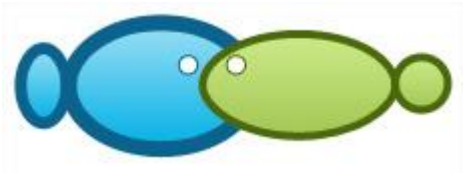

The effects of monoculture or polyculture of tiger grouper (*Epinephelus fuscoguttatus*) and rabbitfish (*Siganus canaliculatus*) on the growth performance of tiger grouper in floating net cage

Carolus P. Paruntu, Suria Darwisito, Antonius P. Rumengan, Hengky J. Sinjal

Faculty of Fisheries and Marine Science, Sam Ratulangi University, Manado 95115, Indonesia. Corresponding author: C. P. Paruntu, carolusparuntu@yahoo.com

Abstract. The aim of this study was to investigate the effects of monoculture or polyculture of tiger grouper (*Epinephelus fuscoguttatus*) and rabbitfish (*Siganus canaliculatus*) on the growth performance of tiger grouper in floating net cage (called *keramba jaring apung* (KJA) in Indonesia). Polyculture research of tiger grouper and rabbitfish, and monoculture of tiger grouper in floating net cage were conducted at South Motandoi Village beach in the Gulf of Tomini, South Bolaang Mongondow Regency, North Sulawesi, Indonesia. Ninety three tiger groupers with an initial average body weight of 72.58±21.17 g/fish and one hundred and eight rabbit fishes with an initial average body weight of 20.36±8.79 g/fish were used on polyculture, whereas ninety three tiger groupers with an initial average body weight of 73.01±26.66 g/fish were used on monoculture. The number of treatments of the research were 2 (*i.e.* tiger groupers were cultured in KJA polyculture (P) and KJA monoculture (M) systems) with three replications. The tiger groupers were hand fed with 10-15% fresh trash fish originated from the anchovies (*Stolephorus* spp.), and rabbitfishes were fed with 5-10% goldfish pellet diet. Test fishes were fed two times a day, which were around 08.00-10.00 am., and 04.00-06.00 pm. 6 floating cages made of polyethylene mesh sized 1 inch were used, each measuring 2x2x2 m and filled with fish density of 5-6 individuals/m^3. The results show that the daily growth rates of tiger grouper and rabbitfish on polyculture are 1.39% and 1.25% of body weight per day respectively, while the growth rate of tiger grouper on monoculture is 0.89% of body weight per day, respectively. Feed conversion ratios of tiger grouper and rabbitfish on polyculture were 6.20 and 4.10, while tiger grouper on monoculture was 6.10, respectively. The mortality rates of fishes both on polyculture and monoculture systems during rearing period were 0%. Tiger groupers cultured with rabbitfishes on polyculture (with the final average body weight of 212.74±68.64 g/fish) grows faster than tiger groupers cultured on monoculture (with the final average body weight of 140±41.19 g/fish).
Key Words: Floating net cage, monoculture, polyculture, tiger grouper, rabbitfish.

Introduction. The development of marine aquaculture or mariculture activities has grown very rapidly in several countries, as well as in Indonesia. Mariculture has become an important industry in the world along with the high demand for marine fishery products due to the increase of human population (Holmer et al 2002). Mariculture is one of the efforts to maximize coastal waters through the culture of fish, shellfish, seaweed, or other marine biota, which has important economic value. In line with economic growth and improving human living standards, especially in big cities, the desire to eat high-quality fresh seafood also increases. This can only be obtained from the cultivation, where the fish can be marketed alive. Fishes that have been successfully cultured and quite popular and have high market prices are groupers and rabbitfishes (Philip 1986). The use of floating net cages for marine aquaculture is one of the most productive systems for intensive cultivation (Teng & Chua 1980; Outtara et al 2003).

Groupers (*Epinephelus* spp.) belong to the *Serranidae* family. Groupers live in coastal areas, coral and deep sea to a depth of 60 m, leading a solitary life and in nature they prey fish and crustaceans (Nurdalila et al 2015). Groupers in nature are often found sheltering among coral reefs, or other submerged objects and ambush prey from their

hiding positions (Teng & Chua 1979). Groupers are an important marine fish in the marine culture industry since they are easily bred in captivity. Groupers are highly prized and sought after since they have a higher market value compared to other marine fishes (James et al 1999). The fish is widely distributed and can be found in the Atlantic, Mediterranean and Indo-Pacific region, including the Red Sea (Hseu et al 2007). Grouper farming appears to have great promise for commercialization, and coastal cage culture has the potential for sustainable development (Nurdalila et al 2015). The tiger grouper, *Epinephelus fuscoguttatus* (Forsskal, 1775) is one of the important fishery commodities in Asian countries. It is very popular for seafood and is cultured intensive and extensively in Malaysia, Indonesia and Hong Kong (Teng et al 1978; Liu & Mitcheson 2008; Sugama et al 2008; Muhammadar et al 2012).

Rabbitfishes (*Siganus* spp.) belong to the *Siganidae* family. The siganids are herbivourous marine fishes which inhibit rocky and weedy areas of the Indo-Pacific area (Al-Abdessalaam 1995; MAF 2003). Naturally the fish browse on fleshy green algae and benthic plants, but also accept other types of food provided (Suardi et al 2016). Both the juveniles and adults are primarily diurnal feeders, feeding almost continuously during the daytime (Armando et al 1999). In a preliminary study of Paruntu & Rompas (1990), the authors stated that rabbitfishes bred in floating net cage can take advantages of the moss or vegetation that stuck in the net as food. Rabbitfishes are clustered, so they can be cultured in confined places with high density of stocking (Lam 1974). The fact that the fish possess most of the desirable characteristics for aquaculture has led to the use of several species to have been tried in many countries for this purpose (Tacon et al 1990; Yousif et al 1996). The white-spotted rabbitfish, *Siganus canaliculatus* (Park 1797) is a common herbivorous fish species of the *Siganidae* family, widely distributed in the Indo-Pacific region from the Arabian Gulf to the Indo-Malay region, Western Australia and North to Hong Kong and Taiwan and can also be found in the Eastern Mediterranean (Randall 1995; Al-Marzouqi 2013; Suardi 2016). *S. canaliculatus* is well distributed in coastal waters within depths less than 40 m (Woodland 1984; Al-Qishawe et al 2014). Rabbitfishes in Indonesia are broadly spread but the distribution of these species is very limited (Sewajo et al 1981). Siganids are generally regarded as good food fishes in spite of their relatively small size. Some species have been cultured because of their herbivorous food habits, rapid growth and economic value. Among other species *S. canaliculatus* is a commercially important species (Jaikumar et al 2011).

Based on the behavior of groupers and rabbitfishes in nature and the potential of both types of fishes in the development of marine aquaculture industry, and which have important economic values, the two types of fishes can provide the possibility to be maintained together with polyculture techniques in floating net cages but also providing effect to the growth performance. The aim of this study is to investigate the effects of monoculture or polyculture of tiger grouper (*Epinephelus fuscoguttatus*) and rabbitfish (*Siganus canaliculatus*) on the growth performance of tiger grouper in floating net cage.

Material and Method. The research was conducted in the Gulf of Tomini waters, South Motandoi Village beach, East Pinolosian District, South Bolaang Mongondow Regency, North Sulawesi Province, Indonesia (Figure 1) for 70 days of rearing period (April-July 2017). Test fishes were obtained from fish farmers in local floating net cages. Tiger groupers and rabbit fishes were cultured in floating net cages in polyculture and monoculture systems. Floating net cages are built with rafts made of wooden beams, wood rep, boards, while buoys are made of styrofoam. Net cages consist of 6 plots and each plot is equipped with a net cage measuring 2 x 2 x 2 meters, with a submerged volume of approximate 6 m^3. Floating net cages are made of polyethylene with mesh size of 1 inch. There were 6 floating net cages used in this experiment (Figure 2). The number of treatments of the research was 2 (*i.e.*, tiger groupers that were cultured in KJA polyculture (P) and KJA monoculture (M) systems) with three replications. In KJA polyculture (P), the tiger grouper *E. fuscoguttatus* was cultured with rabbitfish *S. canaliculatus* while in KJA monoculture (M), only the tiger grouper was cultured. Ninety three tiger groupers with an initial average body weight of 72.58±21.17 g/fish and one

hundred and eight rabbitfishes with an initial average body weight of 20.36±8.79 g/fish were used in KJA polyculture, while ninety three tiger groupers with an initial average body weight of 73.01±26.66 g/fish were used in KJA monoculture. Fish densities in the floating net cages ranged from 5-6 individuals/m^3 (Table 1).

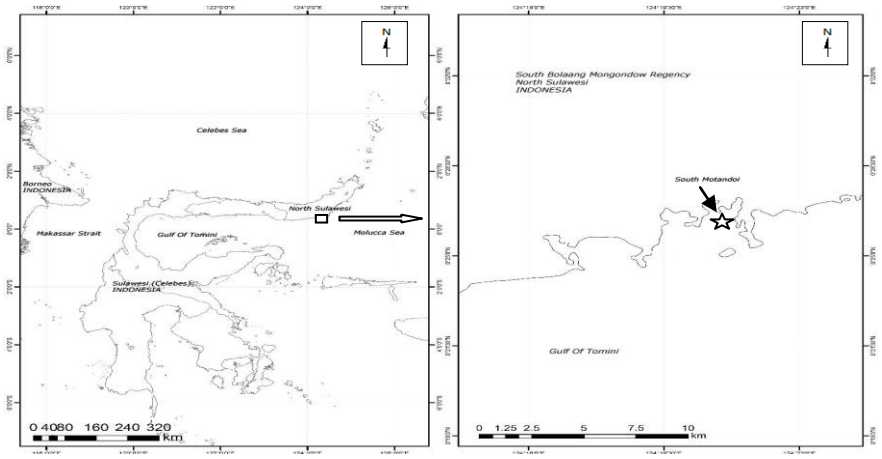

Figure 1. The location of research at South Motandoi Village beach in the Gulf of Tomini, South Bolaang Mongondow Regency, North Sulawesi, Indonesia.

Figure 2. Construction of floating net cages in the study area.

The tiger groupers were hand fed with 10-15% (of the total body weight) fresh anchovies (*Stolephorus* spp.) trash fish. Chemical analyses of the trash fish were made in Research Center for Industrial Standardization of Manado, Ministry of Industry Republic of Indonesia (the proximate test result, 04 October 2017): 73.64% water, 2.44% ash, 1.91% fat, 0.01% crude fiber, 19.85% protein, and 2.16% carbohydrates), while the rabbitfishes were fed with 5-10% (of the total body weight) goldfish pellet (commercial comfeed ISO 9001:2008 (Indonesia) sinking feed: 12% water, 13% ash, 5% fat, 5.5% crude fiber, 25% protein, and 2.16% carbohydrates). Test fishes were fed two times a day, which were around 08:00-10:00 AM, and 04:00-06:00 PM. Feeding was done until the test fishes would not eat again. To avoid the loss of sinking feed, two 40 x 40 cm feeding trays were hung in the water column about 1 m above each of the cage bottom. Each feeding tray was checked for remaining feed prior to the subsequent feed ration. Observation of the daily growth rate of test fishes was done by weighing the fishes and the length of the fish body was measured from the tip of the jaw to the tip of the caudal fin as a total length by using an ordinary ruler with a level of accuracy of 1 mm, entirely every two weeks.

The water quality parameters (water temperature (ºC), salinity (ppt), brightness (m), dissolved oxygen (ml/l), pH, depth (m), and current velocity (m/s)) were measured once every two weeks inside the cage at the time of collecting data of fishes growth.

Temperature, pH, dissolved oxygen, salinity, brightness, depth, and current velocity were measured using Horiba U-50 Series Water Quality Meters.

Statistical test. To examine whether there are significant differences in body length and weight of the fishes between tiger groupers that are cultured in KJA polyculture and KJA monoculture systems a t-*test* (Excel program) statistical test was performed. Mean values and standard deviation were generated for each body length and weight every observation time. Hypothesis (Ho) is accepted if $t_{count} < t_{table}$, while if $t_{count} > t_{table}$, then Ho is rejected (McDonald 2014).

Results and Discussion

Average body length and weight of tiger grouper and rabbitfish. The results of average body length (ABL) of tiger grouper show (Table 1; Figure 3) that during the 70th-day of rearing, tiger grouper on polyculture had longer ABL than tiger grouper on monoculture. The average body length comparison of tiger grouper on polyculture and those bred on monoculture on days 0, 14, 28, 42, 56 and 70 showed significant differences (P<0.001). The average body weight (ABW) of tiger grouper is shown in Table 1 and Figure 3. The results show that tiger grouper on polyculture during the 70 days of rearing has higher values of ABW than tiger grouper on monoculture (P<0.01), except on day 0 of rearing, when the value of ABW is not significantly different (P>0.05).

Table 1

Average body length and average body weight of test fishes that were measured once every two weeks in floating net cage with polyculture and monoculture systems

Observation time (day)	*Floating net cage system (treatment)*	*Species*	*Average body length (cm)*	*Statistics*	*Average body weight (g)*	*Statistics*
0	Monoculture	Tiger grouper	15.15±1.50 (3) ***	t-test: 3.65, P<0.001, df = 92	73.01±26.66 (3)	t-test: 0.13, P>0.05, df = 92
	Polyculture	Tiger grouper	14.44±1,40 (3) ***		72.58±21.17 (3)	
		Rabbit fish	10.39±1.75 (3)		20.36±8.79 (3)	
14	Monoculture	Tiger grouper	15.46±1.64 (3) *	t-test: -2.13, P<0.05, df = 92	80.45±29.58 (3) **	t-test: -2.91, P<0.01, df = 92
	Polyculture	Tiger grouper	16.22±2.95 (3) *		97.47±46.28 (3) **	
		Rabbit fish	11.53±2.92 (3)		33.61±24.12 (3)	
28	Monoculture	Tiger grouper	15.73±1.41 (3) ***	t-test: -7.29, P<0.001, df = 92	84.41±24.09 (3) ***	t-test: -6.82, P<0.001, df = 92
	Polyculture	Tiger grouper	18.25±2.78 (3) ***		125.54±56,02 (3) ***	
		Rabbit fish	12.42±1.82 (3)		34.26±21.79 (3)	
42	Monoculture	Tiger grouper	15.83±2.21 (3) ***	t-test: - 7,22, P<0.001, df = 92	86.72±32.06 (3) ***	t-test: -7.87, P<0.001, df = 92
	Polyculture	Tiger grouper	18.75±2.89 (3) ***		140.48±56.35 (3) ***	
		Rabbit fish	13.19±2.08 (3)		39.34±23.57 (3)	
56	Monoculture	Tiger grouper	17.48±1.38 (3) ***	t-test: -8,36, P< 0.001, df = 92	105.38±28.15 (3) ***	t-test: - 8.99, P<0.001, df = 92
	Polyculture	Tiger grouper	20.22±2.64 (3) ***		175.59±64,86 (3) ***	
		Rabbit fish	14.05±1.52 (3)		42.31±19.72 (3)	
70	Monoculture	Tiger grouper	18.62±1.80 (3) ***	t-test: -7.63, P<0.001, df = 92	140.00±41.19 (3) ***	t-test: -8.51, P<0.001, df = 92
	Polyculture	Tiger grouper	21.06±2.34 (3) ***		212.74±68.64 (3) ***	
		Rabbit fish	14.26±1.41 (3)		51.40±12.93 (3)	

The number in the parentheses represents the replications number of each treatment of the test fishes (i.e., KJA monoculture and KJA polyculture treatments). Thirty one tiger groupers of monoculture, and thirty one tiger groupers and thirty six rabbit fishes of polyculture were measured to calculate average values for each replication. Only tiger groupers of monoculture and polyculture were used for body growth comparison of the test fishes based on statistical test. Asterisks indicate that the values are significantly different from those at other floating net cage system (T test, *P<0.05, **P<0.01, ***P<0.001). Values are not significantly different at the 0.05 level and share a vertical line.

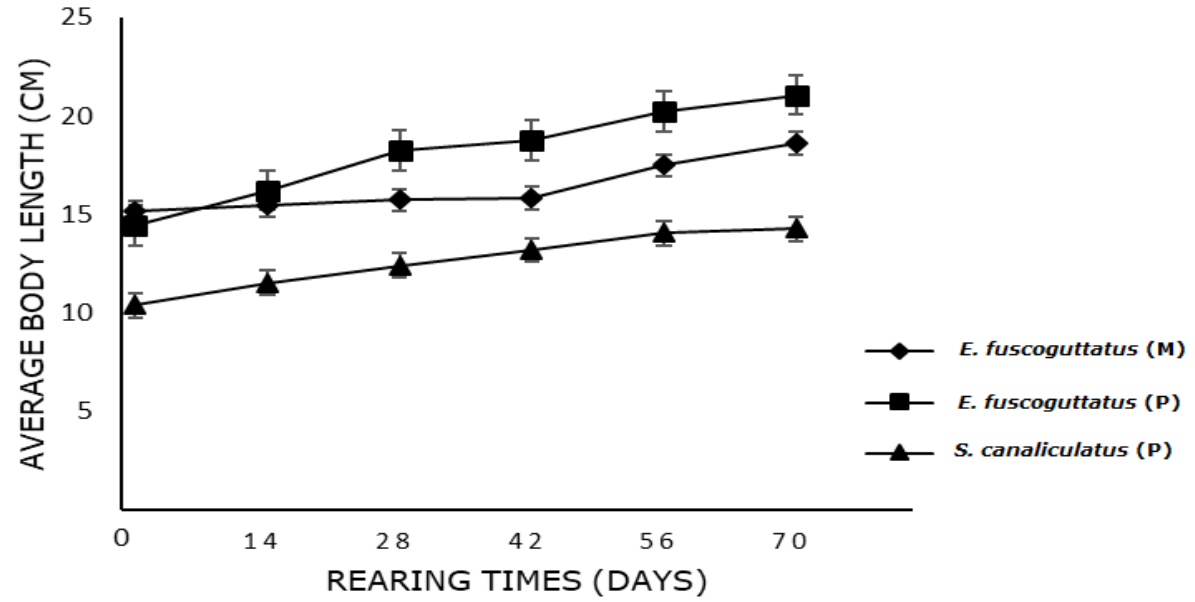

Figure 3. Average body length of tiger grouper (*E. fuscoguttatus*) and rabbitfish (*S. canaliculatus*) reared in floating net cage in polyculture (P) and monoculture (M) systems.

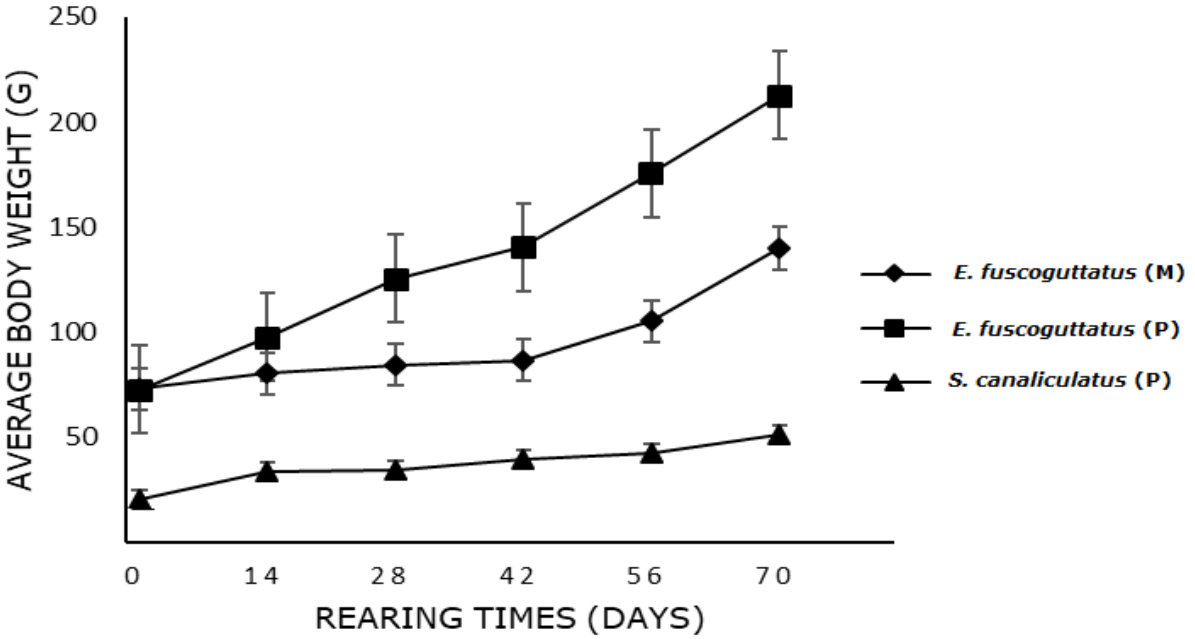

Figure 4. Average body weight of tiger grouper (*E. fuscoguttatus*) and rabbitfish (*S. canaliculatus*) reared in floating net cage in polyculture (P) and monoculture (M) systems.

Daily growth rate, food conversion ratio and mortality rate of tiger grouper and rabbitfish. The results of daily growth rates, feed conversion ratio and mortality rate of tiger grouper and rabbitfish are shown in Table 2. The tiger grouper on polyculture during 70-days of rearing has the bigger values of daily growth rate and feed conversion ratio than tiger grouper on monoculture. The data show that during the study period no fish died in both polyculture and monoculture systems in floating net cages.

Table 2

Data of growth rate, feed conversion ratio and mortality rates of test fishes on polyculture and monoculture systems in floating net cage

Growth parameters	*Treatments*		
	KJA polyculture		*KJA monoculture*
	Tiger grouper	*Rabbitfish*	*Tiger grouper*
Daily growth rate (%)	1.39	1.25	0.89
Food conversion ratio	6.20	4.10	6.10
Mortality rate (%)	0	0	0
Fish density (individuals/m^3)	5	6	5
Period of rearing (days)	70	70	70
Initial amount of fish (individuals)	93	108	93
Final amount of fish (individuals)	93	108	93
Initial average body length (cm)	14.44±1.40	10.39±1.75	15.15±1.50
Final average body length (cm)	21.06±2.34	14.26±1.41	18.62±1.80
Initial average body weight (g)	72.58±21.17	20.36±8.79	73.01±26.66
Total of initial body weight (g)	6750	2198.88	6789.93
Final average body weight (g)	212.74±68.64	51.40±12.93	140±41.19
Total of final body weight (g)	19877.82	5551.2	13020
Increasement of total body weight (g)	13127.82	3352.32	6230.07
Total of feeding food (g)	81392.48	13744.51	38003.43

Sea water quality. The results of seawater quality measurement during the research at KJA monoculture and KJA polyculture sites showed that temperature ranged from 29.94-30.20^{O}C, pH 7.2-8.1, dissolved oxygen (DO) 4.71-6.73 ppm, salinity 29.2-33.1‰, brightness 5.1-7.1 m, a depth of 7.4-8.9 m, and a current velocity of 15.2-31.1 cm/s (Table 3). The data of dissolved oxygen showed lower values at KJA monoculture site than KJA polyculture site (Table 3).

Table 3

The water quality parameters at KJA monoculture and KJA polyculture sites

Water quality parameters	*KJA monoculture site*	*KJA polyculture site*
Depth (m)	7.6-8.5	7.4-8.9
Temperature (ºC)	29.94-30.20	29.80-30.16
pH	7.2-8.0	7.4-8.1
Brightness (m)	5.1-6.5	5.5-7.1
Dissolved oxygen (ppm)	4.71-5.89	5.52-6.73
Current velocity (cm/s)	15.2-30.5	16.1-31.1
Salinity (‰)	29.2-32.3	29.5-33.1

Discussion. The results of this study indicate that tiger groupers cultured with rabbitfishes on polyculture grow faster than tiger groupers cultured on monoculture (Table 1 & 2; Figure 3 & 4). In a preliminary similar study of Paruntu & Rompas (1990) the authors showed that the daily growth rate of groupers (*E. tauvina)* on polyculture is greater than those on monoculture in floating net cages. Effendie (1978) stated that the growth of fish is influenced by genetic factors, behavior and feeding habits. Lilis (1988) stated that the behavior and feeding habit of fish are factors that affect growth. The difference in daily growth rates between the tiger grouper on polyculture and tiger grouper on monoculture in floating net cages are thought to be related to the behavior and feeding habit of groupers in nature. Groupers are often found sheltering among coral reefs or other submerged objects and ambush prey from their hiding positions (Teng & Chua 1979). Observation under KJA condition showed that the feeding habit of tiger grouper on monoculture was inhibited because there was no hiding place to shelter and ambush prey, whereas tiger grouper on polyculture used rabbitfish feeding place as a

hiding place to take shelter and catch prey like their feeding habits in nature. Furthermore, herbivorous rabbitfish on polyculture could utilize grass and moss attached to the floating net cage, so the cage condition was clean and water circulation in floating net cage was good, resulting in increased fish appetite and affected the growth of tiger grouper. In contrast, the cage condition on monoculture, without rabbitfish, looked very dirty, because of the accumulation of feed remains and metabolism results, resulting in the process of decomposition and causing unpleasant odors, which in turn would hamper the process of eating and affected the growth of tiger groupers. Slamet (1989) stated that if the water flow in the floating net cage is too small, the dissolved oxygen concentration will rapidly decline and this will further affect the growth of the fish. Furthermore, fouling on the net of the cage will rapidly take place during the rearing period, thus covering the net eye and inhibiting the water flow which eventually leads to accumulation of metabolic remnants in the net and increases dissolved oxygen demands. Behavior of rabbitfish that are always active to eat in KJA can also affect the appetite level of tiger grouper. Paruntu & Rompas (1990) have observed that grouper (*E. tauvina*) appetite level increased when cultured with rabbitfish in KJA. Fishes in floating net cages usually release energy in relatively large proportions to maintain its position in a floating net cage against continuous streams of water flowing through the net, as well as the result of penetration of sunlight that can increase the water temperature (Slamet 1989). Lilis (1988) stated that if hiding places are provided and fishes are hidden, some of the fish energy can be used for growth. The feeding place of rabbitfish was used as a hiding place for tiger grouper, while on monoculture there was no hiding place for tiger grouper. The same behavior has been observed in *E. tauvina* groupers in study of Paruntu & Rompas (1990). Differences in the growth rates of tiger grouper on polyculture and monoculture systems are assumed to relate with the hiding places. However, only parts of the tiger groupers utilized rabbitfish feeding place as a hiding place to take the shelter and catch prey and some of them were at the bottom of the cage or on the bottom side of the cage as they catch the prey.

The research results indicated that the feed conversion ratio of tiger groupers on polyculture is greater than that of tiger groupers on monoculture. The monoculture grouper used 6.1 grams of feed to increase in body weight with 1 gram, whereas the polycultured grouper used 6.2 grams of feed to increase with the same amount of weight. This may be related to the increased appetite and the digestibility value of tiger grouper on polyculture. Teng and Chua (1980) stated that the food conversion ratio to the culture of groupers in floating net cages is influenced by the quality of the aquatic environment. The quality of the aquatic environment in the KJA polyculture shows a better condition than the KJA monoculture, which is characterized by KJA polyculture having a cleaner net condition (due to the use of grass and mosses attached to floating net cage by the polycultured rabbitfish) and higher dissolved oxygen values than KJA monoculture. The better water quality in KJA polyculture may affect the increased appetite in the polyculture tiger grouper. Haryanto et al (2014) stated that the feed conversion ratio and feed efficiency is closely related to digestibility values that describe the percentage of nutrients that the fish body absorbs. The greater the digestibility value of a feed is, the more nutrients from feed are used for fish growth.

The data showed that during the study no fish dies in both polyculture and monoculture systems in floating net cages. Fish density influences the mortality rates of fish in floating net cages; some studies have found that fish mortality is higher in high fish densities (Teng & Chua 1979, 1980). Lilis (1988) stated that the optimal density of fish in floating net cage is 60 individuals/m^3. In this study the densities of fish for polyculture and monoculture systems are relatively very low, *i.e.* only 5-6 individuals/m^3.

Water quality affects the survival and fish growth, because water is a medium of transporting metabolites and oxygen (Boyd 2000). The results of seawater quality measurement during this research are within the non-hazardous range of fish life, as those are within the ranges recommended by Yokohawa (1982), Antoro et al (1999), Aslianti & Priyono (2009), and Anonimous (2004), except the dissolved oxygen values at KJA monoculture site were lower than the ranges recommended by them are present.

Conclusions. The rate of daily growth of tiger grouper cultured with rabbitfish in polyculture is faster than in monoculture system, the feed conversion ratio of tiger grouper on polyculture is higher than in monoculture, and no fish died during the research period. However, further research needs to be done to find out more about the value of tiger grouper feed conversion ratio that is relatively higher in polyculture than in monoculture. The research of tiger grouper bred in polyculture with rabbitfish in KJA is suggested to be a superior mariculture model to be economically, efficiently and effectively applied by the fish farmers in Indonesia in order to improve the economy.

Acknowledgements. The authors would thank to Government of Indonesia, Ministry of Research, Technology and Higher Education for the program and research grant of PUPT year of 2017, which has been awarded to the authors, and for government of South Bolaang Mongondow Regency for allow us to conduct the research on this area.

References

Al-Abdessalaam T. Z. S., 1995 Marine species of the Sultanate of Oman. An identification guide. Ministry of Agriculture and Fisheries, Sultanate of Oman, 412 p.

Al-Marzouqi A., 2013 Length based stock assessment of the white spotted rabbitfish, *Siganus canaliculatus* (Park, 1797) from the Arabian Sea of Oman. Thalassas: An International Journal of Marine Sciences 29(2):67-76.

Al-Qishawe M. M. S., Ali T. S., Abahussain A. A., 2014 Stock assessment of white spotted rabbitfish (*Siganus canaliculatus* Park, 1797) in Jubail marine wildlife sanctuary, Saudi Arabia. International Journal of Fisheries and Aquatic Studies 1(6):48-54.

Antoro S., Widiastuti E., Hartono P., 1999 Biology of tiger grouper in hatchery grouper technique (*Epinephelus fuscoguttatus*). Mariculture Center-Lampung. Bandar Lampung. 71 p. [In Indonesian].

Armando A. J., Afonso M., Luiz S., 1999 Some aspects of of the biology of three fish species from the seagrass beds at Inhaca Island, Mozambique. Cybium 23(4):369-376.

Aslianti T., Priyono A., 2009 Increased vitality and survival of grouper juvenile, *Epinephelus coioides* through diet enriched with vitamin C and calcium. Torani: Journal of Marine and Fisheries Sciences 19(1):74-81. [In Indonesian].

Boyd C. E., 2000 Calcium water quality in ponds for aquaculture. Department of Fisheries and Allied Aquacultures. Alabama Agriculture Experiment Station, Aubum University, 143 p.

Effendie I. M., 1978 Fisheries biology (Part I: Study Natural History). Faculty of Fisheries IPB, Bogor, 105 p.

Haryanto P., Pinandoyo, Ariyati R. W., 2014 The influence of different feeding dose on growth of juvenile tiger grouper (*Epinephelus fuscoguttatus*). Journal of Aquaculture Management and Technology 3:58-66.

Holmer M., Marba N., Terrados J., Duarte C. M., Fortes M. D., 2002 Impacts of milkfish (*Chanos chanos*) aquaculture on carbon and nutrient fluxes in the Bolinao Area, Philippines. Marine Pollution Bulletin 44(7):685-96.

Hseu J. R., Huang W. I., Yeong T. C., 2007 What causes cannibalization-associated suffocation in cultured brown-marbled grouper, *Epinephelus fuscoguttatus* (Forsskal, 1775)?. Aquaculture Research 38:1056-1060.

Jaikumar M., Kanagu L., Stella C., Gunalan B., 2011 Culturing a rabbitfish (*Siganus canalicullatus*) in cages: A study from Palk Bay, South East Coast of India. International Journal of Water Resources and Environmental Engineering 3(11):251-257.

James C. M., Al-Thobaiti S. A., Rasem B. M., Carlos M. H., 1999 Potential of grouper hybrid *Epinephelus fuscoguttatus* X *E. polyphekadion* for Aquaculture Naga. ICLARM Quarterly 22(1):19-23.

Lam T. J., 1974 Siganid, their biology and mariculture potential. Aquaculture 3:324-354.

Lilis, 1988 Aquaculture of marine fishes and plankton at Sub Research Institute for Coastal Aquaculture (SBPBP) Bojonegoro, Serang, West Java. Faculty of Fisheries IPB, Bogor, 56 p. [In Indonesian].
Liu M., Mitcheson Y. S. D., 2008 Grouper aquaculture in mainland China and Hong Kong. In: The aquaculture of groupers. Liao I. C., Leano E. M. (eds), pp. 111-142, Word Aquaculture Society, USA.
McDonald J. H., 2014 Handbook of biolological statistics. Third Edition. Sparky House Publishing, Baltimore, Maryland, 305 p.
Muhammadar A. A., Mazlan A. G., Samat, A., Asmawati M. S., 2012 Growth of tiger grouper (*Epinephelus fuscoguttatus*) juvenile from wild and hatchery at different type of feeds. Poster. Proceedings of The 2nd Annual International Conference Syiah Kuala University 2012 & The 8th IMT-GT Uninet Biosciences Conference Banda Aceh, 22-24 November 2012, (427).
Nurdalila A. A., Bunawan H., Kumar S. V., Rodrigues K. F., Baharum S.N., 2015 Homogeneous nature of Malaysian marine fish *Epinephelus fuscoguttatus* (*Perciformes; Serranidae*): Evidence based on molecular markers, morphology and fourier transform infrared analysis. International Journal of Molecular Sciences 16:14884-14900.
Outtara N. I., Teugels G. G., N'Douba V., Philippart J. C., 2003 Aquaculture potential of the black-chinned tilapia, *Sarotherodon melanotheron* (*Cichlidae*). Comparative study of the effect of stocking density on growth performance of landlockes and natural populations under cage culture conditions in Lake Ayame (Côte d'Ivoire). Aquaculture Research 34:1223-1229.
Parazo M. M., 1990 Effect of dietary protein and energy level on growth, protein utilization and carcass composition of rabbitfish, *Siganus guttatus*. Aquaculture 86:41-49.
Paruntu C. P., Rompas R. M., 1990 Polyculture of grouper (*Epinephelus tauvina*) and rabbitfish (*Siganus canaliculatus*) in floating net cage. Journal of the Faculty of Fisheries, Sam Ratulangi University I(2):34-43. [In Indonesian].
Philip T. I., 1986 Scientific report of mariculture research and development project (ATA-192) in Indonesia JICA, pp. 400-409. [In Indonesian].
Sewajo M., Burhanudin S., Djamali, Sianipar P., 1981 White spotted rabbit fish: biology, potential and management. LON-LIPI, 45 p. [In Indonesian].
Tacon A. G. J., Rausin N., Kadari M., Cornelis P., 1990 The food and feeding of of marine finfish in floating net cages at the National Seafarming Development Centre, Lampung, Indonesia: rabbitfish, *Siganus canaliculatus* (Park). Aquaculture and Fisheriesn Management 21:375-390.
Teng S. K., Chua T. E, 1979 Use of artificial hides to increase the stocking density and production of estuary grouper *Epinephelus salmoides*, reared in floating net-cages. Aquaculture 16(79):219-232.
Teng S. K., Chua T. E, 1980 Economic production of estuary grouper, *Epinephelus salmoides*: maxwell, reared in floating net-cages. Aquaculture 20:187-228.
Suardi Wiryawan B., Taurusman A. A., Santoso J., Riyanto M., 2016 Variations in size and catch distribution of white spotted rabbit fish (*Siganus canaliculatus*) on bio-FADs from spatially and temporary point of view, at Luwu District, South Sulawesi, Indonesia. AACL Bioflux 9(6):1220-1232.
Randall J. E., 1995 Coastal fishes of Oman. University of Hawaii Press, Honolulu, HI, 439 p.
Slamet, 1989 Biological aspects of groupers. Sub Research Institute for Coastal Aquaculture (SBPBP) Bojonegoro-Serang, 28 p. [In Indonesian].
Sugama K., 1983 The growth of Red Snapper, *Lutjanus altifrontalis* in floating net cage. Marine Fisheries Research Report, Jakarta (29):61-68. [In Indonesian].
Sugama K., Insan I., Koesshahrani I., 2008 Hatchery and growth-out technology of groupers in Indonesia. In: The aquaculture of groupers. Liau I. C., Leano E. M. (eds), 341 p., Word Aquaculture Society. USA.

Teng S. K., Chua T. E., 1979 Use of artificial hides to increase the stocking density and production of estuary grouper, *Epinephelus salmoides*, reared in floating net-cages. Aquaculture 16(79):219-232.
Teng S. K., Chua T. E., 1980 Economic production of estuary grouper, *Epinephelus salmoides*: maxwell, reared in floating net-cages. Aquaculture 20:187-228.
Teng S. K., Chua T. E., Lim P. E., 1978 Preliminary observation on the dietary protein requirement of estuary grouper, *Epinephelus salmoides:* maxwell, cultured in floating net cages. Aquaculture 15:257-271.
Woodland D. J., 1984 Family *Siganidae*. FAO sheets for Western Indian Ocean (Fishing Area 51), Vol. 4 (Looseleaf), FAO, Rome.
Yamaguchi M., 1978 Practical and culture method of Read Sea-Bream. Koseikoku. Japan, 301 p. [In Japanese].
Yokohama T., 1982 Water quality for coastal aquaculture. SCS/82/SBTC/ Lec 19 a. Thailand. 7 p.
Yousif O. M., Osman M. F., Anwahi A. A., Cherian T., 1996 Optimum protein-to-energy ratio for two size groups of rabbitfish, *Siganus canaliculatus* (Park). Aquaculture Nutrition 2:229-233.
*** MAF [Ministry of Agriculture and Fisheries], 2003 Fishes. United Arab Emirates. Cultural Foundation Publications, Abu Dhabi, 255 p.

Received: 26 January 2018. Accepted: 19 March 2018. Published online: 22 May 2018.
Authors:
Carolus Paulus Paruntu, Universitas Sam Ratulangi Manado, JL. Kampus Unsrat Bahu, Kleak, Malalayang, Kota Manado, 95114, Indonesia, e-mail: carolusparuntu@yahoo.com
Suria Darwisito, Universitas Sam Ratulangi Manado, JL. Kampus Unsrat Bahu, Kleak, Malalayang, Kota Manado, 95114, Indonesia, e-mail: darwisitosuria@gmail.com
Antonius Petrus Rumengan, Universitas Sam Ratulangi Manado, JL. Kampus Unsrat Bahu, Kleak, Malalayang, Kota
Manado, 95114, Indonesia, e-mail: antoniusrumengan@unsrat.ac.id
Hengky Julius Sinjal, Universitas Sam Ratulangi Manado, JL. Kampus Unsrat Bahu, Kleak, Malalayang, Kota Manado, 95114, Indonesia, e-mail: hengkysinjal@gmail.com

How to cite this article:
Paruntu C. P., Darwisito S., Rumengan A. P., Sinjal J. H., 2018 The effects of monoculture or polyculture of tiger grouper (*Epinephelus fuscoguttatus*) and rabbitfish (*Siganus canaliculatus*) on the growth performance of tiger grouper in floating net cage. AACL Bioflux 11(3):635-644.