosystem approach to endorse sustainable improvement, equity, and resilience of interlinked socio-ecological systems. Considerably more work will need to be done to determine the application of carrying capacities and socio economic viability assessment. Further work needs to be done to establish the SYSMAR decision support system for the development of floating net cage grouper cultures in Indonesia with respect to environmentally sustainable practice. Therefore, the findings of this study suggest that more comprehensive measurement data from the site are indispensable to evaluate, verify, calibrate, and validate the hydrodynamic and wave modelling results as well as SYSMAR DSS modelling results, including:

a. Talise Island

   It is necessary to make a bathymetric survey in the area surrounding Kinabohutan Island, especially the northern part which is covered by wave and wind and where there are existing grouper fish farming and pearl farming (see Figure 7.1).

b. Galang Island

In general, the findings show that there are many places which are considered to be suitable locations in the area surrounding Galang Island. However in order to confirm the outcomes which specify the most suitable location, it is required to carry out measurement, especially in the eastern part in the vicinity of Galang Island, including Karas Island and Karas Kecil Island (see Figure 7.2).

c. Ekas bay

It is necessary to check the bathymetry at the location of the existing fish farms with the purpose of making decisions for future development of FNC grouper culture, because according to Indonesian nautical chart no. 262, the existing fish farms (Sunoto 2014, 2012) are located in appropriate places with a depth of less than 5m. Wave height measurement and current measurement in the vicinity of Ekas bay will then be carried out to calibrate model results (see Figure 7.3).

Generally, further field surveys are needed to determine integrated coastal zone management as a part of the SYSMAR decision support system.

Urgent questions that are still subject to further investigations are scientifically based recommendations in terms of the sustainable practises and monitoring with respect to feed input and site selection. Other aspects which are not considered in this study, such as the availability and qualification of farmers, feed, seed or other resources play an important role. Monitoring of the suitable area has to be done to check SYSMAR DSS model results, since predictions can only be approximate and decisions cannot be made once only and be expected to hold permanently. The DSS result must be improved as the actual consequences of decisions are obtained in practice. This is an important issue for future research.

In addition, it is important to mention that sustainable mariculture in Indonesia still remains in its infancy, and inappropriate policies play a key role in unsettled mariculture expectation. These policies should be deemed as a improvement work, with possible for extension, adjustment and development in the future. Mariculture policy should focus on the stakeholders or community including government, aqua farmers, investors, traders, exporters as well as experts. Moreover, multi-species cultures in a fish farm (polyculture) should be seriously considered for increasing the sustainability of aquaculture.

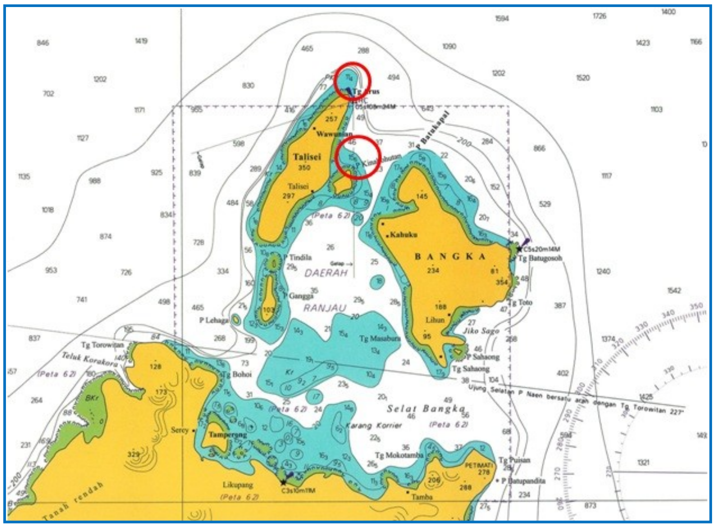


Figure 7.1: Recommendation of Site Monitoring in the vicinity of Talise Island

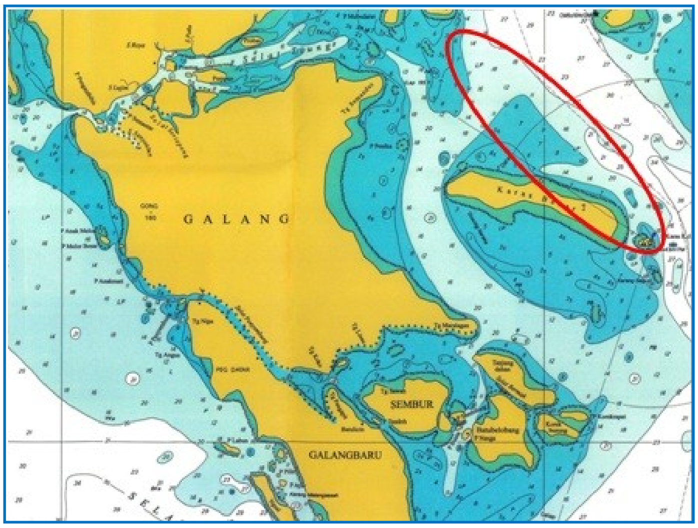


Figure 7.2: Recommendation of Site Monitoring in the vicinity of Galang Island

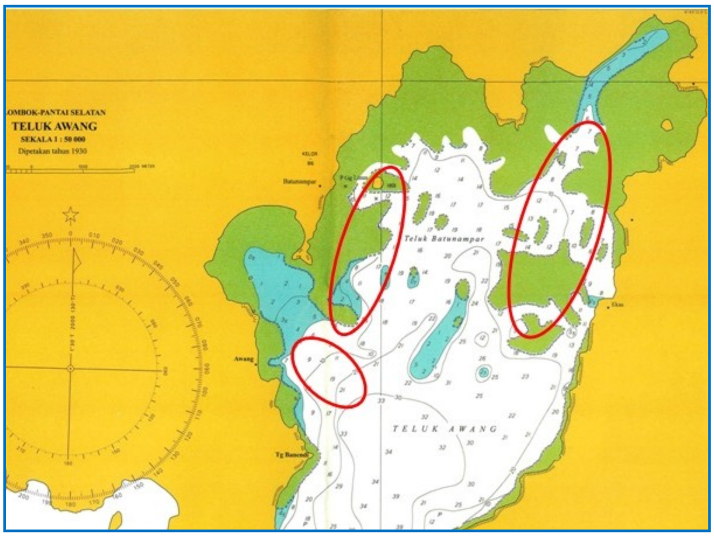


Figure 7.3: Recommendation of Site Monitoring in the vicinity of Ekas Bay

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Appendix 1: Table List of data supplies in Study Area

	Description	Galang Island	Ekas Bay	Talise Island
	Physical Process			
1	Minimum water depth	Indonesian Nautical chart number:42	Indonesian Nautical chart number 262	Indonesian Nautical chart number:344
2	Maximum mooring depth	IOC/IHO/BODC. (2003).[a]	IOC/IHO/BODC. (2003).[a]	IOC/IHO/BODC. (2003).[a]
3	Flushing	Derived from Physical Models	Derived from Physical Models	Derived from Physical Models
4	Exposure to currents	Egbert and Erofeeva. (2002)[c]	Egbert and Erofeeva. (2002): [c]	Egbert and Erofeeva. (2002): [c]
5	Exposure to waves	Derived from Physical Models	Derived from Physical Models	Derived from Physical Models
6	Exposure to wind	NOAA/OAR/ESRLPSD. (2009).NCEP/NCAR Reanalysis 2 data [b].	NOAA/OAR/ESRLPSD. (2009). NCEP/NCAR Reanalysis 2 data [b].	NOAA/OAR/ESRLPSD. (2009). NCEP/NCAR Reanalysis 2 data [b]
	Tides	Derived from Physical Models CRITC LIPI – 2009[d]	Derived from Physical Models	Derived from Physical Models Wantansen, 2008[j]

	Description	Galang Island	Ekas Bay	Talise Island
	Water Quality			
1	Water temperature	CRITC LIPI – 2009[d]	BRKP- 2004[g], CCMRS IPB-2004[h], Krisanti-2006[i]	Wantansen, 2008[j]
2	Salinity	CRITC LIPI – 2009[d]	BRKP- 2004[g], CCMRS IPB-2004[h], Krisanti-2006[i]	Wantansen, 2008[j]
3	Dissolved oxygen	CRITC LIPI – 2009[d]	BRKP- 2004[g], CCMRS IPB-2004[h], Krisanti-2006[i]	Wantansen, 2008[j]
4	pH	CRITC LIPI – 2009[d]	BRKP- 2004[g], CCMRS IPB-2004[h], Krisanti-2006[i]	Wantansen, 2008[j]
5	Water transparency	CRITC LIPI – 2009[d]	CCMRS IPB – 2004[h]	Wantansen, 2008[j]
6	Turbidity	RDCOG Bandung,2005[e]	BRKP- 2004[g], CCMRS IPB-2004[h], Krisanti-2006[i]	
7	Ammonium		BRKP- 2004[g], CCMRS IPB-2004[h], Krisanti-2006[i]	Wantansen, 2008[j]
8	Nitrate	RDCOG Bandung,2005[e]	BRKP- 2004[g], CCMRS IPB-2004[h], Krisanti-2006[i]	Wantansen, 2008[j]
9	Nitrite	RDCOG Bandung,2005[e]	BRKP- 2004[g], CCMRS IPB-2004[h], Krisanti-2006[i]	Wantansen, 2008[j]
10	Phosphate	WOD, NODC, WOA [f]; Schlitzer, 2011[k]	WOD, NODC, WOA; Schlitzer, 2011[k]	Wantansen, 2008; [j] Schlitzer, 2011[k]

Description	Galang Island	Ekas Bay	Talise Island
ICZM	Indonesian Land use Data Bank (ITB) Year 2006 Agency of Regional Planning of Batam City 2004-2014 / National Development Planning Agency	Indonesian Land use Data Bank (ITB) Year 2006 Agency of Regional Planning of Nusa Tenggara Barat 2009-2029 / National Development Planning Agency	Indonesian Land use Data Bank (ITB) Year 2006 Wantansen, 2008[j]

Remarks:

[a] IOC/IHO/BODC. (2003). IOC/IHO/BODC.(2003). General Bathymetric Chart of the Oceans.British Oceanographic Data Centre, Liverpool, U.K. http://www.gebco.net/data_and_products/gebco_digital_atlas/ Global bathymetric grid at 30 arc-second intervals.

[b] NOAA/OAR/ESRLPSD. (2009). NCEP/NCAR Reanalysis 2 data.http://www.cdc.noaa.gov/ Global six hourly reanalysis data with the resolution 1.87 degrees (192 x 94 grid) for wind and sea level pressure

[c] Egbert, G.,D., S.Y., Erofeeva. (2002): Efficient inverse modeling of barotropic ocean tides, J. Atmos. Oceanic Technol.19 (2):183-204. http://www.esr.org/polar_tide_models/Model_TPXO62.html#EgbertErofeeva_2002. Tide extracted from Total Model Driver

[d] CRITC LIPI – 2009Coral Reef Information And Training Centers is a component of COREMAP-LIPI, 2009. (COREMAP II) CRITC LIPI, BPP-PSPL UNIVERSITAS RIAU

[e] RDCOG Bandung,2005, Pusat Penelitian and Pengembangan Geologi Kelautan, Research Development Centre of Ocean Geology (RDCOG), Bandung 2005

[f] WOD World Ocean Database, NODC National Oceanographic Data Center. http://www.nodc.noaa.gov/OC5/SELECT/dbsearch/dbsearch.html, World Ocean Atlas. http://www.nodc.noaa.gov/OC5/WOA09/pr_woa09.html

[g] Badan Riset Kelautan dan Perikanan (BRKP),2004. Agency for Marine and Fisheries research and development, 2004

[h] Center for Coastal and Marine Resources Studies (CCMRS-IPB),2004. Research and Community Empowerment (LPPM)

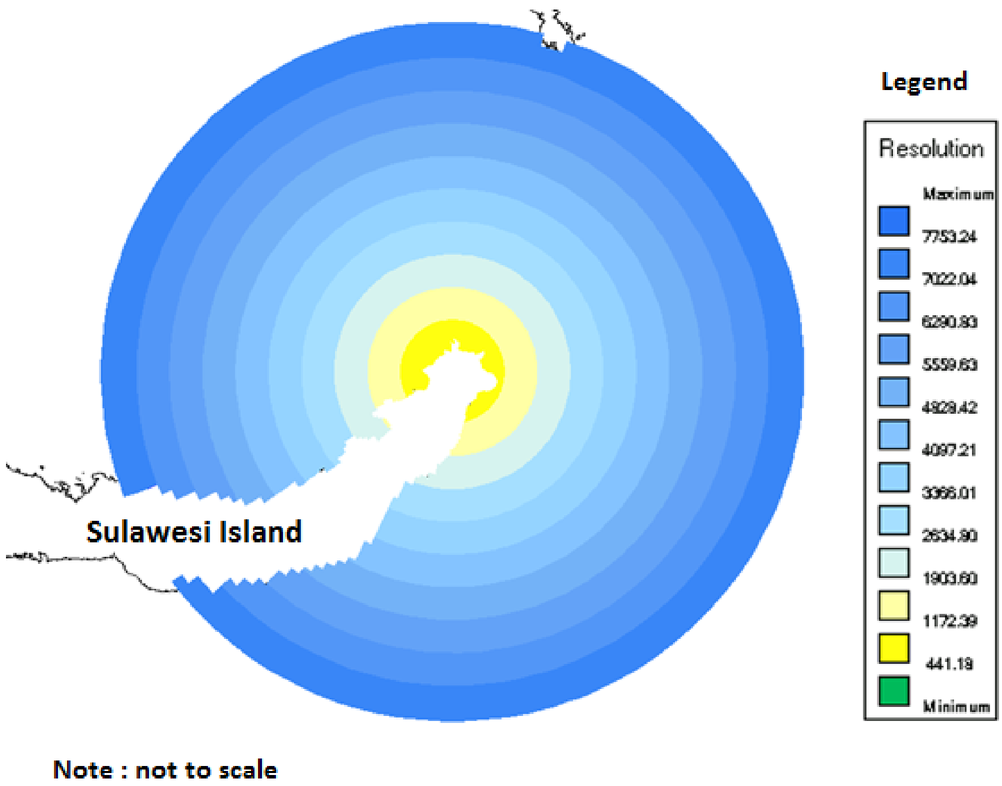
[i] Krisanti, 2006, Bogor Agricultural University

[j] Wantansen, A, 2008. Bogor Agricultural University

[k] Schlitzer, R., Ocean Data View, http://odv.awi.de, 2011

Appendix 2: Pre and Post Talise Island Model

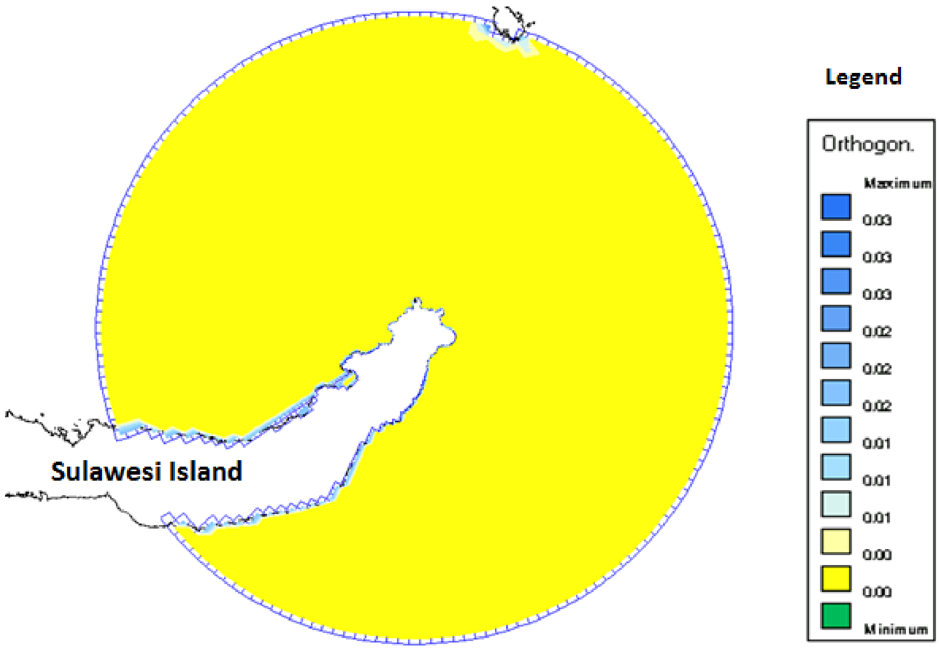
Appendix 2a.Regional grid resolution of Talise Island model



(Pangkey, 2008)

Animportant criteria to be taken into account in setting up the regional grid model is the criteria of a higher resolution in the vicinity of Talise Island. A resolution of about 441 to 7,753 m was obtained by the regional grid of model as shown in Figure 3a.

Appendix 2b.Regional grid orthogonality of Talise Island model

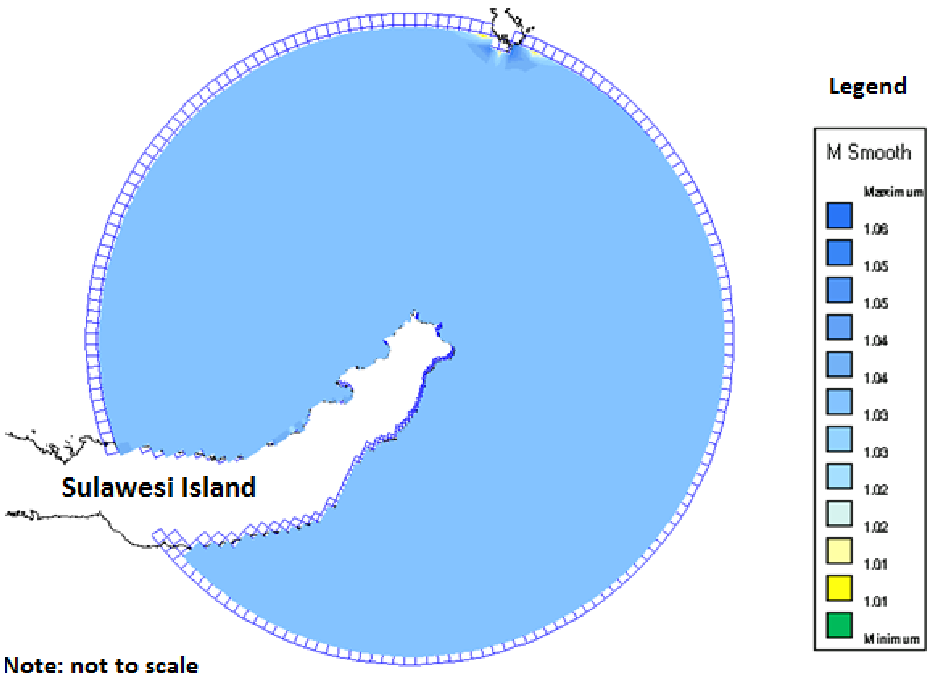


Note: not to scale

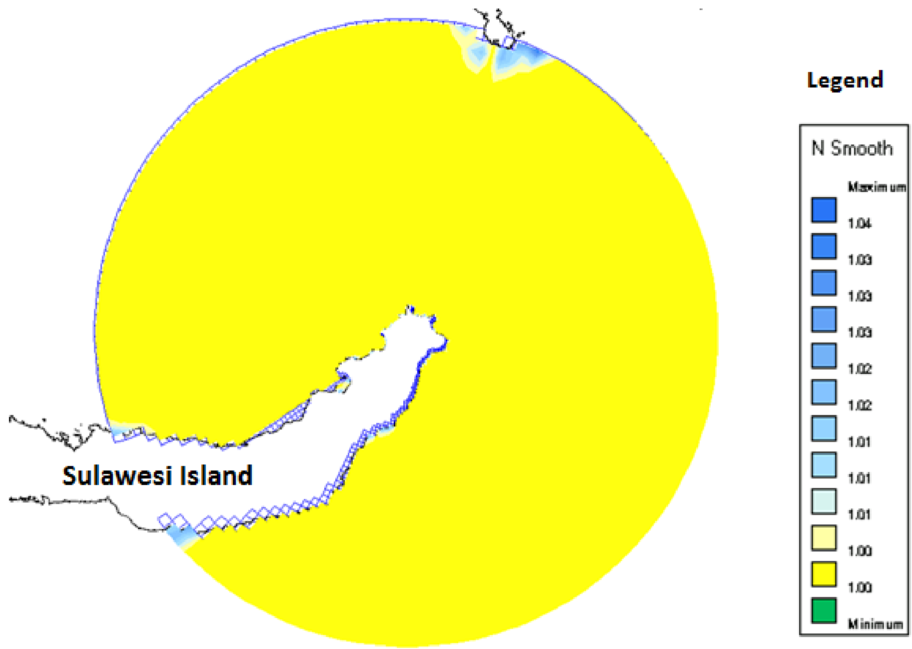
As can be seen in appendix3b, the orthogonality values of the Talise Island model are close to 0.00. It shows that the orthogonality is very good, because the values do not exceed the recommended value of 0.04.

Appendix 2c.Regional grid M-Smoothness of Talise Island Model

The smoothness is the ratio between neighboring grid cell lengths. From the appendix3c we can see that the M and N directions smoothness in the entire domain show almost uniform distribution around a figure of 1.00, whereas a ratio of 1.4 should not be exceeded in the inner part of the model domain.



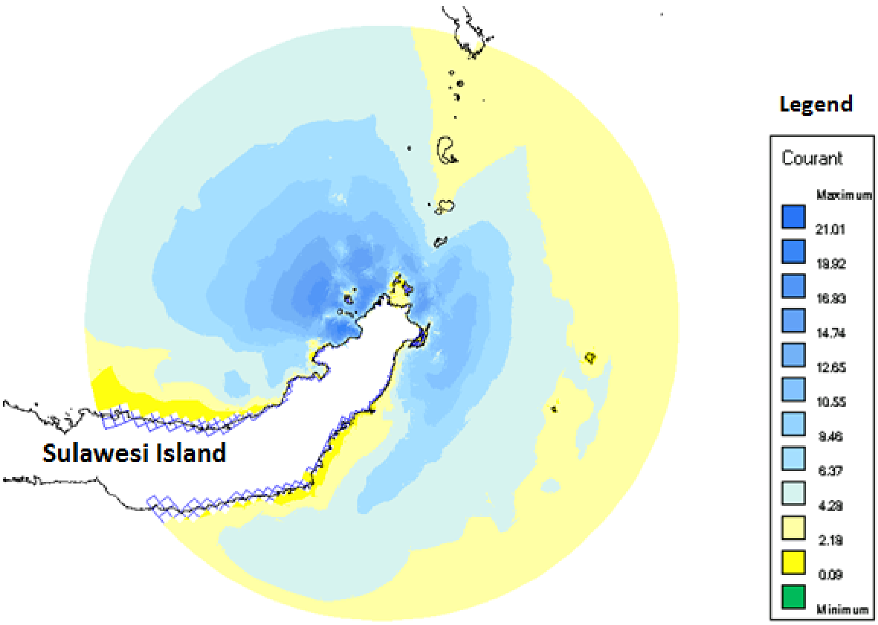
Note: not to scale



Note: not to scale

Appendix 2d.Courant Number

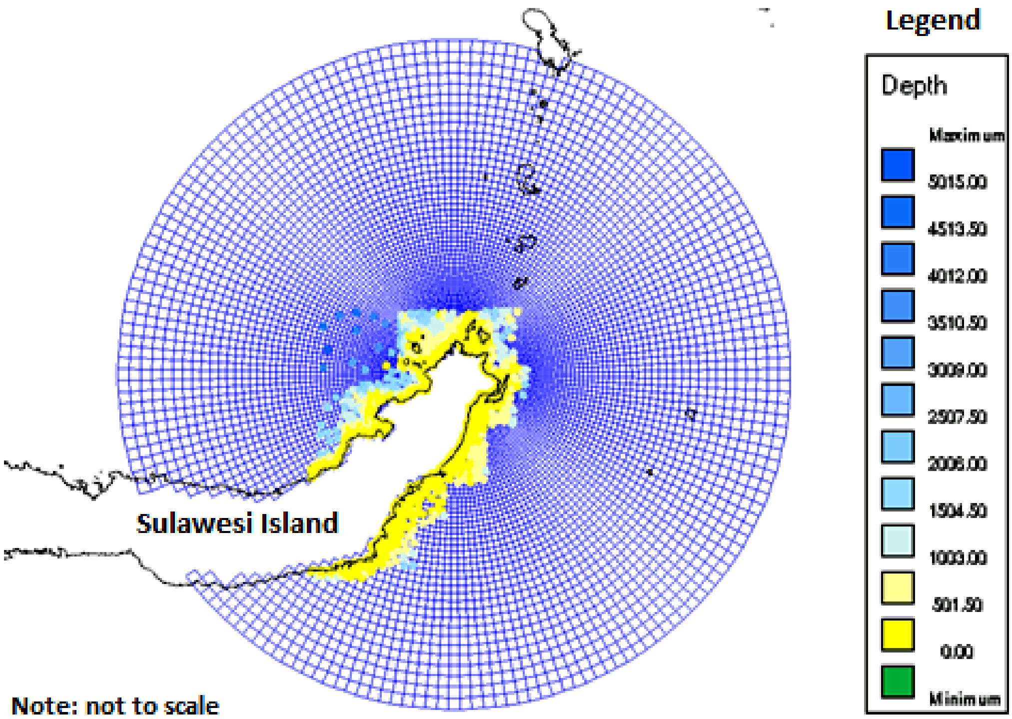
Initially, the courant number is a necessary condition for convergence while solving certain partial differential equations numerically by the method of finite differences. The Courant number should not exceed the value of 10 which gives an idea of accuracy and numerical stability as well as relation between propagation speed and time step. The magnitude of time step determines the total computational time, whereas due to Courant number distribution for fulfilling the Delft3D recommended value the entire domain must not show a figure of more than 40. It can be seen in appendix 3d that the Courant number of Talise Island regional model is below 21.



Note: not to scale

Appendix 2e. Regional model bathymetry : Talise Island Model

Model bathymetry for the regional model has been combined from the depth information samples from different sources. The bathymetry for the near shore area of the regional model domain was digitized from the Indonesian nautical chart number 344: North Sulawesi and Northeast Coast, Tanjung Mamiri to Tanjung Tolu, scale 1: 200.000. Bathymetric information for deep regions was taken from GEBCO online database. In appendix 3e, we can see that the bathymetry sample distributions at near shore area are provided which present a maximum depth of about 5,015 m.



Appendix 2f. Regional model bathymetry : Talise Island Model

As shown in appendix 3e, the depth interpolation for Talise Island regional model is executed with data from nautical chart and GEBCO. It shows that the deepest area at regional model is more than 5,000 m.

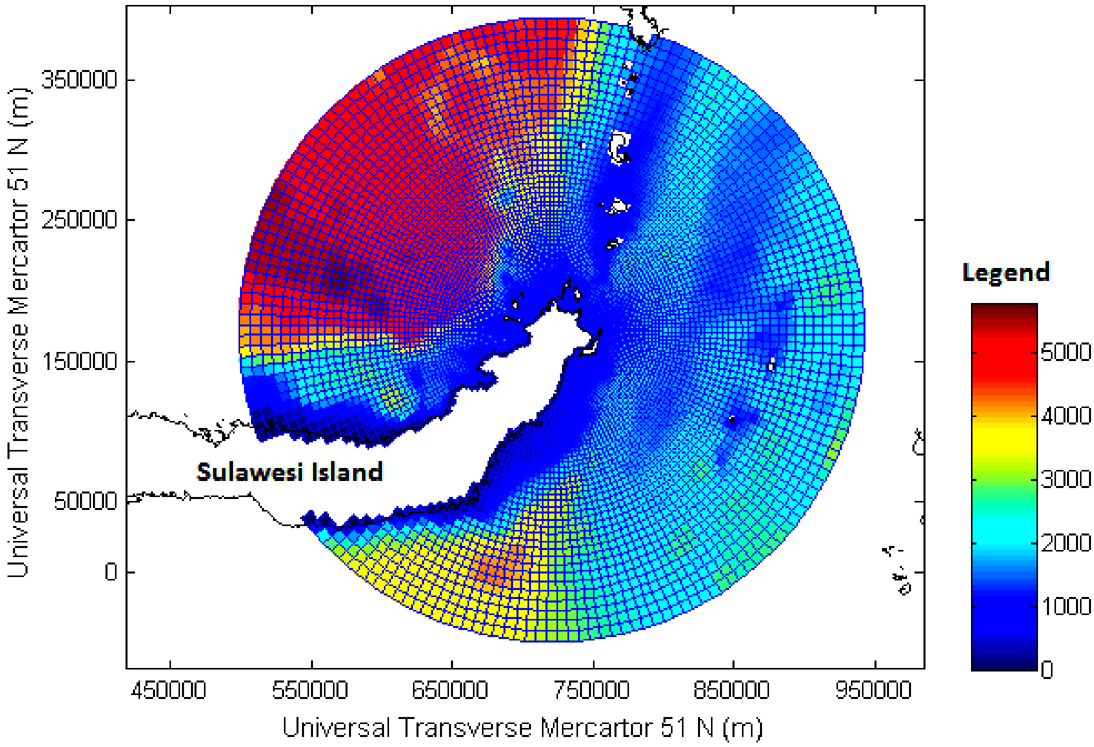


Figure 3g: Regional Depth Interpolation

Appendix 3:Table Astronomical constituent

Source: Egbert, G, D., Erofeeva, S, Y., (2002). Efficient Inverse Modeling of Barotropic Ocean Tides, J. Atmos. Tide extracted from Total Model Driver . Oceanic Technol.19 (2):183-204.http://www.esr.org/polar_tide_models/Model_TPXO62.html#EgbertErofeeva_2002

The open sea boundaries are imposed by astronomical tides derived from a global ocean tide model TPXO 6.2. Thirteen harmonic components (M2, S2, N2, K2, K1, O1, P1, Q1, MF, MM, M4, MS4, and MN4) are used to drive the model. Regarding the National Oceanic and Atmospheric Administration (NOAA), harmonic component constituent name definition is described as follows:

M2 : principal lunar semidiurnal constituent

S2 : principal solar semidiurnal constituent

N2 : larger lunar elliptic semidiurnal constituent

K2 : lunisolar semidiurnal constituent

K1 : lunar diurnal constituent

O1 : lunar diurnal constituent

P1 : solar diurnal constituent

Q1 : larger lunar elliptic diurnal constituent

MF : lunisolar fortnightly constituent

MM : lunar monthly constituent

M4 : shallow water over tides of principal lunar constituent

MS4 : shallow water quarter diurnal constituent

MN4 : shallow water quarter diurnal constituent

(http://www.tidesandcurrents.noa.gov/harmonic_cons_defs.html)

Appendix 3a: Table Astronomical constituent input for Talise Island Model section A and B

A1

Beginning of first segment		
Constituent	Amplitude	Phase
M2	0.605	288.543
S2	0.361	330.724
N2	0.089	277.771
K2	0.101	325.860
K1	0.174	135.588
O1	0.139	119.045
P1	0.061	129.605
Q1	0.031	103.822
MF	0.012	9.547
MM	0.007	10.956
M4	0.001	325.743
MS4	0.001	99.821
MN4	0.001	42.537

A2

End of first segment		
Constituent	Amplitude	Phase
M2	0.611	288.048
S2	0.366	327.082
N2	0.097	274.228
K2	0.104	322.386
K1	0.170	133.837
O1	0.134	117.399
P1	0.060	127.587
Q1	0.030	101.592
MF	0.012	9.678
MM	0.007	11.024
M4	0.001	324.441
MS4	0.001	100.305
MN4	0.001	40.464

B1

Beginning of second segment		
Constituent	Amplitude	Phase
M2	0.611	288.080
S2	0.366	327.083
N2	0.097	274.252
K2	0.104	322.390
K1	0.170	133.798
O1	0.134	117.367
P1	0.059	127.546
Q1	0.030	101.546
MF	0.012	9.687
MM	0.007	11.028
M4	0.001	324.285
MS4	0.001	100.423
MN4	0.001	40.274

B2

End of second segment		
Constituent	Amplitude	Phase
M2	0.588	289.814
S2	0.344	330.462
N2	0.090	278.799
K2	0.095	325.736
K1	0.166	132.375
O1	0.132	116.205
P1	0.058	127.091
Q1	0.029	101.295
MF	0.012	9.939
MM	0.007	11.020
M4	0.001	317.670
MS4	0.001	105.635
MN4	0.000	33.172

Appendix 3b : Table Astronomical constituent input for Galang Island Model section A and B

A1

Beginning for first segment

constituent	amplitude	phase
M2	1.470	61.494
S2	0.700	147.794
N2	0.343	114.968
K2	0.287	146.152
K1	0.066	61.868
O1	0.147	82.026
P1	0.026	348.808
Q1	0.007	0.451
MF	0.012	27.551
MM	0.007	16.558
M4	0.069	106.255
MS4	0.040	170.746
MN4	0.032	166.192

A2

End for first segment

constituent	amplitude	phase
M2	1.283	45.050
S2	0.610	127.271
N2	0.306	95.929
K2	0.249	124.973
K1	0.056	47.019
O1	0.140	73.585
P1	0.026	331.505
Q1	0.006	349.381
MF	0.013	26.309
MM	0.007	15.265
M4	0.039	96.710
MS4	0.024	221.156
MN4	0.023	155.387

B1

Beginning for second segment

constituent	amplitude	phase
M2	1.276	44.781
S2	0.616	125.475
N2	0.309	93.822
K2	0.249	122.772
K1	0.059	48.272
O1	0.140	72.419
P1	0.026	332.916
Q1	0.006	348.668
MF	0.012	27.359
MM	0.007	16.365
M4	0.036	83.709
MS4	0.019	218.859
MN4	0.021	145.777

B2

End for second segment

constituent	amplitude	phase
M2	1.276	44.781
S2	0.705	123.632
N2	0.347	89.528
K2	0.269	118.872
K1	0.080	57.779
O1	0.147	68.402
P1	0.025	349.547
Q1	0.008	348.820
MF	0.008	37.789
MM	0.006	24.424
M4	0.056	42.755
MS4	0.015	114.465
MN4	0.021	94.834

Appendix 3c : Table Astronomical constituent input for Ekas Bay Model section A and B

A1

Beginning of first segment

Constituent	Amplitude	Phase
M2	0.288	93.339
S2	0.12	115.67
K2	0.034	115.961
K1	0.300	184.069
O1	0.195	163.992
P1	0.092	182.166
Q1	0.042	157.965
M4	0.001	286.602
MS4	0.001	79.215
MN4	0.001	264.398

A2

End of first segment

Constituent	Amplitude	Phase
M2	0.294	97.789
S2	0.115	118.326
K2	0.034	118.700
K1	0.296	183.209
O1	0.194	164.221
P1	0.091	181.484
Q1	0.043	157.977
M4	0.001	286.964
MS4	0.001	77.636
MN4	0.001	255.721

B1

Beginning of second segment

Constituent	Amplitude	Phase
M2	0.295	98.280
S2	0.114	118.787
N2	0.063	81.356
K2	0.034	119.185
K1	0.296	183.085
O1	0.193	164.226
P1	0.091	181.387
Q1	0.043	157.976
M4	0.001	286.957
MS4	0.001	77.405
MN4	0.001	254.650

B2

End of second segment

Constituent	Amplitude	Phase
M2	0.305	100.465
S2	0.116	121.159
N2	0.066	78.492
K2	0.035	121.117
K1	0.291	182.077
O1	0.191	164.634
P1	0.091	180.587
Q1	0.043	157.968
M4	0.001	287.092
MS4	0.001	79.016
MN4	0.001	249.989

Declaration

I, Surya Hermawan, born December 10^{th}, 1973 in Bukit Tinggi, West Sumatera Indonesia

Declare

- That apart from the supervisors guidance the content and design of my thesis is all my own work
- The thesis has never been submitted either partially or as a whole as part of a doctoral degree to another examining body and it has not been published or submitted for publication
- That my thesis has been prepared subject to the Rules of Good Scientific Practice of the German Research Foundation

Kiel, May 20^{th}, 2014

Surya Hermawan

About the Author

Surya Hermawan was born in Bukit Tinggi West Sumatera, Indonesia on December 10th , 1973. From 1993 the author started his academic study in Civil Engineering Polytechnic Andalas University Indonesia. He graduated in 1997 to receive Diploma of Civil Engineering and took a final project as his thesis on building and water construction. In the same year he continued his study to the Bachelor degree of Civil Engineering in Gadjah Mada University Indonesia and he graduated in 1999.

In 2000 he continued his study to the Master of Science program in Coastal, Marine and Harbor Engineering, Gadjah Mada University. He completed his study in 2002 with master project on *Predicting of Wave Height in West Region of Indonesia.* Since 2002, he worked as a Researcher and Lecturer of Civil Engineering at Lancang Kuning University Riau Indonesia.

From November 2009 until 2014, he carried out his doctorate study at the Coastal Research Laboratory, the Research and Technology Centre, Westcoast, Kiel University, Germany. His research on the *Improvement and Application of a Decision Support System for Sustainable Floating Net Cage Finfish Cultures Development in Indonesia* was funded by the Directorate General of Higher Education, Ministry of Education and Culture of Indonesia (DGHE), the German Academic Exchange Service or Deutsche Akademische Austauschdienst (DAAD), the Research and Technology Center Büsum / Forschungs-und Technologiezentrum Westküste (FTZ) – Büsum and the International Center and Career Center of Christian-Albrechts-University in Kiel.