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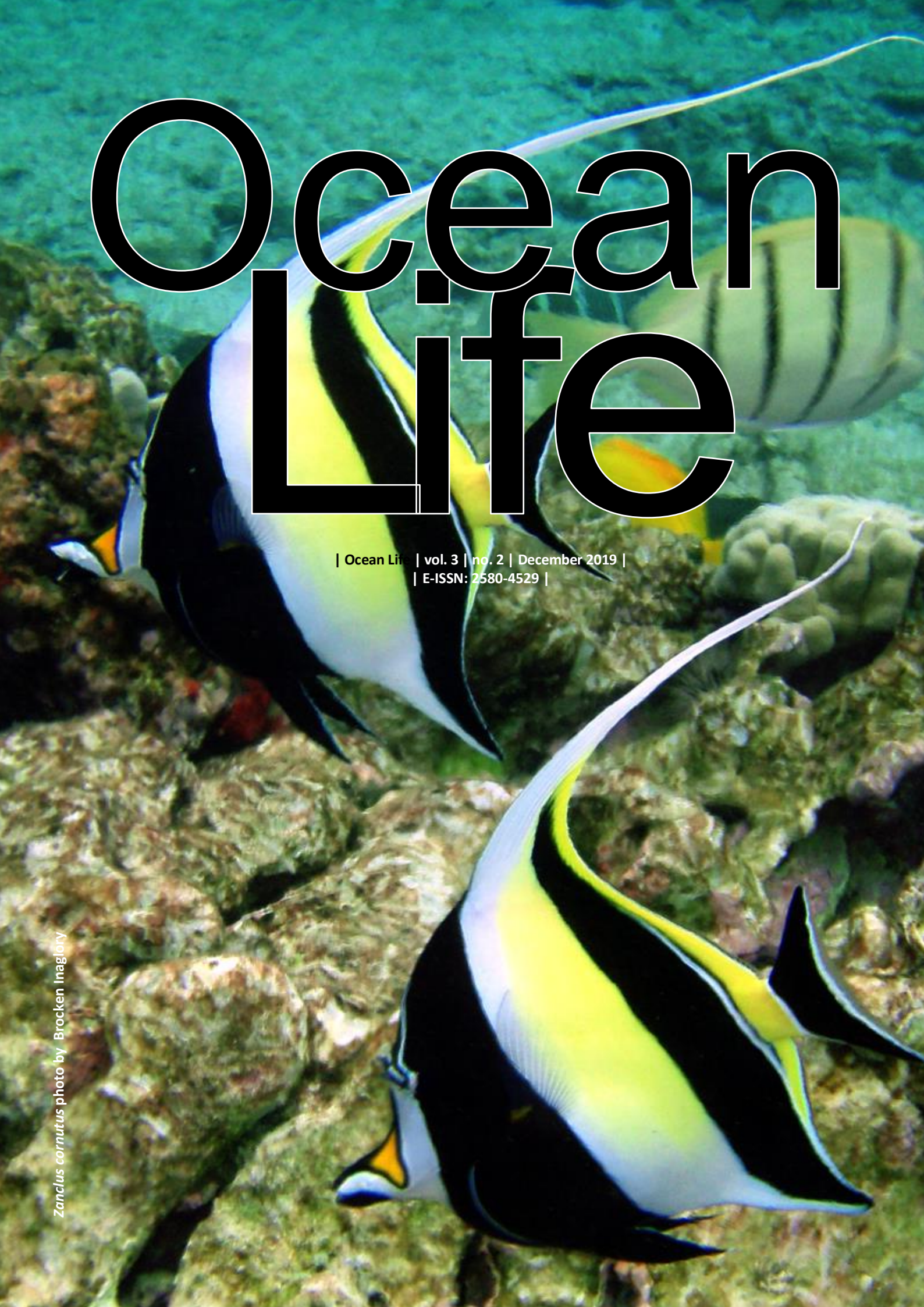

Zanclus cornutus photo by Brocken Inaglory

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Tel./Fax.: +62-986-212156/211455, email: ol@smujo.id, joceanlife@unipa.ac.id, joceanlife@gmail.com

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GUIDANCE FOR AUTHORS

Aims and Scope: ***Ocean Life*** (abbreviated as **Ocean Life**) encourages submission of manuscripts dealing with all aspects of maritime and marine resources in estuaries, coastal zones, continental shelf, the seas and oceans, including marine biodiversity and fisheries resources, biochemistry, physiology, behaviour, and genetics of marine life, socio-economic and cultural aspects, conservation and management, as well as biogeochemistry, marine pollution, and climate change.

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Title of the article should be written in compact, clear, and informative sentence, preferably not more than 20 words. Name of author(s) should be completely written. **Name and institution** address should also be completely written with street name and number (location), postal code, telephone number, facsimile number, and email address. Manuscript written by a group, author for correspondence along with address is required. First page of the manuscript is used for writing above information.

Abstract should not be more than 200 words. **Keywords** is about five words, covering scientific and local name (if any), research theme, and special methods which used; and sorted from A to Z. All important **abbreviations** must be defined at their first mention. **Running title** is about five words. **Introduction** is about 400-600 words, covering the background and aims of the research. **Materials and Methods** should emphasize on the procedures and data analysis. **Results and Discussion** should be written as a series of connecting sentences, however, for manuscript with long discussion should be divided into subtitles. Thorough discussion represents the causal effect mainly explains for why and how the results of the research were taken place, and do not only re-express the mentioned results in the form of sentences. **Concluding** sentence should be given at the end of the discussion. **Acknowledgments** are expressed in a brief; all sources of institutional, private and corporate financial support for the work must be fully acknowledged, and any potential conflicts of interest are noted.

Figures and Tables of maximum of three pages should be clearly presented. Title of a picture is written down below the picture, while title of a table is written above the table. Colored figures can only be accepted if the information in the manuscript can lose without those images; chart is preferred to use black and white images. Author could consign any picture or photo for the front cover, although it does not print in the manuscript. All images property of others should be mentioned source. **There is no appendix**, all data or data analysis are incorporated into Results and Discussions. For broad data, it can be displayed on the website as a supplement.

References: Author-year citations are required. In the text give the authors name followed by the year of publication and arrange from oldest to newest and from A to Z. In citing an article written by two authors, both of them should be mentioned, however, for three and more authors only the first author is mentioned followed by et al., for example: Saharjo and Nurhayati (2006) or (Boonkerd 2003a, b, c; Sugiyarto 2004; El-Bana and Nijs 2005; Balagadde et al. 2008; Webb et al. 2008). Extent citation as shown with word "*cit*" should be avoided. Reference to unpublished data and personal communication should not appear in the list but should be cited in the text only (e.g., Rifai MA 2007, pers. com. (personal communication); Setyawan AD 2007, unpublished data). In the reference list, the references should be listed in an alphabetical order (better, if only 20 for research papers). Names of journals should be abbreviated. Always use the standard abbreviation of a journal's name according to the **ISSN List of Title Word Abbreviations** (www.issn.org/2-22661-LTWA-online.php). The following examples are for guidance.

Journal:

Saharjo BH, Nurhayati AD. 2006. Domination and composition structure change at hemic peat natural regeneration following burning; a case study in Pelalawan, Riau Province. Biodiversitas 7: 154-158.

Book:

Rai MK, Carpinella C. 2006. Naturally Occurring Bioactive Compounds. Elsevier, Amsterdam.

Chapter in book:

Webb CO, Cannon CH, Davies SJ. 2008. Ecological organization, biogeography, and the phylogenetic structure of rainforest tree communities. In: Carson W, Schnitzer S (eds) Tropical Forest Community Ecology. Wiley-Blackwell, New York.

Abstract:

Assaeed AM. 2007. Seed production and dispersal of *Rhazya stricta***.** 50th Annual Symposium of the International Association for Vegetation Science, Swansea, UK, 23-27 July 2007.

Proceeding:

Alikodra HS. 2000. Biodiversity for development of local autonomous government. In: Setyawan AD, Sutarno (eds.) Toward Mount Lawu National Park; Proceeding of National Seminary and Workshop on Biodiversity Conservation to Protect and Save Germplasm in Java Island. Universitas Sebelas Maret, Surakarta, 17-20 July 2000. [Indonesian]

Thesis, Dissertation:

Sugiyarto. 2004. Soil Macro-invertebrates Diversity and Inter-Cropping Plants Productivity in Agroforestry System based on Sengon. [Dissertation]. Universitas Brawijaya, Malang. [Indonesian]

Information from internet:

Balagadde FK, Song H, Ozaki J, Collins CH, Barnet M, Arnold FH, Quake SR, You L. 2008. A synthetic *Escherichia coli* predator-prey ecosystem. Mol Syst Biol 4: 187. www.molecularsystemsbiology.com. DOI:10.1038/msb.2008.24

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Understanding community perception on aquaculture: Lessons from Mauritius as an ocean state

POUVEN NIRSIMLOO[1,♥], SUSHMA MATTAN-MOORGAWA[1,♥♥], RANJEET BHAGOOLI[1,2,♥♥♥]

[1]Department of Biosciences and Ocean Sciences, Faculty of Science and Pole of Research Excellence, Sustainable Marine Biodiversity, University of Mauritius. Réduit 80837, Republic of Mauritius. Tel.: +230-52533192, ♥email: pouv520@gmail.com; ♥♥s.moorgawa@uom.ac.mu;
[2]Institute Oceanography and Environment (INOS), Universiti Malaysia Terengganu, Malaysia. ♥♥♥email: r.bhagooli@uom.ac.mu.

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Abstract. *Nirsimloo P, Mattan-Moorgawa S, Bhagooli R. 2019. Understanding community perception on aquaculture: lessons from Mauritius as an ocean state. Ocean Life 3: 47-53.* Aquaculture is considered one of the fastest food production industries during the past decade and holds high importance in fulfilling the global seafood demand. Globally, limited studies have been conducted on the social acceptability of aquaculture. Thus, it remains a key challenge to understand the perceptions of people on this subject to manage fish farming sustainably. A survey-based approach was developed to have an in-depth assessment of perceptions and attitudes of the public on aquaculture and its implications on the Blue Economy in Mauritius. Respondents' perceptions were evaluated on five aspects of aquaculture: knowledge, socio-economics, environment, food security, and implications for a Blue Economy. Some questionnaires were administered for the study from October 2016 to March 2017, and a response rate of 100% was recorded. Different statistical tests, like Spearman Correlation, Kruskal-Wallis, and Chi-Square, were used to compute data. Descriptive statistical methods revealed that 69.1% of respondents favored expanding the aquaculture industry in Mauritius. A poor but significant correlation ($r=-0.0169$, $p<0.05$) was found between favoring aquaculture expansion and perceived environmental concerns about aquaculture. A chi-square test confirmed a statistically significant association ($p<0.05$) between the educational level of respondents and their knowledge of aquaculture. When aquaculture and Blue Economy in Mauritius were correlated, creating employment opportunities, ensuring food security, and boosting the country's economy were factors chosen by most respondents to acknowledge the implications of aquaculture on the Blue Economy.

Keywords: Aquaculture, attitudes, blue economy, Mauritius, ocean state, perceptions

INTRODUCTION

Aquaculture is rearing or farming aquatic organisms in fresh or saltwater, including fish, shellfish, or aquatic plants (Verbeke et al. 2007). One of the fastest-growing food-producing sectors worldwide has been reported to be aquaculture (FAO 2016). At present, approximately 50 percent of the world's fish that is used for food comes from aquaculture (FAO 2016). Furthermore, it has been predicted that in about a decade after 2012, the production of fish through aquaculture will surpass that of capture fisheries (FAO 2012).

The Mauritian economy depends on various sectors and industries, mainly tourism, textile, and sugar. In the last decade, a diversification of sectors has been encouraged by the relevant authorities of Mauritius to ensure the country's long-term economic growth. These new emerging industries include Blue Economy as well as Communication and Technology. Studies done by the Ministry of Fisheries suggested that Mauritius has the potential to develop commercial aquaculture and predicted annual production of 29,000 tonnes of fish. Promoting export and increasing fish production is the potential of the aquaculture industry in Mauritius (Ministry of Agro-Industry and Fisheries & Board of Investment 2007). In most countries practicing fish farming worldwide, the aquaculture sector is still under study (Grigorakis 2009). Currently, in Mauritius, aquaculture is not adequately developed to become one of the important pillars of the Mauritian economy. On a global scale, a limited number of studies have been conducted on the social acceptability of aquaculture. To manage fish farming sustainably, understanding people's perceptions on this subject remains a key challenge (Bacher et al., 2014).

The Blue Economy has crossed a milestone with the promulgation of the Marine Zones Act 2005, thus encouraging the implementation of research and production activities in the maritime zone of Mauritius (Francois 2016). The Mauritian economy is blessed with an Exclusive Economic Zone (EEZ) stretching over 2.3 million Km^2 and also co-manages about 400,000 Km^2 of its continental shelf with the Republic of Seychelles. That makes the republic of Mauritius the 20th country with the largest EEZ (Intercontinental Trust Ltd 2013). Some islands forming part of the Mauritian territory are Rodrigues, Agalega, Tromelin, St. Brandon, and others (Jahangeer 2004). The inhabited islands are Mauritius, Rodrigues, and Agalega. Making the ocean an economic pillar in future years is one of the main objectives of the Mauritian authorities. However, at present, the economic and exploitation potential of the EEZ of Mauritius is largely untapped.

Sustainable aquaculture is of great importance because it offers prospects of competitive commercial profits and maintains a stable income level over the long term (Sadally et al., 2013). In addition, sustainable aquaculture not only

determines the environmental impacts at a specific site but also considers impacts of aquaculture offsite and combined impacts of human-environmental systems (Costa-Pierce and Page 2010).

Currently, aquaculture is not adequately developed to become one of the important pillars of the Mauritian economy. Therefore, this study aimed to investigate the attitudes and perceptions of the Mauritian population on coastal aquaculture development in Mauritius and its implications for a Blue Economy. The specific objectives were to investigate the perceptions, attitudes, and knowledge of the Mauritian population on coastal aquaculture and also to determine the perceived impacts of aquaculture on the Blue Economy of Mauritius.

MATERIALS AND METHODS

Study site

Found just above the Tropic of Capricorn in the Western Indian Ocean (WIO), Mauritius forms part of the Mascarene Islands and is of volcanic origin. Mauritius has an area of 1865 $km^{2,}$ and its coastline extends over 322 Km. According to Statistics Mauritius (2017), the actual total population of Mauritius stands at 1.26 million.

Survey method

A probability sampling method was used for this study. Random sampling was used for this research. That indicates that each member of the total population has an equal chance of being chosen. This method was mainly chosen since it ensures the validity of statistical conclusions. Questionnaires were used as a research instrument for collecting primary data from individuals since these are the best tools for collecting such information and views. This research tool is also very useful as it provides data agreeable to quantification and saves cost and time (Friel and Wyse 2012).

Questionnaire design

A structured questionnaire was designed to target the Mauritian population. It was designed to balance complexity to ensure depth of analysis and simplicity to ensure ease of completion for respondents. The questionnaire was designed to follow a self-administration system, where the respondents were required to fill in themselves. However, some help was provided to respondents who had difficulty answering questions and those who needed clarifications. The structure of the questionnaire was designed entirely with the latter prefaced with a brief note addressed to respondents as well as a short introduction of the topic and purpose of the survey. The questionnaire was divided into 6 sections, containing 37 questions.

The questionnaire comprised of both open-ended and closed-ended questions. Each section consisted of at least one open-ended question, which the respondent had to answer in their own words. Other questions were designed in closed-ended form, where they were either dichotomous-type or multiple choice- type questions, requiring the respondent to make selections from a predefined list of responses. The questionnaire consisted of 6 sections: knowledge assessment, socio-economic aspects, environmental aspects, food security, blue economy, and respondent profile. All sections except sections 3 and 5 consisted of Likert-type scale questions where the respondent had to state their level of agreement with a series of statements. Likert scale, which is a psychometric response scale designed to obtain the respondent's degree of agreement with a statement, is measured using a five-point scale: (1) Strongly disagree; (2) disagree; (3) Neutral; (4) agree; and (5) strongly agree. Some questions like preferences for aquaculture products and employment opportunities from aquaculture were measured using the 3-point scales ranging from 'Yes,' 'No,' and 'No idea.'

Sample description and sample size

The survey was administered to random samples of the Mauritian population. It was ensured that all participants were above 18 years of age. A fair distribution between male and female respondents was also considered important during data collection to ensure that accurate results were obtained. Based on a census by Statistics Mauritius (2017), the total number of Mauritian population above 18 years was used to calculate the sample size. Some 385 questionnaires were administered in this survey, with a 95% confidence level and a 5% margin of error; the sample size was calculated using the Raosoft Sample Size Calculator (2017).

Study period and data collection

The survey was carried out for three months, from October 2016 to March 2017. In each region where the survey was carried out, it was ensured that an approximately equal number of each gender was given a chance to participate. Furthermore, each participant was approached professionally. Before starting the interview, the respondents were told about the ethics of conducting a survey, such as the confidentiality of information they would provide.

Statistical analyses

Before proceeding to any analysis, a normality test was carried out on data collected to determine whether these were normal. The Shapiro-Wilk Test (IBM SPSS software 21.0) indicated that the data collected was non-parametric. For a sample size of 384, the Shapiro-Wilk Test was most appropriate. A reliability test was also carried out to determine whether or not the research instrument used had strong reliability. The Cronbach's alpha reliability test was carried out, which, according to Laerd Statistics (2016), is most commonly used to determine internal reliability. A Cronbach's alpha reliability value of 0.901 was obtained, indicating that the research instrument used had strong reliability and that the scale used showed a high internal consistency level. Some statistical analyses used the Kruskal-Wallis test, Mann-Whitney U test, Chi-Square test, Spearman's correlations, and others. IBM SPSS version 21.0 was used for statistical analyses, data computing, and the generation of charts, tables, graphs, and figures.

RESULTS AND DISCUSSION

Figure 1 represents the percentage of respondents who live in proximity to the coast. However, most respondents (70.9 %) do not reside near the coast. That could cause a difference in knowledge about coastal aquaculture between respondents living near the coast and those living far.

Perceived development of aquaculture of Mauritius

Forty-one percent of respondents (Figure 2) rated aquaculture development in Mauritius as 'medium.' A lower percentage, 37.7 %, of respondents attributed aquaculture development in Mauritius as 'low.' Only an inferior population of 6 respondents (1.6%) perceived a 'high' aquaculture development in Mauritius.

Relationship between residence in proximity to coast and development of aquaculture in Mauritius

Statistical analysis result (Mann-Whitney U Test; p-value = 0.001) indicated a statistically significant difference between the development rate of aquaculture in Mauritius as perceived by respondents and their residence in proximity to the coast. Furthermore, comparing the mean rank of respondents living close to the coast and those who did not live in proximity to the coast, it was observed that the mean rank value of respondents residing near the coast (220.61) was higher than those who did not (181.67). That indicates that the respondents' perception of aquaculture development is affected by the region in which they live.

Perceived environmental consequences of coastal aquaculture

Figure 3 shows how respondents perceive different consequences of coastal aquaculture. Some 42.8% of respondents agreed that coastal aquaculture impacted the environment, and 15.9% perceived the contrary. The majority of respondents agreed that the transfer of pathogens and diseases (46%), water pollution (45.5%), and eutrophication (52.2%) were potential consequences of aquaculture. It was also observed that 26.5% of respondents did not agree that coastal aquaculture could cause water pollution. A similar proportion of respondents (27.8%) stated that native species in the ocean could be affected by introduced aquacultured species acting as invasive species. Of those who agreed with this environmental consequence of aquaculture, 19% explained that introduced aquacultured species could compete for food with native species.

Moreover, 1.6% of them stated that introduced species could compete for space with native species. In comparison, 2.6% of the respondents suggested that it could cause the spreading of the disease to the natural environment. Other explanations for this consequence include disrupting the food chain (1.6%) and cross-breeding with native species (2.6%).

Relationship between perceived consequences of aquaculture (water pollution) and favoring expansion of aquaculture industry in Mauritius

Spearman's Correlation test was carried out between water pollution as a perceived environmental consequence of aquaculture and respondents favoring expansion of aquaculture in Mauritius. A correlation coefficient ($r = -0.169$) indicated a poor negative correlation between these two variables. That implied that the more the respondents tend to say that aquaculture can cause water pollution, the more they disagree that they favor expanding the aquaculture industry or *vice versa*. Relationship between the two variables were significant (p-value = 0.001).

Access to the beach in proximity to an aquaculture farm

A superior number of respondents (29.6%) rated their access to the beach as 'neutral' (Figure 4). On the other hand, 25.5% of respondents revealed that accessing the beach near an aquaculture farm is likely to be 'difficult.' It should also be noted that 6.5% of respondents rated their access to the beach as 'very difficult,' 11.2% of respondents found their access to the beach 'easy,' and 13% of respondents found it 'very easy' in these specific circumstances.

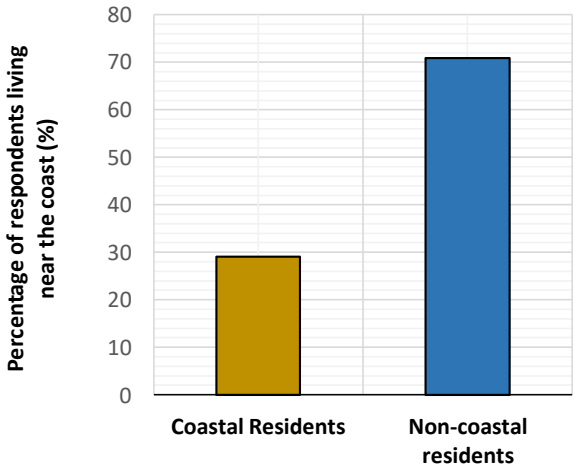

Figure 1. Percentage of respondents who live in proximity to the coast

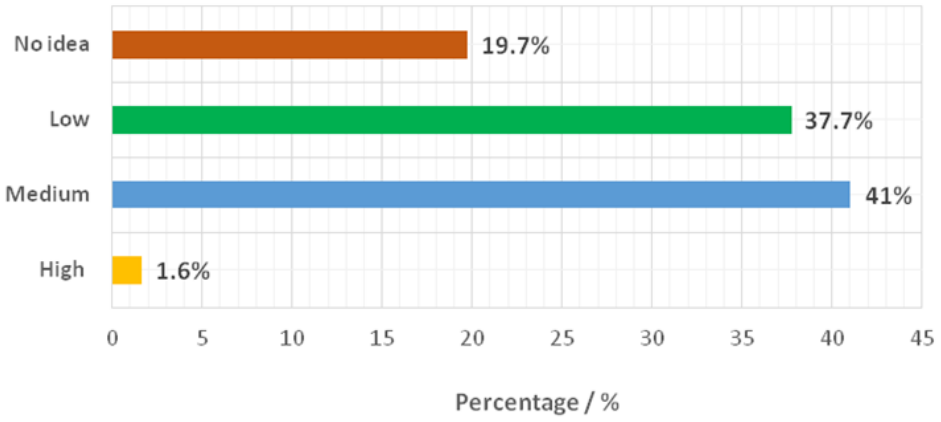

Figure 2. Development of aquaculture in Mauritius as rated by respondents (n=385)

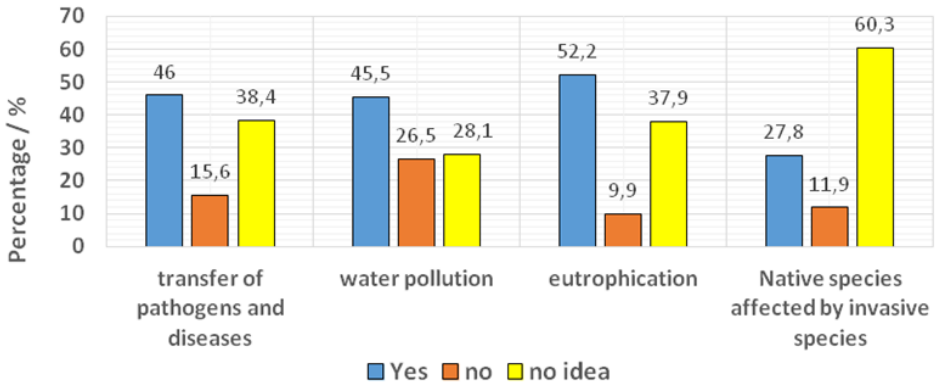

Figure 3. Perceived environmental impacts of coastal aquaculture

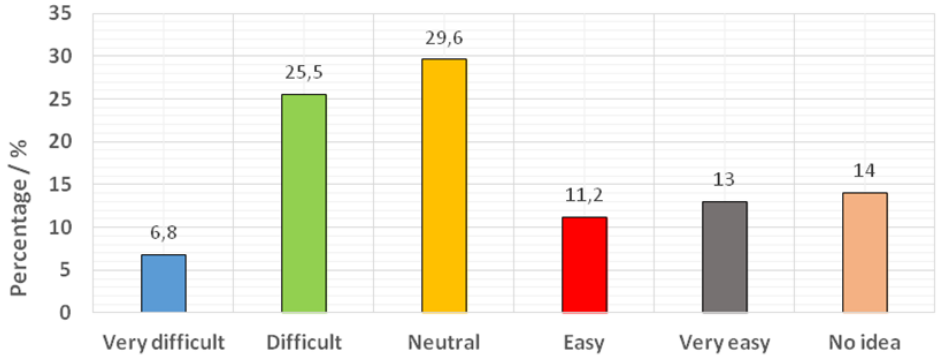

Figure 4. The perception level of respondents on their access to the beach found near an aquaculture farm

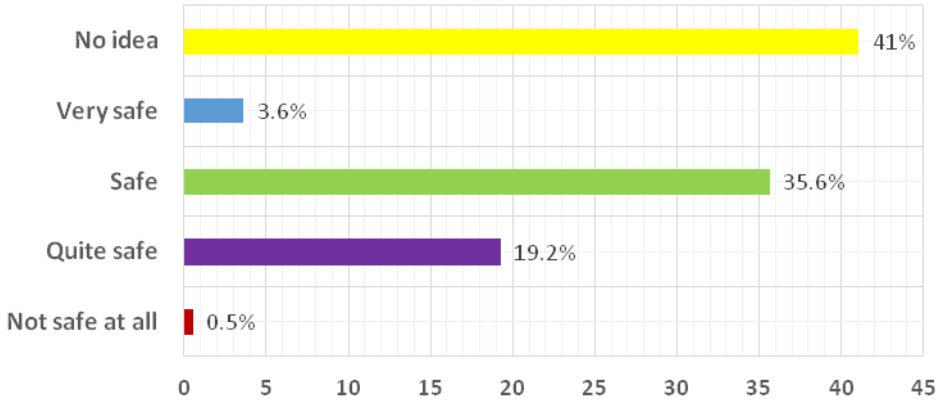

Figure 6. The perceived safety of consuming farmed products by respondents

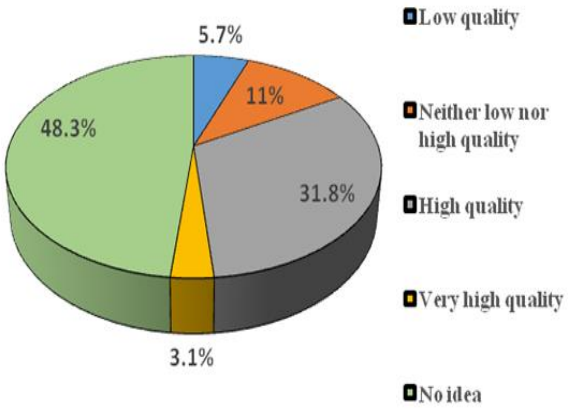

Figure 5. Quality of aquacultured products in Mauritius as perceived by respondents

Relationship between social appreciation of aquaculture as an activity and access to the beach in proximity to an aquaculture farm

Spearman correlation was carried out to find a relationship between social appreciation of aquaculture as an activity and access to the beach in proximity to an aquaculture farm. A correlation coefficient (r = - 0.344) revealed a moderately negative correlation between these two variables indicating that the more difficult the respondents would rate their access to the beach, the more they would agree that aquaculture is an activity of low social appreciation. The relationship between social appreciation of aquaculture as an activity and access to the beach in proximity to an aquaculture farm was significant (p = 0.000).

Perceived fish quality from aquaculture farms in Mauritius

Most respondents (48.3%) had no idea of the quality of aquacultured products in Mauritius (Figure 5). However, 31.8% of respondents suggested that farmed products in Mauritius are of high quality. Furthermore, few respondents (3.1%) reported high-quality farmed products.

Perceived safeness of consuming farmed products

Above 35.6% of respondents find aquacultured products safe for consumption (Figure 6). However, 19.2% of respondents find farmed products quite safe for consumption, meaning there are some doubts and consumer resistance to these products. A further 3.6% of respondents find these products very safe to consume, and a smaller population of respondents (0.5%) think the contrary.

Relationship between quality of farmed products in Mauritius and safeness of these products for consumption

After a statistical analysis (Spearman's Correlation) was conducted, it was found that a correlation coefficient (r = +0.466) existed between the quality of farmed products and the safeness of these products for consumption in Mauritius, indicating a relatively strong positive correlation implying that the more respondents find aquacultured products safe for consumption, the more they would be rating these products as high quality or vice versa. Moreover, this relationship was found to be significant (p= 0.000).

Discussion

Knowledge assessment on aquaculture

A high percentage of respondents (41%) rated aquaculture development in Mauritius as 'medium.' This result conforms with a study by Whitmarsh and Palmieri (2009), where they evaluated aquaculture's social acceptability among Scotland's public. It was found that the respondents' perception of aquaculture development is affected by the region in which they live, similar to the results obtained in Scotland (Whitmarsh and Palmieri 2009). This difference in perception among Mauritian respondents on the development of aquaculture may be mainly due to the level of exposure of respondents to aquaculture activities or information related to this specific topic in different regions of the country.

As for the expansion of the aquaculture industry in Mauritius, 69.1% of respondents favored the expansion of the aquaculture industry. An in-depth study on this topic in Scotland by Whitmarsh and Palmieri (2009) also found that the number of respondents favoring aquaculture expansion greatly outnumbered those against it. However, a study conducted in Baynes Sound of British Columbia by Murray and D'Anna (2015) does not support this outcome; most respondents did not agree with shellfish aquaculture expansion. Katranidis et al. (2003) obtained similar results where respondents from western Greece tended to exhibit a negative perception and attitude towards aquaculture and its expansion. Aquaculture expansion is found undesirable and untenable, including environmental, spatial, and aesthetic impacts (Kite-Powell et al., 2013; Katranidis et al., 2003). Gibbs (2009) suggested the overloading of the local 'carrying capacity of shellfish aquaculture as one of the reasons that local people disagree with the expansion of the aquaculture industry.

Previous studies carried out in Scotland and the Mediterranean suggest evidence that the social acceptability and expansion of the aquaculture industry were directly related to its perceived environmental impacts (Katranidis et al., 2003; Whitmarsh and Wattage, 2006). For example, a correlation analysis was carried out between Mauritian respondents' perceived environmental consequences of aquaculture and their views about favoring the expansion of the aquaculture industry in Mauritius. A poor negative correlation indicates some of the Mauritian respondents tend to think that aquaculture may cause negative environmental impacts and thus may be less in favor of expanding aquaculture into a large-scale industry. One obvious explanation is that most respondents would disagree with expanding such an industry at the expense of the environment, on which they depend a lot for survival. Whitmarsh and Palmieri (2008) confirmed this result in a survey-based study in Scotland. They found that those respondents who attached the lowest priority to the minimization of environmental damage from aquaculture were the ones who favored the expansion of salmon aquaculture in Scotland. Similarly, Freeman et al. (2012) reported a negative correlation between the development and expansion of aquaculture and perceived environmental concerns among respondents in Germany and Israel.

Environmental aspects

A larger proportion of respondents (32.3%) rated their access to the beach in the proximity of an aquaculture farm as difficult compared to those who said the contrary (24.2%). Furthermore, after a correlation was done between the social appreciation of aquaculture by Mauritian respondents and their access to the beach, it was found that these two variables were negatively correlated ($r = -0.344$), indicating that those who find the beach difficult to access tend to say that aquaculture is an activity of low social appreciation. Therefore, the difficulty in accessing these coastal areas will mainly end up causing disagreements and conflicts with other users of the beach and coastal zone (Hoagland et al., 2005; Halwart et al., 2007; Nimmo et al., 2011).

Food security

Verbeke et al. (2007) stated that consumers are always concerned about farm-quality products. Therefore to know the perception of the Mauritian population on this subject, respondents were asked to describe the quality of aquacultured products in Mauritius. Surprisingly, 48.3% of the respondents had no idea of the quality of farmed products, but 34.9% perceived that these products were of good quality. However consumer survey studies carried out in Spain and other European countries suggest that the quality of farmed species was considered to be of lower quality than their wild equivalents by the survey population (Kole 2003; Verbeke et al. 2007; Fernández-Polanco and Luna 2010). Bacher et al. (2014) argued that deficient information provided to consumers concerning the condition and quality of farmed products might result from this perception and distrust.

Nevertheless, the perceived safety of farmed products among Mauritian respondents was quite obvious, with more than 35.6% stating that the products are safe while 0.5% opposed this fact and 41% had no idea. Verbeke et al. (2007) studied consumers' perceptions of farmed and wild products in Belgium and found that 22% of respondents perceived farmed fish as safer than wild ones. They explained this finding by arguing that farmed fish were healthier and safer for consumption since aquaculturists could easily control the presence of diseases and pathogens throughout the aquaculture process. However, it was also debated that concepts of the safety of farmed products rely on the consumers' perceptions about the harvest technology of farmed products (Young et al. 1999) which in turn depends on the quality and quantity of information that reaches the consumers from different sources (Fernández-Polanco and Luna 2012). This study found that the more the Mauritians found the aquacultured products as better quality, the more they found them safer for consumption.

Conclusions

Based on past studies conducted in various countries around the world, the public and stakeholder perceptions and attitudes play a vital role in governing the social acceptability of fish farming. This study was conducted to explore the Mauritian population's perceptions of different aspects of the aquaculture industry in Mauritius. Implications of aquaculture on the Blue Economy have also been assessed in this study. More than half of the survey population had a good knowledge of the Blue Economy. Further studies revealed that their high educational background may have contributed to a good knowledge of this topic. However, most participants chose job creation, boosting the economy, and ensuring food security, among others, as the factors linking aquaculture to the country's Blue Economy. The aquaculture industry in Mauritius still has a long way to go in terms of development to fully exploit its potential advantages and allow Mauritian consumers to make correct decisions based on scientific and unbiased information.

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The impacts of coastal community activities on the existence of the Waranggui mangrove forest in South Manokwari, West Papua, Indonesia

AHMAD AMIR[1,2], RUDI A. MATURBONGS[2,♥], RICARDO F. TAPILATU[2]
[1]Fisheries Service of South Manokwari District. Ransiki, South Papua 98324, Papua, Indonesia
[2]Graduate Program of Environmental Science, Universitas Papua. Jl. Gunung Salju, Amban, Manokwari 98314, West Papua, Indonesia.
♥email: ra_maturbongs@yahoo.co.id

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Abstract. *Amir A, Maturbongs RA, Tapilatu RF. 2019. The impacts of coastal community activities on the existence of the Waranggui mangrove forest in South Manokwari, West Papua, Indonesia. Ocean Life 3: 54-64.* Coastal areas are generally complex, both economically and ecologically. Various community activities involving the use of natural resources in coastal areas impact the ecological sustainability of coastal areas, particularly mangrove ecosystems. Mangrove forests serve as coastal protectors against tsunamis, erosion buffer and sediment traps, recycle nutrients, ensure fishery productivity, reduce the rate of seawater intrusion, support health, maintain biodiversity, and provide habitat for other aquatic ecosystems. The Waranggui area, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia, is one of the coastal areas with a mangrove ecosystem known by the community as a mangrove forest or mange-mange. It is rich in natural resources and widely used by people around it. The objectives of this study are (i) Determining the current area of the Waranggui mangrove forest cover in the Oransbari Sub-district and analyzing its changes related to community activities. (ii) Determining and analyzing the socioeconomic dimensions and the diversity of local wisdom of the Waranggui Village community in utilizing the mangrove forest. This study was descriptive, qualitative-quantitative, and focused on a case in the field. Researchers described the object under study based on the data and facts obtained during observation and interviews. The data obtained were further tested using non-parametric statistics. The data used in this study was both primary data and secondary data. The following conclusions can be drawn from research on the effect of coastal community activities on the Waranggui mangrove forest in Oransbari Sub-district, South Manokwari District: (i) The Data from the DJI Phantom 4 Professional Drone at a flying height of 200 meters and a resolution of 5.1 cm/pixel, yielded data on the Waranggui mangrove forest covering 384.76 ha. After subtracting the measured open land area of 7.91 ha, the actual area is 376.86 ha. The difference in area between the maps is thought to be due to the interpretation of the coastline, the identification of mangrove forest coverage, and the map's resolution. (ii) The variable factor's total scoring value is 270, demonstrating that socioeconomic factors significantly impact the destruction of the Waranggui Oransbari mangrove forest in the South Manokwari District. As many as 100 percent of the community said they knew about mangroves, that their condition had begun to deteriorate, and that they needed to be treated.

Keywords: Coastal community, socioeconomic, Waranggui mangrove forest

INTRODUCTION

Coastal areas are generally complex economically and ecologically (Bengen 2004). Various community activities involving the use of natural resources in coastal areas impact the ecological sustainability of coastal areas, particularly mangrove ecosystems. The existence of mangrove forests is critical because they have the potential to support life in economic, social, and environmental aspects. Mangrove forests in most parts of Indonesia are currently under threat due to deforestation that frequently exceeds the limits of sustainability and carrying capacity. As a result, it is time for many parties to pay attention to coastal management. Development in coastal areas does not need to destroy the mangrove ecosystem as long as a rational arrangement is carried out. Coastal communities are those that continuously interact with mangroves. One model of mangrove ecosystem management is a community-based management approach.

Mangrove forests serve as coastal protectors against tsunamis, buffer erosion and sediment traps, recycle nutrients, ensure fishery productivity, reduce the rate of seawater intrusion, support health, maintain biodiversity, and provide habitat for other aquatic ecosystems (Nybakken 1988; Tomascik et al. 1997; Noor et al. 1999; Rochana 2010; Lapolo et al. 2018). As a result, a policy for the management and utilization of the area is required to preserve the mangrove ecosystem and use it sustainably.

The Waranggui area, Oransbari Sub-district, South Manokwari District West Papua Province, Indonesia, is one of the coastal areas with a mangrove ecosystem known by the community as a mangrove forest or mange-mange. It is rich in natural resources and widely used by people around it. Apart from being a place to find food, the area is also used for transportation and ports, recreation and tourism, a residential area, and a place for waste disposal. Most people who live in this area make a living as fishermen. This area is also used to anchor fishing fleets that are safe from waves and strong winds for fishermen in Oransbari and other areas.

The consequences of every activity carried out by the community lead to ecological problems, including the

impacts of environmentally unfriendly activities and utilization. For example, community activities include excessive logging of mangroves for wood use, conversion of mangrove land to agricultural/plantation areas, and pollution from the activities of the surrounding community are triggers for the destruction of mangrove ecosystems, either directly or indirectly.

Based on the potential and problems of using the mangrove ecosystem in the Waranggui area, Oransbari Sub-district, South Manokwari, it is necessary to research the coastal community activities on the condition of the mangrove ecosystem. This study aims to determine the extent to which these activities impact mangrove forests so that in the future, integrated and environmentally sound management can be carried out by considering the relationship between community interests and the condition of the mangrove forest.

Community-based sustainable management is a management strategy that establishes a threshold for the utilization rate for natural ecosystems and natural resources. Community-based sustainable management is another strategy for utilizing natural ecosystems in which the functional capacity of the ecosystem is sought to be preserved so that it can sustainably benefit human life. Dahuri et al. (1996) suggested four dimensions of sustainable management: (i) Ecological. (ii). Socioeconomic-cultural, (iii) Sociopolitical. (iv) Legal and institutional.

The objectives of this study concerning the problems mentioned above: (i) Determining the current area of the Waranggui mangrove forest cover in the Oransbari Sub-district and analyzing its changes related to community activities. (ii) Determining and analyzing the socioeconomic dimensions and the diversity of local wisdom of the Waranggui Village community in utilizing the mangrove forest.

MATERIALS AND METHODS

Research time and site

The time required to complete all stages of the study was 3 (three) months, from October to December 2018. The research site was in the Waranggui mangrove forest, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia.

Design used

This study was descriptive, qualitative-quantitative, and focused on a case found in the field. Researchers described the object under study based on the data and facts obtained during observation and interviews. The data obtained were further tested by using non-parametric statistics. The type of data used in this study was both primary data and secondary data.

Primary and secondary data collection

Primary data collected includes the area of mangrove cover, community perceptions of the mangrove forest area, socioeconomic conditions of the community, and photos of mangrove conditions. The method used to obtain primary data during the study included field observations and interviews. Secondary data were obtained from a literature study and information from related coastal management agencies. These data were used to assess the mangrove forest management strategy.

Mangrove land cover

Land cover is seen by cropping the image data of the study area using Er Mapper 7.1 software, which results in a Landsat 8 composite map with RGB 654, with references to the 2009 and 2017 time series maps. Image cropping was done to limit the image according to the research area because, in recording the condition of the earth's surface, the satellite would record data over a large area. It corresponded to the spatial resolution of the sensors used by the satellite. Image cropping was used to differentiate between land, forest, and water. To further strengthen the recording of this research area, photogrammetry (drone) with the Dji Phantom 4 Professional, 20 MPLx camera with flight path (Figure 1) was used.

Society's socioeconomic factors

Changes in mangrove conditions are thought to result from community activities in the mangrove area, triggered by socioeconomic conditions. As a result, it is necessary to survey social and economic activities or community activities. The cause of the destruction to the mangrove area is suspected to be the behavior of the community surrounding the area, which is based on the community's economic condition.

A score of 1-3 was assigned to each variable, with a total weight of 100 assigned to each variable. The result was a total score range of 100-300. The weight assigned to each variable was determined by the variable's probability, where the variable directly contributes to the destruction of mangrove forests. Table 1 shows the calculation of mangrove destruction due to socioeconomic factors in the community.

Criteria for concluding socioeconomic factors on mangrove forest destruction will be as follows: (i) Score 100-160: Socioeconomic factors have less effect on the destruction of mangrove areas. (ii) Score 161-200: Socioeconomic factors affect the destruction of mangrove areas. (iii) Score 201-300: Socioeconomic factors are very influential in the destruction of mangrove areas.

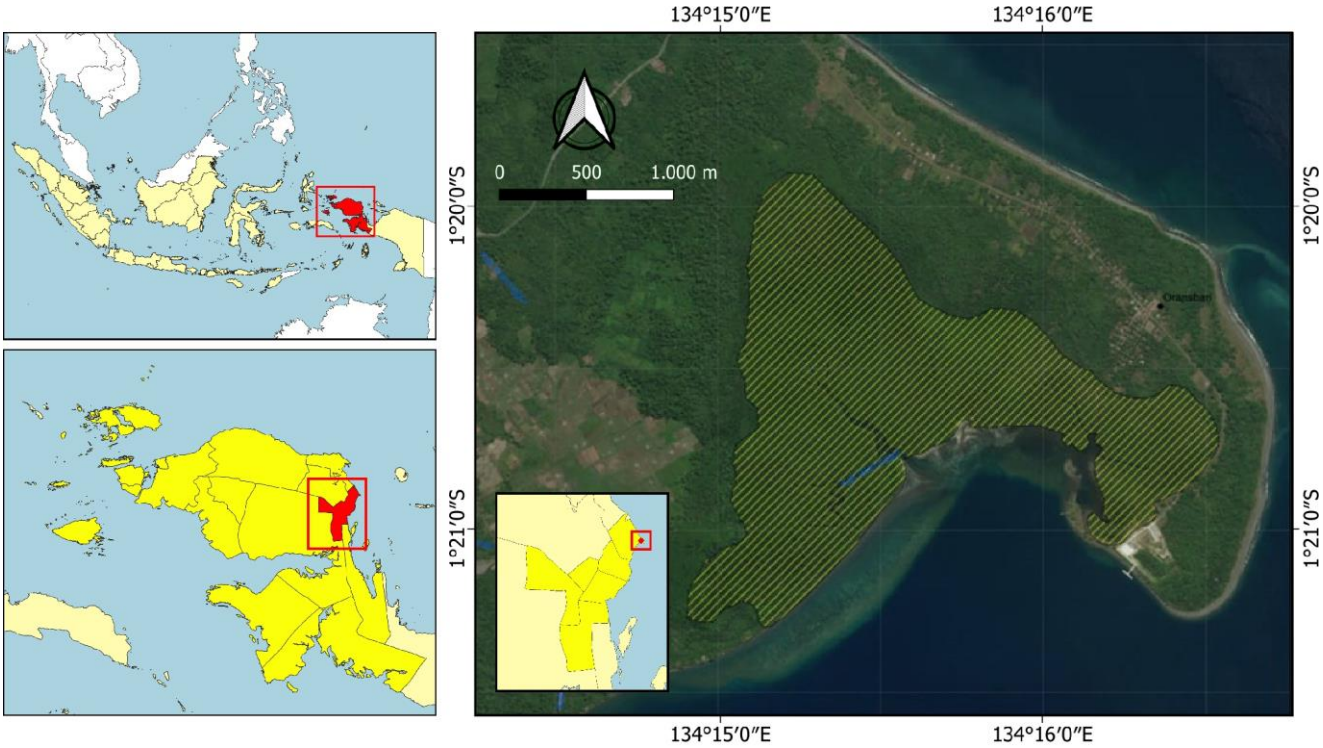

Figure 1. Drone flight path map at the research site (Waranggui mangrove forest, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia)

Table 1. Determination of the magnitude of the weight of socioeconomic factors contributing to the destruction of the Waranggui mangrove forest, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia

Variable	Weight	Score
Livelihood	40	Fishermen
	40	Farmers
	40	Pond Fishermen
Location of	30	< 1 km from mangrove forest
Business Land	30	0.5 - 1 km from mangrove forest
	30	> 1 km from mangrove forest
Land Use	20	Forest
	20	Plantation/Mixed Plantation
	20	Settlement
Perception of	10	To protect the environment
Mangrove	30	To maintain the sustainability of aquatic animals
	30	To use the wood

Source: Directorate General of Land Rehabilitation and Social Forestry and Department of Forestry and Plantations (2000)

Coastal community perception

The perception of coastal communities is descriptive, which will provide an accurate picture of the condition of mangroves and the coastal environment. Data were collected through direct observation in the field and interviews.

According to Arikunto (2007), if the number of research subjects is less than 100, it is best to take all of them as samples; if the number of samples is greater than 100, the sample size should be around 10%. A sample is drawn using the purposive sampling method to obtain data representing the population surrounding the mangrove forest area. As a result, the number of samples taken will be determined using the formula below (Nazir 1988).

$$n = \frac{N}{Nd^2 + 1}$$

Where:
N = Total population
n = number of samples
d2 = Expected precision 10%
1 = Constant

The socioeconomic dimensions and diversity of local wisdom were analyzed descriptively. The analysis of the social dimension focuses on respondent characteristics, livelihoods, and local wisdom systems. Meanwhile, the analysis of the diversity of local wisdom focuses on the existence of customs that inhibit and/or support mangrove conservation, community care, and/or obedience in supporting the preservation of mangrove forests prevailing in the Oransbari village community.

Research variables

The variables measured in this study were: (i) Visualization of the Waranggui mangrove land cover conditions in Oransbari Sub-district in 2018 juxtaposed

with the land cover conditions of the previous 5 to 10 years using time series maps and land cover maps in 2009 and 2017 and reinforced with photogrammetry (drone) to obtain factual cover data accuracy land and the impact of community activities on the Waranggui mangrove forest. (ii) Socioeconomic activities of the community around the Waranggui mangrove forest area, Oransbari Sub-district can affect the ecological functions of the mangrove forest. (iii) Community perception of the benefits of mangrove forests in sustainable management. (iv) The values of local wisdom of the community of Oransbari village in benefiting from the Waranggui mangrove forest.

RESULTS AND DISCUSSION

Geographical, topographical, and demographic conditions

Oransbari Village is one of fourteen villages located in the Oransbari Sub-district. Oransbari Village is also the oldest village in this sub-district. Based on monograph data from Oransbari Village, the area is 111.67 km^2, consisting of three neighborhood units (RT) with administrative boundaries as follows: (i) The east border is the free ocean (Pacific Ocean). (ii) The south border is Muari Village. (iii) The west border is Waroser Village. (iv) The free ocean (Pacific Ocean) is the north border.

Meanwhile, the geographical location is (i) North: 1º19' South Latitude. (ii) South: 1º21' South Latitude. (iii) West: 134º 14' East Longitude and (iv) East: 134º 16' East Longitude. The Waranggui mangrove forest area is bordered by three villages, including (i) The north border is Oransbari Village. (ii) The south border is Muari Village. (iii) The east border is the sea, and (iv) The west border is Waroser Village.

The Waranggui mangrove forest area is included in the administrative area of Oransbari Village and is part of the customary rights of tribal chiefs from Oransbari Village. Oransbari Village is located on a sloping coastal area with a land elevation of 0-6 meters above sea level. The length of the coastline is approximately 10 km, with a coastal estuarine ecosystem consisting of mangrove forests, seagrass beds, and coral reefs in the bay's interior. At the same time, it is a coral beach on the outside.

The inhabitants of the Oransbari Village consist of various indigenous Papuan tribes, such as the Hatam, Biak, Serui, Wandamen, Sough tribes, and several immigrant tribes, including Buton, Makassar, and others. Most of the people in the Oransbari Village make a living as fishermen, farmers, traders, and civil servants. The largest clan is the Waran clan, along with the Anari clan, and holds customary rights in the Oransbari Sub-district. There are 136 families, totaling 577 people (Table 2).

Visualization of the Waranggui mangrove land cover condition

Monitoring changes in land cover can be accomplished by conducting an ongoing analysis of changes in land cover from year to year. However, monitoring is only possible if time series data for the observation interval is available. The land cover time series data available at the Ministry of Environment and Forestry (KLHK) is complete. Land cover data is available from the Ministry of Environment and Forestry from 1990 to 2017, with data series for 1990, 2000, 2003, 2006, 2009, 2011, 2012, 2013, 2014, 2015, and 2016. In addition, the Ministry of Environment and Forestry created a Land Cover Map following Regulation of the Directorate General of Forestry Planning No. P.1/VII-IPSDH/2015 divides land cover into twenty-three (23) land cover classes (Table 3).

There are two categories of mangrove forest cover: Primary Mangrove Forest (2004-HMP) and Secondary Mangrove Forest (20041-HMS). A comparison of KLHK mangrove cover area with mangrove cover using very high resolution (60 cm/pixel) imagery is shown in Table 4.

Table 2. Number of residents of Oransbari Village, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia

Neighborhood units (RT)	Number of the head of the family	Gender		Number of Residents
		Male	Female	
RT. 01	44	95	79	174
RT. 02	37	73	73	146
RT. 03	55	140	117	257
TOTAL	136	308	169	577

Source: Oransbari Village monograph data in 2019

Table 3. Ministry of Environment and Forestry, Indonesia, land cover

Code	Land cover	Abbreviation
2001	Primary Dryland Forest	HLKP
2002	Secondary Dryland Forest	HLKS
2004	Primary Mangrove Forest	HMP
2005	Primary Swamp Forest	HRP
2006	Plantation Forest	HT
2007	Shrubs	SB
2010	Plantation	Perkebunan
2012	Settlement	Pemukiman
2014	Open Ground	TT
2500	Cloud	Awan
3000	Savanna	Savana
5001	Water Body	TA
20041	Secondary Mangrove Forest	HMS
20051	Secondary Swamp Forest	HRS
20071	Swamp Scrub	SBR
20091	Dryland Farming	PLK
20092	Dryland Mixed Bush Farming	PLKC
20093	Ricefield	Sawah
20094	Pond	Tambak
20121	Airport	Bandara
20122	Transmigration	Transmigrasi
20141	Mining	Pertambangan
50011	Swamp	Rawa

Source: Ministry of Environment and Forestry (2015)

According to the data in Table 4, there is a difference in the area of mangrove forest covering an area of 82.03 ha, with details of the difference between primary and secondary mangrove forest being 93.33 ha and -11.03 ha. This wide disparity is caused by the various image data sources used in land cover interpretation. For example, Landsat imagery with a resolution of 30 meters/pixel is used by KLHK land cover, and high-resolution satellite imagery with a spatial resolution of 60 cm/pixel is used in land cover. Furthermore, the difference in area is caused by different interpretations of the coastline on KLHK land cover, with the farthest and closest bias values to the coastline sourced from the Geospatial Information Agency's Indonesian Earth Map (RBI) scale of 1:50,000 in 2018. The greatest distance and proximity to the RBI coastline are shown in Table 5.

The analysis of land cover changes in the Waranggui mangrove area was then refined using aerial photos taken by the DJI Phantom 4 Professional Drone at a flying height of 200 meters at the end of December 2018 and compared to the KLHK Land Cover Map from 2009. Finally, the total area of the Waranggui mangrove forest was calculated based on land cover data. The Ministry of Environment and Forestry reported 414.218 hectares in 2009, with primary mangrove forest covering 361.5 ha and secondary mangrove forest covering 52.7 ha. The forest cover can be seen in Figures 2 and 3.

Table 4. Comparison of Ministry of Environment and Forestry mangrove cover and very high-resolution imagery in Waranggui, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia

Land cover	Area (ha)		
	KLHK 2017 (30 m/pixel)	Very high-resolution imagery (60 cm/pixel)	Total difference
Primary Mangrove Forest	354.31	260.98	93.33
Secondary Mangrove Forest	52.56	63.59	-11.03
Total	406,87	324.57	82.03

Table 5. The furthest and closest distances to mangrove cover in Waranggui, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia

Mangrove forest	Region	Distance (meter)	
		Furthest	Closest
Primary Mangrove Forest	In the coastline	201	22
	Beyond the coastline	115	38
Secondary Mangrove Forest	In the coastline	-	-
	Beyond the coastline	35	1

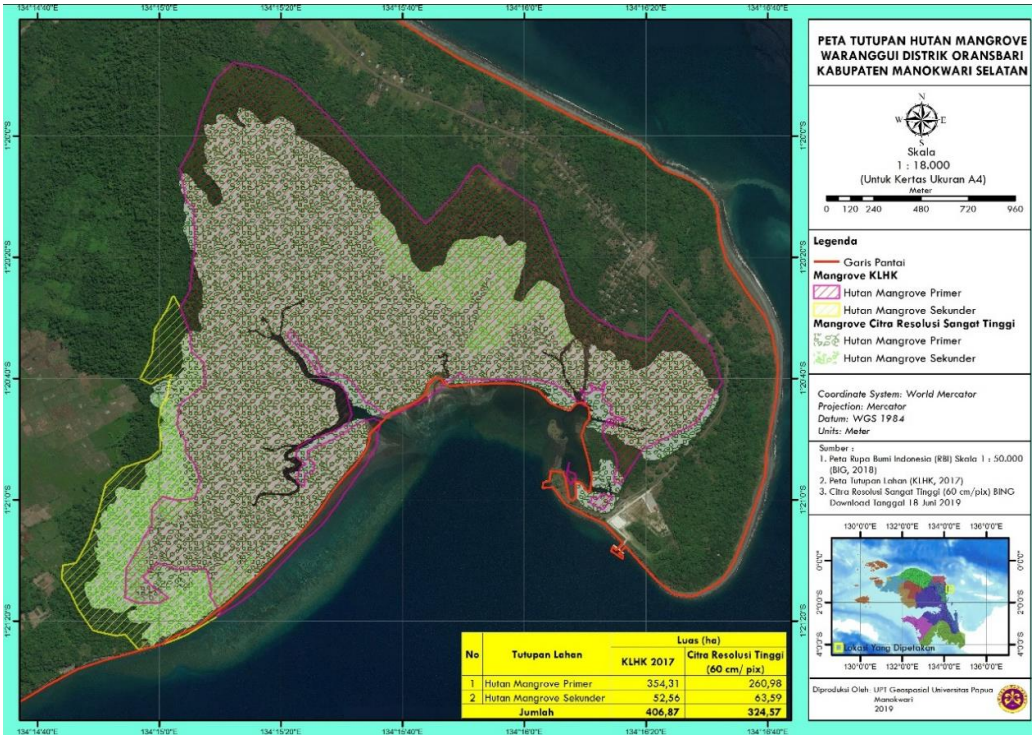

Figure 2. Map of Waranggui mangrove forest cover, Oransbari Sub-district, South Manokwari District, UPT Geospatial, Universitas Papua, Manokwari, Indonesia in 2019

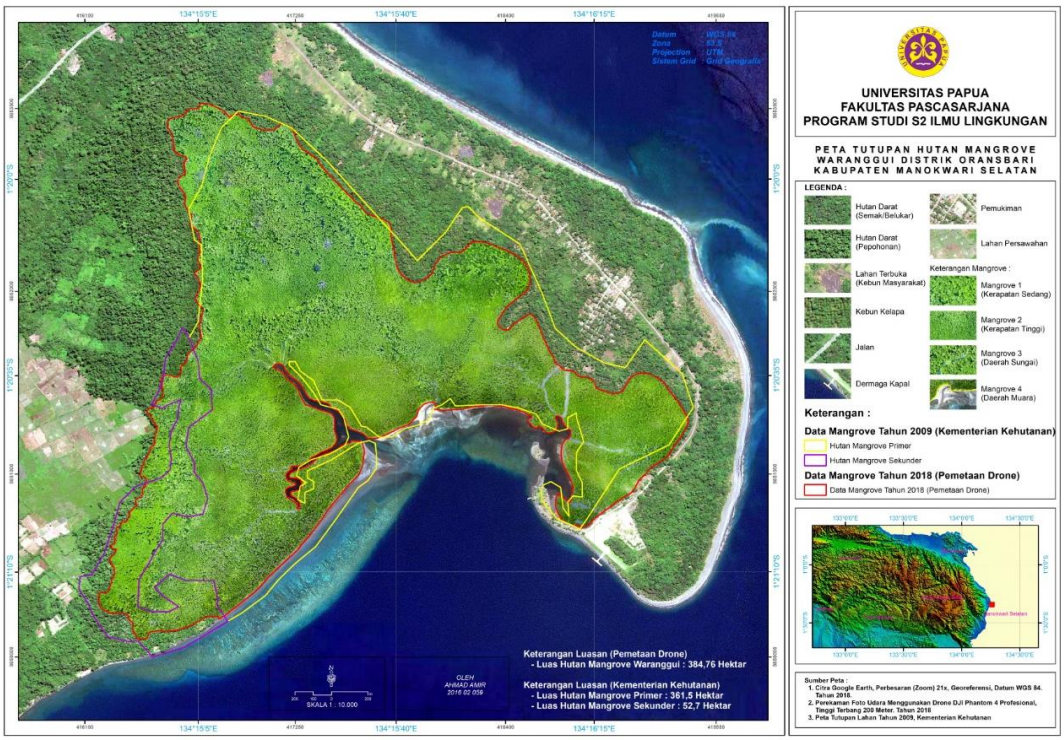

Figure 3. DJI Phantom 4 Professional drone map Waranggui, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia in December 2018

At the end of 2018, the results of mapping using drones were 384.76 hectares. According to the Ministry of Environment and Forestry data on land cover in 2009, there is a difference in the area of the Waranggui mangrove forest, which is 29.46 ha. Still, the researcher does not want to display the distribution of data on the area of primary and secondary mangrove forests solely to preserve the Waranggui mangrove forest comprehensively in this research. Therefore, shortly land cover area data was processed based on photogrammetry results from the DJI Phantom 4 Professional Drone and compared to the 2009 KLHK map (Table 6).

Table 6. Comparison of KLHK mangrove forest cover in 2009 and the results of drone mapping in December 2018 in Waranggui, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia

Land cover	Area (ha)		
	KLHK 2009 (30 m/pix)	Photogrammetry Drone (5,1 cm/pix)	Total difference
Primary Mangrove Forest	361.510	384.76	-23.25
Secondary Mangrove Forest	52.718	-	52.718
Total	414.218	384.76	29.46

Comparison of the three map models used to obtain data accuracy for the Waranggui mangrove land cover area, including the 2009 and 2017 KLHK maps, UPT Geospatial of Universitas Papua maps, and drone results (Table 7).

Table 7. Comparison of Waranggui mangrove cover area, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia

Land cover	Area (ha)			
	KLHK 2009	KLHK 2017	Very high-resolution imagery (60 cm/pixel)	Photogrammetry drone (5,1 cm/pix)
Primary Mangrove Forest	361.510	354.31	260.98	384.76
Secondary Mangrove Forest	52.718	52.56	63.59	
Total	414.218	406.87	324.57	384.76

Source: KLHK (2015), Waranggui drone (2018), UPT Geospatial of Universitas Papua (2019)

The total area of the Waranggui mangrove area, when viewed from the data above based on the KLHK land cover map between 2009 and 2017, has seen a degradation of 7.35 ha of mangrove forest area. And when juxtaposed with the results of the map issued by the Geospatial UPT, Universitas Papua, Manokwari in 2019 with the KLHK 2009 map, there is a comparison of the difference in the number of mangrove forests as much as 89.65 ha. With the KLHK 2017 map, there is a difference of 82.3 ha.

Meanwhile, this study's current mapping relies on DJI Phantom 4 Professional Drone data. The data on the area of mangrove forests produced by the flying height of 200 meters with a resolution of 5.1 cm/pixel differs from the two maps referred to in the previous table. The difference in area between the maps is thought to be due to the interpretation of the coastline, the identification of mangrove forest coverage, and the map's resolution. Drones can also detect destruction to the periphery and inside the Waranggui mangrove forest. The state of mangrove forest destruction from drone mapping can illustrate the findings of interviews with people in Oransbari Village about their activities in utilizing mangrove forests. Government programs and community activities are thought to have contributed to the degradation of the Waranggui mangrove forest due to development programs. The development program involves building a pier, expanding rice fields, and opening access roads to the Sawmiyen beach tourism area directly adjacent to the Waranggui mangrove forest. On the other hand, researchers traced the traces of destruction done by the community with photos taken during field observations using aerial photos (Figures 4 and 5).

Identification of drone mapping of Waranggui mangrove forest area

The condition of the land, as revealed by the drone mapping results, indicates that there has been destroyed at several points. The exposed areas represent the previous logging done by the community to reduce the existing mangrove forest. In addition, some of the identified areas are open land, specifically land that is no longer covered by mangroves because it has transitioned from mangrove forest to shrubs and grass. Some have even been converted to other uses, such as gardens (Tables 8 and 9).

The surrounding community's pattern of mangrove utilization is by pruning or cutting down from within the forest, or more precisely, the community uses a thinning technique so that it is not as visible significantly by aerial photography observations. Identification of mangrove forests occurs when the density decreases in the parts closest to settlements, for example, in Muari and Oransbari (Figure 6).

Factors of the community's socioeconomic activities

While conducting a study to determine the extent to which community activities in the Waranggui mangrove forest area impact, the field observations were conducted in addition to quantitative methods such as photogrammetry using drones and KLHK land cover maps; this study also used a qualitative approach, with interviews conducted with 55 representative respondents (purposive sampling) in three Neighborhood Units (RT) in Oransbari Village. As a result, the total scoring value (TNS) is 270 based on the results of questionnaires and interviews with respondents (Table 10).

This value is the foundation for calculating the magnitude of the socioeconomic factors contributing to the destruction of the Waranggui mangrove forest. Therefore, this value indicates that socioeconomic factors significantly impact mangrove destruction.

Table 8. Waranggui mangrove land, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia, identification

Land identification	Area (ha)	Area (m^2)
Logging Indication	3.38	33,793.08
Open Land	0.96	9,588.28
Sand/Coast	0.14	1,369.00
Coconut Trees	0.22	2,236.14
Water Body	2.08	20,812.87
Water Body and Boat Mooring	1.13	11,315.46
Mangrove	376.86	3,768,555.15
Total Land Identified	7.91	79,114.82
Total Mangrove Land	376.86	3,768,555.15

Source: Drone map results (2018)

Table 9. Information on the identification of the Waranggui mangrove forest land, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia

Identification	Notes
Logging Indication	The location shown on the map is indicated by the appearance of open land with fallen tree stands and land conditions that are starting to become barren and dry.
Open Land	The map shows the location with the appearance of open land only consisting of the land cover of shrubs to grass. Some bare land is seen in the area.
Sand/Coast	The map shows the location with the appearance of land close to the coast that is not overgrown with mangroves and an accumulation of beach sand.
Coconut Trees	The location is shown on the map with the appearance of a tree canopy of a coconut plant. In some locations, coconut plants grow in the middle of a mangrove forest.
Water Body	The location is shown on the map with the appearance of the river water body.
Water Body and Boat Mooring	The location is shown on the map with the appearance of the river water body. Mooring boats used by local fishermen can be seen on some land leading to the mainland.
Mangrove Forest	The map shows the location with the overall cover of primary and secondary mangrove forests in the Waranggui forest.

Figure 4. Drone aerial photos. A. Conditions in the middle, B. Conditions near the Waranggui estuary, C. Conditions at the boat mooring area, D. Conditions with coconut plantations bordering, E. Conditions with paddy fields bordering, and F. Conditions near the settlement

Elements of respondents and mangrove forest utilization

Purposive sampling was used to interview 55 respondents to be more objective and represent all elements. This questionnaire also included traditional Oransbari Village stakeholders. Based on the findings of 55 interviews conducted over a one-year with 55 respondents about the utilization of mangrove forests in the Waranggui area, Oransbari Sub-district, South Manokwari District, it was discovered that 100 percent (one hundred percent) of respondents said they had utilized the Mangrove area, particularly looking for marine biotas such as fish, snails, and others (Table 11).

Wood

When the community was asked about using wood from the mangrove forest for any purpose, whether for personal use or sale to buyers outside the village, the results are shown in Table 12.

By the interview results, when the researchers conducted field observations to test the validity of the interview, the facts show the community activities in utilizing wood in the Waranggui Mangrove forest area for daily needs or needs were discovered, as shown in Figure 7.

Non-timber forest products

Aside from wood, the community uses mangrove trees for various purposes, including food from tree fruit, medicines, ant nests, and orchids attached to mangrove trees. Table 13 presents the findings of interviews on these activities.

Figure 5. Field observation photos (mangrove forest destruction by the community)

Aquatic biota

In addition to using wood, the intensity of community activities in utilizing the waters of the mangrove area is quite high, as presented in Table 14.

Community perception of mangrove forest

According to the results of the interviews, 55 respondents (100%) said they were familiar with mangroves, also known as mange-mange to locals. The community is also aware of the role of mangroves as beach protectors and sources of daily necessities, particularly wood extraction, as well as other ecological functions such as fish feeding grounds, nursery grounds, and spawning grounds. According to 100 percent of community respondents, mangrove forests must be maintained and preserved.

Table 10. Total scoring value

Variables	Weight	Score	Yes	No
Livelihood	40	Fishermen	✓	
	40	Farmers	✓	
	40	Pond Fishermen		✓
Location of business land	30	< 1 km from mangrove forest	✓	
	30	0.5 - 1 km from mangrove forest	✓	
	30	> 1 km from mangrove forest		✓
Land use	20	Forest	✓	
	20	Plantation/Mixed Plantation	✓	
	20	Settlement	✓	
Perception of mangrove	10	To protect the environment	✓	
	30	To maintain the survival of aquatic animals	✓	
	30	To use the woods	✓	

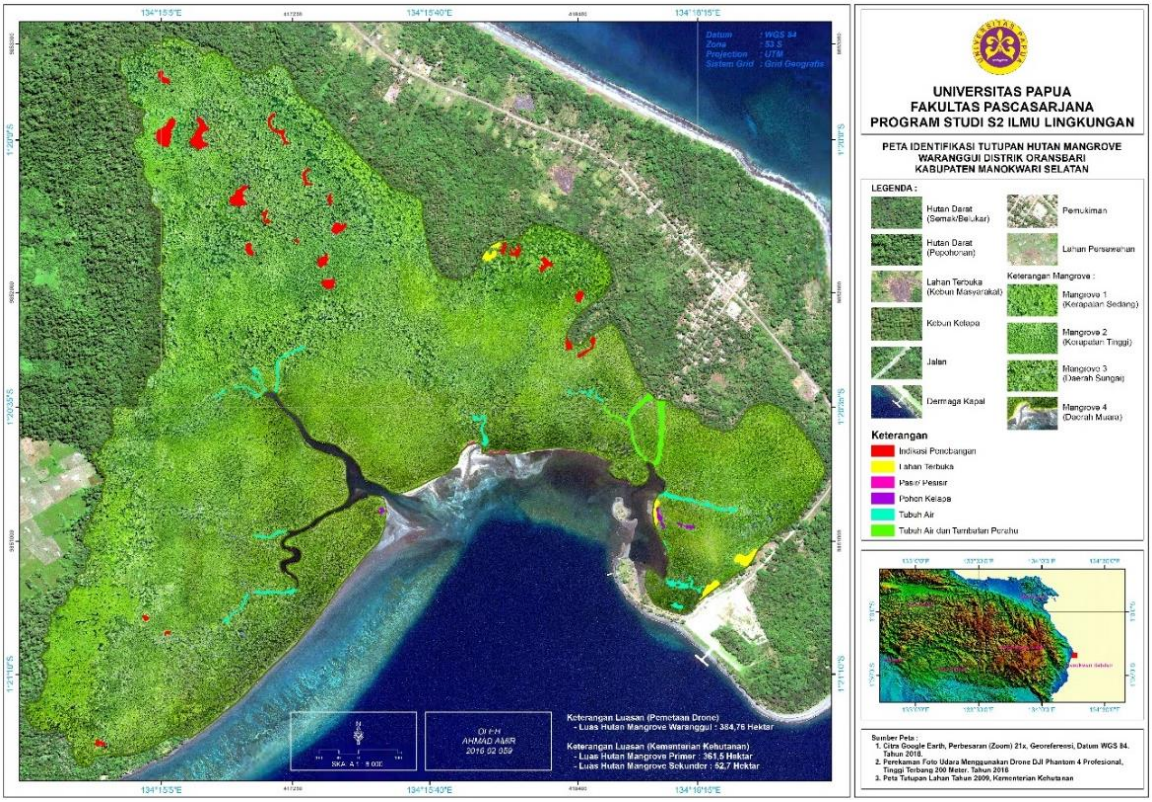

Figure 6. Drone map of land cover identification of Waranggui forest, Oransbari Sub-district, South Manokwari District, West Papua Province, Indonesia

Figure 7. A. Utilization for firewood, B. Utilization of fence poles and other building needs, C. Utilization of garden fences and stakes for plants

Table 11. Types of mangrove forest utilization

Types of utilization	Total of 55 respondents	%
Woods	47	85.45
Non-Timber Forest Products	11	20
Aquatic Biota	55	100

Table 12. Use of mangrove wood

Types of utilization	Total of 55 respondents	%
House Fence Poles	23	41.81
Garden Fence Poles	15	27.27
Construction of Houses/Other Buildings	11	20
Firewood	27	49.09
Stakes for Plants	8	14.54
Fishing Fleet Equipment	38	69.09

Table 13. Utilization of non-timber forest products

Types of utilization	Total
Food Products	11
Medicines	11
Orchids	5

Table 14. Utilization of mangrove forest waters

Types of utilization	Total respondents
Fishing	43
Looking for Crab	12
Looking for Snails	17

The following conclusions can be drawn from research on the effect of coastal community activities on the Waranggui mangrove forest in Oransbari Sub-district, South Manokwari District: (i) The total area of the Waranggui mangrove area based on the KLHK land cover map in 2009 is 414.218 ha, and the 2017 map is 406.87 ha, indicating a 7.35 ha reduction in the area of mangrove forest over 8 years. (ii) The results of the map issued by the Universitas Papua's Geospatial Unit in 2019 using high-resolution satellite imagery at 60 cm/pixel are 324.57 ha. Compared to the 2009 KLHK map, there is a difference in the area of the Waranggui mangrove forest of up to 89.65 ha, and there is a difference of 82.3 ha when compared to the 2017 KLHK map. (iii) Data from the DJI Phantom 4 Professional Drone at a flying height of 200 meters and a resolution of 5.1 cm/pixel yielded data on the Waranggui mangrove forest covering 384.76 ha. After subtracting the measured open land area of 7.91 ha, the actual area is 376.86 ha. The difference in area between the maps is thought to be due to the interpretation of the coastline, the identification of mangrove forest coverage, and the map's resolution. (iv) Using drones can detect destruction to the periphery and inside the Waranggui mangrove forest. The destruction to mangrove forests caused by drone mapping is 3.38 ha. (v) The variable factor's total scoring value is 270, demonstrating that socioeconomic factors significantly impact the destruction of the Waranggui Oransbari mangrove forest in the South Manokwari District. (vi) As many as 100 percent of the community said they knew about mangroves, that their condition had begun to deteriorate, and that they needed to be treated.

Given the various functions and roles of mangrove forests, as well as the consequences of using mangrove land, it is necessary to include the following perspectives from the Regional Government, and traditional stakeholders in mangrove management: (i) Any conversion of mangrove forest area for development or cultivation purposes should carefully consider a feasibility study to maintain the function and role of the mangrove forest to the surrounding aquatic ecosystem, which was done to ensure that the Waranggui mangrove forest area was not destroyed. (ii) The local government should designate the Waranggui mangrove area as an ecotourism/nature education area and a natural laboratory. (iii) It is necessary to increase community knowledge and awareness of ecological, economic, and social values while also paying attention to local wisdom to sustainably use the Waranggui mangrove area.

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Influence of co-management on marine resources sustainability in Shimoni and Wasini areas, Kenya

AGATHA ADHIAMBO OGADA, SAEED MWAGUNI♥
University of Nairobi. University Way, Nairobi, Kenya. Tel./fax.: +254-20-3318262, ♥email: kcmi@africaonline.co.ke

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Abstract. *Ogada AA, Mwaguni S. 2019. Influence of co-management on marine resources sustainability in Shimoni and Wasini areas, Kenya. Ocean Life 3: 65-73.* The research investigated the influence of the co-management of marine resources for sustainable development. Comanagement is proposed as the ideal tool for sustainable management of marine resources and ensuring stakeholders are involved in decision-making and managing their resources. The study was undertaken to generate knowledge on the influence of co-management on sustainable marine resources; the study area chosen had some background in co-management before. The study was conducted through a survey research design using questionnaires, semi-structured questionnaires, interviews, and focus group discussions, with a sample size of 145 respondents. The collected data was coded using SPSS 19 for analysis, including; presenting simple percentages, frequencies, and cross-tabs. In addition, chi-square was used to test the hypotheses. The study's results focused on co-management variables: institutional design, community participation, and socio-ecological dynamics. The results showed that 95% of the respondents perceived the co-management institutional design as adequate. Community participation is a key factor of co-management, which was proven right with 82.5%. There is the agreement that communities' roles in co-management were clearly defined and involved in the decision-making process. Moreover, 92.5% of the respondents said that IK is valuable and was not only applied in co-management but also effective in its application. In conclusion, the study shows that co-management positively influences conservation and community members' well-being. Therefore the researcher concluded that co-management is an adequate tool for planning and sustainable management of marine resources. However, it was recommended that improved intergovernmental and interagency partnerships are needed to address cross-cutting and emerging issues in co-management.

Keywords: Kenya, Kwale County, marine resources, sustainable management

INTRODUCTION

Worldwide, there are efforts to implement environmental standards and regulate activities in coastal and marine areas to manage development activities, control pollution, and conserve marine resources (UNIDO 2000). At the international level, conventions, protocols, and agreements have provided the basis for cooperation among countries at bilateral, regional, and global levels to achieve this objective. In addition, in some countries, national environmental legislation has provided practical frameworks for achieving the best management approach.

An over-centralized management model, where the artisanal fisherman neither participates nor is represented, brings about an incompatibility between the sustainability objective pursued by States and maximizing fishermen's economic objectives favored by market forces. On the other hand, the experience to date shows how the fishermen's involvement in the co-management of fishery resources and the green economy can be a means to achieve sustainable development in its three dimensions (social, economic, and environmental), together with the eradication of poverty (Gunderson et al. 2002).

Except in the immediate past years, the African region's environmental values and natural resources factors have not always been integrated into national development plans. Moreover, development decisions and social trends appear not to have optimized the value of natural resources (Akpabli 2000). Many problems and issues facing fisheries can be resolved through developing co-management institutions on a larger scale. Therefore, the co-management approach focused on developing institutional and legal mechanisms to improve fisheries governance through forming BMUs to ensure that these stakeholders, particularly the marginalized poor, can engage in and influence decision-making processes relating to fisheries management. Thus the avenue needed by the government to meet its double obligation of attending to international agreements while sharing decision-making power for fisheries management with communities. Moreover, to maintain scientific validity and achieve wide acceptance, we must identify a management knowledge base acceptable to stakeholders (Berkes 2009a,b).

Co-management systems need to reconcile both formal scientific knowledge and indigenous knowledge. One approach may be to identify science-based indicators of the status of the resource system that also reflect the resource users' observations (Huntington et al. 2004). Management arrangements may require access rights to be limited to some resource users andto exclude others, often resulting in conflicts that can be managed through participatory approaches, which are crucial for successful co-management. In addition, existing institutions need to be reformed to empower local communities to participate in determining management objectives (Ahmed et al. 2004).

In the early 1990s, Kenya's sustainable fisheries management, development, conservation, and utilization mandates had been structured solely under government departments. However, a combination of environmental threats and growing evidence of the resulting negative impacts convinced national authorities that it was time to adopt a new management approach involving communities as partners in management.

As a result, there was a paradigm (policy) shift from a government-centered approach to stakeholders (co-management) based approach since 2004. The new dimension was taken to ensure fisherfolks and other resource users are involved in fisheries management and decision-making. In addition, a consensus is emerging on the need to manage Kenya's coastal and marine resources through an integrated rather than a sectoral approach. Integrated Coastal Zone Management (ICZM) brings all those involved in the development, management, and use of the coastal zone within a framework that facilitates the integration of their interests and responsibilities (McClanahan et al. 2005).

In case of any fisheries depletion, the major stakeholders (fishers, traders, and consumers) will be the biggest losers in their socio-economic status. At the same time, the government will lose revenue and foreign exchange earnings. In this new approach, the good news is that resource users can solve management problems individually and co-operatively, thus ensuring that resources are managed sustainably to realize their full potential contribution to global food security and the well-being of all humankind. However, despite these new policy changes, capacity, strategies, and management tools have not substantially changed. Moreover, stakeholder management groups, such as Beach Management Units (BMUs), in Kenya, have strongly taken up the management of fisheries at beach levels.

In collaboration with stakeholders, the Kenyan government is currently conducting a comprehensive study of the fisheries legislations, institutional framework, and policy guidelines to address the new shift in fisheries management. Various legislatures legally support this participation, most conspicuous being the Environmental Coordination and Management Act (EMCA) 1999, the Forest Act, 2005ICZM, and the Fisheries bill 2012, Legal notice 402.

This study aimed to investigate the influence of co-management of marine resources for sustainable development in Kwale County, Kenya, with Shimoni and Wasini as the case study.

MATERIALS AND METHODS

Research design

The study assessed the influence of co-management in managing marine resources in Shimoni and Wasini, Kenya. The study was conducted through a survey research design. In the study, both areas were familiar with co-management as a management tool for fisheries resources jointly managed by the Beach Management Units and the Fisheries Department. The principal method of obtaining information was through semi-structured interviews with key stakeholders, whereas questionnaires and focus discussion groups were employed for community groups. Identification of interviewees was purposeful according to their areas of expertise. In addition, stratified sampling was applied to the local community.

Target population

The population targeted is in Shimoni and Wasini areas. The population in Shimoni village is 4,520, according to the administration data from the chief's office, and Wasini Island has a population of 3,600. Therefore, the target population is 8,120, including 396 Shimoni BMU members and 153 Wasini BMU members. The target population already has co-management structures in-place in fisheries management. Community Conserved Areas (CCAs) are also known as Locally Managed Marine Areas (LMMA) in these structures. The Shimoni Community Conserved Area (CCA) is located at the seafront of Shimoni, starting at Waga, and extends to Nyuli and Jironi areas. The Wasini CCA is located at the seafront of the Wasini village, starting at PiliPipa Restaurant (*Domo la Vumba*) in the North and extending westwards through *Masulini* to *Kijiwe Jahazi* in the south.

Sample size and procedure

The following formulae by Bill Godden were identified by the researcher mainly because it is popularly used in descriptive statistics dealing with probability. In these formulae, two calculation processes were applied, the first for the Sample Size for an infinite population (where the population is greater than 50,000) and Sample Size for a Finite Population (where the population is less than 50,000).

$$SS = \frac{Z^2 * (p) * (1-p)}{C^2}$$

Where:

Z = Z value (e.g. 1.96 for 95% confidence level)

p = percentage picking a choice expressed as a decimal (0.75 used for sample size needed)

c = confidence interval, expressed as decimal (0.07)

$$SS = \frac{\text{New SS}}{(1 + (\text{SS} - 1))}{\text{Pop}}$$

Where:

Pop = Population (11,720) (Godden 2004)

Therefore the sample size obtained was 145 people with 14 people as key respondent (Tables 1 and 2).

The sample from the general respondents consisted of any public member selected using stratified sampling to determine if everyone feels the influence of co-management. The key informants mainly included the fisheries personnel, i.e., the area and county fisheries personnel. The other key informants included personnel from Kenya Wildlife Service and, a representative from the tourist hotels in the area, a private tour company representative who will be purposively identified.

Table 1. Number of study respondents

Respondent category	Number in each category	Percentage
Community members	77	53.10%
BMU	61	42.07%
Key informants	7	4.83%
Total	145	100%

Table 2. Number of key respondents

Key informant	No. to be sampled
Fisheries Department	3
KWS	1
Tourist Hotel rep	2
Tour Operators	1
Total	7

Data collection instrument

To obtain the best results, the best way to collect adequate data for the research combined both qualitative and quantitative approaches; some of the data obtained were qualitative in nature and were best obtained through interviews and focus group discussions, while others were qualitative and thus could be gathered through questionnaires and observation schedule.

Questionnaires

Questionnaires are frequently used in quantitative research and social research. They are a valuable method of collecting a wide range of information from many individuals, often referred to as respondents. Adequate questionnaire construction was critical to the success of a survey. The questionnaire was with the general respondents and BMU members. The instruments were pilot tested to ensure they captured the intended information and that the respondents could comprehend the questions asked. Documentary analysis was carried out to draw upon the strengths of the different methods to improve the quality and validity of the data.

Semi-structured interviews

A semi-structured interview was employed because it does not limit respondents to a set of pre-determined answers; it also allows respondents to discuss and raise issues they may not have considered. For this reason, the researcher used this tool with the key informant from the stakeholders in the target area.

Focus group discussion

Focus groups were identified to facilitate discussions that allowed the researcher to see community members" perspectives. Focus groups were employed with the BMU members, including the BMU official.

Desk study review

Desk study will be carried out to examine the global development of marine protected areas, including the growth of community involvement in the management thereof and the objective of sustainability in resource utilization. That is attained through a review of progress in the global attitude to conservation, looking at the case example of techniques in the field.

Data collection procedures

For an adequate response rate, the researcher submitted official writing to relevant stakeholders (Fisheries Department personnel, Beach Management Unit leaders, Kenya Wildlife Service personnel, and other stakeholders). With the help of trained research assistants, the researcher presents the letters, interview schedules, and questionnaires to the respondents. At the local level, the researcher conducted focus group discussions with an assistant helping in note-taking.

Validity of research instruments

Pre-testing questionnaires helped the researcher increase participants' interest, helped discover question content, wording, and sequencing problems before the actual study, and also helped explore ways of improving the overall quality of the study. To establish the research instrument's validity, the researcher sought experts' opinions in the field ofstudy. That facilitated the necessary revision and modification of the research instrument, thereby enhancing validity. Content validity was obtained by asking for the opinion of the supervisor, lecturers, and other professionals on the adequacy of the questionnaire.

Reliability of research instruments

Reliability was increased by including many similar items on a measure, testing a diverse sample of individuals, and using uniform testing procedures. Several measures were taken to ensure reliability. The themes of the interview questions were based on the objectives stated in the study. Furthermore, to achieve reliability of the questionnaire, the instrument was designed with great care, matching questions with objectives for the study. The questionnaire was tested in the two areas of the study in a small group. The responses from the pilot study revealed ambiguity in some questions within the questionnaire; hence they were also left unanswered, while others appear to have been too difficult for the respondents to understand. The questionnaires were therefore revised to address these issues.

Data analysis and presentation technique

Both qualitative and quantitative data were gathered for the study using questionnaires, interviews, focus group discussions, and documentary sources. After collecting the data from the targeted respondents, the questionnaires were coded and fed into SPSS 19 for analysis to generate a descriptive picture of the data. Simple percentages and frequencies were used to analyze the quantitative data from the questionnaire. In addition, chi-square was used to test the hypotheses. The qualitative data from interviews and focus group discussions were analyzed manually by making summaries of their views and supported with data from documentary sources and the researcher "s field observations on the influence of collaborative management

on sustainable development. The analysis was organized under themes from the data and the research questions that guided the entire investigation.

Ethical consideration

Several ethical issues were addressed during the research, including informed consent, access, acceptance, confidentiality, and anonymity. In the conduct of this research, the principle of informed consent was given the required attention by explaining the purpose of the study to participants and making them aware that participation was optional and they could choose to answer any question during the interview. Furthermore, in recognition of the ethical requirements that information obtained from a participant during research was confidential, none of the information provided by interviewees was disclosed to other people.

RESULTS AND DISCUSSION

The study investigated the influence of co-management on the sustainable management of marine resources, using Shimoni and Wasini areas in Kwale County as the case study. The data is presented using frequency distribution tables and percentages; cross-tabulation has also been used to show the relationship of variables. In all instances, the Chi-square statistic was calculated to test the significance of the relationship between variables (Table 3).

Response rate

Table 4 shows the variation in the response rate in each targeted area. Ninety questionnaires were distributed in the two areas considering the population size. Therefore, 60% of the questionnaires were distributed in Shimoni and 40% in Wasini. Response from Shimoni respondents was better, with only three questionnaires not returned, whereas the response from Wasini had seven not returned. Generally, in rating response, 60% is rated as marginal, 70% as reasonable, 80% as good, and 90% would be excellent (Mundy 2002). Therefore the general response was very good, with a response rate of 88%.

Institutional design supporting co-management as a tool for sustainable management of marine resources

The study results show that the respondents believe that the institutional arrangement is currently adequate. According to the response from interviews with FiD and KWS, this is because the transfer of power through the BMU Regulation 2007 Regulation 6, 7, 8 and the by-law were tailor-made by individual BMUs to meet their needs. The interview with KWS personnel revealed that involving community members through co-management is a good move toward sustainable MRM initiatives. In addition, the community has the rights through the BMU to control fisheries' access in their jurisdiction. In that case, the only legal right of access to exploit fisheries resources at gazetted and designated landing sites is through joining a BMU. As a result, 90% of the respondents, as shown in Table 5, agree that co-management has resulted in improved environmental conditions and conservation measures. The institutional structure of the BMUs was found to be adequate. The adaptability of the by-laws and BMU organizational adequacy were generally satisfactory.

The BMU allows control of access to fisheries resources by limiting the numbers and types of fishing boats and gears. But, most importantly, they set their management rules locally at the beach level through by-laws and ordinances.

Conflict management Structures in co-management for sustainable MRM

The conflict management structures result from the institutional arrangement set in co-management. The data collected show that 95% of the respondents perceive that conflict management structures in co-management are adequate in solving marine resource-based issues, and the BMUs demonstrated the ability to resolve internal conflicts. As represented in Table 6, in co-management, BMUs are expected to develop conflict prevention mechanisms that would lessen the possibility of conflicts arising. The responses indicate that the conflict management mechanisms employed are fruitful.

The common sources of resource use conflicts derived from the study are largely related to gear use, overlapping institutional mandates in the government sector such as Kenya Forest Service and FiD, and inadequate BMU leadership, as shown in Table 7.

The FiD heavily relied on early warning signs and information, such as stakeholder complaints and cases, to anticipate conflict. Table 8 demonstrates results obtained on the most preferred conflict resolution mechanism. Moreover, the respondents said that when conflicts were beyond the reach of the BMU, the FiD took over, which is first addressed in conflict resolution meetings involving a wider audience, including village elders and other agencies (local administration, KWS, etc.). During the focus group discussion, newly established BMU networks within the county can be used as a platform to resolve conflicts of a bigger magnitude, such as shared co-management area-related conflicts. To enhance compliance with the decisions made by the resolution committees, BMUs opted to integrate traditional conflict resolution mechanisms with the newly instituted BMU mechanism.

BMU regulation 2007 has opened an avenue of resource use conflict management by forming the Conflict and Management Committee (CMC) in every BMU. However, the local conflict mechanism is still preferred by 12.5 % of the respondents. In addition, the study showed that there had been cases involving BMU members and external persons, such as some tour operators and hoteliers, who sometimes failed to recognize the BMU's legitimacy. Nevertheless, the general perception is that conflict resolution measures are mostly satisfactory at all levels.

The research sought to test the first research hypothesis as per the results obtained to establish the presence or absence of a relationship between the transfer of power through involvement in conflict management and the definition of roles in co-management for sustainable MRM. The study utilized the chi-square test to test this relationship.

H_0 There is no relationship between the transfer of power and co-management for sustainable marine resources management

H_a. There is a relationship between the transfer of power and co-management in the sustainable management of marine resources.

Based on the results of Table 9, the Chi-square value is at 10.679 at a degree of freedom of 1. The chi-square value is higher than the expected value. Therefore the null hypothesis is rejected.

Table 3. Operational definition of variables

Objective	Variable	Indicator	Measurement	Scale	Type of research	Data collection method
1. To examine the institutional design in co-management for sustainable management of marine resources in Shimoni and Wasini.	Institutional design	Conflict management • Definition of roles and responsibilities • Power distribution	How conflict management has been influenced byco-management	Nominal	Survey	Interviews withkey informantsand questionnaire
2. To determine the extent of community participation in co-management for the sustainable management of marine resources	Community participation	Enforcement • Partnerships and agreements	Community members' magnitudeof involvement in decision-making on their resources	Nominal	Survey	Focus group discussion, questionnaire, and interviews
3. To assess the integration of indigenous knowledge in the co-management of marine resource management and utilization	Socio-economic dynamics	Knowledge systems • Diversity	Co-management "s effort in incorporating traditional knowledge for bettermarine resource management	Nominal	Survey	Focus group discussion, questionnaire

Table 4. Questionnaire response rate

Area	Distributed	Returned	Percent %
Shimoni	54	51	94.4
Wasini	36	29	80.6
Total	90	80	100

Table 5. Relationship between Institutional arrangement contribution to resource conservation and its adequacy for Sustainable Development

		Institutional arrangement in co-management is adequate for SD					Total
		Strongly disagree	Disagree	Neutral	Agree	Strongly agree	
The institutional arrangement has enhanced resource conservation	No	0	2	7	1	0	10
	Yes	1	2	7	42	18	70
Total		1	4	14	43	18	80

Table 6. Comanagement as a solution in resource conflict management

	Frequency	Percent	Valid percent	Cumulative percent
No	4	5.0	5.0	5.0
Yes	76	95.0	95.0	100.0
Total	80	100.0	100.0	

Table 7. Main sources of resource-based conflict

	Freq.	Percent	Valid percent	Cumulative percent
Shared co-management areas	14	17.5	17.5	17.5
Gear use	37	46.3	46.3	63.7
Overlapping institutional mandate	6	7.5	7.5	71.3
Inadequate BMU leadership	23	28.7	28.7	100.0
Total	80	100.0	100.0	

Table 8. Mechanisms to address conflict management

Frequency		Percent	Valid Percent	Cumulative percent
CMC in BMUs	44	55.0	55.0	55.0
Local conflict resolution mechanisms	10	12.5	12.5	67.5
Report to fisheries dept	26	32.5	32.5	100.0
Total	80	100.0	100.0	

Community participation in decision-making for sustainable MRM

Community members have been given rights to manage the fisheries resources and make decisions on how to manage and control their resources; this includes the right to decide which gear can be used. The study's response shows a strong relationship between respondents' opinions on the clarity of the co-management roles of BMUs and the community's involvement in decision-making on Natural Resource Management (NRM) (Table 10). 82.5% of the respondents agreed that the roles were clearly defined and that community members are involved in community development. The study showed that the communities' sense of ownership of the marine resources had been developed and enhanced due to community consultation and involvement in decision-making, mainly during assembly meetings. Generally, the response on community participation in decision-making was satisfactory.

H_0 There is no relationship between co-management and community participation in the sustainable management of marine resources.

$H_{a.}$ There is a relationship between community participation and co-management in the sustainable management of marine resources

Based on Table 11, the Chi-square value is at 20.851 at a degree of freedom of 1. The chi-square value is higher than the expected value. Therefore the null hypothesis is rejected.

Integration of indigenous knowledge in co-management for sustainable MRM

With the introduction of co-management, the communities are at liberty to use traditional methods. Table 12 shows that 92.5% of the respondents believe that IKS is applied in co-management and is effective in marine resource conservation.

Table 9. Relationship between the transfer of power and co-management in the sustainable management of marine resources

	Value	Df	Asymp. Sig. (2-sided)	Exact Sig. (2- sided)	Exact Sig. (1- sided)
Pearson Chi-Square	10.679[a]	1	.001		
Continuity Correction[b]	6.618	1	.010		
Likelihood Ratio	7.323	1	.007		
Fisher's Exact Test				.013	.013
Linear-by-Linear Association	10.545	1	.001		
N of Valid Cases	80				

Note: a. 2 cells (50.0%) have an expected count of less than 5. Therefore, the minimum expected count is .65

Table 10. Relationship between defined roles for FiD and BMU and community involvement in decision-making on NRM

		Involvement of community and BMU in decision-making on NRM		Total
		No	Yes	
No	Count	8	6	14
Clearly defined roles for FiD and BMU	% within Involvement of community and BMU in decision making on MR	61.5%	9.0%	17.5%
Yes	Count	5	61	66
	% within Involvement of community and BMU in decision making on MR	38.5%	91.0%	82.5%
Total	Count	13	67	80
	% within the involvement of community and BMU in decision-making on MR	100.0%	100.0%	100.0%

Table 11. Research hypothesis testing

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	**20.851[a]**	**1**	**.000**		
Continuity Correction	17.368	1	.000		
Likelihood Ratio	16.472	1	.000		
Fisher's Exact Test				.000	.000
Linear-by-Linear Association	20.591	1	.000		
N of Valid Cases	80				

Note: a. 1cells (25.0%) have an expected count of less than 5. Therefore, the minimum expected count is 2.28.

Previously IKS had been left out in marine resource management in favor of scientific knowledge systems which were seen as the panacea to resource degradation; however, it has little impact. The focus group discussion highlighted that management measures of conserved community areas (CCAs) are based on traditional ecological knowledge, including fishing gears, biological monitoring of the area, and seasonal closures.

Furthermore, the Chi-square test was used to test the relationship between the application of IKS in co-management and the perceived effectiveness of this application in marine resource conservation.

H_0. There is no relationship between the integration of indigenous knowledge and co-management in enhancing the management of marine resources

H_a There is a relationship between the integration of indigenous knowledge and co-management for enhancing sustainability in the management of marine resources.

The Chi-square statistic was computed at the 0.05 level to determine whether there was a correlation between integrating indigenous knowledge in co-management and the effectiveness of sustainable development. The test results, as shown in Table 13, revealed a significant relationship. The null hypothesis is therefore rejected.

Discussion

In this chapter, the researcher summarizes the findings of the study based on the three objectives of the study. In each case, the researcher briefly states the findings and the general implications of co-management toward sustainable development of marine resources in the study area. At the end of the chapter, the researcher states recommendations and highlights areas that need further research.

The study was designed to assess the influence of co-management in the sustainable management of marine resources. Three areas of focus were identified to guide this assessment. That includes the institutional design or arrangement, level of community participation, conflict management, and the socio-economic dynamics due to the application of IK.

Institutional design

An institutional design for co-management ensures that local communities, the primary resource users, are involved in marine resource management. The transfer of power manifests that; this is a shift from the previously employed top-bottom management style to the bottom-up method. However, the study results show that this has developed a sense of ownership; therefore, the community is forced to be cautious and adopt better ways of sustainable resource exploitation.

Conflict management measures in co-management have resulted in a decline in resource use conflict, and when the conflicts arise, the community members have faith in the mechanisms set. The study showed that compliance and validity of the conflict management committees inthe BMU were dependent on the incorporation of the local and traditional resolution methods; as a result, the committees are composed of members in the community who are known to address general community conflict. Stakeholders such as FiD, KWS, hoteliers, and Tour operators believe co-management has enhanced resource utilization, making it a good environment for the stakeholders undertaking. For example, tourist handlinghas improved, cleanliness of the seascape and general order among fishers as they do their business.

Table 12. Relationship between application of IK and effectiveness of IK in resource conservation

		Effectiveness of IK					
		Not effective	**Little benefit**	**Average**	**Good**	**Very effective**	**Total**
No Application of IK	Count	1	1	2	2	0	6
	% within the effectiveness of IK	100.0%	33.3%	11.8%	4.8%	0.0%	7.5%
Yes	Count	0	2	15	40	17	74
	% within the effectiveness of IK	0.0%	66.7%	88.2%	95.2%	100.0%	92.5%
Total	Count	1	3	17	42	17	80
	% within the effectiveness ofIK	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Table 13. Relationship between the integration of IK in co-management and effectiveness of IK in resource conservation

	Chi-square tests		
	Value	**df**	**Asymp. Sig. (2-sided)**
Pearson Chi-Square	17.497[a]	4	.002
Likelihood Ratio	10.406	4	.034
Linear-by-Linear Association	10.548	1	.001
N of Valid Cases	80		

Note: a. 7 cells (70.0%) have an expected count of less than 5. Therefore, the minimum expected count is 0.08

Community participation

Comanagement is manifested through the active participation of community members, as was realized in the study. Through involvement and participation, the community members have become enlightened on destructive practices in the sea; as a result, this has increased the level of compliance with the set rules and regulations. In addition, the community members have become conversant with their roles and responsibilities in co-management.

The study also discussed leadership in co-management; it appeared that the community is empowered in picking their leaders. Empowerment is equivalent to "letting the power out" since people already have the power. Kenyan leadership is democratic and has been adopted in co-management structures such as the BMUs. The study showed that leadership in BMU affairs was generally satisfactory. However, leadership challenges within BMUs are numerous; they are constantly addressed according to the set regulations. The regulations are guided by the Fisheries Act and the Kenyan constitution, emphasizing critical leadership issues such as integrity.

Socio-economic dynamics due to the application of IK

There have been several notable socio-economic changes since the establishment of co-management. The study showed that the target BMUs had developed sustainable alternative livelihoods for their members; for example, Wasini has established an ecotourism venture through the CCAs, which is rapidly becoming a tourist hot spot, and Shimoni has attracted private companies dealing with octopus harvesting and aquarium fishery which has created employment to the community members and revenue for the BMU.

Assessment of the effectiveness of the integration of IK in co-management showed that Fishers use traditional local knowledge and skills to perform duties. This knowledge is also used in weather forecasting, which is useful in predicting changes in sea conditions to guide fishers. The social-cultural practices were equally observed and applicable in conflict resolution and conveying messages through well-established community social networks in multi-cultural, multi-religious areas, where BMU.

The first objective was to examine the institutional design for co-management as a tool for sustainable management of marine resources. Three indicators were used to inspect thedesign's adequacy, including transfer of power, conflict management, and definition of roles and responsibilities. Response from the study showed that there was general acceptance of the institutional design as adequate for sustainable management of marine resources. According to the respondents from Fisheries Department, co-management of fisheries resources has marked changes in the use of destructive practices and a slight increase in government revenue. Reduction in destructive fishing, as discussed earlier, was largely attributed to co-management arrangements, where BMUs enact and enforce by-laws against these practices, thus enhancing cooperation between the community and Fisheries Department. That is in agreement with views from the literature review that institutional design principles are thought to create conditions conducive to cooperation in common property scenarios (Ostrom 1990) and that high levels of reported conformity are positively related to graduated sanctions designed by co-management partners.

The second objective was to determine the extent of community participation due to co-management for the sustainable management of marine resources. The indicators applied to discuss this include developing a sense of ownership and compliance to set regulations. The results showed that community participation had been enhanced through co-management, creating opportunities for community members to coordinate and collaborate in resource management. Conservation and sustainable development are one of the main goals of BMUs in their activities; they ensure the protection of wildlife hence a boost to tourism. Community members must comply with the set rules on capturing marine mammals and endangered species and not destroying the breeding sites. That has enhanced collaboration with stakeholders such as KWS and hoteliers, who are the most interested parties. That agrees with the literature review that fishing communities can control and properly manage their resources if given exclusive rights and avoid over-exploitation with minimal government intervention. Moreover, Ostrom (1990) suggested that if a community of fishers exhibits a high degree of social, cultural, and economic homogeneity, fishers would be well-prepared to manage the resources successfully.

The last objective was to assess the integration of IK in co-management. Most respondents said indigenous knowledge systems had been heavily employed in co-management, citing examples of its application. For example, an area in Wasini has been successfully closed to fishing to conserve the coral gardens and resident species, generating revenue from tourism; this developed as a result of knowledge passed on through generations. Traditional and scientific knowledge are employed for better management, especially in bio-ecological monitoring of the enclosure. These traditional measures have contributed to improved communities' socio-economic status, especially from tourism and fisheries. The research findings concur with the literature review text from a study on the management of bump head parrot fish in Solomon Island by Aswani and Hamilton (2004), who reported that the integration of traditional knowledge and marine science enabled them to identify species and important associated habitats to develop urgent management needed

Some perceived challenges of co-management in sustainable MRM were mentioned during the study. Generally, co-management with FiD and KWS has been a relatively easy task. However, conflicts with the Kenya Forest Service arise in mangrove management, especially in licensing of loggers. In addition, some corruption cases have been mentioned where BMU leaders get compromised by illegal fishers.

Similarly, changes in stakeholder income and private sector investments were minimal. However, there was a perception that following the introduction of Locally Marine Managed Areas (LMMAs), stakeholders benefited

directly or indirectly by creating fish reservoirs and tourism. Therefore, a slight improvement in stakeholder income could have been realized. On the other hand, some hoteliers and tour operators do not recognize BMUs; thus, they do not comply with the regulations set, which is common, especially with access to CCAs.

The study aimed to assess co-management influence on sustainable management of marine resources. The main co-management structure employed in the study was the BMUs. In conclusion, the study showed a high appreciation of BMUs as management structures in co-management. Due to the perception that community rights over the management of resources have improved since the inception of the BMU/CCA model. There is effectively outlined in the institutional arrangement for co-management, highlighting an improved government-community relation as management is decentralized. In addition, there has been increased compliance to the set marine resource management, thus reducing the use of destructive gears and general degradation of the environment.

Community participation has been enhanced further with the support from stakeholders that have contributed to the success of co-management; The government policy (Fisheries Policy) recognizes co-management is a global phenomenon that covers a range of resources beyond fisheries and is a way to go; therefore providing an effective institutional policy and legal framework for co-management. In co-management, communities have the right to develop mechanisms to resolve internal conflicts. The BMUs have a Conflict Management Committee Conflicts are set up through the by-laws, mainly composed of community members who handle conflicts. That integrates traditional conflict resolution mechanisms with the newly instituted BMU mechanism.

Finally, the study shows that co-management has a lot of positive influences on conservation and community members' well-being. However, indigenous knowledge systems must be incorporated for the ongoing tool to function effectively. Therefore, the researcher believes co-management is an adequate planning and management tool for the sustainable management of marine resources.

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Fishing contributions to the household income in Mafia District, Tanzania

ANTHONIA MPEMBA, FELISTER M. MOMBO♥
Department of Forestry and Environmental Economics, Sokoine University of Agriculture. Morogoro, Tanzania. Tel.: +255232604865, ♥email: fmombo@yahoo.com

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Abstract. *Mpemba A, Mombo FM. 2019. Fishing contributions to the household income in Mafia District, Tanzania. Ocean Life 3: 74-85.* The fishing sector is responsible for providing critical income for many families within fishing communities. Fishing activities explain the levels of income which, in the end, indicate whether a given fishing household is benefiting. This study was undertaken to assess the contribution of fishing to household income in Mafia District, Tanzania. The data were collected from randomly sampled 120 household heads using several methods such as questionnaire survey, Focus Group Discussions (FGD), checklist and field observation. The collected data were analyzed using inferential statistics, descriptive statistics, and content analysis. A box plot was used to establish the significant relationship between household income contributions from fishing and other economic activities. In addition, content analysis was used in the analysis of qualitative data. The results revealed that several economic activities are conducted in the study area, where 41.47% of respondents indicated that fishing is the major economic activity in their households. The results showed that average household incomes from conducting fishing alone as the main economic activity was 51,250 TZS, fish-related activities were 15,000 TZS and other economic activities were 5,000 TZS per day. Since the study has revealed that fishing contributes to higher income in the household than other activities, therefore the study recommends that most of the households in the study area do not have access to credit for improving their activities, especially fishing the government should provide improved fishing gears for fishers with a low-interest rate.

Keywords: Economic, fishing, household, Mafia District, Tanzania

INTRODUCTION

Fishing has been a major source of food for humans and a provider of employment and economic benefits to those engaging in it (FAO 2005; Hosseini et al. 2018). It has been estimated that fisheries and aquaculture assure the livelihoods of 10 to12 percent of the world's population (FAO 2014). World Bank (2012) found that in Africa, the total employment in the fisheries sector was 25.4 million people, with 7.8 million employed in fishing and 17.6 in post-harvest. MLFD (2010) reported that more than 4 million people in Tanzania are engaged in fishing and fishery-related activities, while more than 400,000 fisheries operators are directly employed in the sector.

Tanzania is endowed with water resources, sharing three of the largest inland lakes in Africa, namely Lake Victoria, Lake Tanganyika and Lake Nyasa. In addition, the country is reasonably rich in marine and inland fishery resources, making the fisheries sector important in the economy (Sobo 2012).

Tanzania is among the main producers of fish for inland fisheries in Africa, mostly in Lake Victoria and Lake Tanganyika. The major commercial species in Lake Victoria are Nile perch (*Lates niloticus* Linnaeus, 1758); *Rastrineobola argentea* (Pellegrin, 1904), commonly known as "Dagaa" and Nile tilapia (*Oreochromis niloticus* Linnaeus, 1758); while the major commercial species in Lake Tanganyika are the Centropomidae (*Lates stappersii* Boulenger, 1914) (commonly known as "Migebuka") (FAO 2012). For marine fisheries commercial marine fisheries are mainly concentrated in the Exclusive Economic Zone (EEZ), targeting the tuna and tuna-like species. The major tuna and tuna-like species contributing to the catches include Yellowfin tuna, Skipjack tuna, Big eye tuna, Long tail tuna, and Kawakawa (Anon 2005). In addition, however, small-scale fishing is conducted by artisanal fishers who fish for fins, mollusks, and crustaceans within the inshore (FAO 2012).

The total annual fish production in Tanzania was 347,157 metric tons in 2010 (MLFD 2010) and was reported as the main source of protein for nearly 9 million people along the coast. In turn, fishing provides a source of employment and livelihood to many people (MLFD 2010). Starting from a low 2.9% annual growth in 2000, the sector's growth rate increased to around 6% between 2002 and 2005 and has since steadily dropped to 1.5% in 2010. The decrease in growth between 2009 and 2010 has been attributed to illegal fishing and the destruction of nursery grounds. Currently, the sector accounts for about 10% of the national exports (Planning Commission President's Office 2012; MLFD 2014).

Tanzania is rich in marine and inland fishery resources, making the fisheries sector important in the economy. Fisheries provide substantial employment, income, livelihoods, recreation, foreign earnings, and revenue to the country (Sobo 2012). Marine and inland fisheries are significant regarding food security and nutrition in a household. In addition, fish significantly contributes to

animal protein consumption (FAO 2008). Fisheries also provide both direct and indirect employment. Through employment, the income earned from fisheries and associated activities such as fish processing, fishing agreements, license fees, and distant water fishing fleets serviced at regional ports contributes to government budgets and the gross domestic product (FAO 2008).

These household incomes explain the levels of income in these fishing communities, which ultimately indicate whether a given fishing household is poor or otherwise. For example, in Lake Victoria, the household engaged in fishing (fishers) received net income that ranged between $1300 and $2100, while gear owners earned $5200 and $8400 per month (Bilame 2012). It is also reported that about 40-55% of the income of coastal fishing households in Tanzania is generated by fishing (Ninnes 2004).

Marine and inland fisheries are significant in food security and nutrition for many households, as fish contributes significantly to animal protein consumption (FAO 2008). Mafia Island is among the districts in Tanzania where the fish processing industry supports the dweller's fishing practice and activity. However, even though fishing seems to be the main economic activity, as explained in the district profile, there is no reliable information that explains the contribution of fishing to household income.

The objectives of the study were to determine household income contributed by fishing activity and examine determinants of fishing income. Furthermore, the study's findings are useful for future reference to other researchers who are interested in working further in fisheries studies.

MATERIALS AND METHODS

Description of the study area

Mafia District comprises a chain of small islets, with the main island centered at 7°50′S and 39°45′E some 20 km off the Tanzanian coastline east of the Rufiji Delta. It is approximately 50 km long by 15km across and is surrounded by a barrier reef teeming with marine life (Figure 1). The study area also has a protected area dominated by hard and soft coral reefs, sheltered back reef systems, inter-tidal flats with a hard and soft substrate, mangrove forests, extensive seagrass beds, algal sponges, and soft coral sub-tidal beds. The area is critical for the dugong (*Dugong dugong* Gmelin, 1788) and sea turtles (*Chelonia mydas Linnaeus*, 1758), *Eretmochelys imbricata* (Linnaeus, 1766), *Lipidochelys livaceae* (Eschscholtz, 1829), *Dermochelys coriacea* (Vandelli, 1761) which have been recognized as a critical site for biodiversity. It is popular for marine tourism, especially scuba diving (MCAT 2008).

Climate topography and soil condition

The island consists of a Pleistocene reef covered by sandy and loam soil. It experiences two monsoon seasons, the north-east (NE) (*Kaskazi*) and south-east (*Kusi*) (SE). NE Monsoon wind season starts at the end of November to March. The SE is the longer and windier period, from early July to mid-September. This is reported to be more variable than the NE monsoon, which brings strong winds. Mafia has a relatively dry tropical climate with approximately 1,800 mm of rain each year divided into two seasons of long rains in late March-May and short rains in November-early December (Kamukuru 2003).

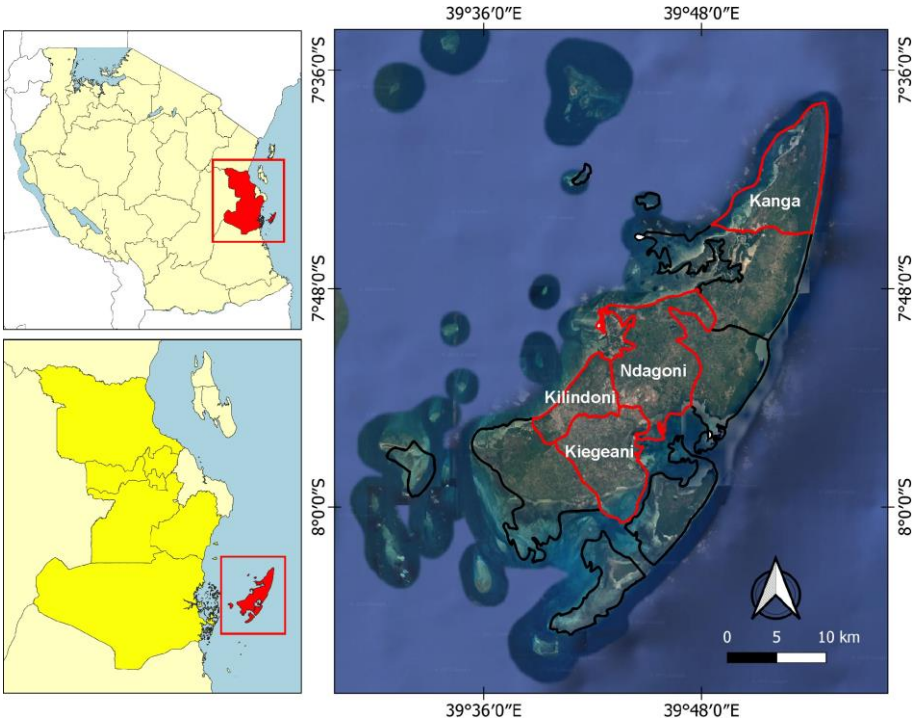

Figure 1. Map of the study area in Mafia District, Tanzania

Population and ethnicity

According to URT (2012), the overall district population was 46,438 inhabitants living in 20 villages. Different ethnic groups inhabit the island, the majority being from Kilwa Chronicle as the Mwera from Songo Island.

Accessibility

The study area is accessed by boat, which takes about three to four hours from Mafia to Rufiji. Islanders typically use jahazis, widely referred to in English as dhows, to commute between Kilindoni and outlying villages on Mafia and for inter-island travel. Flights flying into and out of Mafia every day take only 45 minutes from Dar es Salaam and 1 hour from Zanzibar or the Selous.

Data collection

Primary data was collected through a questionnaire survey, checklist, field observation and Focus Group Discussion. Secondary data was collected through relevant literature reviews (published and unpublished documents). Relevant sources used were Mafia District Fisheries Office, internet, and Sokoine National Agriculture Library, Tanzania.

Research design

The research design for this study was cross-sectional. This design allows data to be collected from a sample to represent a large population at a single point in time. This is appropriate for descriptive study and determination of a relationship between and among variables and is economical in terms of time and financial resources (Babbie 1993). A subject population was selected, and data were collected from these individuals to answer questions of interest.

Sampling procedure

Both purposive and simple random sampling procedures were adopted in this study. First, four wards were selected purposively in the district (Kilindoni, Ndagoni, Kiegeani and Kanga) then a random sampling procedure was adopted to select 4 villages, namely Kilindoni, Kiegeani, Chunguruma, and Bweni.

Sample size

The sampling unit for the study was the household. According to TANGO International (2004), a household is a core analytical unit that defines regular roles, rights, and responsibilities across gender and age. A total of 120 households were randomly selected to obtain 30 households per village, as 30 respondents is the minimum number recommended to represent a population under study (Yurdugul 2008).

Questionnaire survey

A semi-structured questionnaire was used to obtain primary data. This questionnaire was designed to collect demographic characteristics of the households, household income from fishing and its related activities, and determinants of fishing income.

Checklist of questions

A checklist of questions was used to guide interviews with key informants. The key informants included the village chairperson, village elders, and district fisheries officers.

Field observation

Supplementary information was collected through personal observation in the field to cross-check some of the information obtained through the questionnaire. This was true, especially on the type of fisheries resources harvested, type of fishing gears used, fishing related activities conducted. According to Neuendorf (2002), observation and interaction within the society enable a researcher to discover discrepancies between what participants say and what is believed should happen and what happens or between aspects of the formal system.

Focused group discussion (FGD)

FGDs were conducted in each village with 10 people, where 8 were household members, 1 fisheries officer and 1 village elder. A set of questions was used to guide the discussion, including the history of fishery in the study area, different fish captured with their contribution to household income, types of fishing-related activities conducted, the contribution of fish-related activities to household's income, and determinants of fishing income.

Reconnaissance

A preliminary survey was conducted to pre-test the questionnaire before the main survey. This was important since it helped to check and identify weaknesses and ambiguities before embarking on a detailed interview.

Data analysis

Qualitative data analysis

Qualitative information was analyzed by using content analysis. Using this method, the information collected through verbal discussions with key informants and focused group discussion was analyzed. This method enabled the researcher to include a large amount of texture information and systematically identify its properties (Neuendorf 2002). Textual information was categorized to provide meaningful information; the basic idea was to reduce the total content of communication to a set of categories representing some characteristics of research interest (Singleton et al. 1993).

Quantitative data analysis

Both descriptive and inferential statistics were used during data analysis. Questionnaires were coded, cleaned, and data from both open and closed questionnaires were categorized. Information such as socio-economic characteristics, income sources, and contribution of each economic activity to household income, were analyzed descriptively into frequencies, percentages, and mean and presented in tables and graphs.

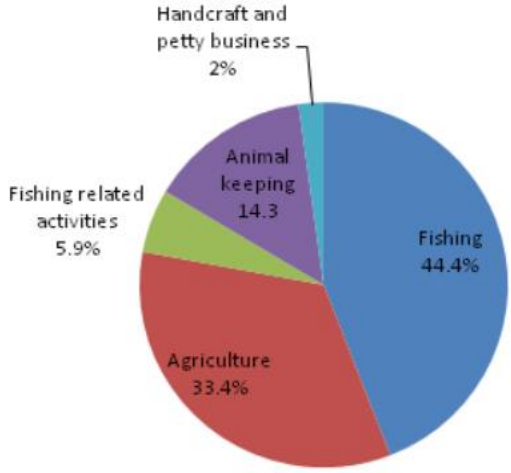

Figure 2. Household income from different sources

Household income contributed by fishing activity

Household income from fishing activities was analyzed and plotted using a box plot to obtain the income distribution from households involved in fishing only. Mean, median and mode were obtained and presented in a box plot (Figure 2).

Household income contributed by fishing-related activities

The dimension of fishing activities was measured as household involvement in fish processing, vessel making, fish trade, and fishing supporting activities. Descriptive statistics captured the contribution through percentage, mean and standard deviation.

Determinants of fishing income

A household questionnaire was used to capture information on determinants of fishing income. To answer this objective, data collected were socio-economic and demographic factors which were age, sex, family size, education level, marital status, fishing gear, fishing season, number of labor per vessel, financial support, and type of where fish are sold. Garoma et al. (2013) also used a multiple regression approach to determine quantitatively the amount of income earned from fish catch and factors affecting fish income.

A stepwise regression method was selected to identify the most suitable factors for determining fishing income. Thus, principal component factor analysis (PCA) was applied to identify the internal structure behind variables represented in a research concept by examining correlation among variables and reducing the number of variables (George and Mallery 2010). This application was further ensured to minimize the multicollinearity effect on regression analysis (Nishantha 2011). Selection criteria for extracting factors were fixed as the first commonality is greater than or equal to 0.5 (Costello and Osborne 2005; Yong and Pearce 2013). Secondly, the Eigen value is greater than 1.000 according to the Kaiser criterion and then the factor coefficient is greater than 0.5 (Shapiro and Wilk 1965).

Later, extracted factors identified by PCA were analyzed using the stepwise method of multiple linear regression and then the standard regression model measured path coefficients to understand the direct, indirect, and correlated impact of predicted determinants of fish income. The criterion was set at significance levels of α-0.05 and 0.01 for the selection of regression coefficients and path coefficients. Finally, details of each step of the statistical process were interpreted, along with an analysis of the results.

$$Y_{Income} = \beta_0 + \beta_1 F_{gear} + \beta_2 N_{labour} + \beta_3 F_{season} + \beta_4 E_{level} + \beta_5 F_{sup\,port} + \mu_1$$

Where, F_{gear}: fishing gear, N_{labor}: number of labor per vessel, F_{season}: fishing season, $F_{sup\ port}$: Financial support, E_{level}: Education level, coefficient-i: 0,1,2,..5, μ_1: stochastic error term, β1-βn: are independent variable coefficients (β) showing marginal effects (negative or positive) of the unit change in the independent variables on the dependent variables, Y: i^{th} is the income of the fishing activity in study area.

Justification of the multiple regression model

A multiple regression model, also known as Ordinary Least squares regression, is a common modeling method for data analysis and has been successfully applied in many studies. For example, Garoma et al. (2013) supported that the method is useful in analyzing the data with numerical (quantitative) dependent variables.

Variables description

The study assumes that household income is influenced by some socio-economic factors used in this study as the explanatory variables. The basis for the assumption was theoretical considerations found in the literature. The variables used in the model are summarized in Table 1.

Education level of household head

The education level of the household is a categorical variable and was measured by the number of years of formal schooling of the household head. Education plays a major role in adapting and innovation. It is also believed that a person with a higher education level is expected to use sophisticated gears that can improve fishing practice, hence increasing income (Jabri et al. 2014). Therefore, it is expected that a positive relationship should exist between the household that has gone to school to have higher income.

Fishing gear

Fishing gear is a categorical variable measured by the kind of gear used by the fisher. Efficient and effective use of any gear on a water body with success is key as the fisher needs mobility to enable him/her to reach both near and distant fishing grounds or markets. This necessitates the acquisition of a craft (Ogundiwin 2014). It is expected that a household that uses modern fishing gear is likely to have more income.

Table 1. Variables in the multiple regression model

Variables	Description	Types	Values
Dependent variable			Number of options
Fishing income			Available to choose
Explanatory variables			
Fgear	Fishing gear	Categorical	Categorical based on kind of gear
Nlabor	Number of labors	Continuous	Number of fishers
Fseason	Fishing season	Categorical	Categorical based on fishing season
Elevel	Education level	Categorical	Categorical based on number of years
Fsupport	Financial support	Categorical	Categorical based on type of credit received

Number of labor per vessel

The number of laborers per vessel is a continuous number which was measured by the number of crew per vessel. An increase in the number of crew per boat may lead to negative marginal returns for small-scale fishermen. Any increase in the number of fishermen may result in a decrease in output, hence, income accruing to each fisherman declines because the revenues must be shared by more people (Canbäck et al. 2006). Therefore, the more income received, the minimum number of crew per vessel is expected.

Financial support

Financial support is a categorical variable measured by the number of credits received to support the fishing activity. All forms of support positively impact fishing operations, which helps reduce costs, raise prices, or increase income.

Favorable fishing season

Fishing season is a categorical variable measured by the type of fishing season, which are NE and SE monsoon winds. Therefore, it is expected that there will be a low catch during SE monsoon during a high catch during NE monsoon season.

RESULTS AND DISCUSSIONS

Based on the analysis of information obtained from the communities in the four villages in the study area and various stakeholders, experience, and literature consulted are described below. Information includes identification of various economic activities, assessment of the economic contribution of fishing activities to the household income, the contribution of fish-related activities to household income, and determinants of fishing income.

Socio-economic characteristics of household head

Socio and economic factors play an important function in utilizing various resources, aiming to improve economic status. However, without considering the environmental impact, this can lead to unhinged natural resource utilization resulting in depletion. The socio-economic characteristics of respondents included sex, marital status, age, education level, and marital status (Table 2).

Sex of household

The social relationship between males and females influences socio-economic activities. The results show that 87% of respondents were male, while 13% were female (Table 2). The results also showed a significant difference between the sex in a study area ($p<0.01$). Gender determines the nature of the activity performed in fishing activities; males are more involved due to the nature of work since it involves more energy (Béné et al. 2003). Although the results show the dominance of the fisheries sector by men, the contribution of women in active fishing cannot be undermined. Williams (2002) reported that women had been restricted in fishing activity due to socio-cultural factors, low technical know-how, and lack of credit facilities.

Marital status

Findings showed that 89% of the households were married, 10% single and 1% widowed. It is also observed that there is no significant difference between marital status and household income from fish in a study area ($p <0.05$).

Age of household head

Most heads of household age (38%) ranged between 34-41 years. 28% ranged between 42-49 years, while 15% ranged between 26-33 years. Other 12% ranged between 50-57 years, 4% ranged between 18-25 years, as well as 3% of respondents, were above 58 years. It is also observed that there is no significant difference between age groups in the study area and the village when ($p<0.05$). Age is an important criterion that normally influences the working ability of an individual. Productivity increases with age and decreases with a late life cycle (Jeyarajah and Santhirasegaram 2015). Fisheries act of 2003 and its regulation of 2009 allow a man with more than 18 years to participate in fishing activities. Age also impacts experience, wealth, and decision-making (Hoppe 2002).

Education level of household head

Table 2 shows that 63% of the respondents have attained primary education, 25% secondary, and 12% have non-formal education. Results also show a significant difference between education levels in a study area ($p<0.01$). These findings imply that the education level for most households was still low because primary education is still considered basic education, which might directly influence the utilization of natural resources, especially

fisheries in the coastal area. Priya and Sreeranganadhan (2015) reported that fishers do not need high education and specialized skills since they have their traditional way of learning, and it is handled from generation to generation.

The findings of Yuerlita and Sylvain (2010) show that percentage of primary school education to households in the fishing community was higher than other levels of education in West Sumatra, Indonesia. Therefore, it could be argued that education is an important factor in providing better livelihood options, as it offers the opportunity for better-paid jobs and hence better livelihood outcomes that can reduce the dependence on fishing.

Households size

Findings show that 38.3% of households had an average household size of 4 people (Table 2). This average household size is within the national average household (URT 2012). It is also observed that there is no significant difference in household size in the study area ($p<0.05$). A large household size implies resource utilization because a large household size means high consumption units within the household (Hatibu 2010). This can lead to more extraction of resources.

Economic activities

Economic activities involve the production, distribution and consumption of goods and services at all societal levels. They can be assessed and forecasted to measure the significant impact of a particular activity (NACE 2008). Findings in the study area show that the main economic activities conducted were fishing, fishing-related activities and agriculture, while petty business and animal keeping were subsidiary activities. Findings in Table 3 show the respondents' economic activities conducted in the study area. Almost all respondents mentioned fishing as one of the daily activities conducted within the household (41.47%), followed by agriculture (14.85%).

Household income from different sources

The findings show that 44.4% (Figure 2) of the household income was from full-time fishing, 33.4% in agriculture, 14.3% in animal keeping, 5.9% in fish-related activity, and 2.0% were households engaging in handcraft and petty business. These findings imply that any activity affecting fisheries also affects the livelihood of a great proportion of the community in the study area. Furthermore, it has been seen that fishing is the activity that is the easiest to perform since it is a commonly accessed natural resource compared to others.

This study's findings align with different studies conducted in coastal areas on fisheries. For example, FAO (2012) reveals that fishing is an activity that contributes a large percentage compared to other activities in coastal communities.

Table 3. Percentage of the respondent in economic activities conducted in the study area

Economic activities	%
Fishing	41.47
Agriculture	14.85
Fishing and agriculture	12.5
Fishing with related activity	11.58
Fishing related activities	9.54
Fishing and livestock	8.6
Fishing and handcraft	0.83
Petty business	0.63
Total	100

Table 2. Social economic characteristics of respondent (n= 120)

Social economic attribute		Village (%)				Total (%)	x^2
		Kilindoni	Kiegeani	Chunguruma	Bweni		
Sex	Male	83.3	80	90	93.3	87	
	Female	16.7	20	10	6.7	13	S
Marital status	Single	6.7	13.3	10	8.3	10	
	Married	90	86.7	90	90.8	89	NS
	Widowed	3.3	0	0	0.8	1	
Age	18-25	6.7	0	0	3.3	4	
	26-33	30	13.3	10	6.7	15	
	34-41	20	46.7	43.3	43.3	38	
	42-49	20	30	30	33.3	28	
	50-57	23	3.3	10	13.3	12	
	Above 58	0	6.7	6.7	0	3	NS
Education level	None	26.7	10	3.3	10.8	12	
	Primary	63.3	46.7	76.7	63.3	63	
	Secondary	10	43.3	20	25.8	25	S
Family size	One	3.3	3.3	3.3	3.3	3	
	Two	3.3	13.3	3.3	5	6	
	Three	10	16.7	20	15.8	16	
	Four	33.3	40	43.3	38.3	39	
	More than four	50	26.7	30	37.5	36	NS

Note: S= Significant at $\alpha < 0.01$, NS= Not significant at $\alpha < 0.05$. Source: Field survey (2015)

Contribution of fishing income

The study found that the average estimated income obtained from households engaged only in fishing was 51,250 TZS per day, giving an estimate of 9,225,000 TZS per annum (Figure 3). In this figure, the income distribution shows that there are some exceptions for the minority who receive higher than others. This might be because they possess their fishing gear, compared to the majority who act as workers. However, at the end of the day, they must pay back the owner; both four FGDs explained this.

Contribution of fishing income by a village. Full-time household fishers in the study area showed different incomes per household per day. For example, in Figure 4, it is illustrated that Kilindoni village received the biggest amount of all, that is 340,000 TZS, whereas, Bweni received 57,200, Chunguruma, 52,000 and Kiegeani 5,950 TZS. It is also observed that in Kilindoni, most households received income ranging from 213 500 to 694,500 TZS in Chunguruma 21,600 to 62,250 TZS, Bweni 16,450 to 47,200 and Kiegeani 2,350 to 6,225 TZS (Figure 4).

Contribution of income by fish type. There are more than 460 fish species found on Mafia Island, few of them are mostly harvested due to their accessibility during fishing and marketability in and outside the island. The study found that 84.8% of the income is contributed by fish species (tuna species, groupers, emperor, mackerels), 11.5% by dagaamcheli (*Stolephorus commersonnii* Lacepède, 1803), while squid contributed only 0.1% of the total fishing income (Table 4). It has been observed that most of the fish harvested were pelagic, epipelagic and estuary simply because most of the fishers have no advanced fishing gear, hence, they only fish in territorial waters (McClanahan et al. 2009). The findings of this study are in line with different studies conducted in Unguja, which found that fish contributed to high income in fisher households; an example of these fish was like tuna, kingfish, sword, octopus, lobster, and shark, while those of low value were an octopus, mackerel, rabbitfish (Fröcklin et al. 2013). Also, FAO (2008) reported that most of the common catches in coastal communities in the Indian Ocean are small and large pelagic species, including herrings, tuna-like species, followed by demersal species like lobsters, shrimps that make a significant contribution to income.

Fishing activities by gender. Women's roles in world fisheries have increased (Bennett 2005), but traditionally, fisheries have been associated with men. Men focus primarily on capture fisheries rather than women-dominated pre- and post-harvest activities, such as processing and marketing the catch (Weeratunge et al. 2010). This study has revealed that more than 90% of fishers were male, while less than 10% were female (Figure 5).

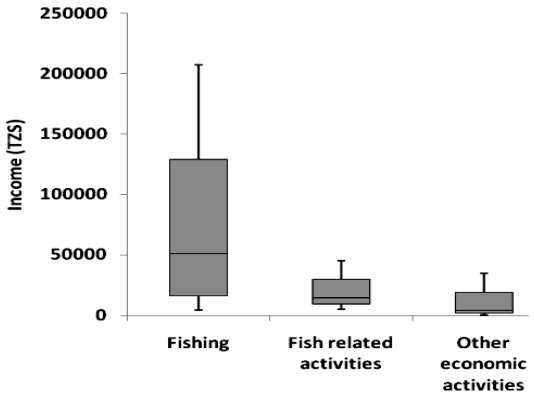

Figure 3. Distribution of fishing income in the study area

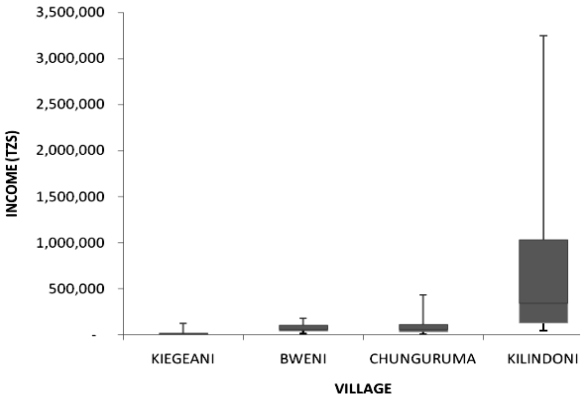

Figure 4. Distribution of fishing income by village

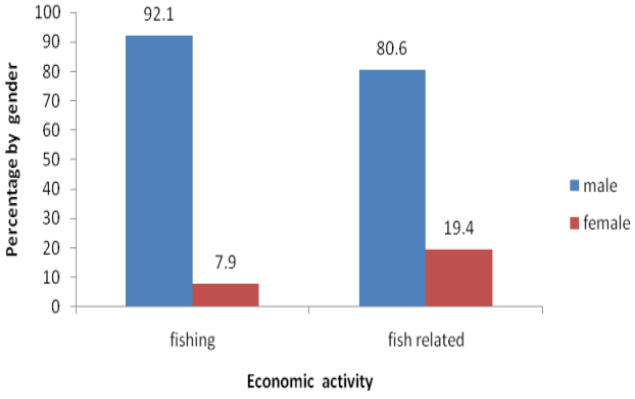

Figure 5. Showing fishing activity by gender

Table 4. Contribution of income by fish type

Fish type	Fish income (TZS)	
	Average mean	Std
Fish (all species)	423,000 (84.8)	90,900.21
Dagaa	243,344 (11.5)	51,899.53
Lobster	90,500 (2)	37,361.89
Ray	72,500 (1.1)	14,446.4
Octopus	6,800 (0.5)	8,300.85
Squid	12,000 (0.1)	5,047.67

Note: In brackets is percentage

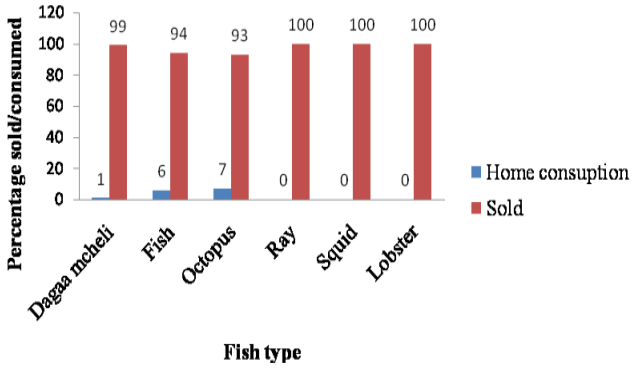

Figure 6. Showing the uses of fish in the study area

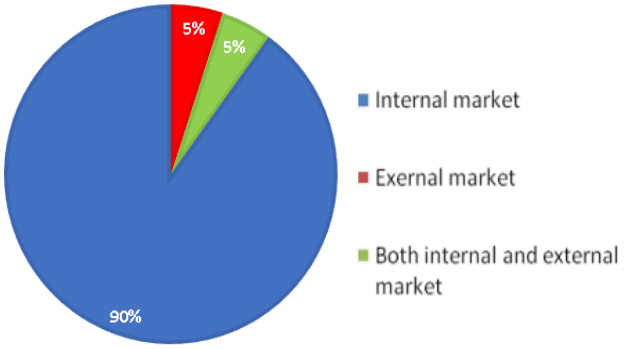

Figure 7. Shows type of market

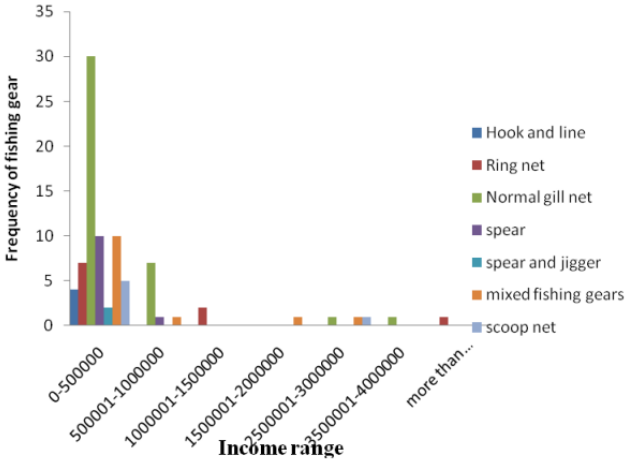

Figure 8. Income contributed by the type of fishing gear

From direct observation during the study, female fishers were found in Kiegeani village only, and they specifically harvest octopus. It is then observed that males conducted more than 80% of fish-related activities while females conducted less than 20%. These activities include fish and dagaa processing (drying, packaging, and transporting), vessel making, and repair. The findings of this study are in line with studies conducted by Williams (2002), who reported that women also perform diverse unpaid tasks such as mending nets, collecting bait, preparing food for fishers, and keeping accounts, which are unacknowledged or undercounted as employment. Therefore, this activity is dominated by men.

Different uses of fish in the study area. The study found different uses of fish in the study area. Ray, squid, and lobster were harvested for commercial purposes, while dagaa, fish, and octopus were used for home and commercial purposes. It has also been observed that dagaa was used in a small percentage of households compared to fish and octopus (Figure 6).

Fish market. The study found that fishers have three options for selling fish. First, they sell within Mafia, second, outside of the Mafia, and thirdly, both within and outside of Mafia. 90% of fish are being sold within the study area, 5% outside the study area, and 5% in both within and outside Mafia Island (Figure 7). The large amounts of fish sold within the study area are taken by the processing industry located at Kilindoni village. This fish processing industry sells its fish in other areas of the country and exports lobster and octopus to Portugal and France. Also, the dagaa market is largely sold while processed (salt drying) in Mtwara, Dar es Salaam, Kilimanjaro, and Singida and sometimes in Malawi and Congo.

The study by Sobo (2012) found that in most coastal zones, including Tanzania, there is no effective central marketing agency in the villages. Fish traders (mongers) usually visit different fish landing sites daily to buy fish and transport it to markets in major towns. Price is set depending on the season, demand for fish, and the distance of villages from the major coastal towns. For this reason, the price of fish is influenced by the variable transportation costs. Prices tend to be lower farther away from the major urban centers.

Contribution of income by fishing gear. The study shows that fishers normally use different fishing gear to catch various fish species. Among the gear used by fishers in the study area were hook and line, spear and jigger, ring net, normal gillnet, scoop net, and others used a mix of different gears at a time. Fishing gears have an impact on fishing income. Normal gill nets were preferred mostly since they capture almost all types of fish species. It has been observed that the ring net contributed a wide range of income from 1,000,000 to more than 5,000,000 TZS per catch per crew (Figure 8).

Fish species captured at different water level

Fish species are captured by using different gears at different water levels. There is a relationship between fish species, gear used, and water level. Figure 9 shows the water levels with the kind of fish species captured. Pelagic waters contributed 53%, where 38% are benthopelagic species and 9% are offshore dwellers. The pelagic species included *Anchoviella* spp. (dagaa), *Lethrinus* spp. (changu), *Siganus oramin* (Bloch & Schneider, 1801) (Tasi), *Restrelliger* spp. (vibua), *Carcharinus* spp. (papa). Almost fishing gears are capturing all these species, benthopelagic species including *Cephalopholis* spp. (chewa), *Aluterus* spp. (kikande), *Palinurus* spp. (kambakoche) *Pastinachus* spp. (taa), *Octopus* spp. (pweza). These species are

captured by normal gillnet and hook and line. Off-show dwellers included Tuna (jodari) and Gymnosarda spp. mostly known as Kingfish (nguru); these are captured by ring net and hook and line.

Contribution of income from fish-related activities

Findings revealed that there were several activities conducted that related to fishing, and those activities were performed by both sexes (Figure 10). Dagaa fishery involved a chain of activities, including carrying dagaa from the vessel to the landing site, drying, and packaging. Other beneficiaries from fishing include fish mongers (middlemen), fish processors (salt drying and smoke drying) as well as vessel makers and repair. Fish collection contributed 67%, whereas intermediaries do the activity, vessel building contributed 26%, dagaa collection and processing contributed 7%. A fish trader generally earns more than anyone involved in other coastal activities (Fröcklin et al. 2013).

Comparison of fishing income with other economic activities

The study showed that the average income from a fish household is much higher than other households that practice other economic activities in the study area (Table 5). The results above show a significant difference between households' fishing income and those from other economic activities, $p<0.05$.

Contribution of income from agriculture

Findings showed that coconuts, followed by paddy, were the main crops that contributed more to household income. Coconut contributed 24 times higher than paddy simply because almost every household has a coconut tree and harvested every three months. However, Table 6 revealed that coconut, paddy and cassava standard deviations are higher than their average mean. This could be because there was no normal distribution of income among the household simply because some of the households interviewed possessed large amounts of coconut trees and big farms of paddy and cassava compared to the majority; that made a big variation among them.

Uses of agricultural crops

The findings from the study observed that cassava, coconut, and paddy are both used commercially and domestically, while cashew nuts are used for commercial only (Figure 11).

Determinants of fishing income

The determinants of fishing income in the Mafia District were fishing gear, number of labor, fishing season, education level, and financial support. However, the independent variables, such as education level and financial support, negatively influenced fishing income, while the other independent variables positively influenced fishing income. Linear regression analysis results show that fishing gear, the number of labor, and fishing season significantly influenced the fishing income ($p<0.01$). On the other hand, some factors that would be thought to influence fishing income were not significant (Table 7).

Table 6. Contribution of income from agriculture

Crops	Agricultural income (TZS)	
	Average mean	Standard deviation
Coconut	2,459,416.67	3,987,031.21
Paddy	69,687.5	165,918.23
Cashew nut	600,000	24,860.97
Cassava	110,000	153,215.53

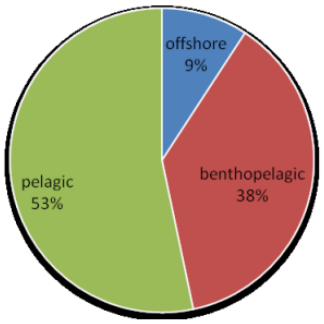

Figure 9. Water level with fish species capture

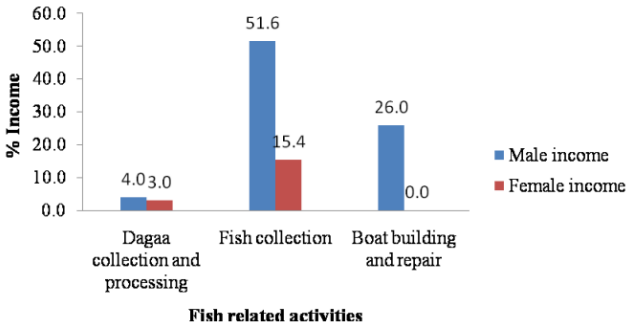

Figure 10. Income contributed by fish related activities

Table 5. Comparison of fishing income with other economic activities

Economic activity	Mean	Std	Std. error mean	t	df	Sig.
Fishing	61 550	36078.28	5245.58	3.575	118	0.048
Other activities	17 000	7821.37	1541.63			

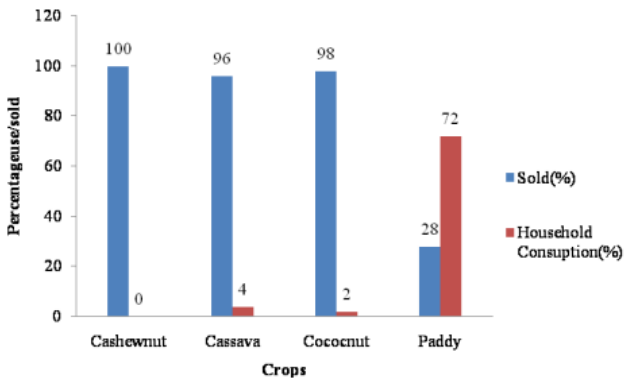

Figure 11. Uses of agricultural crops in the study area

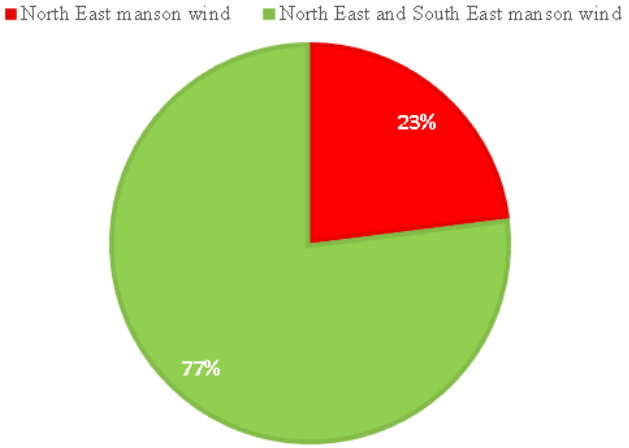

Figure 12. Shows the fishing season

Table 7. Linear regression results for determinants of fishing income

Variable	B	SE	β	t-value	P -value	Significance
Constant	0.398	0.157	0.041	1.023	0.031	S
Fishing gear	0.437	0.125	0.447	3.509	0.001	S
Number of labor	-0.055	0.028	-0.18	-1.95	0.054	S
Fishing season	0.242	0.121	0.258	2.008	0.048	S
Education level	0.007	0.127	0.005	0.055	0.957	NS
Financial support	0.092	0.148	0.056	0.625	0.534	NS

Note: S= significant at p<0.01, NS= Not significant at <0.05, Adjusted R^2= 76.4%, R^2= 73.4%

Fishing gear. The findings from the study showed that the relationship between fishing gear and fishing income was positive and statistically significant (P<0.01). This implies that fishing gears impact increasing fishing income, as the fisher who uses modern gear is likely to have more income (Table 7). The findings of this study concur with the study conducted by Canbäck et al. (2006), who found that fishermen might be in a diseconomy of scale situation, which can be turned around by offering bigger boats or other productive technologies. This means that an increase in output, which results in the average cost in the long run, increases by a greater amount and is proportional to the increase in the input.

Number of labor per vessel. The study found that the relationship between the number of laborers per vessel and fishing income was negative and statistically significant (p<0.01). This implies that a vessel with fewer fishers per vessel has less income (Table 6). Inoni and Oyaide (2007) found comparative results in Delta state in Nigeria that labor input was the factor around which small-scale fishing revolves, without an adequate number of men ready to undertake a fishing trip, there will be no catch. Therefore, the result implies that as the supply of labor increases, other things being equal, fish catch will increase as the income increases.

Fishing season. Findings from the study showed that the relationship between fishing season and fishing income was positive and statistically significant (p<0.01). This implies that the type of monsoon wind prevailing was influencing fishing income. The findings (Figure 12) show that 77% of the fishers were fishing in both NE and SE Monsoon and 23% of fishers were fishing only in NE monsoon. During SE monsoon, the catch is low, while in NE is high. The variation of catch due to reduced effort by fishermen during the SE monsoon wind was caused by rough sea conditions, fish migration and decreased density and activity due to deeper thermocline and cooler waters in the SE monsoon. Generally, the findings of this study support the findings by McClanahan (1988) that catch was low during the SE monsoon and high during the NE monsoon, with a peak in March at the end of NE monsoon. Also, the study conducted by Yaakob and Chau (2005) reported that there was a close relationship between weather and fishing operations as well as fishermen's income. The economy of the artisanal fishers is closely linked to cycles of the moon and tides, seasonal changes in the climate and the breeding patterns of the fish and other species on which they depend (Vieira et al. 2013).

Education level. The findings from the study revealed that education was insignificant in explaining the influence of education level on fishing income. The results are not in line with that of other studies, which reported that education had a significant positive impact on fisheries activities through financial management, which helped in improving general fishing activities, including fisheries businesses, methods of fishing and fish processing, to sustain and develop fisheries resources (Mensah et al. 2014).

Financial support. The findings from the study revealed that financial support was insignificant in

explaining the influence on fishing income. Artisanal fishing seems to be an attractive activity for poor individuals living along the coast since it has a very low startup cost (Silva 2006). The research done by Fröcklin et al. (2013) reported that capital is needed in fishing activities. It doesn't matter which sources it comes from, either in micro-credit, savings, or lent. This shows that access to initial capital is a key factor for income enhancement, increasing the quality of life.

This study has attempted to show the incomes generated from fisheries and how those incomes contribute to general household income. The study has further shown how the incomes of fishers and other people who engage in fishing activities are received. Fishers received higher income from fishing compared to other activities. However, alongside the incomes generated from fisheries, there were no fishing activities, which also greatly increased the household's income. Therefore, there is a need to strengthen fisheries sustainably in a way that enables both fishers and other people who benefit indirectly through fisheries to attain a win-win solution to raise household incomes that could raise the standard of living.

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Aquatic macrophyte diversity, distribution, and control in coastal Southern Ghana, with priority on non-native invasive species

ASARE ERNEST, GABRIEL K. AMEKA♥
Department of Botany, University of Ghana. Legon, Greater Accra, Ghana. Tel.: +233-302213850, ♥email: gameka@ug.edu.gh

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Abstract. *Ernest A, Ameka GK. 2019. Aquatic macrophyte diversity, distribution, and control in coastal Southern Ghana, with priority on non-native invasive species. Ocean Life 3: 87-93.* Southern Ghana has been the focus of research into the variety and distribution of aquatic macrophytes, focusing on invasive species. Greater Accra, the Central Region, the Ashanti Region, the Eastern Region, the Volta Region, and the Western Region were all included in the study. Voucher specimens were obtained from 44 locations and submitted to the Ghana Herbarium. Sixty-two species of aquatic macrophytes were found, representing 48 genera and 30 families. All the aquatic macrophytes seen were classified into two groups, those that were invasive and those that were not; these were further divided into their respective families. With nine species, the Cyperaceae family emerged as the contender. IUCN (2004) criteria were used to determine if a species met the definition of an invasive. Because of this, the observed aquatic macrophytes were classified as invasive or noninvasive. Fifty-two aquatic species were found to be noninvasive, whereas eleven were found to be invasive. The aquatic macrophytes' life histories were also analyzed. There were 41 emergent species (67%), 11 free-floating species (17%), eight submerged species (13%), and two floating-leaf species (3%). Eleven types of invasive aquatic plants were found, and distribution maps were made for each. In the southern region of Ghana, *Pistia stratiotes* were found in seven different locations, making it the most widespread invasive aquatic plant in the region. All 62 invasive and noninvasive species were recorded in a database. Among these were the species' scientific and colloquial names and their genus and family, description, reproduction, habitat, distribution, and uses. Each method of control for invasive aquatic macrophytes was reviewed to make advantage of the most effective strategies for their management and eradication.

Keywords: Aquatic macrophytes, distribution, diversity, Ghana

INTRODUCTION

Macroscopic plants found in or near freshwaters are referred to collectively as "aquatic macrophytes," and this group includes some relatively "big plants" (Sculthorpe 1967; Panda et al. 2018). Large trees, shrubs, ferns, mosses, macroalgae, and a variety of vascular plants all fall under the category of aquatic macrophytes since they require either permanently wet soil or a constant supply of standing fresh water (Sculthorpe 1967). In addition, they are essential to the health of aquatic ecosystems because they are native to water bodies, including lakes, rivers, and wetlands (Sculthorpe 1967). These plant species, which are found in different parts of the same bodies of water, are classified as follows: those that grow completely submerged, whether rooted or unrooted in the sediment (e.g., *Ceratophyllum demersum*; *Elodea canadensis*); those that float freely on the surface of the water (e.g., *Eichhornia crassipes*; *Pistia stratiotes*); those that are rooted in the sediment but have at least some portion of the plant extending above the water into the air (e.g., *Typha domingensis*); and those that are rooted in the sediment but have leaves that float freely on the surface of the water (e.g., *Nymphaea lotus*).

Inevitably, the conditions created by freshwater bodies allow for the growth of vegetation (Westlake 1981). Therefore, macrophytes and other types of aquatic plants play a crucial role in the health of any freshwater ecosystem. They share this characteristic with other photosynthetic species, such as planktonic and periphyton algae (Cooper and Knight 1985), and are primary producers. Furthermore, they contribute to ecological processes, including decomposition and energy transfer (McQueen et al. 1986; Dvorak 1996), and may serve as food for other organisms like birds (Batzer et al. 1993) and fish (Crowder and Cooper 1982).

Because of their ability to assimilate nutrients, aquatic macrophytes can affect water quality and provide a biological indicator of a body of water's nutrient status simply by virtue of their presence, absence, and abundance (Uotila 1971; Wang et al. 2012). In addition, they may manage the quality of the water supply by secreting a wide range of organic and mineral compounds into the body of water. Additionally, they absorb metals from the water they live in (Devlin 1967; Moyo et al. 2013; Ammar et al. 2014; Matindi et al. 2014; Wanyonyi et al. 2014; Puspha et al. 2016; Feng et al. 2017; Arenas et al. 2018; Krupnova et al. 2018; Ting et al. 2018). Furthermore, they help keep sediments stable in water bodies by providing habitats for other creatures (Chung 1974).

As a result of their interactions with the other species in their natural environment, they have natural enemies that help to keep their numbers in control, preventing them from becoming a nuisance. However, when introduced to new ecosystems, invasive aquatic macrophytes generally outcompete native flora. They cause a decline in

biodiversity due to their rapid population growth, high dispersal rate, and short generation period.

The International Union for Conservation of Nature (IUCN 2004) defines invasive species as "animals, plants, or other organisms brought by man into regions out of their normal distribution range, where they get established and disperse, having a negative impact on the local ecosystem and species." When individuals or propagules are transported to areas outside of a taxon's native range, invasion can be considered to have begun (Mooney and Cleland 2001). There are four distinct phases of an invasion: introduction (the act of moving an organism to a new area), establishment (the process of establishing a new population in a new location), naturalization (the process of allowing the population to maintain itself), and invasion (Mooney and Cleland 2001). A worldwide problem, invasive species seriously threaten terrestrial, marine, and freshwater ecosystems (Mooney and Cleland 2001). Ballast water, hull fouling, aquaculture escapes, and accidental or planned introductions spread aquatic invasive species (MEA 2005). The most significant risks to global biodiversity come from the introduction and spread of invasive species, climate change, and habitat degradation (MEA 2005). Because of the compounding effects of these variables, the rate at which biodiversity is being lost in a given area may increase dramatically, and efforts to curb the spread of invasive species may be rendered futile.

The purpose of this research is to catalog the types, distributions, and management strategies for aquatic macrophytes, focusing on invasive species in southern Ghana. The goals of this study are to (i) identify invasive and noninvasive macrophytes in freshwater bodies in southern Ghana; (ii) map the distribution of invasive aquatic macrophytes encountered during the research; and (iii) examine the ecology of and potential solutions for, invasive aquatic plant populations.

MATERIALS AND METHODS

Study area

Six different regions of Southern Ghana were included in the research, i.e., the Western, Eastern, Central, Ashanti, Greater Accra, and Volta regions (Figure 1). Accessibility by vehicle and boat, the effect of the presence of the aquatic macrophytes, and the use that the bordering communities made of the aquatic macrophytes all played a role in the selection of sampling sites.

The southeast coast of Southern Ghana is warm and relatively dry, while the southwest coast is hot and humid. Humidity is another defining feature of the climate. It is especially true at night when the humidity could reach 100%. South Ghana experiences two distinct wet times of the year. It includes the months of April, May, and July, as well as September and October. The GPS coordinates of the sampling sites in southwestern Ghana are shown in Table 1.

Survey of aquatic plants

It was decided to survey the aquatic macrophyte vegetation in Southern Ghana. All locations in the study region were divided into smaller sections, and samples of aquatic macrophytes were taken randomly from each section. A GPS Magellan Smart 5390 was used to record the precise location of the place. All those kinds of aquatic macrophytes found were then given unique identification codes, and images of those plants were taken for inclusion in a database. As most of the aquatic plants observed were fruiting specimens, they were collected and dried in a herbarium press. Herbarium press specimens of plants were checked frequently to ensure rapid drying. The specimens were dried and placed on mounting sheets at the Ghana herbarium. On-site identification of all invasive aquatic macrophytes was validated at the Ghana Herbarium, Department of Botany, University of Ghana, Legon. The following data were provided for each species observed in the wild. Locals were surveyed to get the following information about the macrophyte: its scientific name, synonym, common name, family, description, reproduction, place of collection, and uses.

Invasive aquatic macrophytes

Each aquatic macrophyte that was found had its invasiveness or noninvasiveness evaluated. These species were classified as invasive based on the following criteria (IUCN 2004): lack predators, infections, and diseases that would keep population numbers in check; generate copious amounts of seed with high viability of that seed; employ successful dispersal techniques; very opportunistic; fast-growing, allowing them to displace slower-growing plants;

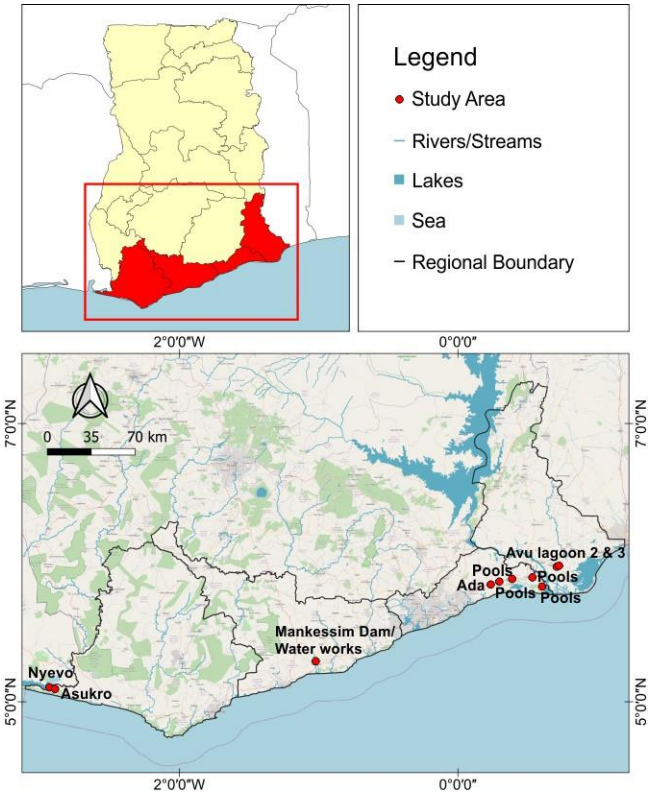

Figure 1. The major sampling sites of water bodies within Southern Ghana

release compounds that impede the growth of other plants nearby; have longer photosynthetic periods; alter soil and habitat conditions where they grow to suit their survival and expansion better; habitat modification. In addition, they may grow in various conditions, are difficult to eradicate, spread rapidly (typically via wind, water, or animals), and remain dormant for long periods.

Distribution of aquatic macrophytes

Each aquatic macrophyte found during the sample visits was included in a comprehensive distribution list.

Table 1. Localities and sampling sites

Locality	Site	Longitude/ latitude
Ada	Dawa	05˚50.726N, 0˚14.533E
Ada	Dawa	05˚52.055N, 0˚18.188E
Ada	Sege	05˚52.792N, 0˚23.792E
Ada	Bedeku	05˚53.672N, 0˚32.562E
Ada	Big Ada road	05˚49.436N, 0˚36.690E
Mankesim	Water works	05°17.425N, 1°00.982W
Avu lagoon	Entrance of channel	05˚58.150N, 0˚42.845E
Avu lagoon	Middle of channel	05˚58.538N, 0˚43.517E
Avu lagoon	Main lagoon	05˚68.660N, 0˚44.051E
Jewi wharf	Nveye	05°06.437N, 2°55.864W
Jewi wharf	Asukro	05°05.651N, 2°53.552W
Kpong headpond	Main dam	06°14.100N, 0°30.841E
Kpong headpond	Main dam	06°07.185N, 0°06.139E
Kpong headpond	Main dam	06°06.444N, 0°06.188E
Weija	Edge of dam	05°34.108N, 0°20.389W
Lower Volta River	Entrance of river	05°59.425N, 0°35.062E
Lower Volta River	Along the bridge	05°59.425N, 0°35.097E
River Ayensu	Channel of River	05°35.376N, 0°37.102W
River Ayensu	Main river	05°38.025N, 0°36.217W
Nungua	Beach road	05°60.322N, 0°07.977W
Prampram	Main road	05°70.671N, 0°11.340E
Tema	Community 10	05°67.668N, 0°02.449E
Samreboi	Main road	05°61.382N, 2°56.341W
Abura Village	Village	05°33.801N, 1°17.126E
Anum	Along the road	06°47.167N, 0°18.900E
Koforidua	Polytechnic	06°09.432N, 0°25.736E
Sakumono	Main road	05°62.524N, 0°06.043E
Keta	Main road	05°89.145N, 0°98.740E
Agbozume	Village	06°07.398N, 1°03.752E
Senchi	Asuogyaman	06°19.916N, 0°06.738E
Dawenya	Information Centre	05°76.760N, 0°05.127E
Battor	Hospital	05°93.020N, 0°36.495E
Akotokyire	Main road	05°13.504N, 1°27.786W
Ejura Village	Village	07°38.159N, 1°36.348W
Wenchi-Techiman	Main road	07°73.974N, 2°11.152W
Afram Plains	Apea Memorial School	06°88.291N, 0°30.125E
Asutsuare	Mepe	06°09.155N, 0°19.560E
Atuabo	Along road	04°99.669N, 2°62.654W
Adawso	Along road	06°51.855N, 0°26.987W
Wiwi River	Kwame Nkrumah Univ.	06°67.419N, 1°56.807W
Owabi Forest	Forest	06°43.045N, 1°38.163W
Ashaiman	Community 22	05°37.361N, 0°02.000W
Achimota Forest	Achimota Forest	05°37.361N, 0°12.479W
Cape coast-Nkafoa	Main road	05°07.534N, 1°16.461W

RESULTS AND DISCUSSION

Diversity of aquatic macrophytes

Sixty-two species of aquatic macrophytes representing 48 genera and 30 families were found throughout the research. These are detailed in Table 2. Lakes, lagoons, ponds, river systems, head ponds, and seasonal pools were suitable for the aquatic macrophytes. Cyperaceae was the most common family found. As many as nine distinct species could be found within this family. The Poaceae family was the second most numerous, with six members, followed by the Fabaceae family, with five members. *Cyperus*, represented by four species, was the most numerous genus in the analysis. Then came *Ipomoea* and *Ludwigia*, both of which had three flowers.

In addition, aquatic macrophytes were classified into the different forms of life-based on their location in the bodies of water they were found in; 41 of the species were found to be emergent, 11 were found to be free-floating, and eight were found to be submerged; however, only two of the aquatic plants found were floating-leaved.

Systematics, diversity, morphology, and distribution of aquatic macrophytes

There were 62 different types of aquatic macrophytes found, 11 of which were considered invasive. The eleven plants represented 11 families of invasive aquatic plants. The *E. crassipes* were placed in the Pontederiaceae family, and *Cyperus papyrus* was placed in the Cyperaceae family. Those of the Poaceae family for *Vossia cuspidata*, the Azollaceae family for *Azolla filiculoides*, and the Fabaceae for *Mimosa pigra*. There is the Salviniaceae for *Salvinia molesta*, the Ceratophyllaceae family for *C. demersum*, the Typhaceae for *T. domingensis*, the Hydrocharitaceae family for *Vallisneria aethiopica*, the Araceae family for *P. stratiotes*, and the Alismataceae family for *Limnocharis flava*.

Several types of invasive macrophytes in water were also classified. There were six adrift, four emergings, and one buried. The southern region of Ghana was home to seven distribution points for *P. stratiotes*. Next in line with 6 locations were *V. cuspidata* and *C. demersum*. The next two species, with five occurrences each, were *A. filiculoides* and *L. flava*. While, *M. pigra* and *V. aethiopica* each had two distribution points, *E. crassipes* had three. Finally, the Jewi wharf and the Kpong head pond were the only places where *S. molesta* and *C. papyrus* could be found.

There were two categories of macrophytes in the water: aquatic and semi-aquatic. It was determined by their degree of reliance on the specific body of water in which they were discovered. Plants that can't survive without water to conduct their life cycle are known as aquatic plants. A lack of water leads to their demise. The semi-aquatic plants might complete their life cycles in dry conditions. However, they are flourishing as terrestrial plants due to evolution and adaptation. There were 62 different kinds of aquatic macrophytes, 25 of which were true aquatic plants and the other 37 semi-aquatic.

Table 2. Aquatic plants of southern Ghana

Species	Family	Growth form
Aeschynomene elaphroxylon Guill & Perr.	Fabacee	Emergent
Alternanthera sessilis (L) DC	Amaranthaceae	Emergent
Aponogeton pectinatus L.	Aponogetonaceae	Emergent
Azolla africana Desv.	Azollaceae	Free-floating
Azolla filiculoides Lam.	Azollaceae	Free-floating
Celosia pseudovirgata Schinz	Amaranthaceae	Emergent
Celosia pseudovirgata Schinz	Amaranthaceae	Emergent
Ceratophyllum demersum L.	Ceratophyllaceae	Submerged
Ceratopteris cornuta (P. Beauv.) Lepr.	Parkeriaceae	Emergent
Chara canescens J.L.A. Loiseleur	Characeae	Submerged
Commelina diffusa Burm.f.	Commelinaceae	Emergent
Commelina nudiflora Linn.	Commelinaceae	Emergent
Cyclosorus striatus (Schum.) Ching	Thelypteridaceae	Emergent
Cyperus articulatus Linn.	Cyperaceae	Emergent
Cyperus distans Linn. f.	Cyperaceae	Emergent
Cyperus nudicaulis Poir	Cyperaceae	Emergent
Cyperus papyrus L.	Cyperaceae	Emergent
Echinochloa stagnina (Retz.) P.Beauvois	Poaceae	Emergent
Eichhornia crassipes (Mart.) Solms-Layb.	Pontederiaceae	Free-floating
Eichnochloa pyramidalis Lam. Hitchc.& Chase	Poaceae	Emergent
Eleocharis complanata Boeck.	Cyperaceae	Emergent
Fureina umbellata Rottb	Cyperaceae	Emergent
Ipomoea aquatica Forsk.	Convolvulaceae	Emergent
Ipomoea asarifolia (Desr.)Roem. &Schult	Convolvulacea	Emergent
Ipomoea carnea Jacq.	Convolvulaceae	Emergent
Leersia hexandra Sw.	Poaceae	Emergent
Lemna paucicostata var. *membrabacea* Hegelm.	Lemnaceae	Free-floating
Linmocharis flava (L.) Buchenau	Alismataceae	Free-floating
Linmophyton obtusifolium L.	Alismataceae	Emergent
Ludwigia erecta (L.) H.Hara	Onagraceae	Emergent
Ludwigia hyssopifolia (G Don) Exell	Onagraceae	Emergent
Ludwigia stolonifera Guill. &Perr. Raven	Onagraceae	Emergent
Luffa aegyptica Mill.	Cucurbitaceae	Emergent
Mariscus alternifolius Vahl	Cyperaceae	Emergent
Marsilea minuta L.	Marsileaceae	Free-floating
Marsilea polycarpa Hook. & Grev.	Marsileaceae	Emergent
Mimosa pigra L.	Mimosaceae	Emergent
Najas pectinata (Parl.)	Hydrocharitaceae	Submerged
Nauclea latifolia Sm.	Rubiaceae	Emergent
Neptunia oleraceae Lour.	Fabaceae	Emergent
Nymphaea lotus Linn	Nymphaceae	Floating-leaved
Nymphaea maculata Schumacher & Thonning	Nymphaceae	Floating-leaved
Oxycarium cubense (Poepp.&kunth)Lye	Cyperaceae	Emergent
Panicum maximum Jacq.	Poaceae	Emergent
Phragmites karka (Retz.) Trin.	Poaceae	Emergent
Pistia stratiotes Linn.	Araceae	free-floating
Polygonum lanigarum R.Br	Polygonaceae	Emergent
Polygonum senegalense Meins.	Polygonaceae	Emergent
Potamogeton octandrus Poir.	Potamogetonaceae	Submerged
Rhynchospora corymbosa (Linn.) Britt.	Cyperaceae	Emergent
Ruppia maritima L.	Ruppiaceae	Submerged
Salvinia molesta D.S Mitchell	Salviniaceae	Free-floating
Salvinia nymphellula Desv.	Salviniaceae	Free-floating
Sesbania sesban (L.) Merr.	Fabaceae	Emergent
Sida acuta Burm. f.	Malvaceae	Emergent
Sphenoclea zeylanica Gaertner	Sphenocleaceae	Emergent
Typha domingensis Pers.	Typhaceae	Emergent
Utricularia imflexa L.	Lentibulariaceae	Emergent
Utricularia reflexa L.	Lentibulariaceae	Submerged
Vallisneria aethiopica Fenzl.	Hydrocharitaceae	Submerged
Vossia cuspidata (Roxb.) Griff	Poaceae	Emergent
Wolfia arrhiza Benth.	Lemnaceae	Free-floating

The Lentibulariaceae member *Utricularia reflexa*, and the Parkeriaceae member *Ceratopteris cornuta*, were two of the most notable. It is important to note that the only known homes for these species are the Avu lagoon in the Volta Region and the Mankesim swamp in the Central Region.

Description of the vegetation of the selected major freshwater bodies within southern Ghana

Voucher specimens were collected from each sampling site and sent to the Ghana Herbarium for preservation. In Western Region, for instance, one may find aquatic and semiaquatic plant species near the Nveye entrance, a part of the Tano lagoon complex. The sudd neighborhood, mostly made up of Vossia-Oxycarium, was plain to discern. Plant species ranged in structure and geography across the Tano lagoon system. *E. crassipes* was another easily recognized invasive aquatic plant. It was kept under control via a biological management program that is still active today. It was possible to see the biological control agent, *Neochetina bruchi*, on and under the water hyacinth leaf.

The southern part of the Kpong Head pond was home to various aquatic and semiaquatic plants. There were emergent, free-floating, floating-leaved, and submerged types of life to be seen at the Head pond's deep water edge. Coves, shallow waterways, deep seas, sudds, and the peripheries of islands provided ideal habitats for various plant life in Head pond. However, primarily *T. domingensis*, *C. demersum*, *N. lotus*, and *L. hexandra* thrived in the water.

Several species of aquatic and semiaquatic plants were identified in the Avu lagoon in Adutor, particularly along the channel leading to the main water body. Likewise, some aquatic organisms seemed freely floating, while others were clustered at the channel's boundaries. The tiny blooms of *Utricularia imflexa* and *A. filiculoides* predominated along the canal. Several types of aquatic plants were found in the main body of water, with *C. demersum* being the most numerous and largest. *C. demersum* looks like an island from afar.

Most Ada sampling locations were temporary pools used only during certain times of the year. The *N. lotus* was the most common water plant in these temporary pools. In addition, a small quantity of *E. crassipes* was discovered in the water body beneath the Bedeku Bridge.

The reddish-blooming *A. filiculoides* were the most numerous and dominant species in the pool where the samples were taken in Mankesim. Sedges such as *C. articulatus* and *E. complanata* were spotted both in and around the pool. The Mankesim location was also near some rice plantations. Some farmers claim that harvesting and dumping *A. filiculoides* onto their rice farms could increase crop yields by using *Azolla* species' nitrogen-rich soil.

Typha domingensis was the preeminent plant at Weija; it occurred in the central body of water and periphery. The Weija sampling location also has abundant *C. demersum* and *V. cuspidata*.

Classification of encountered aquatic plants into their families

Of the aquatic macrophytes identified, nine belonged to the Cyperaceae family, six to the Poaceae family, five to the Fabaceae family, and three each to the Convolvulaceae, Lemnaceae, and Onagraceae families. In addition, two members of the families Amaranthaceae, Azollaceae, Commelinaceae, Pontederiaceae, Marsileaceae, Nymphaceae, Polygonaceae, Salvinaiceae, Lentibulariaceae, Alismataceae, and Hydrocharitaceae; one member each of the families Parkeriaceae, Ceratophyllaceae, Thelypteridaceae, and Cucurbitaceae.

Discussion

Systematics of aquatic macrophytes present in the study

There were 62 species of aquatic macrophytes found, representing 48 different genera. Eleven of them were found to be invasive. There were 11 distinct families represented among the invading species. In his research on the macrophytes of the Kpong head pond, Amissah (2010) found 50 species representing 26 different families. Also, Amissah (2010) found 17 non-native species in the Kpong head pond. Amissah (2010) identified six aquatic species that IUCN (2004) classified as noninvasive but which Amissah (2010) classified as invasive. Accumulating invasive aquatic macrophytes in Ghana's waterways raises the risk of floods, reduces fish habitat, and makes boating and other water-based activities more difficult (Boyd 1971). The Kpong headpond's hydropower generation could be disrupted, and fish populations could plummet (Charudattan 2001). Their economic sector would feel the effects of this in the long run.

Fifty-one different noninvasive aquatic macrophytes were found, spread over twenty-six different families. Eight of the noninvasive plant species were members of the family Cyperaceae. For the Kpong head pond, Amissah (2010) found a total of 33 noninvasive aquatic plants from 19 different families. Amissah (2010) documented ten species of the Cyperaceae family of aquatic macrophytes. Cyperaceae contains nearly the same amount of noninvasive species as other studies conducted by deGraft-Johnson (1991).

Distribution of aquatic macrophytes encountered

Like other aquatic organisms, water macrophytes have a greater global distribution than terrestrial plants. It is because the components or conditions needed by aquatic plants are more standardized than those needed by terrestrial plants. In this research, *P. stratiotes* was the most pervasive aquatic invasive species. There were seven locations in Southern Ghana where this was disseminated (Figure 1). Additionally, *P. stratiotes* was found in both the Kpong head pond and Lower Volta (deGraft-Johnson 1996). In addition, the researchers found *E. crassipes* in both the Kpong head pond and the Lower Volta. It first appeared in 1990 in the Western Region's Abby-Ehy-Tano-Nveye River and Lagoon complex, then in 1998 in Lake Volta's Oti River Arm, and finally in 2003 in Kpong Head pond (deGraft-johnson 1991). The researchers also came across *E. crassipes* at Ada. It was located on the Bedeku Bridge that connected to Ada Main Township. *V. cuspidata* and *C. demersum* can be found in the Kpong head pond and the Lower Volta. *V. cuspidata* and *C. demersum* were also found in the Kpong head pond, according to the research of Amissah (2010).

Uses of aquatic macrophytes

Aquatic macrophytes have provided researchers with a new field to explore. Aquatic macrophytes found were mostly utilized for food, compost, and medicinal purposes, as demonstrated in sections 4.2 and 4.3. According to Boyd (1974), *S. molesta* is a valuable addition to compost piles and mulch beds. It is used in this capacity around Kariba Lake, where it is combined with animal manure to fertilize crops. Mitchell's (1974) research in Lake Kariba shows that Salvinia mats serve as critical habitats for juvenile fish and their food. In addition, it has been suggested that they serve as a source of nutrition for other species, including birds (Batzer et al. 1993) and fish (Crowder and Cooper 1982). Personal observations were taken in the Volta Region at a place called Adutor. Many fishermen gathered Ipomoea aquatica as a vegetable in soups and stews. Aquatic macrophytes may also be useful for producing biogas in other contexts. For example, invasive aquatic macrophytes could be researched for biofuel generation as new regions are investigated to generate energy to fulfill global industrialization. The energy produced could be put to use in the automotive sector. In addition to filtering out pollutants, aquatic macrophytes can be employed to improve water quality. Because of their ability to assimilate nutrients, aquatic macrophytes can affect water quality and serve as a biological indicator of a body of water's nutrient status simply by virtue of their presence, absence, or abundance (Uotila 1971). They may also regulate water quality by secreting different organic and mineral components into the water body.

Problems created by invasive aquatic plants

When an aquatic plant grows to the point where it disrupts other activities that use water, it is called a nuisance (Adeniji 1979). Invasive aquatic macrophytes threaten both native aquatic life and the human communities that rely on healthy aquatic ecosystems for subsistence. The only method to stop the spread of harmful aquatic macrophytes was to figure out how they got there in the first place. Invasive aquatic plants' transmission routes were crucial because they revealed the specific processes and vectors by which these plants were disseminated. It was found that the 11 invasive aquatic macrophytes almost all followed the same transmission routes. Water currents carried the seeds and segments of plants that the wind had propelled. Many local and migratory aquatic birds also carried the seeds on their feet and feathers. Because of this and other factors, invasive aquatic macrophytes have spread to virtually every major body of water and river across mainland Africa and even to several African ocean island nations. In addition, the mud attached to the feet of birds, people, and agricultural tools would sometimes transport the seeds.

Control methods for the invasive species encountered

Eleven different invasive species were found, all of which required some management strategy. This action was taken to facilitate the availability of control methods vital to eradicating aquatic invasive species. Three basic categories were created to organize those eleven species' control strategies. Mechanical, biological, and chemical means of regulation were described.

The following physical approaches managed the 11 aquatic invasive species. When it comes to the physical management of invasive macrophytes, employing a combine harvester for their harvesting was the simplest and most effective method. In certain cases, lines were strung between poles to restrict the spread of these aquatic macrophytes to uninfested areas, which proved to be highly effective. In addition, aquatic macrophytes could be physically managed by raking or hand plucking from affected water bodies. Finally, it is possible to physically manage aquatic macrophytes by chopping them down and setting them on fire.

Chemical methods of regulation came next. 2, 4-D (2, 4-dichlorophenoxy), Diquat (6, 7-dihydrodipyridyl pyrazinediumion), and Glyphosate (Isopropilamine salt of N-phosphonomethyl glycine) were the three most widely used aquatic herbicides. Plant Protection Agencies had to approve them before being used, and only qualified technicians could apply. Nevertheless, eleven invasive aquatic macrophytes could be managed with the pesticides indicated above, except for *V. aethiopica*, for which no chemicals were recommended. Paraquat was also efficient in suppressing *Salvinia* (Dias and Santos 1966).

Biological methods had previously been used as a form of management. One method of reducing pest populations is employing natural enemies particular to that insect's host (Howard and Harley 1998). Historically, the most common method of biological weed control involved the introduction of exotic natural enemies (predators, parasites, and viruses) to an area to lower exotic pest populations and keep them at economically negligible densities (McFadyen 1998). Although no biological control agent was available for *L. flava* at the time this strategy was developed, all other 11 invasive aquatic macrophytes were successfully eradicated using host-specific organisms. Studies have been conducted on the effectiveness of arthropods and diseases in controlling *E. crassipes*. Few arthropods, such as mites, moths, and weevils, were shown to diminish water hyacinth development considerably; nonetheless, the following species were deemed worthy of introduction to other countries: the mite *Orthogalumna terebrantis* (Bennet 1981); the moth *Acigona infusella* (Deloach and Cordo 1983 and *Sameodes albiguttalis* (Deloach and Cordo 1976); the Miridae *Eccritotarsus catarinensis* (Hill et al. 1999); the weevils *Neochetina eichhorniae* and *N. bruchi* (Deloach 1976; Deloach and Cordo 1976; Center and Durden 1986).

Ceratophyllum demersum was controlled using the Chinese grass carp as a biological agent, while *Vossia* was managed by utilizing grazing animals in the affected region. *S. molesta* had been thought to have a permanent biological control in the form of the curculionid *Cyrtobagous salviniae*, which would be both cost-effective and environmentally friendly. For biological control, the stem-boring moth *Neurostrota gunniella* and the fungal plant pathogen *Phloeospora mimosae-pigrae* were introduced to the *Mimosa* plant (Cullen et al. 2004). Either species could be released at once or separately. Biological control was considered our only hope when considering how to eradicate this weed permanently (Hill 1999). Insects that feed on *A. filiculoides* leaves, such as the flea beetle *Pseudolampsis guttata* and the weevil *Stenopelmus rufinusus*, have proven effective in their role as biocontrol agents (e.g., in South Africa) (Henderson 2001). Muskrats can potentially eradicate *Typha* spp. in temperate regions (Kadlec et al. 2007), reducing the invasive plant population. Most efforts to manage *V. aethiopica* relied on biological methods of pest management. Several fish species use this submerged aquatic macrophyte as a food source and population regulator.

From February 2013 to January 2015, researchers in southern Ghana studied aquatic macrophytes at 44 sites throughout six regions: Greater Accra, Volta, Central, Eastern, Western, and Ashanti. Sixty-two different types of aquatic macrophytes were found in southern Ghana waters. Of these, only 11 were invasive species, while the rest 51 were noninvasive. Forty-eight genera and 30 families were represented among the aquatic macrophytes found, with the Cyperaceae family being the most common. The various species were classified into the following four lifestyle categories: emergent, free-floating, submerged, and floating-leaved. There were 41 emergent species, two floating-leaved species, eight submerged species, and 11 free-floating species; the most widely distributed species in southern Ghana were *P. stratiotes*, *V. cuspidata*, *C. demersum*, and *T. domingensis*, with *P. stratiotes* having seven distribution sites and the other three having six each. In addition, the researchers compiled information on the 62 different types of aquatic macrophytes we found, including their scientific names, common names, uses, habitat, and reproduction strategy. The study also included photographs of the aquatic plants found; the majority of the invasive aquatic plants found in the study were located in the Volta River System.

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