Characteristics of purse seine fisheries in the Sulawesi Sea
(case study in Tumumpa fishing port)

Baihaqi*, Mahiswara and T W Budiarti

Research Institute for Marine Fisheries - Jl. Pasir Putih 1 Ancol, Jakarta Utara, Indonesia

*Corresponding author e-mail : baihaqibrpl@gmail.com

Abstract. The purse seine is the dominant fishing gear operating at the Tumumpa Fishing Port with a vessel of >90%. The purse seines that have developed are large pelagic targets, with the main catch targets being skipjack, mackerel tuna, and tuna. Tuna, mackerel tuna and skipjack are important commodities for fisheries in Indonesia. This study aims to determine the characteristics of purse seine fishing gear and its catch in the Sulawesi Sea. Data collection was carried out for two years from 2019-2020 at Tumumpa Fishery Port. Indications for the use of fish resources are calculated by comparing the length-at-first-capture (Lc) with the length-at-first-mature (Lm). The results showed that purse seines are very dominant in exploiting large pelagic resources (skipjack, mackerel tuna and tuna) with the proportion reaching 78%, small pelagic (21% scads and 1% other fish). The large pelagic fishing season using the purse seine vessel occurs in May – November, with 2 peak seasons in July and September. While the small pelagic occurs in May – September, with the peak occurring in July. The size when the frigate tuna was first caught was at a fork length of 25.15 cm (Lc) and Lm in a size of 28.52 cm for females and 28.29 cm for males. Meanwhile, the first scads was caught (Lc) at a length of 21.4 cm with the length-at-first-mature (Lm) being 20 cm for the female and 19 cm for the male. Based on this analysis, it was shown that the purse seines is a selective fishing gear for small pelagic fish but not selective for large pelagic fish.

1. Introduction
Sulawesi Sea is one of Indonesian open water and directly related to Pacific Ocean, and included into the Regional Fisheries Management (WPP) 716; Sulawesi Sea and Halmahera Sea. Administratively, Sulawesi Sea covered by three provinces; North Sulawesi, Gorontalo and North Kalimantan. Based on the Ministry Decree, pelagic fishery is the largest potential commodity in the waters of Sulawesi Sea which reached 85% of the total fish resources [1]. Purse seine is the major fishing gear that used to utilize pelagic resources in Sulawesi Sea. Other fishing gear operated in these waters were hand line, lift net, bouke ami, pole and line, seine net. The fishing gear which is dominated by purse seine targeting for skipjack, tuna and neritic tuna.

Tumumpa is one of the fishing ports in the Sulawesi Sea. Geographically, Tumumpa is located in Manado (North Sulawesi) facing the Sulawesi sea. The fishing activities based in Tumumpa consists of several fishing gears. Fish landed consist of various species, namely yellowfin (Thunnus albacares), bigeye (Thunnus obesus); skipjack tuna (Katsuwonus pelamis), neritic tuna (Euthynnus sp and Auxis spp), mackerel scad (Decapterus macarellus), short mackerel (Rastrelliger brachysoma), indian mackerel (Rastrelliger kanagurta), big eye scad (Selaroides crumenopthalmus), sardine (Sardinella...
spp.), carangidae (*Carangids nai*) etc. During 2013 to 2020 period the dominant landing catch of purse seine vessels in Tumumpa is skipjack which reached 40% of total landing.

During the period 2013 to 2020 the number of purse seine vessels tends to increase, and is dominated by > 30 GT vessel size. In 2020 there were 105 unit active purse seine vessels. Purse seine vessels based at Tumumpa Fishing Port use Fish Aggregated Devices (FADs) as an auxiliary fishing. Fishing ground distribution of Tumumpa purse seines were in territorial waters, and most of FADs positions in Sangihe-Talaud waters. A purse seine is a large wall of netting deployed around an entire school of fish or a Fish Aggregating Device (FAD). The seine has floats along the top line with a lead line threaded through rings along the bottom and equipped with a purse line [2]. Based on design and construction Tumumpa purse seine targeted for small pelagic resources. The current Indonesian regulation for fishing gear [3], purse seine consists of two types, namely: small pelagic purse seine and large pelagic purse seine. The difference between the two types of purse seines is the size of the mesh used. This paper provides results from the study of characteristic purse seiner in Sulawesi Sea based on data collected with particular data from Tumumpa Fishing Port.

2. Materials and Methods

2.1. Data collection

Fishery data were obtained through daily enumeration including interviews with skippers at the earliest opportunity after their catches were unloaded, and also by direct observations and biological sampling during February to November 2019 and February to November 2020. Fishery information on production and number of active vessels were obtained from local port authorities, fisheries offices and fishing companies. The enumeration was carried out at Tumumpa Fishing Port in Manado (North Sulawesi).

The types of data and information collected from interviews with boat skippers include operational aspects fisheries (vessel tonnage, fishing gear dimension, crew number, fishing days, location of fishing ground, number and positions of a-FADs), estimation of total catch, catch by species and catch rate (nominal catch per unit effort or CPUE). The types of data collected from biological sampling include catch composition and individual size of mackerel scad and frigate tuna species (cm-fork length-FL). The sampling was done on a subsample of the catch at time of catch unloading. Data were first recorded onto hard-copy Landings, Operational and Biological Samplings Forms, and then later entered into an eBRPL database system.

2.2. Data analysis

Analysis of the length at first capture (Lc) of fish was obtained from the Beverton & Holt method in [4] and the size of the fish at first maturity (Lm) referring to the Sperman - Carber procedure carried out by [5] by calculating the logarithmic value of the cumulative increase in the mean value.

\[ SL = \frac{1}{1 + \exp(a - bL)} \]  
(1)

\[ Lm \left( \frac{1}{SLc} - 1 \right) = a - bL \]  
(2)

\[ Lc = \frac{a}{b} \]  
(3)

2. Results and Discussion

3.1. Results

The purse seine vessel that is actively unloading has a size range between 6 – 99 GT. Most of the purse seine vessels have a size of more than 30 GT. In 2019 the number of purse seine vessels > 30 GT was 103 units (74%) and < 30 GT was 36 units (26%). In 2020, the purse seine vessel with volume > 30 GT slightly increased to 105 units (77%) and < 30 GT decreased to 31 units (Figure 1).
The catch of fish landed at PPP Tumumpa during 2013 to 2020 was dominated by large pelagic fish species, which was about 79% of the total catch, while small pelagic fish were around 21% of the total catch. The composition of the caught fish consisted of skipjack tuna by 41% and the highest catch dominance, mackerel scad 21%, tuna 14%, mackerel tuna 23% and another fishes only a small part (Figure 2).

Purse seines can reach more than 450 m in length and 120 m in depth, varying in size according to the vessel, mesh size, and target species. The main fishing gear used by fishermen in PPP Tumumpa is a purse seine that operates around FADs. The design of purse seine and FAD fishing gear used by Tumumpa fishermen can be seen in Figures 3 and 4.
Before operating, the Tumumpa purse seine fishermen first prepare supplies and equipment related to fishing operations. These supplies and equipment include refueling, food supplies, fresh water and ice, this ice function to maintain the freshness of the fish because the purse seine vessel of Tumumpa fishermen is not equipped with a freezer, as well as preparation of fishing gear. Fishing activities are carried out at 4 - 5 am, before setting up, first look at the condition of the fish under the lamp boat or FADs whether the fish have been collected. This activity is carried out by 2 crew members and when the fish have been collected, the officer will give a code to the fishing boat that the setting can begin. In the first stage, permanent FADs will be pulled away from temporary FADs and the temporary FADs are given lighting in the form of petromak lamps or fluorescent lights intended so that the schools of fish under permanent FADs move to temporary FADs, if all the fish schools have moved to temporary FADs and If the position of the fish rises to the surface, the setting begins immediately. The net began to be lowered at a speed of ± 5-6 knots, after the net was fully coiled as soon as possible the drawstring was pulled using the garden so that the ring rose to the top of the boat deck so that the shape of the net had resembled a bowl and the fish could not get out of the net, then followed the body of the net. Until the remaining part of the code end which is where the fish are? The fish caught are taken using a small net.
which is then put into the hold. After the fish raising process is complete, the nets are rearranged as before to facilitate the next setting process.

3.1.1 Fishing ground. The fishing grounds for the purse seine vessel from 2019 to October 2020 are almost the same. Generally only in the Sulawesi Sea, about 30 – 150 miles from the Manado city, precisely around the Talaud and Sangihe islands, which are west of Makalihi and Naen islands and in front of Amurang, which is commonly called local fishermen, namely the Mediterranean Sea (Figure 5).

3.1.2 Fishing season. Fishing season pattern is indicated by a high Index of Fishing Season (IFS). This indicates that this month is a good time to carry out fishing operations. An IFS value that is above the average value can be said to be a good time to catch large pelagic fish, namely in May to November with the peak season in September (Figure 6), the lowest season index occurs in May and August. While the famine season occurs in January – April and December and for small pelagic commodities, namely from May to September with the peak season in July (Figure 7), the lowest season index occurs in September. While the famine season occurs in January - April and October – December.
3.1.3 **Length at first caught (Lc) and gonad maturity (Lm)**. The size distribution of frigate tuna (*A. thazard*) caught in purse seine ranged from 13.75-35.75 cm with the size of the length at first caught (Lc) of 25.15 cm (Figure 8). Meanwhile, for mackerel scad (*D. macarellus*), the size distribution ranges from 14.25 – 30.75 cm with the size of the length at first caught (Lc) of 21.4 cm (Figure 9).
The size of the first gonadal maturity (Lm) is one of the important parameters in determining the size of fish that can be caught. The length of the first gonad maturity of frigate tuna landed at PPP Tumumpa was 28.52 cm female and 28.29 cm male. While the mackerel scad is 20 cm female and 19 cm male.

3.2 Discussion
In this study, the developed purse seine was a small pelagic purse seine type (PSPK). Purse seine operating in the Sulawesi Sea generally use FADs as fishing aids. FADs have been shown to increase fishing efficiency through precise fishing grounds [6]. The use of FADs can increase fishing activities to be more effective and efficient. However, excessive use of FADs can damage aquatic ecosystems [7]. One way to regulate the use of FADs is to place monitoring officers during arrest operations. This is important because the placement of FADs needs to be arranged at a certain distance so as not to limit fish migration patterns and not become an ecological barrier [8]. The Ministry of Marine Affairs and Fisheries itself has made provisions on the distance between one FADs and other FADs not less than 10 nautical miles [9].

The average fork length (FL) of frigate tuna caught with purse seines in Fisheries Management Area (FMA) 716 was 13.75 – 35.75 cm with an Lc value of 25.15 cm. This value is smaller than that of frigate tuna caught in Sibolga ranging from 19 - 45 cm with a size first caught (Lc) of 31.7 cm [10] and 21-40 cm in West Sumatra [11]. The size of the first gonadal maturity (Lm) of frigate tuna was 28.52 in females and 28.29 in males, smaller than the results of a study by [12] which stated that the first size of the gonads of frigate tuna was 32 cm for females and 30.8 cm for males. The results of research conducted by Research Institute for Marine Fisheries in 2008 showed that the catch of the surface tuna group was relatively young, which generally had a length below the maturity of the first gonad [13].

The average fork length (FL) of mackerel scad caught with purse seine in PPP Tumumpa is 14.25 – 30.75 cm with an Lc value of 21.4 cm. This value is relatively the same as the mackerel scad caught in Southeast Sulawesi ranging from 17.5 to 30.5 cm with the size of the first caught (Lc) of 23.22 cm [14]. The size of the first maturity of the mackerel scad gonads (Lm) was 20 in females and 19 in males, smaller than the results of research by [15] Ikisan et al., (2018) which stated that the size of the first maturity of the blue kite gonads was 25.8 cm and 22.5 cm in Southeast Sulawesi [14].

Most of the fish caught with purse seine were in immature gonadal condition, indicated by the size at first caught which was smaller than the size at first maturity gonad (Lc< Lm), especially in large pelagic fish. This is due to the specification of the fishing gear used today as a small pelagic purse seine [3]. This condition is not ideal for maintaining the sustainability of the fish population, where fish need to spawn at least once to maintain their survival [16][17]. Strong efforts are needed in the management of purse seine fisheries in the Sulawesi Sea. Especially for large pelagic commodities. For frigate tuna, the utilization status is already fully exploited [18]. So that if a lot of gonadly immature frigate tuna are caught, it is estimated that in the next few years they will experience more catch status. This condition will not only cause ecological losses but also economic losses because the catch of fish caught is smaller than when conditions can be achieved optimally [19]. One method to prevent growth overfishing is to increase the mesh size. This method has been successfully used in trap fishing gear with reef fish commodities in Jamaica. With this method, reef fish catches have increased significantly after three years since additional mesh sizes were used [20].

The placement of observers on board vessels can also be applied to monitor purse seine fishing activities and their catch. Since 2010, in the Pacific Ocean, the Western and Central Pacific Fisheries Commission (WCPFC) has required all purse seine vessels operating in the area between 20 North Latitude to 20 South Latitude [21]. Meanwhile, in the Indian Ocean, the Indian Ocean Tuna Commission (IOTC) implements a regional monitoring program to monitor the transfer of catch activities at sea [22]. In Indonesia, this onboard monitoring program was first conducted in 2005 on a tuna longline fishery based in Benoa Fisheries Port [23]. This program was then strengthened by a Ministerial Regulation concerning monitoring of fishing vessels and carrier vessels [24]. This regulation regulates in detail the duties and functions of the monitoring officers (observer) as well as the obligations of ship owners to facilitate this monitoring program.
4. Conclusions
The purse seine vessel dominates the use of large pelagic and small pelagic resources at FMA 716. However, the size of fish caught is dominated by immature gonads and low selectivity, especially for large pelagics. Therefore, rules are needed to regulate fishing operations with purse seine. The use of purse seine fishing gear is not recommended for catching pelagic fish. In an effort to maintain the sustainability of large pelagic fish resources, it is necessary to apply one of them by increasing the size of the mesh according to applicable regulations. This needs to be done to maintain the sustainability of fish resources in the Sulawesi sea.

Acknowledgements
The authors wish to thank the enumerators who conducted surveys and BRPL operators for database support in this study. We also thank the port authorities and fisheries offices, vessel owners, and skippers who provided cooperation and additional information for the study. This paper is an output of BRPL Project; Fisheries Resources Stock Assessment Research in FMA 716 in 2019 and 2020 period.

References
[1] Keputusan Menteri KP. 2017. Kepmen KP Nomor 50/KEPMEN-KP/2017 Tentang Estimasi Potensi, Jumlah Tangkapan yang Diperbolehkan, dan Tingkat Pemanfaatan Sumber Daya Ikan di Wilayah Pengelolaan Perikanan Negara Republik Indonesia. Kementerian Kelautan dan Perikanan, Jakarta
[2] Mahiswara, Budiarti, T. W., & Baihaqi. 2013. Karakteristik teknis alat tangkap pukat cincin di Perairan Teluk Apar, Kabupaten Paser, Kalimantan Timur. J.Lit.Perikan.Ind. 19(1), 1-7. doi: http://dx.doi.org/10.15578/jppi.19.1.2013.1-7
[3] Peraturan Menteri KP. 2020. Permen KP Nomor 59/PERMEN-KP/2020 tentang Jalur Penangkapan Ikan dan Alat Penangkapan Ikan di Wilayah Pengelolaan Perikanan Negara Republik Indonesia dan Laut Lepas. Kementerian Kelautan dan Perikanan, Jakarta
[4] Sparre, P. & Venema, S. C. 1998. Introduction to tropical fish stock assessment. Part 1:manual. FAO Fish. Tech. Paper. No. 306.1, Rev. 2 (p. 407). Rome: FAO
[5] Udupa, K. S. 1986. Statistical method of estimating the size at first maturity in fishes. ICLARM, Metro Manila, Fishbyte. 4(2), 8-10. URL: http://pubs.iclarm.net/Naga/na_2900.pdf
[6] Barus & Hery Riah. 1992. Pedoman Teknis Peningkatan Produksi Ikan Pelagis Dengan Penerapan Teknologi Rumpon. Seri pengembangan Hasil Penelitian Perikanan No. PHP/KAN/PT/21/1992, Badan Penelitian dan Pengembangan Pertanian
[7] Yusfiidayani, R. 2013. Fish aggregating devices in Indonesia: Past and present status on sustainable capture fisheries. Galaxea, Journal of Coral Reef Studies. (Special Issue) 260-268. doi:https://doi.org/10.3755/galaxea.15.260
[8] Dagorn, L., Holland, K. N., Restrepo, V., & Moreno, G. 2013. Is it good or bad to fish with FADs? What are the real impacts of the use of drifting FADs on pelagic marine ecosystems? Fish and Fisheries. 14, 391-415. doi: https://doi.org/10.1111/j.1467-2979.2012.00478.x
[9] Peraturan Menteri KP. 2014. Permen KP Nomor 26/PERMEN-KP/2014 Tentang Rumpon. Kementerian Kelautan dan Perikanan, Jakarta
[10] Hartaty, H & Setyadji, B. 2016. Parameter Populasi Ikan Tongkol Krai (Auxis thazard) Di Perairan sibolga Dan Sekitarnya. BAWAL. 8 (3) Desember 2016: 183-190. http://ejournal-balitbang.kkp.go.id/index.php/bawal/article/view/1601
[11] Noegroho, T., Hidayat, T., & Amri, K. 2013. Some biological aspects of frigate tuna (Auxis thazard), bullet tuna (Auxis rochei) and kawa kawa (Euthynnus affinis) in West Coast Sumatera IFMA 572, Eastern Indian Ocean. IOTC–2013–WPNT03–19, 13
[12] Jude, D., Neethiselvan, N., Gopalakrishnan, P., & Sugumar, G. 2002. Gill net selectivity studies for fishing frigate tuna, Auxis thazard Lacepede (Perciformes scrombidae) in Thoothukkudi (Tuticorin) waters southeast coast of India. India Journal of MarineSciences, 31(4), 329-333
[13] Raharjo Priyanto, Mardlijah, S., & Rahmat E. 2008. Penelitian Indeks Kelimpahan Stok Sumberdaya Ikan Di Perairan Samudera Hindia : Laporan Teknis Pelaksanaan Kegiatan Riset (Tidak dipublikasi), Balai Riset Perikanan Laut

[14] Widiyastuti, H., Herlisman., & Pane A. R. P. 2020. Decent Size Capture of Small Pelagics in Kendari Waters, Southeast Sulawesi. Marine Fisheries Vol. 11, No. 1, Mei 2020 Hal: 39-48. DOI: http://dx.doi.org/10.20884/1.oa.2020.16.3.851

[15] Iksan, K. H & Irham, nFN. 2009. Growth and reproduction of mackerel scads, Decapterus macarellus (Cuvier, 1833) in North Moluccas waters. Jurnal Ikhtiologi Indonesia. Vol 9 No 2 (2009): 163-174. https://doi.org/10.32491/jii.v9i2.191

[16] Lappalainen, A., Saks, L., Sustar, M., Heikinheimo,O., Jurgens, K., Kokkonen, E., Kurkilahti, M.,Verliin, A., & Vetemaa, M. 2016. Length at maturity as potential indicator of fishing pressure effects on coastal pikeperch (Sander lucioperca) stocks in the northern Baltic Sea. Fisheries Research. 174(2016), 47-57. doi: https://doi.org/10.1016/j.fishres.2015.08.013

[17] King, M. 2010. Fisheries Biology, Assessment and Management, Second Edition (p. 381). Oxford,England: Blackwell Publishing Ltd

[18] Mahiswara, Budiarti, T. W., Rahmat E., Widodo, A., & Kuswoyo, A. 2020. Penelitian Karakteristik Biologi Perikanan, Habitat Sumberdaya dan Potensi Sumberdaya Perikanan di WPP 716: Laporan Teknis Pelaksanaan Kegiatan Riset (Tidak dipublikasi), Balai Riset Perikanan Laut

[19] Diekert, F. K. 2011. Growth overfishing: The race to fish extends to the dimension of size. Environmental and Resource Economics. doi:10.1007/s10640-012-9542-x

[20] Sary, Z., Oxenford, H.A., & Woodley, J.D. 1997. Effects of an increase in trap mesh size on an over exploited coral reef fishery at Discovery Bay, Jamaica. Marine Ecology Progress Series. 154,107-120

[21] Western and Central Pacific Fisheries Commission. 2018. Guidelines for the Regional Observer Programme. Pohnpei, Micronesia

[22] Indian Ocean Tuna Commission. 2011. On a Regional Observer Scheme. Victoria, Seychelles

[23] Jatmiko, I., Nugraha, B., & Satria, F. 2015. Capaian perkembangan program pemantau pada perikanan rawai tuna di Indonesia. Marine Fisheries. 6(1), 1-9. doi: https://doi.org/10.29244/jmf.6.1.23-31

[24] Peraturan Menteri KP. 2013. Permen KP Nomor 1/PERMEN-KP/2013 Tentang Pemantau Kapal Penangkap Ikan dan Kapal Pengangkut Ikan. Kementerian Kelautan dan Perikanan, Jakarta