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Benefits and Risks of Grouper Sea-Ranching in Karimunjawa National Park, Indonesia

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M.Sc. Irfan Yulianto

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Gutachter:

1. Prof. Dr. Harry W. Palm, Aquakultur und Sea-Ranching, Universität Rostock
2. Prof. Dr. Cornelius Hammer, Institut für Ostseefischerei
3. Dr. Budy Wiryawan, Marine Fisheries, Bogor Agricultural University

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Zusammenfassung

Zackenbarsche haben eine große ökonomische sowie ökologische Bedeutung für den Lebensraum Korallenriff. Aus diesem Grund ist es kommerziell bedeutsam, die Fische besser zu verstehen. Der hohe wirtschaftliche Wert der Zackenbarsche verursachte in der Vergangenheit einen ständig steigenden Fischereidruck, was häufig mit einer Überfischung der Bestände einhergeht. Dennoch betreiben Fischer weiterhin einen hohen Aufwand Zackenbarsche zu fangen, um die ständig steigende Nachfrage zu bedienen. Verschiedene Maßnahmen wurden bereits vorgeschlagen und durchgeführt um dieser Entwicklung entgegenzuwirken. Darunter zum Beispiel Fangbegrenzungen sowie Fangverbote bedrohter Arten, die Errichtung von Schutzgebieten sowie Besatzmaßnahmen.

Das Hauptziel dieser Arbeit war es, das Potenzial sowie den möglichen Einfluss von Besatzmaßnahmen auf Zackenbarschbestände in indonesischen Gewässern zu bewerten. Derartige Maßnahmen sind ein relativ neuer Ansatz im Gebiet des Fischereimanagements und es bestehen viele Möglichkeiten diese zu verbessern, besonders im Bereich der angewandten Methodik, Technik sowie der Bewertung der vorhandenen Ressourcen. Um den Einfluss von Besatzmaßnahmen auf den Bestand zu untersuchen, ist es wichtig die Populationsbiologie der Zackenbarsche und diese beeinflussende Faktoren im untersuchten Gebiet zu verstehen. Des Weiteren ist es entscheidend, standardisierte Methoden anzuwenden um die tatsächliche Größe einer Zackenbarschpopulation im natürlichen Habitat abschätzen zu können, dabei spielt die Längenbestimmung unter Wasser eine wesentliche Rolle.

Die Feldarbeit dieser Untersuchung wurde auf der Inselgruppe „Karimunjawa" in Indonesien durchgeführt, welche im Jahre 1999 zum Nationalpark erklärt wurde, daher war es wichtig, eine Untersuchung des Nationalparkmanagement einzubeziehen. Die vorliegende Arbeit setzt sich aus vier konkreten Zielsetzungen zusammen:

1. Die Darstellung der Managementmethoden des Karimunjawa Nationalparks zur Aufrechterhaltung der marinen Ressourcen
2. Die Quantifizierung des Fehlers bei der Längenmessung von Fischen unter Wasser sowie die Verbesserung der Abschätzung der Biomasse von Rifffischen
3. Die Analyse der Größe des Zackenbarschbestandes in Karimunjawa zwischen 2005 und 2012 auf der Grundlage von Unterwasserbeobachtungen sowie Anlandungsdaten

4. Die Bewertung des Potenzials sowie der Risiken von Zackenbarschbesatzmaßnahmen zur Erhöhung des Bestandes

Um diese Teilbereiche zu beleuchten, wurde eine Studie zur Fischlängenmessung unter Wasser, eine Abschätzung des Zackenbarschbestandes anhand vorhandener Daten sowie ein Besatzexperiment mit Zackenbarschsetzlingen mit anschließendem Monitoring durchgeführt. Das Monitoring bestand aus einer Unterwasserbeobachtung, der Aufnahme von Anlandungen und einer parasitologischen Untersuchung der Besatzfische.

In der vorliegenden Arbeit konnte dokumentiert werden, dass das Management im Karimunjawa Nationalpark in dem Zeitraum von 2005 bis 2010 dazu geführt hat, dass die Akzeptanz der lokalen Bevölkerung gegenüber einiger fischereilichen Beschränkungen gestiegen ist. Dies führte dazu, dass sich das Korallenriff regenerieren konnte, was vor allem auf die Beschränkung destruktiver Fischereimethoden sowie eine verbesserte Integration der lokalen Bevölkerung in das Management der marinen Schutzzonen zurückzuführen ist. Diese Erkenntnisse zeigen, dass die Schaffung mariner Schutzzonen sowie die Regelung der Fischereimethoden das soziale Wohlbefinden sowie die politische Selbstbestimmung von artisanalen Fischereigemeinschaften verbessern kann, insbesondere wenn angemessene ökonomische, legale und partizipative Fördermaßnahmen gewählt werden. Dies ist eine Voraussetzung, um die natürlichen Zackenbarsch Vorkommen im Nationalpark, der auch Laichgebiete von höchster Bedeutung für die natürliche Ansammlung der lokalen und regionalen Zackenbarsch Populationen miteinschließt, zu beschützen und zu warten.

In Bezug auf die zweite Zielsetzung dieser Arbeit konnte festgestellt werden, dass die derzeit genutzten Methoden zur Erhebung von morphometrischen Daten von Fischen unter Wasser deutlich verbessert werden müssen, besonders wenn seltene, hochpreisige Fische Gegenstand der Untersuchung sind. Es zeigte sich, dass ein Taucher durch entsprechendes Training die Genauigkeit seiner Längenbestimmung von Fischen relativ schnell erheblich verbessern kann. Das spricht dafür, dass das genutzte Kalibrierungstraining eine zweckmäßige Methode ist um in Zukunft die Länge eines Fisches unter Wasser feststellen zu können und so eine genauere Vorstellung der Biomasse zu erlangen.

Anhand der Studie der Zackenbarschfischerei vor der Inselgruppe „Karimunjawa“ ist die Einrichtung von Schutzzonen (drei Kernzonen im Karimunjawa Nationalpark) nicht ausreichend um den natürlichen Bestand zu schützen. Es sind zusätzlich Einschränkungen der Fischerei und die Unterstützung der lokalen Bevölkerung von Nöten. Es gibt suffiziente Anzeichen, dass das Abkommen der lokalen Fischer von 2011 über die Selbstregulation des Fischereigeschirrs seinen Zweck erfüllt. Es wurde im Jahr 2012 eine signifikante Erhöhung der durchschnittlichen Biomasse sowie des gesamten Zackenbarschbestandes im Nationalpark beobachtet und es liegt nahe, dass die von der lokalen Bevölkerung und vom Park verordnete Begrenzung der Harpunenfischerei sowie die Abnahme der illegalen Fischerei die Ursachen dafür waren. Das Besatzexperiment zeigte, dass die größte Gefahr für die Setzlinge (10cm) Prädation darstellt. Auch wenn das Habitat genügend Versteckmöglichkeiten bot, waren die Setzlinge nicht in der Lage diese zu nutzen. Den künstlich reproduzierten Fischen fehlte die Adaptation an den natürlichen Lebensraum. Es konnte kein positiver Einfluss des Besatzes dokumentiert werden. Dies kann auch auf andere, von der Regierung Indonesiens durchgeführte Besatzmaßnahmen mit Fischen von 10cm (oder weniger) angenommen werden. Allerdings sind künstlich reproduzierte Zackenbarsche ab einer Größe von 15cm sehr wohl in der Lage Versteckmöglichkeiten aufzusuchen und sich so Jägern zu entziehen. Auf Grund dieser Tatsache sollten Besatzmaßnahmen nur mit wenigstens 15cm langen Setzlingen durchgeführt werden, wenn der Zackenbarschbestand eines Korallenriffs erhöht werden soll. Auf Grund unserer Kosten-Nutzen-Analyse raten wir dazu, dass die offiziell empfohlene Mindestgröße für den Besatz mit *E. fuscoguttatus*-Setzlingen von 10 auf 15cm angehoben wird.

Diese Besatzgröße bietet die beste Möglichkeit den Bestand von *E. fuscoguttatus* in Indonesien zu erhöhen. Obwohl der Besatz mit 15cm Setzlingen kostenintensiv ist (eine längere Aufzucht verursacht erhöhte Kosten und verringert die Besatzmenge), ist die Gefahr einen Großteil durch Prädation zu verlieren gering. Allerdings sollte der Besatz nur an abgeschiedenen Inselgruppen durchgeführt werden, um ein Abwandern der Tiere in andere Gebiete zu vermeiden.

In der durchgeführten Studie wurden keine metazoischen Parasiten in den Zackenbarschsetzlingen nachgewiesen. Demnach ist die Gefahr derzeit gering, Parasiten durch den Besatz mit künstlich reproduzierten Fischen in das natürliche System einzubringen. Allerdings sind viele Parasiten, die für *E. fuscoguttatus* beschrieben wurden, nicht wirtsspezifisch und können somit auch andere Zackenbarscharten befallen. Parasiten können vor allem für Marikulturanlagen problematisch sein, da häufig hohe Mortalitätsraten auftreten. Dies führte in Indonesien dazu, dass die Intensivierung der Marikultur ins Stocken geriet. Die indonesische Regierung setzt jedoch stark auf die Marikultur um der ständig steigenden Nachfrage nach Zackenbarsch gerecht zu werden. Nach der Analyse verschiedener Marikulturmethoden in Indonesien empfehle ich dringend, die Fütterungsstrategien sowie Managementtechniken zu überarbeiten und nach Alternativen zu suchen, um die Verbreitung von Parasiten sowie Massenausbrüche einzudämmen.

In Zukunft sollten weitere und systematische Studien über den Besatz mit Zackenbarschen in Indonesien durchgeführt werden, wenn derartige Maßnahmen dauerhaft in das Fischereimanagement aufgenommen und angewandt werden sollen. Auf Grundlage der vorliegenden Arbeit sind die wichtigsten wissenschaftlichen Fragestellungen um zukünftige Zackenbarschbesatzmaßnahmen in Indonesien zu optimieren: (1) Wie können Setzlinge künstlich erbrütet werden, die eine Adaptation an natürliche Bedingungen zeigen und sich so Gefahren (z.B. Prädation) eines natürlichen Ökosystems entziehen können? (2) Welche ökologischen Risiken entstehen durch Besatzmaßnahmen und die damit verbundene potenzielle Einschleppung von Parasiten sowie das Einbringen von Zuchtfischen in den Genpool einer natürlichen Population? (3) Welchen sozialökonomischen Einfluss haben Besatzmaßnahmen auf die lokale Bevölkerung? (4) Was ist die beste Methode, um den Einfluss von Zackenbarschbesatzmaßnahmen nachzuverfolgen? (5) Welchen Beitrag können Besatzmaßnahmen in Bezug auf ein nachhaltiges Management von Zackenbarschbeständen in Indonesien leisten?

Summary

Groupers play a major economic and ecological role in coral reef habitats. For this reason it is very important to study groupers more deeply. In the past, the high economic value of groupers caused fishermen to increase their fishing effort, and as a consequence groupers are often heavily exploited. Still fishermen exert high fishing effort due to the increasing of grouper demand. Several solutions have been suggested and implemented to solve this problem such as protection and regulation of overfished grouper species, the establishment of marine protected areas, and stock enhancement as a methodology to increase depleted stocks.

The overall objective of this study was to examine the potential and possible effects of grouper stock enhancement activities in Indonesia. Stock enhancement is a relatively new approach in fisheries management and needs further improvement especially on relation with the applied methods, techniques and also in view of quantifying the resources. As a prerequisite to study the potential effects of stock enhancement, it is important to understand the grouper populations in the region of interest and the stock size influencing factors. Furthermore, a standardised method to study groupers in their natural habitat, commonly known as the length estimation by underwater visual census, is also of major importance to determine actual grouper population sizes. The research was conducted in Karimunjawa Islands, Indonesia, which has been established as a national park since 1999; therefore, it is important to include a study of the established Karimunjawa National Park management strategy. There are four specific tasks in order to meet the overall objective:

1. To describe the management strategy in Karimunjawa National Park in order to protect the natural marine resources
2. To quantify the bias of fish length measurements under water and to enhance the current methodology to estimate the reef fish biomass in the natural habitat
3. To analyse groupers stock sizes in the Karimunjawa islands between 2005 and 2012, based on underwater visual census and fish-landing monitoring
4. To examine the impact of grouper stock enhancement activity, concerning the potentials and risks involved

To address the objectives, a fish length estimate underwater study, grouper stock assessment from the existing monitoring and catch recorded data, fingerling grouper release

experiments and monitoring the impact of the released fish were conducted. The monitoring consisted of underwater and fish-catch monitoring as well as parasite investigations.

This study revealed that the Karimunjawa National Park authority management over a five year period from 2005 to 2010 has improved the community support for some fishing control, promoted the recovery of coral reef habitats through restrictions on destructive fishing practices and improved the community involvement in MPA management. Monitoring programs have demonstrated some ecological improvements and reductions in destructive fishing in the park over the five year period. The findings demonstrate that MPA policies and regulations can improve the social well-being and political power of fishing communities, particularly when appropriate economic, legal and participatory incentives are provided. This is a prerequisite to protect and maintain the natural grouper stocks in the National Park, that also includes spawning aggregation sites of high importance for the natural recruitment of the local and regional grouper populations.

With regard to the second objective, it is obvious that the underwater visual census currently in use requires significant improvement, especially dealing with rare, often highly valuable fish. The different divers can improve the accuracy and precision of their estimations by training and calibration training that are relatively quickly, indicating that this is a useful method. Proving its reliability, the performance in underwater visual census (UVC) can be reliably tested and improved, and it is suggested that it is substantial to apply a useful and reliable method for future assessments of the coral reef fish biomass.

Based on the study of grouper fisheries in Karimunjawa Islands, the installation of marine protected areas alone, as exemplified by the installation of three core zones in Karimunjawa National Park, is not sufficient to protect the natural grouper populations. In addition, fishing-gear regulation and community support are required. There is enough evidence that the fishermen's 2011 agreement to self-regulate the fishing gear is achieving its purposes. It appears that the agreement to regulate the speargun fishery and the decreasing fishing pressure of illegal fishing activities, which were also affected by community support in the national park, promoted a significant increase in groupers mean biomass and stock size in 2012.

According to the experiment on grouper stock enhancement, it was found that the greatest peril for the released grouper of 10 cm length was falling immediately prey to predators in the reef habitat, even though enough space to hide was available at the release site. This was attributed to the fact that groupers of this particular size class were not experienced to survive under such field conditions. A positive impact of stock enhancement activities that used grouper of 10 cm (or less) during our experiment, and also in earlier government projects, could not be verified. Cultured grouper of 15 cm, however, seemed well capable of seeking shelter and avoiding predators. This leads to the clear recommendation that released groupers should have a size of at least 15 cm before releasing them in stock enhancement programmes in coral reef habitats. According to our experiments the so far officially recommended minimum size of release (10 cm) is therefore too low and should be increased to 15 cm for *E. fuscoguttatus*. Hence the future adjustment of the official recommendations in use is required.

Based on the costs and benefits analysis of grouper stock enhancement, the best option for stock enhancement and sea-ranching of *E. fuscoguttatus* in Indonesia is the release of 15 cm of juvenile fish. Although the release of 15 cm *E. fuscoguttatus* is more expensive and produces lower direct benefits through higher costs involved and lower released numbers, the uncertainty of a significant fish loss through predation is much lower. Nevertheless, to avoid the migration of fish from the selected sea-ranching release site into other areas, this activity should be best conducted at remote island areas.

No macro-parasites could be observed during the parasitological investigation of young groupers before the release experiment was done. Thus it limited the risk of spreading parasites and diseases within the Indonesian archipelago trough releasing cultured fingerlings. However, many parasites of *E. fuscoguttatus* are widespread and can infect different grouper species. The parasite infection can cause parasite diseases and create constrains to the grouper mariculture intensification program which is the main program of Indonesian Government to increase grouper production in order to meet the increased grouper demand. Based on the analyses of different grouper mariculture methodologies that are used in Indonesia, it is strongly recommended to search for alternative feeding strategies and management techniques in the grouper mariculture that prevent parasite spreads and outbreaks.

In the future, systematic research on a broad scale should be conducted if stock enhancement and sea-ranching stand a chance to be implemented and used as a regular tool for grouper fisheries management in Indonesia. Based on the present study, suggested future research activities are : a. the production of “educated” small size (fingerling) groupers that are ready for release and adapted to natural environmental conditions such as predators, b. a better knowledge on the negative impact of stock enhancement programmes on parasite transmission, the introduction of mariculture fish to natural populations, and other ecological effects caused by the grouper release, c. the social impact of stock enhancement to local people behaviour, d. the adoption of the best appropriate methods to monitor the impact of grouper stock enhancement, and e. monitoring the contribution of stock enhancement to the improvement of grouper fisheries management in Indonesia.

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I. Campbell SJ, T Kartawijaya, I Yulianto, R Prasetia, J Clifton. 2013. Co-management approaches and incentives improve management effectiveness in Karimunjawa National Park, Indonesia. Marine Policy (41): 72-79.

(*will be referred to as Campbell et al. 2013*)

II. Yulianto I, C Hammer, B Wiryawan, T Kartawijaya, S Pardede and HW Palm. 2015. Improvement of fish length estimate for underwater visual census of reef fish biomass. Journal of Applied Ichthyology 31 (2): 308-314.

(*will be referred to as Yulianto et al. 2015a*)

III. Yulianto I, C Hammer, B Wiryawan, and HW Palm. 2015. Fishing-induced groupers stock dynamics in Karimunjawa National Park, Indonesia. Fisheries Science 81: 417-432.

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IV. Yulianto I, C Hammer, B Wiryawan, and HW Palm. 2015. Potential and risk of grouper (*Epinephelus* spp., Epinephelidae) stock enhancement in Indonesia. Journal of Coastal Zone Management (18): 1.

(*will be referred to as Yulianto et al. 2015c*)

V. Palm HW, I Yulianto, S Theisen, S Rückert, S Kleinertz. 2015. *Epinephelus fuscoguttatus* mariculture in Indonesia: Implications from fish parasite infections. Regional Studies in Marine Science. In Press.

(*will be referred to as Palm et al. 2015*)

The authors' contribution to the single publication

I. Co-management approaches and incentives improve management effectiveness in Karimunjawa National Park, Indonesia. (*Campbell et al. 2013*)

SJ Campbell: Study design, data analyes, writing, editing

T Kartawijaya: Study design, field work, data processing and analyses

I Yulianto: Study design, field work, data processing and analyses

R Prasetia: Field work, data processing

J Clifton: Editing

II. Improvement of fish length estimate for underwater visual census of reef fish biomass. (*Yulianto et al. 2015a*)

I Yulianto: Study design, data processing and analyses, writing, editing

C Hammer : Study design, data analyses, editing

B Wiryawan : Study design, data analyses, editing

T Kartawijaya : Field work, editing

S Pardede : Field work, editing

HW Palm : Study design, data analyses, editing

III. Fishing-induced groupers stock dynamics in Karimunjawa National Park, Indonesia. (*Yulianto et al. 2015b*)

I Yulianto : Study design, field work, data processing and analyses, writing, editing

C Hammer : Study design, data analyses, editing

B Wiryawan : Study design, data analyses, editing

HW Palm : Study design, data analyses, editing

IV. Potential and risk of grouper (*Epinephelus* spp., Epinephelidae) stock enhancement in Indonesia. (*Yulianto et al. 2015c*)

I Yulianto : Study design, field work, data processing and analyses, writing, editing

C Hammer : Study design, data analyses, editing

B Wiryawan : Study design, data analyses, editing

HW Palm : Study design, data analyses, editing

V. *Epinephelus fuscoguttatus* mariculture in Indonesia: Implications from fish parasite infections. (*Palm et al. 2015*)

HW Palm : Study design, data analyses, writing, editing

I Yulianto : Data processing and analyses, writing, editing

S Theisen : Field work, data processing and analyses, writing, editing

S Rückert : Study design, field work, data analyses and processing , writing, editing

S Kleinertz : field work, data processing and analyses, writing, editing

1. Introduction

1.1 Marine fisheries and aquaculture

In many parts of the world the human population is concentrated along the coastal regions (FAO 2014a). Consequently, the protection of the coastal zone including its importance to provide food for the local communities is one of the main important tasks for our and future generations. Fish is one of the most important food commodities in many countries. The Food and Agricultural Organization (FAO 2014a) reported that the fish production increased in the last five decades, and reached 158.0 million tonnes in 2012. However, since 1990s, the production of capture fisheries is stagnant (Garcia and Grainger 2005). Marine capture fisheries and aquaculture contributed 79.7 and 24.7 million tonnes in 2012, respectively. It was more than 65 % of the total production of fish.

Capture fisheries and aquaculture provide both; health and wealth, because they do not only provide fish as food but also jobs for 10 million people in the world (FAO 2014a). Based on the FAO's report, the five major marine capture fisheries producers are China, Indonesia, the United States of America, Peru and Russia Federation, while the major countries for marine aquaculture are China, Norway, Chile, and again Indonesia. Hence, China and Indonesia are the leading countries that provide marine fish as food resources as well as jobs in fisheries sector for millions people in the world. However, it must be noted that these countries rely on very different conditions concerning their fisheries production, resulting from their geographical and climatic conditions.

1.2 Fisheries and aquaculture in Indonesia

Indonesia is the largest archipelago country in the world, located between two Oceans, the Pacific and Indian Ocean. It has more than 17,000 islands extending 5,120 km from East to West and 1,760 km from North to South. Indonesia´s maritime areas are approximately 5,800,000 km^2, consisting of archipelagic waters, territorial seas, and exclusive economic zones. The length of its coastline is almost 81,000 km, and covers approximately 75 % of the total areas (MMAF 2009). Indonesia is also known as the centre of the coral triangle or the "amazon of the seas", encompassing more than 86,700 km^2 of coral reefs, 24,300 km^2 of mangrove areas, 18,000 km^2 of sea grass areas and 2000 species of reef fish

(Huffard et al. 2012, Nontji 2010, Allen and Adrim 2003). Based on the existing conditions, the vast territory, high biodiversity, and enormous variations of marine natural resources result in the high potential for fisheries and aquaculture activities in Indonesian waters.

Indonesia is the highest marine fish producer behind China (FAO 2014a). The total production of the marine capture fisheries in 2012 was 5.44 million tonnes (MMAF 2013a). The annual growth rate of the fish production from marine capture fisheries between 2008 and 2013 was 3.05 %. The marine commodities from marine capture fisheries are classified into (1) large pelagics (e.g. skipjack, other tunas, billfish, oceanic sharks, and small tuna); (2) small pelagics (e.g. scads, mackerels, sardines, trevallies, engraulids, anchovies); (3) demersal and reef fish (e.g. groupers, snappers, rabbit fishes, slipmouth); and (4) prawn, shrimp, other crustaceans (FAO 2006). Especially the small scale fisheries are the major contributor to the total production of marine fisheries in Indonesia. In 2006 the small scale fisheries contributed 94.6 % of the total marine capture fisheries production (FAO 2006). Although the large scale fisheries industry provides less contribution to the total production, the large scale fisheries targets specifically the high value fish. Hence, the fisheries industry significantly contributes to a higher amount to the economic value than the small-scale fisheries production.

A total of 616,690 fishing boats operated in Indonesian waters in 2012, most of them belonging to the small-scale fisheries. The number of boats which were non-powered boats, outboard motor, and inboard motor (less than 5 GT) was 90.1 % from the total fishing fleet in Indonesia (MMAF 2013a). The number of fishing gears operated in Indonesian waters was 1,060,449 units in 2012. As the small-scale fisheries is predominant in Indonesia, the most frequently used fishing gears of Indonesian fishermen are hook and lines, traps, beach seine, lift net, and gillnet (MMAF 2013b). Taking into consideration the vast water area, the high fisheries potential and its direct link to the coastal communities, the government of Indonesia through the Ministry of Marine and Fisheries affairs has the responsibility to manage the fisheries sector very well. To optimize the fisheries management in Indonesia, the Ministry Marine Affairs and Fisheries (MMAF) divided the Indonesian marine waters into eleven fisheries management areas (Fig. 1-1). Within each fisheries management area, the MMAF developed a fisheries management plan to guide all of stakeholders in the implementation of fisheries management in the respective fisheries management area. In addition, the MMAF also divided the marine waters of Indonesia into several fishing zones to reduce the conflict between the different fishing gears in use.

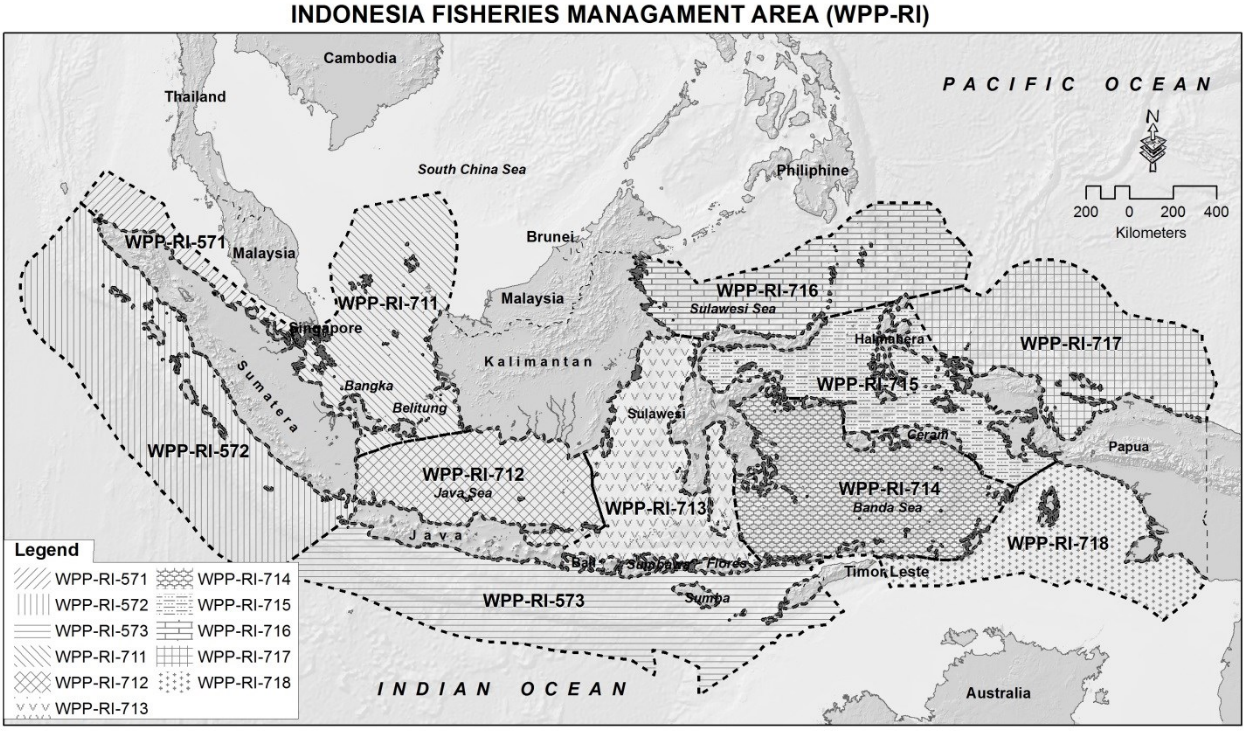

Figure 1-1. The fisheries management areas (FMA) also called as WPP in Indonesian waters are divided into 12 WPP

To assist the MMAF in fisheries resources management, the Government of Indonesia established the National Commission on Fish Stock Assessment to determine the potential and the level of exploitation of marine capture fisheries in Indonesia. Based on the study conducted by the commission in 2011, the potential of marine capture fisheries in Indonesia was 6.52 million tonnes per year. The study also discovered that the level of exploitation was over-exploited for shrimp in most fisheries management areas, moderate to over exploited for demersal, small pelagic and large pelagic fish (Table 1-1) (MMAF 2011).

Similar to marine capture fisheries, Indonesia also has a high production of marine cultured finfish after Norway, China, and Chile, with the total production in 2012 of 582,100 tonnes (FAO 2014a). Marine cultured finfish commodities in Indonesia are dominated by groupers, milkfish, and giant sea perch (MMAF 2013b). Besides finfish, Indonesia is one of the top producers for seaweed after China, and marine cultured crustaceans' producer after China, Vietnam, and Thailand. The total production of seaweed and crustaceans in 2012 was 6,514,800 t and 387,700 t respectively (FAO 2014a). Still, the annual growth rate from marine culture production is high. Especially seaweed and groupers most recently reached 32 % and 30 % respectively (MMAF 2013a).

Table 1-1. The exploitation rate of each group of fish in all Indonesian fisheries management areas (Source: MMAF 2011)

Fisheries Management Area	571 Malacca Strait and Andaman Sea	572 India Ocean (west) and Sunda Strait	573 Indian Ocean (south), Sawu Sea, Timor Sea (west)	711 Karimata Strait, Natuna Sea and South China Sea	712 Jawa Sea	713 Makassar Strait, Bone Bay, Flores Sea, and Bali Sea	714 Lolo Bay and Banda Sea	715 Tomini Bay, Maluku Sea, Halmahera Sea, Seram Sea, and Berau Bay	716 Sulawesi Sea and Northern Halmahera Waters	717 Cendrawasih Bay and Pacific Ocean	718 Aru Sea, Arafuru Sea, and Timor Sea (east)
Shrimp	Overfished	Overfished	Overfished	Overfished	Overfished	Overfished	Not Available	Overfished	Not Available	Overfished	Overfished
Demersal	Moderately Exploited	Moderately Exploited	Fully Exploited	Moderately Exploited	Moderately Exploited	Overfished	Moderately Exploited	Fully Exploited	Fully Exploited	Fully Exploited	Overfished
Small Pelagic	Moderately Exploited	Overfished	Moderately Exploited	Moderately Exploited	Moderately Exploited	Moderately Exploited	Moderately Exploited	Moderately Exploited	Fully Exploited	Fully Exploited	Fully Exploited
Skipjack Tuna	Fully Exploited	Fully Exploited	Fully Exploited	Not Available	Not Available	Fully Exploited	Fully Exploited	Fully Exploited	Fully Exploited	Fully Exploited	Not Available
Yellowfin Tuna	Not Available	Moderately Exploited	Moderately Exploited	Not Available	Moderately Exploited	Overfished	Overfished	Overfished	Overfished	Overfished	Not Available

Legend: Not Available; Moderately Exploited; Fully Exploited; Overfished

Brackishwater ponds, net cages, and floating net cages are common aquaculture practices to culture marine finfish and crustaceans. As for seaweed, the fish farmers are use floating bamboo, long line, and bottom line techniques. There are large available areas for pond or aquaculture installations in Indonesia. The available areas for ponds are 2,963,700 ha, while the existing ponds in Indonesia are 657,300 ha which comprise only 22 % from the total available areas. The available areas for seaweed or finfish aquaculture installations are 12,545,100 ha and the existing areas that have been used as aquaculture areas are only 178,400 ha or comprise 1.4 % from the total available areas (MMAF 2013a). However, it must be kept in mind that an entire cover of all available potential aquaculture sites might have effects onto other fisheries activities in the region.

To support aquaculture in Indonesia, MMAF has developed several agencies to fulfil the needs of the fish farmers. The aquaculture research institutions serves as hatchery centres, fish diseases laboratories, post-harvest centres, etc. Eight marine and brackish aquaculture agencies as local technical units of MMAF were developed in several provinces to ensure the availability of fingerlings for the fish farmers in Indonesia. Significant increase in aquaculture industries both in Indonesia and worldwide coherently increases the demand for fingerlings supply. Currently, aquaculture research institutions and also fish farmers in Indonesia receive fingerling supply also for other countries such as Singapore, Malaysia, Vietnam, Thailand, Taiwan, Hong Kong and China (Sugama et al. 2013).

1.3 The history of fisheries and marine aquaculture development in Indonesia

The total production of the capture fisheries in Indonesia reached 5.44 million tonnes in 2012 (Fig 1-2), which was more than fifteen times of that of the early years of independence in 1950, more than seven times of that of the beginning of the New Order Era in 1966, and one-half time of that of the Reform Era in 1998 (Comitini and Hardjolukito 1983, MMAF 2002, MMAF 2013a). Rapid development of the marine capture fisheries in Indonesia started in the late of 1960's (Comitini and Hardjolukito 1983) at the New Order Era when the fisheries management was centralized (Satria and Matsuda 2004). Prior to the New Order Era, before and after independence, several programmes have been implemented by the Dutch and Indonesian Governments to develop marine capture fisheries in Indonesia.

However, the programmes implemented before the independence until the early years of the independence did not succeed as intended (Comitini and Hardjolukito 1983). Significant development of marine capture fisheries was recorded before the New Order Era since 1951. The total production of marine capture fisheries doubled from 324,000 tons to 628,000 tons between 1951 and 1967 (Fig. 1-2), as well as the number of fishermen. However, a significant development only occurred in Malacca Strait so that Krishnandhi (1969) concluded that the overall development of marine capture fisheries in Indonesia during 1951 and 1967 was low.

Motorization of the fishing boats and the commercial fisheries development during the beginning of the New Order Era influenced the fast development of marine capture fisheries (Comitini and Hardjolukito 1983). A boat motorization programme was implemented to improve the small-scale fisheries because more than 95 % of all boats were without engines. However, the boat motorization programme could not solve the main problem of the fishermen; poverty (Stanford et al. 2014). The poverty of fishermen was not only caused by capital weakness (engine) but also of social and cultural reasons, which were not touched by the governmental programmes. Besides a motorization programme to improve small-scale fisheries, the Government of Indonesia developed fisheries facilities such as landing piers, auction halls, and fish markets. To stimulate commercial fisheries, the Indonesian Government stipulated the Foreign Investment Act in 1967 and the Domestic Investment Act in 1968 as well as bilateral and multilateral loan agreements to support the development of commercial fisheries in this era. Moreover, the introduction of trawls in the western part of Indonesia also influenced the fast development of marine capture fisheries. Trawl fishing was introduced by Thai and Malaysian trawler because the trawler intended to expand their fishing grounds due to depleted demersal fisheries in the Gulf of Thailand (Bailey 1997, Heazle and Butcher 2007) and high abundance of shrimp in Indonesian waters. The extended jurisdiction of Indonesian waters to 200 nm as an implication of the UN Convention on the Law of the Sea in 1982 also provided the opportunity to the Government of Indonesia to cooperate with other countries to exploit the fisheries resources.

The trawlers entered Indonesia based on several agreements with the Indonesian Government and companies to operate the trawl fisheries in Indonesian waters under the Investment Act (Heazle and Butcher 2007). The expansion of trawling induced the decrease of fisheries resources in Indonesia and also created a conflict with small scale fishermen in the Java Sea and the Malacca Strait, as both areas were the main fishing grounds of the trawl fishery (Bailey 1997). As a result, the Government of Indonesia totally banned trawl operations in 1980 by the Presidential Decree number 39/1980 because previous zoning regulations of trawl operations were not complied by the trawlers (Bailey 1997). The following increase of the catch rates per hour of research vessel operations (CPUE=catch per unit effort) in the northern Java waters indicated a positive impact of the fishing ban regulation. The increase of the demersal fish catches rate and the number of small-scale fishermen was also recorded in Malacca Strait. Due to the trawl ban regulation, trawls were from then on only allowed to operate in the exclusive economic zone (EEZ) in the Arafura Sea and the South China Sea and the trans-boundary area by Presidential Decree number 85/1982.

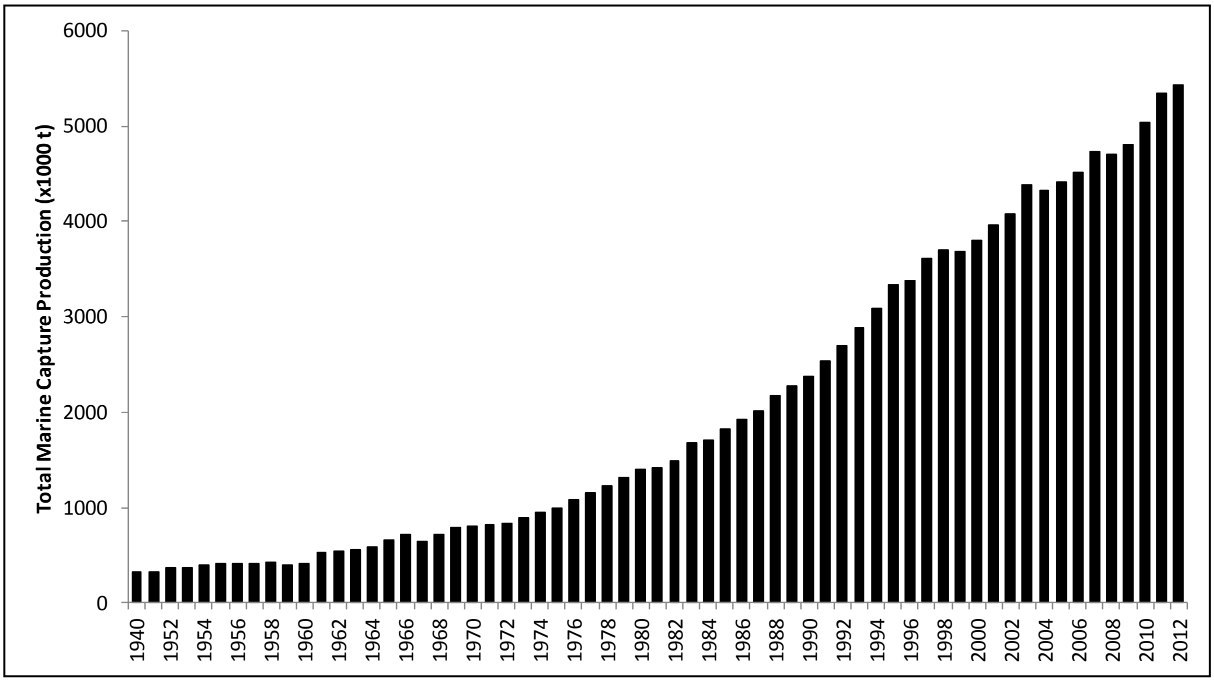

Figure 1-2. Marine captured fisheries production in Indonesia from 1940 to 2012 (sources: Comitini and Hardjolukito 1983, MMAF 2002, MMAF 2013a)

After the trawl ban regulation came into force, the marine capture fisheries in Indonesia shifted to the purse seine fisheries and tuna fisheries (Martosubroto 1987). The purse seine was introduced in the late of 1960's in the northern Java waters. Purse seine fisheries did not pose a conflict with the small-scale fisheries and the purse seine could be developed in harmony with the small-scale fisheries. Though a couple of conflicts were recorded between purse seine fishermen and gillnet fishermen, the overall number of conflicts was reduced.

Beside purse seine, the live reef fish trade (LRFT) was also introduced to the small-scale fishermen in 1980s (Davis 2001, Sadovy et al. 2003). Prior to 1980s, coral reef fisheries for LRFT were only found in the Philippines and China (including Hong Kong) (Davis 2001). Degradation of coral reef ecosystems and depleted reef fish resources in the Philippines and China led to the expansion of the fishing grounds to the Indonesian coral reef ecosystem, moreover, the demand of live reef fish increased (Davis 2001).

Introduction of the LRFT in Indonesia led to an increase of the grouper production. The grouper production increased more than two-fold from 1981 to 1987 (SEAFDEC 2014). Moreover, Indonesia contributed up to 60 % to the total live coral reef fish production in Southeast Asia between 1991 and 1995 (Bentley 1999). Fishermen in Indonesia used handlines, traps, and poison to catch live coral reef fish. Apart from its impact on the increase of grouper production, the introduction of LRFT in Indonesia created new problems in the region. As earlier recorded from China and the Philippines, along with the coral reef degradation and depletion of the coral reef fish, the fishermen often used destructive fishing methods such as poison (Erdmann and Pet-Soede 1997, Tadjuddah 2012) to catch live reef fish, particularly groupers. This had consequences for the coastal fisheries resources, and produced further conflicts among the artisanal fishermen.

In 1998, a shift of policy in Indonesia occurred, when the Reform Era replaced the New Order Era. The shift of the government policy also influenced the development of the capture fisheries (Satria and Matsuda 2004). In the New Order Era, the fisheries management was centralised since the local government had no sufficient jurisdiction and enforcement. Although the central government delegated several authorities to the local government on fisheries management, the local governments could not employ their authorities because at the end, all final decisions were made by the central government (Satria and Matsuda 2004). In the Reform Era, especially after the Indonesia Government stipulated the Local Government Act in 1999 (also known as the Autonomy Act), the fisheries management shifted from centralised to decentralised. By means of the Autonomy Act, the local government gained jurisdiction to the fishing areas, and hence the local government acquired the authority to manage their local fisheries resources. The local governments also had the ability to stipulate the local regulations on fisheries management based on the local and community needs.

The shift of the government policy in 1999 did not only influence the decentralisation of the fisheries management but also influenced the strengthening of national institution. In the New Order Era, the national institution of fisheries management was the Directorate General of Fisheries which was under the Ministry of Agriculture. Then, in the Reform Era, the Government of Indonesia established a new institution at the ministerial level that had the authority related to the marine resources; the Ministry of Marine Exploration. Then, the Ministry of Marine Exploration changed into Ministry of Marine Affairs and Fisheries (MMAF). The Government of Indonesia paid more attention to the fisheries sector and recognised the fisheries resource as very important for the future development. Of course this also impacted the capture fisheries development in Indonesia. Following the establishment of the MMAF, the Government of Indonesia placed more effort into the development of the marine capture fisheries, by means such as the development of management plans for the fisheries management areas (FMA), the development of a marine capture fisheries management as well as the establishment and strengthening of several research and training agencies. Moreover, community participation and public service on fisheries management were improved after the establishment of the MMAF (Suseno 2004).

In recent years, the sustainability of fisheries resources became an issue for the Indonesian fisheries management. It is not only focusing on the exploitation of the fisheries resources, but also on the sustainability of the exploitation of these resources. Several strategies and approaches have been implemented to address the sustainability issue in the fisheries management such as the declaration of marine protected areas, collaborative management, and ecosystem approaches to the fisheries management. The government of Indonesia expected that the development of marine protected areas (MPAs) in Indonesia could solve the problem of the foreseen collapse in marine fisheries (Wiadnya et al. 2011). Several coastal and marine areas in Indonesia have been declared as marine protected areas e.g. Karimunjawa National Park, Savu Sea National Park, and Gili Trawangan Recreational Marine Park (Yulianto et al. 2013a). MPAs declared by the central government frequently faced problems with the local community and fisheries users (e.g. compliance of zoning regulation). To overcome this problem, the authority of the marine protected areas was challenged to design an accepted and consequently effective management approach (Wiadnya et al. 2011).

The sustainability issue also led MMAF to establish a strategy to increase the fisheries production without increasing the fishing pressure and fishing effort due to limitations of the natural fisheries resources. The main answer was the development of marine aquaculture activities that should reduce the fishing pressure, provide more jobs in the fishing sector and increase production and rural development. Contrary to the history of inland aquaculture in Indonesia that dates back to the 15th century, aquaculture for marine finfish and seaweed or mariculture is a relatively new sector in Indonesia (Rimmer et al. 2013). Some of the developed mariculture commodities are seaweed and finfish. The production of cultured seaweed increased significantly since 2005, and reached more than 6 million tonnes in 2012 (Fig. 1-3), mainly of cultured seaweed *Kappaphycus* and *Eucheuma* (MMAF 2013a, Rimmer et al. 2013).

The most popular commodity for mariculture of finfish in Indonesia is groupers besides barramundi, Asian seabass, snappers and milkfish (DGA 2013). In the 1990s, the mariculture of groupers started out as capture-based aquaculture, where the fish farmer collected the seed from the wild and fed the fish with trash fish (Pomeroy et al. 2002). Capture-based aquaculture is usually called a "grow out system", regularly found in the areas of Aceh, North Sumatra (Nias and Sibolga), Riau Islands, Bangka Islands, Lampung, West Java, Karimunjawa Islands (central Java), Teluk Saleh, (West Nusa Tenggara), South Sulawesi, North Sulawesi and Southeast Sulawesi (Pomeroy et al. 2002).

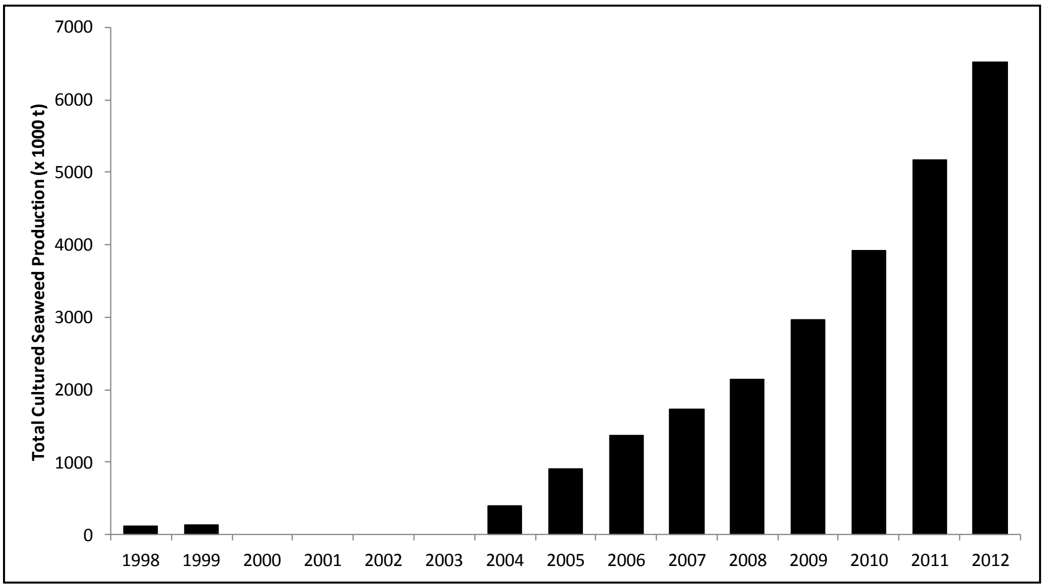

Figure 1-3. Seaweed production in mariculture in Indonesia from 1998 to 2012 (Source: MMAF 2013a, FAO 2014a)

The production of cultured groupers fluctuated from 1999 to 2007, and then steadily increased until 2012 (Fig. 1-4). However, the mariculture of groupers increased significantly since 2001, when the aquaculture agency of the MMAF and private hatcheries provided enough fingerling fish for the commercial mariculture (Pomeroy et al. 2002, Sugama et al. 2013). It seems that the hatchery development was the most influencing factor of the mariculture development in Indonesia, and this not only for grouper but also for shrimp and milkfish. The hatchery study in Indonesia started in 1987 (Mayunar 1993) and developed in 1988 to fulfil the demand of shrimp seed. Later the hatchery started to develop fingerling production of milkfish in 1995 (Siar et al. 2002). Since 1997, the shrimp seed production decreased in line with the decrease of tiger shrimp hatchery number due to white spot disease problem caused by virus (Kontara et al. 2009, Rimmer et al. 2013). From the late of 1990s, the hatcheries started to produce grouper fingerlings, followed by the successful development of hatchery research for mass fingerling production of groupers in early 2000s, which was initiated by the Aquaculture Agency in Gondol (Bali), Lampung, and Situbondo (East Java) (Siar et al. 2002, Sim et al. 2004).

The success of the Aquaculture Agency was replicated by several private hatcheries, so that the supply of grouper fingerlings nowadays can be maintained through several private hatcheries around Indonesia (Pomeroy et al. 2002). The number of hatcheries increased significantly from 5 in 1999 to 123 in 2001 (Kawahara and Ismi 2003 in Sim et al. 2004). The fast increase of hatcheries was started by the development of small-scale “backyard” hatcheries with low capital costs and short capital payback time (less than 1 year) (Rimmer et al. 2013). Over-production of grouper fingerlings in 2001 caused by the blooming sector and increasing number of hatcheries influenced the price of grouper fingerlings, and the number of hatcheries decreased subsequently to 67 in 2002 (Sim et al. 2004). However, the fingerling production of grouper still increased. Indonesian hatchery centres became fingerling suppliers for other countries such as Singapore, Malaysia, Vietnam, Thailand, Taiwan, Hong Kong and China (Sugama et al. 2013).

Currently the Government of Indonesia focuses on the expansion of mariculture areas as well as cultured species diversity due to the great potential of mariculture areas (DGA 2013, Rimmer et al. 2013). The Government of Indonesia now engages the public and private sector to develop mariculture in Indonesia due to their role concerning the investment and community development (Sari 2010). Another issue concerning the expansion of mariculture in Indonesia addressed is the environmental sustainability (Sari 2010, Rimmer et al. 2013).

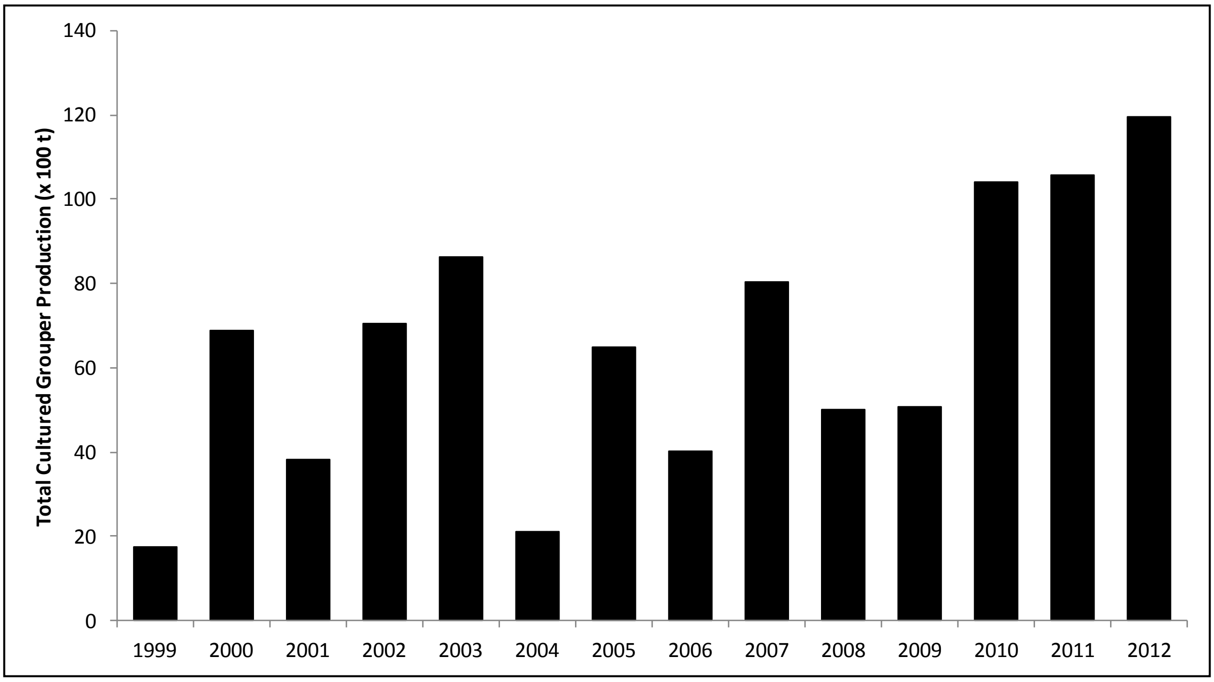

Figure 1-4. Cultured grouper production in Indonesia from 1999 to 2012 (Source: MMAF 2013a, SEAFDEC 2014)

1.4 Grouper (family Epinephelidae)

The family of Epinephelidae was recently established as an own family. Previously, the sub-family Epinephelinae was part of the family Serranidae. Smith and Craig (2007) resurrected the Epinephelidae as a new family based on the genetic analysis of its members. Groupers have a wide body and a large head and mouth with three spines in operculum, three spines in front of anal fin, one spine on pelvic fin, and complete-continuous Literal line without reaching onto caudal fin; however their sizes vary greatly from 18 cm for *Cephalopholis leopardus* to 300 cm for *Epinephelus lanceolatus* (Heemstra and Randall 1993, Pears 2005, Nelson 1994, Froese and Pauly 2014). Most groupers have a long life cycle and slow growth rates (Anahita 2009, Heemstra and Randall 1993). The family Epinephelidae consists of 163 members belonging to 16 genera. 58 members belonging to 8 genera are found in Indonesia (Allen and Adrim 2003, Craig et al. 2011). The genera of groupers recorded from Indonesia are *Aethaloperca*, *Anyperodon*, *Cephalopholis*, *Cromileptes*, *Epinephelus*, *Gracila*, *Plectropomus*, and *Variola* (Allen and Adrim 2003).

1.4.1 Ecology

Groupers are demersal fish found in tropical and subtropical waters (Heemstra and Randall 1993). The groupers' habitat is mostly coral reef, but few of them occur also in estuaries or rocky reef (Heemstra and Randall 1993). Groupers are particularly associated with certain coral reef habitat types and particularly found in massive coral areas (Madduppa et al. 2012). Larger groupers tend to occur in deeper water around 200 m depth (occasionally 500 m), while juveniles of many groupers species occur in shallow waters, such as mangroves, sea grass beds or estuaries (Heemstra and Randall 1993, Leis 1987 in Anahita 2009, Brule et al. 2004). Grouper eggs and larvae are pelagic and the larvae preferentially distribute in the continental shelf waters rather than the oceanic zones (Leis 1987 in Anahita 2009).

Groupers are predators and only few species are adapted to feed on plankton. Groupers prey usually on a variety of fish, larger crustaceans, and cephalopods (Heemstra and Randall 1993). Groupers usually swim to search for their prey, hiding between the coral reef and rock area until fish or crustaceans cross the area, then the groupers catch their prey with a quick rush (Heemstra and Randall 1993). Belonging to the top predators, groupers can be used as indicator organisms for coral reef fish populations and assemblages (Eggleston et al. 1997, Almany 2003, Almany and Webster 2004).

Most groupers are protogynous hermaphrodites, i.e. they are born as female and change their sex from female to male (Ferreira 1993). Groupers spawn before they change from female into male in certain spawning aggregation sites of coral reefs (SPAGS) (Heemsta and Randall 1993). The SPAGS usually share the shame characteristic, thus location of these areas can be predicted within the coral reef areas (Pet et al. 2005). During the spawning time, groupers gather at the spawning sites and present specific characteristics that indicate the mating season,e.g. by colour change (Johannes et al. 1999, Pet et al. 2005).

One of important grouper habitats in Indonesia is Karimunjawa Islands, which have a coral reef ecosystem in good condition (Nababan et al. 2010). The Karimunjawa islands, located in the Java Sea, consist of 27 small islands and include Karimunjawa National Park, which has a total area of 1116 km^2, including 22 islands. The national park is recognized as one of effective national parks in Indonesia to maintain coral reef ecosystems after the re-zoning process in 2005 (Ardiwijaya et al. 2008, Campbell et al. 2013) and divided into zones, including the core zone, protected zone, tourism zone, rehabilitation zone, aquaculture zone, and traditional fisheries or utilization zone. In 2005, the core zone was established around known groupers spawning aggregation sites in order to protect the spawning stock and enhance the productivity of the groupers fishery.

Groupers species found in Karimunjawa Islands have a low diversity and are evenly distributed across the region. According to Mujiyanto and Sugianti (2014), only seven species were found in Karimunjawa Islands. However, Muttaqin et al. (2013) listed 26 species of grouper in Karimunjawa Islands. Six spawning aggregation sites of grouper were identified (Kartawijaya et al. 2010). Groupers conduct a spawning activity during new moon period (Kartawijaya et al. 2010). Grouper ecology and distribution in Karimunjawa Islands were influenced by physical and chemical factors, fishing activities, and other human activities (see Mujiyanto and Sugianti 2014).

1.4.2 Fisheries and mariculture

Based on the Food and Agricultural Organization of the United Nations (FAO) data, the total catch of grouper increased by 25 % between 1999 and 2009 and increased by more than 17 times between 1950 and 2009, responding to the increase in demand (Sadovy et al. 2013). Indonesia is one of the countries in the Asian region that plays an important role in grouper supply (Johnston and Yeeting 2006, Pet-Soede et al. 2004). According to the fisheries statistics (MMAF 2002), the groupers production from capture fisheries in Indonesia was 15,800 t in 1990 and increased to more than the double in 2000, reaching 48,400 t. In 2012, grouper catches reached 92,200 t or more than 5 times within two decades (MMAF2013b).

Grouper fisheries in Indonesia based on the purpose of trading are divided into two types, the live reef fish trade (LRFT) and local trade. Groupers fisheries for LRFT is usually for high economic value, and consist of groupers such as squaretail coral grouper (*Plectropomus areolatus*), camouflage grouper (*Epinephelus polyphekadion*), and brown-marbled grouper (*Epinephelus fuscoguttatus*), which are caught alive (Sadovy 2005), mostly related to artisanal and small-scale fisheries in the Pacific Ocean (Rhodes and Tupper 2007). Groupers caught in dead condition by regular fisheries are landed at the fish landing sites or the fish auctions are called grouper fisheries for local trade. Most of grouper genera found in Indonesia are regularly caught by the fishermen. However, the fishermen receive high economic values only through the LRFT (Erdmann and Pet-Soede 1997).

Fishermen employ handline, longline, trollline, trap, speargun, and cyanide (poison) to catch groupers. Specifically for trap, trolling line, and poison, fishermen employ these gears to catch live groupers for LRFT (Habibi 2009, Yulianto et al. 2013b, Pet and Pet-Soedoe 1999). Speargun is the most affective fishing gear to catch grouper for consumption. The gear is efficient since some grouper species are easily caught using speargun especially during night time (Hamilton et al. 2005). In addition to the previously mentioned gears, Yulianto et al. (2013b) found that groupers are also caught by muroami, encircling gillnet, and purse seine as by-catch. Fishermen usually catch groupers in SPAGS during spawning seasons, which is a combination that increases the general vulnerability of natural grouper stocks (Heemstra and Randall 1993, Sadovy et al. 2013).

Beside marine capture fisheries, mariculture is important to supply the grouper demand. MMAF announced that the demand on grouper is still increasing, leading to an increasing fishing pressure on groupers, promoting the grouper production from aquaculture (Masnun 2013). Mariculture of groupers increased significantly since 2001 (see above, chapter 1.3). Its production is doubled from 2009 to 2010 and reached 11,950 t in 2012 (MMAF 2013a). The significant increase of production is enhanced by an increasing supply of fingerlings from the aquaculture agency of the MMAF and private hatcheries (Pomeroy et al. 2002, Sugama et al. 2013). Grouper species cultured in Indonesia are orange-spotted grouper (*Epinephelus coioides*), spotted coralgrouper (*Plectropomus maculatus*), leopard coralgrouper (*Plectropomus leopardus*), duskytail grouper (*Epinephelus bleekeri*), humpback grouper (*Cromileptes altivelis*), and brown-marbled grouper (*Epinephelus fuscoguttatus*) (WWF 2011).

Before the hatchery was well developed in Indonesia, fishermen in Indonesia raised groupers that were captured from the natural population. Capture-based aquaculture, well known as grouper grow-out culture, can be found in the areas of Aceh, North Sumatra (Nias and Sibolga), Riau Islands, Bangka Islands, Lampung, West Java, Karimunjawa Islands (central Java), Teluk Saleh, (West Nusa Tenggara), South Sulawesi, North Sulawesi and Southeast Sulawesi (Pomeroy et al. 2002). Fishermen use trap and line to catch the grouper fingerlings and sell the seed to mariculture. Later, the groupers are placed into net cages or pen cages based on their size classes (Ottolenghi et al. 2004). Fishermen use trash of fish to feed groupers in the grow-out culture (Pomeroy et al. 2002).

1.4.3 Stock enhancement and sea-ranching

The most recent development to develop grouper fisheries and aquaculture is stock enhancement and sea-ranching, that started in Indonesia in 2011. The release of cultured fish into the natural populations can be distinguished by three main objectives, a. restocking, b. stock enhancement, and c. sea-ranching (Bell et al. 2008). Restocking is the release of cultured fish into the natural population to recover depleted fish populations. Stock enhancement is the release of cultured fish into the natural populations to enhance the supply of juveniles. Sea-ranching is the release of cultured fish into unenclosed areas to harvest at a later time. The history of stock enhancement already started in 1762, when a traditional river seed system was developed in Japan to enhance salmon stock (Masuda and Tsukamoto 1998). The history of marine stock enhancement developed more recently but also in Japan in 1962 (Masuda and Tsukamoto 1998). Then, the number of countries implementing successful marine fish stock enhancement rose in the 1990s (Bell et al. 2008), such as New Zealand for the southern scallop fishery (Lorenzen 2008), Western Australia for shrimp (*Penaeus esculentus*) (Loneragan et al. 2006), and Japan for finfish (Masuda and Tsukamoto 1998, Kitada and Kishino 2006). In 2010, the Indonesian Government through the Ministry of Marine Affairs and Fisheries announced a new and ambitious policy on the fisheries sector to increase the fish production by more than 300 % by 2014, to make Indonesia the world´s largest fish producer (MMAF 2010a). Several programmes have been developed and implemented to reach the goal, e.g. aquaculture intensification, marine protected areas establishment, and fish stock enhancement. The latter programme, in particular, was conducted by the release of cultured fish into the natural populations. Prior to 2010 in Indonesia, the release of cultured fish to enhance fish stock was known only for freshwater fish or inland fisheries (Syafei 2005, Maskur 2002).

Following a new regulation in 2010 to create Indonesia as the world´s largest fish producer, the Ministry of Marine Affairs and Fisheries conducted stock enhancement for marine fish, one of them was grouper. The marine finfish stock enhancement project in Indonesia was named "one man one thousand fries" and the Ministry of Marine Affairs and Fisheries produced a guideline to implement that programme (MMAF 2010a). The "One man one thousand fries" project was implemented in several provinces such as North Sumatera, Kepulauan Riau, Bangka Belitung, DKI Jakarta, West Java, Central Java, Bali, East Kalimantan, Central Sulawesi, Gorontalo, North Sulawesi, and North Maluku. Besides the Ministry of Marine Affairs and Fisheries, other institutions also conducted similar activities i.e. the District Government of Seribu Islands in collaboration with the Centre of Coastal and Marine Research Study-Bogor Agricultural University in Seribu Islands and the Karimunjawa National Park Authority in Karimunjawa Islands.

1.5 Objectives

As groupers play a major economic and ecological role in coral reef habitats (Morris et al. 2000), it is important to study grouper. The high economic value of groupers influence fishermen to increase the fishing effort to catch grouper, therefore the groupers will be heavily exploited (Sadovy et al. 2013). However, fishermen still exert high fishing effort to catch groupers even though the groupers are already heavily exploited due to high grouper demand (Sadovy et al. 2013). Several solutions have been implemented to solve the problem such as protection and regulation of depleted groupers species, marine protected areas, and stock enhancement.

The overall objective of this study was to examine groupers stock enhancement in Indonesia as the stock enhancement is important for sea-ranching and a relatively new approach in fisheries management and needs further improvement especially related to the science, methodology and techniques (Bell et al. 2008). To study stock enhancement, it is important to understand the groupers natural population and the influencing factors of its population since stock enhancement is greatly influenced by these factors. Furthermore, the method to study groupers, especially the length estimation in underwater visual census, is an important methodological approach to determine groupers population. The research was conducted in Karimunjawa Islands, Indonesia, which was established as a national park since 1999. Therefore, it was important to include a study of the Karimunjawa National Park fisheries management policy into this study. Hence, there are four specific objectives in order to meet the overall objective:

1. To describe the management strategy in Karimunjawa National Park in order to protect the natural marine resources
2. To quantify the bias of fish length measurements under water and to enhance the current methodology to estimate the reef fish biomass in the natural habitat
3. To analyse groupers stock sizes in the Karimunjawa islands between 2005 and 2012, based on underwater visual census and fish-landing monitoring
4. To examine the impact of grouper stock enhancement activity, concerning the potentials and risks involved

1.6 Thesis structure

This thesis consists of eight chapters. Chapter 1 is the introduction that consists of the general information and history of Indonesian fisheries and mariculture, the general information on grouper's ecology, fisheries and mariculture in Indonesia, and the research objectives. Chapter 2 describes the Karimunjawa National Park management and the contributing factors that relate to the protection of the natural marine resources. Chapter 3 investigates the impact of length estimates training for estimating reef fish biomass. This is done in order to improve the current methodologies in use. Chapter 4 investigates the dynamics of grouper fisheries in Karimunjawa National Park from 2005 to 2012. Before any sea-ranching activity, it is important to find out the natural fish population size and its influencing factors. Chapter 5 describes the potential and risks of grouper stock enhancement in Indonesia. Because reef fish is transferred throughout the Indonesian archipelago, this might have consequences for the grouper population and mariculture activities in general. Chapter 6 investigates the impact of different management strategies to the parasite composition from different mariculture facilities in Lampung Bay and Pulau Seribu, Indonesia. Chapter 7 summarizes and elaborates the findings from the five publications into two sub-chapters, a. strategies to increase the reef fisheries production in Indonesia and b. cost benefit analysis of sea-ranching. Chapter 8 suggests future implications and research activities that are needed to further develop sea-ranching as a strategy to improve the grouper populations in Indonesia.

2 Co-management approaches and incentives improve management effectiveness in Karimunjawa National Park, Indonesia[1]

Abstract

Karimunjawa National Park (KNP) was among the first maritime areas recognized in Indonesia as being important for the conservation of marine biodiversity. Economic incentives in the KNP aim to decrease community dependency on wild-captured natural resources and achieve biodiversity and development objectives. Various participatory mechanisms facilitate community involvement in governance, whilst other incentives promoting awareness and support for fishery regulations are being delivered. Monitoring programs have demonstrated some ecological improvements and reductions in destructive fishing in the park over the past five years. The findings demonstrate that MPA policies and regulations can improve the social well-being and political power of fishing communities, particularly when appropriate economic, legal and participatory incentives are provided.

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2.1 Introduction

Karimunjawa National Park (KNP) was among the first maritime areas recognized in Indonesia as being important for the conservation of marine biodiversity. It was formally declared a Strict Natural Reserve in April 9, 1986 by the Minister of Forestry (PHKA Decree No. 123/Kpts-II/1986), and has since been declared a priority area for marine biodiversity conservation in Southeast Asia. In 1988, the Minister of Forestry declared the area a National Park and, in 1990, the park zonation plan was released. On February 22, 1999, the Karimunjawa archipelago was declared as the Karimunjawa Marine National Park, now referred to as Karimunjawa National Park under the Ministry of Forestry and Plantation Decree No. 78/kpts-II/1999. In 2001, all marine waters of Karimunjawa National Park were designated as a marine conservation area by the Ministry of Forestry Decree No.74/Kpts-II/2001. The park includes both marine and terrestrial components, including 1,101 km^2 of sea, 13 km^2 of tropical lowland forest and 3 km^2 of mangrove forest (Figure 2-1). The park includes a total of 27 islands with a resident population of around 9,000, concentrated on the islands of Karimunjawa, Kemujan, Parang and Nyamuk. The islands were first zoned into four zones (i.e. core zone, protection zone, utilization zones and buffer zones) under Director General of PHKA Decree No. 127/Kpts/DJ-VI/1989. From 2003-2005 the Karimunjawa National Park Authority (KNPA), Wildlife Conservation Society (WCS), Taka (local NGO) and the University Diponegoro conducted a spatial planning and stakeholder consultation process to revise the zoning system. The new zoning system was legislated on June 30, 2005 under the Director General of PHKA, Decree No. 79/IV/Set-3/2005. This zoning system consists of eight zones (i.e core zone, protection zone, tourism zone, aquaculture zone, rehabilitation zone, religious and historical zone, residential zone and utilization of traditional fisheries zone). Subsequently as part of the governments remit to rezone the park every 5 years, the park was re-zoned in 2012 under Director General of PHKA, Decree No. 28/IV/Set/2012 on 6 March 2012.

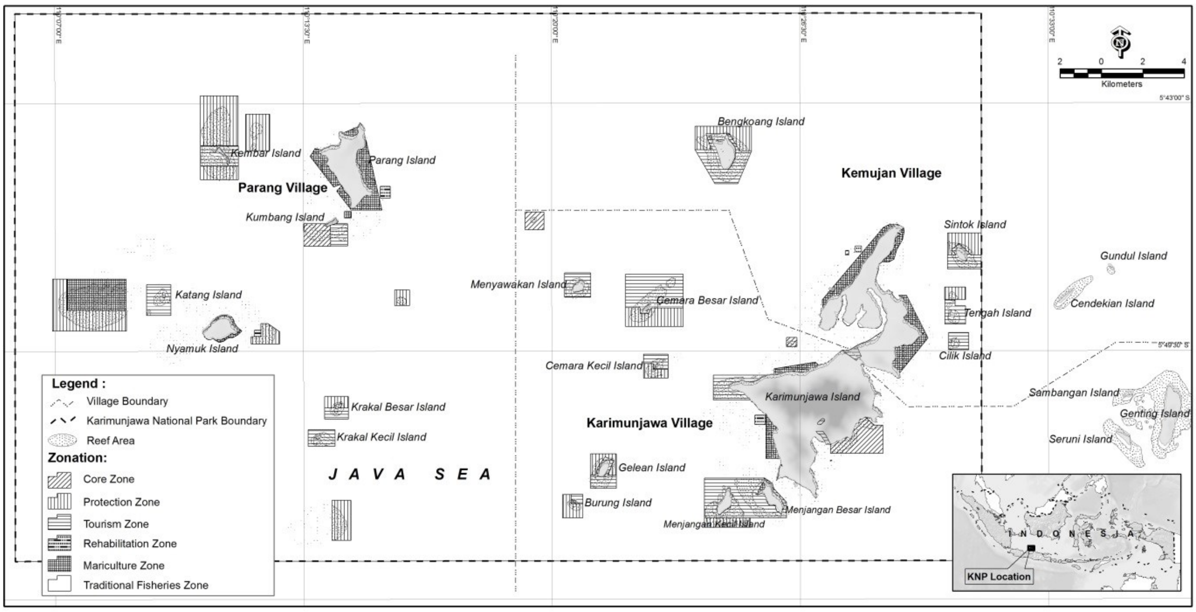

Figure 2-1 Location map and 2012 zoning plan for the Karimunjawa National Park.

The Ministry of Forestry, which retains responsibility for all of Indonesia's national parks, remains a highly centralized institution within the state government structure. However, decentralization reform and ineffective management by the KNPA since the park was established in 1999 have resulted in an increased emphasis on community involvement and participation in management activities. The need for decentralization and a more participatory approach in Indonesian coastal zone management emerged more than a decade ago (Siry 2011). These new decentralization laws provide an opportunity to recognize and institutionalize community-based management and co-management into the local and national systems of governance (Patlis 2005). The laws also promote a system of shared responsibility among the great range of stakeholders who have a vested interest in the improved management of marine and coastal resources in an archipelagic nation as large and as diverse as Indonesia. In addition, the laws recognize that local community roles must be promoted in the management of local resources.

Community involvement and participation are widely acknowledged in the literature as providing opportunities for improving natural resource management (Thorburn 2002, Crawford et al. 2004, McCleo et al. 2009). From 2003 to 2005, the KNPA conducted a spatial planning process that resulted in changes in the zones and regulations inside the park. The planning process involved consultation with a wide range of stakeholder groups and sought inputs from communities into the design and adoption of rules that impact marine resource use. Since 2005, communities have been more involved in park management including surveillance, monitoring and involvement in implementing management strategies to help reduce destructive fishing. A positive outcome of improved community participation has been the stabilization of reef fish biomass in some areas since new zoning regulations have been in place (Ardiwijaya et al. 2008).

2.2 Objectives

The revised 25 year management plan produced in 2005 defined a new vision for the park which involves the preservation of biological diversity and ecosystem types for the enhancement of public welfare and quality of life through sustainable use principles and economic development strategies. These goals and objectives are in accordance with national regulations relating to marine conservation, fisheries and small island development. The change from the 1989 zoning plan, which for the most part prioritized protection of biodiversity, reflects the need for regional tiers of government to achieve greater financial self-sufficiency in the current era of decentralization within Indonesia (Crawford et al. 2004). Key habitats are identified as priorities in the management plan comprising coral reefs, seagrass meadows, fish spawning aggregation sites, mangroves, cetaceans, water bird nesting areas and turtle nesting sites, together with undefined economically valuable marine species. Reference is made to obligations associated with the Convention on Biological Diversity and domestic Acts, foremost amongst which is Act 5/1990 relating to the conservation of natural resources and protected area management. The current zoning plan and associated regulations are illustrated in Fig. 2-1 and Table 2-1. These are used to derive management objectives consisting of effective zone management and monitoring of reefs, seagrass meadows, mangroves and fish spawning aggregation sites, together with engaging in public awareness raising exercises with local communities. The main changes to zoning in 2012, compared with 2005, included the doubling of maritime protection and tourism zones, a 42% increase in areas in mariculture zone coverage and the establishment of a zone to protect religious and historical features.

KNP. Key: ✓: permitted, *'en; p: prior permit*

	Core Zone	*Prtotection Zone (marine)*	*Prtotection Zone (terrestrial)*	*Utilization zone (terrestrial)*	*Toursim Zone*	*Traditional Use Zone*	*Mariculture Use Zone*	*Religious and Historical Zone*	*Rehabilitation Zone*	*Residential Zone*
Area covered (ha)	445	2600	1452	56	2733	100327	1371	1	68	2572
Fishing (all techniques)	x	x	n/a	n/a	p	✓	x	n/a	✓	n/a
Research	p	p	p	n/a	p	p	p	n/a	p	n/s
Boat transit only	[✓]	✓	n/a	n/a	✓	✓	✓	n/a	✓	n/a
Boat transit and anchoring	[✓]	✓	n/a	n/a	✓	✓	✓	n/a	✓	n/a
Tourism	x	x	x	n/a	✓	✓	✓	n/a	✓	n/s
Restoration and rehabilitation	x	x	x	n/a	✓	✓	✓	n/a	✓	n/s
Education	p	p	p	n/a	p	✓	✓	n/a	✓	n/s
Traditional and ritual use	p	p	p	n/a	p	✓	✓	✓	✓	n/s

Awareness raising has been implemented through village meetings, development of village forums to administer community based economic and conservation strategies, public engagement activities, establishing boundary markers around core zones and assistance with livelihood development strategies linked to community obligations to comply with zoning. Effective zone management is also directly related to enforcement through patrolling, which is constrained by availability of sufficient funding. Monthly patrols take place and increasingly are being more effective at targeting and punishing fishers who violate the zoning laws. Yet resources available to effectively patrol the park are insufficient and the KNPA have begun to advocate training for communities to become more involved in the protection of their local natural resources.

2.3 Drivers and conflicts

2.3.1 Fisheries pressure

Unsustainable large and small-scale fishing practices that deplete fish biomass and damage fish habitats represent the primary threat to biodiversity conservation within the park. Artisanal fishing is the most common activity in the KNP with 70% of the local community involved in fishing related activities. Fisheries resources have declined over the past 20 years and mariculture activities are expanding in the park (Campbell et al. 2010). Although destructive fishing practices including cyanide fishing and the use of illegal fishing gears are prohibited by park regulations, they are still practiced inside the national park and within the no-take zones. Commonly used fishing gears in the KNP include muro-ami nets (Tomascik et al. 1997), gill nets, hook-and-line, and fish traps. The number of muroami fleets, each consisting of three boats, declined from 18 in 2003 to one fleet in 2010, and presently no fleets operate and cyanide use is also declining. These changes are most likely associated with declines in catches, increasing enforcement from the marine park, incentives from the KNPA to practice sustainable fishing and changes in the economic viability of these practices. There has been an increase increase in awareness of spatial, species and gear restrictions following the rezoning in 2005 and increase in coral health throughout the park (Campbell et al. 2012). Nonetheless many fishers perceive a decline in catches over the past 5 years, some fishers still use destructive fishing methods, and 250 boats were recorded fishing in protection and core zones in 2009-10. Management controls, and in particular spatial controls on fishing, are clearly not well acknowledged by all fishers, yet an increasing understanding by fishers of the effects of overfishing and destructive fishing is most likely a key factor that drives improvements in coral reef health.

The decline in the biomass of reef fish, the weak compliance by fishers with fishery closures (Ardiwijaya et al. 2008, Campbell et al. 2012), and low densities and size of species of high commercial value are also low, indicates heavy fishing pressure (Campbell and Pardede 2006). To address the issue of declining biomass of highly valued carnivores and herbivores (Ardiwijaya et al. 2008), the government and NGOs have since 2010 initiated community and tourism development programs (eg. training for community tourism enterprises, RARE PRIDE campaign) which have resulted in new signage and marker buoys for fishery closures, and increased stakeholder awareness of fishery closures and bans on destructive fishing. These activities are the direct result of decentralization laws in Indonesia which allow more active involvement of local governments and communities in the management of the park with the aim of soliciting improvements in the biodiversity of the KNP.

2.3.2 Live reef fish trade

The live reef fish supply network that extends across the Indo-Pacific (Muldoon et al. 2005) created demand for fish such as Serranidae which are caught mainly using cyanide in the KNP. The demand came from Hong Kong markets from 2000 to 2005, with around 2500 kg caught per annum, mostly from the wild. In 2009 the domestic market centered in Java has been the primary driver for live reef fish trade. Monitoring by the KNP authorities indicates that the live reef fish catch totaled 1104 kg in 2009. The highly valued napoleon wrasse (*Cheilinus undulatus*) is protected under national law within the national park as well as being regulated under Appendix II of the CITES Convention, and is generally not fished or exported to external markets.

2.3.3 Tourism

Tourism has developed rapidly in the KNP (BTNKJ 2008), with visitor numbers increasing by a factor of 20 from 450 in 1998 to over 9000 in 2005 (Fig. 2-2). Improvements in political stability, local infrastructure and global economic factors are the likely drivers of the tourism sector. Tourism is driven mainly by the growing domestic and regional tourism markets, with foreign tourists accounting for around 12% of the total between 1998 and 2008. Tourism aims to promote sightseeing, diving and snorkeling, while educational tourism focused on sea turtles, mangroves and lowland forest and encourages the growth of tour guiding, home stays and local resorts. The latter has resulted in new buildings and resorts for accommodation and the increased use of boats for tourists. Zoning of terrestrial areas for accommodation and village infrastructure, along with the zoning of tourism in terrestrial and marine areas, aims to accommodate these activities in the park while achieving sustainable management of ecosystems. The proportion of reef habitats within marine tourism zones is 9.7% and tourism in these areas needs to be closely monitored and regulated so that activities do not damage marine habitats through anchor damage and trampling. Tourism may also increase demand for marine based food products, and demand driven improvements in access to and availability of fish markets may also deplete local fish stocks (Brewer et al. 2009).

2.3.4 Marine pollution

The impacts of pollution from domestic sewage, infrastructure and mariculture developments are likely to increase as economic development accelerates in the KNP. Water pollution from coastal development, including the construction of hotels and new village infrastructure, has increased in recent years in the KNP. Such developments often have inadequate sewage controls and nearshore marine areas may be impacted by sewage runoff. The use of cyanide to catch high value reef fish contributes to water pollution and coral habitat mortality. Since 2008, an increased awareness within local communities of the detrimental consequences of destructive fishing has reduced the incidence of these practices. The need for economic alternatives to destructive fishing and use of highly exploitative fishing gears has led to the expansion of mariculture facilities in nearshore waters, driven by a high domestic demand for seaweed, clam and reef fish. Unpublished monitoring data collected by the KNP shows annual seaweed mariculture production totaled 1151 kg in 2009. These facilities can pollute marine waters, through inputs of organic nitrogen from fish and seaweeds, causing anoxic conditions and mortality of benthic habitats. Zoning of mariculture within the KNP aims to manage, control and limit these impacts.

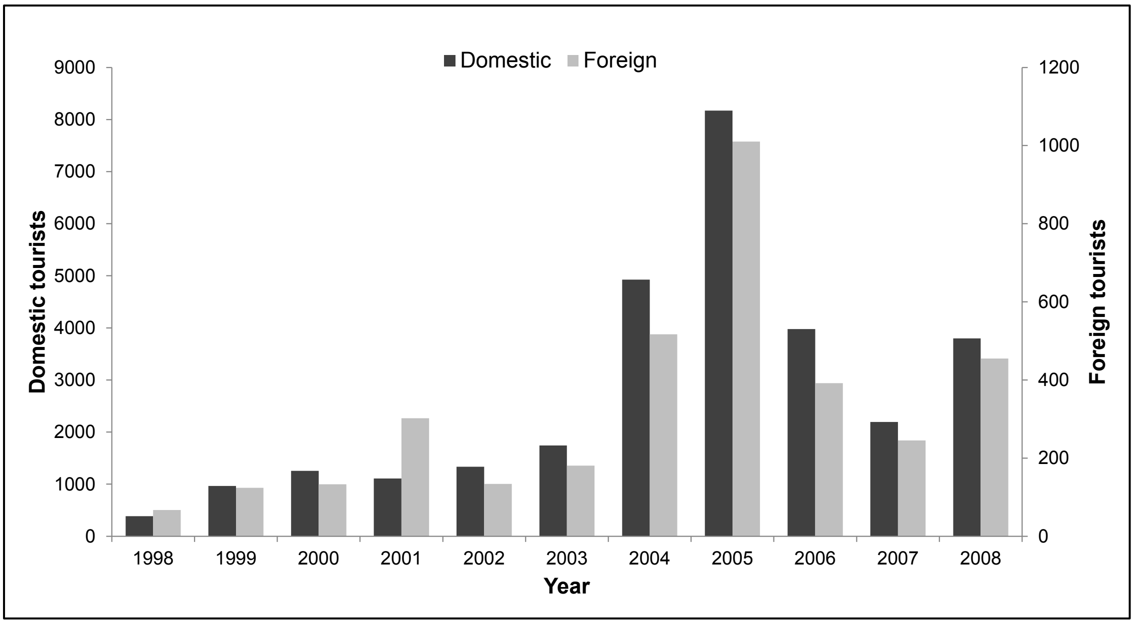

Figure 2-2 Tourism (numbers of people) in the KNP from 1998 to 2008. Source: (BTNKJ 2010)

2.4 Governance framework

Overall, the governance system in the KNP has performed weakly in relation to addressing conflicts and achieving objectives, particularly those related to legal obligations on protecting fishery resources from unsustainable and destructive practices. That being said, improvements since 2009 have occurred with a cessation of dynamite fishing, a reduction in cyanide fishing, support from communities for no take zones, fines for those caught harvesting clams and other protected species and a reduction in the use of muro-ami nets. These changes are linked to both increasing efforts of governments in improving community awareness of fishing regulations, and the perception among fishers that fisheries have been depleted and consequent support for new industries (e.g. tourism, formal employment, animal husbandry, emerging industries) that provide increased disposable income which subsistence fishing cannot support (Jennings and Polunin 1997, Turner et al. 2007). Communities with a high dependency on marine resources, such as those in the KNP, are generally more supportive of strategies that restrict fishing gears rather than fishery closures, as many fishers depend on subsistence fishing for food security more than income (Cinner 2007). In the KNP the increasing support for and adoption of gear restrictions by government and communities are also viewed as long-term investments in marine resources and alternatives to the short-term profits gained by destructive fishing and muro-ami netting. Gear restrictions may reduce the cost of fishing, increase the proportion of self-employed fishers, build up the biomass of fisheries and improve catches and the price of fish (McClanahan 2010). More success in cross-sectoral efforts by government including the KNPA and representatives from fisheries and tourism authorities is needed to fulfil legal obligations related to the park.

Governance systems that respect customary knowledge, rules and decision-making processes are more likely to be supported by local communities (Aswani 2005, Hoffman 2006, Tiraa 2006, Cinner and McClanahan 2006) and are commonplace in many Pacific societies (Aswani et al. 2007, Cinner and Aswani 2007). In Indonesia, there are relatively few cases of communities having co-management arrangements with governments in marine resource management (Glaser et al. 2010). The KNP represents an important exception as a collaborative management approach involving multiple government departments and community groups since 2007. Management outcomes have assisted local people with alternative incomes to unsustainable fishing, and have included community ranger patrols, alternative fisheries practices such as mariculture, switches in fishing gear use from destructive and exploitative net fishing to handlines, and an increase in tourism and support for the tourism industry. Such approaches by government should improve the socio-ecological outcomes for coastal communities in the KNP, whilst decentralized policies which provide greater management stewardship by local stakeholders are being developed through central government policies (Patlis 2005). These policies aim to improve food and financial security for communities and access rights to resources, both of which have benefited coastal communities elsewhere (McCleo et al. 2009, Aswani 2005).

Many of the drivers behind infringements including market pressure and demand for live reef fish are not easily addressed by national park laws and policies. Addressing such drivers requires that legislation at national and local levels in areas relating to conservation and fisheries management is effectively enforced. This in turn requires political will and increased capacity to support the implementation of existing laws. The poor implementation of national laws and policies in the fishery sector undermines the conservation objectives of the KNPA and makes the KNPA unable to control fishery resources within its jurisdiction. With recent community support for national park laws and zones, the situation is starting to stabilize with some infringements acted upon through legal processes. For example, although enforcement by government patrols has been poor in the past, since 2005 controls on the harvesting of clams and fish in protected areas are being enforced to some extent, reflecting the effect of community involvement in designing the new park rules and zones. Recently (2008-09), fishers harvesting clams and other species in no take zones have been fined, reflecting greater community support for these zones. The approach towards enforcement is evolving in response to government policies that aim to involve communities in management and reporting infringements through local community ranger patrols, with training provided by government and NGO's to support these efforts. Through support from government policies and local NGOs, community surveillance and livelihood programs such as grouper mariculture and micro-credit financing were established, which aim to reduce exploitative fishing activities and community dependency on natural resources.

2.5 Effectiveness

The effectiveness of marine park or marine spatial planning processes in Indonesia is rarely assessed or debated within the literature (Glaser et al. 2010). The KNP therefore provides an interesting case study as it represents one of the eight nationally protected marine parks under similar types of governance regimes, all of which are subject to decentralization policies, which in turn are influential with respect to park governance and zoning.

The KNP is managed by the Karimunjawa National Park Authority (KNPA) within the Ministry of Forestry (MOF). The Wildlife Conservation Society has an MOU with MOF, and is giving technical assistance to the KNPA. The University of Diponegoro also provides technical assistance. The park zonation plan was finalized in 1999, re-evaluated from 2003 to 2005, amended in August 2005, and again revised in 2012 after a 2 year evaluation to improve the zoning regulations. Zoning of the park allows regulatory controls on uses to be defined within the context of conservation objectives outlined in the management plan, permits the use and harvest of some natural resources in a sustainable manner and reduces conflicts among natural resource user groups.Small marine protected areas governed by local communities have been shown to provide greater improvements in biodiversity than larger government-controlled MPAs, due largely to a higher level of compliance (McClanahan et al. 2006a). Therefore the rezoning processes of the KNP have been used as opportunities to work more with local stakeholders, to help define KNP management policies and develop a zoning plan agreed to by all stakeholders. Workshops and consultation meetings during spatial planning were conducted in the district capital of Jepara and three villages in KNP to foster better communications and commitment from stakeholders to work together and to enable co-ordinated implementation of the agreed zoning plan. Surveys conducted to serve as the basis for planning and designing of the zones included ecological surveys (coral reef, invertebrates and reef fish); socioeconomic perception surveys (to assess level of community understanding on zoning); and muro-ami fishing (to assess the ecological and socioeconomic impacts of such fishing activities).

The first KNP zonation plan was completed in 2005, incorporating basic ecological factors and sociopolitical considerations. The improved planning of the KNP led to an increased awareness of fishing restrictions and other regulations, enhanced compliance with fisheries controls and a higher level of support among coastal communities for zoning regulations (Campbell et al. 2012). The head of KNP requested that WCS help the community become more involved in direct management activities of KNP and increase their capacity to fulfill such functions. The process of 'Rencana Strategis' or 'Renstra' (strategic planning) is a formal process that WCS initiated in the village of Parang in 2007. A management plan that guides the implementation of a number of programs linked to economic development and conservation and exploitation of marine resources was produced. The process begins with informal meetings among village elders, followed by formal meetings among village officers and community groups. The outcome was the development of three community action plans for the villages of Parang, Karimunjawa, and Kemujan. The District Development Planning Board, which is the regional body responsible for planning and development, has adopted the Village Management Plans as the first strategic plans to facilitate communications between the community and other local government agencies within the district of Jepara. KNP leadership take the lead on organizing regular meetings and forums to facilitate community participation and assist communities to operationalize action plans with endorsement from the district government of Jepara. Through these plans, communities are provided with some economic and participatory incentives to become engaged in livelihood programs, management programs and capacity building programs.

Ecological improvements in all zones have included increases in coral cover and reduced macroalgal cover, providing important habitats for reef fish. It could be that the benefits of the improved decentralized governance of the national park system have yet to be fully realized, as the biomass of reef fish remained relatively stable from 2004 to 2008 (Ardiwijaya et al. 2008), including important trophic groups, such as herbivores that are essential for promoting reef resilience. More recent analyses suggest that some zones have shown some declines in reef fish biomass (Campbell et al. 2012), whilst fish biomass in KNP is generally lower or comparable with estimates in other coral reef systems where management has restricted the use of fishing gears (Cinner et al. 2005, McClanahan et al. 2006b, Aswani et al. 2007, Tyler et al. 2011) and areas with permanent fisheries closures (Russ et al. 2005, Bartlett et al. 2009, Cinner et al. 2009). Although protected areas may take many years to yield improvements in fish biomass

(McClanahan and Graham 2005), the trends in KNP suggest that levels of non-compliance with fishing regulations continues to be a main threat to marine ecosystem health. Improvements in compliance with controls on destructive fishing and exploitative fishing gears will most likely increase the biomass of reef fish, by limiting damage to coral habitats and decreasing the catch of species vulnerable to fishing (Tyler et al. 2011). Such improvements are also important for protecting functionally important groups of fish that builds coral reef resilience (Bellwood et al. 2006).

Ongoing assessments of the effectiveness of the controls in KNP are providing management options to improve the processes through which KNP zones are further improved to achieve increases in fish populations. Such assessments provide critical feedback for management authorities to adapt its management to changes in the threats to marine resources. In combination with other management efforts and regulations, especially those relating to large scale threat reduction and targeted fisheries and conflict resolution instruments, performance evaluation should test for additional ecological and socio-economic improvements over time in comparison to unmanaged areas as part of an adaptive management regime (Hargreaves-Allen et al. 2011).

2.6 Incentives

The impacts of MPAs on local fishers and other stakeholders may either boost or thwart efforts to expand MPAs (Fiske 1992, Mascia et al. 2010), and it is common for new resource governance regimes, as described here for KNP, to influence the involvement by communities in management planning through a range of incentives (Gelcich et al. 2005, Leslie 2005, Stoffle and Minnis 2008). Incentives being applied by the KNPA to address conflicts and improve governance of the KNP include economic, interpretative and knowledge incentives, while although laws are in place to protect the park, enforcement of these laws is poor (Table 2-2).

Economic incentives are a primary mechanism through which the conflict between biodiversity conservation and local development needs is being addressed in the KNP. Promotion of economically and ecologically sustainable resource use is being supported through programs that improve local infrastructure and develop mariculture and tourism industries as alternative income sources for coastal communities. By legislating marine zones for aquaculture practices, the government has provided legal incentives resulting in a total of 2020 fishers being currently involved in seaweed mariculture and enabling a further 15 fishing families to diversify into grouper mariculture (Susmiati et al. 2010). For the latter, village agreements between fishers and government require the commitment of those who receive economic assistance to comply with fisheries regulations and cease the use of destructive fishing practices. Incentives have included provision of infrastructure, training in husbandry and grants for obtaining grouper fry. All of these economic incentives aim to empower fishing communities in MPA governance and decisions on fishing rights, minimize conflict among coastal communities through controls on fishing gears and offer a viable strategy for enhancing food security through greater stewardship of marine resources and improved governance over marine resource use (Pollnac et al. 2010, Gutiérrez et al. 2011).

Incentives were also provided to enable resource dependent communities of KNP to participate in new management revisions, building stewardship and rights of local users for fishing within the KNP, and promoting community participation in park planning, monitoring and enforcement. During the rezoning process in 2003-5, communities self-organized into village planning groups and received funding to help them contribute to MPA planning and help decide on new locations for fishery closures in core and protection zones, and decide on the location of new zones for aquaculture, tourism and traditional fishing where restrictions on fishing gear use and bans on destructive fishing apply. Village forums have also received training and resources to participate in monitoring of the MPA, in particular surveillance and reporting of destructive fishing. Participation in MPA planning and management also provided opportunities for communities to receive interpretative and knowledge incentives. These enabled community organization and involvement in public communication, education and awareness raising programs including community events promoting recognition of MPA regulations and sustainable fishing, and school education programs on marine conservation (Table 2-2).

Increased involvement of village institutions in community decision making related to park management and enforcement is also needed to reduce conflicts among fishers and improve legal obligations for protecting fishery resources from unsustainable and destructive practices. As communities have become involved in the surveillance and reporting on the poaching of protected marine species such as clams, napoleon wrasse and turtles, infringements have been acted upon by the KNPA through legal processes.

The strong support by some fishing communities for fisheries regulations reflects an alignment of shared objectives and stewardship among community and government institutions, which has been shown to improve the governance of natural resources (Cinner and Aswani 2007). Nonetheless, there exists considerable room for improvement to ensure that laws in place receive sufficient state capacity, political will, technological input and financial resources to provide effective enforcement practices that tackle external and internal factors driving non-compliance. In particular, the alignment of KNPA enforcement programs with those of the district fisheries government agency will improve consistency in the prosecution of laws. In many cases local fishers may support small no-take areas but violators are often not apprehended due to poor surveillance techniques. The inconsistent application of law is an important barrier for community support for fishing restrictions. To increase capacity and effort in law enforcement and target the organized offenders an integrated approach is needed that recognizes community involvement in harm reduction and law enforcement in the context of broader socio-economic priorities (Hauck and Kroese 2006). Such approaches are becoming more closely aligned with emergent forms of marine area protection such as non-formal self-organizing island exclusion zones that are locally constructed within existing institutional frameworks (Glaser et al. 2010).

Table 2-2 Summary of governance incentives in the KNP

<table>
<tr><th>Incentive type</th><th>Incentives applied</th><th>Incentives needed</th><th>Cross-cutting issues</th></tr>
<tr><td>Economic</td><td>Promoting economically and ecologically sustainable resource use;
Allocation or reinforcement of community / user property rights;
Promoting alternative livelihoods;
Improvements in local infrastructure and living standards;
Funding from private or NGO sources to promote the effectiveness of the MPA</td><td></td><td rowspan="5">Stewardship has been generated through recognizing the rights of local users for tourism, mariculture and fishing within the KNP, whilst also promoting community participation in park planning, monitoring and enforcement</td></tr>
<tr><td>Interpretative</td><td>Public communication, education and awareness raising;
Promoting recognition of MPA regulations and restrictions, including boundaries</td><td></td></tr>
<tr><td>Knowledge</td><td>Maximising scientific knowledge to guide / inform MPA decision-making;
Promoting mutual respect and collective learning between different knowledge owners</td><td></td></tr>
<tr><td>Legal</td><td></td><td>Legal or other official basis for cross-sectoral / jurisdictional MPA restrictions;
Ensuring that sufficient state capacity, political will, surveillance technologies and financial resources are available to enforce all restrictions equitably on all local and incoming users, including addressing driving forces</td></tr>
<tr><td>Participative</td><td>Participative governance structures and processes;
Participative enforcement</td><td></td></tr>
</table>

2.7 Cross-cutting issues

In KNP the establishment of village institutions and forums for community decision making and leadership is comparable to co-management or 'hybrid' institutions of customary and modern management. These forms of management often are adaptively established with support from communal norms and practices and able to respond to changes in access to natural resources by allocating resources in accordance with the preferences of the majority of residents or ecosystem users (Cinner and Aswani 2007). More attention therefore should be placed on capacity building for adaptive management by local level management institutions and organizations to encourage mechanisms that promote flexible and responsive policies and management strategies (Berkes and Folke 1998). For example, increased understanding of the ability of communities to adapt to and support localized fishery closures and fishing restrictions and take advantage of positive opportunities that may result from changes in fishing access can feed back to improve management of networks of protected areas in Indonesian national parks. In the KNP, the village institutions and government agencies are supporting the stewardship of marine resources by recognizing the rights of local users in zoning plans, with traditional fishing permitted in 83% of the park, building infrastructure and skill training in tourism and mariculture within the KNP, and promoting community participation in park planning, monitoring and enforcement.

2.8 Conclusion

A key finding of this paper is that economic support from government, community and non-governmental sectors is a crucial factor enabling the transition of livelihoods to sustainable fishing practices, reducing destructive fishing and achieving biodiversity protection (Aswani et al. 2007). The improved governance in KNP appears to meet, in part at least, many of the governance design principles recognized as being important for successful local management (Cinner et al. 2009). For example, resource dependent communities in the KNP recognized the social and economic implications of new management revisions being developed in 2003 and accordingly self-organized and contributed through participatory planning processes to protect their diverse interests (e.g., income, food security, sense of place) and directly influenced the final set of regulations legislated in 2005. The resulting promotion of community participation in management processes has raised awareness of graduated sanctions, clearly defined geographic boundaries and improved rights to participate in devising rules and regulations of fishing restrictions that have minimized conflict among coastal communities.

KNP management over the five year period from 2005 to 2010 has also improved community support for some controls on fishing, promoted the recovery of coral habitats through restrictions on destructive fishing practices and improved community involvement in MPA management. However, fish stocks in the KNP have not increased due to non-compliance with fishery closures (Ardiwijaya et al. 2008, Campbell et al. 2012) as external factors continue to drive infringements in the KNP. These include market pressure and demand for live reef fish which require increased enforcement of laws at both the national and regional levels and integration of community approaches in law enforcement in the context of broader socio-economic priorities and harm reduction (Hauck and Kroese 2006). Increased involvement of village institutions in community decision making related to park management and enforcement will help reduce conflicts among fishers and enable legislation of community supported restrictions and sanctions that protect fishery resources from unsustainable and destructive practices.

A highly diversified approach is required to provide incentives for local communities to comply with fishing regulations in the KNP to reverse the depletion in coral reef fisheries. The establishment of village institutions and forums for community decision-making and leadership have provided incentives for communities to address conflicts between biodiversity conservation and local development needs. Through improved knowledge and participation in planning processes and management, and economic support from government and NGOs for livelihood programs such as grouper mariculture, seaweed culture, tourism ventures and micro-credit financing, the primary aim is to reduce exploitative fishing activities and decrease community dependency on wild-captured natural resources. The provision of capacity building and infrastructure is often conditional on recipients' compliance with fisheries regulations, including the prohibition of destructive fishing practices, that can have ecological impacts similar to prohibiting all extractive uses (Galal et al. 2002, Abesamis 2006).

The governance approaches described in this study represent 'emergent' or hybrid forms of marine area protection in the local context (Cinner and Aswani 2007) that are respected and locally enforced and may, if enforced, achieve high fishery compliance rates and food security (McClanahan and Mangi 2000, Roberts et al. 2001, Aswani and Sabetian 2010). The second re-zoning of the KNP was finalised in 2012 as part of the KNPA's adaptive management mandate. To achieve its primary aims of biodiversity protection and social improvement, sustained investment in resources and expertise is needed to deliver incentives that maintain and build sustainable industries, allow traditional subsistence fisheries to flourish, and provide disincentives to outside fishers and destructive fishing (Brewer et al. 2009, BTNKJ 2010).

2.9 Acknowledgments

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3 Improvement of fish length estimate for underwater visual census of reef fish biomass[2]

Summary

Accuracy and precision are of great importance for the assessment of reef fish biomass in conducting underwater visual census (UVC). Quantification and subsequent correction of the bias is required in order to standardize the estimates and to correct the underwater distortion. To optimize the UVC, the observer should conduct length-measurement training, obtaining in situ-measurements which are as accurate and precise as possible. The objective of this study was to quantify the bias of fish length measurements with and without training in order to enhance reef fish biomass estimates. We analysed the diver adaptation to estimate the fish length as a part of reef fish biomass monitoring in Karimunjawa National Park. Two divers estimated repeatedly different fish styrofoam models in the natural environment where the models were placed by string and sinker. The analyses showed that by training the diver can improve his/her accuracy and precision of the estimate substantially. By means of proving its reliability, the underwater visual census becomes a useful and reliable method to assess reef fish biomass.

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3.1 Introduction

Underwater visual census (UVC) is a method that has often been used to estimate the abundance and biomass of reef fishes. The UVC that was pioneered by Brock (1954) is the most efficient and non-destructive method to assess the abundance of reef fish. Kadison et al. (2002) mentioned that many managers use the UVC as a tool to estimate the length frequency and abundance of reef fish. The UVC method was also used in Indonesia in order to estimate the reef fish biomass in Karimunjawa National Park, Aceh Province, Seribu Islands, North Sulawesi, Wakatobi National Park, Lombok Island, Bali, Komodo National Park, and Raja Ampat (Pet et al. 2005, Campbell and Pardede 2006, McClanahan et al. 2006a, Unsworth et al. 2007, Rudi et al. 2009, Madduppa et al. 2012, Purwanto et al. 2012, Yulianto et al. 2012).

For calculating the reef fish biomass, which is an important parameter for fishery management (Cochrane 2002), a high accuracy of fish length estimate is required. The accuracy of the fish length estimate depends on the ability of the observers to estimate the accurate fish length underwater, and the effect of under environmental conditions that create optical distortion, such as visibility, colour absorption, and light (Mille and Van Tassel 1994). Underwater objects appear larger less than 4/3 angular magnification, creating a biased size perception and therefore impact directly the estimate (Ross and Nawaz 2003). As an impact of distortion, errors in size estimate may be common in novice divers, but can be solved with constant training and practice (Ross et al. 1970, Bell et al. 1985), thus, the diver can improve his/her precision and achieve an accurate size estimate by learning (Ross 1965).

In the light of the importance of accurately assess the reef fish biomass, it is important to improve the method of UVC. The objective of this study was to quantify the bias of fish length measurements with and without training to enhance reef fish biomass estimates. Here, we analyse the divers' adaptation to estimate the fish length as a part of reef fish biomass monitoring in Karimunjawa National Park by means of quantifying repeatedly the accuracy and precision of the estimates.

3.2 Materials & methods

The monitoring of reef fish biomass in Karimunjawa National Park, located in Karimunjawa Islands, Central Java, Indonesia, was established in 2005. A total of 43 sites were chosen as monitoring sites inside and outside the national park to evaluate the effectiveness of the protection measures to fisheries resources (Fig. 3-1). Before the monitoring started, training of fish total length estimate was conducted to reduce the bias of fish total length estimate and the bias inter observer (diver). Mille and Van Tassel (1994) suggested conducting training and practice of length estimate in the survey area to adapt to the local environmental conditions.

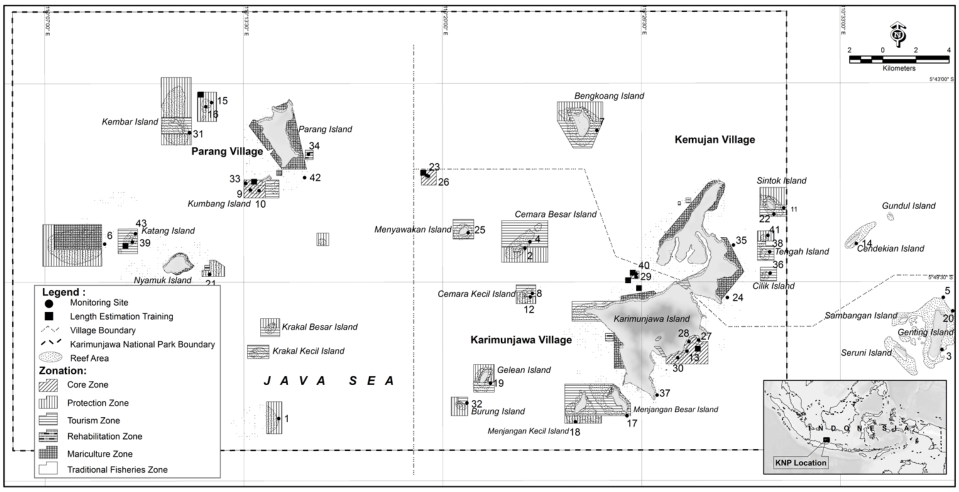


Figure 3-1. The 43 reef fish monitoring sites in Karimunjawa National Park and the location of the training for the estimate fish total length.

The experiments were carried out in May and November 2004 before the monitoring program was started. Two types of training were performed, which were technically the same. First an extensive training was performed (5 days) for non-experienced divers. Second, a reduced training was conducted for the divers who were already skilled in underwater length estimate to control and calibrate (thus "calibration training") the divers skills in underwater total length estimate. For both trainings, a total of 45 different styrofoam models representing different reef fish species and 9 different sizes from small to large were used. The fish models were tied with strings and sinkers to the natural environment to let it appear natural, like real fish swimming in the water, moving back and forth under the impact of the currents and the waves. The training was conducted for 5 days and the calibration trainings were conducted up to 5 days until the diver reached the bias < 5%. Ten fish models were chosen randomly per day from the 45 fish models to be estimated by each diver, at a distance of 2.5 meters (Fig. 3-2). They randomly represented a maximum of 5 different shapes (damselfishes-Pomacentridae, butterflyfishes-Chaetodontidae, moorish idol-Zanclidae, parrotfishes-Scaridae, groupers-Epinephelidae) and different sizes, similar to the typical condition on a reef habitat in the region. The next day, ten other fish models from remaining 35 fish models were randomly chosen. At day 5, ten fish models were randomly chosen from the 45 fish models. This selection was chosen in order to avoid a learning effect of the divers (model induced bias). Discussions were conducted every day during the training concerning the error of estimate, so that the diver was able to improve the accuracy of fish total length estimate in the following days.

To analyse the data from the divers' estimate, the data were plotted, the Mean Normalized Bias (MNB) calculated and tested with t-paired test. Plotting the data was used to compare the length estimate from each diver with the true value of the fish model. The MNB was used to analyse the bias of estimate. The MNB equation was $MNB = 1/N(\sum(Le - Lt/Lt)x100\%)$, where N is number of the estimated fish model, Le is the total length estimate of the fish model, and Lt is the true value of the fish model total length. T-paired test was used to compare the length estimate between the divers.

Figure 3-2. Two divers conducting the fish length estimate training to reduce the bias of the data and the bias inter diver (a), the distance between the divers and the fish model was 2.5 meters (b).

3.3 Results

During the first experiment two divers who had previously been trained in reef fish taxonomy estimated the same fish models. Figure 3-3 gives the total length estimate from diver 1 and diver 2. The range of +/- 5 cm from the true value of the fish model was considered to be the acceptable range of error. These divers estimated satisfactorily well; almost all of estimates were in the acceptable range of estimate and most of them were close to the true value. Diver 1 overestimated the size of one fish model with a value out of the acceptable range at the second day of training (Fig. 3-3).

We also grouped the data into three size classes (<= 10 cm, 11 – 20 cm, and > 21 cm) and calculated the mean and standard deviation of each class from the true value of the fish model, length estimate from diver 1 and 2 (Fig. 3-4). The mean of the first length class (<= 10 cm) from the true value of the fish model, diver 1 estimate and diver 2 estimate was 7.23 (SD = 1.88) cm, 7.45 (SD = 2.65) cm and 7.18 (SD=2.36) cm respectively. The mean of the second class (11 – 20 cm) was 14.75 (SD = 2.21) cm, 15.88 (SD = 2.83) cm, and 14.38 (SD = 2.42) cm. The means of the third class was 25.28 (SD = 2.02) cm, 24.90 (SD = 3.03), and 22.80 (SD = 2.35). Comparison of the mean and its standard deviation between true value of fish model total length and the total length estimate of both divers indicated that the divers have accurate estimate to estimate total length of fish model.

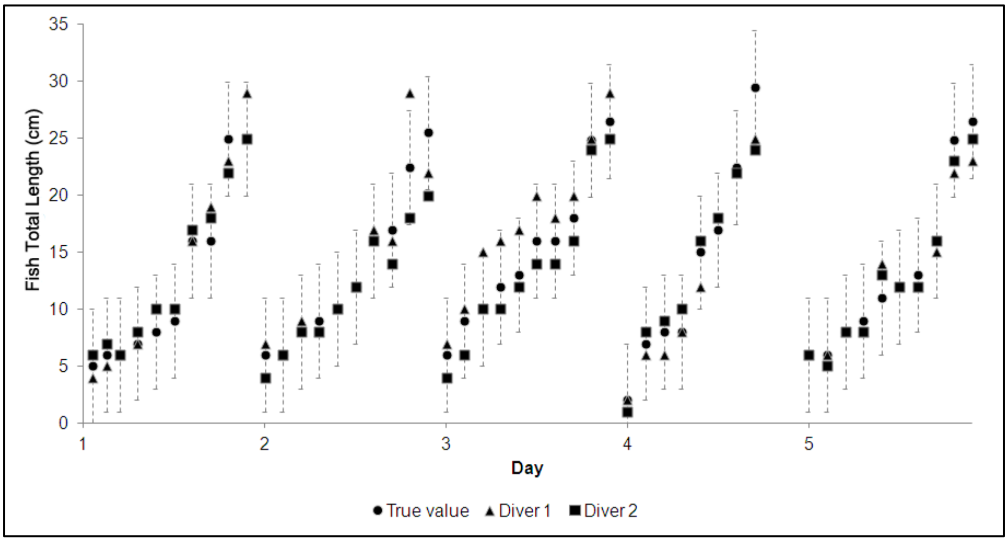


Figure 3-3. Total length estimate of 10 fish models that were randomly chosen and randomized placed per day on the test area during the first training in May 2004; the error bars of +/- 5 cm from the true value of the fish model are the acceptable range of estimate.

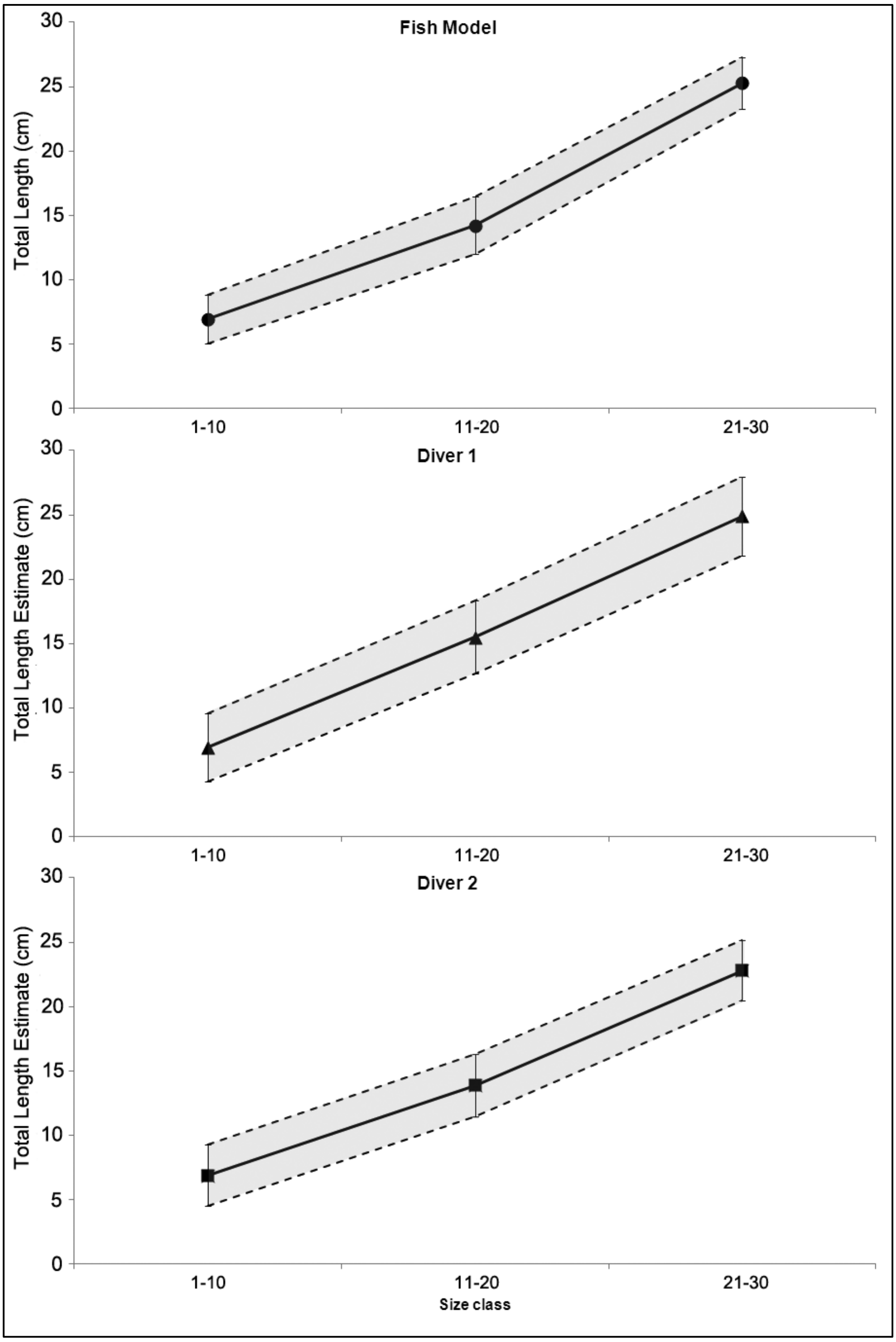


Figure 3-4. Total length means with standard deviation of all fish models divided into three different size classes, and estimate of the two divers during training that represent the bias and precision of the divers; given are the true values of the fish models (●), estimate of diver 1 (▲) and 2 (■).

A paired t-test was conducted to analyse the difference of estimate from the two divers (Table 3-1). At the first day of training, the length estimates from the divers were not significant different from the true value (diver 1; p = 0.17, diver 2; p = 0.11) and no significant difference was observed between diver 1 and diver 2 (p = 0.50). During the second day of training, the length estimates from diver 2 was significantly different from the true value ($p < 0.05$). At the third day of training, the estimates from the divers were significantly different from the true value (diver 1, diver 2; $p < 0.05$), and significantly different between diver 1 and diver 2 ($p < 0.05$). The mean difference of estimate at the third day was the highest during the training. During the fourth, the length estimates from the diver 1 were significantly different from the true value ($p < 0.05$), and the length estimates from the diver 2 were not significantly different from diver 1 (p = 0.07) and the true value (p = 0.44). At day 5, the length estimates from the divers were not significantly different from the true value (diver 1; p = 0.14, diver 2; p = 0.12) and not significantly different between the divers (p = 0.25). Based on the MNB calculation, the accuracy of the divers increased after five days of training. The MNB values of both divers decreased over time. Based on the MNB values, at the fifth day of training, the bias of both divers was less than 5 % (Fig. 3-5).

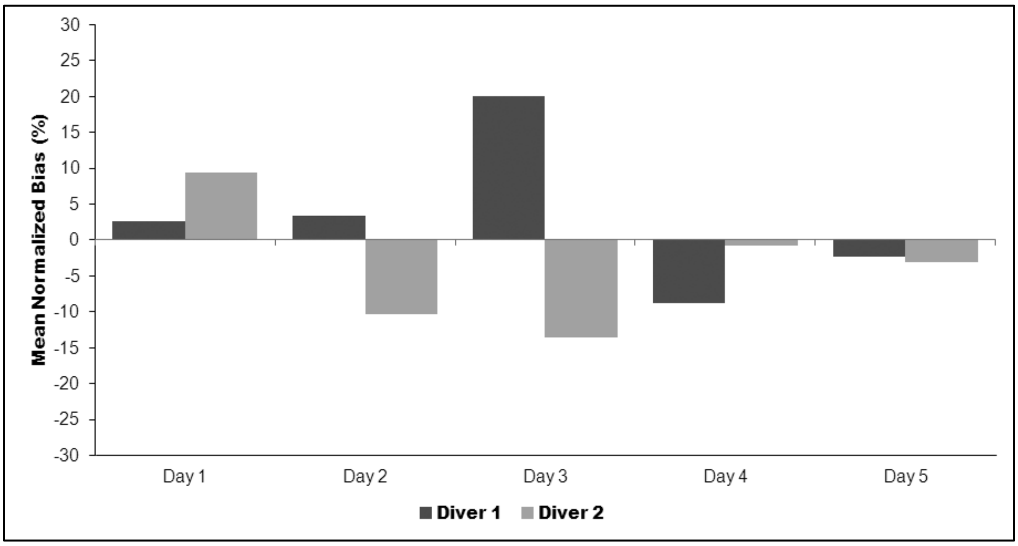


Figure 3-5. Mean normalized bias (%) from two divers during the training in May 2004; positive percentages represent overestimate and negative percentages represent underestimate.

*Table 3-1. The mean difference from paired t-test between true value, estimation from diver 1, and estimation from diver 2 from training in May 2004; + represent overestimate, - represent underestimate, and * represent a significant difference at 95 %.*

Day	True value Vs Diver 1	True value Vs Diver 2	Diver 1 Vs Diver 2
Day 1	+ 0.60	+0.60	0.00
Day 2	+ 0.40	*- 1.60	*- 2.00
Day 3	*+ 2.56	*- 1.64	*- 4.20
Day 4	*- 1.25	- 0.12	+ 1.12
Day 5	-0.64	- 0.44	+ 0.20

After around six months of length estimate training, calibration training was conducted to control and calibrate the divers' skills in underwater length estimate. Figure 3-6 shows the results of the three days calibration training. Both divers still had a good estimate of the total length of the fish models. All of the length estimates were in the acceptable (i.e. < 5% deviation) range. Although having a good estimate, biases of both divers were highest at the first day of the calibration training. The MNB value reached – 29.13 %. Bases on the paired-t test, the length estimate from both divers and the true value were significantly different at 95 % (Table 3-2). Figure 3-7 presents the mean of each size class of fish length, where the divers made inaccurate estimates. Diver 1 made inaccurate estimate for the second length class (11 – 20 cm) and diver 2 for the first and the third class. Inaccurate estimate was contributed by the high bias in the first day of calibration training.

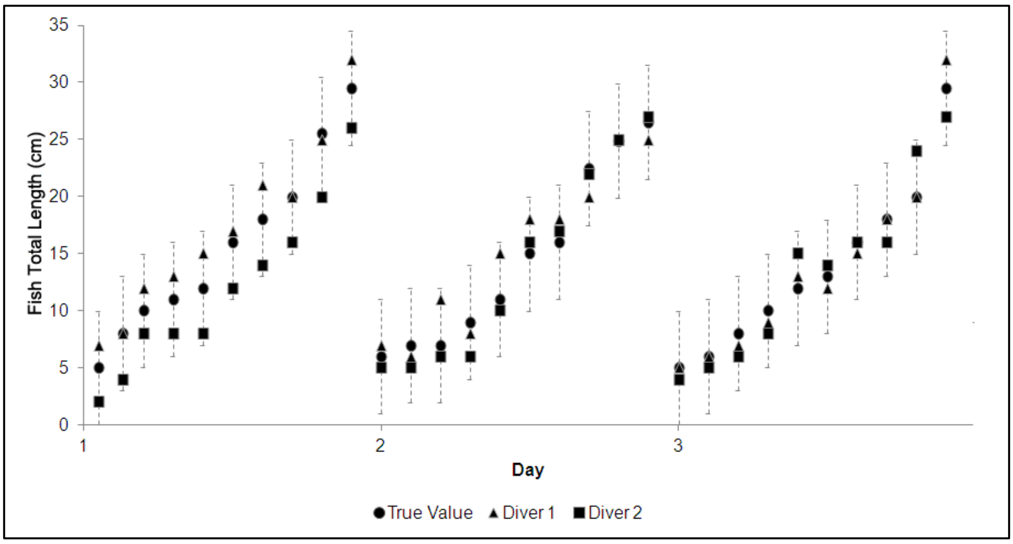


Figure 3-6. Total length estimate of 10 fish models that were randomly chosen and randomized placed per day on the test area during the calibration training in November 2004; the error bars of +/- 5 cm from the true value of the fish model are the acceptable range of estimate.

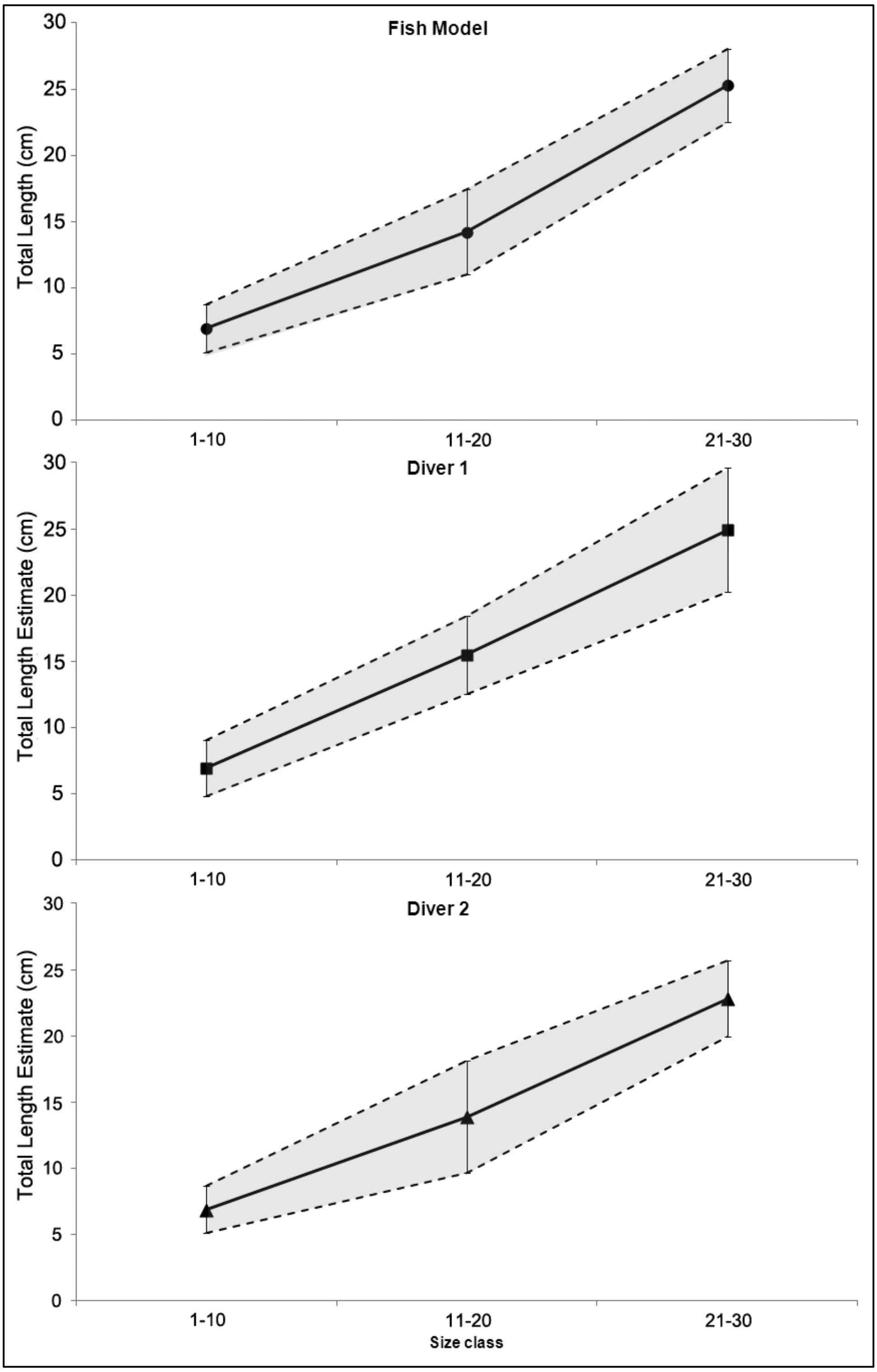


Figure 3-7. Total length means with standard deviation of all fish models divided into three different size classes, and estimate of the two divers during training that represent the bias and precision of the divers; given are the true value of the fish models (●), estimate of diver 1(▲) and 2 (■).

Over the time of practices and discussions, the accuracy of the divers increased within three days. Both divers reached the MNB below or equal to 5 % in three days (Fig. 3-8) and the length estimate from both divers were not significantly different from the true value and not significantly different between both divers (Table 3-2). This result was reached faster than during the first training that lasted five days.

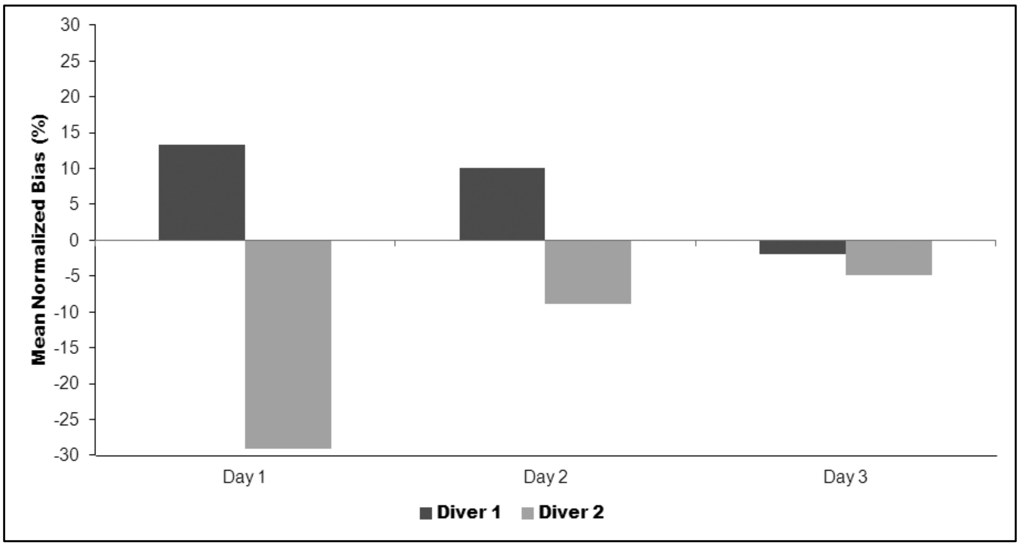


Figure 3-8. Mean normalized bias (%) from two divers during the calibration training in November 2004; positive percentages represent overestimate and negative percentages represent underestimate.

*Table 3-2. The mean difference from paired t-test between true value, estimation from diver 1, and estimation from diver 2 from the calibration in November 2004; + represent overestimate, - represent underestimate, and * represent a significant difference at 95 %.*

Day	True value Vs Diver 1	True value Vs Diver 2	Diver 1 Vs Diver 2
Day 1	*+ 1.50	*- 3.70	*- 5.20
Day 2	+ 0.80	- 0.59	*- 1.40
Day 3	- 0.05	- 0.25	- 0.20

3.4 Discussion

This study demonstrates that the performance in underwater visual census (UVC) can be reliably tested and improved, and it may be assumed that it is of substantial help to apply a useful and reliable method to assess reef fish biomass. According to Kadison et al. (2002), training of a new observer improved the accuracy of the diver`s length class estimate from 40 % to 89 % after a dozen training dives over a six-week period . The tested divers in the present study improved their skills in size estimate of 5 different model fish species, reaching a bias below 5% within 5 (first training) and 3 (calibration training) days.

Our experiments demonstrate, to what extent corrections were translated into over-compensation. It is important for each individual diver to have a reflection of his/her response to criticism and individual bias and thus to learn about his individual learning curve. However, a good performance in the training with model fish does not necessarily imply that the divers measure life fish under water with the same precision and accuracy. Even though it may be assumed that the training and calibration will improve the estimate competence of the divers generally, the ultimate prove in the field is still pending. Never the less, under the given circumstances which prevail at most field stations in tropical regions and taking the practicability of dealing with life fish of known size in the field into consideration, then the approach with model fish as employed here is a cost-efficient and robust approach for improving, quantifying and qualifying the precision of the subsequent field measurements. This study also demonstrates that the diver can improve the accuracy of estimate by training and calibration training relatively quickly, indicating that this is a useful method. However, the estimates were made from a more or less predefined distance of 2.5 m whereas under natural conditions the distance of estimate inevitably varies. It can be assumed that the accuracy of life fish length estimate in the survey will be lower than the accuracy of fish model length estimate in our experiments. Edgar et al. (2004) could demonstrate that UVC estimates of divers were on average 7 % greater than the measured length of life fish. However, this result was also size dependent, when divers possessed a clear tendency to make increasingly inaccurate size estimates as fish length deviated in either direction from 300 mm (175 mm underestimated by ≈20% and 400 mm overestimated by ≈10%). Our experiments show furthermore that calibration training is needed when the diver has not participated in underwater survey to estimate the fish length for least for six months; this result is similar to the time frame mentioned by Bell et al. (1985), where the diver will lose the accuracy of estimate after six months without practice.

We selected 5 different fish species at 9 different sizes each, to prevent the divers from easily recognizing the size of a selected model fish. Here is a weakness of the training because the divers have observed the same fish model several times during regular and calibration training. On the other hand, arbitrary species selection and a high number of size variables in each model fish species makes single model recognition difficult, especially under regular field conditions in the reef. Consequently, proper species and size selection of the most common size classes expected to occur in the study area is a requirement to apply model fish and regular and calibration training to improve the diver´s performance for scientific UVC data collection.

This study focuses on the total length estimate for reef fish biomass calculation and is believed to add significantly to the improvement of reef fish stock assessment. A lack of taxonomic knowledge of the divers that is also of importance has the potential to create an additional bias in underwater visual census survey (Thompson and Mapstone 1997). This however was not addressed in this study, but it is unquestioned that the length estimate training should be attended by divers only who have already a good knowledge in reef fish taxonomy.

3.5 Acknowledgements

We wish to acknowledge the support provided by Balai Taman Nasional Karimunjawa for the great cooperation and hospitality during the fieldwork. Special thanks to The David and Lucile Packard Foundation for their support to the field research, and to IGSP-DAAD (German Academic Exchange Service) for providing the scholarship.

4 Fishing-induced groupers stock dynamics in Karimunjawa National Park, Indonesia[3]

Abstract

As a result of high levels of exploitation, groupers (Epinephelidae) populations are at risk in many regions and are declining steadily for instance in Indonesia. This study aims to determine groupers stock sizes in Karimunjawa National Park, Indonesia. To be an effective national park with no-take zones to protect groupers biomass, the groupers biomass should increase or at the minimum should be maintained. From 2005 to 2012, groupers mean abundance declined, with a fluctuating mean biomass, whereas the mean biomass increased again from 2009 to 2012. A significant difference was found in groupers abundance and biomass between the different zones. However, no significant difference could be observed for three observed species between the different zones. Three fishing gear types were used to catch groupers; speargun fisheries were the most effective. In 2011, the speargun effort decreased, based on self-regulation by the fishermen, which also changed the groupers target size and impacted to the recruitment success. This resulted in an increase of groupers stock size and biomass in 2012. We conclude that the installation of marine protected areas alone, as exemplified by the installation of three core zones in Karimunjawa National Park, is not sufficient to protect natural groupers populations, requiring also fishing-gear regulation and community support.

[3] This article was published as: Yulianto I, Hammer C, Wiryawan B, Palm HW (2015) Fishing-induced groupers stock dynamics in Karimunjawa National Park, Indonesia. Fisheries Science (81): 417-432. Published online: 18 March 2015.

4.1 Introduction

One of Indonesia's most important fishery commodities is groupers (Epinephelidae), which play a major economic and ecological role in coral reef habitats (Morris et al. 2000). Being a favorite in seafood restaurants around the world, groupers have great economic value (Johannes and Riepen 1995, Mouset al. 2000, Sadovy and Vincent 2002). This has resulted in a great demand and increasing fishing effort, especially in the surrounding coral reef habitats (Mendoza and Larez 2004, Johnston and Yeeting 2006). Groupers are particularly associated with certain coral reef habitat types, and found particularly in massive coral areas (Madduppa et al. 2012).

The Karimunjawa islands form an archipelago of 27 small islands in the Java Sea and includes Karimunjawa National Park, which has a total area of 1116 km^2, including 22 islands. Karimunjawa is recognized as one of the most successful and effective national parks to maintain coral reef ecosystems after the re-zoning process in 2005 (Ardiwijaya et al. 2008, Campbell et al. 2013). Increasing coral cover, involvement of the community in the national park management, good governance in managing the national park, and implementation of adaptive management were the main features of this activity. In 2005, the core zone was established around known groupers spawning aggregation sites in order to protect the spawning stock and enhance the productivity of the groupers fishery. Surrounded by a limited-access utilization zone, the park functions as a protected area for groupers recruitment.

Grouper caught in Karimunjawa National Park are used for live reef fish trade (LRFT) or food consumption. The most targeted species include the highfin coralgrouper *Plectropomus oligacanthus*, squaretail coralgrouper *Plectropomus areolatus*, leopard coralgrouper *Plectropomus leopardus*, spotted coralgrouper *Plectropomus maculatus*, white-streaked grouper *Epinephelus ongus*, orange-spotted grouper *Epinephelus coioides*, brown-marbled grouper *Epinephelus fuscoguttatus*, areolate grouper *Epinephelus areolatus*, slender grouper *Anyperodon leucogrammicus*, and bluespotted hind *Cephalopholis cyanostigma*. The estimated demand for live groupers from the park is 3000 kg per year. In 2009, 2256 kg of live groupers were harvested, and in 2010, 1608 kg were harvested (Campbell et al. 2010). Most recently, groupers mariculture has been established to cope with the increasing demand.

Populations of commercially valuable groupers are at risk (Morris et al. 2000) and are likely overfished in many areas. This is mainly caused by catching live coral reef fish, which causes reef degradation and the disappearance of fingerling fish (Erdmann and Pet-Soede 1996, Pet and Pet-Soede 1999). Several management strategies have been implemented to protect groupers populations in their natural habitats, including the establishment of marine protected areas, gear restrictions and limitations, closing groupers spawning aggregation sites to fishing, and size restrictions and limitations (Beets and Friedlander 1992, Sadovy 1999). Such protection measures have also been implemented in the Karimunjawa islands, where groupers are the main fishing target. However, an assessment of the effectiveness of management and protective measures requires the assessment of the status of groupers stocks in currently protected and non-protected areas. The purpose of this study is to analyze groupers stock sizes in the Karimunjawa islands between 2005 and 2012, based on underwater visual census and fish-landing monitoring. This study examines the impact of zoning on biomass and abundance of groupers. It contributes to the marine protected area management in Indonesia, since many marine protected areas in Indonesia are not effective and many of them were only recently established (Wiadnya et al. 2011). Further options to increase the groupers population biomass, including mariculture, stock enhancement, and sea-ranching measures, are discussed.

4.2 Material and methods

4.2.1 Study site

The Karimunjawa islands are located in the Java Sea as part of the Jepara District, Indonesia. Of the 27 islands, 22 were designated in February 22, 1999 as a national park under the management of the Indonesian Ministry of Forestry. Karimunjawa National Park is divided into zones, including the core zone, protected zone, tourism zone, rehabilitation zone, aquaculture zone, and traditional fisheries or utilization zone. The core zone is a no-take zone; the activities allowed in the core zone are only research and education with prior permit required. As well as the core zone, the protected zone is a non-exploitation zone; research and education with prior permit is required, but boat transit and anchoring is allowed. Tourism activities are allowed in the tourism zone, rehabilitation zone, aquaculture zone, and utilization zone. Fishing activities are only allowed in the rehabilitation and utilization zone. Three core zones, including groupers-spawning aggregation sites (SPAGS), have been established to secure a sustainable use of groupers stocks in and around Karimunjawa National Park.

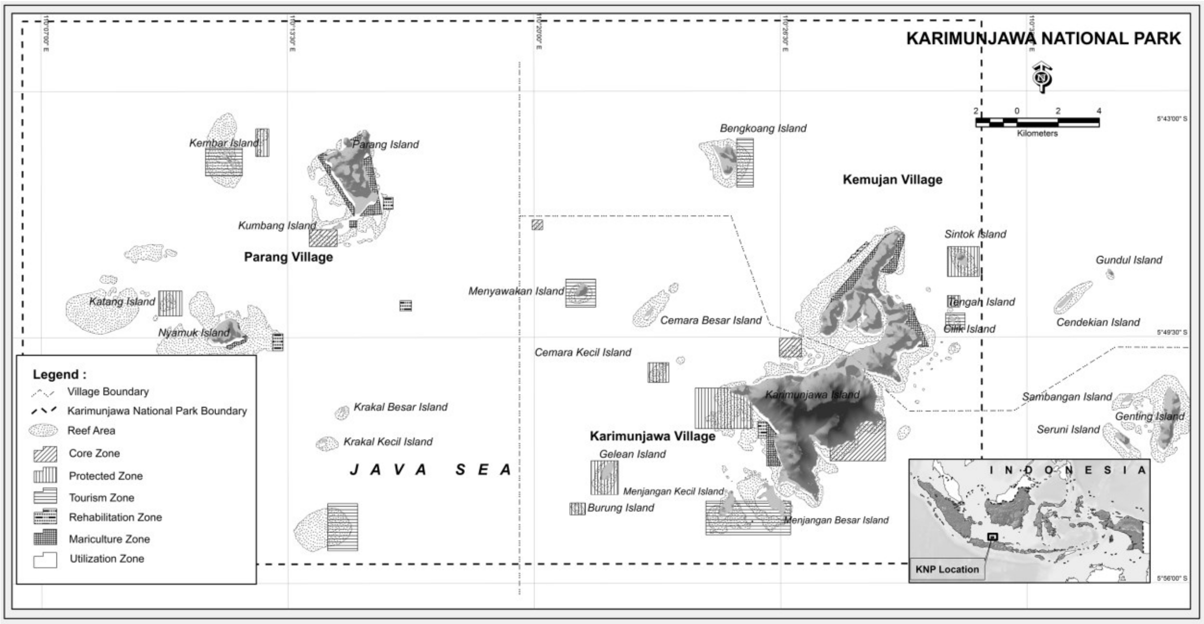


Figure 4-1. Map of the Karimunjawa islands (modified from BTNKJ 2005).

4.2.2 Data collection

The data were collected under the Karimunjawa National Park Authority and Wildlife Conservation Society Program, and extracted from the Karimunjawa National Park reef fish database between 2003 and 2012. An underwater visual census (UVC) using the belt transect technique was conducted at 34 sites in 2005 and 43 sites in 2006, 2007, 2009, and 2012 (Table 4-1). The surveys in 2005 focused on the core zone, protected zone, and utilization zone, and on selected sites in the tourism zone. The surveys were conducted in the same sites that were marked by GPS position and the same season; between April and May each year. The size of all groupers along 50-m transects at the reef crests (2-4 m) and reef slopes (6-8 m) with 2 to 4 replications was recorded at each site by means of the modified belt transect technique from English et al. (1994). The surveyed transects were 2 m wide for fish ≤10 cm, and 5 m wide for fish >10 cm (Campbell and Pardede 2006, Campbell et al. 2012). The fish were recorded by total length, estimated in 5-cm size classes. To reduce the bias of data and the bias among observers, the observers conducted length estimation training in 2004 and in general the same observers were employed every year. Besides the estimation training, the calibration training was also conducted five days before the monitoring activities started each year. The accuracy of length estimation training and calibration training is ± 1 cm that is in an acceptable range and the bias of estimation is ±5 cm and 5 % respectively (Yulianto et al. 2015a).

Table 4-1. Number of sites surveyed in each zone and number of replication at each site

Zone	Number of site survey				
	2005	**2006**	**2007**	**2009**	**2012**
Core Zone	11	11	11	11	11
Outside		4	4	4	4
Protected	11	11	11	11	11
Tourism	2	6	6	6	6
Utilization	10	11	11	11	11
Total	34	43	43	43	43
Replication each site	2	2	2	4	3

Fish-catch surveys were conducted by landing site surveys, which only recorded successful trips (Campbell et al. 2012). The observers recorded the number and weight of fish that were landed at the landing sites and also interviewed concerning fishing gear and fishing effort. Fish-catch surveys were conducted at five major landing sites in Karimunjawa Island as the biggest landing site the Karimunjawa Islands. Fish-catch surveys were conducted in 2003, 2004, 2005, 2009, 2010, and 2011 during May, September, and December, corresponding to the east, transition, and west monsoon seasons. 30-day surveys were conducted to collect the data in each season. Fish-catch surveys between 2003 and 2005 were conducted using photography for length and subsequent weight measurement, according to Cinner et al. (2005). Direct measurements were conducted for fish-catch surveys between 2009 and 2011. In 2009, fish-catch surveys were conducted only in the west monsoon season, and data on the total length were not taken, although data on species name and total catch (kg) of fish were recorded. We separately analyzed all collected groupers species known from Karimunjawa Islands that were treated as one as well as the five predominant and most important species, *Epinephelus merra*, *Cephalopholis cyanostigma*, *C. argus*, *Plectropomus oligacanthus*, and *P. areolatus*. The latter represented 54.4 % of the total catch and could be characterized as non targeted (*C. argus*), targeted (*E. merra* and *C. cyanostigma*), and the high economic value targeted fish species (*P. oligacanthus* and *P. areolatus*).

4.2.3 Data analysis

The mean abundance, mean biomass, and catch per unit effort (CPUE) were calculated to analyze groupers status. Abundance was obtained by dividing the number of groupers by the transect areas of UVC (100 m^2 for fish ≤10 cm, and 250 m^2 for fish >10 cm).

Groupers biomass was obtained by converting total length into weight, by using length–weight relationships, and then dividing by the transect area. The length-weight relationship W = a*L^b, where W is weight, L is total length, and a and b are constants obtained from Kulbicki et al. (2011), was also used to determine the weight of fish from the fish-catch surveys between 2003 and 2005. Two-way ANOVA were conducted to compare mean biomass and mean abundance in different years (2005, 2006, 2007, 2009, 2012) and different zones (core zone, protected zone, tourism zone, utilization zone).

The CPUE was used as the average catch of groupers for each fishing gear, resulting from the fish-catch survey. As all fishermen in Karimunjawa Islands conduct one day fishing trips, then the CPUE equation is CPUE = total catch / number of trips, with the total catch (kg) for each fishing gear during one survey period, and the number of trips for each fishing gear during one survey period. A generalized linear model was used to standardize the CPUE of all groupers catches, and a one way ANOVA was conducted to compare the mean of catch each fishing gear in different years.

4.3 Results

4.3.1 Abundance, biomass, and stock size

Based on the underwater visual censuses throughout the survey period (2005–2012), overall mean groupers (all Epinephelidae) abundance declined from 81.8 (SE = 7.3) ind. ha^{-1} to 59.2 (SE = 6.1) ind. ha^{-1}, but between 2009 and 2012, mean abundance was not significantly different ($P = 0.670$). A different pattern was found in mean groupers biomass, which fluctuated throughout the survey period. Mean biomass of all Epinephelidae in 2012 (mean = 11.2, SE = 1.9 kg ha^{-1}) significantly increased starting in 2009 (mean = 4.8, SE = 0.6 kg ha^{-1}; $P < 0.05$.), whereas the mean abundance was not significantly different (Fig. 4-2). The same pattern was found in mean abundance and mean biomass of *E. merra*, which fluctuated between 2005 and 2012. The highest mean abundance and biomass of *E. merra* reached 17.4 (SE = 2.6) ind. ha^{-1} in 2006 and 1.7 (SE = 0.3) kg ha^{-1} also in 2006 respectively. The lowest mean abundance and biomass of *E. merra* were found in 2012 (mean = 8.8, SE = 2.1 ind. ha^{-1}) and 2009 (mean = 0.9, SE = 0.2 kg ha^{-1}) respectively (Fig. 4-2b). The mean abundance and biomass of *C. cyanostigma* decreased between 2005 and 2012 ($P < 0.05$). The lowest mean abundance and biomass of *C. cyanostigma* was found in 2009, with only 12.4 (SE = 1.7) ind. ha^{-1} and 2.2 (SE = 0.5) kg ha^{-1} respectively (Fig. 4-2c). Mean abundance and biomass of *C. cyanostigma* were not significant difference between 2009 and 2012 ($P = 0.689$). Similar to *C. cyanostigma*, the mean abundance and biomass of *C. argus* decreased extremely in 2009. Its mean abundance and biomass were only 1.4 (SE = 0.5) ind. ha^{-1} and 0.1 (SE = 0.06) kg ha^{-1} respectively. The mean abundance of

P. oligacanthus fluctuated between 2005 and 2012. The highest abundance was found in 2007 (mean = 1.6, SE = 1.0 ind. ha^{-1}) and the lowest abundance was found in 2009 (mean = 0.6, SE = 0.3 kg ha^{-1}). A different pattern was recorded for the mean biomass of *P. oligacanthus*, which decreased from 2005 to 2009, although this was not significant (P = 0.532), whereas it increased from 2009 to 2012 which however was not significant either (P = 0.313). The mean abundance and mean biomass of *P. areolatus* fluctuated from 2005 to 2012. The abundance of *P. areolatus* was very low in 2009, where no *P. areolatus* was found during the underwater visual census survey at 43 sites in 2009. The mean abundance and biomass of *P. areolatus* increased in 2012 and reached 0.8 (SE = 0.6) ind. ha^{-1} and 0.8 (SE = 0.6) kg ha^{-1} respectively.

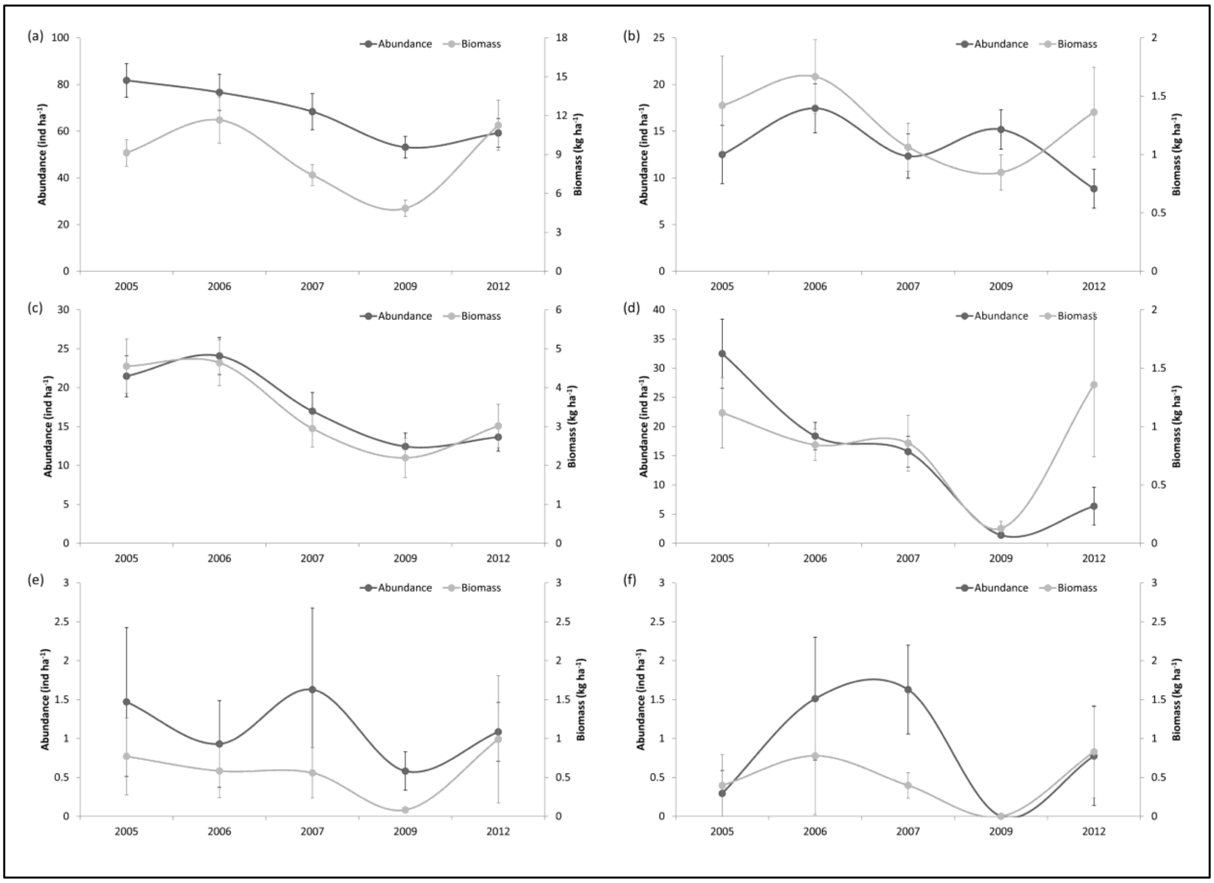


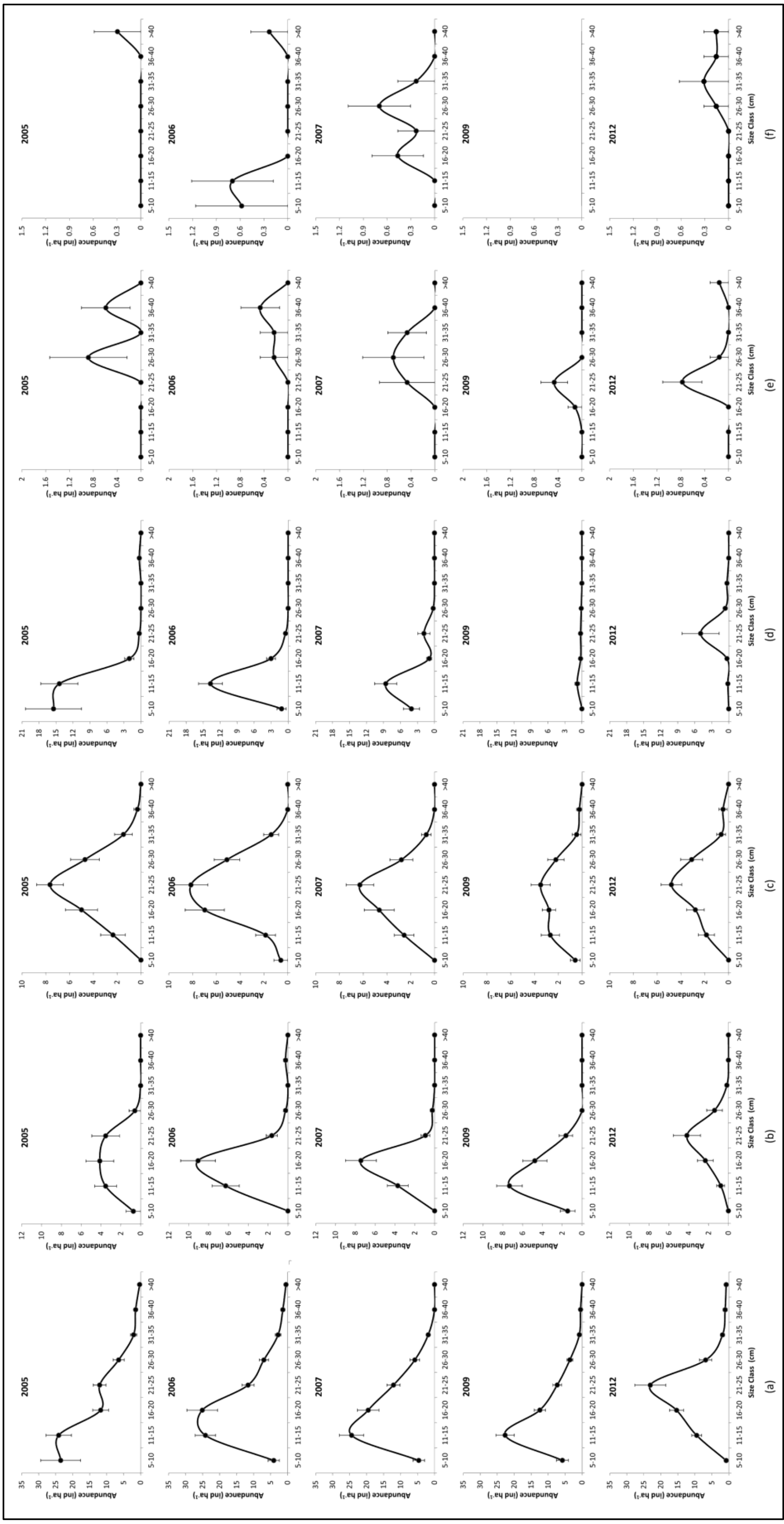
Figure 4-2. Mean abundance (ind. ha^{-1}) and mean biomass (kg ha^{-1}) of grouper (mean ± SE) in the Karimunjawa islands between 2005 and 2012; (a) all groupers, (b) Epinephelus merra, (c) Cephalopholis cyanostigma, (d) C. argus, (e) Plectropomus oligacanthus, and (f) P. areolatus.

Groupers size changed between 2005 and 2012. The fish size in 2005 and 2006, the period with the greatest mean groupers abundance of all size classes, was 11–15 cm and 16–20 cm, respectively. The greatest size abundance in 2007 and 2009 was equal to the size in 2005 (11–15 cm). The mean sizes of groupers most commonly found in 2012 were 21–25 cm (Fig. 4-3), and as such, were the greatest since 2005. The change of groupers size in 2012 was driven by *E. merra*, *C. cyanostigma, C. argus*, and *P. oligacanthus*, of which the abundance of individuals of 21- 25 cm in 2012 was higher than the abundance in 2009. *P. areolatus* also contributed to the change of median size, where *P. areolatus* > 25 cm were found in 2012 and no *P. areolatus* was found in 2009.

4.3.2 Spatial distribution of abundance, biomass, and stock size

Significant differences were found between mean abundance and biomass in the different utilization zones of Karimunjawa National Park (biomass: $F(4,182) = 3.396$ $P < 0.05$ and abundance: $F(4,182) = 4.664$ $P < 0.05$). Mean biomass and mean abundance were highest in the core zone. Mean biomass and mean abundance in the core zone were significantly higher ($P < 0.05$) than in the utilization zone and outside the national park. However, mean abundance and mean biomass in the core zone were not significantly different than the protected and tourism zones (Table 4-2). The conditions in the different areas are mirrored in the observed species, there were however no significant differences between the abundances and biomasses in the different zones of Karimunajawa National Park. The significant differences were only observed in the biomass of *E. merra* and abundance of *E. merra* and *C. cyanostigma.*

Mean biomass in the core, protected, and tourism zones fluctuated and had fairly equal patterns throughout the survey period. The biomass in the utilization zone decreased between 2005 and 2012. Meanwhile, the mean abundance decreased in all zones throughout the survey period. However, stock size increased apparently between 2009 and 2012 and caused an increase in mean biomass in 2012. In 2012, groupers abundance and biomass in the core and protected zones were higher than in the tourism and utilization zones. Higher biomass in the core zones in 2012 was contributed by higher biomass of *E. merra*, *C. cyanostigma*, *C. argus* and *P. areolatus*. Higher biomass in the protected zones in 2012 was contributed by *E. merra*, *C. cyanostigma*, *C. argus, P. oligacanthus*, and *P. areolatus*. Moreover *P. areolatus* were only found in the core and protected zones in 2012 (Fig. 4-4 and Fig. 4-5).



ize class and year in the Karim

C. argus, (e) Plectropomus oliga

Table 4-2. Results of two-way ANOVA comparing grouper biomass and abundance by survey periods (2005, 2006, 2007, 2009, 2012) and zones (core zone, protected zone, tourism zone, utilization zone, and outside national park); F-ratios and P-values (in parentheses) are shown, significant values (P < 0.05) are given in bold.

Biomass

Source	*df*	All Groupers	*Epinephelus merra*	*Cephalopholis cyanostigma*	*C. argus*	*Plectropomus oligacanthus*	*P. areolatus*
Survey period (year)	4	**3.206**	0.860	**2.623**	1.242	0.257	0.519
		0.014	0.489	**0.036**	0.295	0.905	0.722
Zone	4	**3.396**	**3.288**	2.120	0.859	0.596	0.432
		0.010	**0.012**	0.080	0.489	0.666	0.785
Survey period x zone	15	0.815	0.837	1.105	0.873	0.706	1.062
		0.660	0.636	0.354	0.595	0.776	0.395
Residuals	182						

Abundance

Source	*df*	All Groupers	*E. merra*	*C. cyanostigma*	*C. argus*	*P. oligacanthus*	*P. areolatus*
Survey period (year)	4	**2.576**	**2.689**	**3.699**	**12.714**	0.192	2.332
		0.039	**0.033**	**0.006**	**0.000**	0.943	0.058
Zone	4	**4.664**	**10.900**	**2.729**	1.147	0.839	0.741
		0.001	**0.000**	**0.031**	0.336	0.502	0.565
Survey period x zone	15	0.562	1.459	0.878	0.845	0.498	1.273
		0.901	0.125	0.589	0.627	0.939	0.223
Residuals	182						

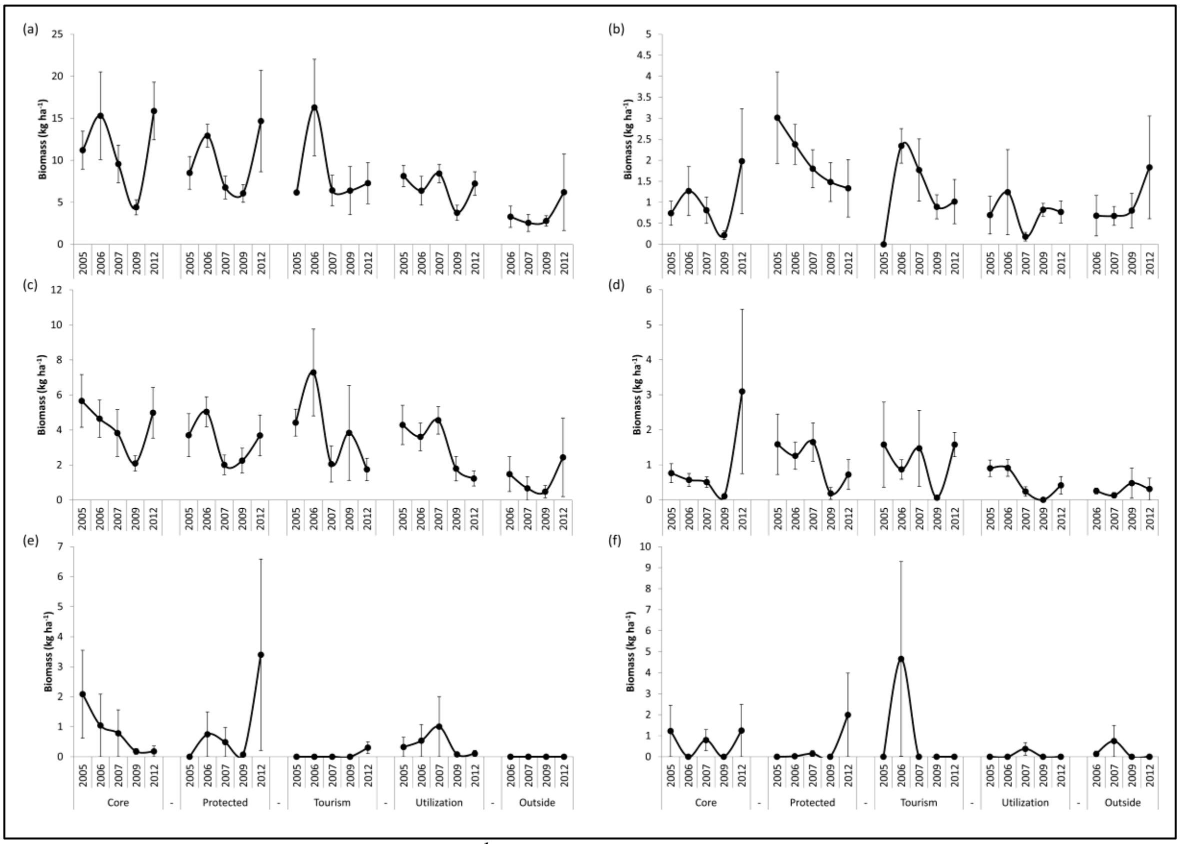


Figure 4-4. Grouper biomass (kg ha^{-1}) in the different zones of Karimunjawa National Park between 2003 and 2012 (mean ± SE); (a) all groupers, (b) Epinephelus merra, (c) Cephalopholis cyanostigma, (d) C. argus, (e) Plectropomus oligacanthus, and (f) P. areolatus.

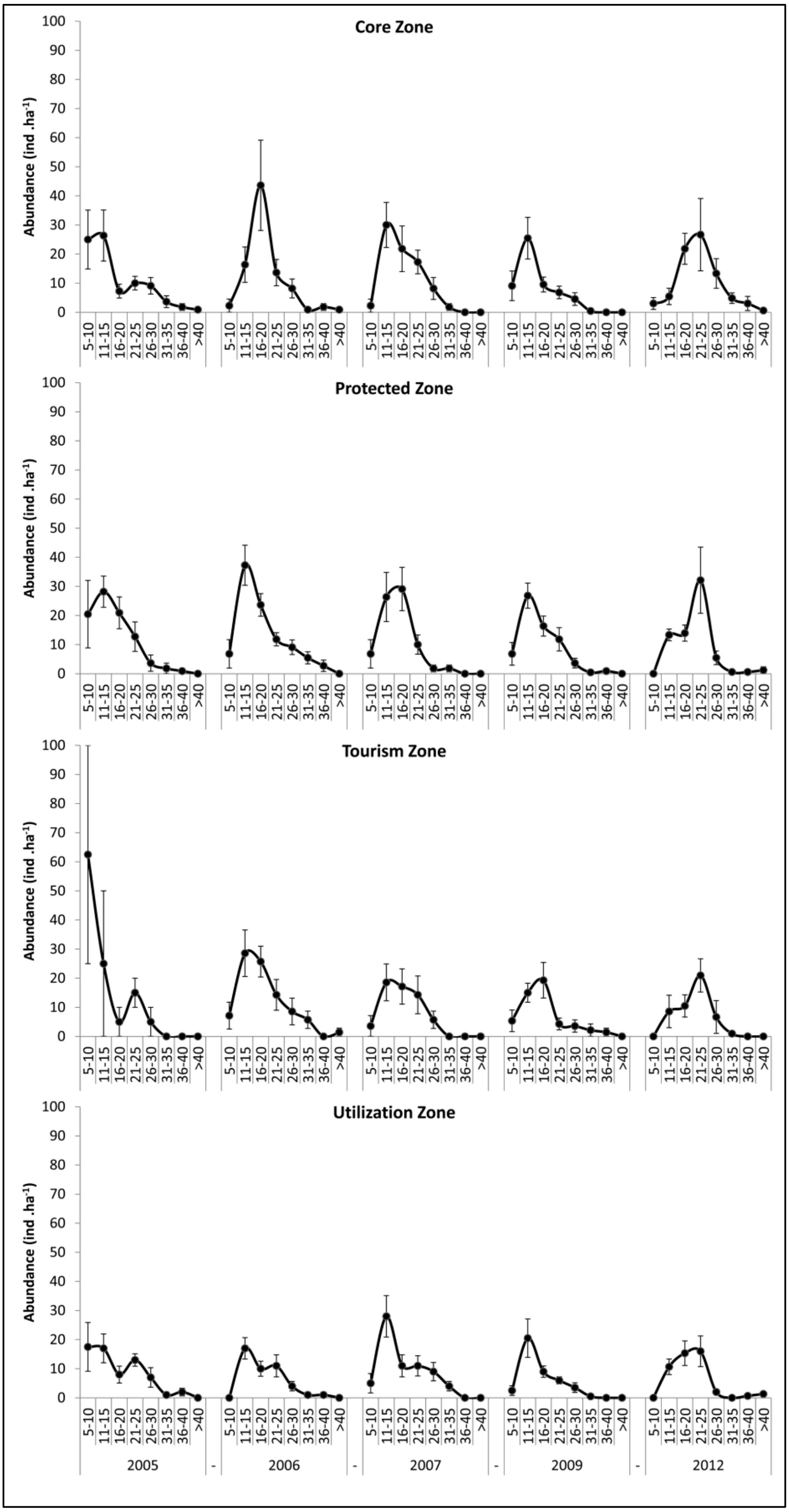


Figure 4-5. Mean abundance (ind. ha^{-1}) based on size classes in the different zones of Karimunjawa National Park for different survey periods (mean $\pm$ SE).

4.3.3 Groupers catches

During the survey period (2003–2011), a total of 1561 trips were recorded, 933 of them yielded groupers. Seven types of fishing gears to catch groupers are employed in the Karimunjawa islands, namely handline, trap, speargun, drive-in nets (muroami), encircling gillnet, gillnet, and troll line. However, only handline, speargun, and trap were used to catch groupers as a target species. Recorded trips at which groupers of the above three fishing metiers were caught amounted to 802 trips (Table 4-3), with a fluctuation of the total trips with handline caught groupers between 2003 and 2012. The annual highest number of successful recorded trips was 126 trips in 2004 and the lowest was 53 in 2011. The number of trips successfully catching groupers per day by using handline ranged from 1.31 to 3.38 trips per day between 2003 and 2011. Recorded trips of speargun caught grouper increased from 2004 to 2010 and decreased from 2010 to 2011. The annual highest number of trips with speargun caught groupers was 123 trips in 2010, and no successful speargun trip was recorded in 2003 and 2005. The number of trips successfully catching groupers per day by using speargun ranged from 0.07 to 2.42 trips per day between 2004 and 2011. Similarly, the number of successful trips that used traps fluctuated between 2003 and 2012, with the highest annual number of 46 trips in 2005, and no successful trap fishing in 2009 and 2011. The number of successful trips per day of trap fishing ranged from 0.20 to 1.07 trips per day between 2004 and 2010.

Table 4-3. The number of total trips and trips per day that successfully caught groupers

Year	Handline		Speargun		Trap	
	Total trips	**Trips. day^{-1}**	**Total trips**	**Trips. day^{-1}**	**Total trips**	**Trips. day^{-1}**
2003	59	1.84	0	0.00	25	0.78
2004	126	2.07	4	0.07	38	0.62
2005	63	1.47	0	0.00	46	1.07
2009	81	3.38	58	2.42	0	0.00
2010	72	1.31	123	2.24	11	0.20
2011	53	1.39	43	1.13	0	0.00

Groupers CPUE of handline decreased between 2003 and 2011, from 6.9 (SE = 2.8) kg trip^{-1} to 0.8 (SE = 0.1) kg trip^{-1}. The decrease of handline catch started in 2005, groupers CPUE of handline significantly ($F(5,1006) = 8.028$ $P < 0.05$) decreased from 9.07 (SE = 3.26) kg trip^{-1} to 4.07 (SE = 0.59) kg trip^{-1} between 2004 and 2005 (Table 4-4). *E. merra* was caught by handline only between 2003 and 2005, after 2005 no *E. merra* was caught by handline. The highest *E. merra* CPUE of handline was 6.8 (SE = 0.03) kg trip^{-1} in 2004. The *C. cyanostigma* CPUE of handline fluctuated between 2003 and 2012. The highest *C. cyanostigma* CPUE of handline was 0.25 (SE = 0.14) kg trip^{-1} in 2005 and the lowest *C. cyanostigma* CPUE of handline was 0.03 (SE = 0.01) kg trip^{-1} in 2010. *C. argus* is not fishing target of Karimunjawa fishermen as only one trip that caught *C. argus* in 2004. *P. oligacanthus* and *P. areolatus* are the most fishing target of Karimunjawa fishermen due to high price. The highest *P. oligacanthus* CPUE of handline was 6.19 (SE = 2.88) kg trip^{-1} in 2004. *P. oligacanthus* CPUE of handline from 2009 to 2011 were very low, it was between 0.06 (0.02) kg trip^{-1} and 0.15 (SE = 0.05) kg trip^{-1}. *P. areolatus* CPUE of handline significantly decreased in 2004 ($P < 0.05$) and no *P. areolatus* was caught by handline in 2010 and 2011.

Meanwhile, the CPUE of speargun increased between 2004 and 2010, reaching 6.40 (SE = 0.84) kg trip^{-1} in 2010, however the mean difference between 2004 and 2010 was not significant different ($P = 0.245$). In 2011, the groupers CPUE of speargun decreased to 4.8 (SE = 0.4) kg trip^{-1}, but it was also not significantly different ($P = 0.219$). *E. merra* and *C. cyanostigma* are not fishing targets of speargun fishermen, thus, no *E. merra* and *C. cyanostigma* was caught by speargun fishermen between 2003 – 2011. *C. cyanostigma*, *P. oligacanthus*, and *P. areolatus* are fishing target of speargun fishermen. *C. cyanostigma* CPUE of speargun increased from 2009 (CPUE = 0.6, SE = 0.1 kg trip^{-1}) to 2010 (CPUE = 1.0, SE = 0.1 kg trip^{-1} $P = 0.042$). CPUE *P. oligacanthus* and *P. areolatus* of speargun were relatively similar from 2009 to 2011 and from 2004 to 2010 respectively. No *P. areolatus* was caught by speargun in 2011.

Table 4-4. Results of one-way ANOVA comparing grouper CPUEs by survey periods (2003, 2004, 2005, 2009, 2010, 2011); significant values (P < 0.05) are given in bold.

Grouper Species	Sources	Handline			Speargun			Trap		
		df	***F***	***P***	***df***	***F***	***P***	***df***	***F***	***P***
All groupers	Between groups	5	**8.028**	**0.000**	3	0.902	0.441	3	3.561	0.016
	Within groups	1006			258			128		
Epinephelus merra	Between groups	2	0.062	0.940				2	1.734	0.182
	Within groups	245						106		
Cephalopholis cyanostigma	Between groups	5	**2.874**	**0.014**	3	1.930	0.125	3	1.577	0.198
	Within groups	1006			258			128		
C. argus	Between groups	5	1.409	0.218	3	0.293	0.831			
	Within groups	1006			258					
Plectropomus oligacanthus	Between groups	5	**6.714**	**0.000**	3	0.920	0.432	3	**3.163**	**0.027**
	Within groups	1006			258			128		
P. areolatus	Between groups	5	**8.289**	**0.000**	3	2.225	0.086	3	0.776	0.509
	Within groups	1006			258			128		

Between 2003 and 2010, grouper CPUE of traps fluctuated. In 2010, groupers catches by traps yielded only 2.33 (SE = 0.75) kg trip^{-1}. There was no catch recorded for trap fishing during the 2011survey. The CPUE *P. oligacanthus* of traps also fluctuated between 2003 and 2010. *E. merra C. cyanostigma,* and *P. areolatus* were caught by traps only between 2003 and 2005 as well. No *C. argus* was caught by traps (Fig. 4-6).

Standardized CPUE decreased from 2003 to 2004 and increased from 2004 to 2005. After 2005, standardized CPUE decreased again until 2011. However, general trend of standardized CPUE was similar with handline, decreased from 2003 to 2011 (Fig. 4-7). The highest standardized CPUE was 8.75 (SE = 2.67) kg trip^{-1} in 2003 and the lowest was 2.40 (SE = 3.31) kg trip^{-1} in 2011.

The groupers catch size in Karimunjawa ranged from 10 to longer than 40 cm (Fig. 4-8); however, the size classes were dominated by fish >40 cm. Moreover, between 2003 and 2005, the catch of the size class >40 cm was more than 50%. In 2011, the fishermen changed the target size to groupers longer than 25 cm. The weight of groupers caught in Karimunjawa ranged from 0.01 kg to more than 2 kg. The weight of the fish was dominated by fish less than 1 kg (>60%). Moreover, 50% of the fish caught in 2010 was fish with less than 0.4 kg. In 2011, the weight of fish was dominated by fish above 0.6 kg (>60%).

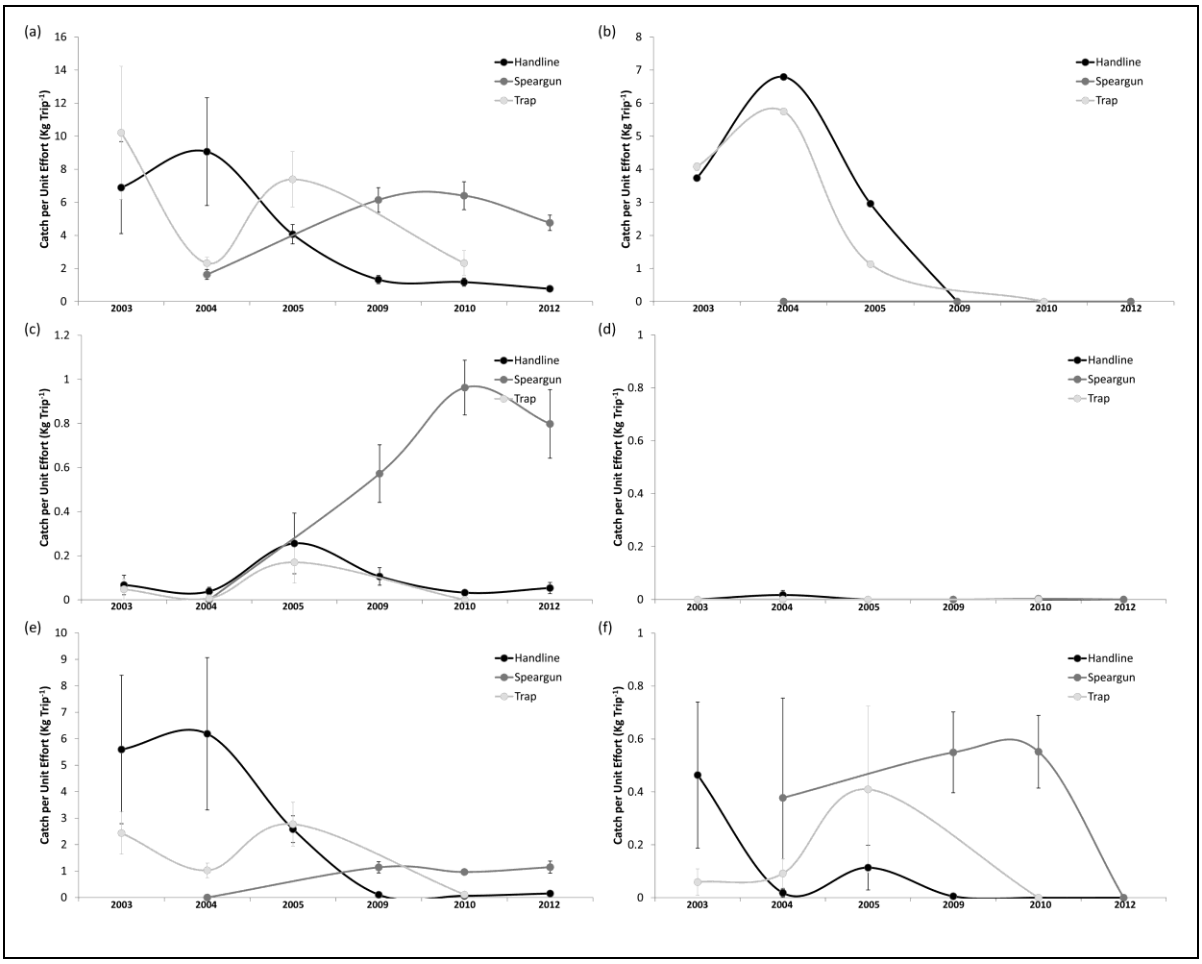


Figure 4-6. Grouper catch per unit effort (kg trip^{-1}) for handline, speargun, and trap fishing in the Karimunjawa islands (mean ± SE); (a) all groupers, (b) Epinephelus merra, (c) Cephalopholis cyanostigma, (d) C. argus, (e) Plectropomus oligacanthus, and (f) P. areolatus.

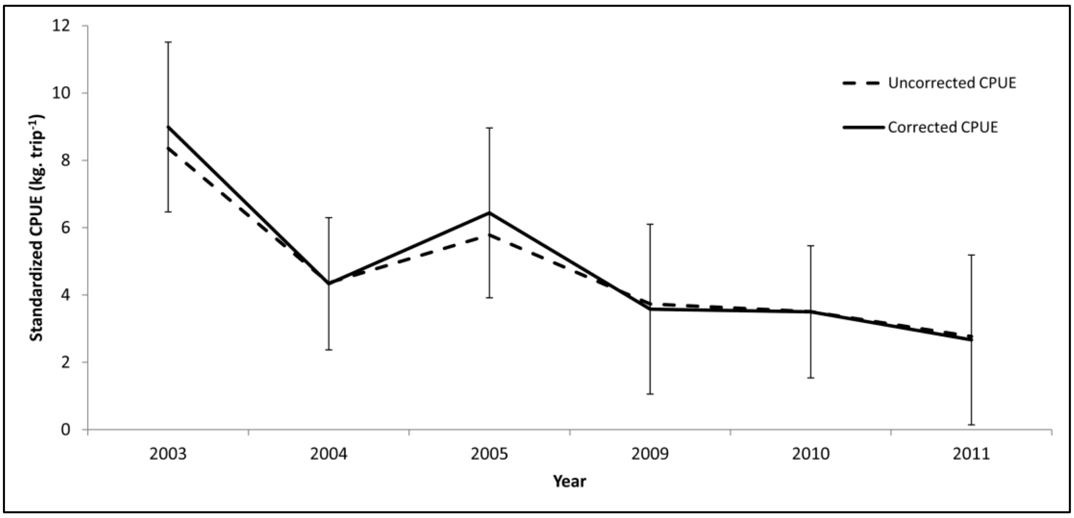


Figure 4-7. Standardized catch per unit effort (kg trip^{-1}) by fishing gear.

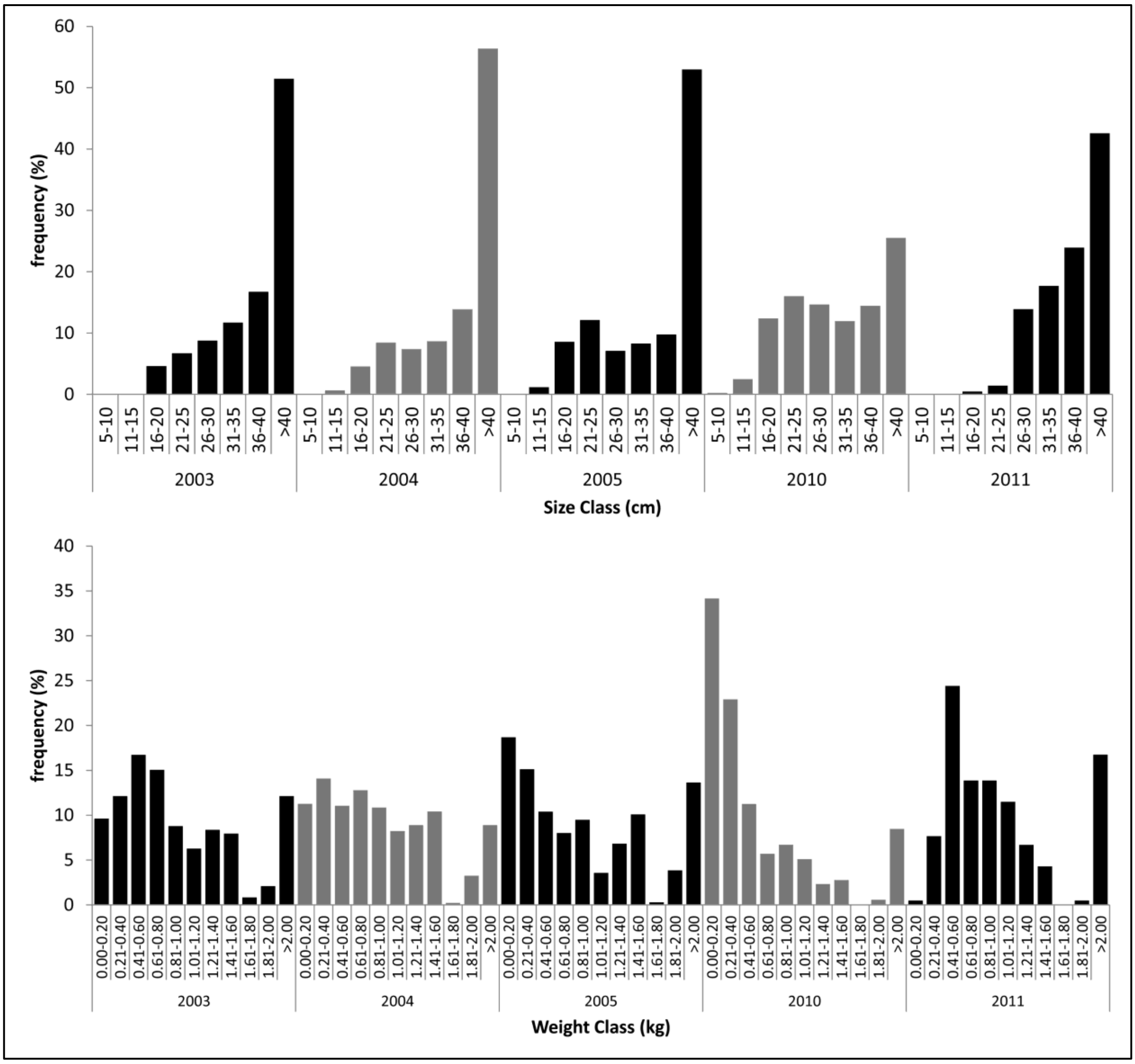


Figure 4-8. Frequency of occurrence (%) of grouper catches based on size and weight from two survey periods, 2003–2005 and 2010–2011.

4.4 Discussion

4.4.1 Abundance, biomass, and stock size

The predominant size in the groupers catches from the Karimunjawa islands changed between 2005 and 2012. The change in size was the major influence on mean biomass. This suggests that the observed increase in mean abundance did not necessarily correspond to an increase in mean biomass, and vice versa. Between 2005 and 2012, the greatest mean abundance was observed in 2005 and the greatest mean biomass in 2006. However, the predominant groupers size in 2006 was larger than the predominant size in 2005. Similar conditions were observed for e.g. *C. argus* and *E. merra*, where the predominant size in 2012 was larger than the predominant size in 2009.

The increasing biomass from 2009 to 2012 resulted from a change in predominant grouper size in the national park during this period. The abundance of several larger sized species (>21 cm) such as *E. merra*, *C. argus*, *P oligacanthus*, and *P. areolatus* increased in 2012. Based on life history data (L_{infinity}, *k*, and t_0) obtained from fishbase (FishbaseWeb: http://www.fishbase.org "Accessed 15 Dec 2014".), *E. merra*, *C. argus*, *P. oligacanthus*, and *P. areolatus* can reach 21 cm at age 22, 18, 14, and 14 months respectively. Consequently, these larger fish (>21 cm) in 2012 originated most probably from the recruitment success of *E. merra* and *C. argus* in 2010 and *P. oligacanthus* and *P. areolatus* in 2011. Although we have no UVC data from 2010 and 2011, we can assume that there was a successful recruitment of several grouper species in Karimunjawa Islands during 2010 and 2011.

Several studies have already recorded a greater biomass of groupers populations in no-take zones within MPAs compared with those in the exploitation zones (Chiappone et al. 2000, Friedlander and Demartini 2002, Unsworth et al. 2007). In this study, the mean biomass of groupers in the core zones was the greatest and differed significantly ($P < 0.05$) from mean biomass in the utilization zone and outside the national park. However, there was no significant difference between mean biomass in the core zone and the protected and tourism zones. Although fishing in the core zone and protected zone is not allowed, and a permit is required in the tourism zone (Campbell et al. 2013), weak compliance of fishing regulation recorded in the national park (Campbell et al. 2012). The significant difference between the core zone and utilization zone might be explained by the difference of fishing pressure (Campbell et al. 2012). Higher biomass of *E. merra*, *C. cyanostigma*, *C. argus* and *P. areolatus*, presumably, contributed to the significant difference between the core zone and utilization zone in 2012. Although the mean biomass of *E. merra*, *C. cyanostigma*, *C. argus*, and *P. areolatus* in the core zones were not statistically higher than the biomass in the utilization zones and outside the national park, but when all groupers species treated as one entity, the mean biomass in the core zone becomes significantly higher than the biomass in the utilization zones. We could not observe any significant difference of *C. argus* in the different zones, because this species is not targeted by regular fishing activities, and the biomass distribution was relatively similar in all zones. *E. merra* also became a non targeted species from 2009 to 2011, resulting in no significant difference of this species between the sampled study sites. This contrasts *C. cyanostigma* and *P. areolatus* , that were affected by fisheries, caused by a weak compliance of handline, speargun, and trap fishermen to avoid the no-take zone from 2003 to 2009 (Campbell et al. 2012). Moreover, weak compliance of handline fisheries in Karimunjawa Islands is still recorded until 2011 (Kartawijaya et al. 2012), and today.

4.4.2 Impact of fishing on groupers abundance, biomass, and stock size

The pattern of abundance and biomass of groupers are correlate with the study that conducted by Campbell et al. (2012) that analyzed the abundance and biomass of reef fish between 2005 and 2009. The abundance and biomass of reef fish significantly decreased from 2007 to 2009. Campbell et al. (2012) mentioned that the decrease of reef fish biomass was caused by illegal fishing e.g. Danish seine and shifting fishing gear e.g. speargun as well as weak compliance to the no-take zone. Danish seine is operated in Karimunjawa Islands as illegal fishing gear by fishermen from Central Java (outside of the national park) because it is not allowed to operate in the national park. Impact of Danish seine can be found in the abundance and biomass of *C. argus*. Although *C. argus* is not a fishing target of Karimunjawa fishermen (fig. 4-6d), the abundance of *C. argus* decreased extremely from 2007 and 2009 ($P < 0.05$). One plausible hypothesis to explain the decreasing of abundance and biomass of *C. argus* in 2009 was the employment of the Danish seine, which was operated by fishermen from Central Java and also landed the fish in outside Karimunjawa Islands.

The mean abundance of small size (<15 cm) *C. argus* decreased from 2005 to 2007 (Fig. 4-3d). This was most probably caused by low abundance or absence of adult *C. argus* due to Danish seine operations, hence eggs and larvae supply or recruitment of *C. argus* was very low. *C. argus* can spawn for the first time at a size of at least 22 cm (FishbaseWeb: http://www.fishbase.org "Accessed 15 Dec 2014".), and between 2003 - 2007 we recorded a very low mean abundance of >20 cm *C. argus*. This condition, i.e. low recruitment and high fishing pressure on the adult fish between 2003 and 2007, contributed most likely to the extremely low mean abundance and biomass of *C. argus* in 2009. Based on this situation, the national park authority established community-based patrols and a call center concerning the violations of fishing gear inside national park since 2010 (Syaifudin 2012). This program was effective to reduce the violations inside national park from Danish seine, based on compliance monitoring (Kartawijaya et al. 2012) the number of Danish seine recorded decreased in 2010 and 2011.

Speargun is the main fishing gear affecting the average size of groupers (Sluka and Sullivan 1998), causing a decrease in groupers populations in Papua New Guinea (Hamilton et al. 2011). The speargun, which was introduced to Karimunjawa in 2004, is the most effective fishing gear for catching groupers. Although groupers CPUE of speargun was not significantly increased, the number of speargun trip that caught groupers increased from 2 trips per month (0.07 trips per day x 7 days x 4 weeks) to 68 trips per month (2.41 trips per day x 7 days x 4 weeks) between 2004 and 2009, i.e. the total speargun effort increased strongly. Some groupers species are easily caught using speargun especially during the night time (Hamilton et al. 2005). Moreover fish caught by speargun fishermen render a lower price due to broken condition requiring speargun fishermen catching as much as possible in one night or one trip.

The impact of speargun fisheries is reflected in the dynamics of the mean abundance and biomass of *P. areolatus*. In 2005, the national park authority revised the zones to improve the effectiveness of the park. In 2006 we recorded only small (<15 cm) *P. areolatus,* apparently due to the protection effect of the park zones revision. In 2007 larger sized (16-35 cm) *P. areolatus* were recorded that might have originated from the small size *P. areolatus* in 2006 (Fig. 4-3f). However we did not find small sized fish (<15 cm) in 2007. The only explanation for this result is very low recruitment of *P. areolatus* in 2007. The increasing fishing effort of speargun fisheries before 2009 and the low recruitment in 2007 contributed to the absence of *P areolatus* during the survey in 2009.

The number of groupers caught with a handline declined after the speargun came into operation, and consequently, according to the Karimunjawa fishermen, the increasing number of spearguns caused catches by handline to decrease (Fig. 4-6). Competition based on different fishing gears (i.e. handline and speargun) can generate “gear war” conflicts (Charles 1992). In 2011, Karimunjawa fishermen jointly developed an agreement for self-regulating fishing gear, especially the speargun. According to the agreement, speargun fishermen are not allowed to catch squaretail coralgrouper (*P. areolatus*), and restrictions on time and site have been imposed on the fishing of camouflage grouper (*E. polyphekadion*) and brown-marbled grouper (*E. fuscoguttatus*). Squaretail coralgrouper, camouflage grouper, and brown-marbled grouper have great economic value in Asian live reef fish trade (Sadovy 2005) and are important species for the artisanal and small-scale fisheries in the Pacific Ocean (Rhodes and Tupper 2007). Although this agreement did not add significantly to the decline of groupers catches taken by speargun in 2011, the agreement seemed to have impact on the total speargun effort. The number of speargun trip per week that caught groupers decreased from 64 (2.24 trips per day x 7 days x 4 weeks) to 32 (2.41 trips per day x 7 days x 4 weeks) trips per month between 2010 and 2011. The decrease of speargun trips is assumed to be due to time restriction for grouper fishing, since the speargun fishermen are not allowed to operate speargun in grouper spawning season times. Moreover, the grouper catch data showed that no *P. areolatus* were caught by speargun fishermen in 2011 (Fig. 4-6). This is an indication that the fishermen comply to the their self-regulation on fishing gear.

The composition of the fish caught by fishermen was dominated by large-sized fish (> 35 cm). As the most of groupers are protogynous hermaphrodites (Ferreira 1993), it is likely that fishermen caught more male fish than female fish. Consequently the possibility is given that male groupers in the population become rare. However, an intra-specific compensatory mechanism leads to sex change at smaller individual size, when male abundance in the territory becomes low, due to absent of large fish by fishing pressure ; the smaller fish (female) can change to be male (Vincent and Sadovy 1998 in Adams et al. 2007). In the present study, no analysis of the fisheries impact on the composition of males and females was made, because information on the sex of landed fish was not collected.

The observed frequency of catch size and weight in 2011 differed from the frequency of catch sizes between 2003 and 2010. Sizes of fish caught between 2003 and 2010 ranged between 15 and >40 cm, and the sizes in 2011 ranged between 25 and >40 cm (Fig. 4-8). Also the weight of fish caught between 2003 and 2010 was smaller than in 2011. The change of catch size can also be seen in the mean size and catch size frequency of *C. cyanostigma* caught in 2010 and 2011 (Fig. 4-9). The mean size of *C. cyanostigma* was significantly different between 2010 (mean = 21.5, SE = 0.7 cm) and 2011 (mean = 31.0, SE = 0.9 cm; $F(1, 75) = 67{,}5$ $P < 0.05$), ranging from 16 to 35 cm in 2010 and from 26 to >40 cm in 2011. The catch size with the highest frequency of occurrence in 2010 and 2011 were 21-25 (49.4%) and 36-35 (57.1%) cm, respectively. A similar change in catch size was also recorded for *P. oligacanthus*. These results indicate that the target size of fishermen in 2010 was similar with the predominant size of UVC recorded groupers in 2009 (Fig 4-3). The size of *C. cyanostigma* and *P. oligacanthus* found in 2009 was predominated by 11-25 and 16-25 cm respectively. Although we cannot analyze the impact of smaller catch sizes in 2010 due to missing UVC data, the groupers size found in 2010 was assumed to be similar to the size observed in 2009. The change to a larger target size in 2011, influenced by a new speargun regulation, reduced the fishing pressure to the smaller sized fish and most probably contributed to the recruitment success in 2011, allowing them to grow and contribute to the higher biomass found in 2012 (Fig. 4-3).

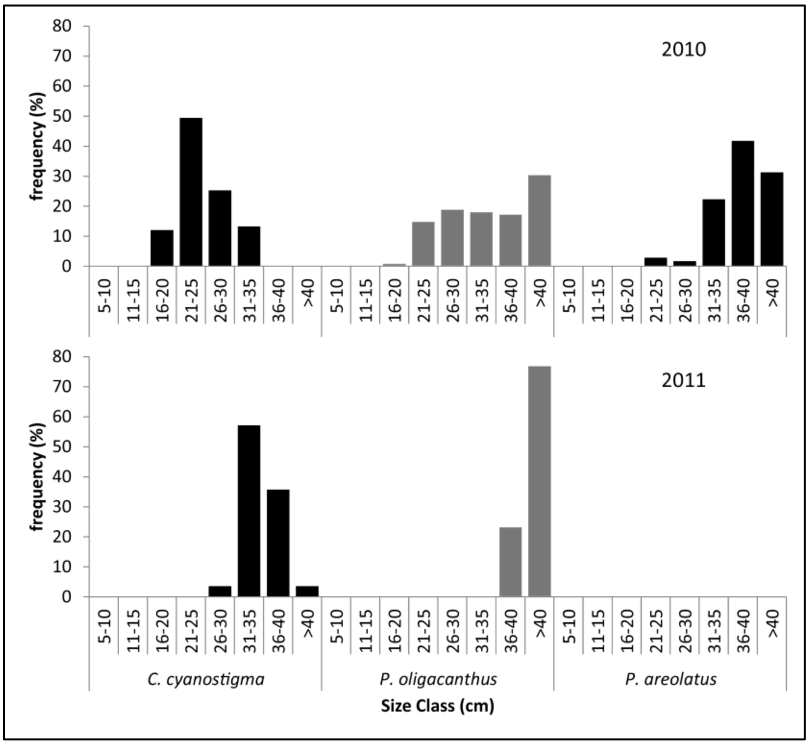


Figure 4-9. Length frequency (%) Cephalopholis cyanostigma, Plectropomus oligacanthus, and P. areolatus caught between 2010 and 2011

The size distribution in the catches was influenced by the different sizes of each fishing gear and speargun regulation in 2011. Speargun fishery exerts higher fishing pressure to small fish of certain species than handlines. Spearguns are generally operated in the shallow water, while handlines are operated in the deeper water. High fishing pressure results in smaller groupers as with other fish stocks (Rochet 1998, Shin et al. 2005); decreasing fishing pressure results in increasing abundance of large groupers (Chiappone et al. 2000). There is a non-significant trend of declining standardized CPUE, potentially indicating that the fishing pressure on groupers in Karimunjawa Islands decreased, this however is still in need of verification. The decreasing standardized CPUE, effort, and increasing sizes of fish caught in 2011 as well as the recruitment success must have contributed to the predominant stock size of groupers that was found through the underwater visual census survey in 2012. The predominant groupers stock size increased significantly in 2012, resulting in increased mean biomass in 2012 (Fig. 4-2). Although the mean biomass of grouper increased from 2009 to 2012, the recruitment of several species was low in 2012. We recorded extremely low abundance of smaller fish (<15 cm) for *C. argus*, *P. oligacanthus*, and *P. areolatus* in 2012 (Fig 4-3a, see above). This may also contribute to a decreasing biomass for these species in future.

4.4.3 Marine protected area and conventional fishery management

Marine protected areas are one management option that has been used widely to protect reef fish populations (Sadovy 1999, Chiappone et al. 2000). Several studies found that groupers biomass in no-fishing zones (the no-take zone within MPAs) was greater than in the fishing zone (Polunin and Roberts 1993, Unsworth et al. 2007). However, the three core zones did not give enough support to protect all groupers populations in the entire area. Mean abundance and mean biomass decreased between 2005 and 2009. This result correlates with the study that was conducted by Campbell et al. (2012), where the abundance and biomass of reef fish decreased between 2005 and 2009 due to weak compliance to the no-take zones and may be caused by the poverty of the fishermen and poor enforcement of the different utilization zones by the park authority. The national park authority realized that the weak compliance caused the decreasing of reef fish abundance and biomass in 2009. The authority in collaboration with international non-government organizations were conducting massive campaigns on the importance of the no-take zone to the Karimunjawa fishermen since 2010. As the result, most of villagers in Karimunjawa Islands understood the importance of the no-take zone (Syaifudin 2012). However violations of the no-take zone especially by handline were still recorded in 2011 (Kartawijaya et al. 2012).

There is evidence that the fishermen's 2011 agreement to self-regulate the fishing gear is achieving its purpose. It appears that the agreement to regulate the speargun fishery in the national park promoted a significant increase in groupers mean biomass and stock size in 2012. Another factor that also contributed to increase in groupers mean biomass is the decreasing fishing pressure of Danish seines that was also supported by the community. Based on our study we can recommend to strengthen the community support and involvement of the local people into grouper fisheries management activities, resulting in a better compliance to the suggested zoning and increasing fishing regulation. This promotes a "following to the rule" practice, with a direct positive impact onto the grouper biomass. This strongly suggests that, although the MPAs are widely recommended as a tool for reef fish protection and management (Gaines et al. 2010), they require community support to work effectively (Hamilton et al. 2011), and a regulation on the fishing gears allowed (conventional fishery management) to improve the available fishery resources (Hilborn et al. 2004).

The estimated demand for live groupers from Karimunjawa National Park is 3000 kg per year (Campbell et al. 2010). However, in recent years, wild catches contributed only

2256 kg of live groupers in 2009 and 1608 kg in 2010. Nevertheless, grouper, also traded outside the park, is an important source of income for the fishermen. There is concern that the sustainability of the grouper stock in Karimunjawa Islands is weak, caused by poor recruitment in recent years (2007-2012). We recorded poor or absent abundance of small fish (<15 cm) especially of *C. argus*, *P. oligacanthus*, and *P. areolatus* in 2012. This may contribute to decreasing natural grouper abundance and biomass in future. To solve this problem, we suggest that the national park authorities and local government should regulate the allowed size limits of grouper catches and the prohibition to catch spawned groupers especially for certain high economics species, reducing the current high fishing pressure to the juveniles and spawning groupers. This regulation should address the different life history traits of the species. Although more fishing regulation is required to increase the level of wild catches, further activities such as stock enhancement or sea-ranching of grouper might be possible to enhance juveniles supply, increase groupers stocks, and fulfill market demand (Bell et al. 2008) also in future. Adjusted groupers sea-ranching methodologies should be tested in the Karimunjawa islands to determine if sea-ranching is an option to increase groupers stocks and to maximize the maximum sustainable yield.

4.5 Acknowledgments

We are grateful to Balai Taman Nasional Karimunjawa for kind cooperation and supporting this research. We also thank Dr. A Soemodinoto, Dr. HA Susanto, Dr. SJ Campbell, P Ningtias, T Kartawijaya, and ST Pardede for carefully reading the manuscript and providing useful input and anonymous reviewers for their constructive comments. Special thanks to Dr. J Gröger professor at the Thünen Institute for helping the data analysis and Indonesian-German Scholarship Program - German Academic Exchange Service (DAAD) for providing the scholarship.

5 Potential and risk of grouper (*Epinephelus* spp., Epinephelidae) stock enhancement in Indonesia[4]

Abstract

Indonesia is one of the countries in Asia region that plays an important role in the grouper supply. Grouper production in Indonesia increased 5-fold within two decades aside a continuous increase in grouper demand. To enhance grouper yield, the Indonesian Government initiated stock enhancement programmes releasing cultured grouper into the natural habitats. The purpose of the present study was to examine the impact of grouper stock enhancement onto natural grouper populations in Karimujawa National Park, Indonesia and to monitor the potential risks involved. Experimental release of 10 cm cultured *Epinephelus fuscoguttatus* (brown-marbled grouper) from the backyard multi-species hatchery system was monitored using underwater visual census and fish-catch monitoring. As a result, it was found that the greatest peril for the released grouper of 10 cm length was falling immediately prey to predators in the reef habitat, even though enough places to hide were available at the release site, since groupers of this particular size class were not trained to survive under field conditions. However, groupers of 15 cm are well capable of seeking shelter and avoiding predators. This leads to the clear recommendation that released grouper should have a size of at least 15 cm for release in stock enhancement programmes. According to our experiments, the prior officially recommended minimum size of release (10 cm) is too low and has to be increased to 15 cm for *E. fuscoguttatus*, and requires future adjustment of the official recommendations in use. Parasitological examination of the released fish was conducted in order to analyse potential risks involved. No macro-parasites could be observed, limiting the risk of spreading parasites and diseases within the Indonesian archipelago. However, many parasites of *E. fuscoguttatus* are widespread and can infect different grouper species.

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5.1 Introduction

Groupers belong to the high valuable Asian fish commodities, 80 % of the world grouper production in 2008 originates from the region (Sadovy et al. 2013). Based on the Food and Agriculture Organization of the United Nations (FAO 2014b), the total production of grouper increased 25 % between 1999 and 2009, and more than 17 times between 1950 and 2009 (Sadovy et al. 2013). Indonesia plays an important role in grouper supply (Johnston and Yeeting 2006, Pet-Soede et al. 2004). According to the fisheries statistics (MMAF 2002), grouper production in Indonesia was 15,786 t in 1990 and increased to more than the double in 2000, reaching 48,422 t (Fig. 5-1). In 2012, grouper production reached 92,183 t or increased more than 5 times in two decades (MMAF 2013b). The Indonesian Government announced a new and ambitious policy for the fisheries sector to increase the fish production by more than 300 % until 2015 (MMAF 2010a), making Indonesia becomes the world´s largest fish producer. Several programmes have been implemented to realize the new policy, e.g. aquaculture intensification, establishment of marine protected areas, and fish stock enhancement programmes, the latter included the release of cultured fish into the natural populations.

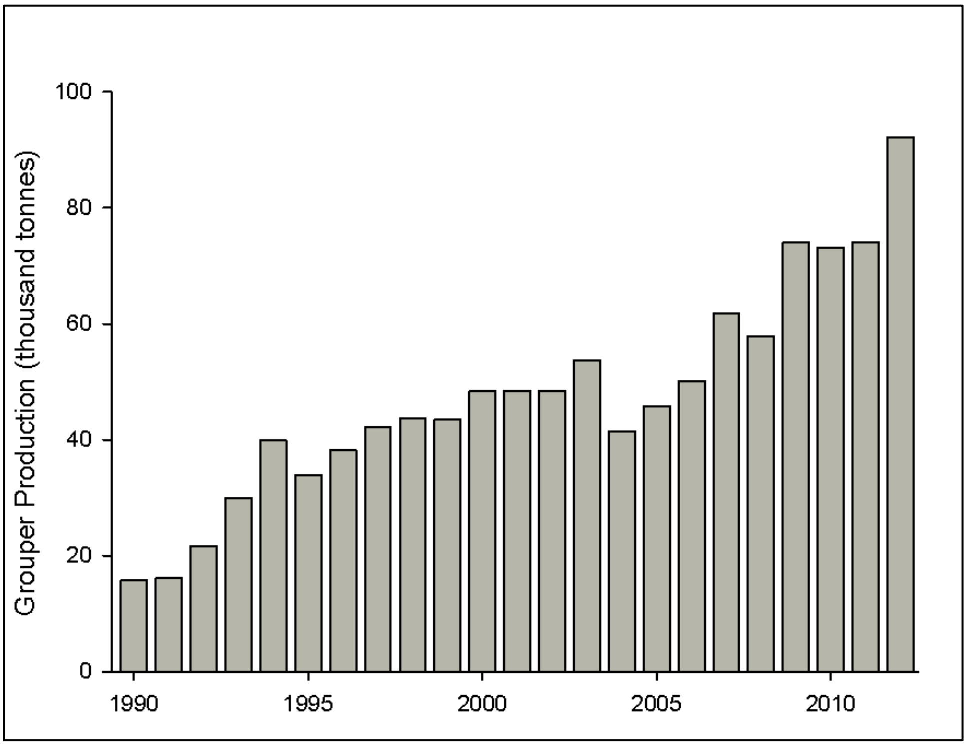

Figure 5-1. Captured grouper production in Indonesia (kg) from 1990 to 2012

According to Bell et al. (2008), the release of cultured fish into the natural populations falls into three categories, i.e. restocking, stock enhancement, and sea-ranching. Restocking is the release of cultured fish into the natural population to recover fish populations that are in depleted condition. Stock enhancement is the release of cultured fish into the natural populations to enhance the supply of juveniles. Sea ranching is the release of cultured fish into unenclosed areas to harvest later, with definite benefit for releasing company or institution. Stock enhancement was introduced in 1762 for freshwater fish and implemented for marine fish the first time in 1962, both in Japan (Masuda and Tsukamoto 1998). In 1990s, the number of countries implementing marine fish stock enhancement raised (Bell et al. 2008), including successful stories such as the southern scallop fishery enhancement in New Zealand (Lorenzen 2008), shrimp (*Penaeus esculentus*) stock enhancement in Western Australia (Loneragan et al. 2006), and salmon (Masuda and Tsukamoto 1998), and other finfish (Kitada and Kishino 2006) stock enhancement in Japan. However, several lessons learned were reported, providing input to future stock enhancement programmes especially related to the science, methodology and techniques involved (Bell et al. 2008). The most prominent risks and problems that probably arise and should be avoided occur after the release of the cultured fish concerning the fish adaptation to the new habitat (Brown and Day 2002), parasites that probably are transferred from the culture facility (Bartley et al. 2006), and strong fisheries exploitation before the fish reach suitable market size (Liao 2007).

Prior to 2010, the release of cultured fish for stock enhancement in Indonesia was only known for freshwater fish. In 2010, the Ministry of Marine Affairs and Fisheries initiated a stock enhancement programme for marine fish called “one man one thousand fries” including groupers. Other institutions also started similar activities, i.e. the District Government of the Seribu Islands in collaboration with the Centre of Coastal and Marine Research Study-Bogor Agricultural University in Seribu Islands and Karimunjawa National Park Authority in Karimunjawa Islands. There are only few studies with impact via stock enhancement in Indonesia especially for marine species, such as squid stock enhancement by squid attractor (Baskoro et al. 2008), napoleon wrasse stock enhancement by artificial reef (Panggabean et al. 2010), sea cucumber stock enhancement (Taurusman et al. 2012) and grouper sea ranching (Kurnia 2012). Apparently, there is only one study employing a model of grouper stock enhancement in Indonesia based on the biological information (Kurnia 2012), however, studies on the potential of these activities and the risks involved are still missing.

The objective of this study was to examine the impact of grouper stock enhancement, including a success monitoring and recommendations for future stock enhancement activities in the region. An experimental release of aquaculture produced *Epinephelus fuscoguttatus* into their natural coral reef habitat was conducted and monitored. The juveniles were studied for fish parasites before the release. The future potential of grouper stock enhancement and potential risks involved are discussed.

5.2 Materials and methods

5.2.1 Study site

Karimunjawa Islands with around 9000 inhabitants belong to Jepara District, and are located in the Java Sea, 79 km north of Java Island. Five tropical ecosystems can be found in these islands; low land forest, mangrove, beach vegetation, seagrass, and coral reef (Nababan et al. 2010). Grouper demand in these islands is estimated to be 3000 kg per year, but the fishermen cannot fulfil the demand (Campbell et al. 2010). In 1999, the Indonesian Ministry of Forestry designated 22 of 27 islands as Karimunjawa National Park. To manage the park, the National Park is divided into a core zone, protected zone, tourism zone, rehabilitation zone, aquaculture zone, and a traditional fisheries or utilisation zone. The core zones and the protected zones are the areas of highest protection and are dedicated to ensure the grouper resources, which including the grouper spawning aggregation site (Campbell et al. 2013).

5.2.2 Grouper release

Groupers were bought from Jepara, the nearest place of mariculture facility that was able to provide the fingerlings which were reared by the backyard multi-species hatchery system. Groupers were bought two weeks before the release time, and adapted within a net cage to the local conditions in Karimunjawa Islands. Four days before the release, fingerling of *Epinephelus fuscoguttatus*, Forsskål*,* 1775 were tagged with T-bar extra small anchor FF-94 tags (Floy Tag) of 38.1 mm length. The tags were inserted by a pistol grip into the dorsal musculature of the fish. One day before release, the fish were not fed to prevent transportation mortality. The tagging mortality was 1.01%; 15 of 1482 fish died in net cage probably due to the first transport or tagging process, and 35 fish (2.36%) died due during boat transportation from the net cage to Taka Malang.

On November 27th, 2012, 1432 cultured brown-marbled groupers were released into two sites; 623 tagged fish were released in Taka Malang and 809 tagged fish were released in

Cemara Kecil Island. The size of the released grouper was 10 cm as it is the common available size of fingerling grouper in mariculture centre, and the minimum size of grouper for stock enhancement recommended by Kurnia (2012) and MMAF (2010b). Kurnia (2012) assumed that groupers of 10 cm can survive in nature. Taka Malang is the core zone or the no-take zone and Cemara Kecil Island is the protected zone in the National Park. Apart from research and education with prior permit, no activity is allowed in Taka Malang, and fishing activities are not allowed in Cemara Kecil Island. Taka Malang is a patchy reef complex and located close to the main land of Karimunjawa Island. Taka Malang is indicated as a spawning aggregation site for grouper (Kartawijaya et al. 2010), and is an open area; we assumed that the cultured fish is able to migrate to other areas. Based on the underwater visual census survey in 2012, the grouper biomass in Taka Malang was 40.6 kg ha^{-1} with the greatest fish size in the range of 20-25 cm.

Cemara Kecil Island is a small island in the western part of Karimunjawa Island, surrounded by coral reef and can be considered a semi-closed area. We assumed that the released fish has limited migration areas. In Cemara Kecil Island, grouper biomass in 2012 was 10.1 kg ha^{-1} with the largest fish size between 15 and 20 cm. Reef fish biomass in the marine protected area can reach 1200 kg ha^{-1} (McClanahan et al. 2009). Assuming that about 10% are grouper, then grouper biomass can reach 120 kg ha^{-1}. This value is close to the highest grouper biomass found in the marine protected area of 130 kg ha^{-1} (Karkarey et al. 2014). Comparing the grouper biomass that can be reached in the marine protected area with the grouper biomass in Taka Malang and Cemara Kecil Island, it should be possible to enhance the stock of grouper at both release sites.

After the release of fish, we conducted meetings with fishermen and sent a message via "short message service blast" to disseminate the information on the stock enhancement programme to fishermen and the community. The meetings were conducted twice with more than 50 fishermen and their community and the messages were sent twice to more than 1000 phone numbers of fishermen and the community in Karimunjawa Islands. Besides the meetings and the short messages, we also informed the fishermen when we met them and had informal discussion. In the meetings, discussions and messages, we informed about the grouper release as part of the stock enhancement programme; we requested the fishermen not to catch the tagged fish until the suitable size, and to inform us when they accidentally caught fish with tags. We also informed them that they would be rewarded by the double regular price of fish if they caught the fish after May 2013 or when the fish had reached a weight of 0.25 kg.

5.2.3 Underwater monitoring

Underwater monitoring was conducted to study the grouper distribution and change of abundance in the natural population. The method used in the surveys was underwater visual census with timed swim and belt-transect technique according to Campbell and Pardede (2006) and Yulianto et al. (2012) as well as Yulianto et al. (2015a) for fish total length estimate. The timed swim technique covered an area of about 300 m×100 m, the divers started from the surface, diving to the bottom of the reef and then returned to the shallow for 60 minutes where most of the swim time (30 minutes) was spent. For the Belt transect technique, the divers recorded the size of all groupers along three 50 m transects at reef crest and reef slope at each site. The surveyed transects were 2 m wide for fish <=10 cm and 5 m wide for fish > 10 cm.

The surveys were conducted every day in the first week, every ten days in the first month, the third of month, and the sixth of month after the release of the grouper. The belt transect surveys were conducted in December 2012 and in May 2013. In December 2012, we conducted belt transect survey Taka Malang and Cemara Kecil Island. In May 2013, we conducted belt transect survey at 43 sites of the reef crests and reef slopes in all of reef areas of Karimunjawa Islands which was included Taka Malang and Cemara Kecil Island. The divers recorded the number and size of the total length of grouper with tags and without any tags. Moreover, the divers also observed the behaviour of the released and tagged fish in the natural environment in the first week after the release. Based on this preliminary finding on the behaviour of the released and tagged fish, we attempted to find larger brown-marbled grouper from mariculture in Karimunjawa Islands in order to release and observe their adaptation as well. We could only purchase 35 cultured brow-marbled groupers of 15 cm total length and released them on June 26th, 2013 in Cemara Kecil Island.

5.2.4 Fish-catch monitoring

Fish-catch monitoring was divided into two types of monitoring; fish-catch monitoring for landed dead fish (“fish landing survey”) and fish-catch monitoring for live grouper catches (“live grouper catch survey”). Fish-catch monitoring was conducted from January 2013 for 15 days every month during new moon phase, since few or no fishermen went out fishing during the full moon phase. The fish landing survey was conducted in Karimunjawa Island with the largest landing site. Live grouper catch survey started in March 2013 due to bad weather in January and February 2013. As fishermen are not allowed to fish at the release sites in the no-take zone and protected zones, we operated traps to catch grouper in the release sites. Three traps were operated at each site in March, April, and June 2013. For groupers caught by trap and from fish landing survey, the total length and total weight per fish were recorded. During live grouper catch surveys; we only recorded the number of fish and weight of grouper. Grouper caught alive were directly sold to a fish collector and/or placed into the net cage. For this reason, it was not possible to measure the total length of the fish. The weight of live grouper catches was calculated based on the trading receipts or fishermen estimation.

The catch per unit effort (CPUE) of brown-marbled grouper was calculated per year for the fish landing survey and per month for the live grouper catches survey. The CPUE from fish the landing survey was compared with the CPUE of each fishing gear from the fish landing surveys in 2011 and 2012. The fish landing data in 2011 and 2012 were collected from Karimunjawa National Park reef fish database, under the Karimunjawa National Park Authority and Wildlife Conservation Society Program. Independent t-tests were conducted to compare the CPUEs. We compared the CPUEs of live brown-marbled grouper catches each month and analysed the fishing ground of brown-marbled grouper.

5.2.5 Parasite investigation

Parasite investigation was conducted to investigate the parasites in the cultured brown-marbled groupers that were released to the natural population. Thirty-five cultured groupers were randomly chosen and frozen at -20°C until subsequently dissected in the laboratory. In the laboratory, we examined the ectoparasite from the skin, fins, eyes, gills, mouth- and gill-cavity, and the endoparasite in the inner organs; digestive tract, liver, gall bladder, spleen, kidneys, heart and swim bladder. The inner organs were separated into different petri dishes with saline solution and investigated under a Zeiss Stemi DV4 binocular microscope (Palm 2011). The gut wash and body soak method (Cribb and Bray 2010) were also used for a complete investigation. The isolated parasites were preserved in 70% ethanol. To identify the parasite species, we transferred the parasite from graded ethanol to 100 % glycerine (Riemann 1988). We analyse the parasite by calculating the prevalence of infection.

5.3 Results

5.3.1 Underwater monitoring

During timed swim survey at both release sites, we only recorded cultured brown-marbled grouper during the first five days. The first day after the release, we found 42 tagged brown-marbled groupers in Taka Malang and 2 tagged groupers in Cemara Kecil Island.

The second day 9 brown-marbled groupers were found in Taka Malang and 3 in Cemara Kecil Island. Third day, 7 and 1 tagged groupers were found in Taka Malang and Cemara Kecil Island respectively. The fourth and fifth day, 5 and 2 tagged groupers were recorded only for Taka Malang (Figure 2). The groupers found during the first three days were within a 3 m radius from the release site. The fourth day, the maximum distance from the release site was 10 m. During belt transect surveys, we did not find any brown-marbled grouper, even though we have used 258 of the 50 meters line transects to survey brown-marbled grouper in all of reef areas within Karimunjawa Islands.

Based on the observation of the brown-marbled grouper in their natural environment, we found that the cultured grouper did not quickly adapt to the natural conditions. After the release, the cultured grouper laid themselves on the bottom of the release site and did not swim to a shelter in the coral reef formation to hide from potential predators. Moreover, they also did not flee when they were approached by bigger sized of groupers, thus they were easy prey. Figure 5-3 demonstrates the process of bigger size grouper preying upon the cultured grouper. Only during the second or third day, the released grouper started to adapt to the natural conditions, hiding themselves in the coral reef formation. However, they were too weak to defend their hiding spot and rather swam away when other similar sized fish approached them or when similar sized wrasse fish bit the tags.

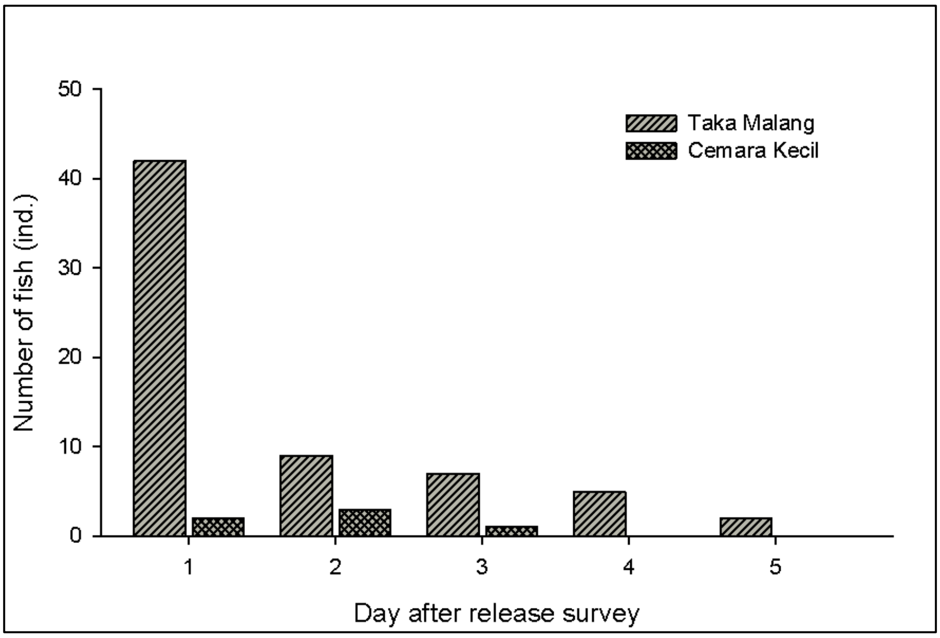

Figure 5-2. Numbers of released (ind.) cultured grouper that were found during the timed swim survey.

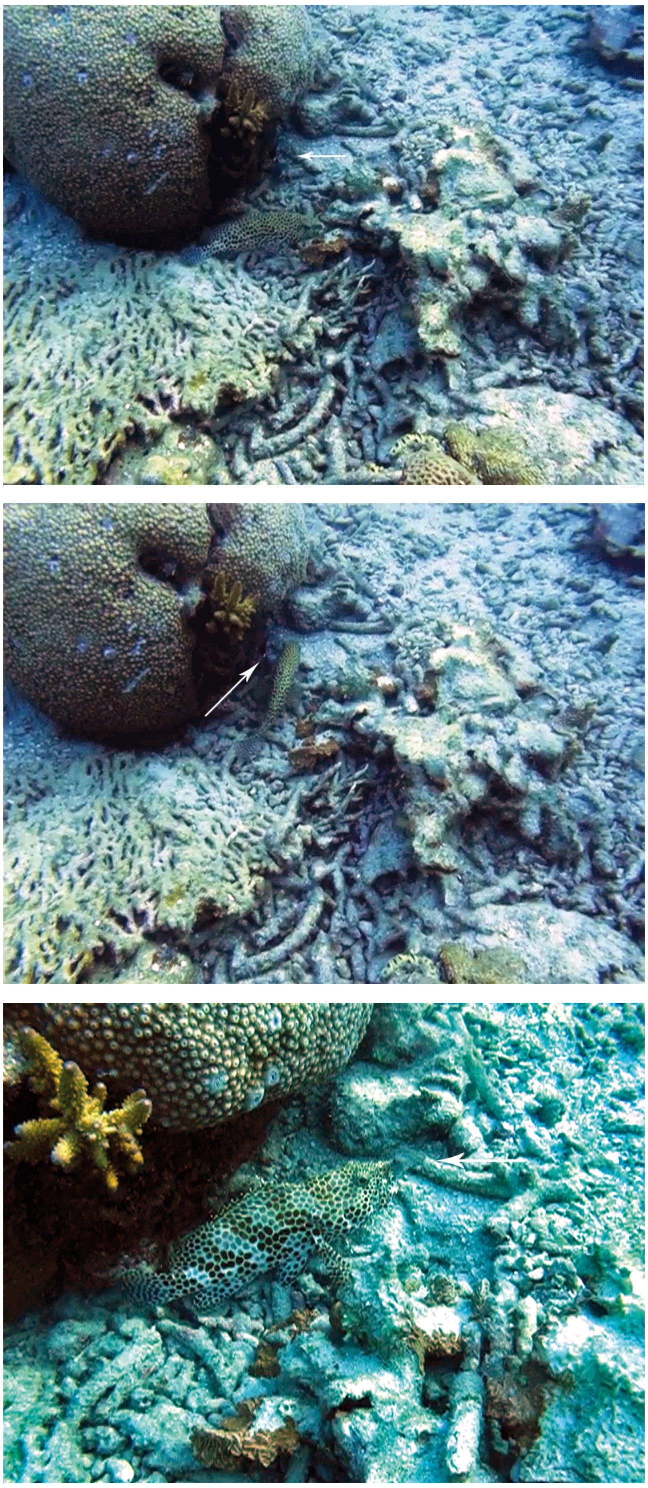

Figure 5-3. Predation of cultured grouper by another grouper; (a) Larger grouper noticed the cultured grouper that did not move (white arrow indicates the position of the cultured grouper with a tag), (b) Larger grouper approached the cultured grouper and the cultured grouper still did not move (white arrow indicates the position of the cultured grouper with a tag), and (c) the cultured grouper was eaten by the larger grouper (white arrow indicates the position of cultured inside the larger grouper mouth)

Based on the observation of larger cultured brown-marbled grouper in their natural environment after the release, the cultured grouper of 15 cm directly adapted to the natural conditions. After the release, they swam directly to the caves of the coral reef formation, and after one hour, they were not detectable anymore and remained undetectable in the process. This leads to the assumption that bigger sized fish directly adapted to the natural conditions and was able to hide themselves in the coral reef formations more effectively.

5.3.2 Fish-catch monitoring

We only received three reports on recaptured brown-marbled grouper. The first report of recapture was received at the end of December 2012 or one month after the release. A tourist guide accidently speared a tagged brown-marbled grouper when he accompanied visitors to Cemara Kecil Island and speargunned in the shallow water of the seagrass. The second report of recapture was also received the end of December 2012. A grouper with tag was caught by speargun fisherman in the deep reef outside of the protection zone in Cemara Kecil Island. We received the third report in March 2013, a brown-marbled grouper with tag that was caught by trap in deep reef of Cemara Kecil Island, and the fisherman released the fish again. Moreover, we also caught once a brown-marbled grouper in Cemara Kecil Island while we operated the traps at the release site in March, April, and June 2013, but this grouper was not a released one.

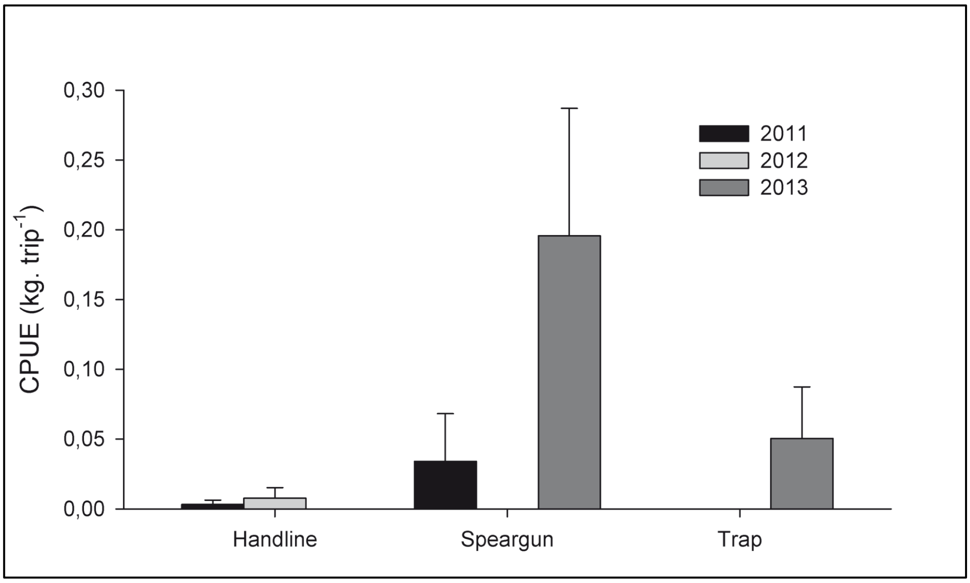

Figure 5-4. Catch per unit effort (kg. trip^{-1} $\pm$ SE) of brown-marbled grouper from fish landing survey.

During fish landing survey, the catch per unit effort of speargun and trap in 2013 was 0.196 (SE = 0.091) kg trip^{-1} and 0.050 (SE = 0.037) kg trip^{-1}, respectively. It was higher than CPUE for both fishing gears in 2012 where no brown-marbled grouper was caught. CPUE of Speargun in 2011 was also significantly lower ($p < 0.05$) than CPUE in 2013, it was only 0.034 (SE = 0.034) kg trip^{-1}. There was no brown-marbled grouper caught by handline in 2013, and the CPUE of handline in 2011 and 2012 was very low; it was only 0.003 (SE = 0.003) kg trip^{-1} in 2011 and 0.008 (SE = 0.008) kg trip^{-1} in 2012 (Fig 5-4). Although CPUE of speargun and trap in 2013 was higher than CPUE of both fishing gears in 2012, it is assumed that it was not an effect of the stock enhancement since no a single tagged brown-marbled grouper was recorded (if not tags were lost). During the live grouper catch survey where fishermen only used traps to catch live grouper, high CPUE was recorded in March, April, May, and June 2013. The highest CPUE in weight was recorded in June 2013, it reached 0.30 (SE = 0.10) kg trip^{-1}. The highest CPUE in number of fish was recorded in April, it reached 0.58 (SE = 0.19) ind trip^{-1}. In July 2013, the CPUE of live grouper decreased dramatically to 0.07 (SE = 0.03) kg trip^{-1} or 0.17 (SE = 0.08) ind trip^{-1}. The CPUE of live brown-marbled grouper was still low until December 2013 (Fig. 5-5).

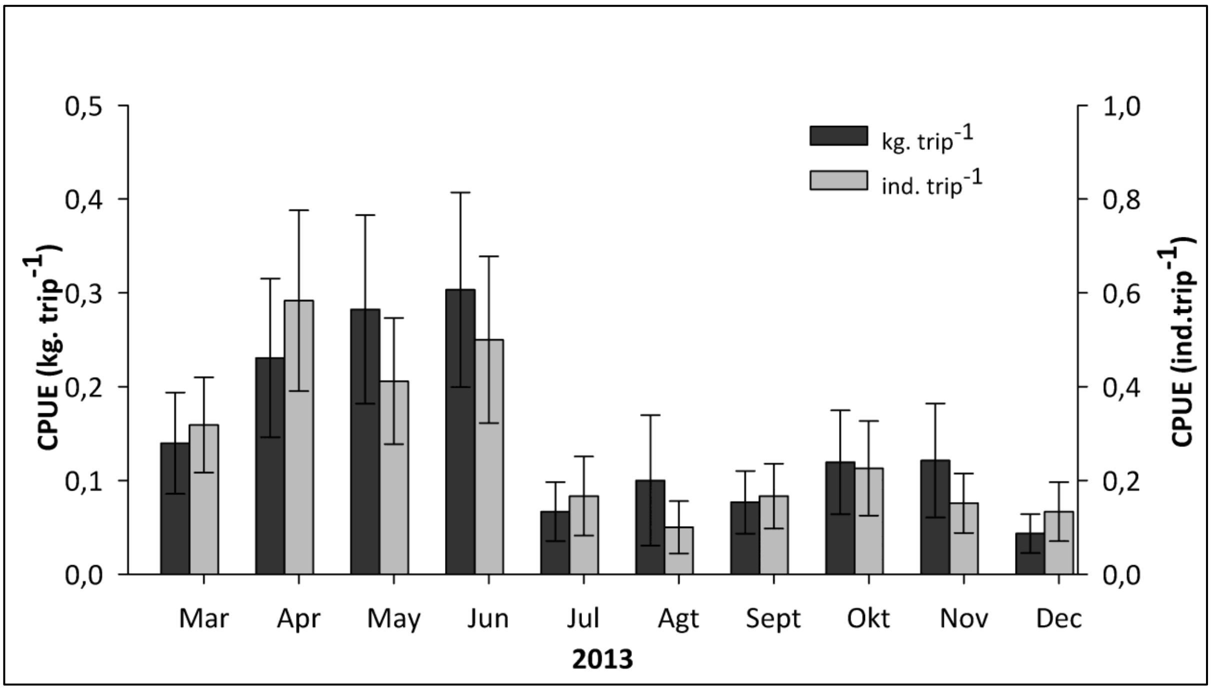

Figure 5-5. Catch per unit effort (kg. trip$^{-1}\pm$ SE and ind. trip$^{-1}\pm$ SE) of brown-marbled grouper from live grouper catch survey.

Most brown-marbled grouper caught between March and June 2013 were close to the release sites (Fig 5-6). In March 2013, most of brown-marbled groupers were caught at the deep reef of Cemara Kecil Island (around 0.6-1 km from the release site of Cemara Kecil Island), Terusan (around 2.7 km from the release site Taka Malang), Nyamplungan (around 1.2 km from the release site Taka Malang), Alang-alang (around 2.3 km from the release site Taka Malang) and Tanjung Gelam (around 2.3 km from the release site Taka Malang). In April 2013, most of brown-marbled groupers were caught at deep reef of Cemara Kecil Island, Cemara Besar Island (around 2.6 km from the release site of Cemara Kecil Island) and Tanjung Gelam. In May 2013, fishing grounds of brown-marbled grouper that were near the release sites were Alang-alang and Tanjung Gelam. In June 2013, several brown-marbled groupers also were caught close to the release site; Tanjung Gelam. Between July and December 2013, the fishing grounds of brown-marbled groupers were farther than the fishing ground between March and June 2013. Most of the brown-marbled groupers were caught at the southern part of Karimunjawa Island, Menjangan Besar Island, and Menjangan Kecil Island, which are located 7-9 km from the release site in Cemara Kecil Island or 8-11 km from the release site in Taka Malang. Although a high CPUE was recorded between March and June 2013 and most of the fish were caught close to the release sites, this could not be attributed to the stock enhancement since only one tagged brown-marbled grouper was recorded in March 2013 which was released again by the fisherman.

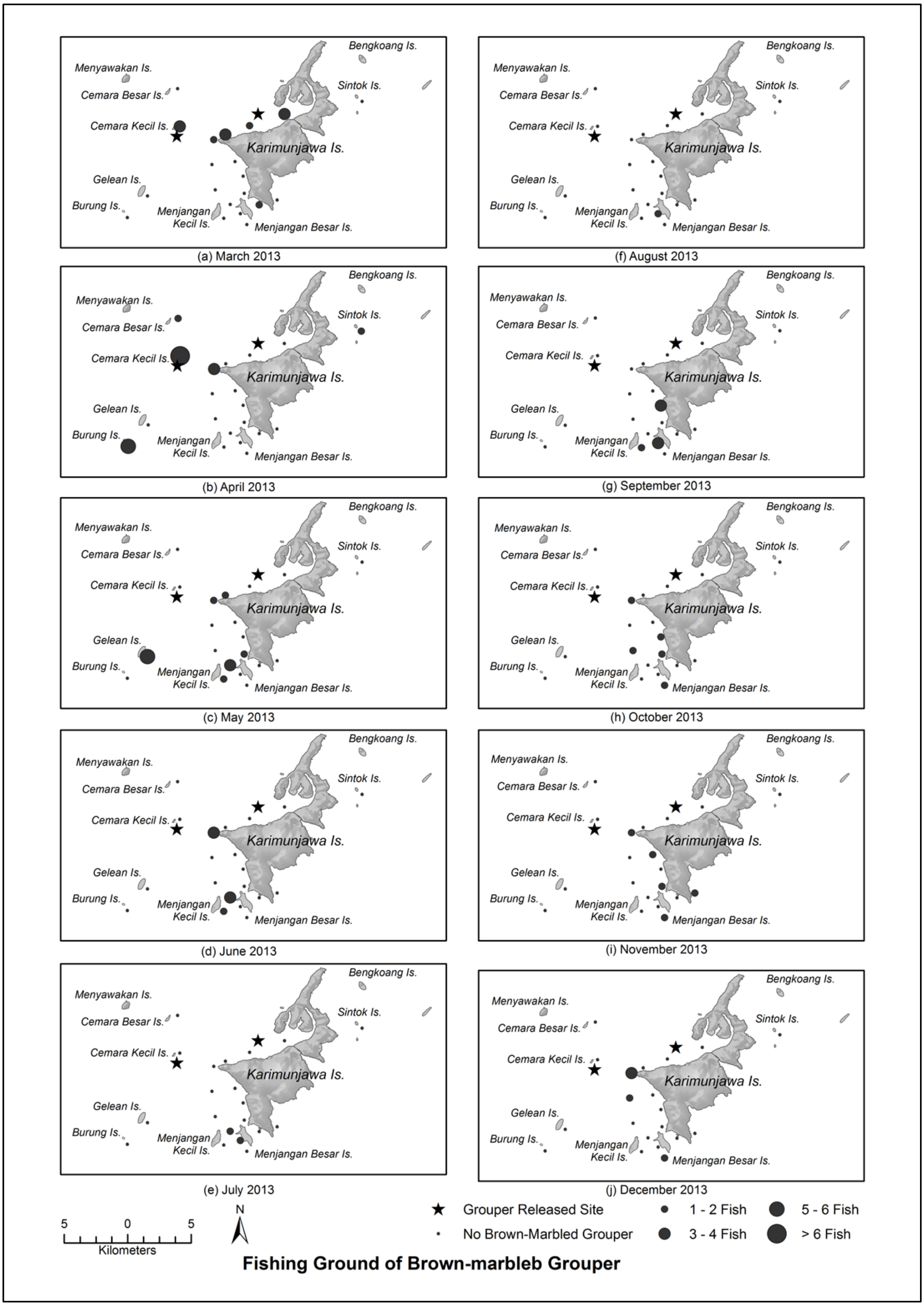

Figure 5-6. Fishing ground of trap that caught live grouper from March to December 2013

5.3.3 Parasite

We examined 35 brown-marbled grouper to investigate the ecto- and endoparasite that could be brought by cultured brown-marbled grouper from mariculture facility to the natural population. No metazoan parasite species was found in cultured brown-marbled grouper; we only found some cysts that were attached to the fins and gill. The cysts were white and had a rounded shape, 120-200 µm in diameter (Fig. 5-7) at a prevalence of 45.71%. We could not identify the cause of these cysts even under high magnification.

5.4 Discussions

5.4.1 Risks

Several studies on the potential risks of releasing fish to enhance the natural populations have been conducted in order to improve the restocking, stock enhancement, and sea-ranching programmes. The greatest difficulty to release juvenile fish to the natural population is predation. Blankenship and Leber (1995) and Bartley and Bell (2008) applied field experiments to identify the methods and techniques to significantly reduce the predation rate. Kurnia (2012) investigated the minimum size of sea ranched brown-marbled grouper in the Seribu Islands, Indonesia. Based on the catch history he assumed that the minimum size of brown-marbled grouper to survive from predator is 10 cm. Moreover, the Ministry of Marine Affairs and Fisheries produced a guideline for stock enhancement for marine fish mentioning that the minimum size of fish is 10 cm (MMAF 2010b).

Figure 5-7. The cysts recorded in the gill filaments of cultured brown-marbled grouper.

Contradictory to Kurnia (2012) and MMAF (2010b), this study demonstrates that 10 cm of fingerling size brown-marbled grouper is too small for release at Karimunjawa Islands due to the lack of pre-adaption and appropriate avoidance reaction to predators. Based on our observation, brown-marbled grouper at 10 cm cannot adapt directly at the condition under presence of predators, and need at least 2-3 days before they actively search for shelter. Slow adaptation of the released fish to the natural environment is caused by less learning opportunities under cultivation conditions, because the fish are kept in a plain and homogenous cultivation tank in the mariculture facility (Salvanes et al. 2013). Moreover, the natural camouflage with cryptic ability usually exhibited by brown-marbled grouper (Pears 2005) was less well developed on the released fish, which adds to the inadequate behaviour of the 10 cm fish.

Education and awareness of the fishermen to protect the released fish are important for any stock enhancement program, allowing them to reach suitable size (Matsuoka 1989 in Liao 1997). The release of cultured brown-marbled grouper in the no-take zones and protected zones was appropriate in the view of them from fisheries activities. However, this cannot prevent grouper migrating to non-protection zones. It appears to be better to release the fingerling fish in an area with limited migration possibilities, leading to a better protection e.g. at Cemara Kecil Island. However, our experiment demonstrates that released brown-marbled groupers were already caught by fisherman before they had reached a suitable size one month after the release, although we released the fish into the no-take and protection zone with limited migration area. It was not prevented that the fish was caught by fishermen before reaching a suitable size. Outreach to the fishermen community can reduce the risk of exploitation, and fisheries pressure. One fisherman who caught a brown-marbled grouper with tag in March 2013 released it again, knowing stock enhancement programme. Community support on national park management including self-fishing regulation influences the management effectiveness and the grouper fish stock (Campbell et al. 2013, Yulianto et al. 2013c). Tringali et al. (2008) already recommend that to optimally succeed, it be not only by providing information to society (fishermen community) but also developing the institutional capacity, possibly involving them in the stock enhancement programme.

Another risk, not apparent in the present study, is the potential transfer of parasites. The cultured grouper from mariculture potentially carry parasites and may transfer these to other wild fish (Rückert et al. 2009a, Rückert et al. 2010, Palm et al. 2011), potentially causing a problem to the natural population. *E. fuscoguttatus* in Indonesia harbours a rich parasite community, including 1 protozoan, 4 monogeneans, 1 hirudinean, 1 copepod, 4 isopods, 1 microsporean, 2 myxozoans, 10 digeneans, 4 cestodes, 9 nematodes and 2 acanthocephalans (Rückert et al. 2010, Palm et al. 2011). Based on our investigation to 35 fish, we did not find any metazoan parasites, due to the original cultivation conditions inside the farm; however, we recorded cysts in the gills and fins of the fish, of undetermined origin. Such cysts can be caused by single celled parasites or fungi. Mariculture facilities - that create controlled cultivation conditions and implement the codes to prevent the cause of high mortality of the cultured fish caused by parasite - can reduce the risk of parasite transfer to wild populations (Bartley et al. 2006). Rücker et al. (2010) could not find the ectoparasites on cultured brown-marbled grouper that had a length between 20.5 and 34.5 cm, obtained from net cages in Lampung Bay. However, endoparasites were present. The observed low risks of parasite transfer in the present study cannot be generalized to all of the fish and circumstances, depending on the mariculture facility condition for the fingerlings.

5.4.2 Potential and progress of grouper stock enhancement in Indonesia

The Ministry of Marine Affairs and Fisheries of Indonesia announced that the grouper demand is increasing, leading to increase grouper production (DGA 2013), and promoting the grouper production from aquaculture. However, the price of cultured grouper is lower than that of wild fish. The difference in price is caused by the buyers' perception on the different taste of cultured grouper and the relatively poor survival of cultured grouper during transportation from farm to market (Rahmansyah et al. 2009). Although Rahmansyah (2009) stated that the buyers' perception was not tested, Chan and Johnston (2007) showed that more than 70% of respondents preferred wild caught fish, and in fact, the price of wild grouper catches is higher than the price of cultured grouper. Higher prices of the wild grouper catches certainly lead fishermen to still catch wild groupers and even fishermen increase the fishing effort under already overfished conditions. Increasing fishing effort to wild grouper leads to increase fishing pressure to the grouper habitats, and later on to the ecosystem (Sadovy et al. 2013). Stock enhancement of grouper has a potential to lower the problems caused by the wild grouper catches. However, the availability of juveniles is one of the very important preconditions in stock enhancement (Bell et al. 2006). The production of fingerling size of grouper in Indonesia increases significantly since 2001 and is sufficient, and supplies fingerling grouper demand around the world, even though sometimes the grouper fingerling production has a surplus production due to inconsistency of demand (Halwart et al. 2007, Sugama et al. 2013). However, so far none of the production methodologies prepares the fish for a subsequent release into the wild, preparing them to survive and evade predation. This is a prerequisite for a successful use of the Indonesian fingerlings in stock enhancement programmes.

Stock enhancement for marine fish in Indonesia as part of “one man one thousand fries” programme was conducted by the release of snapper, milkfish, and grouper. The latter group, in particular, was released to enhance the yield and to fulfil the increasing demand. Selected species in 2011 were brown-marbled-grouper (*Epinephelus fuscoguttatus*) and Humpback grouper (*Cromileptes altivelis*). Around 199,950 juveniles were released into the wild in 12 provinces in Indonesia (Table 5-1) (Directorate of Fisheries Resources 2011). To evaluate the impact of grouper stock enhancement, we calculated the increasing grouper production between 2011 and 2012 in each province in Indonesia, and compared the difference of increasing grouper production between the provinces with and without stock enhancement. We chose the provinces that had a surplus grouper production between 2012 and 2011: 9 provinces that had implemented stock enhancement and 13 provinces that had not implemented stock enhancement programmes yet. Based on the box plot comparison (Figure 8) and the mean of the increasing grouper production between the provinces with and without stock enhancement, the stock enhancement did not significantly contribute ($p>0.05$) to the increasing of grouper production. We assume that the size of released grouper contributed to the inefficiency of the stock enhancement programme in 2011. The size of grouper released in 2011 was from 3 to 12 cm, with the median size of released grouper below 8 cm. Our experiment demonstrates that predation becomes the main problem at a release of 10 cm of fingerling grouper (*E. fuscoguttatus*). Of course, the predation risk becomes even higher when the released grouper is below 8 cm. Our experiment indicates that to decrease the predation risks and to optimise the impact to the grouper yield in grouper stock enhancement, the minimum size of brown-marbled grouper should be 15 cm. Since the available size of cultured grouper in the mariculture centre is 10 cm or less, the cultured fish need to be kept in the net cages for several weeks to reach the size of 15 cm. In addition, the cultivation technique in the farm for the fingerlings would require conditions that prepare the fish for a later release, e.g. by adding hiding places into the tanks, and larger sized fish might be more susceptible to transfer fish parasites from the farm into the wild (Rückert et al. 2010).

Table 5-1. Grouper released during one man one thousand fries program in 2011.

No	Species	Number of fish	Size (cm)	Province
1	*Epinephelus fuscoguttatus*	4,000	-	Kepulauan Riau
2	*Epinephelus fuscoguttatus*	3,500	9	DKI Jakarta
3	*Chromileptes altivelis*	6,500	7	Central Java
4	*Epinephelus fuscoguttatus*	6,000	-	Central Java
5	Grouper	6,700	-	East Kalimantan
6	*Epinephelus fuscoguttatus*	17,000	5 - 12	Central Sulawesi
7	*Epinephelus fuscoguttatus*	12,500	3 - 4	Gorontalo
8	*Chromileptes altivelis*	15,000	3 - 4	North Maluku
9	Grouper	75,000	5 - 8	North Sumatera
10	*Epinephelus fuscoguttatus*	5,000	8	Bali
11	Grouper	5,000	8	Bali
12	*Chromileptes altivelis*	5,000	3-5	Bangka Belitung
13	*Epinephelus fuscoguttatus*	~30,000	-	North Sulawesi
14	*Epinephelus fuscoguttatus*	6,250	3	West Java
15	Grouper	2,500	3	North Sulawesi
	Total	199,950		

Stock enhancement is relatively new and needs improvement especially concerning the applied methods and techniques (Bell et al. 2008). Based on the lesson learned from the successful sea trout stock enhancement (HELCOM 2011), the release of eggs or larvae of grouper could be another option to increase the success of stock enhancement. The release of eggs or larvae of grouper could be conducted at best at the spawning aggregation sites and during spawning season. Release during this life phase is expected to increase the learning ability of grouper, which is apparently reduced when larvae of grouper are grown inside a mariculture facility. An additional benefit is that the release of eggs or larvae is less costly. Another important measure is the development of the success indicators, as suggested by Palm and Stoye (2014). Underwater visual census, fish-catch monitoring and fish tags are among available methods to monitor the impact of grouper stock enhancement. However, the study found underwater visual census not to be an appropriate method to monitor the impact of stock enhancement. During the study, we did not find any brown-marbled groupers using underwater visual census but we recorded brown-marbled groupers from the fish-catch monitoring. It seems that the fish-catch monitoring is one of the appropriate methods to monitor the impact of grouper stock enhancement. As regards to the fish tags, more studies need to be conducted on the use of these in the stock enhancement research. Several other attempts on recapture tagged fish resulted in similarly low number of recaptured tagged fish (HELCOM 2011, Bo and Zhou 2002, Egli et al. 2010). Consequently, future stock enhancement programmes in Indonesia must be accompanied by clear success indicators, experimentally justify the juvenile release size and training condition, and might be supported with eggs and larvae release.

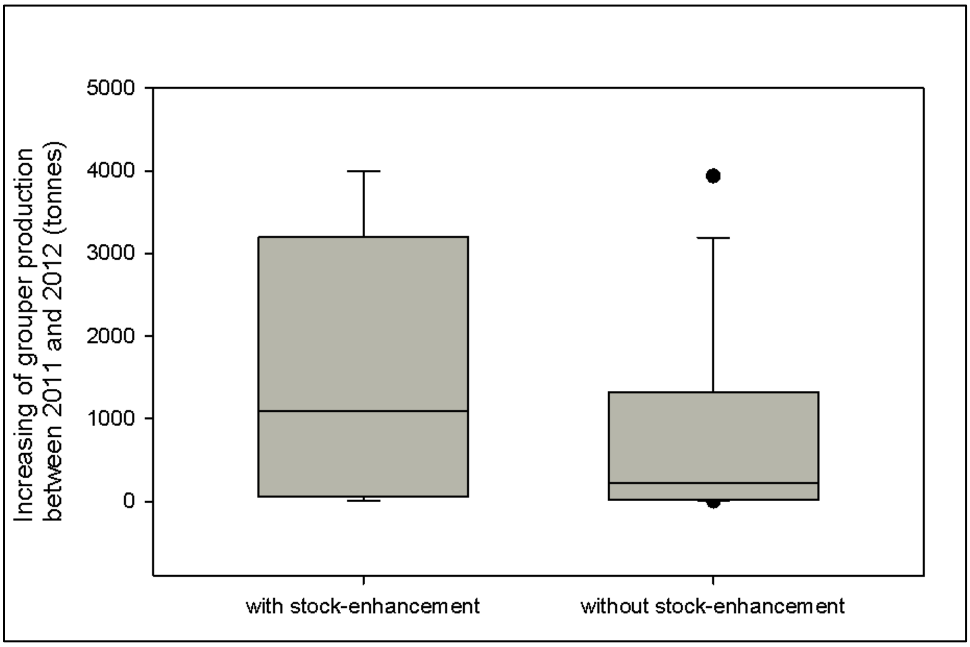

Figure 5-8. Box plot of the increasing of grouper production between 2011 and 2012 in the provinces in Indonesia, which were implemented with and without stock enhancement.

5.5 Acknowledgments

We wish to acknowledge the support provided by Balai Taman Nasional Karimunjawa for the great cooperation and hospitality during the fieldwork. We also thank Jamaluddin, Ripanto, T Kartawijaya, E Muttaqin and SAR Tarigan for helping the field research, K Neubert and S Theisen for helping parasite investigation, P Ningtias for carefully reading the manuscript and providing useful inputs, and anonymous reviewers for their constructive comments. Special thanks to Wildlife Conservation Society for their support to the field research, and to Ministry of Education Indonesia-German Academic Exchange Service (IGSP-DAAD) for providing the scholarship.

6 *Epinephelus fuscoguttatus* mariculture in Indonesia: Implications from fish parasite infections[5]

Abstract

Indonesia plays a major role in grouper supply for the Hong Kong based Live Reef Food Fish Trade. Hong Kong is the biggest consumer of Live Reef Food Fish in the world and around 50% of the grouper originate from Indonesia. In order to match Hong Kong market demands, the Indonesian Ministry of Marine Affairs and Fisheries started to implement plans to intensify mariculture farming, to boost grouper production. One inevitable consequence of this intensification is the increase of fish diseases and parasite infections. Samples of *Epinephelus fuscoguttatus* were obtained from four mariculture facilities in Lampung Bay (South Sumatra) and one in Pulau Seribu (North off western Java), Indonesia, to investigate and compare the parasite composition. In total 35 parasite species were detected. Different ecological parameters e.g. ecto/endoparasite ratio and Shannon-Wiener diversity Index were utilized to analyze the parasite composition at the different mariculture sites. We also recorded the cultivation methods for each facility including e.g. density of fish in the cages and other cultivation strategies. Our results demonstrate that the feeding strategy and e.g. the stocking density of fish in the cages significantly affect the composition of the grouper's parasite fauna. As trash fish, which enables parasite transmission, is still one of the main feed sources, one of the major future tasks is the search for alternative feed sources and feeding strategies to prevent parasite spread and pathogenic outbreaks. Education of the farm management and unified standards for the often small size producers are required in order to safeguard grouper mariculture development in the future.

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6.1 Introduction

Increasing fish demand, as a result of a growing human population, challenges fish producing countries, companies, and fishermen to enhance fish production worldwide. According to Dey et al. (2008a), Asia supplied 60 % of the world fish production. Around 13 % of their food expenditure is spent to buy fish. With still exponential population growth, capture fisheries and aquaculture production is and will be of increasing importance in the future.

Groupers belong to the most important fish species in Asia (Sadovy et al. 2013). They form the base of the Live Reef Food Fish (LRFF) trade with its major market being Hong Kong, followed by Singapore and China. Indonesia plays a major role in the supply of grouper for the LRFF (Lau and Jones 1999, Pet-Soede et al. 2004, Johnston and Yeeting 2006). In 2012, 87 % originated from capture fisheries and only 13 % from mariculture facilities (MMAF 2013a). In 2009, the Indonesian government declared the ambitious vision to become the main producer of aquaculture-raised fishes until 2015 under a new fisheries policy (MMAF 2010a). The Indonesian Ministry of Marine Affairs and Fisheries (MMAF) is implementing a variety of activities to support the country wide grouper production, involving fisheries, mariculture and stock enhancement (Yulianto et al. 2015c).

The grouper production increased significantly since 2001, when MMAF and private hatcheries started providing fingerlings for mariculture (Sugama et al. 2013). Moreover, the harvest doubled from 2009 to 2010 based on the new fisheries policy (MMAF 2013a). However, the intensification of mariculture has several constraints. From a fish health point of view these are viruses, bacteria, fungi, and parasites (Zafran et al. 1998, Koesharyani et al. 2001, Bondad-Reantaso et al. 2005). The latter group has been the focus of several studies due to their implications for fish disease outbreaks, food safety and functions as biological indicators for e.g. environmental change and fish health (Leong 1997, Jakob and Palm 2006, Palm 2011, Palm et al. 2011, Kleinertz and Palm 2013, Kleinertz et al. 2014). Fish parasites of the most popular grouper species (e.g. *Cromileptes altivelis*, *Epinephelus areolatus, E. fuscoguttatus*) from tropical marine waters have been of special interest in recent years (Rückert et al. 2009a, b, 2010, Kleinertz and Palm 2013).

Indonesia's coastal region comprises one of the highest levels of aquatic biodiversity on earth (Veron et al. 2009, Palm 2004). This includes, beside many other organisms, fish species as well as their parasite fauna, but only about 4 % of the estimated fish parasite fauna in Indonesia has been explored (Jakob and Palm 2006, Kleinertz and Palm 2013).

Since the 1980's several authors have worked on parasites (mainly ectoparasites) and diseases of groupers from mariculture facilities in Indonesia (e.g. Diani 1989, 1992, 1995, Diani and Rukyani 1990, Diani et al. 1996, Asmanelli and Partasasmita 1992, Asmanelli et al. 1993, 1994, Koesharyani et al. 1998, 1999a,b,2001, Bu et al. 1999, Kurniastuty and Hermawan 1998, Diani et al. 1999, Kurniastuty et al. 1999, 2000, Wijayati and Djunaidah 2001, Zafran et al. 1997, 1998, 2000, Akbar and Sudaryanto 2001). More recent studies on parasites from cultured groupers focused on protozoans (trichodinids) and metazoans (ecto- and endoparasites) (Rückert 2006, Rückert et al. 2009b, 2010, Kleinertz 2010, Palm et al. 2011). More recent studies on parasites from cultured groupers focused on protists (e.g. trichodinids) and metazoans (ecto- and endoparasites) (Rückert 2006, Rückert et al. 2009b, 2010, Kleinertz 2010, Palm et al. 2011). So far, nine different epinephelid species belonging to three different genera (*Epinephelus*, *Cromileptes*, *Plectropomus*) were studied from Indonesian mariculture facilities.

Factors that can influence the occurrence of parasites inside mariculture facilities are: fish density, environmental conditions and water quality (e.g. temperature, salinity, pH), fish handling, nutrition, feed source, feeding pattern, and also parasite-/host-species relationships (SEAFDEC 2001, Rohde 2002). High stocking densities provide in excellent conditions for the spread of monoxenous ectoparasites that are transferred directly from fish to fish (Balasuriya and Leong 1994). Farmers using locally caught trash fish as feed for valuable fish species can promote transmission of parasites from surrounding areas into the mariculture facilities (Rückert et al. 2009b). In general, managers of mariculture facilities and fish farmers have a big influence on possible parasite infections through their choice of holding conditions, feed source and treatments, which is mainly based on their experience, but also on economic efficiency and profitability. There is the need for rapid diagnostics and information transfer to allow quick and correct treatment after the infection of cultured fishes with parasites has been detected.

The aim of this study was to examine possible impacts of different management methods and feeding strategies commonly used in Indonesia on the parasite compositions of cultured groupers from several mariculture facilities in Lampung Bay and Seribu Islands (Pulau Seribu), Indonesia, and to identify possible threats for grouper mariculture. In addition, we summarize all available information on fish parasites from Indonesian grouper mariculture, including parasite species, site of infection, locality, and when possible prevalence of infection. This has direct implications for the available grouper quality on international markets that originate from Indonesian mariculture facilities.

6.2 Materials and methods

6.2.1 Fish samples and parasitological examination

Samples were taken at different mariculture facilities in Indonesia (Fig. 6-1): in Lampung Bay (South Sumatra) during dry season in 2003 and rainy season 2003/04 and at Pulau Seribu (North off western Java) during rainy seasons 2003/04, 2010/11 and 2011/12. A total of 175 specimens of *Epinephelus fuscoguttatus* were studied from Lampung Bay and 105 specimens from Pulau Seribu (Fig. 6-1, Table 6-1). According to total length of fish and the growth parameters of wild Epinephelus fuscoguttatus, all fish samples were between 4 to 6 months (less than 1 year) of age, and all individuals within a sample were transferred to the facilities as small fingerlings of the same age/size.

The fish were examined directly after collection from the net cages, timed to not collide with any recent freshwater treatment, to avoid an underestimation of ectoparasites such as Monogenea. The fish were examined directly after catch. Total fish length (TL) and weight (TW), were measured to the nearest 0.1 cm and 0.1 g (Table 6-1) prior to the parasitological examination (see Rückert et al. 2009b). The skin, fins, eyes, gills, mouth- and gill cavity were studied for ectoparasites. The inner organs (digestive tract, liver, gall bladder, spleen, kidneys, gonads, heart and swim bladder) were separated and transferred into saline solution for examination under a dissecting scope. Isolated parasites were fixed in 4 % borax-buffered formalin and preserved in 70 % ethanol. Finally, the musculature was sliced into 0.5 – 1 cm thick filets, pressed between two petridishes and examined on a candling table to identify and isolate parasites from the musculature. For identification purposes, Nematoda were dehydrated in a gradated ethanol series and transferred into 100 % glycerine through the evaporation techniques described by Riemann (1988). Digenea, Monogenea and Cestoda were stained with acetic carmine, dehydrated, cleared with eugenol and mounted in Canada balsam. Crustacea were dehydrated and transferred into Canada balsam. Parasite identification literature included original descriptions (details see Palm et al. 2011). Trichodinid ciliates were not identified to the species level.

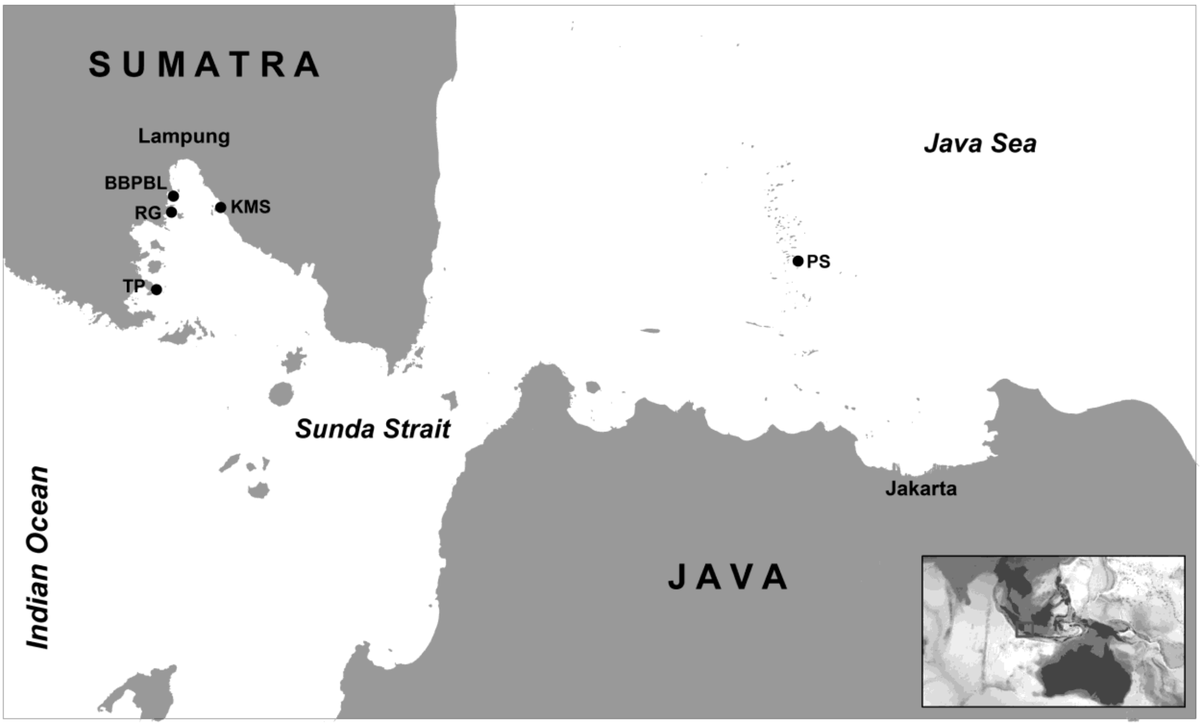

Figure 6-1. Locations of the visited mariculture facilities in Indonesia BBPBL: Balai Besar Pengembangan Budidaya Laut Lampung, KMS: PT Kedamaian Makmur Sejahtera, RG: Ringgung, TP: Tanjung Putus and PS: Nuansa Ayu Karamba - Pulau Seribu.

Table 6-1. Morphometric characteristics of cultured Epinephelus fuscoguttatus sampled from mariculture facilities in Indonesian waters: Sampling time, season, number (n) of dissected specimens, mean total length (TL in cm) and mean total weight (TW in g) (range in parentheses) are given, BBPBL: Balai Besar Pengembangan Budidaya Laut Lampung, KMS: PT Kedamaian Makmur Sejahtera, RG: Ringgung, TP: Tanjung Putus, PS: Nuansa Ayu Karamba - Pulau Seribu.

Sample/Season	n	TL [cm]	TW [g]
BBPBL dry season 2003	35	28.0 (24.0-34.5)	451.0 (264.6-976.9)
KMS (pellets) dry season 2003	35	23.2 (21.0-25.5)	253.4 (150.0-320.0)
KMS (trash fish) dry season 2003	35	23.1 (21.0-25.0)	247.4 (200.0-300.0)
RG rainy season 2003/2004	35	25.7 (23.0-29.5)	330.5 (255.1-544.9)
TP dry season 2003	35	28.7 (20.0-34.5)	477.8 (302.0-800.0)
PS rainy season 2003/2004	35	26.9 (23.5-33.0)	429.9 (272.0-743.0)
PS rainy season 2010/2011	35	26.9 (24.9-29.7)	387.6 (302.5-476.3)
PS rainy season 2011/2012	35	25.6 (23.1-27.8)	335.1 (249.5-389.8)

6.2.2 Parasitological parameters

Different ecological parameters were evaluated to indicate regional differences, such as the diversity indices Shannon-Wiener and Evenness, fish ecological indices like Hepatosomatic Index (HSI), and parasitological parameters like ecto- endoparasite ratio (Ec/En ratio) and prevalence of infection of different parasite taxa (see Palm et al. 2011, Palm and Rückert 2009, Palm et al. 2011, Kleinertz and Palm 2013, Kleinertz et al. 2014).

The parasitological terms follow Bush et al. (1997): prevalence (P) is the number of infected fish with one or more individuals of a particular parasite species (or taxonomic group) divided by the number of hosts examined (expressed as a percentage); intensity (of infection, I) is the number of individuals of a particular parasite species in a single infected host (expressed as a numerical range); mean intensity (of infection, mI) is the average intensity, in other words, it is the total number of parasites of a particular species found in a sample divided by the number of infected hosts.

The present study applies the method by Palm and Rückert (2009) and Palm et al. (2011) to monitor the parasite community of groupers from Indonesia. The diversity of the metazoan endoparasite fauna of each fish species was determined by using the Shannon–Wiener diversity Index (H') and the Evenness Index (E) of Pielou (Magurran 1988). Microsporean and myxozoan parasites were not considered because it is not possible to calculate their intensities. The ratio of ecto- to endoparasites was calculated [Ec/En ratio (R)=No. of ectoparasite species/No. of endoparasite species], with trichodinid ciliates treated as present or absent. The Hepatosomatic Index was calculated to verify the pollution impact on the fish host, which affects liver weights (W_L) in relation to the total weight (W_T) of the host [$HSI=W_L/W_T \times 100$] (see Kleinertz and Palm 2013, Kleinertz et al. 2014). A t-test was used to compare the ecological indices (Shannon-Wiener diversity Index) from different sites (see Zar 2010) and a two-way ANOVA (site and region) was conducted with SPSS to analyze the HSI from different sites. Different statistical methods including correlation analysis (Pearson), Spearman ranked correlation, polychoric correlation, linear regression, one-sample t-test, two-sample t-test and Mann-Whitney U test were performed with SAS and Minitab to define the relationships between management strategies and parasitological parameters. Data were normalized using square root or Log10(x+1), if needed. Nine of the management strategies (marked with * in Table 6-5) were tested against all parasitological parameters, if given data were allowing statistical analyses.

We used PRIMER (release 6, Primer-E Ltd. 6.1.11, Meadow View, UK) for multivariate statistical analyses. Prevalence data were square-root transformed in order to compare the parasite community. A similarity matrix was constructed using the Bray-Curtis similarity measure. The relation between samples based on the comparison of similarity matrices was displayed using cluster analysis and multi-dimensional scaling (MDS) with stress value estimation: < 0.05 excellent, < 0.2 reliable, > 0.2 start of loss of accuracy (see Kleinertz and Palm 2013).

6.3 Results

Fish parasitological studies on *E. fuscoguttatus* from mariculture facilities of Indonesian coastal waters revealed a total of 35 different parasite species, ten with a monoxenous (single host) and 25 with a heteroxenous (multiple hosts) life-cycle. Information on prevalence and (mean) intensity of the collected parasite species is summarized in Table 6-2. Most species rich were grouper parasites from the mariculture at Ringgung (RG) in the rainy season 2003/2004 (22 taxa) followed by those from Balai Besar Pengembangan Budidaya Laut Lampung (BBPBL, formerly Balai Budidaya Laut, BBL) in the dry season 2003 (18 taxa) and 15 taxa in fish from the mariculture PT Nuansa Ayu Karamba in Pulau Seribu (PS) in the rainy season 2003/04. Pellet fed groupers from PT Kedamaian Makmur Sejahtera (KMS) showed the lowest species richness within this study (6 taxa) (Table 6-2).

Table 6-3 presents an overview of parasite infections in cultured grouper (*E. fuscoguttatus*) in Indonesia. All endoparasites isolated from Rückert (2006), Rückert et al. (2010), and Palm et al. (2011), not otherwise stated in that table, represented new host records for *E. fuscoguttatus*, including *Allopodocotyle epinepheli*, *Lecithochirium magnaporum*, *Lecithochirium neopacificum*, *Prosorhynchus luzonicus*, *Prosorhynchus* sp. 1 and 2, Enenteridae gen. et sp. indet., *Nybelinia indica*, *Parothobothrium balli*, *Scolex pleuronectis*, *Camallanus carangis*, *Hysterothylacium* sp., *Raphidascaris* sp. I and II, *Terranova* sp., *Neoechinorhynchus* sp., and *Serrasentis sagittifer*. Endoparasite data of fish from PS 2010/11 and 2011/12, which were not previously published, include new host records for cultured *E. fuscoguttatus*, such as a *Camallanus* and a *Philometra* species. Rückert et al. (2010) showed that some parasites occurred only in cultured grouper while others were only found in wild grouper. Parasites that could only be isolated from cultured *E. fuscoguttatus* so far include the Digenea *P. luzonicus* and *L. neopacificum,* Enenteridae gen. et sp. indet. as well as Acanthocephala, *S. sagittifer* and *Neoechinorhynchus* sp.

(Rückert et al. 2010, Palm et al. 2011). Some of these parasites were also found in the present study. Except for Enenteridae gen. et sp. indet. those parasite species occurred only with very low prevalences.

To analyze the parasite composition at the respective sampling sites, ecological parameters as suggested by Palm and Rückert (2009), Palm et al. (2011), Kleinertz and Palm (2013) and Kleinertz et al. (2014) were considered as given below. Regional differences between the sampled mariculture facilities of *E. fuscoguttatus* were found in terms of Hepatosomatic Index (HSI), endoparasite diversity, ecto-/endoparasite ratio, prevalence of trichodinids, and prevalences of infection of selected metazoan endoparasites (*Scolex pleuronectis*, *Raphidascaris* sp., *Terranova* sp.) as well as prevalence of all parasites. All results described below are summarized in Table 6-4.

6.3.1 Ratio of ecto-/endoparasites, metazoan endoparasite diversity (Shannon-Wiener diversity Index), Evenness and Hepatosomatic Index

The ecto-/endoparasite ratios ranged from 0.40 (KMS trash fish) to 2.00 (KMS pellet), with an even or higher number of endoparasites compared to ectoparasites for most of the facilities. The diversity of endoparasites found in groupers fed with pellets at the mariculture KMS was so low that the Shannon–Wiener diversity Index (H) and the Evenness Index (E) of Pielou could not be calculated. However, besides these low values, the Shannon-Wiener diversity Index for endoparasites of *E. fuscoguttatus* ranged from 0.39 (PS 2011/12) to 1.83 (PS 2003/04). The Shannon-Wiener Indices of parasites from fish farmed at RG, BBPBL, and TP were not significantly different ($P > 0.05$), but all were significantly different ($P < 0.01$) from parasites of grouper farmed at KMS. The Shannon-Wiener Indices of parasites from fish at PS in 2010/11 and in 2011/12 were not significantly different ($P > 0.05$), but both were significantly different ($P < 0.001$) from the index for PS in 2003/04. The highest Evenness value was recorded in PS 2003/04 (0.83) in contrast to the lowest (0.2) at PS in 2011/12. The values for the Hepatosomatic Index ranged from 0.55 to 2.24 (KMS pellet vs. RG) (Table 4). The highest HSI was recorded in RG, which was significantly different ($P < 0.01$) from all other sites. The second and the third highest HSI were recorded in PS 2010/11 and PS 2011/12. The HSI in PS 2010/2011 and 2011/2012 were significantly higher than the HSI in PS 2003/04. The lowest HSI was recorded for KMS pellet, which was significantly different ($P<0.01$) from all other sites. There was also a significant difference ($P < 0.01$) between the mean HSI of fish in Lampung and the mean HSI of fish in PS. The mean HSI value of fish in Lampung was 0.31 lower than the mean HSI value of fish in Pulau Seribu.

mean intensity (mI) of the pa
lai Besar Pengembangan Bu
sa Ayu Karamba - Pulau Se

	BBPBL D03 (n=35)		RG R03/04 (n=35)		TP D03 (n=35)		KMS trashfish D03 (n=35)		KMS Pellet D03 (n=35)		PS R03/04 (n=35)		PS R10/11 (n=35)		PS R11/12 (n=35)	
	P [%]	mI (I)	P [%]	mI (I)	P [%]	mI (I)	P [%]	mI (I)	P [%]	mI (I)	P [%]	mI (I)	P [%]	mI (I)	P [%]	mI (I)
Monoxenous parasites																
Trichodina spp. (P)	51.5	526.6 (1-5845)	2.9	1.0 (1)	17.1	7.7 (1-26)	2.9	1.0 (1)			2.9	1.0 (1)				
Benedenia epinepheli (M)	57.1	2.9 (1-8)	54.3	4.3 (1-21)	25.7	2.3 (1-4)							2.9	1.0 (1)	8.6	3.7 (1-5)
Neobenedenia melleni (M)	5.7	1.0 (1)	2.9	1.0 (1)												
Capsalidae gen. et sp. indet. (M)	68.6	4.5 (1-17)	74.3	5.1 (1-30)	45.7	6.4 (1-24)			5.7	1.0 (1)						
Pseudorhabdosynochus spp. (M)*	100.0	179.5 (61-586)	97.1	61.1 (13-175)	100.0	652)	57.1	4.0 (1-9)	51.4	5.1 (1-37)	100.0	377)				
Pseudorhabdosynochus epinepheli (M)													2.9	1.0 (1)	82.9	17.0 (1-107)
Pseudorhabdosynochus lantauensis (M)													88.6	6.1 (1-34)	91.4	8.0 (1-61)
Alcirona sp. (CR)			2.9	5.0 (5)							5.7	1.0 (1)				
Argathona rhinoceros (CR)			14.3	1.0 (1)												
Gnathiidae gen. et sp. indet. (CR)			2.9	1.0 (1)												
Zeylanicobdella arugamensis (H)													14.3	1.2 (1-2)	57.1	2.4 (1-7)
Heteroxenous parasites																
Microsporea gen. et sp. indet. (MI)	48.6	8.2 (1-39)	14.3	8.2 (1-33)	68.6	13.5 (1-197)										
Myxozoa gen. et sp. indet. (MY)	65.7		42.9		88.6		80.0		45.7		20.0					
Prosorhynchus luzonicus (D)							2.9	1.0 (1)								
Prosorhynchus sp. I (D)**	8.6	1.3 (1-2)					2.9	1.0 (1)			42.9	8.7 (1-42)				
Prosorhynchus sp. II (D)**											48.6	10.1 (1-57)	8.6	4.3 (1-11)	2.9	1.0
Prosorhynchus indet. (D)			5.7	1.5 (1-2)			11.4	1.3 (1-2)			8.6	3.0 (1-7)			8.6	5.7 (1-14)
Pseudopecoelus sp. (D)															25.7	1.4 (1-3)
Lecithochirium magnaporum (D)	5.7	1.0 (1)	17.1	1.0 (1)												
Lecithochirium neopacificum (D)	2.9	1.0 (1)														
Digenea gen et sp. indet. (D)													2.9	1.0 (1)		
Enenteridae gen. et sp. indet. (D)											51.4	2.7 (1-7)				
Allopodocotyle epinepheli (D)			100.0	3.5 (1-8)	5.7	6.0 (1-11)					28.6	3.0 (1-7)				
Parotobothrium balli (C)	20.0	1.4 (1-3)	60.0	2.4 (1-5)	5.7	1.5 (1-2)	2.9	1.0 (1)								
Scolex pleuronectis (C)	45.7	7.1 (1-78)	94.3	30.2 (3-166)	5.7	1.0 (1)	60.0	14.4 (1-116)	2.9	1.0 (1)	25.7	1.7 (1-4)				
Pseudophyllidea gen. et sp. indet. (C)			2.9	1.0 (1)												
Hysterothylacium sp. (N)	2.9	2.0 (2)	8.6	1.0 (1)			8.6	1.7 (1-2)					5.7	1.0 (1)		
Terranova sp. (N)	25.7	1.3 (1-2)	88.6	2.3 (1-6)			2.9	1.0 (1)			57.1	2.6 (1-9)				
Raphidascaris sp. (N)	17.1	1.3 (1-3)	97.1	7.5 (1-17)	22.9	2.5 (1-6)	51.4	1.7 (1-4)			82.9	4.1 (1-8)	48.6	2.4 (1-7)	57.1	5.4 (1-24)
Camallanus carangis (N)			65.7	1.4 (1-3)	2.9	1.0 (1)					2.9	1.0 (1)				
Camallanus sp. (N)															2.9	1.0 (1)
Nematoda gen. et sp. indet. (N)	8.6	1.0 (1)			2.9	1.0 (1)	5.7	1.0 (1)								
Philometra sp. (N)															2.9	1.0 (1)
Neoechinorhynchus sp. (A)	2.9	1.0 (1)														
Acanthocephala indet. (A)					2.9	1.0 (1)										
Pennellidae gen. et sp. indet. (CR)			2.9	1.0 (1)			2.9	1.0 (1)	8.6	1.3 (1-2)	5.7	1.0 (1)				

* Note : *Pseudorhabdosynochus* spp. from BBPBL, KMS, TP, RG, and PS (03/04) included the species *P. epinepheli* and *P. lantauensis*.

** according to Bray and Palm (2009)

of cultured groupers from Indon
cv: abdominal cavity, bcv: body c
us: musculature, no: nostrils, op:
ce, A: Acanthocephala, C: Cestod
, My: Myxozoa, N: Nematoda. n.d
malabaricus, Ep: E. Polyphekad
*Ps: Plectropomus spp. *according*

Total taxa		Parasite taxa	Taxa	Site	References	Locality	*Ea*	*Eb*	*Ec*	*Ef*	*Em*	*Ep*	*Es*	*Ca*	*Pl*	*Pm*	*Ps*
							P [%]	**P [%]**	**P [%]**	**P [%]**	**P [%]**	**P [%]**	**P [%]**	**P [%]**	**P [%]**	**P [%]**	**P [%]**
Fl	**4**	***Amyloodinium ocellatum***	Fl	gi	Zafran et al. 2000	Bali: Gondol Research Station								n.d.			
		***Amyloodinium* sp.**	Fl	fin, gi, mouth, op	Asmanelli et al. 1993	Sumatra: Riau Archipelago							n.d.				
		***Ichthyododo* sp./ *Costia* sp.**	Fl	gi	Asmanelli & Partasasmita 1992*, Asmanelli et al. 1994	Sumatra: Riau Archipelago, Alang Island										n.d	n.d.
Ci	**6**	***Brooklynella* sp.**	Ci	n.d.	Asmanelli et al. 1993, Diani et al. 1996	Java: Serang, Sumatra: Riau Archipelago			n.d.								n.d.
		Cryptocaryon irritans	Ci	gi, su, eye, fins	Asmanelli et al. 1993, Diani 1989, Koesharyani et al. 1998, Kurniastuty & Hermawan 1998, Kurniastuty et al. 1999, Yuasa et al. 1998, Zafran et al. 1998, 2000	Bali: Gondol Research Station, Sumatra: Lampung, Riau Archipelago, Java: Serang, Banten Bay		n.d.		n.d.	n.d.		n.d.	n.d.			
		***Cryptocaryon* sp.**	Ci	gi, su, eye, fins	Akbar & Sudaryanto 2001, Asmanelli & Partasasmita 1992, Asmanelli et al. 1993, 1994, Diani 1992, Wijayati & Djunaidah 2001	Java: Jepara, Bojonegara, Sumatra: Riau Archipelago, Alang Island, Indonesia: unknown				n.d.				n.d.			20.6
		***Trichodina* sp.**	Ci	gi, su, fins, op	Asmanelli et al. 1993, Akbar & Sudaryanto 2001, Asmanelli et al. 1993, Diani 1989, 1995, Diani & Rukyani 1990, Diani et al. 1996, Kleinertz 2010, Koesharyani et al. 1998, Kurniastuty & Hermawan 1998, Palm et al. 2011, Wijayati & Djunaidah 2001, Yuasa et al. 1998, Zafran et al. 1998, 2000	Bali: Gondol Research Station, Java: Serang, Banten Bay, Bojonegara, Jepara, Pulau Seribu, Sumatra: Lampung, Riau Archipelago, Indonesia: unknown		n.d.	n.d.	2.9			n.d.	n.d.			n.d.
		***Trichodina* spp.**	Ci	gi, op	Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Java: Pulau Seribu			3.3-15.4	1.4-51.5							

Total taxa		Parasite taxa	Taxa	Site	References	Locality	*Ea*	*Eb*	*Ec*	*Ef*	*Em*	*Ep*	*Es*	*Ca*	*Pl*	*Pm*	*Ps*
							P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]
		Uronema sp.	Ci	su	Zafran et al. 2000	Bali: Gondol Research Station								n.d.			
Mi	**1**	**Microsporea gen. et sp. indet.**	Mi	in, li, stw, fat, go, mus, sb	Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Java: Pulau Seribu			3.3-41.5	2.9-77.1							
My	**1**	**Myxozoa gen. et sp. indet.**	My	gall bladder	Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Java: Pulau Seribu			21.0-63.3	2.9-88.6							
		Allopodocotyle epinepheli	D	in, pyl	Kleinertz 2010, Palm et al. 2011, Rückert 2006, present study	Sumatra: Balai Budidaya Laut Lampung,Ringgung, Java: Pulau Seribu			1.5	2.9-100							
		***Aporocotyle* sp.**	D	in	Asmanelli et al. 1993	Sumatra: Riau Archipelago											n.d.
		Lecithochirium magnaporum	D	stl	Kleinertz 2010, Palm et al. 2011, Rückert 2006, Rückert et al. 2010, present study	Balai Budidaya Laut Lampung, Lampung Bay, Ringgung, Java: Pulau Seribu			4.6	3.8-23.0							
		Lecithochirium neopacificum	D	stl	Palm et al. 2011,Rückert 2006, Rückert et al. 2010, present study	Balai Budidaya Laut Lampung, Lampung Bay, Java: Pulau Seribu				1.0-6.0							
		Prosorhynchus luzonicus	D	in, pyl, stl	Rückert 2006, Rückert et al. 2009, 2010, present study	Balai Budidaya Laut Lampung, Lampung Bay, Cobra			43.3-90.8	1.0-40.0							
		Prosorhynchus* sp. I	D	in, pyl	Kleinertz 2010, Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010 (*see Bray & Palm 2009), present study	Balai Budidaya Laut Lampung, Lampung Bay, Cobra, Java: Pulau Seribu			6.7-24.6	2.9-43.0							
D	**14**	***Prosorhynchus* sp. II***	D	in, pyl	Kleinertz 2010, Palm et al. 2011, Rückert 2006 (*see Bray & Palm 2009), present study	Java: Pulau Seribu				2.9-49.0							
		***Prosorhynchus* sp.**	D	in, st	Asmanelli et al. 1993	Sumatra: Riau Archipelago											n.d.
		***Prosorhynchus* indet.**	D	in, pyl	Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Cobra, Ringgung, Java: Pulau Seribu			1.5-6.7	1.9-11.4							
		***Pseudoecoelus* sp.**	D	st	present study	Java: Pulau Seribu				25.7							
		Didymozoidae gen. et sp. indet.	D	li, st	Kleinertz 2010, Palm et al. 2011	Java: Pulau Seribu				3.0-14.3							
		Enenteridae gen. et sp. indet.	D	in, pyl	Palm et al. 2011, Rückert 2006, present study	Java: Pulau Seribu				3.0-51.4							
		Sanguinicolidae gen. et sp. indet.	D	sb	Rückert 2006	Sumatra: Balai Budidaya Laut Lampung			1.5								
		Trematoda/Digena gen. et sp. indet.	D	in, st	Asmanelli et al. 1993, present study	Sumatra: Riau Archipelago, Java: Pulau Seribu				2.9							n.d.

Total taxa	Parasite taxa	Taxa	Site	References	Locality	*Ea*	*Eb*	*Ec*	*Ef*	*Em*	*Ep*	*Es*	*Ca*	*Pl*	*Pm*	*Ps*
						P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]
	Benedenia epinepheli	M	gi, su	Kleinertz 2010, Koesharyani et al. 1999a, b, 2001, Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Bali: Gondol Research Station, Balai Budidaya Laut Lampung, Lampung Bay, Java: Pulau Seribu			10.0-70.8	2.9-89.0				n.d.	n.d.		
	***Benedenia* sp.**	M	su, eye	Koesharyani et al. 1998, 2001, Yuasa et al. 1998, Zafran et al. 1998, 2000	Bali: Gondol Research Station		n.d.	n.d.	n.d.	n.d.			n.d.	n.d.		
	***Benedeniella* sp.**	M	gi, fins, su, eye, mouth, op, no	Asmanelli & Partasasmita 1992, Asmanelli et al. 1993, 1994	Sumatra: Riau Archipelago, Alang Island										n.d.	53.3
	Diplectanum grouperi	M	gi	Bu et al. 1999	Sumatra: Medan	n.d.		n.d.								
	***Diplectanum* sp.**	M	eye, gi, liver, su, fins	Akbar & Sudaryanto 2001, Asmanelli & Partasasmita 1992, Asmanelli et al. 1993, 1994, Diani 1989, 1995a, Diani & Rukyani 1990, Diani et al. 1996, Koesharyani et al. 1998, Wijayati & Djunaidah 2001, Zafran et al. 1997, 1998	Bali: Gondol Research Station, Java: Serang, Banten Bay, Bojonegara, Sumatra: Lampung, Riau Archipelago, Alang Island, Indonesia: unknown			n.d.		n.d.			n.d.	n.d.	n.d.	100
	***Entobdella* sp.**	M	mouth, no, op, su	Asmanelli et al. 1993	Sumatra: Riau Archipelago							n.d.				
	***Haliotrema* sp.**	M	gi	Koesharyani et al. 1998, Yuasa et al. 1998, Zafran et al. 1997, 2000	Bali: Gondol Research Station, Indonesia: unknown								n.d.			
	***Hexabothrium* sp.**	M	gi, fins, su	Asmanelli et al. 1993	Sumatra: Riau Archipelago							n.d.				
M 17	***Neobenedenia melleni***	M	su, eye, fins	Koesharyani et al. 1999 a, b, 2001, Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Bali: Gondol Research Station, Balai Budidaya Laut Lampung, Lampung Bay			7.7-16.7	1.9-6.0				n.d.	n.d.		
	***Neobenedenia* sp.**	M	su	Koesharyani et al. 1998, Yuasa et al. 1998, Zafran et al. 1998, 2000	Bali: Gondol Research Station		n.d.	n.d.	n.d.	n.d.			n.d.	n.d.		
	Pseudhabdosynochus coioidesis	M	gi	Bu et al. 1999	Sumatra: Medan	n.d.		n.d.								
	Pseudhabdosynochus epinepheli	M	gi	Rückert 2006, present study	Balai Budidaya Laut Lampung, Cobra, Ringgung, Tanjung Putus, Java: Pulau Seribu				2.9-100							
	Pseudhabdosynochus lantauensis	M	gi	Bu et al. 1999, Kleinertz 2010, Rückert 2006, present study	Sumatra: Medan, Balai Budidaya Laut Lampung, Cobra, Ringgung, Tanjung Putus, Java: Pulau Seribu	n.d.		n.d.	54.3-100							

Total taxa		Parasite taxa	Taxa	Site	References	Locality	*Ea*	*Eb*	*Ec*	*Ef*	*Em*	*Ep*	*Es*	*Ca*	*Pl*	*Pm*	*Ps*
							P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]
		***Pseudhabdosynochus* sp.**	M	gi	Koesharyani et al. 1998, Zafran et al. 2000	Bali: Gondol Research Station		n.d.	n.d.		n.d.			n.d.			
		***Pseudhabdosynochus* spp.**	M	gi	Rückert et al. 2009, present study	Sumatra: Lampung Bay, Java: Pulau Seribu			100	51.4-100							
		Capsalidae gen. et sp. indet.	M	gi, su	Koesharyani et al. 2001, Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Bali: Gondol Research Station, Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Cobra, Ringgung, Tanjung Putus, Java: Pulau Seribu			56.7-96.7	2.9-90.0							
		Monogenoidea gen. et sp. indet.	M	gi, su	Asmanelli & Partasasmita 1992, Asmanelli et al. 1993, 1994	Sumatra: Riau Archipelago, Alang Island							n.d.			n.d.	40.0
		Nybelinia indica	C	stw, stl	Rückert 2006, Rückert et al. 2010	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay				1.0-2.9							
		Parothobothrium balli	C	go, stw, stl	Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Cobra, Ringgung, Tanjung Putus, Java: Pulau Seribu			6.7-15.4	1.4-60.0							
C	**5**	***Scolex pleuronectis***	C	in, stl, pyl	Kleinertz 2010, Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Cobra, Ringgung, Tanjung Putus, Java: Pulau Seribu			3.3-16.9	2.9-94.3							
		Pseudophyllidea gen. et sp. indet.	C	in	Rückert 2006, present study	Sumatra: Ringgung				2.9							
		Trypanorhyncha gen. et sp. indet.	C	viscera, sb	Koesharyani et al. 2001	Bali: Gondol Research Station								n.d.			
		Camallanus carangis	N	in, stw, go, pyl	Kleinertz 2010, Palm et al. 2011, Rückert 2006, Rückert et al. 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Tanjung Putus, Ringgung, Java: Pulau Seribu				2.9-65.7							
		***Camallanus* sp.**	N	pyl	present study	Java: Pulau Seribu				2.9							
		***Hysterothylacium* sp.**	N	in, li, stw, go	Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Cobra, Ringgung, Java: Pulau Seribu			3.3-10.8	1.0-9.0							
		***Philometra* sp.**	N	bcv	present study	Java: Pulau Seribu				2.9							
		***Raphidascaris* sp. I**	N	in, fat, stl, stw, go, mes, pyl	Kleinertz 2010, Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Cobra, Tanjung Putus, Java: Pulau Seribu			3.3-10.8	2.9-100							
N	**10**	***Raphidascaris* sp. II**	N	in, stl, stw, go	Palm et al. 2011, Rückert 2006	Sumatra: Balai Budidaya Laut Lampung, Ringgung, Java: Pulau Seribu			1.5	1.4-97.1							

Total taxa		Parasite taxa	Taxa	Site	References	Locality	*Ea*	*Eb*	*Ec*	*Ef*	*Em*	*Ep*	*Es*	*Ca*	*Pl*	*Pm*	*Ps*
							P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]
		***Terranova* sp.**	N	in, li, pyl, go	Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Cobra, Ringgung, Java: Pulau Seribu			3.3-12.3	1.4-88.6							
		***Anisakis* sp.**	N	n.d.	Asmanelli et al. 1993	Sumatra: Riau Archipelago							n.d.				n.d.
		Anisakidae gen. et sp. indet.	N	viscera, sb, go, li	Koesharyani et al. 2001	Bali: Gondol Research Station								n.d.	n.d.		
		Nematoda gen. et sp. indet.	N	in, stw, stl, go, pyl, mes, acv	Asmanelli et al. 1993, Kleinertz 2010, Kurniastuty et al. 2000, Rückert 2006, Rückert et al. 2010, Yuasa et al. 1998, Zafran et al. 2000, present study	Bali: Gondol Research Station, Sumatra: Lampung, Balai Budidaya Laut Lampung, Riau Archipelago, Cobra, Tanjung Putus, Java: Pulau Seribu			4.6	1.4-11.4			n.d.	n.d.			
		***Corynosoma* sp.**	A	fins, gi, su	Asmanelli et al. 1993	Sumatra: Riau Archipelago							n.d.				
		***Gorgorhynchus* sp.**	A	go	Rückert 2006	Sumatra: Balai Budidaya Laut Lampung			6.2								
A	**5**	***Neoechinorhynchus* sp.**	A	in	Rückert 2006, Rückert et al. 2010, present study	Sumatra: Balai Budidaya Laut Lampung				1.0-2.9							
		Serrasentis sagittifer	A	go	Rückert 2006, Rückert et al. 2009, 2010	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay			3.3-12.3	2.9							
		Acanthocephala gen. et sp. indet.	A	n.d.	Rückert 2006, present study	Sumatra: Tanjung Putus				2.9							
		***Branchellion* sp.**	H	n.d.	Asmanelli et al. 1993	Sumatra: Riau Archipelago							n.d.				
		***Piscicola* sp.**	H	n.d.	Diani et al. 1999	Java: Serang, Bojonegara,				n.d.						n.d.	
H	**4**	***Zeylanicobdella arugamensis***	H	fins, gi, mcv, su	Kleinertz 2010, Palm et al. 2011, present study	Java: Pulau Seribu				14.3-57.1							
		Hirudinea gen. et sp. indet.	H	fins, gi, mcv, op	Koesharyani et al. 2001	Bali: Gondol Research Station			n.d.	n.d.		n.d.		n.d.			
		***Alcirona* sp.**	Cr	gi, gicv, no, su	Palm et al. 2011, Rückert 2006, present study	Sumatra: Ringgung, Java: Pulau Seribu				2.9-6.0							
		***Alitropus* sp.**	Cr	gi	Asmanelli & Partasasmita 1992, Asmanelli et al. 1994	Sumatra: Riau Archipelago, Alang Island										n.d.	13.3
		Argathona rhinoceros	Cr	gi, gicv	Rückert 2006, present study	Sumatra: Ringgung				14.3							
		***Bomolochus* sp.**	Cr	gi, mouth, op	Asmanelli et al. 1993	Sumatra: Riau Archipelago											n.d.
		***Caligus* sp.**	Cr	su, fins	Koesharyani et al. 2001, Wijayati & Djunaidah 2001, Yuasa et al. 1998, Zafran et al. 2000	Bali: Gondol Research Station, Java: Jepara				n.d.				n.d.			
		Cymothoa elegans	Cr	gicv	Rückert 2006, Rückert et al. 2010	Balai Budidaya Laut Lampung, Lampung Bay				1.0-2.9							

Total taxa		Parasite taxa	Taxa	Site	References	Locality	*Ea*	*Eb*	*Ec*	*Ef*	*Em*	*Ep*	*Es*	*Ca*	*Pl*	*Pm*	*Ps*
							P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]	P [%]
Cr	13	***Lepeophtheirus* sp.**	Cr	su	Asmanelli et al. 1993, Koesharyani et al. 1998, Yuasa et al. 1998, Zafran et al. 1998, 2000	Bali: Gondol Research Station, Sumatra: Riau Archipelago			n.d.	n.d.	n.d.		n.d.		n.d.		n.d.
		***Monogenia* sp.**	Cr	su, fin, gi	Akbar & Sudaryanto 2001, Kurniastuty et al. 2000	Sumatra: Lampung, Indonesia: unknown				n.d.	n.d.						
		***Nerocila* sp.**	Cr	gi	Diani 1989, Diani & Rukyani 1990	Java: Serang, Banten Bay, Bojonegara,							n.d.				
		Isopoda gen. et sp. indet.	Cr	gicv, mcv, no	Asmanelli et al. 1993, Koesharyani et al. 2001	Bali: Gondol Research Station, Sumatra: Riau Archipelago			n.d.								n.d.
		Gnathiidae gen. et sp. indet.	Cr	gi, gicv, su	Kleinertz 2010, Palm et al. 2011, Rückert 2006, Rückert et al. 2009, 2010, present study	Sumatra: Balai Budidaya Laut Lampung, Lampung Bay, Ringgung, Java: Pulau Seribu			3.3	1.0-3.0							
		Pennelidae gen. et sp. indet.	Cr	gi	Rückert 2006, Rückert et al. 2009, present study	Sumatra: Lampung Bay, Ringgung, Ringgung, Java: Pulau Seribu			3.3	2.9-8.6							
		Crustacea gen. et sp. indet.	Cr	gi, su	Kurniastuty & Hermawan 1998	Sumatra: Lampung				n.d.							
total		*80 Taxa*															

from the studied cultured *Epinephelus fuscoguttatus*. BBPBL: Balai Besar Pengembangan
Makmur Sejahtera, RG: Ringgung, TP: Tanjung Putus, PS: Nuansa Ayu Karamba - Pulau
rd error, n.a.: not available.

Sampling	BBPBL D03		RG R03/04		TP D03		KMS trash fish D03		KMS pellet D03		PS R03/04		PS R10/11		PS R11/12	
Parameter	**x**	**± SE**	**x**	**± SE**	**x**	**± SE**	**x**	**± SE**	**x**	**± SE**	**x**	**± SE**	**x**	**± SE**	**x**	**± SE**
Hepatosomatic index	1.47	0.08	2.24	0.12	1.42	0.08	0.97	0.06	0.54	0.04	1.34	0.05	1.84	0.25	1.73	0.74
Shannon-Wiener (endoparasites)	1.07	0.03	1.17	0.01	1.15	0.06	0.33	0.02	n.a.	n.a.	1.83	0.01	0.51	0.06	0.39	0.04
Evenness (endoparasites)	0.49	n.a.	0.51	n.a.	0.72	n.a.	0.25	n.a.	n.a.	n.a.	0.83	n.a.	0.24	n.a.	0.20	n.a.
Ec/En ratio	0.50	n.a.	0.83	n.a.	0.56	n.a.	0.40	n.a.	2.00	n.a.	0.50	n.a.	1.00	n.a.	0.67	n.a.
Trichodinids (P %)	51.50	0.08	2.90	0.03	17.10	0.06	2.90	0.03	0.00	0.00	2.90	0.03	0.00	0.00	0.00	0.00
Scolex pleuronectis (P %)	45.70	0.08	94.30	0.04	5.70	0.04	60.00	0.08	2.90	0.03	25.70	0.07	0.00	0.00	0.00	0.00
Raphidascaris sp. (P %)	17.10	0.06	97.10	0.03	22.90	0.07	51.40	0.08	0.00	0.00	82.90	0.06	48.57	0.08	57.14	0.08
Terranova sp. (P %)	25.70	0.07	88.60	0.05	0.00	0.00	2.90	0.03	0.00	0.00	57.10	0.08	0.00	0.00	0.00	0.00

6.3.2 Prevalence of infestation for selected parasite species

The prevalence of infestation with the trichodinid ciliate *Trichodina* spp. varied from 0 % (KMS pellet) to 51.5 % at BBPBL, they were documented for five of the eight sampling periods. They have a direct life-cycle, and are transmitted from grouper to grouper without intermediate hosts. The larval tetraphyllidean cestode *Scolex pleuronectis* has an indirect life cycle and utilizes copepods and chaetognaths as first and fish as second intermediate hosts (Marcogliese 1995). Adult Tetraphyllidea infect the intestines of different elasmobranchs and holocephalans (Rohde 1984). The prevalence of these larval cestodes ranged from 2.9 % at KMS (pellet) up to 94.3 % in groupers from RG. None was detected at PS in the rainy seasons 2010/2011 and 2011/2012. The heteroxenous, fish-parasitic nematode *Raphidascaris* sp. utilizes invertebrates as first and small fish as second intermediate hosts (Anderson 2002). During the present study the infection with this nematode was highest (97.1 % prevalence) in groupers from RG followed by groupers from PS (82.9 %) from 2003/04. Pellet fed grouper from KMS were free of *Raphidascaris* sp., while groupers from all other mariculture facilities were infected with this nematode. The lowest prevalence was recorded at BBPBL with 17.1 % (Table 6-4). The indirect life-cycle of the elasmobranch parasitic nematode *Terranova* sp. includes fishes as intermediate hosts (Moravec 1998) and was isolated from fish of four out of the six mariculture sites. The prevalence ranged from 2.9 % at KMS (trash fish) up to 88.6 % at RG. At the maricultures in TP, KMS (pellet) and PS in the rainy seasons2010/2011 and 2011/2012, these nematodes were absent (Table 6-2).

Cluster analysis (Fig. 6-2) and multi-dimensional scaling (MDS) (Fig. 6-3) of the infection prevalence of all parasites resulted in three groups at a similarity of 49 % and a stress level of 0.04 (excellent). Due to similarities in the grouper parasite fauna, the samples from Nuansa Ayu KarambaPS taken in the rainy season of 2010/11 and 2011/12 formed one group, and the pellet fed grouper sample from KMS was separated from all other mariculture facilities. Samples taken from the rest of the mariculture facilities formed a wider cluster.

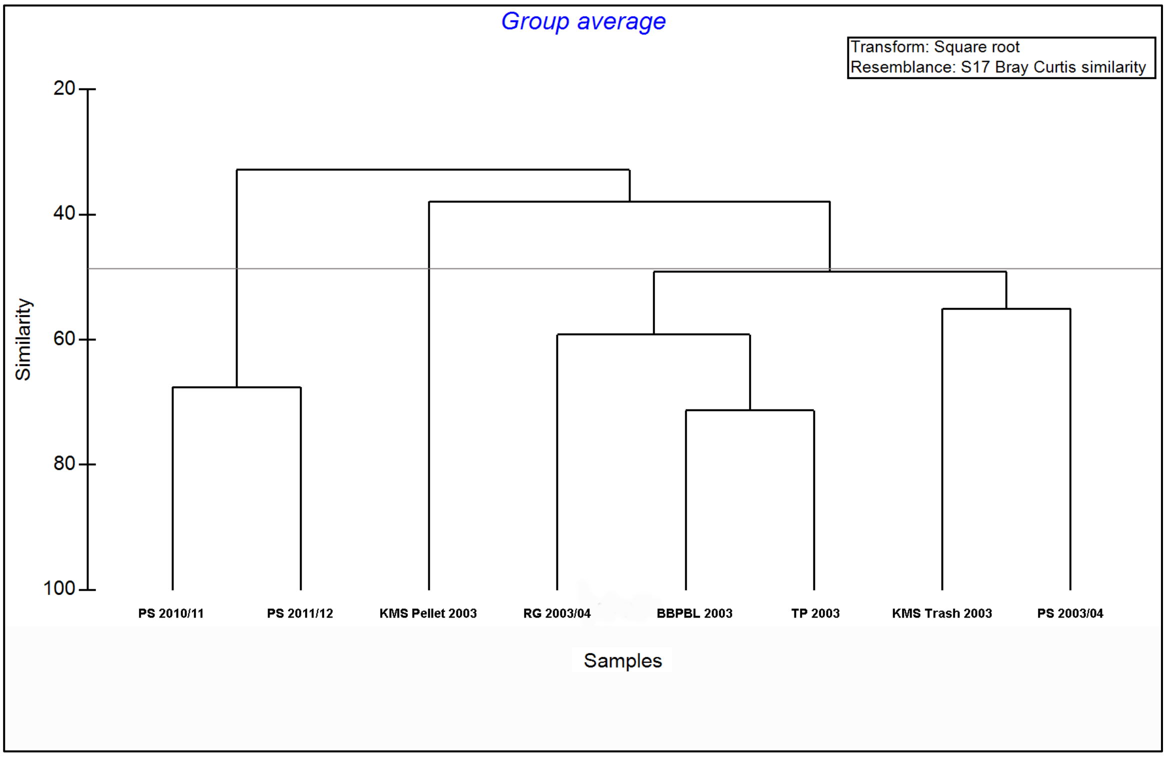

Figure 6-2. Cluster based on parasite prevalences found during the study in Lampung Bay and Pulau Seribu. BBPBL: Balai Besar Pengembangan Budidaya Laut Lampung, KMS: PT Kedamaian Makmur Sejahtera, RG: Ringgung, TP: Tanjung Putus, PS: Nuansa Ayu Karamba - Pulau Seribu). Grey line indicates similarity at 49 %.

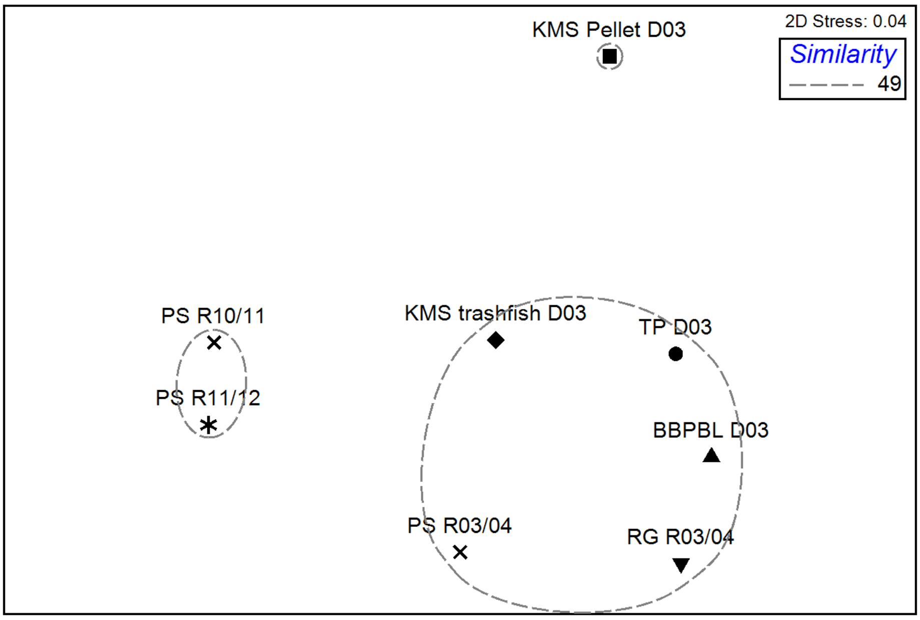

Figure 6-3. MDS plot based on parasite prevalences found during the study in Lampung Bay and Pulau Seribu. BBPBL: Balai Besar Pengembangan Budidaya Laut Lampung, KMS: PT Kedamaian Makmur Sejahtera, RG: Ringgung, TP: Tanjung Putus, PS: PT Nuansa Ayu Karamba - Pulau Seribu.

6.3.3 Feeding and treatment pattern

The mariculture facilities in Lampung Bay and Pulau Seribu showed differences in their overall management strategies. Specific cultivation methods for each mariculture facility are summarized in Table 6-5. The mariculture facilities used different net- and mesh sizes, and varied in the maintenance patterns. The size criteria of small and large fish varied, e.g. in PS: the small fish was defined as sizes < 10 cm, large fish > 10 cm; in KMS small fish was defined as sizes < 14 cm, large fish > 14 cm. The cage size for small fish ranged from 1.5 to 24 m^3. Most mariculture facilities used nets with sizes about 27 m^3 for the large fish. Only in PS, net cages with sizes of 64 m^3 were used during 2003/2004. The density of small and large fish in the net cages ranged from 60 to 200 fish m^{-3} and from 10 to 75 fish m^{-3}, respectively. The mesh size used for small fish and large fish ranged from 0.1 to 1.5 cm and 0.3 to 2 cm, respectively. The net cages were changed and cleaned from 1 to 4 times per month.

The feeding patterns varied at the facilities depending on management strategies. At KMS pellets were fed regularly to some batches of the cultured groupers. Different feeding patterns were not only found in mariculture facilities in Lampung Bay and Pulau Seribu but also for small and large fish within a single mariculture facility. The frequency of feeding ranged from 1 to 4 times a day, and in general small fishes were fed more frequently than larger ones. The feed for small fish consisted of chopped fishes (with or without head, inner organ, and/or fins) or pellets. In BBPBL and KMS a combination of chopped fishes and pellets was provided for small sized fish. The diet of large fish consisted of larger pieces of, or whole fishes (sometimes cleaned and decapitated). One batch of grouper in KMS was fed with pellets only in a separate cage. In PS, the feeding strategy has been changed after 2003/04; they changed from fresh trash fish obtained from local fishermen to previously frozen trash fish as feed. They also feed only pellets to fish smaller than 10 cm. Additionally, vitamin C and multivitamin for better nutrition were fed to the fish, ranging from one time per month to a maximum frequency of 30 times per month. During rainy season in 2011/2012, in PS additional nutrients were utilized when required only.

Anti-parasite treatments included freshwater, acriflavine or “gold 100” baths and diets enriched with formol, potassium permanganate, peroxide, methylene blue, antibiotics, ampicillin, oxytetracycline, and perfuran. The majority of fish at Lampung Bay and Pulau Seribu were bathed in freshwater for one to eight times per month. Fish in cages at BBPBL, RG and TP were bathed in acriflavine or gold 100 solutions every month. In the event of a parasite and disease outbreaks, chemo-therapy was used. However, fish in TP were fed with a potassium permanganate enriched diet four times a month and fish in PSwere treated with antibiotics administered via the feed from one to three times a month.

6.3.4 Evaluation of the effects of management strategies on parasitological parameters and HSI

We found significant relationships between some of the management strategies and parasitological parameters that were used in the analyses. There was a significant relationship between maximum density of fish and the prevalence of trichodinids. 65 % of the variance in the trichodinid prevalence is explained by the fish stocking density (Trichodinids = -3.59 + 1.22 x fish density, R-sq (adj) = 65.0 %, *df* =1, *F*=14.02, *n* = 8, *P* = 0.010). An increase in the maximum density of cultured fish results in an increase of trichodinid prevalence. A Mann-Whitney test showed a significant difference between the prevalence of *Raphidascaris* sp. for whole fish feed (N1) and gutted fish feed (N2) (N1 = 5, N2 = 3, W = 15.0, *P* = 0.037). As there was only one sample for pellet fed fish, the statistical analyses of the difference in parasitological parameters between pellet and trash fish fed fish was challenging. In the end we used a one-sample t-test hypothesizing that for the Ec/En ratio the values for the trash fish fed fish were significantly different from the value for the pellet fed fish. The results show that this is the case (*P* < 0.001). The Ec/En ratio in trash fish fed fish was significantly lower than in pellet fed fish. Polychoric correlation showed similar results, where pellet feed was strongly correlated with the Ec/En ratio (R = 1.0, ASE = 0.0003). There were no correlations between the HSIs and all evaluated management strategies. However, the mean HSI of pellet fed fish was significantly lower (ANOVA, P < 0.001) than the mean HSI of trash fish fed specimens.

...mented at different Indonesian mariculture facilities. BBPBL: Balai Besar Pengembangan
...akmur Sejahtera, RG: Ringgung, TP: Tanjung Putus, PS: PT Nuansa Ayu Karamba - Pulau
...ment strategies used for analyses on their effects on parasitological parameters.

Feeding and treatment pattern	BBPBL D03		RG R03/04		TP D03	KMS D03		PS R03/04		PS R10/11		PS R11/12	
	<12 cm	>15 cm	< 3 months	> 3 months		8-14 cm	> 15 cm	< 10 cm	> 10 cm	< 10 cm	> 10 cm	< 10 cm	> 10 cm
Facility													
Net cage size (m^3)	1.5 (1x1x1.5)	27 (3x3x3)	1.5 (1x1x1.5)	27 (3x3x3)	12 (2x2x3)	n.a	27 (3x3x3)	24 (4x4x1.5)	64 (4x4x4)	22.5 (3x5x1.5)	27 (3x3x3)	9.4 (5x1.5x1.25	27 (3x3x3)
Mesh Size (Inch) *	0.5	1-1.25	0.1	1-1.5	1.25	0.30-1.5	0.30-2	0.25	0.75	0.64	1.91	n.a	1.5
Change the net (per month) *	2	2	2	1	4	2	1	1-2	1-2	1-2	1-2	n.a	2
Density of fish (fish/m^3) *	150-200	50-75	85	20	10-20	500	20	60	15	60	15	100-150	20-25
Residence time (months)	2	5-7	2	6-8	n.a	2	5-6	12-18	n.a	n.a	n.a	n.a	n.a
Food													
Frequency of feeding (per day) *	2-3	1-2	4	3	[illegible]	3	2	2-3	1	2-3	1	3	3
Food item and preparation *	small pieces, without head and gut	large pieces, whole fish	medium pieces, without head, inner organ, fins.	large pieces, without head and gut	large pieces, whole fish	small fish	large fish	small pieces, fillet	large pieces, without inner organ	small pieces, without head and gut	large pieces, whole fish	pellets	large pieces, without head and gut
Quantity (% of body weight)	10-7.5	7.5-5	3-6	3-6	16 (gr)	4	n.a	3-6	3	3-6	3	6	3
Pellets *	yes	no	no	no	no	yes	yes	no	no	no	no	yes	no
Food (additional supplement)													
Vitamin C (per month) *	12	12	1	1	30	4	4	4-8	4-8	4-8	4-8	in case	2
Multivitamin (per month) *	12	12	1	1	30	4	4	4-8	4-8	4-8	4-8	in case	in case
Treatments													
Wash with freshwater (per month (minutes)) *	8 (15-20)	1 (15-20)	2 (5)	1 (5)	2	2	1	-	-	-	1	2-3	2-3
Wash with Acriflavine or Gold 100 (per month)	8	-	in case	in case	4	-	-	-	-	-	-	-	-
Formol	-	-	-	-	-	in case	in case	-	-	-	-	-	-
Potassium permanganate	-	-	-	-	4	-	-	-	-	-	-	-	-
Peroxide	-	-	in case	in case	-	-	-	-	-	-	-	-	-
Methylene blue	-	-	in case	in case	-	-	-	-	-	-	-	-	-
Antibiotics	-	-	-	-	-	-	-	in case	in case	1	1	1-2	2-3
Ampicilin	-	-	in case	in case	-	-	-	-	-	-	-	-	-
Oxytetracycline	-	-	in case	in case	-	-	-	-	-	-	-	-	-
Perfuran	-	-	in case	in case	-	-	-	-	-	-	-	-	-

6.4 Discussion

The parasite diversity observed for fish from Indonesian grouper maricultures is high, according to the available literature and the present study (Table 6-3). A diverse array of ecto- and endoparasites was found and even the pellet fed fish harbor a variety of parasitic organisms. A total of 35 different parasite species, ten with a monoxenous (single host) and 25 with a heteroxenous (multiple hosts) life-cycle, were collected from 280 specimens of *E. fuscoguttatus*. Most abundant were *Pseudorhabdosynochus* spp. (prevalence up to 100 %, including *P. epinepheli* and *P. lantauensis*), *Allopodocotyle epinepheli* (prevalence up to 100 %), *Raphidascaris* sp. (prevalence up to 97.1 %), and *Scolex pleuronectis* (prevalence up to 94.3 %).

According to Rückert et al. (2010), free living *E. fuscoguttatus* in Lampung Bay are infected with 30 parasite species, 10 of them with a monoxeneus and 20 with a heteroxenous life cycle, whereas cultured grouper are infected with 25 parasites. In another study (Rückert et al. 2009a), the authors analyzed experimentally the difference between pellet and trash fish fed *E. coioides*, which showed a reduced number of endoparasite species in the pellet fed fish (pellet:13 species in total, 8 ectoparasites, 5 endoparasites; trash fish: 14 species in total, 5 ectoparasites and 9 endoparasites). Most abundant for free living *E. fuscoguttatus* were *Pseudorhabdosynochus* spp. (prevalence up to 100 %, comprising *P. epinepheli* and *P. lantauensis*), *Allopodocotyle epinepheli* (prevalence up to 100 %), and *Raphidascaris* sp. (prevalence up to 100 %). These parasites represent the core species of this fish species in Indonesia. The present study confirms this, as the prevalence for these species was quite high as well (Table 6-2). The trash fish fed groupers from BBPBL, RG, TP and KMS (Lampung Bay) had a more diverse parasite fauna (in total 33 parasite species) than the free living *E. fuscoguttatus*, with up to 22 different species in one location (RG).

Comparing our results to the known parasite species recorded for *E. fuscoguttatus* from mariculture facilities so far, we were able to record 80 % of the regularly occurring species diversity. This reflects the general use of locally sourced and often freshly fed trash fishes in Indonesian grouper mariculture. Even though our sampling took place between 2003 and 2012, this is still the common practice (last confirmed July 2013). Many of these parasite species seem to infect a variety of groupers in Indonesia, generally or occasionally. Cage reared specimens are often fed with trash fish species, some of these fish species do not fall into their natural food range. Therefore, cultured grouper can be infected with parasite species that do not normally occur in the wild. Our results demonstrate that parasite species such as e.g. *Lecithochirium neopacificum* and *Serrasentis sagittifer* that were isolated from cultured fish have not been recorded for free living *E.fuscoguttatus*. Due to ecological reasons and thus possible restrictions in parasite transmission, these parasites do not infect grouper under natural conditions, but are probably transmitted to cultured fish through the trash fish feed. *Serrasentis sagittifer* was found in five trash fish species *Nemipterus furcosus*, *N. japonicus*, *Scolopsis taeniopterus*, *Upeneus moluccensis* and *U. sulphureus* in Lampung Bay (Rückert et al. 2009a). This demonstrates that grouper in Indonesian mariculture facilities can still be affected by parasites for which no grouper-parasite records have been reported before.

So far 77 parasite taxa belonging to protists (10), metazoans (67) have been reported to infect different grouper species in Indonesian mariculture facilities, of them 44 ecto- and 33 endoparasites. Due to the lack of taxonomic information from Indonesian waters, some parasites could not be identified to species level, but the following higher taxa were identified: Flagellata (4), Ciliophora (6), Microspora (1), Myxozoa (1), Digenea (13), Monogenea (17), Cestoda (5), Nematoda (8), Acanthocephala (5), Hirudinea (4) and Crustacea (13) (Table 6-3). On fish genus level, 60 species/taxa were isolated from *Epinephelus* spp., 17 from *Cromileptes altivelis* and 21 from different *Plectropomus* species. Highest parasite diversity was found for *E. fuscoguttatus* with 46 parasite species/taxa, 25 of which were ectoparasites and 21 were endoparasites (Ec/En ratio: 1.2). *Epinephelus coioides* harbors 36 parasite species/taxa (21 ecto- and 15 endoparasites; Ec/En ratio: 1.4). Lowest parasite diversity was found for *E. areolatus* (three ectoparasites only) (Table 6-3). One reason for this is that *E. areolatus* is not usually cultured in mariculture facilities and only few data exist from Indonesian maricultures. Most of the parasite species found in this study have the ability to induce fish diseases when hosts are heavily infected. Disease symptoms range from slight alterations in the fish condition to rapid death (Cruz-Lacierda and Erazo-Pagador 2004). The manifestation depends on the parasite species and numbers. Several cases of grouper mass mortalities due to parasitic infections (e.g. Trichodina sp., Acineta sp., Vorticella sp., and Epistylis sp.) have been reported to cause economic losses in Indonesia (Purwanti et al. 2012, Diani et al. 2013). Cruz-Lacierda and Erazo-Pagador (2004) listed the parasite species that can trigger diseases and therefore, pose a threat to grouper mariculture. These parasites consist of Ciliophora (*Trichodina* sp.), Monogenea (*Benedenia* sp., *Noebenedenia* sp., *Pseudorhabdosynochus* spp., *Megalocotyloides* spp., and *Diplectanum* sp.), Digenea (*Gonapodasmius* sp.), Nematoda (*Philometra* sp., *Anisakis* sp., *Raphidascaris* sp.), Copepoda (*Caligus* sp., *Lepeophtheirus* sp.), and Hirudinea (*Zeylanicobdella arugamensis*). If fish farmers are able to maintain good culture conditions and therefore healthy fish, the cultured fish are more likely to survive the parasite infection. To date there is no concern for fish-born parasitic zoonoses in grouper maricultures. Some fish parasites, such as anisakid nematode species (e.g. *Anisakis simplex*) (Jakob and Palm 2006), are of potential risk for human health, and 11 % of 244 tested people from East Java were positive for *Anisakis* during a serioepidemiological survey (Uga et al. 1996). However, beside the earlier record by Asmanelli et al. (1993, see table 6-3), we could not detect *Anisakis* in the sampled mariculture groupers during the present study.

Several maintenance activities and treatments are recommended for mariculture facilities to provide healthy holding conditions for cultured fishes and therefore to prevent disease outbreaks. These include changing and washing the nets of the cages, bathing the fish in fresh water, chemical bathing treatments, as well as feeding supplements and/or drugs to the fish (Supriyadi and Rukyani 2000, Cruz-Lacierda and Erazo-Pagador 2004). During the time this study was conducted, fish farmers in Lampung Bay and Pulau Seribu adopted different regimes of these activities and treatments to maintain healthy holding conditions (Table 6-5). Feeding strategies have a big influence on the parasite composition. Our results show that *E. fuscoguttatus* cultured at KMS fed with pellets had low parasite diversity. They harbored the lowest number of endoparasites compared to the fish from other mariculture facilities (Table 6-2) and the overall parasite composition differed (Fig. 6-2). We were able to show a direct relationship between the choice of pellet or trash fish feed and the Ec/En ratio. This is due to a reduced or no transmission of endoparasites, when the fish is fed with pellet (Rückert et al. 2010). The stocking density of fish in the cages has an influence on the prevalence and numbers of directly transmitted ectoparasites. Our results show this exemplarily on the basis of the trichodinid prevalence, which significantly increase with increasing fish density. The link between stocking densities and ectoparasite disease outbreaks has been shown in several studies (e.g. Balasuriya and Leong 1994, Banerjee and Bandyopadhyay 2010). There was also a significant difference in the prevalence of the nematode *Raphidascaris* sp. for grouper that were fed with whole trash fish and grouper that were fed with gutted trash fish. Our results showed, that grouper fed with whole fish were infected with less nematodes than grouper fed with gutted fish. The result is the opposite of what we would have expected as *Raphidascaris* is mainly found in the viscera of Indonesian trash fish species such as *Gazza minuta*, *Nemipterus furcosus*, *Scolopsis taeniopterus*, *U. moluccensis*, *U. sulphureus* and *U. vittatus* (Rückert et al. 2009a). As these nematodes are also found in the muscle tissue of these fish species, one explanation could be that the investigated grouper in this study were fed with whole specimens of trash fish species infected with low numbers or no nematodes and that the muscle tissue of the gutted trashfish was infested with higher numbers of *Raphidascaris*. Another cause for the variation in nematode or helminth infections in the different facilities could be, among others, differing intermediate host abundance in the vicinities of the mariculture facilities. A change in the feeding strategy at PS after 2003/04 did also influence the parasite composition. Especially the endohelminths *Terranova* sp., *Allopodocotyle epinepheli*, Enenteridae gen. et sp. indet. and some prosorhynchids in PS vanished from 2003/2004 until 2011/2012. Palm et al. (2011), reported already a decrease in prevalence and intensity of these species in 2004/2005. The authors explained this fact with changing culture (feeding) methods and environmental change (lacking intermediate hosts in the surroundings). The number of parasite species further decreased after the fish farmer in PS used defrosted frozen trash fish and pellets only for the small sized fishes. Some of the parasites do not survive freezing over a prolonged period of time (EFSA 2010), hence this method decreases the number of endoparasites that can be successfully transmitted to the grouper. Multivariate analyses showed a clear separation of the fish sampled at PS in 2010/11 and 2011/12 from fish at PS in 2003/04 and several facilities in Lampung Bay as well as from fish fed with pellets at KMS, which were different from all other facilities (Fig. 6-3).

The feeding strategy did not only have an effect on parasite numbers and compositions, but also on the HSI values. Fish fed with trash fish had higher HSIs than fish fed with pellets. Moreover, the HSIs of fish at PS in 2010/2011 and 2011/12 were significantly higher than the HSI of fish at PS in 2003/04. This means, the change of feeding strategies at PS after 2003/04 did not only affect the parasite composition but also affected the HSI of the fish. According to Rosenlund et al. (2004) and Montenegro and Gonzales (2012), the HSI value is affected by the fish's diet, environmental conditions, as well as parasite infections (Heath 1995 in Montenegro and Gonzales 2012). However, fish from PS in 2010/11 and 2011/12 had lower parasite infections. A plausible reason for higher HSI values for fish from PS after 2003/04 is that the HSI was more influenced by the different feeding strategy and the existing environmental conditions. Anthropogenic activities in PS are higher than in Lampung Bay and fish inhabiting environments with high anthropogenic activities are known to show higher HSI values (Yuasa et al. 1998).

Thereby, our results also shed light onto some methodological problems in analyzing the parasite diversity of groupers in Indonesian mariculture facilities. There is a clear long-term change in the parasite communities, as can be seen in the different clustering pattern for parasite data from PS 2010/11, 2011/12 and the data from 2003/04 (Fig. 6-2). A possible reasons for those changes might be seen in different feeding and management strategies (here a change in feed preparation), resulting in less parasitized fish. However, the mariculture activity itself influences the parasite composition at a certain location, as seen during monitoring the parasite composition of *E. fuscoguttatus* in PS (Palm et al. 2011). All management and feeding strategies were put into place in order to keep the cultured fish healthy until it reaches its marketable size. Still, the effects of these strategies depend on their enforcement. For one of the routine treatments (freshwater bath), we observed that after the fish was bathed for ectoparasite treatment, the workers poured the water with the previously attached ectoparasites (such as *Benedenia* sp.) directly back into the ocean and therefore into the floating net cages. Reinfections with the same parasites could therefore easily occur, if some of the detached ectoparasites survived the treatment.

6.5 Conclussion

The present study demonstrates that using non-identified composites of trash fish as main feed sources bears the risk of introducing new, unknown and potentially disease causing as well as zoonotic parasites into Indonesian grouper mariculture facilities. Consequently, the natural fish feed opens a new route of parasite dispersal, causing unpredictable parasite infections. Different management practices result in different parasite infection patterns in each of the five sampled mariculture facilities, suggesting necessary improvements for already existing treatments in order to prevent parasite spread and disease outbreaks. In combination with the regular transport of grouper seed and juveniles throughout the archipelago and the Life Reef Food Fish trade to Hong Kong and Singapore, mariculture activities can have expansive consequences, resulting in parasite-borne disease outbreaks not only in Indonesia, but also in the whole South-East Asian region. The recent intensification of the grouper production spread this activity throughout the Indonesian archipelago. However, fish production in open net cages and the lack of standardized treatment and cultivation methodologies results in an unpredictable quality range of the marketed product, which is a constraint for future grouper producing industries.

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7. Discussion

The main purpose of this thesis is to show a case study on stock enhancement activities of groupers from coral reef habitats in Karimunjawa National Park, Indonesia. Stock enhancement is a new methodology implemented in many regions around the world (Masuda and Tsukamoto 1998, Kitada and Kishino 2006, Loneragan et al. 2006, Bell et al. 2008, Lorenzen 2008) in order to cope with high fishing pressures on the natural fisheries resources, overfished stocks and anthropogenic depleted coral reef habitats. The Karimunjawa National Park was chosen to obtain the data from a protected environment, allowing a better analysis of the potentials and arising problems caused by stock enhancement activity. Groupers as the selected fish species are predominant importance in Asia, especially in the South-East Asian region (Johannes and Riepen 1995, Mous et al. 2000, Sadovy 2005, Sadovy et al. 2013). Hence, the results of the present study are suitable to be implemented not only in Indonesia but also in other regions with a high pressure on the natural fisheries resources.

7.1 Strategies to increase fisheries production in coral reef habitats

According to Dey et al. (2008b), there have been many different attempts to increase marine fisheries production in depleted habitats through sustainable strategies. Traditionally, adaptive fisheries management through community based systems, co-management, law enforcement, public awareness and others are the methods to maintain and increase marine fisheries production (Walters 2007, Dey et al. 2008b). Other options that have been already implemented in different Asian countries are the declaration of marine protected areas, habitat restoration (e.g. artificial reefs), aquaculture, and stock enhancement (Dey et al. 2008b). Marine Protected Areas (MPAs) are widely used to protect and enhance reef fish populations (Sadovy 1999, Chiappone et al. 2000). An artificial reef is an artificial structure made from concrete materials and built similar to coral reef structure at damaged coral reef areas to support the coral reef development. However, Grossman et al. (1997) reported that artificial reef in some cases had negative impacts to reef fish; therefore they advised to carefully evaluate the positive and negative impacts of artificial reef when it would be implemented. Aquaculture is a main substitution to increase fish production when wild capture fisheries collapse due to declining of marine fish resources (Naylor et al. 2000).

Stock enhancement that is relatively new methodology is being recently used to enhance fish production (Bell et al. 2006).

In Indonesia, there are no specific strategies of the Ministry of Marine Affairs and Fisheries (MMAF) to increase specifically fisheries production in coral reef habitats. However, there is an increasing awareness of local communities about the problems resulted from depleted fish stocks that affect the natural biodiversity of the country. There are several programmes in the MMAF strategic plan 2010-2014 aimed to increase fisheries production including coral reef fisheries through sustainable activities. Those activities concern on: fisheries (improvement the adaptive fisheries management, strengthening and improvement of the fishing capacity, establishment of marine protected areas, and coral reef rehabilitation including fish stock enhancement program), aquaculture (aquaculture intensification) and coastal resources management (MMAF 2012, DGCF 2013, DGA 2013, DGMCSI 2013). Due to the objectives of this thesis, I herewith discuss the aquaculture intensification program, marine protected areas and the implementation of stock enhancement programmes in more detail.

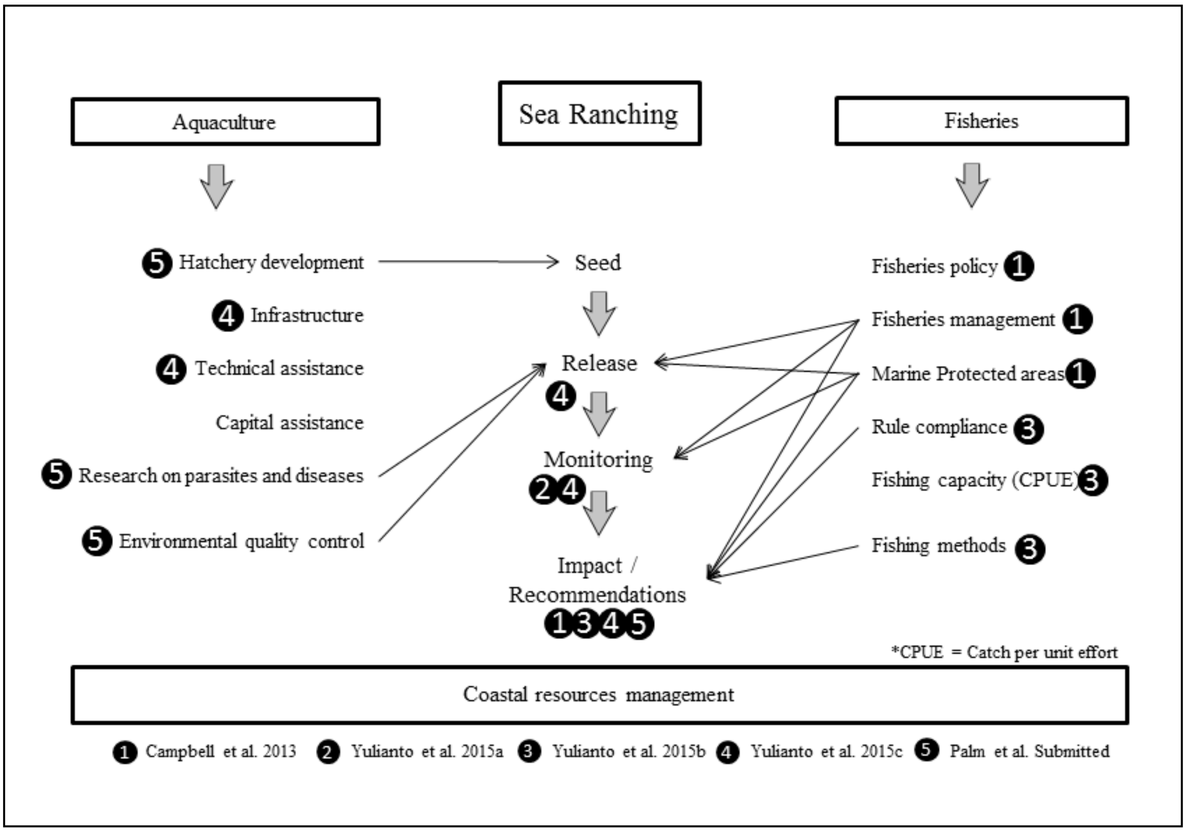

Figure 7-1. Government programmes conducted to increase reef fish production and published papers that correlate to the programmes

7.1.1 Aquaculture intensification programme

Indonesia has a long history in aquaculture. However, mariculture is a just recently developed activity in Indonesia (Rimmer et al. 2013). Mariculture also develops around the world (Campbell and Pauly 2013) but it becomes the most rapid growing aquaculture practices in Asian-Pacific countries (Hishamunda et al. 2009, Rimmer et al. 2013).

The intensification programmes of aquaculture through the MMAF include: an increase of coral reef fisheries production through mariculture based on the development of new hatchery systems, the provision of technical assistance, the development of mariculture infrastructure, fish farming capital assistance, modern research for a parasite and fish disease, and environmental quality control (DGA 2013). The development of hatchery systems was implemented to ensure the availability of fingerlings for the fish farmers. Thousands hatcheries were built between 2002 and 2014, producing a total more than 30 million fingerlings of groupers (Sim et al. 2004, DGA 2015). The supply of relevant numbers of grouper fingerlings at a low price is essential for subsequent stock enhancement or sea-ranching programs, releasing small fish into the wild (NOAA Fisheries 2015). Seeds or fish juveniles produced from hatchery systems are the main sources for stock enhancement (Fushimi 2001). Therefore, the success of stock enhancement depends on the availability of juveniles (Bell et al. 2006). According to Halwart et al. (2007) and Sugama et al. (2013), aquaculture in Indonesia nowadays can provide grouper fingerling to supply the demand of the entire world. Due to inconsistent demands, surplus grouper fingerling productions occur providing a possible fingerling source to support a successful stock enhancement and sea-ranching programme in Indonesia.

Technical assistance from MMAF was conducted by means of establishing a number of aquaculture technical units. Nine aquaculture development centres have been established in Indonesia. They are mariculture development centres in Ambon (Maluku), Batam (Kepulauan Riau), Central Lombok (West Nusa Tenggara), and Pesawaran (Lampung), and brackishwater aquaculture development centres in Jepara (Central Java), Situbondo (East Java), Takalar (South Sulawesi), Tatelu (North Sulawesi), and Ujung Batee (Aceh). The farmers can address those technical units to enhance their own aquaculture practices. The remaining activities directly support the fish farmers to expand their mariculture businesses or to establish new mariculture facilities throughout the country while they reduce possible constraints, such as diseases and parasite outbreaks. According to Palm et al. (2015), mariculture activities can cause parasitic disease outbreaks in Indonesia as well as in the Asian region. For example, heavy monogenean gill fluke infections can induce an increase of mortality rates, and these parasites can be transported by living fish over long distances. In the commercially important Indonesian grouper mariculture, the recorded diversity of fish parasite is high. So far 77 parasite taxa belonging to the Protozoa (10) and Metazoa (67) have been reported to infect different grouper species; 44 of them are ectoparasites and 33 are endoparasites (Palm et al. 2015). Most of parasite species found in cultured groupers have the ability to create diseases when the fish are heavily infected (Palm et al. 2015). Disease symptoms caused by parasites range from slight skin alterations, reduced fish condition to rapid death (Cruz-Lacierda and Erazo-Pagador 2004).

Different management strategies result in a different parasite infection of the mariculture fish (Rückert et al. 2009a, Palm et al. 2015). For instance, pellet fed fish had lower endoparasites species richness than trash fish fed fish (Rückert et al. 2009a, Palm et al. 2015). A similar result concerns on different densities of the cultured fish. According to Balasuriya and Leong (1994), Banerjee and Bandyopadhyay (2010) and Palm et al. (2015) the density of cultured fish in the net cages has an influence on the prevalence and the number of directly transmitted ectoparasites. To prevent parasites spread and outbreak that can create serious problem to the mariculture development in Indonesia, it is strongly recommended to develop alternative feeding strategies and management procedures for the growing grouper mariculture industry (Palm et al. 2015).

It appears the programmes that have been implemented by MMAF since the beginning of 2010 effectively increase the aquaculture production in Indonesia. In 2010 the production of coral reef fisheries, especially the groupers production, increased two times compared with the production in 2009 (MMAF 2013a).

7.1.2 Marine protected areas

The establishment and management of marine protected areas in Indonesia are resulted from the commitment of the Government of Indonesia to the Convention on Biological Diversity's Program (Wiadnya et al. 2011). The goal is to establish 10 million hectares MPAs in 2010 and a further 20 million hectares MPAs until 2020 (Wiadnya et al. 2011). Several studies revealed that the reef fish abundance and biomass (e.g. groupers) in the core zones of the MPAs were higher than that in the exploitation zones (Polunin and Roberts 1993, Chiappone et al. 2000, Friedlander and Demartini 2002, Unsworth et al. 2007). According to the Directorate General of Marine, Coastal, and Small Islands (DGMCSI), the MMAF and the local governments have established 11.1 million hectares of MPAs since 2004, 3.6 million hectares of them were under effective management (DGMCSI 2014a). Before 2004, the Ministry of Forestry established 4.7 million hectares of MPAs. In total, the number of MPAs in Indonesia is 131 MPAs, covering so far 15.8 million hectares (DGMCSI 2014a).

Apart from the establishment of the MPAs in Indonesia, the Government of Indonesia also intends to intensify the management effectiveness of the MPAs (Campbell et al. 2013, White et al. 2014). For this purpose, the MMAF developed a monitoring and management system for the MPAs as a tool to increase their benefits (DGMCSI 2012, White et al. 2014). The effectiveness of the MPAs is important to ensure the impact of the MPA, supporting the sustainable use of the marine and coastal resources, especially of the coral reef habitats and the depending fisheries (White et al. 2014). According to the DGMCSI that has the authority for the MPA development and management in Indonesia under the MMAF, there are two important components with regard to the effectiveness of the MPA management in the new Indonesian MPA system. These are the decentralisation of the MPA management and the zoning system (DGMCSI 2014a). However, according to Yulianto et al. (2015b) the zoning system in the MPA alone is not sufficient to protect coral reef fish resources from fishing pressures. There is evidence that the fishermen's agreement to self-regulate the fishing gear meets the conservation purposes (Yulianto et al.2015b). High fishing pressure has negative impact to the success of fish recruitment (Yulianto et al. 2015b). It creates smaller fish stocks (Rochet 1998, Shin et al. 2005). On the other hand, a decrease of fishing pressure correlates with an increase in abundance of large groupers (Chiappone et al. 2000). Hence, although the MPAs are widely recommended as tools for reef fish protection and management (Gaines et al. 2010), a community support is required to support the work efficiency of the MPA (Hamilton et al. 2011). A regulation of the use of fishing gear is needed in order to maintain the fishery resources in the coral reef habitats (Hilborn et al. 2004).

Based on MPA management study in Karimunjawa National Park, strengthening of the community support and the involvement of the local people into the zoning process and the fisheries management activities create a better compliance to the suggested zoning and increase the fishing regulation effectiveness (Campbell et al. 2013, Yulianto et al. 2015b). This promotes regulation compliance practices of local people that have a direct positive impact onto the reef fish communities and fisheries, and as an important indicator of the MPA management effectiveness (Yulianto et al. 2010, Campbell et al. 2013, Yulianto et al. 2015b). Local communities usually support the governance systems that consider the customary systems at a place (Aswani 2005, Hoffman 2006, Tiraa 2006, Cinner and McClanahan 2006, Campbell et al. 2013). These are commonplace in many Pacific societies (Aswani et al. 2007, Cinner and Aswani 2007). Community based-marine protected areas that usually cover small MPAs have demonstrated that they provide much better improvements in biodiversity than larger government-based MPAs, mainly due to a higher level of compliance by local people (McClanahan et al. 2006a). Community agreements to regulate the fishing gear in the MPA promoted a significant increase in reef fish mean biomass and stock size (Yulianto et al. 2015b). Hence, to increase the reef fish resources in the MPA, it requires proper fisheries regulation and community support (Yulianto et al. 2015b). As suggested by Campbell et al. (2013), this can be supported by incentives for local communities (e.g. economic incentives, community involvement incentives) that promote compliance with the zoning and fishing regulations inside the marine protected area, preventing a further depletion of the reef fish and fisheries.

7.1.3 Stock enhancement

One of the strategies to restore fish population in overfished regions is fish stock enhancement, a relatively new methodology (Bell et al. 2008). Fish stock enhancement is defined as the release of cultured fish into the natural population (Bell et al. 2008). Stock enhancement was first introduced in Japan in 1762 for freshwater fish and in 1962 for marine fish (Masuda and Tsukamoto 1998). Several success stories of stock enhancement were reported for stripped mullet in Hawai (Leber et al. 1995), the southern scallop fishery in New Zealand (Lorenzen 2008), shrimp (*Penaeus esculentus*) in Western Australia (Loneragan et al. 2006), salmon (Masuda and Tsukamoto 1998) and other finfish (Kitada and Kishino 2006) in Japan.

Based on to the guideline of rehabilitation produced by MMAF (DGMCSI 2014b), the rehabilitation of damaged coral reef areas can be conducted by artificial reef development and coral transplantation. Fish stock enhancement can be conducted to restore depleted fish populations. Thus, the MMAF conducted the release of marine fish in several provinces in Indonesia (Directorate of Fisheries Resources 2011). A first stock enhancement programme for marine fish in Indonesia was called "one man one thousand fries", and it was conducted by the release of snapper, milkfish, and grouper juveniles, started in 2011. The brown-marbled-grouper (*Epinephelus fuscoguttatus*) and Humpback grouper (*Cromileptes altivelis*) were released in order to enhance the yield and fulfil the increasing demand (Yulianto et al. 2015c). Approximately 200,000 juveniles were released into the wild in 12 provinces in Indonesia.

The required juveniles for this program were produced in Situbondo, Jepara, Bali, Lampung and transferred to the release sites (see above). The price of - a wild caught grouper is higher than that of cultured fish. According to Rahmansyah et al. (2009), the difference in price is caused by the buyers' perception that buyers prefer the "wild grouper taste". Chan and Johnston (2007) could demonstrate that more than 70% of respondents preferred wild caught fish when they did consumers tests of grouper in Hong Kong sea food restaurants. However, Rahmansyah et al. (2009) stated a missing proof of the buyers' perception on grouper taste. A second reason for a higher price is a relatively higher survival rate of wild groupers during transportation from the fishermen or farm to the market. Fishermen are attracted to catch wild grouper due to a higher price, resulting in increasing fishing effort even under already overfished conditions (Yulianto et al. 2015b,c). The fishing pressure correlates with the fishing efforts; an increasing fishing effort to wild groupers affects the fishing pressure to the grouper habitats, and later it threats the surrounding ecosystem (Sadovy et al. 2013). Consequently, stock enhancement of groupers might be a potential solution to reduce the problems caused by constantly high wild grouper catches.

Figure 7-2. Locations of "one man one thousand fries" programme implemented in 2011 and stock enhancement experiment.

According to Yulianto et al. (2015c), the stock enhancement activities conducted by the MMAF did not contribute significantly to an increase of grouper production. It is evident that the size of the released grouper determined the efficiency of the stock enhancement programme in 2011. The size of grouper released in 2011 ranged from 3 to 12 cm, with a median size below 8 cm (Directorate of Fisheries Resources 2011). Due to the lack of pre-adaption and appropriate avoidance reaction to predators, 10 cm fingerlings of brown-marbled groupers are too small to be released at Karimunjawa Islands (Yulianto et al. 2015c). Brown-marbled groupers at 10 cm need at least 2-3 days to adapt to the conditions under presence of predators before they actively search for their shelter and hide themselves from predators (Yulianto et al. 2015c). Less learning opportunities under hatchery conditions cause the slow adaptation of the released fish to the natural environment, because the fish are regularly kept in a plain and homogeneous cultivation tank inside the hatchery facility (Salvanes et al. 2013), without any exposure to the natural conditions. Moreover, the natural camouflage with the cryptic ability usually exhibited by brown-marbled grouper (Pears 2005) was less well developed in the released fish, which adds to the inadequate behaviour of the 10 cm fish. There is also evidence in the literature that small and young animals are more susceptible to predation compared with larger and older animals (Hixon 1991), which coincides with the findings from the experiment at Karimunjawa National Park.

Successful sea trout stock enhancement in the Baltic Sea (HELCOM 2011) depended on the release of the eggs and juveniles of sea trout at the spawning areas, which close to the upstream gravel beds. In these places, where the sea trout or brown trout spawns, a number of predators are relatively low. After reaching a certain size when the juvenile sea trout can survive from predators at a greater likelihood, they migrate to the sea. Groupers in the coral reef habitat with a high number of predators require adaptation before they are released to prevent predation. The life strategy of grouper is similar to sea trout in which they are both moderate r-strategists and the juveniles appear openly in the natural habitat at a larger body size. Supported by the findings in the present study, it is required to define the grouper size with the highest survival rate towards the pressure of the predators in coral reef habitat. If the fish is released at a too small body size (less than 10 cm), the natural mortality due to predation is apparently exorbitantly high. Because the natural mortality of grouper decreases with increasing age and size of fish, the natural mortality of grouper (e.g. red grouper) can reach more than 150 per year at larvae stage and 0.49 per year at the sub-adult stage (Gimenez-Hurtado et al. 2008).

The stock enhancement experiment indicates that to decrease the predation risks and to optimise the impact to the grouper yield in grouper stock enhancement, the minimum size of brown-marbled grouper should be 15 cm or preferably larger (Yulianto et al. 2015c), and not as small as in the earlier governmental stock enhancement programs. Since the available size of production of cultured groupers in the mariculture centres is 10 cm or less, caused by the regular fingerling demand, the cultured fish needs to be kept inside the net cages for several more weeks to reach the size of 15 cm. In addition, the cultivation technique inside the farm for the fingerlings would require a certain condition to prepare the fish for a later release, e.g. by adding hiding places into the tanks or using a co-cultivation with other fish species.

Besides predators, another risk involved in stock enhancement is the potential parasite transmission because cultured grouper is kept in open water net cages. Parasites can get in contact with cultured grouper in the net cage and may be transferred also to other wild fish (Rückert et al. 2009a, Rückert et al. 2010, Palm et al. 2011, Palm et al. 2015) when the cultured fish is released to the natural population (Palm et al. 2015). This risk should be considered and anticipated in stock enhancement programmes by maintaining fish health at the highest possible standard before they are released to nature.

7.2 Reef fish monitoring

Fish biomass and abundance is one of the important indicators to evaluate MPA effectiveness (Pomeroy et al. 2005, Yulianto et al. 2010) and stock enhancement programmes (Blankenship and Leber 1995, Yulianto et al. 2015a). The underwater visual census (UVC) is one of the most effective and reliable methods to estimate the reef fish biomass (Brock 1954, Yulianto et al. 2015a). Consequently, this methodology is used all around the world (Jennings and Polunin 1995, Jennings et al. 1996, Friedlander and De Martini 2002, McClanahan and Graham 2005, Stevenson et al. 2007) including Indonesia. Studies on the estimation of the reef fish biomass exist in Karimunjawa National Park, Aceh Province, Seribu Islands, North Sulawesi, Wakatobi National Park, Lombok Island, Bali, Komodo National Park, and in Raja Ampat (Pet et al. 2005, Campbell and Pardede 2006, McClanahan et al. 2006a, Unsworth et al. 2007, Rudi et al. 2009, Madduppa et al. 2012, Purwanto et al. 2012, Yulianto et al. 2012).

One of the main concerns for estimating the reef fish biomass by UVC is the fish length estimate, requiring a high accuracy of the fish length estimates (Yulianto et al. 2015a). According to Kadison et al. (2002). Problems of length estimates in UVC can be solved by training and calibration. Yulianto et al. (2015a) also demonstrated that the UVC technique can be improved in estimating reef fish biomass by training and calibration only in five days, requiring only little time and additional expenses. Hence, by training and calibration, the underwater visual census becomes an even more useful and reliable tool to assess reef fish biomass (Yulianto et al.2015a). It is beyond the data obtained through fisheries science methodologies based on capture data (Yulianto et al.2015a, b). A remaining concern related to grouper stock enhancement is an adequate monitoring and evaluation of the impact of stock enhancement (Palm and Stoye 2014). Underwater visual census, fish-catch monitoring, and fish tags are among the currently available methods to monitor the impact of grouper stock enhancement. However, the present study shows that, the underwater visual census is not an appropriate method to monitor the impact of the stock enhancement experiment. The brown-marbled grouper were not recorded any more than five days after the release experiment (Yulianto et al. 2015c). Similarly, recaptured fish with tags were not recorded, and the only available data were recorded from the fish-catch monitoring. It seems that the fish-catch monitoring was the only appropriate method to monitor the long-term impact of the grouper stock enhancement activity in Indonesian waters, focusing on the coral reef habitat. However, more studies in higher quantities are needed in order to identify the real potential of grouper tags, and to use them in stock enhancement research.

7.3 Costs and benefits of stock enhancement and sea-ranching in Indonesia

The costs of grouper sea-ranching depend on the released grouper size and the survival of the fish, allowing comparative data of the potential benefits resulted from the two different strategies. Principally, the costs of stock enhancement and sea-ranching can be much lower than the costs involved in mariculture; this is because it does not need the costs of maintaining the grow-out facilities, maintenance, and food for the fish kept under mariculture conditions. The major costs for stock enhancement and sea-ranching are the purchase of the fish and the transportation cost to the release site. Based on the stock enhancement experiment, the price of 10 cm and 15 cm grouper were 10,000 IDR (0.7 €) and 25,000 (1.8 €) IDR per fish (1€ = 14,000 IDR), respectively. The costs of transportation and maintenance were 1,000 IDR (0.07 €) per fish. The total costs of the stock enhancement for 1000 grouper of 10 cm and 15 cm length were 11,000,000 IDR (785.7 €) and 26,000,000 IDR (1857.1 €), respectively (Table 7.1).

Estimating the economic benefits of stock enhancement is not trivial (Uwate and Shams 1997). Hence, several assumptions need to be addressed to calculate the economic benefits of *E. fuscoguttatus* stock enhancement and sea-ranching. These are the natural mortality (m = 0.445 and 0.460 per year, see Table 7.1), growth parameters of grouper (L_{inf} = 97.48 cm, k = 0.27, t_0 = -0.44), and length weight relationship (a = 0.008, b = 3.16). All parameters were obtained from the research conducted by Kurnia (2012), who studied *E. fuscoguttatus* in the Thousand Islands (Pulau Seribu) located in the North of Java Island, about 420 km West to Karimunjawa Islands. In addition, the value for the natural mortality estimated from the length of *E. fuscoguttatus* was provided by Sattar et al. (2008). Based on the equation ($M = 25L^{-0.5} + 0.15$, L = length in cm) (see Sattar et al. 2008), the natural mortality of 10 and 15 cm *E. fuscoguttatus* is 0.213 and 0.202 respectively, under the assumption of zero fishing mortality and the catch of the fish at a total weight of 0.57 kg. According to the growth parameters, 10 cm and 15 cm grouper can reach 0.57 kg after 1.2 and 1 year respectively, by using the equation $L(t) = L_{inf}$ (1 - EXP(-k*(t- t_0)) and $W = a\ L^b$ (see above). The equation $N_t = N_0$ EXP (-z.t) was used to estimate the survival fish, where N_t is the number of fish after t time, N_0 is the number of fish at initiation time of stock enhancement (i.e. 1000 fish), Z is the total mortality, and in this calculation, Z is equal to the fishing mortality M.

The natural mortality from Kurnia (2012) was taken to estimate the survival of 1000 groupers after the release at 10 cm (around 590 fish will have survived after 1.2 years) and at 15 cm (640 fish will probably have survived after 1 year, see Table 7.1). Using the different natural mortality from Sattar et al. (2008) and the above equation (M=0.21 and 0.20, see above), from 1000 groupers released at 10 cm, a total of around 770 fish are most likely survive after 1.2 years, while around 820 individuals will have survived from 1000 specimens released at a size of 15 cm after 1 year; this is under the absence of fishing mortality. These natural mortalities derived from the equation are most likely to be realistic for natural free living groupers since they were calculated from the length of *E. fuscoguttatus.* However, it must be considered that Sattar et al. (2008) used the length equation and the resulting values that were more precise, compared with Kurnia (2012). On the other hand, the natural mortality from Sattar et al. (2008) can be considered very low in which the survival of 770-820 fish from 1000 after 1.2 years is highly unlikely.

Table 7-1. The economic costs and benefits of sea-ranching in Karimunjawa Islands (inflation is not considered in the calculation).

No	Description	Note	Scenario 1		Scenario 2	
			Kurnia (2012)	**Sattar et al. (2008)**	**Kurnia (2012)**	**Sattar et al. (2008)**
1	Number of fish (initiated time)	N_0		1,000		1,000
2	Size (cm)			10		15
3	Price per fish (IDR)	P		10,000		25,000
4	Total price of fish at initiated time (IDR)	$TP = N_0*P$		10,000,000		25,000,000
5	Transportation and maintenance (IDR, per fish)	Tr		1,000		1,000
6	Total price of transportation per 1000 (IDR)	$TT = N_0*Tr$		1,000,000		1,000,000
7	Total cost (IDR, per 1000 fish)	TC = TP+TT		**11,000,000**		**26,000,000**
8	Natural mortality (M)	M	0.460	0.213	0.445	0.202
9	Fishing mortality (F)	F	0.00	0.00	0.00	0.00
10	Total mortality (Z)	Z = M+F	0.46	0.21	0.45	0.20
11	Time to captured size (year)	t	1.20	1.20	1.00	1.00
12	Number of fish at captured size (0.57 kg) (ind)	Nt = No*EXP(-Z*t)	576	774	641	817
13	Total Weight (kg)	TW = Nt*0.57	328	441	365	466
14	Price at captured size (IDR/kg)	Pt	120,000	120,000	120,000	120,000
15	Total price at captured size (IDR)	TR = TW*Pt	**39,384,519**	**52,956,889**	**43,832,380**	**55,909,429**
16	Benefit (IDR)	R = TR – TC	28,384,519	41,956,889	17,832,380	29,909,429
17	Benefit per year (IDR)	Ry = R/t	**23,653,766**	**34,964,074**	**17,832,380**	**29,909,429**
18	Benefit per year (€)	Ry = R/t	**1690**	**2497**	**1274**	**2136**

Based on the above calculation, the stock enhancement or sea-ranching of 10 cm and 15 cm individuals can theoretically produce around 330 and 370 kg of grouper respectively, with stocking of 1000 individuals each. The theoretical benefit of the stock enhancement or sea-ranching activity with 10 and 15 cm sized grouper is around 28 million IDR (2027 €) and 18 million IDR (1274 €), or 24 million IDR (1690 €) and 18 million IDR (1274 €) per year, respectively (Table 7-1). However, this theoretical benefit as derived from the calculation is not the true benefit for the grouper fishermen or sea-ranching institution, because not all fish, resulting from the stock enhancement or sea-ranching program, are necessarily caught by the fishermen or sea-ranching institution. The benefit in this calculation is only the theoretical value of the fish that is produced through the program. Although the calculated benefit of the stock enhancement with 10 cm groupers is higher than the benefit of 15 cm sized fish, the possibility to harvest the benefit from the release of 10 cm grouper is much lower, due to the low adaptation and presumably high mortality of the released 10 cm *E. fuscoguttatus* compared with those from the natural population under presence of predators. So far, no elaboration of the impact of the stock enhancement with 10 cm (or less) groupers from the experiment and from the governmental project do exist.

As a result of these investigations and based on the cost and benefit calculations with 37 % less theoretical outcome for the 15 cm fish, a 20 % better survival of 15 cm fish would already give advantage to a larger size grouper release (if 1 instead of 5 fish from 10 cm fish are eaten by predators, a most likely scenario, see Figure 7-3). According to the observation in the reef where the 10 cm fish fell easy prey to other groupers (Yulianto et al. 2015c), the real mortality seems to be much higher. Consequently, the better option for stock enhancement and sea-ranching of *E. fuscoguttatus* in Indonesia is the release 15 cm sized fish. Although the release of 15 cm *E. fuscoguttatus* is more expensive and produces lower economic benefit, the likelihood of falling prey is much lower impact.

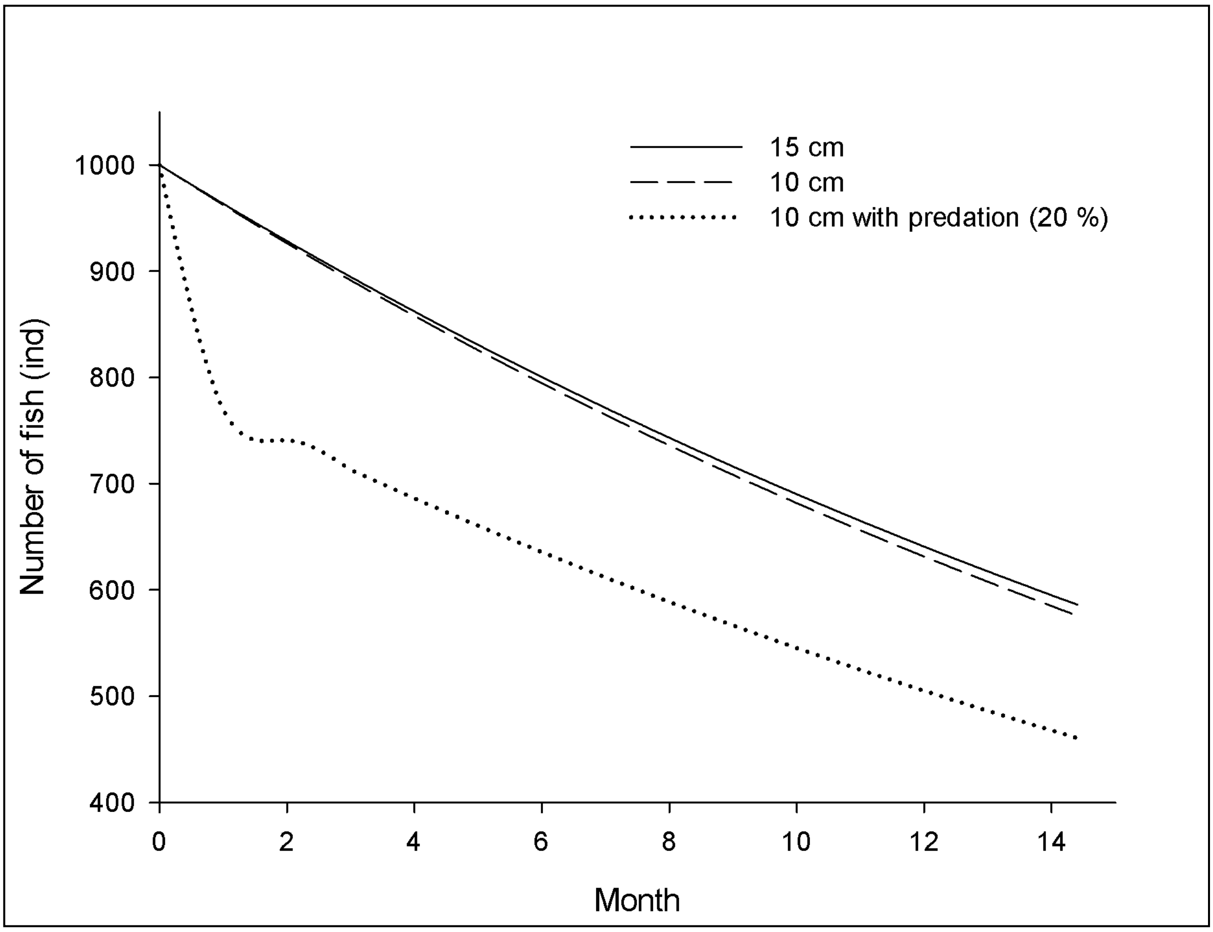

Figure 7-3. Estimated numbers of fish that are calculated from fish population model for 15 cm, 10 cm, and 10 cm with predation.

Although the impact of stock enhancement could not be verified through the experiment, several studies already demonstrated that besides the economic benefits, stock enhancement also has additional advantages. Stock enhancement activities support aquaculture through the production of juveniles, strengthen fisheries management, promote monitoring programmes and increase community support and awareness (Leber et al.2012, Lorenzen et al. 2010). Tourism activities are positively impacted by grouper stock enhancement (Leber et al. 2012, Lorenzen et al. 2010), such as recreational fishing and diving. Grouper is one of the favourite reef fish for recreational fishing in Indonesia (IFF 2014). Recreational diving as one of the favourite tourism activities in Indonesia is also potentially impacted by grouper stock enhancement, because the divers usually want to dive at the sites with high fish abundance. Through the combination of stock enhancement in marine protected areas and at remote islands where fishing pressure is lower, fish migration of the released animals is minimalized; recreational activities are relevant to grouper stock enhancement related to socio-economic activities. Another important factor of stock enhancement is the ecological benefit at the release site. If it is successful, stock enhancement raises yield, recovers the depleted stock, protects and conserves the endangered species, and provides knowledge on the ecology, life history and environment situation of important marine species (Lorenzen et al. 2010, Leber et al. 2012). However, stock enhancement might also influence the wild stocks, its population genetics, and habitat if this activity is conducted without scientific knowledge or without applying the best possible practice and approach (Blankenship and Leber 1995, Kanaiwa and Harada 2002, Leber et al. 2012). Consequently, future studies on the possible impact and limitations of fish stock enhancement programmes in tropical coral reef habitats are needed.

8. Outlook

It is important to manage and maintain grouper populations in Indonesia, due to the high economic value and increasing demand. However, resulting from constantly increasing fishing effort to catch grouper, some species have been heavily exploited, such as *Epinephelus fuscoguttatus*, *Plectropomus oligacanthus*, and *Plectropomus areolatus*. Without significant effort to manage and maintain the different grouper populations, the number of heavily exploited species will still increase some grouper species become endangered, and the sustainability of grouper fisheries is under threat.

Table 8-1. Problems and possible solutions for stock enhancement and sea-ranching programmes in Indonesia

Problem	Description	Solution
Ecology	Predation	Produce "educated" small size grouper that are ready for the release and adapted to the natural environment
	Population genetics	Selection of different grouper juveniles to prevent impact on natural stocks
	Species introduction that can harm the natural population	Avoid stock enhancement with species that potentially harm the natural population. These species should be listed as prohibited species for stock enhancement
	Parasite transmission	Investigate the best management practice in mariculture to reduce unwanted parasite transmission and parasite outbreaks
Social	Lack of capacity and knowledge of communities concerning stock enhancement and sea-ranching produces negatively impact these activities	Investigate community perception and knowledge on stock enhancement and sea-ranching activities, supporting community involvement and participation
Management	Lack of understanding the impact of stock enhancement and sea-ranching	Develop optimal monitoring and evaluation to understand the impact of stock enhancement and sea-ranching
	Disharmony of stock enhancement and sea-ranching to fisheries management	Monitor the contribution of stock enhancement to the improvement of grouper fisheries management

Stock enhancement and sea-ranching can be used as complementary management tool to the existing grouper fisheries management in Indonesia, such as fishing gear regulation and the declaration of marine protected areas. Through stock enhancement and sea-ranching programs, fishermen, the private sector, and the government can increase the grouper production to match the increasing demand, with little or without adverse impact to the natural grouper populations and habitats. However, due to limited knowledge and research activities of grouper stock enhancement, a number of weaknesses became apparent during the governmental stock enhancement project in 2011.

Several investigations are needed in order to consequently implement stock enhancement programmes as a new tool for grouper fisheries management in future. Based on the lessons learned from stock enhancement implementation in the USA, it took two decades to develop a staunch stock enhancement methodology, which maximized the advantages, reliably reduced unwanted effects on the fish stock, and scaled up the results of the research to a larger scale (Leber et al. 2012). Fishermen should also be considered and involved in the stock enhancement research and implementation, because they are not only recipients but also drivers (Garaway et al. 2006). The research from the USA and other countries concerning stock enhancement activities provides references to further development of the best methodology for grouper stock enhancement in Indonesia. Based on these lessons that have been learned and the results of the presented research, priorities for the best grouper stock enhancement and sea-ranching practices are:

a. to produce “educated” small size grouper (fingerlings) that are ready for release and adapted to the natural environment conditions, especially predator avoidance
b. to address the negative impact of stock enhancement (see Table 8-1), such as parasite transmission, the introduction of potentially harmful species, natural grouper population genetics and other ecological effects
c. to take the social impact of stock enhancement into account
d. to adopt the best possible practices to monitor the impact of grouper stock enhancement
e. to closely monitor the contribution of stock enhancement to the improvement of grouper fisheries management

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Hiermit erkläre ich, dass ich diese Arbeit selbstständig verfasst und keine anderen als die dabei angegebenen Hilfsmittel benutzt habe.

Rostock 30.10.2015, Irfan Yulianto____________________

Aus der Professur für Aquakultur und Sea-Ranching
der Agrar- und Umweltwissenschaftlichen Fakultät

Thesen der Dissertation

Benefits and Risks of Grouper Sea-Ranching in Karimunjawa National Park, Indonesia

zur
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Doktor der Agrarwissenschaften
(doctor agriculturae (Dr. agr.))

an der Agrar- und Umweltwissenschaftlichen Fakultät
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vorgelegt von
M.Sc. Irfan Yulianto
Indonesien

Rostock, den 30.10.2015

Gutachter: Prof. Harry W. Palm, Professur für Aquakultur und Sea-Ranching, Universität Rostock
Prof. Cornelius Hammer, Institut für Ostseefischerei
Dr. Budy Wiryawan, Marine Fisheries, Bogor Agricultural University

I Rational and objectives of the research

Groupers play a major economic and ecological role in coral reef habitats. For this reason it is very important to study groupers more deeply. In the past, the high economic value of groupers caused fishermen to increase their fishing effort, and as a consequence groupers are often heavily exploited. Still fishermen exert high fishing effort due to the increasing of grouper demand. Several solutions have been suggested and implemented to solve this problem such as protection and regulation of overfished grouper species, the establishment of marine protected areas, and stock enhancement as a methodology to increase depleted stocks.

The overall objective of this study was to examine the potential and possible effects of grouper stock enhancement activities in Indonesia. Stock enhancement is a relatively new approach in fisheries management and needs further improvement especially on relation with the applied methods, techniques and also in view of quantifying the resources. As a prerequisite to study the potential effects of stock enhancement, it is important to understand the grouper populations in the region of interest and the stock size influencing factors. Furthermore, a standardised method to study groupers in their natural habitat, commonly known as the length estimation by underwater visual census, is also of major importance to determine actual grouper population sizes. The research was conducted in Karimunjawa Islands, Indonesia, which has been established as a national park since 1999; therefore, it is important to include a study of the established Karimunjawa National Park management strategy. There are four specific tasks in order to meet the overall objective:

1. To describe the management strategy in Karimunjawa National Park in order to protect the natural marine resources
2. To quantify the bias of fish length measurements under water and to enhance the current methodology to estimate the reef fish biomass in the natural habitat
3. To analyse groupers stock sizes in the Karimunjawa islands between 2005 and 2012, based on underwater visual census and fish-landing monitoring
4. To examine the impact of grouper stock enhancement activity, concerning the potentials and risks involved

To address the objectives, a fish length estimate underwater study, grouper stock assessment from the existing monitoring and catch recorded data, fingerling grouper release experiments and monitoring the impact of the released fish were conducted. The monitoring consisted of underwater and fish-catch monitoring as well as parasite investigations.

II Main research results

- Marine protected area policies and regulations can improve the social well-being and political power of fishing communities, particularly when appropriate economic, legal and participatory incentives are provided.
- The diver can improve the accuracy and precision of the estimate of fish length by training and calibration training relatively quickly, indicating that fish length estimate underwater training is a useful method. The underwater visual census becomes a useful and reliable method to assess reef fish biomass.
- The installation of marine protected areas alone, as exemplified by the installation of three core zones in Karimunjawa National Park, is not sufficient to protect natural groupers populations, requiring also fishing-gear regulation and community support.
- The greatest peril for the released grouper of 10 cm length in grouper stock enhancement was falling immediately prey to predators in the reef habitat, even though enough space to hide was available at the release site, since groupers of this particular size class were not trained to survive under field conditions. However, grouper of 15 cm are well capable for seeking shelter and avoiding predators.
- The feeding strategy and the stocking density of fish in the cages significantly affect the composition of the grouper's parasite fauna. The natural fish feed in grouper mariculture opens a new route of parasite dispersal, causing unpredictable parasite infections, parasite spread and disease outbreaks.

III Conclusion and Outlook

- The Karimunjawa National Park authority management over a five year period from 2005 to 2010 has improved the community support for some fishing control, promoted the recovery of coral reef habitats through restrictions on destructive fishing practices and improved the community involvement in MPA management.
- Monitoring programs have demonstrated some ecological improvements and reductions in destructive fishing in the park over the five year period.
- The diver can improve the accuracy and precision of the estimate by training and calibration training relatively quickly, indicating that this is a useful method.
- The performance in underwater visual census (UVC) can be reliably tested and improved, and it is suggested that it is substantial to apply a useful and reliable method for future assessments of the coral reef fish biomass.

- The installation of marine protected areas alone, as exemplified by the installation of three core zones in Karimunjawa National Park, is not sufficient to protect the natural grouper populations.
- Fishing-gear regulation and community support are required; there is enough evidence that the fishermen's 2011 agreement to self-regulate the fishing gear is achieving its purposes.
- The agreement to regulate the speargun fishery and the decreasing fishing pressure of illegal fishing activities, which were also affected by community support in the national park, promoted a significant increase in groupers mean biomass and stock size in 2012.
- The impact of stock enhancement that used 10 cm (or less) of grouper from our experiment and from government project could not be verified.
- It was found that the greatest peril for the released grouper of 10 cm length was falling immediately prey to predators in the reef habitat, even though enough space to hide was available at the release site.
- Cultured grouper of 15 cm seemed well capable of seeking shelter and avoiding predators; this leads to the clear recommendation that released groupers should have a size of at least 15 cm before releasing them in stock enhancement programmes in coral reef habitats.
- The release of 15 cm *E. fuscoguttatus* is more expensive and produces lower direct benefits through higher costs involved and lower released numbers, the uncertainty of a significant fish loss through predation is much lower.
- No macro-parasites could be observed, limiting the risk of spreading parasites and diseases within the Indonesian archipelago by releasing cultured fingerlings, however, many parasites of *E. fuscoguttatus* are widespread and can infect different grouper species.
- The parasite infection can cause parasite diseases and create constrains to the grouper mariculture intensification program which is the main program of Indonesian Government to increase grouper production in order to meet the increased grouper demand.
- It is strongly recommended to search for alternative feeding strategies and management techniques in the grouper mariculture that prevent parasite spreads and outbreaks.

- In the future, systematic research on a broad scale should be conducted if stock enhancement and sea-ranching stand a chance to be implemented and used as a regular tool for grouper fisheries management in Indonesia.
- Based on and the results of the presented research and lessons that have been learned, priorities for the best grouper stock enhancement and sea-ranching practices are:
    a) to produce “educated” small size grouper (fingerlings) that are ready for release and adapted to the natural environment conditions, especially predator avoidance
    b) to address the negative impact of stock enhancement, such as parasite transmission, the introduction of potentially harmful species, natural grouper population genetics and other ecological effects
    c) to take the social impact of stock enhancement into account
    d) to adopt the best possible practices to monitor the impact of grouper stock enhancement
    e) to closely monitor the contribution of stock enhancement to the improvement of grouper fisheries management

Curriculum Vitae

Personal Information

Name	: Irfan Yulianto
Place/date of birth	: Jember, Indonesia, 04.08.1978
Nationality	: Indonesian
Marital status	: Married with one daughter
Address	: St-Georg-Str. 104-108, 18055 Rostock, Germany
	: Blok F6/18 Taman Sari Persada, Bogor, Indonesien
Email Address	: irfan.yulianto@uni-rostock.de irfanyulianto@yahoo.com

Formal Education

Year	School
2012 – 2015	Dr. agr. in Aquaculture and Sea-Ranching, Rostock University
2008 – 2010	M.Sc. in Fisheries, Bogor Agricultural University
1996 – 2001	B.Sc. in Marine Sciences, Bogor Agricultural University
1993 – 1996	SMAN 1 Kalisat Jember (Senior High School)

Work Experienced

Year	Position
2009 – 2012	: Department of Marine Fisheries, Bogor Agricultural University (IPB)
2006 – 2012	: MPA Planner, Wildlife Conservation Society
2005 – 2006	: Project Coordinator, Sebesi Island Management Project (Telapak).
2003 – 2004	: Marine Conservation Program Officer, The Nature Conservancy
2002 – 2002	: Extension Officer, Coastal Resources Management Project - USAID.
2001 – 2001	: Internship Coastal Resources Management Project - USAID.
1998 – 2001	: Assistant Lecturer, Faculty of Fisheries and Marine Sciences, IPB

Workshop and Seminar

Year	Seminar/Workshop	Place	Detail
2014	Doktorandentag der Agrar-Umwelt. Fakultät	Rostock, Germany	Presenter
2013	International conference of marine sciences	Bogor, Indonesia	Presenter
2011	4th Capture fisheries conference	Bogor, Indonesia	Presenter
2010	7th Coastal zone national conference	Ambon, Indonesia	Presenter
2010	Small island and coral reef management	Ambon, Indonesia	Presenter
2010	Asia pacific coral reef symposium	Phuket, Thailand	Presenter
2009	International marine conservation congress	Virginia, USA	Presenter
2009	Coral reef management on coral triangle	Jakarta, Indonesia	Presenter
2008	Coral triangle MPA learning workshop	Taygatay, Philippine	Presenter

Awards and Fellowships

Year	Award/Fellowship
2012 - 2015	: PhD Scholarship, Indonesian Germany Scholarship Program - DAAD
2010	: The best master student, IPB
2005 - 2006	: Small Grant Award, Global Greengrant Funds
2005	: Rufford Small Grant Award
1997 - 2001	: Bukoppin and Supersemar Scholarship for bachelor program, IPB

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