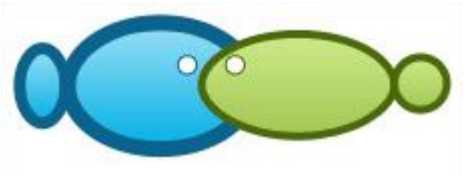

# Bio-economic model of demersal fish resources in Banten Bay waters

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**Abstract**. The decline in fish production is a serious problem that threatens the world community lately. Therefore, optimality, efficiency, and sustainability of the fisheries resources management are important things to do. The objective of this research is to analyze the optimal utilization of demersal fish resources in Banten Bay waters. Economic parameters that used in this research are price and fishing cost. Biological parameters are estimated using the Schaefer model. The set gillnet, boat seine, and trammel net are the fishing gear for catching the demersal fish in this research. The result shows that the sustainable yield of demersal fish is 1,569.39 tons year$^{-1}$; optimum effort is 3,316 units year$^{-1}$; the utilization rate is 54% and the effort rate is 27%. The production rate of demersal fish from 2012 continued to increase until 2014, but then declined in 2015 and was continued to decrease until 2016. It decreases, allegedly due to decreasing operating boat seine. These results indicate that the use of boat seine, in the long run, will cause biological overfishing. The maximum production at maximum economic yield (MEY) level of 1,567.81 tons is reached before the MSY production level. Economic profit at MEY was IDR 14,714,684,821. The effort rate in MEY is more efficient that the effort rate in MSY. The utilization of demersal fish can still be optimized, but it should be done carefully and wisely so as not to cause damage to fish resources and the environment.
**Key Words**: Banten Bay, demersal fish, optimal utilization, profit, Schaefer model.

**Introduction**. Exploitation of demersal fish resources in the waters of Banten Bay is quite high. This can be seen from the demersal fish production which reaches 41% of the total fish productions (Pelabuhan Perikanan Nusantara Karangantu 2017). Demersal fishing businesses in the waters of Banten Bay are the main source of income for local people who inhabit their coastal areas. About 2,672 fishermen (Dinas Perikanan dan Kelautan 2018) are working in the bay using different types of fishing gears. Some of them are very harmful to the bay fisheries.

Demersal fish are caught with set gillnet, trammel net and boat seine. The use of boat seine for catching demersal fish is feared to cause a decrease in stock and overfishing. Although there have been rules prohibiting the use of boat seine, but it is still found in the waters of Banten Bay. In 2016, 724 trips of boat seine were still operating in the bay (Pelabuhan Perikanan Nusantara Karangantu 2017).

Demersal fish resources are resources that are very vulnerable to exploitation. This is due to the nature of demersal fish resources which generally settle in waters and have a limited level of spatial migration. Therefore, when there is high or excessive capture pressure it will cause a decrease and even extinction (Budiman et al 2006; Wiadnyana et al 2010). A proper management of fish resources is right way to do.

The decline in fish production is a serious problem that threatens the world community lately. Therefore, optimality, efficiency, and sustainability of the fisheries resources management are important things to evaluate. In order to prevent a decline in demersal fish stock due to high intensity of capture activity, information on demersal fish resources is needed to support the preservation and development of its resources, including aspects of biological and economic parameters. Bio-economics is a combination of biological and economic aspect that can predict the most favorable rate of fishing effort, while still taking into account the sustainability of fish stock. This analysis is needed in the management of fish resources that are not only focused on biological

factors, so there need to be a study of production factors and costs in the fisheries business (Grafton et al 2000; Libecap 2009; Fauzi 2010). The objective of this research is to analyze the optimal utilization of demersal fish resources in the Banten Bay waters.

**Material and Method**. The research was conducted from March to October 2018 at Karangantu fishing port, Banten Province, as a fish landing center from Banten Bay waters. The primary data includes fish prices and operating cost that derived from interview process with fisherman, government officer of Karangantu fishing port, and fish landing place manager. The published time series data (5 years) from government office were also collected including types and number of fish production, production of each fishing gear (set gillnet, trammel net and boat seine), and number of fishing unit.

The bio-economic model is estimated based on the biological model of Schaefer (1975) and Gordon's economic (1954). The bio-economic model is composed of models of biological parameters, fishing cost and fish prices. The utilization of demersal fish resources is carried out with different fishing tools, namely set gillnet, trammel net and boat seine. So the standardization of fishing gear needs to be done before calculating the estimation of potential fish resources. The relationship of catches with fishing efforts was analyzed using the surplus production method with Schaefer model (Sparre & Venema 1998).

**Results and Discussion**. The calculation result shows the sustainable potential of demersal fish resources ($C_{MSY}$) is 1,569.39 tons year$^{-1}$ with optimum number of fishing efforts ($E_{MSY}$) of 3,316 units year$^{-1}$, as presented in Figure 1. The production level and effort level of demersal fisheries during 2012-2016 was still below of maximum sustainable yield (MSY) values. The development of demersal fish production has continued to increase from 2012 to 2015, and has decreased in 2016. While the development of actual fishing effort increased from 2012 to 2014, but then continued to decreased from 2015 to 2016 (Pelabuhan Perikanan Nusantara Karangantu 2017). The decreased in the amount of this fishing effort is in the line with the decline of the number of boat seine operating in the water of Banten Bay. This result indicates that the use of boat seine in the long run will lead to biological overfishing.

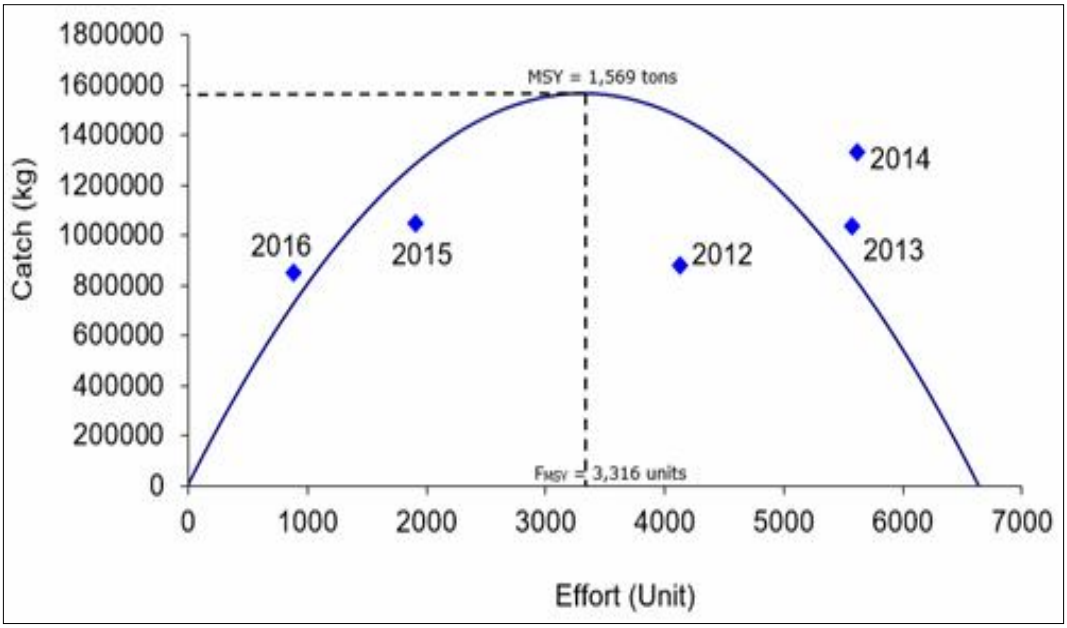

Figure 1. The relationship between the catch and fishing effort of demersal fish.

The maximum production at Maximum Economic Yield (MEY) level ($C_{MEY}$) of 1,567.81 tons year$^{-1}$, as presented in Figure 2, was reached before the MSY level which was 1,569.39 tons year$^{-1}$ ($C_{MSY}$). The optimum number of fishing effort in MEY level is 3,211 units ($E_{MEY}$), which the amount is still under the amount of optimal fishing effort needed to

produce fish at MSY level of 3,316 units ($E_{MSY}$). This means that each fishing effort at the MEY level is more efficient than the fishing effort at the MSY level. So that the rent or economic benefit in the MEY condition is greater than the rent in the MSY condition.

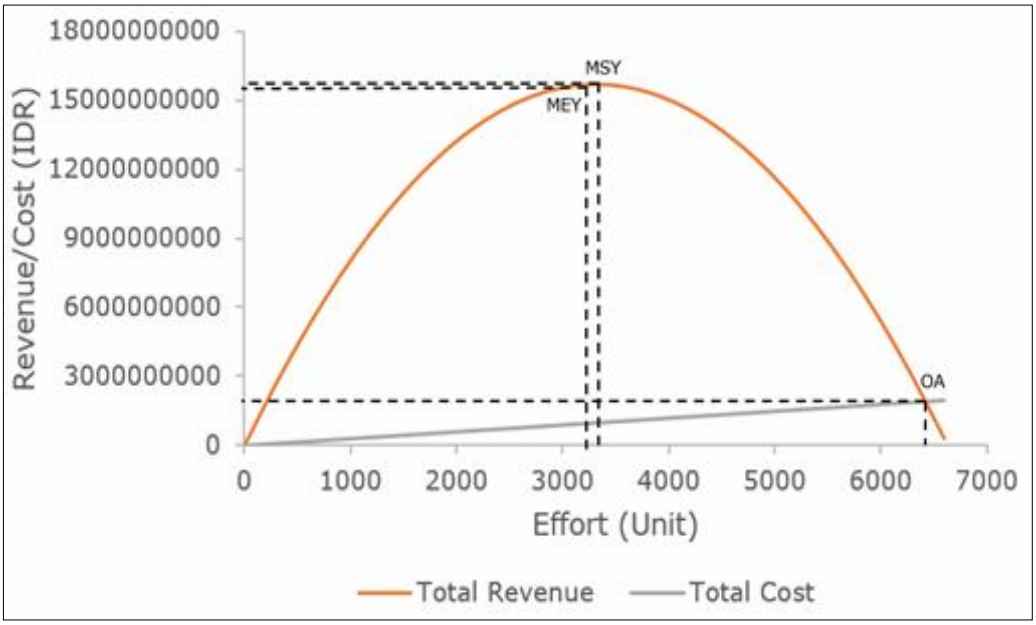


Figure 2. Gordon-Schaefer bio-economic balance for demersal fish management in the Banten Bay waters.

Figure 2 and Table 1 show the existence of three management positions, which are maximum economic yield (MEY), maximum sustainable yield (MSY) and open access (OA). The point of MSY illustrates the amount of maximum fish production that can be captured sustainably without damaging the sustainability of existing fish resources. The MEY point illustrated the conditions that can provide optimum benefits without damaging the sustainability of fish resources. The OA point describes the condition of the fishery, where each person is free to carry out fishing activities, where in this condition the amount of profit obtained is only able to cover operating cost (break-even point/BEP) (Fauzi 2010).

Table 1

Bio-economic optimization in each management positions

| *Variable* | *Actual* | *MSY* | *MEY* | *OA* |
|---|---|---|---|---|
| Catch (kg) | 849,390 | 1,569,385 | 1,567,808 | 192,679 |
| Effort (unit) | 882 | 3,316 | 3,211 | 6,423 |
| Revenue (IDR) | 8,493,900,000 | 15,693,848,600 | 15,678,079,829 | 1,926,790,016 |
| Cost (IDR) | 264,600,000 | 994,932,549 | 963,395,008 | 1,926,790,016 |
| Profit (IDR) | 8,229,300,000 | 14,698,916,051 | 14,714,684,821 | 0 |

The actual amount of demersal fishing effort is 882 unit and production of 849,390 kg. The actual utilization rate is 54% with the actual fishing effort rate of 27%. The actual condition of demersal fisheries is still below the condition of MEY management. This condition shows that the demersal fisheries in the Banten Bay waters have not been overfished. This condition is caused by a reduced number of boat seine operating in the Banten Bay waters.

The highest economic profit occurred at MEY level of IDR 14,714,684,821. It means the level of effort in MEY is more efficient than the level of effort in MSY (Figure 2 and Table 1). The utilization of demersal fish can still be optimized, but it needs to be done carefully and wisely so as not to cause damage to fish resources and the environment.

The use of boat seine in Banten Bay waters has been proven to cause a decline in demersal fish stock. The use of boat seine in the Istanbul Strait caused overfishing (Uzer et al 2017) and also in Kendal Regency water (Budiman et al 2006). The current demersal fishing in Banten Bay waters is dominated by the use of set gillnet. The fishing trips number of set gillnet continues to increase along with the prohibition policy on the use of boat seine. Gillnet is a recommended fishing gear to replace boat seine in the waters.

The use and addition of future fishing gear, therefore, need to be carried out very carefully and wisely. This is very important because biological sustainability will automatically support the economic sustainability of fishing businesses. This is important act to do because demersal fisheries in many regions as in Kendal Regency water (Budiman et al 2006); Mediterranean (Colloca et al 2017); India (Zacharia & Najmudeen 2017); Istanbul Strait (Uzer et al 2017) have experienced a tendency to decline due to overfishing. The world's marine fisheries had 33.1 percent of stocks classified as overfished (FAO 2018).

The optimization concept in bio-economic models according to Grafton et al (2000) and Sumaila & Hannesson (2010) is directed towards achieving the highest level of sustainable production and emphasized not to achieve the highest production level, but on the level of sustainable production that provides the highest efficiency.

Increasing the effort of fishing will increase the fish production which means it will be followed by increasing business revenue to MSY conditions, with the highest business occurs in MSY conditions. On the other hand, increasing the fishing effort will also be accompanied by increasing of fishing cost. Therefore, economic efficiency is reached during the MSY condition. If it continues to make additional fishing effort, it will reach an open access condition and continue until it reach zero point.

Open access condition of demersal fisheries will be achieved when the number of fishing effort ($E_{OA}$) reaches 6,423 units with production ($C_{OA}$) of 192.68 tons year$^{-1}$. The open access condition does not provide further benefits for fishermen. If further fishing effort are made, production will continue to decline and fishermen will not get a profit or will suffer losses.

Forcing a fishery to be unprofitable in the short term is also impractical, even if longer-term gains would be realized. Although a theoretical economist would argue that fishing is still worthwhile, the ability of fishers, many of whom may have experienced low levels of profitability in the past, to survive a period of negative profits may be limited because vessels still need to cover their variable costs (Dichmont et al 2010).

The use of the bio-economic model in this study is because the assessment of fish resources potential is not only based on biological models, but also based on its economic value. In fisheries bio-economic, the basic model uses biological theories and concept which are then combined with economic concept. The concept of bio-economics fisheries was developed because there were fears of the tragedy of the common in fisheries resources (Grafton et al 2000; Libecap 2009). If a fish resource becomes the joint or unclear property of its ownership, where each party can freely access it, the exploitation of fish resources cannot be controlled which results in over exploitation. If the use of fish resources exceeds the ability to recover of fish resources or stock regeneration, then the fish resources stock will decline and can lead to extinction. Therefore, the MSY approach was developed. At the MSY level, the utilization of fish resources does not disturb the sustainability of fish resources, where the catch is at the limit of the surplus production.

**Conclusions**. Demersal fishing in Banten Bay waters in terms of biology have not experienced a biological overfishing, as well as from economic perspective. The sustainable yield of demersal fish resources is 1,569.39 tons year$^{-1}$ with optimum fishing effort of 3,316 units. The highest economic profit was obtained in MEY of IDR 14,714,684,821. The actual utilization rate of demersal fisheries is 54% with the actual fishing effort rate of 27%. The actual condition of demersal fisheries is still under the condition of MEY management. The utilization of demersal fish can still be optimized, but it needs to be done carefully and wisely so as not to cause damage to fish resources and the environment.

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## References

Budiman, Supriharyono, Asriyanto, 2006 [Distribution analysis of demersal fish in Kendal Regency water as management basic of coastal resources]. Jurnal Pasir Laut 2(1):52-63. [in Indonesian]

Colloca F., Scarcella G., Libralato S., 2017 Recent trends and impacts of fisheries exploitation on Mediterranean stocks and ecosystems. Frontiers in Marine Science 4:244.

Dichmont C. M., Pascoe S., Kompas T., Punt A. E., Deng R., 2010 On implementing maximum economic yield in commercial fisheries. Proceedings of the National Academy of Sciences of the USA 107(1):16-21.

Dinas Kelautan dan Perikanan, 2018 Kelautan dan Perikanan Dalam Angka 2017. Dinas Kelautan dan Perikanan Provinsi Banten, Serang, 140 pp. [in Indonesian]

FAO, 2018 The state of world fisheries and aquaculture - meeting the sustainable development goals. Licence: CC BY-NC-SA 3.0 IGO, Rome, 227 pp.

Fauzi A., 2010 Ekonomi perikanan. Teori, kebijakan, dan pengelolaan. PT Gramedia Pustaka Utama, Jakarta, 224 pp. [in Indonesian]

Gordon H. S., 1954 The economy theory of a common property resources: the fishery. Journal of Political Economy 61(2):124-142.

Grafton Q. R., Squires D., Fox K. J., 2000 Private property and economic efficiency: a study of a common-pool resource. Journal of Law and Economics 43(2):679-713.

Pelabuhan Perikanan Nusantara Karangantu, 2017 Laporan Tahunan Pelabuhan Perikanan Nusantara Karangantu Tahun 2016. Pelabuhan Perikanan Nusantara Karangantu, Serang, 83 pp. [in Indonesian]

Libecap G. D., 2009 The tragedy of the commons: property rights and markets as solutions to resource and environmental problems. The Australian Journal of Agricultural and Resource Economics 53(1):129-144.

Schaefer M. B., 1975 Some aspect of the dynamics of population important to the management of commercial marine fisheries. Inter-American Tropical Tuna Commission Bulletin 1(2):27-56.

Sparre P., Venema S. C., 1998 Introduction to tropical fish stock assessment. Part I - Manual. FAO Fisheries Technical Paper 306, No. 1, Review 1, FAO, Rome, 376 pp.

Sumaila U. R., Hannesson R., 2010 Maximum economic yield in crisis? Fish and Fisheries 11(4):461-465.

Uzer U., Yildiz T., Karakulak F. S., 2017 Catch composition and discard of the boat seine in the Istanbul Strait (Turkey). Turkish Journal of Zoology 41:702-713.

Wiadnyana N. N., Badrudin, Aisyah, 2010 Tingkat pemanfaatan sumberdaya ikan demersal di wilayah pengelolaan perikanan Laut Jawa. Jurnal Penelitian Perikanan Indonesia 16:275-283. [in Indonesian]

Zacharia P. U., Najmudeen T. M., 2017 Diversity and exploitation status of demersal fishery resources in India. In: Course manual summer school on advanced methods for fish stock assessment and fisheries management. Lecture Note Series No. 2/2017. CMFRI; Kochi, pp. 32-46.

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