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Fishing gear allocation and catch landing of purse seine in southern coast of Sulawesi, Indonesia

Eko Sri Wiyono[1,*], Mahiswara[2] and Hufiadi[2]

[1]Department of Fisheries Resources Utilization, Faculty of Fisheries and Marine Science, IPB University, Indonesia

[2]Research Institute for Marine Fisheries, Bogor, Indonesia

[*]Corresponding Author: eko-psp@apps.ipb.ac.id

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ABSTRACT

Various theories regarding the linkage of fish resources and human resources (fishermen) have been discussed and become alternatives in relation to fisheries management. One of the most important to be studied in studying human interrelationships and fish resources is the dynamics of fishing gear. The fishermen's decision to operate fishing gear is essentially a function of various factors, both internal and external. In order to describe the factors that influence fisherman behaviour in allocate fishing gear, we have studied the relationship of external factors to fishing gear allocation and the catch landing. On this occasion, we have studied the fishing gear allocation pattern and correlation of external factors (fishing ground, fishing seasons and their interaction) to purse seine allocation and their catch landing in Bone, South Sulawesi. The results of the study indicated that purse seine allocations were similarly between season but significantly different between fishing grounds. Meanwhile, the main catch landing relating to purse seine catches (scads and skipjack) were significantly different between seasons and fishing grounds partially. However, further analysis confirmed that interaction between the fishing ground and fishing season only affects skipjack but does not affect scads.

INTRODUCTION

Over the last decade, fishing management focused on fish biology (Myer and Cadigan, 1995; Tanaka, 2006; Watari *et al*., 2016) and paid scant attention to the fishing fleet, including fishing gear dynamics and fishers' behaviour (Hilborn 1985; Pet-Soede *et al*., 2001; Bene and Tewlik, 2001; Wiyono *et al*., 2006). As natural predators, fishermen develop and implement certain fishing strategies in response to constraints they encounter, and their intended objectives given their particular human, social, cultural and economic contexts (Hilborn and Walter, 1992; Pope, 2002; Maravelias, 2014).

It should be mentioned that fishermen consider both the spatial factor (where the fishing operation will be conducted) and the temporal factor (when is the preferred season to go fishing) in allocating fishing fleet. In response to the changes in catches and the economic conditions in the fisheries sector, fishermen are allocating or redistributing the gear (spatially or temporally), modifying gears, increasing technology and expanding their fishing grounds (Hilborn and Walter, 1992; Pet-Soede *et al*., 2001; Bene and Tewlik, 2001; Wiyono *et al*., 2006; Maravelias, 2014). In a single area, the allocation of gear is a determinant of cost among fishermen, information uncertainty, gear testing and the objective of fishing. Nevertheless, in multi areas or species, the allocation of gear is a determinant of uncertainty, cost in each area, cost of movement, preference of the fishermen, and the skills or knowledge of the fishermen (Hilborn and Walters, 1992).

In the case of tropical fisheries, the allocation of fishing gear is more complicated. The fisheries are characterised by great spatio-temporal variations, diversity of gears-target species, fishing activity scattered along coasts and also consist of increased uncertainty regarding catch landing (van Oostenbrugge, *et al*., 2001; 2002). Since the catch landings of fisheries in tropical fisheries comprise high uncertainty and the fleets in multispecies-multifleet interact with resources utilisation, the management of tropical coastal fisheries should consider the measurement of the fleet dynamics. This is because the study of fishing fleets dynamics could help generate information on the direction and magnitude of fishing effort dynamics. One of the central challenges to understanding the impact of fisheries on coastal ecosystems is the lack of fishing effort data (i.e., the number of boats, the amount of gear deployed or the frequency of fishing activities).

To provide the necessary knowledge-base for promoting sustainable and profitable utilisation of fish resources in tropical areas, especially in Indonesia it is essential to recognise the effects of external factors and their interaction in relation to fishing gear allocation. For this reason, the study was conducted in Bone, South Sulawesi Indonesia. Bone fishing port is one of the centres of the fisheries industry in South Sulawesi. The fishing gear operated by Bone fishermen is exceedingly diverse and includes purse seine. Bone's purse seiners catch scad and skipjack tuna all year round and concentrations of these particular vessels generally operate around the waters of the Flores Sea, Bone Bay and the waters of Southeast Sulawesi. The main objective of this study is to describe the allocation of fishing gear and the effect of fishing ground, fishing season and its interaction with the gear allocation and purse seine catches off the southern coast of Sulawesi, Indonesia, as well as the spatial and temporal allocation of fishing gear.

MATERIALS AND METHODS

Mapping the allocation of fishing gear between fishing ground and fishing season is one approach to quantifying the relative intensity of fishing effort. Due to the lack of resources data, we utilised the monthly record of Marine and Fisheries Resources Surveillance and local marine and fisheries office data from 2014-2018. The data contained monthly information of the types and number of gear (units), number of fishing trips (days), fishing grounds and total weight of fish landings (kg) by species of fishing activity of gear which landed catches in Bone (Fig. 1). As this study has focused on purse seiners, data were classified first into purse seiner activity and other fisheries. For this study, we aggregated the daily catch data and fishing gear allocation data on a monthly basis. This option was performed in order to relate the dynamic of the catch and fishing gear allocation to fishing season (month) and fishing ground.

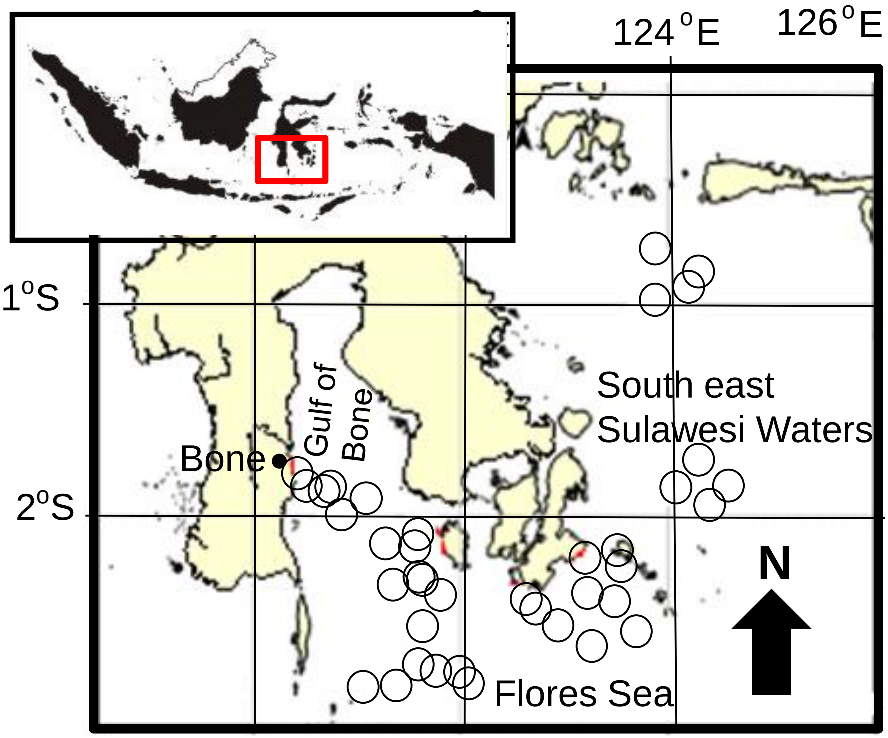

Fig. 1. Map of fishing ground (o) of purse seine from Bone (Modified from Geospatial Information Agency of Indonesia, 2014)

Data analysis

Fishing gear and catch landing

In order to gain an idea of the allocation of fishing gear and catch landing in a certain fishing ground seasonally, we firstly clustered the purse seine activity (trips) and their catch landing data. The fishing activity data regarding purse seine (trips) and their catch landing were grouped into monthly basis. Furthermore, the monthly fishing trips and catch landing data were specified again based on the size of the fishing gear vessel (GT) and fishing ground where they capture the catch. We divided purse seine operating from Bone into two groups: a) small purse seine (SPS) in which fishing gears are operated by fishing vessels < 30GT and b) medium purse seine (MPS) where fishing gears are operated by fishing vessels >30 GT. The number of purse seine allocated, and their catch were then aggregated. Information on the number of purse seine fishing fleet and catch in each fishing ground on a monthly basis were then tabulated and illustrated in the form of bar charts.

Similarities of fishing gear allocation

The similarities in fishing gear allocation (in each month) were described by using cluster analysis (Wiyono *et al*., 2006). Based on the Z-score transformation for monthly fishing gear allocated data (number of MPS and SPS per month in each fishing ground), we computed the proportion (%) of monthly fishing gear allocation similarity patterns among months. If the month is clustered into one group, it means that the allocation of fishing gear in a certain month has a similar fishing season to the capture target species. On the contrary, if a month is not included in the group, it denotes that the allocation of fishing gear in a certain month does not have the same fishing pattern. The distinctive fishing allocation similarity patterns between months were described by hierarchical clustering analysis based on the centroid and squared Euclidean distance interval methods (van Tongeran, 1995).

Dynamic fishing gear allocation and catch landing

The correlation of fishing ground, fishing season, fishing gear allocation and catch landing of purse seine were analysed using general linear model (GLM) (Tsitsika and Maravelias, 2006). The allocation of fishing gear seasonally was expressed as the number of purse seine (both MPS and SPS), which operate in a month (units). Similarly, the allocation of fishing gear in a certain fishing ground was also expressed as the number of purse seine (units) which operated in a certain fishing ground, while the catch was expressed as the volume (kg) of catch landed by purse seine during a certain month and fishing ground. The monthly total allocation of fishing gear and catch (kg) of purse seine are expected to be influenced by fishing season (month) and fishing ground (units). Additionally, the monthly total catch (kg) of purse seine are expected to be influenced by the number of fishing gear which operate in a certain fishing season and fishing ground (units).

RESULTS

Fishing gear and catch dynamics

The number of fishing gear operated in Bone totalled 4.734 units. The fishing gears were dominated by traditional fishing gear (for instance hooks, gillnets and traps) and contributed approximately 83 % of total fishing gear (Fig. 2). The remaining 17 % of fishing gear were operated by semi-modern fishing gear, such as purse seine, troll line and lift net. The scale of fishing gear were also reflected by the size of the fishing boat. Most of the fishing gear (91 %) which operates in Bone is operated by small scale fishing boats (< 5 GT), and only 1.2 % are operated by fishing vessels > 10 GT.

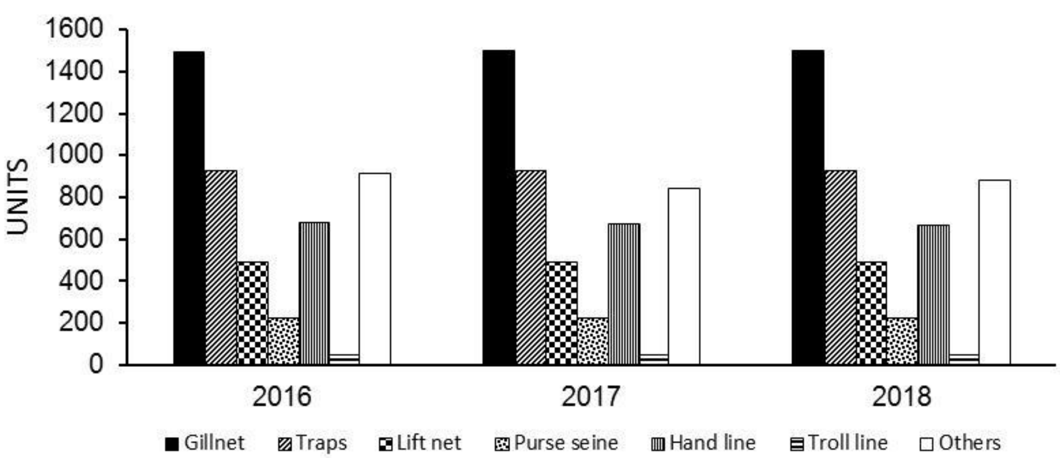

Fig. 2. Fishing gear in Bone, 2016 - 2018

It is imperative to note that in 2018 approximately 221 purse seine were operated by fishermen from Bone. Although they only contributed roughly 4.9 % from the total fishing gear, purse seine delivered significant catches. The main target species of purse seine in Bone are scads and skipjack tuna which contribute approximately 59 % of the total fish landing (Fig. 3). From 2014-2018, scads landings increased sharply and contributed in the region of 66 % of the total

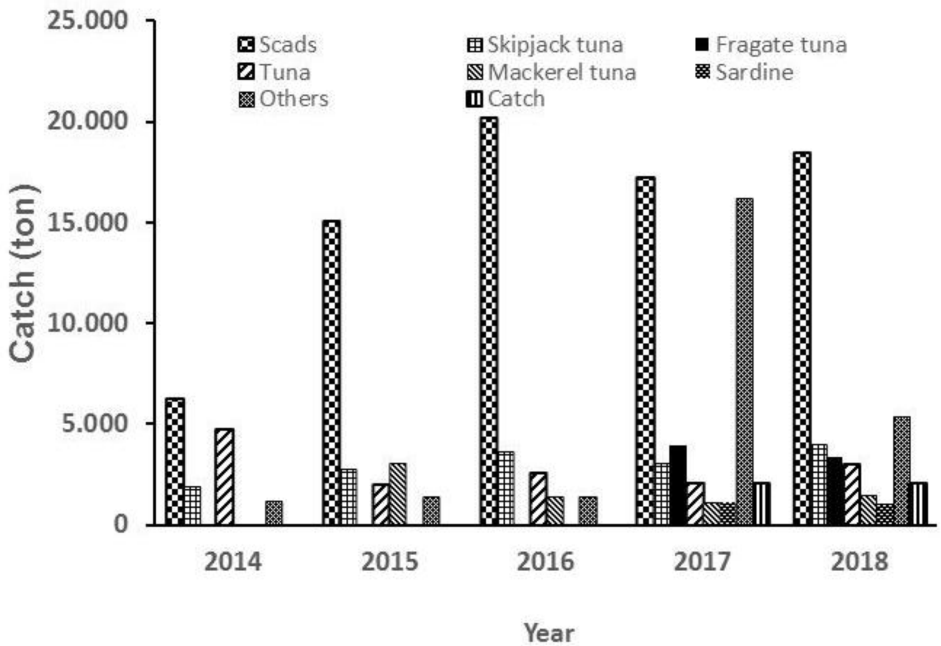

Fig 3. Fish landings in Bone during 2014 – 2018

Fishing ground, fishing season, fishing gear allocation and catch landing

The most favourable fishing ground for purse seine is in the waters of South East Sulawesi, followed by Bone Gulf and the Flores Sea (Fig. 1 and 4). The fisherman decisions in relation to the allocation of fishing gear in the waters of Southern Sulawesi were dynamic. The allocation of fishing gear in a certain fishing ground changed gradually following the monsoon season. After the south west monsoon season passes, the purse seine fishing season is expected to start in May (first cluster). During May, the fishing gears operated in each fishing ground were relatively equal. The allocation of fishing gear in most fishing grounds consists of a moderate number. The second cluster is marked by a similar allocation of SPS during June and July. During this period, the allocation of SPS in the Flores Sea increased considerably, whereas the allocation in the Gulf of Bone and the waters of South West Sulawesi were relatively stable. However, from August–December the allocation of fishing gear in the Flores Sea is at its lowest and the fishing ground moved to the Gulf of Bone and the waters of South East Sulawesi. In these periods, the fishing season in the Gulf of Bone and the waters of South East Sulawesi reach the highest peak season. The waters of South East Sulawesi experiences its peak season during September, while the Gulf of Bone reaches its peak fishing season in December. After encountering its low fishing season between August and December, the fishing ground in the Flores Sea has its peak fishing season in June.

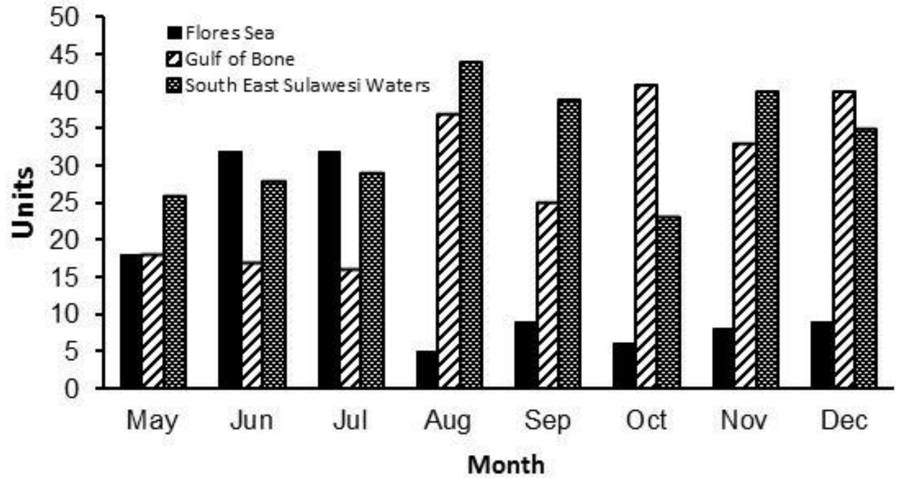

Fig. 4. Number of purse seine operated in each fishing ground per month

Conversely, the purse seine fish landing is seasonally dynamic and hence, follows the movement of fishing ground that also changes seasonally. Scads (78 %), the majority of purse seine catch landing, showed dynamic seasonally varied among fishing grounds. Additionally, from May-July, the scads catch landings are relatively equal between fishing grounds. However, from August–December, the catch landing varied among fishing ground. Similar to scads, the skipjack tuna landings varied seasonally among fishing grounds too. The skipjack tuna catch landing was more dynamic than the scads. Skipjack tuna can be captured in all fishing grounds from May–July. After this specific period, the skipjack tuna were mostly captured in the waters of South East Sulawesi and captured in in small quantities in the Gulf of Bone (Fig. 5).

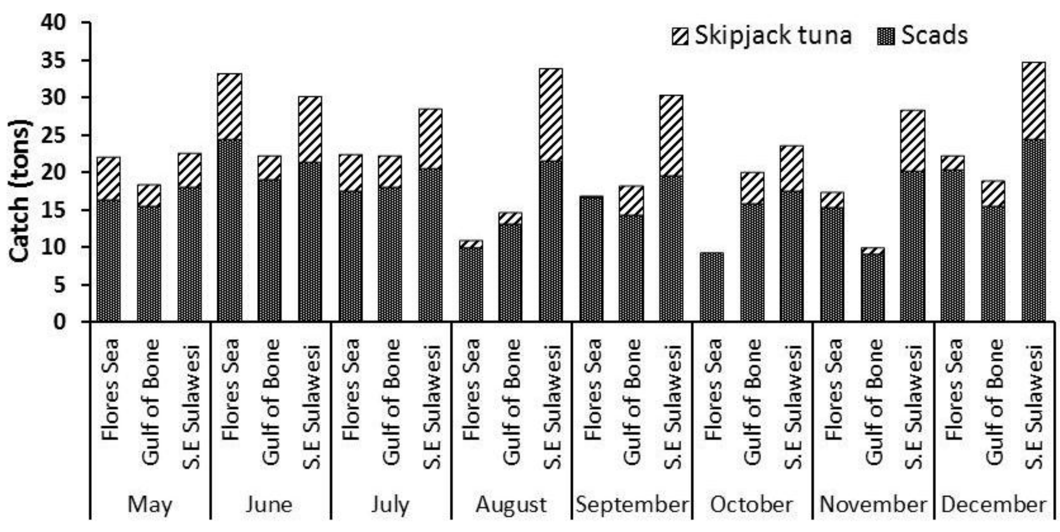

Fig. 5. Dynamic of fish landings from each fishing ground per month

By using the value of the level of rescaled distance cluster combine, we determined the cluster pattern of fishing gear allocation. As the cut off value, we used the 5 scale distance level of rescaled distance cluster combine. In general, the result of the cluster analysis revealed that the allocation of SPS and MPS is different. Firstly, in May, when the fishing season begins, the allocation of MPS and SPS were relatively equal in the small number. Starting from June, allocation of SPS and MPS demonstrated a different pattern. From June–July, most SPS were allocated in the Flores Sea, while MPS were predominantly assigned to the waters of South East Sulawesi. Near the end of the northwest monsoon (August), the fishing gears allocation pattern of the SPS were different to the MPS. The allocation of SPS were concentrated in the Gulf of Bone, while MPS were primarily allotted to the waters of South East Sulawesi. At the beginning of the monsoon season (December), the allocation of SPS in the Flores Sea and the waters of South East Sulawesi decreased markedly, while the distribution of MPS was comparatively stable.

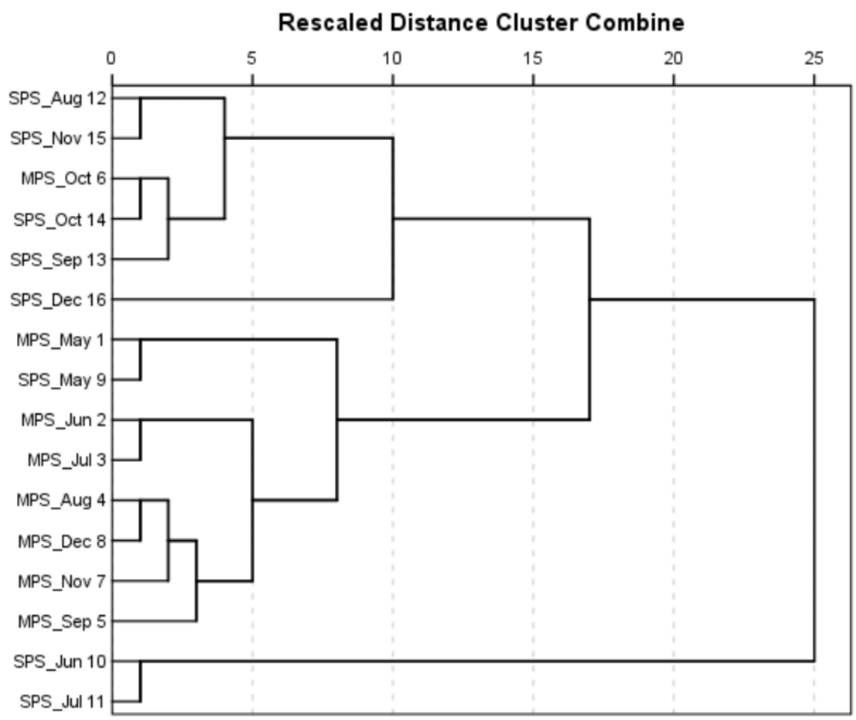

Fig. 6. Cluster of fishing seasons on the southern coast of South Sulawesi

In order to determine the factors that affect the distribution of fishing gear allocation, we have analysed the correlation of fishing gear allocation in different fishing grounds each month. We used GLM multivariate to analyse how fishing gear allocation were affected by fishing season and fishing ground. The result of the analysis signified that the allocation of fishing gear was significantly affected by fishing ground. Moreover, further analysis showed that fishing season (month) and the interaction of fishing ground and month did not significantly affect fishing gear allocation (Table 1).

Table 1. The result of the multivariate analysis of variance (MANOVA): effect of dependent variable (fishing ground, fishing season and its interaction) on fishing gear allocation

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1,844.917	23	80.214	2.146	0.035
Intercept	8,060.083	1	8,060.083	215.654	0.000
Fishing ground	789.292	2	394.646	10.559	0.001
Season month	54.583	7	7.798	0.209	0.980
Fishing ground * Season (month)	1,001.042	14	71.503	1.913	0.079
Error	897.000	24	37.375		
Total	10,802.000	48			
Corrected Total	2,741.917	47			

Table 2. The results of the multivariate analysis of variance (MANOVA): effect of dependent variable (fishing ground, fishing season and its interaction) on the independent variable (total catch, scads and skipjack tuna)

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Total	1.107E8	23	4,812,694.710	6.522	0.000
	Scads	3.612E7	23	1,570,486.014	2.416	0.001
	Skipjack tuna	2.702E7	23	1,174,847.373	15.802	0.000
Intercept	Total	1.155E9	1	1.155E9	15,65.459	0.000
	Scads	6.961E8	1	6.961E8	1070.993	0.000
	Skipjack tuna	5.583E7	1	5.583E7		0.000
Season (month)	Total	1.603E7	7	2,289,324.524	3.102	0.004
	Scads	9,392,205.000	7	1,341,743.571	2.064	0.049
	Skipjack tuna	1,125,656.250	7	160,808.036	2.163	0.039
Fishing Ground	Total	7.149E7	2	3.575E7	48.441	0.000
	Scads	1.723E7	2	8,617,087.917	13.258	0.000
	Skipjack tuna	1.809E7	2	9,042,697.917	121.624	0.000
Season (month) * Fishing ground	Total	2.318E7	14	1,655,382.560	2.243	0.007
	Scads	9,494,797.500	14	678,199.821	1.043	0.411
	Skipjack tuna	7,810,437.500	14	557,888.393	7.504	0.000
Error	Total	1.594E8	216	737,920.787		
	Scads	1.404E8	216	649,974.722		
	Skipjack tuna	1.606E7	216	74,349.537		
Total	Total	1.425E9	240			
	Scads	8.726E8	240			
	Skipjack tuna	9.891E7	240			
Corrected Total	Total	2.701E8	239			
	Scads	1.765E8	239			
	Skipjack tuna	4.308E7	239			

Furthermore, using GLM we also analysed how catch landing of purse seine were affected by fishing season and fishing ground. Using the model, we also analysed the effect of the interaction of fishing season and fishing ground on the purse seine catch landing (scads, skipjack tuna and total). Analysis of the result (Table 2) indicated that fishing ground, fishing season (month) and their interaction significantly affected the model ($P < 0.01$).

To understand the effect of fixed factors variable (fishing ground, fishing season and its interaction) on the dependent variable (total catch, scads and skipjack tuna), we employed multivariate analysis of variance (MANOVA). Analysis of the results (Table 2), revealed that fishing season (month) affects total catch ($P < 0.00$), skipjack tuna ($P < 0.05$) and scads catch ($P < 0.05$). Further analysis of the result proved that fishing ground effects total catch, scads and skipjack tuna ($P < 0.00$). If fishing season and fishing ground separately affected all the independent variables, the interaction of fishing ground and fishing season affected total catch and skipjack tuna catch but did not affect catches of scads.

DISCUSSION

Nowadays, the world is faced with an excess of fishing effort, which is creating deterioration in fish resources (Clark *et al*., 2005; FAO, 2008). Indeed, the deterioration in fish resources is not only due to the excessive number of fishing fleets but is related to our ignorance in understanding the allocation of fishing gear. The effort allocation, when and where to operate fishing gear is a dynamic process that is influenced by external and internal factors. Hence, understanding fishing effort dynamic is important for fisheries stakeholders, especially managers (Pet-Soede *et al*., 2001; Salas *et al*., 2004).

The result of the cluster analysis confirms the relationship of fishing gear allocation between fishing grounds seasonally. As Monroy *et al.*, (2010) stated, fishermen have a preferred fishing ground in regard to allocating their fishing gear. We expected the different fishing gear allocation to be influenced by catch landing, which is controlled by the monsoon season. From May–July, the fishing season was marked by similarities in catch proportion between fishing ground and month. The proportion of scads and skipjack tuna in May, June and July captured in the Flores Sea, Gulf of Bone and South East Sulawesi were comparatively similar (Fig. 6). As the fishing ground provides a similar advantage, the fishermen have the freedom to choose their fishing ground. However, allocation of purse seine in the Flores Sea during this period was relatively higher and gave a substantial catch compared to other seasons. This was expected seeing as this period is the peak fishing season in the Flores Sea, especially for skipjack tuna. Zainuddin *et al*., (2017a) explain that the potential fishing season for skipjack in and around the Gulf of Bone and Flores Sea begins in May. During this period, Chlorophyll-a (0.125–0.213 mgm^{-3}) and sea surface temperature (30.25 ^{o}C) reach the optimum condition for skipjack tuna. The increasing allocation of purse seine in the Flores Sea in this period is natural because of the economic value of the skipjack tuna. Therefore, the fishermen attempt to capture as many fish as possible before the fish migrate to other fishing grounds.

When the transition monsoon entered (August), the purse seine fishing activity demonstrated a significant change**.** From August–November, fishing activities were marked by the migration of the purse seine fishing ground from the Flores Sea to the Gulf of Bone and the waters of South East Sulawesi. The allocation of purse seine in the Flores

Sea decreased although conversely, purse seine allocation in the Gulf of Bone and South East Sulawesi increased. The fishing ground migrations of purse seine were thought to be influenced by the change in catch composition in each fishing ground. The skipjack tuna catches in the Flores Sea and Gulf of Bone decreased significantly, whereas the skipjack tuna catches in South East Sulawesi increased appreciably. Besides revealing a decrease in skipjack tuna catches in the Flores Sea. this period was also marked by a decrease in catches of scads in most fishing grounds.

After going through the transition season, the allocation of purse seine changed at the beginning of the northwest monsoon. The allocation of purse seine in the Gulf of Bone decreased and moved to the Flores Sea and waters of South East Sulawesi. It should be mentioned that the increase in scads and skipjack tuna catch landings in the Flores Sea and waters of South East Sulawesi were believed to be caused by moving fishing ground. Since the sea surface temperature (SST) in the Flores Sea and western part of the Banda Sea is suitable for skipjack tuna. Zainuddin (2017b), explain that the CPUE of skipjack tuna in this period reaches its greatest during December.

In view of the fact that the purse seine allocation between fishing ground and fishing season were dynamic, it is vital to understand the main factors that influence the dynamics. The result of the analysis confirmed that the total catch landing, skipjack tuna and scads catches are significantly different between fishing season and fishing ground separately. This study is in accordance with the study conducted in the Gulf of Pagasitikos, Greece (Tsitsika and Maravelias, 2006). Further analysis of the result confirmed that the interaction of fishing ground and fishing season significantly affect the total catch landing and catch of skipjack tuna but do not affect catches of scads. This suggests that the fishing season and fishing ground affect catch landing (total catch landing. skipjack tuna and scads catch) separately, though their interaction affected the total catch and skipjack tuna catch landing but do not affect the scads. This is because scads have a long fishing season and spread evenly between fishing ground and season. Conversely, skipjack tuna only have a short fishing season and are irregular between fishing grounds.

We anticipated that economic reasons have influenced the fishermen’s strategy (Yew and Heap, 1996; Tsitsika and Maravelias, 2008; Maravelias *et al*., 2014). Therefore, in order to maximise profit, the purse seine fishers seek to capture as many fish as possible by changing the fishing ground seasonally. This behaviour can be understated because fishing activity is now under considerable pressure and capturing fish is more difficult. Conversely, fishing costs increase year-on-year and create restrictions concerning fishing operations. Given that fishing is the principal source of income for most fishermen, they will try to capture fish every day, as long as the weather allows them to do so.

CONCLUSION

The results of this study confirmed that fishing ground and fishing season affect fishing gear allocation and catch landing. Further analysis indicates that the interaction of fishing ground and fishing season affects the total catch and skipjack tuna catch landing but do not affect the scads. Using the above information and findings. we can also understand the fishermen’s strategy and behaviour in response to changes in external factors. In order to maximise catches. fishermen move from one fishing ground to other fishing grounds seasonally. Management measures can be recommended by calculating fishing allocation based on fishing ground every month. Moreover. it is expected that the policy approach can help to calculate fishing effort more precisely. We hope by adopting this policy. the fisheries management which is based fishing effort will be more appropriate and operational in practice.

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