grocentre.is/ftp Final Project 2021

EVALUATION OF MILKFISH (*Chanos chanos*) STOCK ENHANCEMENT IN THE JATIBARANG AND SEMPOR RESERVOIR, CENTRAL JAVA, INDONESIA

Aisyah
Research Center for Fisheries
Jakarta, Indonesia
icha_saraimanette@yahoo.com

Supervisor(s):

Pamela Woods: pamela.woods@hafogvatn.is
Hlynur Bardarson: hlynur.bardarson@hafogvatn.is
Sandra Rybicki: sandra.rybicki@hafogvatn.is

ABSTRACT

The main objective of a stock enhancement through fish stocking is to increase fishable stocks. Milkfish (*Chanos chanos*) is one of the stocked species that have been recommended in a reservoir in Indonesia, because it cannot reproduce in freshwater. Therefore, it has no chance of becoming an invasive species. The objectives of this study were first to gather information about how fishing activitiess in the Jatibarang and Sempor reservoirs related to stock enhancement programs in Indonesia, and second to estimate gear selectivity by using the life history of milkfish and catch data from the Jatibarang and Sempor reservoirs to evaluate the success of fish stock enhancement. This study used catch data including length and weight of milkfish from both the Jatibarang and Sempor reservoirs. This also includes a monthly overview of catch, stocking time, and number of fingerlings. Data were analysed using a simulation of milkfish stocks to estimate expected catch at size compared to the actual catch data. A yield per recruit analysis was then used to estimate the effect of selectivity on yield. The growth and the simulation of expected and observed catch do not seem to describe the real picture of stocked milkfish in Jatibarang. Hence, Sempor data was then used for further analysis. Yet, some mismatches between the simulated expected catch and the actual catch were observed. Fishery dependent data of milkfish in both reservoirs are responsible for the vague results, however, the selectivity in Sempor reservoir shows that gears seem to target a certain fish size. Moreover, yield did not reach the maximum level, which would be an indication of the success of stocking related to the aims of stock enhancement. This study produced valuable information about future evaluation steps of the stock enhancement program. This will increase the quality of the sampled data as well as implement scientific experimental fishing over a longer time-series directly following the stocking events, and the possibility to conduct a tagging program.

This paper should be cited as:
Aisyah. 2022. *Evaluation of milkfish (Chanos chanos) stock enhancement in the Jatibarang and Sempor Reservoir, Central Java, Indonesia.* GRÓ Fisheries Training Programme under the auspices of UNESCO, Iceland. Final project.
https://www.grocentre.is/static/gro/publication/1725/document/Aisyah21prf.pdf

TABLE OF CONTENTS

1 INTRODUCTION 4
1.1 Background 4
1.2 The stock enhancement programme in Indonesia 5
1.3 Fishery in Indonesian reservoirs 6
1.4 Rationale 7
1.5 Objectives 8
2 RESEARCH DESIGN AND METHODOLOGY 8
2.1 Study area 8
2.2 Fish species in the study area 9
2.3 Gear types used in Jatibarang and Sempor reservoirs 10
2.4 The importance of milkfish 11
2.4.1 Biology of milkfish 11
2.5 Data sources 13
2.5.1 Stocking info 13
2.5.2 Catch data 13
2.5.3 Data analysis 14
2.5.4 Simulating expected catch of milkfish 14
2.5.5 Fishing mortality rates and gear selectivity 16
2.5.6 Yield per recruit 17
3 RESULTS 18
3.1 Biological stock characteristics 18
3.1.1 The growth of milkfish 18
3.1.2 Length and weight relationship 18
3.1.3 Expected and observed catch of milkfish in Jatibarang 19
3.1.4 Expected and observed catch of milkfish in Sempor 20
3.1.5 Gear selectivity, natural and fishing mortality rates 22
3.2 Yield per recruit 23
4 DISCUSSION 24
4.1 Actual and expected catch of the stocked milkfish 25
4.2 The yield per recruit analysis 25
4.3 Tagging as other methods in evaluating fish stocking 27
5 CONCLUSIONS AND RECOMMENDATIONS 27
ACKNOWLEDGEMENTS 29

LIST OF FIGURES

Figure 1. Type and number of fish stocked in Indonesia from 1965 to 2018. 6
Figure 2. Location of the Jatibarang and Sempor reservoir in Central Java, Indonesia............. 9
Figure 3. Rods gear in Jatibarang reservoir.. 11
Figure 4. Gears in Sempor reservoir, (a) gillnet, (b) Lift net, (c) photograph of gillnet.......... 11
Figure 5. Milkfish (*Chanos chanos*) (potograph of milkfish from Sempor reservoir) 12
Figure 6. Production of milkfish from capture fisheries. 13
Figure 7. Growth of milkfish in Jatibarang (left), Sempor (right) 15
Figure 8. Growth of milkfish in Sempor reservoir, produced by FiSAT and ELEFAN.......... 16
Figure 9. Natural log-transformed total length and weight of milkfish from Sempor reservoir, 2014-2015.. 19
Figure 10. Expected (black) and observed catch (red) of Jatibarang using growth parameters of milkfish in Jatibarang produced by FiSAT 19
Figure 11. Expected (black) and observed (red) catch of Jatibarang using growth parameters of milkfish in Sempor produced by FiSAT 20
Figure 12. Expected (black) and observed catch (red) of Sempor using growth parameters of milkfish in Sempor produced by FiSAT 21
Figure 13. Expected (black) and observed catch (red) of Sempor using growth parameters of milkfish in Sempor produced by ELEFAN... 21
Figure 14. Expected (black) and observed catch (red) of Sempor using growth parameters of milkfish in Sempor produced by FiSAT and ELEFAN 22
Figure 15. Length-converted catch curve of milkfish in Sempor reservoir (above); Selectivity curve of age at 50% probability of capture (t_{50}) (below) 23
Figure 16. Yield and biomass trajectories related to fishing mortality and Isopleth graph showing yield per recruit... 24
Figure 17. Graph of fishing activities in Jatibarang reservoirs are related to stock enhancement programs.. 24

LIST OF TABLES

Table 1. Fisheries production, area, and number of fishermen in Indonesian inland fisheries.. 7
Table 2. Fish species found in Jatibarang and Sempor reservoirs 10
Table 3. Growth parameters value of milkfish in Jatibarang and Sempor reservoir................ 16

1 INTRODUCTION

1.1 Background

The main purpose of building dams and reservoirs in Indonesia is to ensure the availability of water for irrigation and power generation (Guntoro, 2019; Miftahudin, 2020). But reservoirs also play a role in flood control, to ensure water supply, for tourism and recreation, and fisheries. Natural and man-made lakes can be found throughout the archipelago in Indonesia, ranging in size from 50-3,800ha (Kartamihardja, 2015; Fauzi & Mulyono, 2017). There are 4,429 of reservoirs and 5,807 lakes (PUPR, 2020; LIPI, 2020). Reservoir management comes under the Centre of River Basin, Directorate General of Water Resources, Ministry of Public Works, and Public Housing.

Fisheries that are generally developed in reservoirs of Indonesia include both aquaculture and capture fisheries. The catch in the reservoir is not only for the people who live around the reservoir, but also for the people who are far from the reservoir and who buy these fishery products through the nearest markets. The surrounding community is a group of communities that directly utilise the reservoir as a source of water and animal protein. Community sizes of a reservoir range between 30 to 37,000 people, some are also members of fisheries groups (MMAF, 2018). To enrich fisheries in reservoirs and provide fish for the community, the government of Indonesia carries out stock enhancement (in the form of stocking, restocking, and introduction of new species), which is one of the methods used within the fisheries management in Indonesian inland waters.

Stock enhancement is a programme to release juvenile fish from hatcheries or transfer fish between locations in the wild. This is widely practised in several countries, such as Lao PDR (or Laos), Vietnam, Brazil, Bangladesh, Sri Lanka, China, Cambodia, and Indonesia (De Silva et al., 2006; De Silva et al., 2015). Stocking and introduction of fish is one of the stock enhancement methods, in addition to other strategies, rehabilitation and modification of habitats, water enrichment, elimination of predators or competitors of the target fish (FAO, 1999). The main objective of stock enhancement practice is to increase stock size (the fishable stock) (De Silva & Funge-Smith, 2005).

Stock enhancement in Indonesia is usually carried out following a previous scientific evaluation, but stocking is done haphazardly. Some of the stock enhancement in lakes and reservoirs of Indonesia are, for example, stock enhancement of Siammes catfish (*Pangasiodon hypopthalmus*), freshwater giant prawn (*Macrobrachium rosenbergii*), bilih (*Mystacoleucus padangensis*), and milkfish (*Chanos chanos*) (Kartamihardja, 2015). These successes have been evaluated by the increase in yield after stocking (De silva & Funge-Smith, 2005; Kartamihardja, 2015).

Milkfish is a type of fish that has recently been recommended to be introduced in reservoirs of Indonesia because it is considered ecologically safe. It has no chance of becoming an invasive species because it cannot reproduce in freshwater (Buri et al., 1980; Jaikumar et al., 2013; Kartamihardja, 2015; Umar et al., 2016). As the main objective of a stocking is to increase fishable stocks, by stocking milkfish, it is hoped that communities will be able to utilise these fish to meet their needs for animal protein. Milkfish has also been stocked into reservoirs to reduce eutrophication, this is related to the species’ ability to utalise phytoplankton as their natural food which decreased the orthophosphate and nitrate concentration (Maskur & Kartamihardja, 2010; Warsa et al., 2018).

Evaluation of the stock enhancement program needs to be performed to understand the success or failure. One of the evaluation steps is to analyse milkfish fishing patterns after stocking to the Sempor reservoir in 2014 and Jatibarang reservoir in 2016 and 2017. This study aims to determine the success of fish stocking as well as the impact of fishing on the milkfish population in the Jatibarang and Sempor reservoir, by investigating the selectivity of rods (from Jatibarang reservoir), gillnet and lift net (from Sempor reservoir), and comparing size distributions of the fish caught (size selectivity). How selectivity can affect yield for both reservoirs will be estimated and compared using a yield per recruit analysis. Moreover, this analysis enables to test how yield is affected by, for example, different gear selectivities. In general, more studies to determine effective patterns of the stock enhancement are needed. In the end, the analyses performed for the Jatibarang and Sempor reservoir are expected to be used as a reference for the stock enhancement in other reservoirs of Indonesia and will help to determine and improve future data collection.

1.2 The stock enhancement programme in Indonesia

Before 1950, stock enhancement programs were carried out in a few Indonesian lakes and reservoirs (Sarnita, 1999). Stock enhancement in Indonesia has several objectives, they are to enhance the native species, for example the stock enhancement of bilih fish in Lake Toba (Kartamihardja & Purnomo, 2006; Kartamihardja, 2012). Stocking can also be done to increase fish production as is the case for the stocking of milkfish.

The Research Centre for Fisheries started implementing scientific stock enhancement in 1999 (Kartamihardja, 2015). The stock enhancement was done in Toba Lake (Sumatra island) and four reservoirs on Java (the Gajahmungkur, Malahayu, Darma, and Djuanda reservoirs). Preliminary research included ecologic and socio-economic studies, which were conducted before the programme (Kartamihardja & Purnomo, 2006). An increase in yield of the stocked species were reported (Kartamihardja, 2015). However, some stocking programmes that have been done so far in Indonesia have only been done for political purposes, sometimes carried out just before the election, without a scientific base and evaluation of the impact (Triharyuni et al., 2018). Because stocking is sometimes haphazard, there is a lack of consistent monitoring and evaluation programs focusing on stocking recommendations, such as selection of species and the number of juveniles to be stocked.

Most of the species stocked in Indonesian reservoirs are non-native species. Tilapia (*Oreochromis mossambicus* and *O. niloticus*), common carp (*Cyprinus carpio*), and giant gourami (*Osphronemus niloticus*) are commonly used in stock enhancement (Sarnita, 1999; Kartamihardja, 2012). Almost 70% of stocking activities have used tilapia, common carp, and catfish (Figure 1) (Aisyah et al., 2019). Whether a species is chosen or not depends on the availability of fingerlings in hatcheries operated by local communities or the government hatchery under the Directorate General of Aquaculture. The Indonesian government suggested the size of milkfish to be stocked is 1 cm, but research indicates that 3-5 cm fingerlings should be used to reduce predation and increase survival rate (Umar et al., 2016).

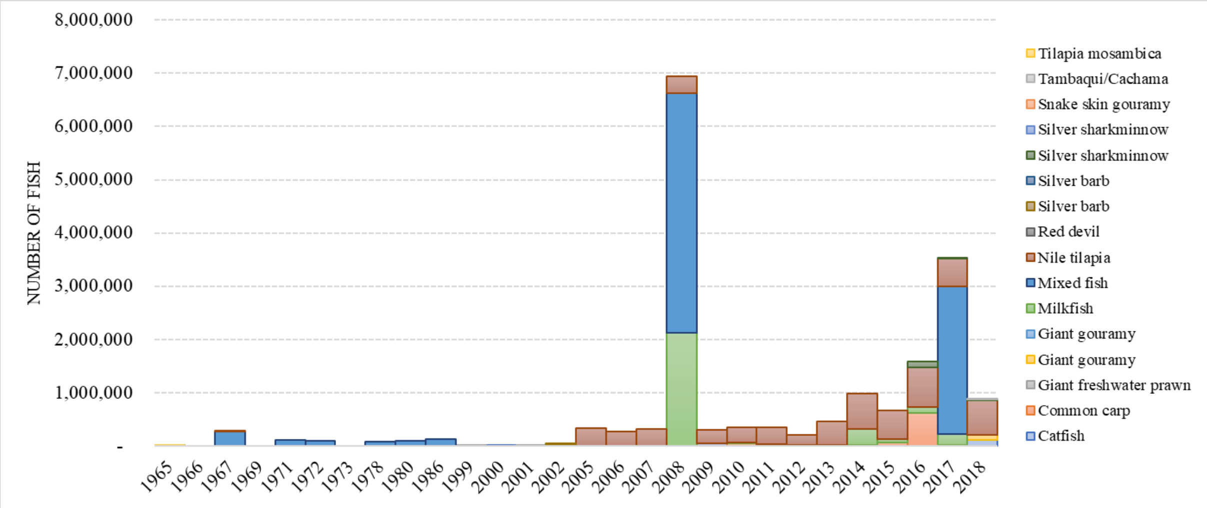

Figure 1. Type and number of fish stocked in Indonesia from 1965 to 2018.

Recently there has been increased interest in stocking milkfish in Indonesia due to reduced catches of other species in some inland waters in Indonesia. Ongoing research tries to obtain the appropriate and effective model of stock enhancement programmes in some areas. One example of such research on milkfish introduction was conducted in the Sempor and Jatibarang reservoirs and will be further analysed in this study.

1.3 Fishery in Indonesian reservoirs

Inland waters of Indonesia consist mainly of rivers and swamps, lakes, and reservoirs which have a total surface area of about 13.85 million hectares (Sukadi & Kartamihardja, 1995). Inland fisheries are critical for several developing countries like Indonesia, as they provide an important source of nutrition and food security (Béné et al., 2007). Inland fisheries contribute almost 500,000t or around 7% of capture fisheries in Indonesia which stood at 7,200,000t in 2018 (FAO, 2020), providing food security and employment to local communities.

Capture fisheries are permitted in all reservoirs, whereas aquaculture is only permitted in a few reservoirs. Reservoir fisheries are the third largest contributor to the total production of inland capture fisheries, which is approximately 7% or 35,013 t (Table 1). Sukadi & Kartamihardja (1995) stated, the area of the reservoir is less than 1% of the total area of inland waters and is thus relatively productive (Table 1). The total number of reservoir fishermen in Indonesia are around 37,600 and who are members of fisheries groups (MMAF, 2018). There are usually two or three fisheries groups in a reservoir each choosing their own leader (Muhartono & Koeshendrajana, 2013). The election process is simple, there are no accountability reports for the previous period and no canvassing before elections. Serving as group leader is a personal choice or social responsibility and the position does not carry any benefits, only loyal fishermen are willing and chosen.

Table 1. Fisheries production, area, and number of fishermen in Indonesian inland fisheries (Sukadi & Kartamihardja, 1995; MMAF, 2018)

Ecosystems	Production (t)	Area (million ha)	Number of fishermen
River	331,701	12.00	271,546
Lake	84,709	1.80	60,594
Reservoir	35,013	0.05	37,609
Swamp	31,265		62,173
Other	2,640		21,996
Total	485,329	13.85	453,918

Reservoir fisheries are influenced by the water level. As a tropical country, Indonesia only has two seasons, namely the dry season and the rainy season. Fishing in a reservoir generally occurs during the dry season. The dry season occurs during May-September, while the rainy season occurs during October-April. Seasonal conditions affect the reservoir water regulation in Indonesia. The peak season of fish harvest in Gajahmungkur reservoir generally occurred at the beginning of the rainy season (Adjie & Utomo, 2010). The increase of catch also occurred in Cirata reservoir while there is a fluctuation of water level or when rainy season started to come (Wahyuni et al., 2014). Similar condition of high catch in Djuanda reservoir occurred at low water level and vice versa, and it is assumed that the drawdown rate has correlated to it (Umar & Kartamihardja, 2006). Drawdown is a condition when reservoir water level drops seasonally (FAO, 2011), fishing gears are used more variably during this time and the fish habitat becomes more narrow because not all the parts of the reservoir are covered by water (Umar & Kartamihardja, 2006).

1.4 Rationale

Fish yield in Indonesian reservoirs usually reaches a peak five years after impoundment (Sarnita, 1977). Stock enhancement is then believed to be a management option to maintain the performance of fisheries and has been practiced for in freshwater ecosystems for over 100 years (Molony et al., 2003; De Silva & Funge-Smith, 2005).

Both native and introduced species have been used for stock enhancement in Indonesia. Stocking of exotic species can have negative impacts, depending on the level of invasiveness, by reducing native fish populations. The selection of milkfish in the stock enhancement programme in several reservoirs is expected to have a positive impact on the ecology and sustainability of the fishery, such as reduction in eutrophication due to the consumption of phytoplankton by milkfish.

Scientific planning and evaluation of the stocking programme objectives are part of best-practice stock enhancements (Leber, 2002). This study aims to evaluate how the yield is influenced by size selective fishing methods. Essential base life history information is needed to achieve this aim. This can be used to evaluate the success of stock enhancement or restocking programmes and provide information about data gaps that need to be addressed for further sampling in the future.

1.5 Objectives

The general objective of this study is to evaluate the success of fish stock enhancement practises by analysing the catch of milkfish (*Chanos chanos*) in Jatibarang and Sempor reservoirs, Central Java, Indonesia. The specific objectives are:

1. To gather information about how fishing activities in the Jatibarang and Sempor reservoirs related to stock enhancement programs in Indonesia
2. To use information about the life history of milkfish and catch data from the Jatibarang and Sempor reservoirs to analyse and compare gear selectivity to evaluate the success of fish stock enhancement

2 RESEARCH DESIGN AND METHODOLOGY

2.1 Study area

The Jatibarang and Sempor reservoirs are both in Central Java, Indonesia (Figure 2). Construction of the Jatibarang reservoir began in 2009 and was completed in early 2014. It has a catchment area of 53 km^2, an inundation area of 189 ha, an average discharge of 2.9 m^3s^{-1}, and storage capacity of 20.4 million m^3. Normal water levels are at approximately 150 m.a.s.l. (Sarminingsih & Samudro, 2020). This reservoir was built to mitigate frequent floods in Semarang city and lack of drinking water. Building of the reservoir was also supposed to mitigate exploitation of groundwater and intrusion of seawater through rivers and waterways (SDA PUPR, 2014; Prima, 2018).

The Sempor reservoir is in the Kebumen regency in the southern part of Central Java. This reservoir has been operating since 1987. It is built to last 50 years and has a storage capacity of 56.7 million m^3, inundation area of 270 ha (BBWS Serayu Opak, 2022). Both, the Sempor and Jatibarang reservoirs are categorised as medium-sized dams (De Silva & Funge-Smith, 2005). The Sempor reservoir was originally built to control the flood of Jatinegara river, and to produce hydroelectricity, provide drinking water and support capture fisheries and tourism (BBWS Serayu Opak, 2022).

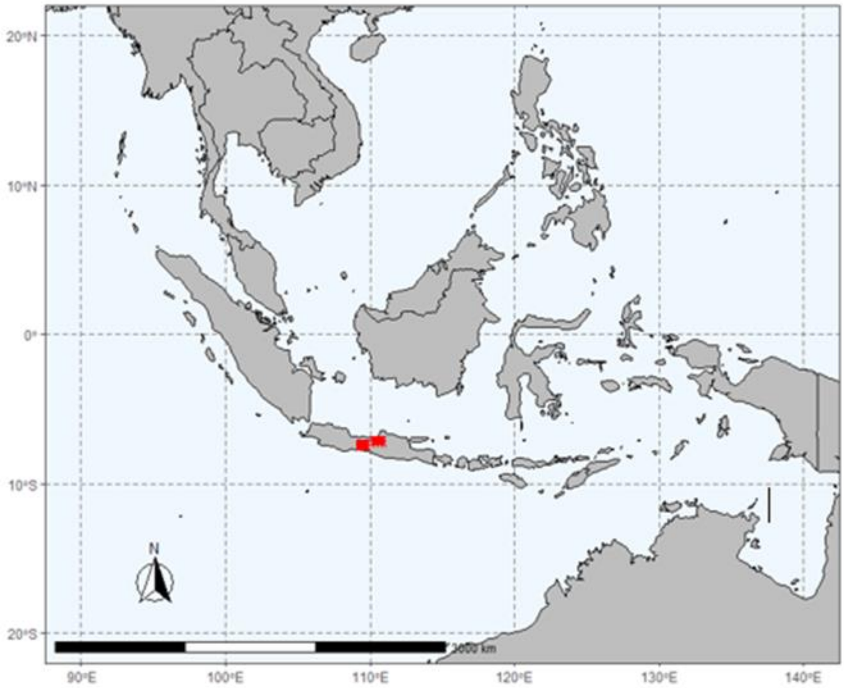

Figure 2. Location of the Jatibarang and Sempor reservoir in Central Java, Indonesia

2.2 Fish species in the study area

The Jatibarang and Sempor reservoirs both have native and stocked fish (Table 2). Native fish can still be found in small numbers, while introduced species have become dominant. Experimental fishing was done in Jatibarang, in 2018 and 2021, by using several rods and gillnet (Triharyuni et al., 2018; Hermalasari, 2021). In both instances, catches were dominated by Nile tilapia. Fishermen are only allowed to use rods, therefore the types of fish that are most likely to be caught are tilapia, milkfish, and other fish preferred by the community.

The Sempor reservoir has experienced the dominance of non-native species similar to the Jatibarang reservoir. The application of diverse fishing gears in the Sempor reservoir does not seem to influence the primary species caught, which is Nile tilapia. Nile tilapia in the Sempor reservoir was chosen as a stocking species in the past due to community preferences, seed availability, and fast growth (Umar et al., 2015). Invasiveness of Nile tilapia has not been studied in Indonesia, yet it is categorised as an invasive species. Nile tilapia is not thought to be directly responsible for the extinction of several native species in Indonesian waters, but the very fast growth is of concern (Champneys et al., 2021). In addition, the government imposes restrictions on the stocking and culturing of tilapia to avoid the Tilapia Lake Virus (TiLV) (MMAF, 2017). Milkfish is a type of fish that has recently been recommended to be introduced in reservoirs of Indonesia. Milkfish is assumed to be a safe species as it cannot reproduce in freshwater (Kartamihardja, 2015; Umar et al., 2016).

Table 2. Fish species found in Jatibarang and Sempor reservoirs (Triharyuni et al., 2018; Hermalasari, 2021)

Common name	Scientific Name	Description of Fish	
		Jatibarang	Sempor
Amazon catfish	*Liposarcus pardalis*	Stocked	
Asian Redtail Catfish	*Mystus nemurus*	Native	
Banded jewelfish	*Hemichromis elongatus*	Stocked	
Bonylip barb	*Osteochilus vittatus*	Stocked	
Catfish	*Clarias* spp	Stocked	Native
	Clarias batracus	Native	
Common carp	*Cyprinus carpio*	Stocked	Stocked
Crayfish	*Cherax spp*		Indirectly stocked
Giant freshwater prawn	*Macrobrachium rosenbergii*	Native	
Giant gourami	*Osphronemus goramy*		Stocked
Hampala barb	*Hampala macrolepidota*	Stocked	Stocked
Jaguar cichlid	*Parachromis managuensis*		
Java barb	*Barbonymus gonionotus*	Native	Native
	Barbonymus baleroides	Native	
Marble goby	*Oxyeleotris marmorata*		Native
Minnows	*Mystacoleucus marginatus*	Stocked	
Milkfish	*Chanos chanos*	Stocked	Stocked
Mozambique tilapia	*Oreochromis mossambicus*	Stocked	
Nile tilapia	*Oreochromis niloticus*	Stocked	Stocked
Pastel cichlid	*Amphilopus alfari*	Indirectly stocked	
Red devil	*Amphilopus labiatus*	Indirectly stocked	
Silver rasbora	*Rasbora argyrotaenia*	Native	
Silver sharkminnow	*Osteochilus hasseltii*	Native, stocked	Native
Snakehead murrel	*Channa striata*	Native	Native
Spotted barb	*Barbodes binotatus*	Native	Native
Tambaqui/Cachama	*Colossoma macropomum*		Stocked
Three spots cichlids	*Cichlasoma trimaculatum*		Indirectly stocked

2.3 Gear types used in Jatibarang and Sempor reservoirs

Fishing rods are the only gear type allowed in Jatibarang reservoir (Figure 3). Fishing activities are not only carried out by the community around the reservoir, but also by recreational fishers (Triharyuni et al., 2018). Fish caught by the recreational fishermen are for their own consumption, and some are sold to small restaurants around the reservoir. Local communities decided on restricting the use gear to fish rods. The number of rods allowed is announced at a monthly meetings of fishermen groups. The limitation of fishing gear to only rods aims to provide a safe area for the transportation of tourists. Recreational fishing is becoming more popular in this reservoir as a side effect of tourism (Triharyuni & Aisyah, 2021).

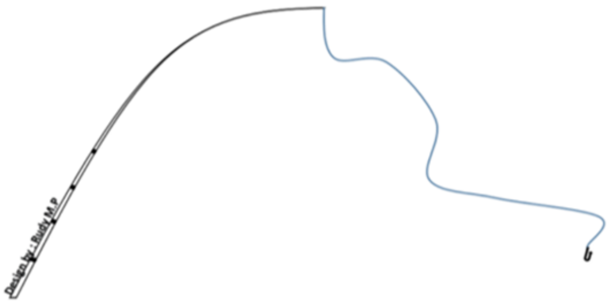

Figure 3. Rods gear in Jatibarang reservoir (picture courtesy of Rudy Masuswo Purwoko)

Unlike the Jatibarang reservoir, the usage of other fishing gear in addition to rods can be found in other reservoirs in Indonesia, such as gillnets and lift nets in the Sempor reservoir (Figure 4). Fisheries in the Sempor reservoir were developed by the local government through a fish stocking program. Like the Jatibarang reservoir, fisheries in the Sempor reservoir are both for recreation but also for family consumption and occasionally by fishermen selling the fish on a market for their livelihoods (Umar et al., 2015).

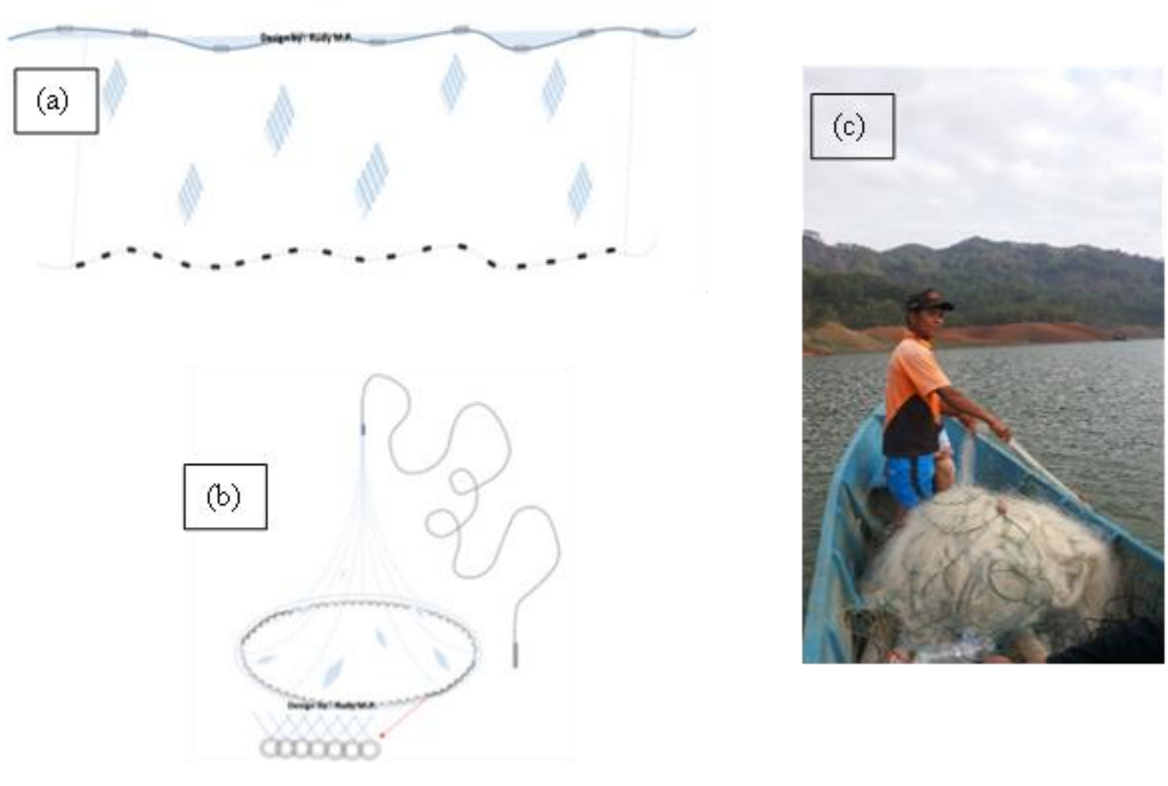

Figure 4. Gears in Sempor reservoir, (a) gillnet, (b) Lift net, (c) photograph of gillnet (picture courtesy of Rudy Masuswo Purwoko)

2.4 The importance of milkfish

2.4.1 Biology of milkfish

Milkfish (*Chanos chanos*) is a euryhaline species that can live in coastal waters, estuaries, mangroves, lagoons, tidal areas, and rivers (Figure 5). Adults can usually be found in littoral waters, which are used as a nursery area. Juveniles prefer mangroves or enter the freshwater ecosystems (Bagarinao, 1991). The ability to tolerate a wide range of salinity indicates the possibility of culturing or stocking in freshwater.

This species is often found in schools during the spawning season. It is found in the low latitude tropics or the subtropical northern hemisphere, along continental shelves, and surrounding islands, where temperatures are above 20˚C tropical and subtropical Indo Pacific oceans, Africa, Pacific waters of Central America, South of Hawaii, Mexico, Southern Australia, and New Zealand (Lee, 1995).

Figure 5. Milkfish (*Chanos chanos*) (potograph of milkfish from Sempor reservoir)

Milkfish are commercially cultured and known to be farmed in Indonesia, Taiwan, Thailand, Philippines, and India (Imelda-Joseph et al., 2016). The growth of milkfish in culture shows that 3-4cm fingerlings can grow to a 200-400g of body weight or equal to 20cm length within 2 months (Jaikumar et al., 2013), and the growth rate of a fry/fingerling in a pond in Kenya, can reach to 0.016-1.0 $gday^{-1}$ (Requintina et al., 2008). A slower growth of milkfish is described by Sumawidjaja et al. (2007). 17.7g of seed was reared in a floating net cage in brackish water of Indonesia for 56 days, and then reached a bait size (60-64 g or equal to 18.1-18.7 cm).

Buri et al. (1980) describes the life history of milkfish in Philippines, and duration of each developmental stage. The subadult stage takes the longest or about 3-5 years to reach 20 – 50cm. Growth slows down as the fish reaches the adult stage which takes about 2 years to reach the 50 – 150cm. In general, it takes 2-6 years for milkfish to reach the adult stage. There are very few publications on its growth in nature, especially in freshwater, most of which comes from aquaculture.

As powerful swimmers, habitat space of milkfish is very wide, including open sea for adults, to shallow areas such as coral reefs and coastal areas for juveniles and subadults (Bagarinao, 1991). Milkfish are generally found in schools therefore easy to catch in large quantities, depending on the gear type used. As the juveniles develop into adults, the milkfish continue to be an opportunistic feeder, consuming anything from large zooplankton to benthic algae and deposits (Buri et al., 1980).

Globally, milkfish is one of the top 12 aquaculture species in the world (FAO, 2020). Milkfish aquaculture began around 4-6 centuries ago in Indonesia, Taiwan, and the Philippines (Imelda-Joseph et al., 2016). In Indonesia, milkfish is among the top seven aquaculture species, with 822 thousand tons being produced in 2019 (MMAF, 2021). Milkfish from capture fisheries production is not as large as aquaculture. Marine capture production of milkfish is 12,858t on average or 90% of the total milkfish from Indonesian capture fisheries, and the rest comes from inland waters (Figure 6) (MMAF, 2021). A milkfish fishery in inland waters developed after a stock enhancement program was carried out in reservoirs of West Java and Central Java, Indonesia (Kartamihardja, 2015).

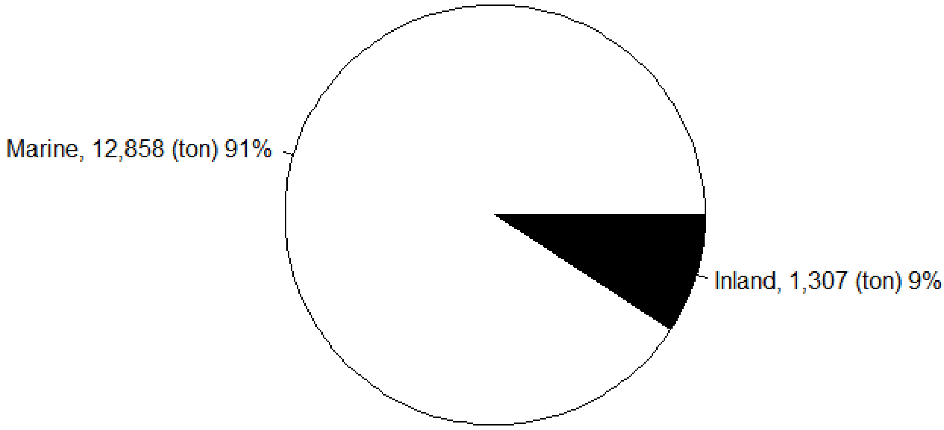

Figure 6. Production of milkfish from capture fisheries. Black represents production of milkfish from inland waters, white represent the production of milkfish from marine, both in tons and percentage (MMAF, 2021)

Milkfish has been stocked into several reservoirs of Indonesia, i.e., Djuanda and Cirata in 2008, Sempor reservoir in 2014, Jatibarang in 2016 and 2017. Milkfish stocked in the Djuanda reservoir was recruited into the fishery three months later and contributed to increase the yield from 27-32 $kgha^{-1}yr^{-1}$ to 178-181 $kgha^{-1}yr^{-1}$ (Tjahjo et al., 2011; Kartamihardja, 2015).

2.5 Data sources

2.5.1 Stocking info

Milkfish fingerlings, 3-5cm, were stocked in Jatibarang reservoir in 2016 and 2017:

- August 2016 (100,000 individuals),
- May 2017 (200,000 individuals),
- September 2017 (1,500 individuals).

And in Sempor reservoir in 2014 and 2015:

- June 2014 (200,000 individuals),
- September 2014 (100,000 individuals),
- November 2015 (50,000 individuals).

2.5.2 Catch data

Catch data used in this study includes length and weight data of milkfish from both the Jatibarang and Sempor reservoir. These data represent a monthly overview of catch from April-November 2018 in Jatibarang reservoir (a total of 1,326 individuals, 13-59cm total length, and 139-1,097g of body weight) and September 2014-December 2015 for Sempor reservoir (a total of 6,199 individuals, 14-57cm total length, and 28-1,665g of body weight). Data were collected through an enumerator programme by daily record of catch for both reservoirs. Enumerators always stay in one place that is assumed as the main landing site. The record includes all of types of fish of each fisherman catches. Measurements of length and weight are taken, using the same equipment, during the research periods.

2.5.3 Data analysis

Data were analysed by using a simulation of milkfish stocks to estimate expected relative catch at size compared to the actual catch data to estimate selectivity. A yield per recruit (YPR) analysis was then used to estimate the effect of selectivity on yield in the Jatibarang and Sempor reservoirs. Simulation of expected catch is used because of the unusual pattern of recruitment that is presented by stocking.

The simulation of expected catch used to estimate the selectivity pattern compares different fishing gears used in different locations (rods in Jatibarang only compared to rods, gillnets and liftnet in Sempor). This step requires growth information, which was taken from length distribution data or literature sources documenting milkfish in similar environments (Aisyah et al., 2018). Catch data of milkfish from Jatibarang and Sempor reservoir has already been collected, and population dynamics of milkfish in Sempor has been documented through publications (Umar et al., 2015; Triharyuni et al., 2018; Aisyah et al., 2018).

The estimated selectivity is used as input for a yield per recruit model. This model requires the age or length depending on gear selectivity. In the case of this study, recruitment enters the population from stocking as there is no natural milkfish recruitment occurring in freshwater environments. The YPR model is used to estimate the yield in both the Jatibarang and Sempor reservoirs and helps to understand how selectivity induced by different gear types impacts each reservoir's yield. In the end, this exercise provides information about data gaps that should be addressed to enhance future sampling programs and reservoir evaluations.

2.5.4 Simulating expected catch of milkfish

The simulated expected milkfish catch, and selectivity aims to investigate the performance of rods (from Jatibarang reservoir), gillnet and lift net (from Sempor reservoir) by comparing the expected and actual catch distributions. This simulation requires information about the growth rate of milkfish, as well as length data, fingerling size and numbers, and stocking time. The expected length distribution is then simulated by using the growth rate of milkfish in each reservoir (Jatibarang uses the Jatibarang growth rate, and Sempor uses the Sempor growth rate). The first growth curve and parameters for both reservoirs were done by using ELEFAN (ELectronic LEngth Frequency ANalysis) in FiSAT (FAO-ICLARM Stock Assessment Tools), then named as FiSAT in this paper. The growth information of milkfish in Jatibarang was discontinued for further analysis such as yield per recruit, because the data showed a mismatch information between the growth and stockings.

Determination of growth parameters ($L\infty$, K & to) using ELEFAN in R TropFish package was assumed to follow von Bertalanffy growth function (VBGF) (Sparre & Venema, 1998). The ELEFAN module both in FiSAT was used to estimate the growth parameters ($L\infty$ & K) of VBGF for standard length (L) at age (t) (Pauly, 1984; Sparre & Venema, 1992) as describe below:

$$Lt = L\infty \{1 - \exp[-K(t - t0)]\}$$

where L∞ is the asymptotic length of fish, K, the growth coefficient, and to, theoretical age at zero length.

t_o was calculated from the empirical equation (Pauly, 1980):

$$Log10\ (to) = 0.392 - 0.275\ Log10\ L\infty - 1.038\ Log10\ K$$

Simulation of catch of Jatibarang then using the Sempor growth, which is expected to be more precise. The ELEFAN methods in TropFishR package (then named as ELEFAN in this paper) also used to perform the growth parameters of milkfish from both reservoirs, as a comparison to look for the better approach. This package is a single-species fish stock assessment with length frequency data, and growth parameters such as L∞, K, and the theoretical length at age zero (to) of the von Bertalanffy growth function (VBGF) (Pauly, 1980), as well as previous FiSAT step. All these steps are conducted to produce a histogram of simulated catch and expected catch, therefore there will be five histograms, they are simulated catch and expected catch from FiSAT and from ELEFAN of Jatibarang and Sempor reservoirs.

The growth curve and the parameters of milkfish in Jatibarang includes asymptotic length (L∞) = 80.3cm, growth coefficient (K) = 0.16 year^{-1}, and the theoretical length at age zero (to) = 0.81 (Triharyuni et al., 2018), and L∞, K, and to of Sempor are 55.97cm, 0.38 year^{-1}, and 0.37 respectively (Aisyah et al., 2018) (Figure 7). These parameters were used to estimate the monthly growth and to simulate the catch data. The initial population is number of fingerlings. Standard deviations are considered to cover the whole population. Natural mortality is assumed to be 0 to avoid the complexity of density dependence.

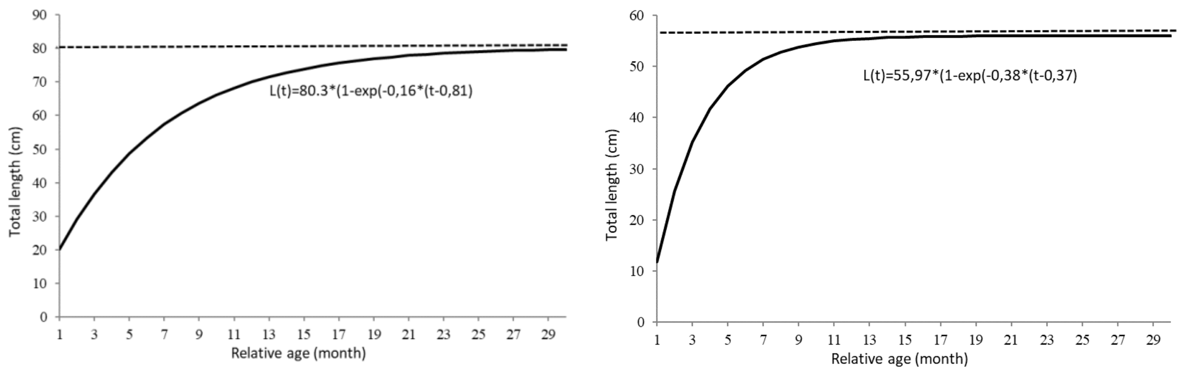

Figure 7. Growth of milkfish in Jatibarang (left), Sempor (right)

A combination of L∞ produced by FiSAT and K produced by ELEFAN then used to have a better of growth pattern in Sempor. Therefore, all of growth curve and parameters both in Jatibarang and Sempor are described below (Tabel 3 and Figure 8).

Table 3. Growth parameters value of milkfish in Jatibarang and Sempor reservoir

Study area	L∞ (cm)	K ($year^{-1}$)	t_0	Description & Reference
Jatibarang	80.3	0.16	-0.81	Value from FiSAT, Triharyuni et al. (2018)
Sempor	55.97	0.38	-0.37	Value from FiSAT, Aisyah et al. (2018)
	64.65	0.26	-0.52	Value from ELEFAN, this study
	55.97	0.26	-0.52	Combination of FiSAT and ELEFAN, Aisyah et al. (2018) and this study

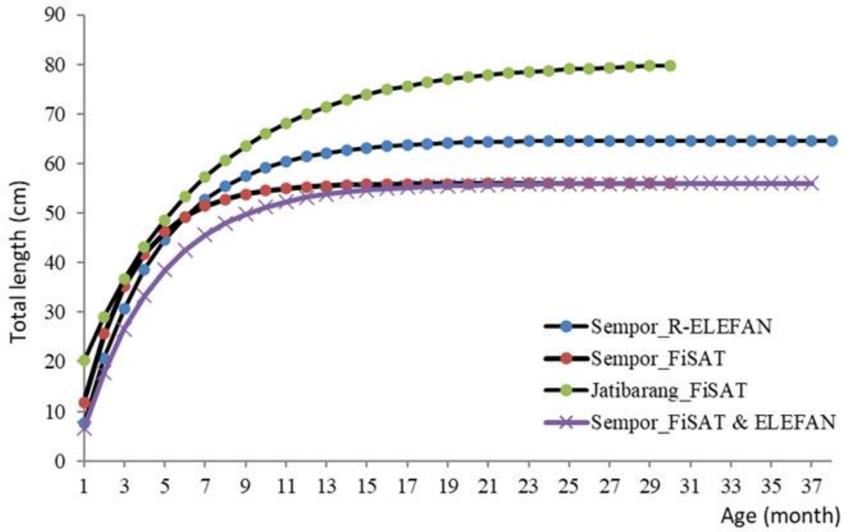

Figure 8. Growth of milkfish in Sempor reservoir, produced by FiSAT and ELEFAN (green dotted line represents the growth curve of Jatibarang produced by FiSAT, red represents Sempor by FiSAT, blue represents Sempor by ELEFAN, and purple represents the *combination* of Sempor by L∞ from FiSAT and K from ELEFAN)

2.5.5 Fishing mortality rates and gear selectivity

Most of the fishing gear is selective for a specific size of fish, excluding both extremely small and very large fish, especially gear used in targeting certain size or type of fish, such as gill net for Nile tilapia in Sempor reservoir. However, the rods in Jatibarang were not targeted a certain fish, and operates in a shallow part of the reservoir.

The word *selectivity* was defined by Thompson and Ben-Yami in 1984 as the ability of any sort of gear to capture fractions or sections of the fish population, whether classified by species, age, and size (Froese et al., 2004; Froese et al., 2008). In age-structured stock assessment models, it is usually expressed as the standardised vector of age-specific fishing mortalities (F-at-age) divided by the maximum F observed for any age–class (Sampson & Scott, 2012). Selectivity studies illustrate that there is a trade-off between F and selectivity; catching larger fish allows stocks to sustain a higher F without collapsing, while catching too many small fish can lead to stock depletion even at moderate levels of F (Prince & Hordyk, 2019). The selectivity in this study is estimated by using the TropFish R package and is also used to estimate the yield per recruit.

2.5.6 Yield per recruit

Yield equation is the response of a population to fishing mortality on a per-recruit basis depends on mortality (natural mortality, M, fishing mortality, F), growth function, selectivity of fishing gears to fish of different sizes, as described by Beverton and Holt (1957) (Sparre & Venema, 1998).

$$\frac{Y}{R} = F * exp\ [-M * (tc - tr)] * W\infty * [\frac{1}{Z} - \frac{3S}{Z+K} + \frac{3S^2}{Z+2K} \quad - \frac{S^3}{Z+3K}\ ]$$

$$S = exp[-K(Tc - T0]; W\infty = asymptotic\ weight$$

Originally being an age-based model, it can also be converted into a length-based model by applying certain principles. This applies specifically to fisheries in which the data mainly consists of length frequencies of the catch of species which could not be aged.

Mortality, which is separated into natural mortality (M) and fishing mortality (F), is a continuous process over time during which the number of individuals is constantly reduced from the initial number R (number of recruits). In the yield per recruit (YPR) model, the yields are relative to recruitment, and it is possible to calculate YPR by varying the input parameters such as F (proportional to effort) and Tc (function of gear selectivity) which are possible to control via fisheries management. The assumption used in this study is that natural mortality is considered non-existent or ignored and focus only on fishing mortality as there is not enough information available regarding wild milkfish. We also assume that fishing and natural mortality are constant (Jennings et al., 2001). ELEFAN was used to estimate growth parameters, selectivity, and YPR. YPR models require the intercept and slope value from the length-weight relationship. The length-weight relationship was measured by using the FSA package in R (Ogle, 2013[a]) and was examined using length (L, in this study refers to total length) and weight (W, refers to the weight of the fish when it was captured) data of individual fish. In this study, data of milkfish in Sempor reservoir was used for further analysis (the reason behind is already stated in 2.5.4 section). Length-weight relationship follows following equation:

$$W = aL^b$$

where W is the weight (g), a and b are parameters of the function, referring to intercept and slope, and L is the length (cm). This equation can be transformed to a linear model by taking the natural logarithms (abbreviated with “log”) of both sides and simplifying as describe below:

$$Log\ W = Log\ a + bLog\ L$$

The total mortality (Z) was estimated using ELEFAN (Gayanilo et al.,1994) from linearised length-converted catch curve analysis of the length data (Pauly, 1984; King, 1995). The annual total mortality coefficient (Z) of the fish species was determined from the slope of the descending right arm of the length – converted catch curves.

The instantaneous natural mortality (M) of the fish species was determined using empirical formulas, because the controlled data such as tagging data was not available. The empirical formula behind the ELEFAN in R TropFish package was based on Then et al. (2015). This method requires estimates of the VBGF growth parameters ($L\infty$ and K).

ELEFAN also allows the estimate of the instantaneous fishing mortality coefficient, and it was obtained by the subtraction of M from Z.

YPR estimation requires an exploitation rate, and the maturity parameter value to estimate L25, L50 or L75 (assuming a knife edge selection) as required in the Thompson and Bell model (Sparre & Venema, 1998). The maturity parameters include length and age maturity (Lm and tm) were obtained from FishBase (www.fishbase.se, *Chanos chanos*), that is from maturity studies for *Chanos chanos.* In this study we used 72 cm (average Lm of male and female), and age maturity of 4 years.

3 RESULTS

3.1 Biological stock characteristics

3.1.1 The growth of milkfish

The growth parameters of milkfish in Jatibarang and Sempor produced by FiSAT, ELEFAN, and the combination of both FiSAT and ELEFAN are listed in Tabel 4. Based on those values, milkfish in Jatibarang grow faster than in Sempor (Figure 7 and 8). Growth parameters of milkfish in Sempor produced by FiSAT and ELEFAN estimate very similar values and growth patterns, even though the FiSAT values show a faster growth than ELEFAN (Figure 8). The slowest growth show by the combination of $L\infty$ produced by FiSAT and K produced by ELEFAN (Figure 8).

3.1.2 Length and weight relationship

The length weight relationship of milkfish in Sempor was $W = 0.02135\ L^{2.6899}$. The value of the slope (b) was 2.6899 which is significantly different from 3 ($p < 0.005$) indicating negative allometric growth (Figure 9).

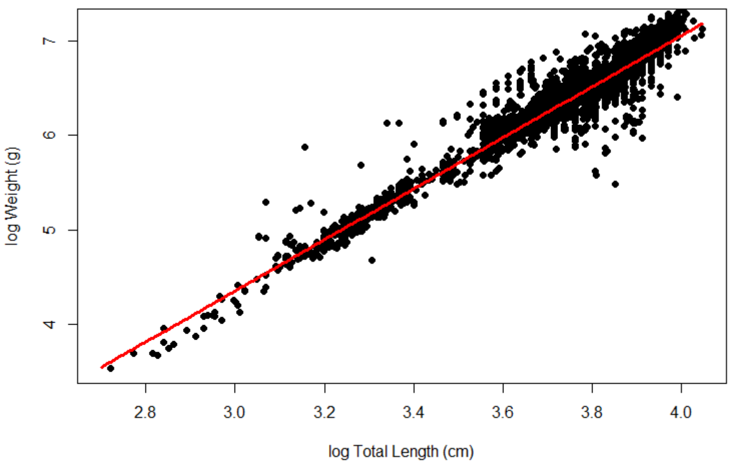

Figure 9. Natural log-transformed total length and weight of milkfish from Sempor reservoir, 2014-2015

3.1.3 Expected and observed catch of milkfish in Jatibarang

The catch of milkfish here is divided into two, which are expected catch (estimated catch by considering the stocking time, fingerling size and numbers, and the growth), and observed catch (the actual data). There are two histograms of Jatibarang reservoir produced by a simulation using growth parameters from FiSAT and ELEFAN (Figure 10 and 11). Observed data showed that individuals caught by the fishermen were getting larger over time, indicated by the movement of modal length. This histogram is not really referring to the stocking event, seen by the difference of expected and observed catch, but still the size of fish is going to be very large.

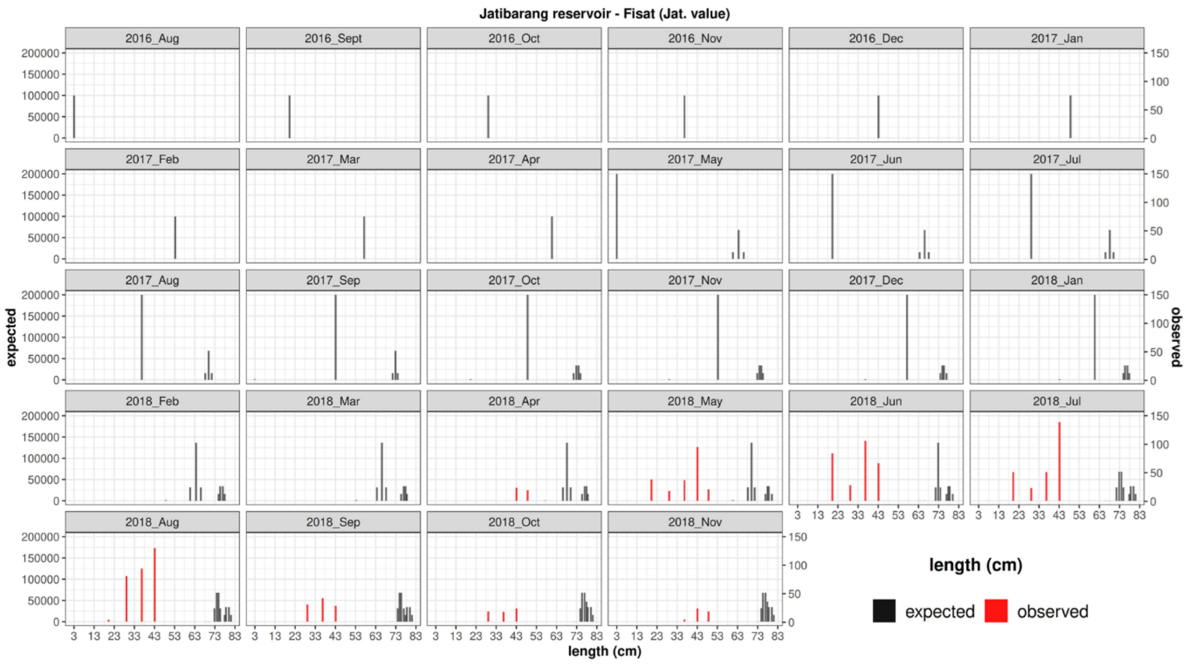

Figure 10. Expected (black) and observed catch (red) of Jatibarang using growth parameters of milkfish in Jatibarang produced by FiSAT

When looking at the expected and observed catch using the growth parameters of milkfish in Sempor produced by FiSAT (Figure 11), the expected and observed catch are closer to each other, but still there is no overlap between both.

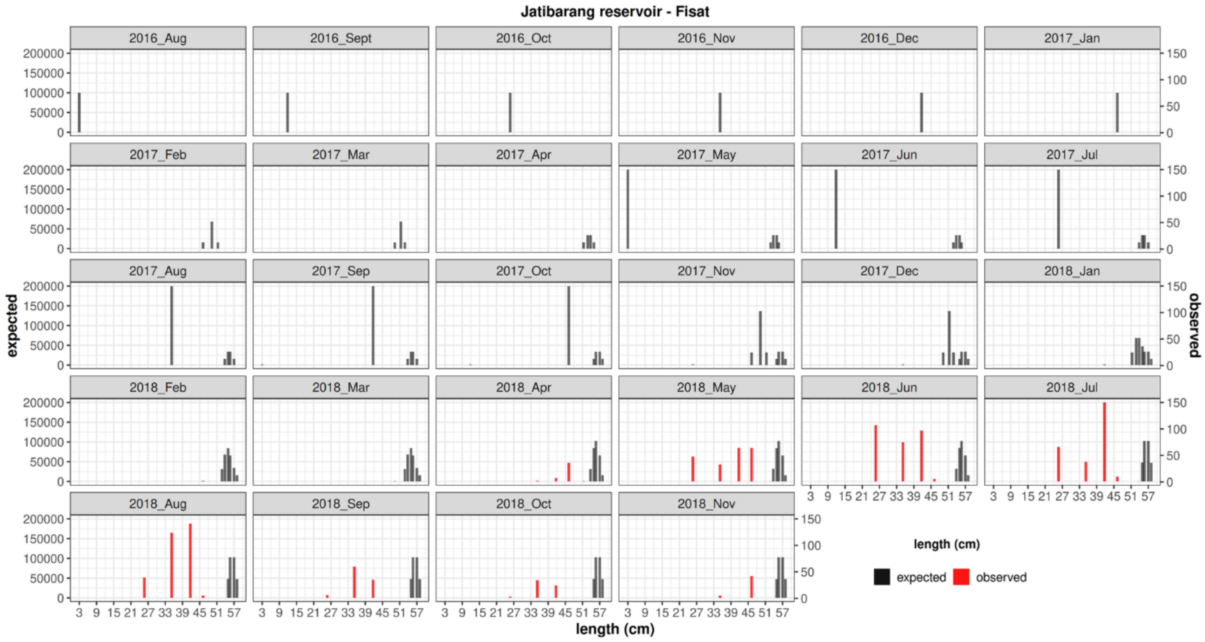

Figure 11. Expected (black) and observed (red) catch of Jatibarang using growth parameters of milkfish in Sempor produced by FiSAT

3.1.4 Expected and observed catch of milkfish in Sempor

There are three histograms of Sempor reservoir produced by a simulation using growth parameters from FiSAT, ELEFAN, and combination of L∞ produced by FiSAT value and K value produced by ELEFAN (Figure 12-14). The observed catch of milkfish in Sempor reservoir were measured between September 2014 – December 2015, or three months after the first stocking events, ranging between 14.9 – 57 cm (average 43.7 cm ± 6.92) with 6,122 individuals. The observed data show that again larger individuals were caught over time, seen by the movement of modal length (Figure 12-14). The overlap of both expected and observed catch can however be observed in this case, by using growth parameters of milkfish in Jatibarang (L∞ of 80.3 and K of 0.16), and the fish from first stocking event are starting to be caught in September 2014. This is a good example in describing the maximum length which is close to the actual data and shows a better fit of the growth parameters to the actual catch data than in the Jatibarang reservoir (Figure 12).

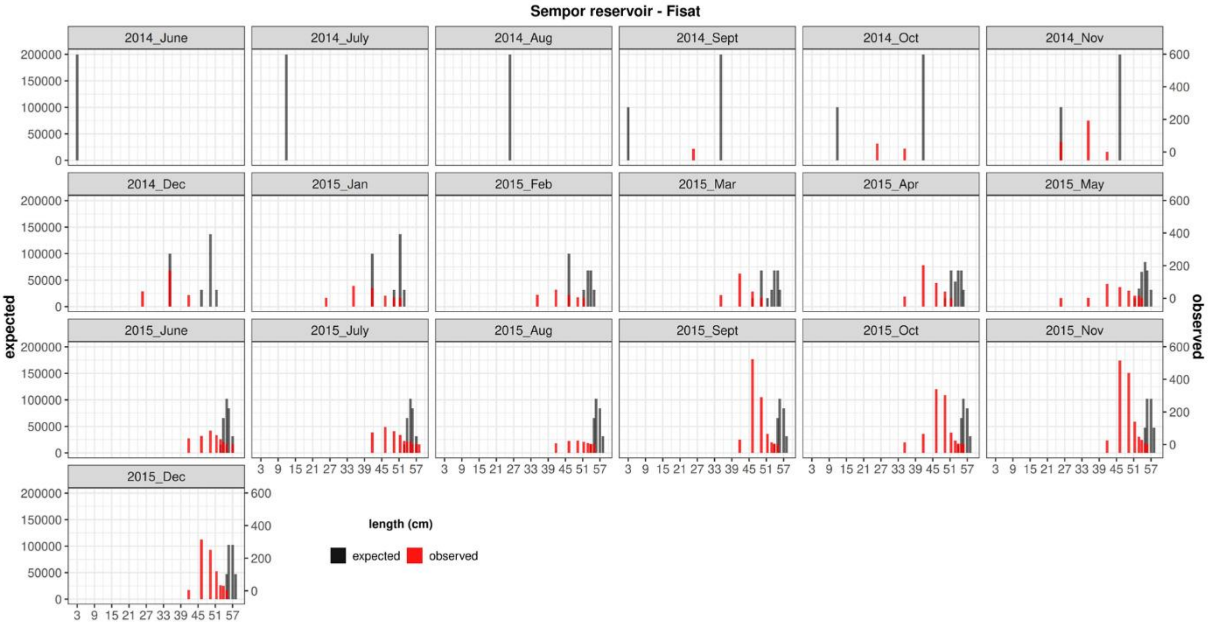

Figure 12. Expected (black) and observed catch (red) of Sempor using growth parameters of milkfish in Sempor produced by FiSAT

Additionally, expected and observed catch using the growth parameters of milkfish in Sempor produced by ELEFAN were simulated and compared (Figure 13). The expected and observed catch shows that the maximum of stocked fish is quite far away compared to observed catch (63 cm), but nevertheless an overlap between both can be seen.

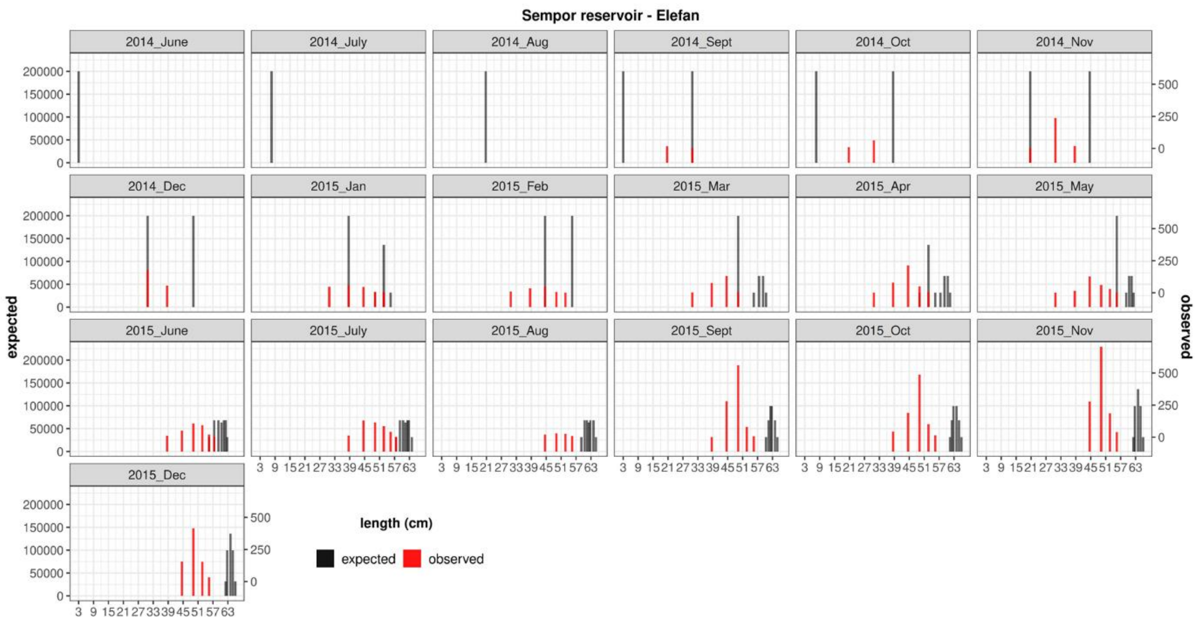

Figure 13. Expected (black) and observed catch (red) of Sempor using growth parameters of milkfish in Sempor produced by ELEFAN

When using a combination of the growth parameters of milkfish in Sempor produced by FiSAT (using an $L\infty$ of 55.97) and ELEFAN (using a K of 0.26; Figure 14). The expected and observed catch shows the maximum stocked fish is closer to the observed catch (57cm), and the overlap between both can be seen, but the second stocking event is missing. The expected catch is not consistent with the observed catch. It is assumed that this is related to the inappropriate time of stocking and the fingerling condition at the time of stocking.

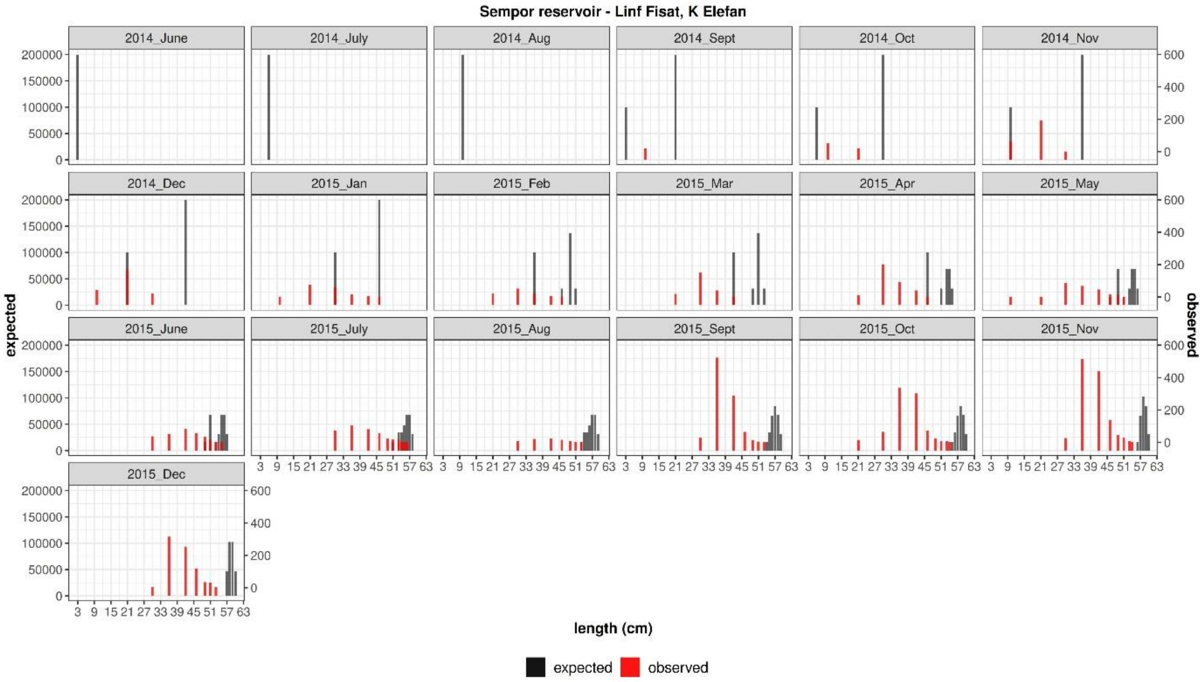

Figure 14. Expected (black) and observed catch (red) of Sempor using growth parameters of milkfish in Sempor produced by FiSAT and ELEFAN

3.1.5 Gear selectivity, natural and fishing mortality rates

The estimation of total mortality (Z), natural mortality (M) and fishing mortality (F) was done for observed data (the actual catch) by using the growth parameters produced by ELEFAN. Length converted catch curve estimates of total mortality (Z) as 1.9 $month^{-1}$ (Figure 15), estimated of M was 0.39 $month^{-1}$, therefore a fishing mortality rate (F) is equal to 1.51month-^{1} (Gulland, 1969). The selectivity function of the catch curve estimated an age at 50% probability of capture (t_{50}) of 5 months, this age is close to the size of 45-49 cm (on average 47 cm) (Figure 15).

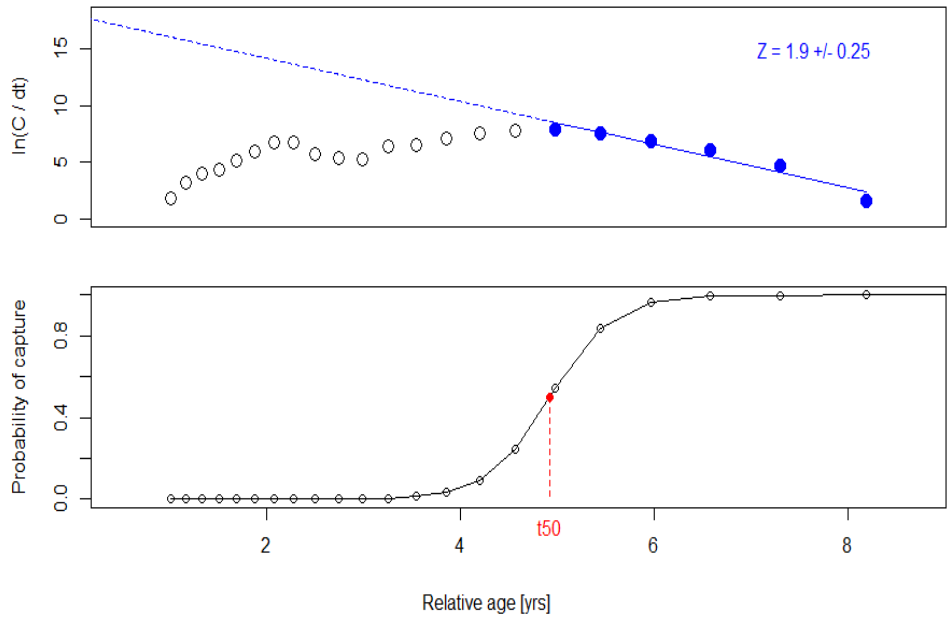

Figure 15. Length-converted catch curve of milkfish in Sempor reservoir (above); Selectivity curve of age at 50% probability of capture (t_{50}) (below)

3.2 Yield per recruit

Yield per recruit (YPR) described the relationship of yield and fishing mortality (F), meaning an option to select the optimum growth potential of year classes by estimates the F_{msy}, F0.1, and F0.5 (Figure 16). Figure 16 shows that the yield could be increased when fishing mortality is reduced. The gear related analysis reveals that the current gear characteristics and exploitation rate produce a yield of above 125g per recruit, which could be increased to above 141.93g.

YPR value in the pristine levels is equal to 125g was obtained at M = 0.39 month-^{1}, F = 1.51 month^{-1}, and Lc = 14.9. The pseudo maximum of YPR is 141.93, was obtained at F_{max} = 5 month^{-1}. This indicate yield maximum is 17% of present yield. The F_{msy}, F0.1 and F0.5 were 5, 0.812 and 2.28 month^{-1}, respectively (Figure 16). The current fishing mortality (F_{curr}) is equal to 1.51, was lower than F0.1, and F_{msy}. The results estimate that the current fishing mortality (F = 1.51 month^{-1}) is lower than the fishing mortality for ‘maximum sustainable yield’ (F_{msy} = 5 month^{-1}), indicating under-exploited or in this case means the stocked fish is not well utilized.

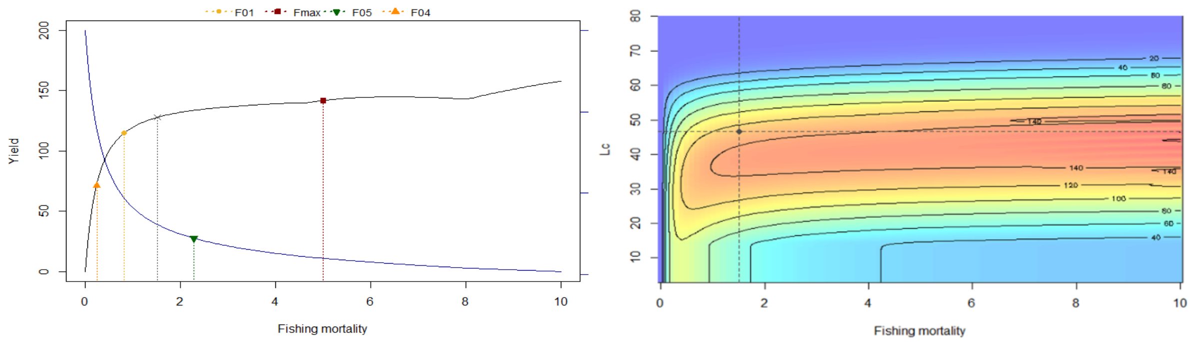

Figure 16. Yield and biomass trajectories related to fishing mortality (left picture: the black dot represents yield and biomass per recruit under current fishing pressure. The red and green dashed lines represent fishing mortality for maximum sustainable yield (F_{msy}) and fishing mortality associated with a 50% reduction relative to the virgin biomass (F0.5), respectively. The x axis corresponds to the fishing mortality of the fully exploited length class(es); right picture: Isopleth graph showing yield per recruit, the black dots represents the current fishing regime, the x axis displays the exploitation rate (F/Z) of the fully length class (es)).

Results of the Thompson and Bell model show the curves of isopleth of yield and biomass per recruit with a Lc of 50cm (Figure 16). Most of the catch in Sempor ranges from 30-47cm, which means that the gear was targeting the narrow size of fish, because the same mesh size was used.

The catch in Jatibarang reservoir shows a tendency to target a certain size of milkfish, and it clearly shows the difference target size based on location (Figure 17). Bigger fish mostly caught in Mijen area (western part of Jatibarang reservoir), and wider range of size caught in Gunung Pati area.

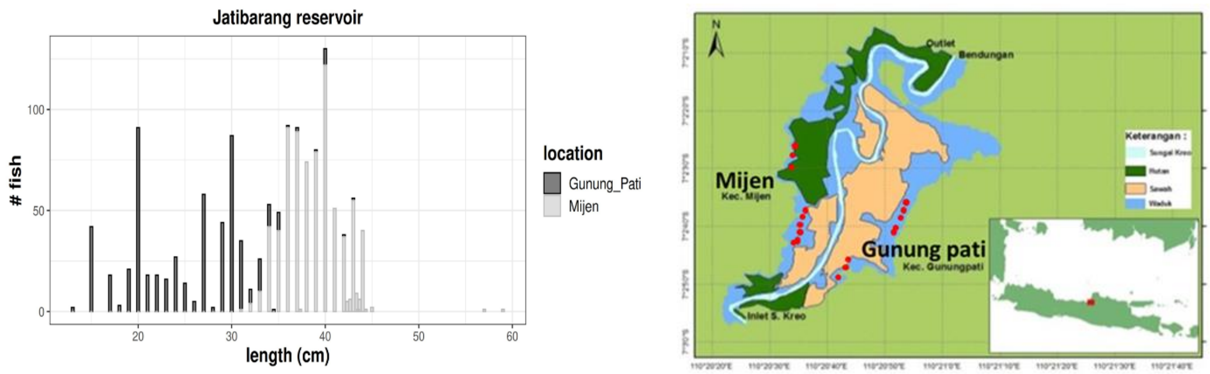

Figure 17. Graph of fishing activities in Jatibarang reservoirs are related to stock enhancement programs

4 DISCUSSION

An evaluation of the stock enhancement was performed in a first attempt to assess its success (Lorenzen, 2005). To achieve the main objective of a stocking that is to increase fishable stocks, good knowledge about the yield is needed. Fishing patterns can be used as a tool to analyse a stocked species after stocking. Fishing patterns highlight the chance of a fish to be caught because of a certain fishing method (Kolding, 2016). In this study we found that data collection on Java, Indonesia could be enhanced. We identified specific points that can be addressed to considerably improve both the data collection as well as the accuracy of the evaluation process. The need to improve because the lack of data collection is thought to mostly occur regarding tropical fisheries, especially freshwater fisheries (Hilborn & Walters, 1992).

4.1 Actual and expected catch of the stocked milkfish

Assuming that the FiSAT growth curves are correct, milkfish in Jatibarang reservoir seemed to relatively faster compared to milkfish in Sempor reservoir (shown by K and $L\infty$ values). The fast growth could also be observed in stocked milkfish in Djuanda reservoir, indicated by the comparatively large value of K 3.381. The range of 2.8 – 8.5 cm fingerlings was stocked in July and August 2008 and reached 14.7-31 cm after a month (Tjahjo et al., 2011).

This study, however, shows a mismatch between stocking and actual catch in all our cases, although the Sempor values estimated by FiSAT still illustrated the best fit. Firstly, we hypothesise that the growth curve of milkfish in the Jatibarang reservoir is actually incorrect, as indicated by the absence of large fish in the catch data. However, the incorrectness cannot be proved because the catch data of milkfish from the Jatibarang reservoir was obtained two years after the implementation of the stocking program. Moreover, the histograms of expected and observed data show a new group exists in 2018, which is assumed to be indicate an unreported stocking event. A recent study showed that milkfish were caught in 2021 (Hermalasari, 2021) and it proves the hypothesis of unreported stocking event since the last is in 2017, because it still found a relatively small size of milkfish in this reservoir. Another recent information is a video in June 2019 showing milkfish being caught by fishermen which are relatively small (approximately 20 cm), and some bigger ones in March 2019 (approximately 30-40 cm) (Anonymous, 2019). This information shows the incompatibility between the growth of milkfish and stocking event. The presence of small fish shows new recruitment in form of stocked fingerlings came into the fishery, and we therefore assume that it did not come from the officially documented stocking events.

Compared to the Jatibarang reservoir, the catch and the growth of stocked milkfish in Sempor are better described. The catch is dominated by sizes ranging from 30-47cm, which means the gear is selecting only certain size classes and it assumed that larger milkfish are not caught. The success of first stocking was seen because of catch data from Sempor is based on the stocking event (Figure 12-14). The size of milkfish can be used to address which stocking events belong to the population even though there must be some variation of growth, which should not be too large though. The number of individuals can be used as a good indicator of the success of the stocking. Milkfish cannot reproduce in freshwater, therefore the population should decrease over time, as also shown in Sempor after 1.5 years of stocking (Aisyah et al., 2018). According to information from fishermen, milkfish were never caught 2 years later, even though there is a stocking event of milkfish in November 2015. These results show that any estimation of whether the stocking program was successful or not has a significant dependency on the existing data and therefore what the simulations are based on and predict.

4.2 The yield per recruit analysis

Related to the ratio between $L\infty$ and maximum length, milkfish in Jatibarang show a high mortality, indicating that gear only targets a relatively small size fish range (13-59cm)

(Magnifico, 2007). Those fisheries do not seem to target older or rather larger milkfish, however there must be many larger sized fish available in the reservoirs as indicated by the growth pattern (Triharyuni, et al., 2018). In Sempor, on the other hand, the FiSAT values of growth parameters ($L\infty$ of 55.97) and maximum size of 59 cm show that older or larger milkfish in Sempor were targeted (Magnifico, 2007). This is understandable because $L\infty$ is an average growth of the whole fish and the growth of fish could be varying in wild population, some are growing bigger, and some are not reaching the maximum growth possible. However, ELEFAN values show the opposite, similar to the Jatibarang reservoir, that is length maximum of 59 cm is smaller than $L\infty$ of 64.65, which means gear only targets a relatively small size fish range (14-59cm). These results are underlining the outcomes of the yield estimation that the gear was targeting a certain size of fish because the same mesh size was used. Gear used in Sempor reservoir targets Nile tilapia, which still is the species preferred by the communities because of fingerling availability and its relatively fast growth (Umar et al., 2015). However, the ecological concerns, such as the interactions with native species, lead the government to introduce a safe species like milkfish as it cannot reproduce in freshwater and therefore cannot spread. The increase of desirability of milkfish by the community instead of Nile tilapia is another challenge.

However, when considering the catch curve of our analysis, an irregular pattern compared to the common curve is noticeable. The catch curve produced by ELEFAN is a linear regression, which is a method to estimate natural mortality, and it is a described by the age and size proportions that are harvested by the fishery (Ricker, 1975). A common catch curve usually has three sections with specific characteristics of each, and dome shape in the middle sections (Ogle, 2013[b]). The catch curve of length frequency data of milkfish in Sempor shows a difference, which is specifically uncommon in the middle section of the curve. It is both much wider than then a usual mid-section and had the shape of a ‘valley’ instead of a maximum (Figure 15). This indicates a slow rate of exploitation and the exploitation rate per time is low especially in the month 3 (here refers to November). November is a rainy season in Indonesia, where fishing activities are very low (Aisyah et al., 2018). Hydro-climatic factors, such as rainfall associated with changes in water level, influences the catchability and therefore affects catch per unit effort (CPUE) in many inland reservoirs (Moses et al., 2002; Patrick, 2016).

Gillnets and lift nets with specific mesh sizes depending on the target species are mostly used in inland fisheries, lakes, reservoir, rivers, and floodplains in Indonesia. The selection of a certain size is known as gear selectivity. Gillnets are often used to estimate size selectivity when the total number of fish is unknown (Hovgard & Lassen, 2000). Length data of fish that have a 50% chance of being captured, L_{50} or L_c value, show that the milkfish in Sempor are caught when reaching around 45-49cm (on average of 47cm). Nevertheless, of the whole range of fish sizes is needed when evaluating fish stocking. The need of a wider range of length distributions is also stated by Yem (2014). In their study, gillnets with smaller mesh sizes were needed to cover the gap between each mesh size of gillnet selectivity of *Salmo trutta L.* from two lakes in Iceland. Comparing length compositions from multiple mesh sizes or sizes of a fishing gear is a common method to estimate gear selectivity (Millar and Holst, 1997 *in* Punt et al, 2014).

The relationship between current fishing mortality (F_{curr} of 1.51) and maximum fishing mortality (F_{msy} of 5) gives the same conclusion with catch curve analysis, that is low in exploitation rate of milkfish in Sempor. However, instead of using the actual level of exploitation that is not needed in terms of stocking, but the maximum yield value to achieve the goal of stocking in providing as much fish as possible to the community.

The yield per recruit analysis here was used to achieve the objective of fish stocking by look at to which maximum yield is estimated from the existing fishing pattern. The maximum yield cannot be seen in this study, even though there is a difference in the value of pristine yield (125g per recruit) and the pseudo maximum yield (141.93g per recruit). The absence of maximum yield often exists in tropical fisheries, and the usual concern of overfishing (increasing effort to reach the maximum yield) is not the concern of our fish stocking case, because the main objective of stocking is to optimize the yield.

4.3 Tagging as other methods in evaluating fish stocking

Tagging was used widely specially to assess fish population, by using the probability of fish recaptured. Early tagging was conducted in 1873 to see the performance of tag and the methods (Atkins, 1885 in Miller, et al., 2012). Tagging can be used to describe the effect of hydro-power plants and dams on the fish stock (Enderlein, 1984). Tagging also can be used to evaluate the recaptured of fish stocking, and to distinguish stocked fish from multiple stocking events, for example the returns of adult Atlantic Salmon from multiple stocking sites (Lipsky et al., 2012).

A visible implant elastomer tags has been used for juvenile red snapper (*Lutjanus campechanus*) from stock enhancement program in the Gulf of Mexico (Brennan, 2007). This study also underlined the weakness of this tag types, such as the invisible colour in the nose of fish due to pigmentation, and the visibility of red and orange colour that easily to distinguish rather than green or yellow, or between red and pink.

In Indonesia, a tagging programme was used to investigate migration patterns of Siammes catfish (*Pangasianodon hypophthalmus*) before released or stocked in Kedungombo reservoir, Central Java (Aida, et al., 2014). The important habitat for Siammes catfish then known in certain part of reservoir. This study is the basis for the issuance of the Government rules of protected area in Kedungombo reservoir.

5 CONCLUSIONS AND RECOMMENDATIONS

Catch data used in this study are fishery dependent, without a scientific survey as back up data. This kind of data is complicated to use for predicting growth and yield per recruit models. Data used here shows the irregular pattern in describing the milkfish fisheries, such as the growth, the movement of modal length used to identify the stocked fish. Catch data of milkfish in Sempor reservoir is much better in describing the growth, however still the vague size selectivity by certain mesh size could be noticed.

To address a better way to evaluate the stock enhancement, a scientific experimental fishing with multiple mesh sizes to cover all possible sizes of milkfish is needed. The record of data suggested not only when it is needed but rather as a time series. In the case of the reservoir fisheries on Java, Indonesia, this would specifically refer to the data collection directly conducted after the events as well as the recording of stocking events. The use of tagging data is highly recommended to describe growth of stocked fish. Here we recommend elastomer tag that is good to see different colours per each stocking event, however the strength and weakness of previous studies using the same principles should be taking into account.

ACKNOWLEDGEMENTS

I offer my sincere appreciation for the learning opportunities provided by GRO FTP, Thor Heiðar Ásgeirsson, M.Sc, Mary Frances Davidson, M.Sc. Stefán Þ. Úlfarsson, M.Sc, Agnes Eydal, M.Sc, and Julie Ingham, M.Sc, for the continued support and encouragement. I also thank to Research Center for Fisheries and Ministry of Marine Affairs and Fisheries for the chances to attend to this training: Ibu Yayan Hikmayani, M.Si, Pak Waluyo S. Abutohir, Dr. Duto Nugroho, and Prof. Husnah.

I cannot express enough thanks to my supervisors for their patient guidance, enthusiastic encouragement, useful corrections, and leading me on an exciting project: Pamela Woods, Ph.D, Hlynur Bardarson, Ph.D, and Sandra Rybicki, Ph.D. My sincere thanks also go to GRO FTP fisheries expert: Tumi Tomasson, Ph.D, and ARAM specialization leader: Jonas P. Jonasson, Ph.D, for the constructive comments and hard questions.

I thank my fellow classmates in ARAM specialization for the stimulating discussions, togetherness, up and down feeling during the class, project, and in the guesthouse. Big hug for other fellows that I cannot mention one by one for the warm friendship even we are in a different specialization. Special thanks to my home office colleagues for their help and support: mas Bimo, mbak Ria, and Yuyun. I also thank my mother ‘Ummu’ Fatimah for supporting me throughout my life, my siblings, and my beloved ‘kamuuu’ for their warm love, motivations, and patience to wait me.

REFERENCES

Adjie, S., & Utomo, A. D. (2010, April 33-44). Catch of some fishing gear in Solo river (in Bahasa). *BAWAL Widya Riset Perikanan Tangkap, 3*(1).

Agostinho, A. A., Gomes, C., & Latini, J. D. (2004). Fisheries management in Brazilian reservoirs : lesson from/for South America. *Interciencia, 29 (6),* 334-38.

Agostinho, A. A., Pelicice, F. M., Petry, A. C., Gomes, L. C., & Julio, J. H. (2007). Fish diversity in the upper Paraná River basin: habitats, fisheries, management and conservation. *Aquatic, 10*, 174-186.

Agustinho, A. A., Pelicice, F. M., Gomes, C., & Julio, H. F. (2010). Reservoir fish stocking: when one plus one may be less than two. *Natureza & Conservacao, 8 (2)*, 103-111.

Aida, S. N., Utomo, A. D., Hidayah, T., Ali, M., Mentari, R. D., Subroto, G., . . . Juadi. (2014). *Percobaan penebaran ikan patin (Pangasianodon hypophthalmus) di Waduk Kedungombo, Jawa Tengah.* Palembang, Sumatra Selatan: Balai Penelitian Perikanan Perairan Umum.

Aisyah, Triharyuni,, S., Prianto, E., Purwoko, R., & Husnah. (2019). Culture based fisheries as an effort to increase fish production in reservoir. *Jurnal Kebijakan Perikanan Indonesia, 11*, 53-63. doi:http://dx.doi.org/10.15578/jkpi.11.1.2019.53-63

Aisyah, Umar, C., Triharyuni, S., & Husnah. (2018, April). Population dynamic and exploitation rate of milkfish (Chanos chanos) in the Sempor reservoir, Central Java (Indonesia). *BAWAL, 10*(1), 29-39.

Aisyah; Triharyuni, S; Prianto, E; Purwoko, R M; Husnah;. (2019). Culture based fisheries (CBF) as an effort to increase fish production in reservoir (in Bahasa). *Jurnal Kebijakan Perikanan Indonesia, 11 (1)*, 53-63. doi:http://dx.doi.org/10.15578/jkpi.11.1.2019.53-63

Aisyah; Triharyuni, S; Prianto, E; Purwoko, Rudy M;. (2020). Study on carrying capacity of fish resources (in Bahasa). *J.Lit.Perikan.Ind., 26 (1)*, 1-9.

Amarasinghe, U. S., & Weerakoon, D. E. (2009). Present status and future strategies for the management of reservoir fisheries in Sri Lanka. In S. S. De Silva, & U. S. Amarasinghe, *Status of reservoir fisheries in five Asian countries* (pp. 69-98). Bangkok, Thailand: Network of aquaculture centres in Asia-Pacific.

Amri, K., & Khairuman. (2003). *Intensively aquaculture of Nile tilapia (in Bahasa).* Jakarta: Agromedia Pustaka.

Andriyono, S., & Fitriani, M. (2021). Non-native species existence and its potency to be invasive species on freshwater ecosystem in East Java Province, Indonesia. *Egyptian Journal of Aquatic Biology and Fisheries, 25*(2), 1013-1024. Retrieved from www.ejabf.journals.ekb.eg

Anggawati, A. M., Imanto, P. T., Tazwir, Suryanti, & Krismono. (1991). Study on aquaculture of black Nile tilapia in floating fish cage, Sendang Biru, East Java (in Bahasa). *Buletin of fisheries research*(3).

Anonymous. (2015). Summary of culture-based fisheries developments in Lao PDR. In S. S. De Silva, B. A. Ingram, & S. Wilkinson, *Perspectives on culture-based fisheries developments in Asia* (pp. 47-51). NACA Monograph Series No. 3, 126p.

Anonymous. (2019). Strike bandeng berkali-kali di Waduk Jatibarang. Indonesia.

Asmaranto, R., & Suryono, A. (2017). Study of reservoir carrying capacity for aquaculture (case study : Cengklik Reservoir) (in Bahasa). *Pertemuan Ilmiah Tahunan XXXIV HATHI - Papua*, (p. 11).

Bagarinao, T. U. (1991). *Biology of Milkfish (Chanos chanos Forsskal).* Aquaculture Department Southeast Asian Fisheries Development Center.

BBWS Serayu Opak. (2022). *sda.pu.go.id*. Retrieved January 17, 2022, from https://sda.pu.go.id/balai/bbwsserayuopak/projects-item/bendungan-sempor-2/.

Béné, C., Macfadyen, G., & Allison, E. (2007). *Increasing the contribution of small-scale fisheries to poverty alleviation and food security.* FAO.

Biswas, G., Sundaray, J. K., Thirunavukkarasu, A. R., & Kailasam, M. (2011, June). Length-weight relationship and variation in condition of Chanos chanos (Forsskal, 1775) from tide-fed brackishwater ponds of the Sunderbans-India. *Indian Journal of Geo-Marine Science, 40*(3), 386-390.

Boyd. (2004). *National Standar of Indonesia 01-6139-1999 (production of black nile tilapia, Oreochromis niloticus) (in Bahasa).* Jakarta.

Brennan, N. P., Leber, K. M., & Blackburn, B. R. (2007). Use of coded-wire and visible implant elastomer tags for marine stock enhancement with juvenile red snapper Lutjanus campechanus. *Fisheries Research*, 90-97.

Buri, P., Kumagai, S., Banada, V., & Castillo, N. (1980). *Developmental and ecological stages in the life history of milkfish Chanos chanos Forsskal.* Buri, P., Kumagai, S., Bañada, V., & Castillo, N, Aquaculture Department. SEAFDEC.

Bwanika, G. N., Makanga, B., Kizito, Y., Chapman, L. J., & Balirwa, J. (2004). Observations on the biology of Nile tilapia, Oreochromis niloticus L., in two Ugandan crater lakes. *African Journal of Ecology*, 93-101.

Chairulwan, U., & Sulaiman, P. S. (2013). Fish introduction status and sustainable implementation strategy in Indonesia inland water (in Bahasa). *Jurnal Kebijakan Perikanan Indonesia, 5 (2)*, 113-120.

Champneys , T., Genner, M. J., & Ioannou, C. C. (2021). Invasive nile tilapia dominates a threatened indigenous tilapia in competition over shelter. *Hydrobiologia*(848), 3747–3762. doi:https://doi.org/10.1007/s10750-020-04341-8

Cowx, I. G. (1999). An appraisal of stocking strategies in the light ofdeveloping country constraints. . *Fisheries Management and Ecology, 6*, 21-34.

De Silva, S S; Amarasinghe , U S; Nguyen, T T;. (2006). Better-practice approaches for culture-based fisheries development. *ACIAR Monograph*, p. 96.

De Silva, S. S. (2001). Reservoir and culture-based fisheries: biology andmanagement. *ACIAR Proceedings, 98*, pp. 7-15.

De silva, S. S., & Funge-Smith, S. J. (2005). *A review of stock enhancement practices in the inland water fisheries of Asia.* Asia-Pacific Fishery Commission, Bangkok, Thailand: RAP Publication No. 2005/12.

De Silva, S. S., & Song, S. L. (2015). Challenges and constraints for developing CBF in Cambodia and a possible strategy for success. In S. S. De Silva, B. A. Ingram, & S. Wilkinson, *Perspectives on culture-based fisheries development in Asia* (pp. 53-57). NACA Monograph series no. 3, 126p.

De Silva, S. S., Ingram, B. A., & Wilkinson, S. (2015). *Perspectives on culture-based fisheries developments in Asia.* NACA Monograph series No.3.

DGCF-MMAF. (2020). *National Fisheries Statistic of 2004-2020.* Jakarta, Indonesia.

Djumanto, Pranoto, B. E., Diani, V. S., & Setyobudi, E. (2017). Food and the growth of introduced milkfish, Chanos chanos (Forsskål, 1775) in Sermo Reservoir, Kulon Progo (in Bahasa). *Jurnal Iktiologi Indonesia, 17*(1), 83-100.

Djumanto; Pranoto, B E; Diani, V S; Setyobudi, E. (2017). Food and the growth of introduced milkfish, Chanos chanos (Forsskal, 1775) in Sermo reservoir, Kulon Progo (in Bahasa). *Jurnal Ikhtiologi Indonesia, 17*(1), 83-100. doi:https://doi.org/10.32491/iii.v17i1.306

Enderlein, O. (1984). Stocking of fish in Sweden from the perspective of tagging. *Symposium on stock enhancement in the management of freshwater fish, 31 May – 2 June 1982 in conjunction with the Twelfth Session of EIFAC.* Budapest: FAO.

FAO. (1999). *Irrigation in Asia in figures.* Rome.

FAO. (2011). Review of tropical reservoirs and their fisheries - the cases of Lake Nasser, Lake Volta and Indo-Gangetic Basin reservoirs. (P. A. van Zwieten, C. Bene, J. Kolding, R. Brummet, & J. Valbo-Jorgensen, Eds.) (557), p. 148.

FAO. (2011). *Review of tropical reservoirs and their fisheries – The cases of Lake Nasser, Lake Volta and Indo-Gangetic basin reservoirs.* (P. M. van Zwieten, C. Bene, J. Kolding, R. Brummet, & J. Valbo-Jorgensen, Eds.) Rome: FAO Fisheries and Aquaculture Technical Paper. No. 557.

FAO. (2014). *CWP handbook of fishery statistical standards, section G: fishing areas - General.* Rome, Italy.

FAO. (2017). *The futureof food andagricultureTrendsand challenges.*

FAO. (2020). *SOPIA.*

FAO. (2020). *The State of World Fisheries and Aquaculture 2020, Sustainability in action.* Rome. doi:https://doi.org/10.4060/ca9229en

FAO. (2021, September 16). *Aquaculture and Inland Fisheries: Fact Sheet*. Retrieved from http://www.fao.org/3/y2419e/y2419e02.htm.

Fauzi, C., & Mulyono, J. (2017). *setengah abad HCV Bendungan Jatiluhur.* Jakarta: PT. Gading Media Utama.

Fitri, N., Hidayat, A., & Gandhi, P. (2016, December). Daya dukung lingkungan dan kelembagaan usaha keramba jaring apung di waduk Jatiluhur. *Risalah Kebijakan Pertanian dan Lingkungan, 3*(3), pp. 248-261. doi:http://dx.doi.org/10.20957/jkebijakan.v3i3.16257

Froese, R. (2004). Keep it simple: three indicators to deal with overfishing. *Fish and Fisheries , 5*, 86–91.

Froese, R., Stern-Pirlot, A., Winker, H., & Gascuel, D. (2008). Size matters: How single-species management can contribute to ecosystem-based fisheries management. *Fisheries Research, 92*(2-3), 231-241.

Ganga, U. (-). Beverton and Holt's yield per recruit model. *Summer School on Advanced Methods for Fish Stock Assessment and Fisheries Management*, p. 4. Retrieved December 2021

GRO-FTP. (2021). Retrieved from https://www.grocentre.is/ftp.

Gulland, J. A. (1969). *Manual of Methods for fish stock assessment. Part 1. Fish population analysis.* FAO.

Guntoro, H. (2019, July 24). *https://www.gesuri.id/pemerintahan/terkuak-ini-alasan-pemerintah-masif-bangun-bendungan-b1Wj3ZlsK*. Retrieved from www.gesuri.id.

Halim, A. e. (2020). merumuskan definisi skala kecil untuk mendukung pengelolaan perikanan tangkap di Indonesia. *Journal of Fisheries and Marine Research*.

Hastuti, I. B., & Hastuti, E. D. (2016). Changes in allometric growth of milkfish (Chanos chanos) cultured in silvofishery ponds in Semarang city (in Bahasa). *Prosiding Seminar Nasional from Basic Science to Comprehensive Education* (pp. 16-18). Makassar: Department of Biology, Faculty of Science and Technology, UIN Alauddin, Makassar.

Hatmoko, W., & Rauf, A. (n.d.). Water level of reservoir as a dryness indicators, case study in Kedung Ombo and Cacaban reservoir (in Bahasa). p. 15. Retrieved January 16, 2022, from https://adoc.pub/queue/tinggi-muka-air-waduk-sebagai-indikator-kekeringan-studi-kas.html

Hedianto, D. A., Purnomo, K., & Warsa, A. (2013). Interaksi pemanfaatan pakan alami oleh komunitas ikan di Waduk Penjalin, Jawa Tengah. *BAWAL, 5*(1), 33-40.

Hendrawan, A. L., Hedianto, D. A., & Sentosa, A. A. (2021). Risk assessment of introduced fish species in Djuanda reservoir, West Java (in Bahasa). *Zoo Indonesia*, 58-68.

Hermalasari, D. (2021). *Biodiversity study and potency status of utilized fish types in Jatibarang reservoir, Semarang city (in Bahasa).* Semarang: Walisongo Islamic University.

Hilborn, R., & Walters, C. J. (1992). Quantitative fisheries stock assessment: Choice, dynamics and uncertainty. *Reviews in Fish Biology and Fisheries, 2*(2), 177– 178.

Hoggarth, D. D., Abeyasekera, S., Arthur, R. I., Beddington, J. R., Burn, R. W., Halls, A. S., . . . Welcomme, R. L. (2006). *Stock assessment for fishery management – A framework guide to the stock assessment, tools of the Fisheries Management Science Programme (FMSP).* Rome: FAO.

Hordyk, A., Ono, K., Valencia, S., Loneragan, N., & Prince, J. (2014). A novel length-based empirical estimation method of spawning potential ratio (SPR), and tests of its performance, for smallscale, data-poor fisheries. *ICES Journal of Marine Science, 72 (1)*, 217-231.

Hovgard, H., & Lassen, H. (2000). *Manual on estimation of selectivity for gillnet and longline gears in abundnace surveys.* Rome: FAO.

Huisman, E. A. (1979). *Report of the EIFAC Workshop on mass rearing of fry and fingerlings of freshwater fishes.* European Inland Fisheries Advisory Commission (EIFAC). Rome: FAO.

ICOLD. (2002). *Constitution status.* Paris: ICOLD/CIGB.

Imelda-Joseph, Sarimol, C. N., & Venugopalan, K. M. (2016). Cage culture of milkfish Chanos chanos (Forsskal, 1775) in brackishwater systems at Kochi, Kerala. In A. Gopalakrishnan, & e. al. (Ed.), *Proceedings of the fifth International Symposium on Cage Aquaculture in Asia* (pp. 215-221). Kochi, India: Asian Fisheries Society, Malaysia, and ICAR-Central Marine Fisheries Research Institute.

Insan, I. (2009). *Trophic status and carrying capacity towards floating cage culture in Cirata reservoir (in Bahasa).* Bogor - West Java: Bogor Agricultural Institute.

Integrated Taxonomic Information System - Report. (n.d.). Retrieved from https://www.itis.gov/servlet/SingleRpt/SingleRpt?search_topic=TSN&search_value=162838#null.

Jaikumar, M., Suresh Kumar, C., Robin, R. S., Karthikeyan, P., & Nagarjuna, A. (2013). Milkfish culture: alternative revenue for Mandapam Fisherfolk, Palk Bay, southeast coast of India. *International Journal of Fisheries and Aquaculture Sciences, 3*(1), 31-43.

Jennings, S., Kaiser, M. J., & Reynolds, J. D. (2001). *Marine fisheries ecology.* Blackwell Science L.td.

Jutagate, T. (2009). Reservoir fisheries of Thailand. In S. S. De Silva, & U. S. Amarasinghe, *Status of reservoir fisheries in five Asian countries* (pp. 99-116). Bangkok, Thailand: Network of aquaculture centres in-Asia Pacific.

Kartamihardja, E. (2007). Fish stock enhancement: optional technology for increasing fisheries production in inland open waters of Indonesia. *Indonesia Fisheries Research Journal, 1*, 1-10.

Kartamihardja, E. S. (2008). Change of fish community composition and the influencing important factors during fourty years of The Djuanda reservoir impounded (in Bahasa). *Jurnal Iktiologi Indonesia, 8*(2), 12.

Kartamihardja, E. S. (2012, December). Stock enhancement in Indonesian lake and reservoir fisheries. *Indonesian Fisheries Research Journal, 18*(2), 91-100.

Kartamihardja, E. S. (2012, December). Stock enhancement in Indonesian lake and reservoirs fisheries. *Indonesia Fisheries Research Journal, 18*, 91-100.

Kartamihardja, E. S. (2015). Potential of culture-based fisheries in Indonesian inland waters Network of Aquaculture Centres. In S. S. Desilva, B. A. Ingram, & S. Wilkinson, *Perspectives on culture-based fisheries developments in Asia* (pp. 73-81). Bangkok/Thailand, Network of Aquaculture Centres in Asia-Pacific.

Kartamihardja, E. S., & Purnomo, K. (2006, March Edition). Sustaining bilih fish population to a new habitat at Toba Lake. *Demersal: From the Sea to Development*.

Kartamihardja, E. S., & Umar, C. (2016). Structure, food, and feeding habits of fish community in limnetic zone of the Djuanda rcseruolr, West Java (in Bahasa). *Jurnal Penelitian Perikanan Indonesia, 12*(3), 159-166.

Kartamihardja, E. S., Purnomo, K., & Umar, C. (2009). Inland fisheries resources of Indonesia-neglected (in Bahasa). *Jurnal Kebijakan Perikanan Indonesia, 1*(1), 1-15.

Kartamiharja, E., Purnomo, K., Tjahjo, D., Umar, C., Sunarno, M., & Koeshendrajana, S. (2010). *Technical Guideline, Fisheries Enhancement at Inland.* Research Center for Fisheries Management and Conservation, Agency Research and Development for Marine and Fisheries, MMAF.

Kentaro, H. (2021). Initial growth characteristics of poor-return stocks of chum salmon Oncorhynchus keta originating from the Okhotsk and Nemuro regions in Hokkaido on the basis of scale analysis. (Kentaro et al, Ed.) *Fisheries Science*.

King, M. (1995). *Fisheries biology assessment and management.* Fishing News Books, Blackwell Science Ltd, Osnymead, Oxford OXZ OEL, England.

Koeshendrajana, S., Apriliani, T., Maulana, F., Nasution, Z., & Nurfiarini, A. (2011). Introducing Milkfish in the Jatiluhur Reservoir: Analysis of Impacts and Policies Development (in Bahasa). *J. Kebijakan Sosial Ekonomi Kelautan dan Perikanan, 1*(1), 17.

Kolding, J., & van Zwieten, P. (2006). *Improving productivity in tropical lakes and reservoirs. Challenge Program on Water and Food review series on aquatic ecosystems and fisheries, theme 3.* Cairo: WorldFish Center.

Kolding, J., Law, R., Plank, M., & van Zwieten, P. M. (2016). The optimal fishing pattern. In J. F. Craig (Ed.), *Freshwater Fisheries Ecology, First Edition.* (pp. 524-540). John Wiley & Sons, Ltd.

Leber, M. K. (2002). Advances in marine stock enhancement: shifting emphasis to theory and accountability. (R. a. Stickney, Ed.). (R. a. Stickney, Ed.) *Responsible Marine Aquaculture*, 79-90.

Lee, C. S. (1995). Aquaculture of milkfish (Chanos chanos). *Aquaculture Series*(I), 141.

LIPI. (2020). *Identifikasi Danau Indonesia: peranan strategis dari ketersediaan data dasar danau-danau di Indonesia.*

Lipsky, C., Hastings, E. M., Brown, R., & Dill, R. B. (2012). Correcting visual implant Elastomer Tag identification to better evaluate adult Atlantic Salmon returns from multiple stocking sites in the Penobscot river, Maine, USA (an abstract).

Lorenzen, K. (2005). Population dynamics and potential of fisheries stock enhancement: practical theory for policy analysis and management. *Phil. Trans. Roy. Soc. B*(360), 171–189.

Lorenzen, K. (2006). Population management in fisheries enhancement: Gaining key information from release experiments through use of a size-dependent mortality model. *Fisheries Research*(80), 19–27.

Magnifico, G. (2007). *New insight into fish growth parameters estimation by means of length-based methods.* University of Rome "Tor Vergata".

Maskur, & Kartamihardja, E. S. (2010). Inland fisheries resource enhancement and conservation in Indonesia. In W. Miao, S. De-Silva, & B. Davy, *Inland Fisheries Enhancement and Conservation in Asia* (pp. 61-76). Bangkok, Thailand: FAO.

Miftahudin, H. (2020, November 18). *https://www.medcom.id/ekonomi/bisnis/PNgYJQok-menteri-pupr-ungkap-alasan-banyak-bangun-bendungan*. Retrieved January 2022, from www.medcom.id.

Miller, A. S., Sheehan, T. F., Spencer, R. C., Renkawitz, M. D., Friedland, K. D., & Meister, A. L. (2012). *Description of the historic US Atlantic salmon (Salmo salar L.) tagging programs and subsequent databases.* Fish Sci Cent Ref Doc., USDepartment of Commerce, National Marine Fisheries, Old Town, Maine, USA.

MMAF. (2017, Juli 14). Prevention and monitoring of TiLV disease in tilapia (in Bahasa). *Instruction letter(3975/DJPB/VII/2017)*. Jakarta, Indonesia: Directorate General of Aquaculture.

MMAF. (2018). *One data of marine and fisheries production 2017 (in Bahasa).* Jakarta: Data Center - Statistic, and Information, Secretariat General of Ministry of Marine Affairs and Fisheries, Indonesia.

MMAF. (2021). *statistik-kkp*. (Ministry of Marine Affairs and Fisheries, Indonesia) Retrieved January 20, 2022, from https://statistik.kkp.go.id/home.php.

Molony, B. W., Lenanton, R., Jackson, G., & Norris, J. (2003). Stock enhancement as a fisheries management tool (a review). *Fish Biology and Fisheries , 13*(4), 409-432.

Moses, B. S., Udoidiong, O. M., & Okaon, A. O. (2002). A Statistical survey of the artisanal fisheries of south-eastern Nigeria and the influence of hydroclimatic factors on catch and resource productivity. *Fisheries Research, 57*(3), 267-278.

Mulyadi, A., & Atmaja, E. S. (2011, October). Impact of pollution to cage floating culture in Saguling reservoir (in Bahasa). *Gea, 11*(2), 21.

Nontji, A. (1989). *Inland Water Resources and Limnology*.

Nugroho, E. (2013). *Nila Best (in Bahasa)* (1 ed.). Penebar Swadaya.

Nugroho, E. (2013). *Nila unggul* (I ed.). Jakarta: Penebar Swadaya.

Ogle, D. (2013, December 16). Fish R vignette - catch curve estimates for mortality. p. 17.

Ogle, D. (2013, December 16). *http://derekogle.com/fishR/examples/oldFishRVignettes/LengthWeight.pdf.* Retrieved February 7, 2022, from https://derekogle.com/fishR/packages.

O'Neill, F. G., Feekings, J., Fryer, R. J., & Fauconnet, L. (2019). Discard avoidance by Improving fishing gear selectivity: helping the fishing industry help itself. In S. e. Uhlmann (Ed.), *The European Landing Obligation* (pp. 279-296). doi:https://doi.org/10.1007/978-3-030-03308-8_14

Patrick, A. S. (2016). Influence of rainfall and water level on inland fisheries production: A review. *Arch. Appl. Sci. Res. , 8*(6), 44-51.

Pauly, D. (1980). *A selection of simple methods for the assessment of tropical fish stocks* (Vol. Fish. Circ. No. 729). Rome: FAO.

Prima, A R. (2018). The construction of Jatibarang reservoir in Semarang city (in Bahasa). *Engineer Weekly*, p. 5.

Prima, A. R. (2018). Konstruksi bendungan Jatibarang Kota Semarang. *EngineerWeekly,* p. 5.

Prince, J., Hordyk, A., Valencia, A. R., Loneragan, N., & Sainsbury, K. (2014). Revisiting the concept of Beverton–Holt life-history invariants with the aim of informing data-poor fisheries assessment. *ICES Journal of Marine Science, 72 (1)*, 194-203.

Punt, A. E., Hurtado-Ferro, F., & Whitten, A. R. (2014). Model selection for selectivity in fisheries stock assessments. *Fisheries Research , 158*, 124–134.

PUPR. (2020). *Informasi statistik dan infrastruktur PUPR.* Jakarta: Ministry of Public Works and Public Housing of Indonesia.

PUPR. (2020). *Informasi statistik infrastruktur PUPR.* Ministry of Public Works and Public Housing, Indonesia.

Purnomo, K., Warsa, A., & Kartamihardja, E. S. (2013). Carrying capacity and potential fish yield of Sempor reservoir at Kebumen regency-Central Java . *Jurnal Lit. Perikanan Ind.*, 203-212.

Purnomo, K., Warsa, A., & Kartamihardja, E. S. (2013). Carrying capacity and potential fish yield of Sempor reservoir at Kebumen regency-Central Java province. *Jurnal Penelitian Perikanan Indonesia, 9*(4), 203-212.

Requintina, E. D., Mmochi, A. J., & Msuya, F. E. (2008). *A guide to milkfish culture in the Western Indian Ocean Region.* Western Indian Ocean Marine Science Assciation, Institute of Marine Sciences, University of Hawaii, Hilo and the Coastal Resources Center, University of Rhode Island.

Ricker, W. E. (1975). Computation and interpretation of biological statistics of fish populations. *Bulletin of the Fishery Research Board , 191*, pp. 1–382.

Ruffino, M. L. (2014). *Status and trends of the fishery resources of the Amazon Basin in Brazil.* (R. L. Welcomme, J. Valbo-Jorgensen, & A. S. Halls, Eds.) Rome: FAO.

Sagasta, J. M., Zadeh, S. M., & Turral, H. (2017). *Water pollution from agriculture: a global review executive summary* . Rome: FAO & The International Water Management Institute on behalf of The Water Land and Ecosystem Research Program, Colombo.

Sarminingsih, A., & Samudro, G. (2020). Perfomance evaluation of Jatibarang reservoir due to land use changing. *IOP Conf. Series: Earth and Environmental Science 448*, (p. 7). doi:10.1088/1755-1315/448/1/012009

Sarnita, A. (1977). Some aspects of fisheries and their development in man-made lakes in Indonesia with special reference to Lake Jatiluhur, West Java . *IPFC*, *17*, pp. 272-291.

Sarnita, A. (1999). Introduction and stocking of freshwater fishes into inland waters of Indonesia. In W. T. van Densen, & M. J. Morris (Eds.), *Fish and fisheries of lakes and reservoirs in Southeast Asia and Africa* (pp. 143-150). Otley, West Yorkshire, U.K.: Westbury Academic and Scientific Publishing.

SDA PUPR. (2014, Mei 5). *https://sda.pu.go.id/berita/view/pengisian_awal_waduk_jatibarang*. (Ditjen. Sumber Daya Alam - Kementerian PUPR) Retrieved January 10, 2022, from Berita SDA.

SEAFDEC. (2021). Retrieved from http://www.seafdec.org/.

Sparre , P., & Venema, S. C. (1998). *Introduction to tropical fish stock assessment Part 1: Manual. FAO Fisheries Technical Paper No. 306.1 Rev. 2.* FAO.

Sparre, P., & Venema, S. C. (1998). *Introduction to tropical fish stock assessment, part 1: manual* (No. 306.1 Rev. 2 ed.). Rome: FAO.

Sub Directorate of Regional Arrangements - Directorate General of Aquaculture Fisheries, M. (2017, November 11). The policy of stock enhancement in inland waters. (I. F.-R. Fisheries, Interviewer)

Sugiarto. (1988). *Nile tilapia (in Bahasa).* Jakarta: Penebar Swadaya.

Sukadi, M., & Kartamihardja, E. (1995). *Inland fisheries management of lakes and reservoirs with multiple uses in Indonesia.* Bangkok.

Sumawidjaja, K., Yusdiana, T., Effendi, I., & Dharmadi. (2007). Rearing of milkfish, Chanos chanos, in net cages at sea at various ctocking densities (in Bahasa). *Jurnal Akuakultur Indonesia, 1*(2), 53-55.

Syafei, L. (2005). Fish restocking for sustaining fisheries resources. *Jurnal Ikhtiologi Indonesia, 5*, 69-75.

Tawwab, M. A. (2003). Occurence of phytoplankton in stomach content and its selectivity by Nile tilapia (Oreochromis niloticus) cultured in fertilized Earthen Ponds. *Qatar Univ. Journal*, 153-166.

Then, A. Y., Hoenig, J. M., Hall, N. G., & Hewitt, D. A. (2015). Evaluating the predictive performance of empirical estimators of natural mortality rate using information on over 200 fish species. *ICES Journal of Marine Science , 72*(1), 82-92. doi:doi:10.1093/icesjms/fsu136

Thia-Eng, C. (1986). an overview of the fisheries and aquaculture industries in Asia. In J. L. Maclean, I. B. Dizon, & L. V. Hosillos (Ed.), *The first Asian fisheries forum* (pp. 1-8). Manila, Philippines: Asian Fisheries Society.

Tjahjo, D. H., Purnamaningtyas, S. E., & Kartamihardja, E. S. (2011, April). Evaluationof successfulness of fish stocking on bandeng(Chanos chanos) in Ir.H. Djuanda reservoir. *BAWAL, 3*(4), 231-237.

Tjahjo, D. W., & Purnamaningtyas, S. E. (2010). Fish diversity in Djuanda reservoir. *Seminar Nasional Ikan VI*, (pp. 161-167).

Triharyuni, S., & Aisyah. (2021). Economic benefits of fisheries activities in Jatibarang reservoir, Central Java. *The 3rd International Conference on Fisheries and Marine Sciences* (p. 8). IOP Publishing. doi:doi:10.1088/1755-1315/718/1/012057

Triharyuni, S., Husnah, Aisyah, Prianto, E., Purwoko, R. M., & Umar, C. (2018). *Restocking impact of fisheries resources in FMA 434 (Nothern Java).* Annual Report (in Bahasa), Research Center for Fisheries, Jakarta.

Triharyuni, S., Husnah, Kartamihardja, E. S., Umar, C., & Aisyah. (2017). *Increasing of fish production in Java Island (in Bahasa).* Jakarta: Research Center for Fisheries.

Umar, C., & Kartamihardja, E. S. (2006, December). Relationship between water level fluctuation and fish yield of the Djuanda reservoir in West Java (in Bahasa). *J. Lit. Perikan. lnd, 12*(3), 149-158.

Umar, C., Aisyah, Husnah, Prianto, E., Triharyuni, S., Kasim, K., . . . Budi, E. (2015). *Pematangan Teknologi CBF Ikan Bandeng dan Pengendalian Ikan Asing Invasif di Waduk Sempor, Jawa Tengah.* Research Center for Fisheries.

Umar, C., Kartamihardja, E. S., & Aisyah. (2015, May). Invasive impact of red devil (Amphilophus citrinellus) to fish diversity in inland water of Indonesia (in Bahasa). *Jurnal Kebijakan Perikanan Indonesia, 7*(1), 55-61. doi:http://dx.doi.org/10.15578/jkpi.7.1.2015.55-61

Umar, C., Kartamihardja, E. S., & Aisyah. (2016). The development strategy of culture-based fisheries at reservoir : case study of milkfish introduction in Sempor reservoir, Central Java (in Bahasa). *Jurnal Kebijakan Perikanan Indonesia*, *8*(1), 21-28.

Utomo, A. D., Aida, S. N., & Hidayah, T. (2016). *Spatial and carrying capacity of cage floating aquaculture in Kedung Ombo (Central Java) reservoir (in Bahasa).* Research Institute of Inland Fisheries. Palembang - South Sumatra: Research Institute of Inland Fisheries, Research Center for Fisheries, Agency of Marine and Fisheries Research and Human Resources, MMAF.

Wahyuni, S., Sulistiono, & Affandi, R. (2014). Spatial and temporal distribution of fishes in Cirata reservoir, West java (in Bahasa). *Bumi Lestari, 14*(1), 74-84.

Warsa, A., Hariyadi, J., & Astuti, L. P. (2018, July). Mitigation of Phosphorus Loading from Aquaculture Activity by Milk Fish (Chanos chanos) Stocking at Cirata, Reservoir, West Java (in Bahasa). *Jurnal Teknologi Lingkungan, 19*(2), 259-266.

Warsa, A., Hariyadi, J., & Astuti, L. P. (2018, July). Mitigation of phosphorus loading from aquaculture activity by milkfish (Chanos chanos) stocking at Cirata reservoir, West Java (In Bahasa). *Jurnal Teknologi Lingkungan, 19*(2), 259-266.

Weimin, M. (2009). Development of reservoir fisheries in China. In S. S. De Silva, & U. S. Amarasinghe, *Status of reservoir fisheries in five Asian countries* (NACA Monograph No. 2 ed., pp. 3-15). Bangkok, Thailand: Network of Aquaculture Centres in Asia-Pacific.

Yem, I. Y. (2014). *Gillnet selectivity of Salmo trutta L. from two lakes in Iceland as a reference for practical application on Lake Keinji fisheries.* Iceland: United Nations University Fisheries Training Programme.