Bioeconomic analysis of the impact of 'cantrang' (Danish seine) toward gill net in Pati regency, Indonesia

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Abstract. 'Cantrang' (danish seine) is considered as an un-environmentally friendly fishing gear in Indonesia. Enhancement use of 'cantrang' caused a decrease in gill net fisheries production, including in Pati regency. Therefore, the Indonesian government issued a regulation prohibiting 'cantrang'. However, this regulation has caused a conflict of interest, between pros and cons. Then 'cantrang' ban regulation move from technical and regulation issues to social, economic and political issues. This research purpose was to analyze the effect of 'cantrang' to gill net fisheries production in Pati regency. This research used the Gordon-Schaefer model that has been modified by our research team. This research proved that our research model can be applied to estimate a relationship between gill net fisheries production and fishing effort of 'cantrang'. It is estimated that an average loss value of gill net fisheries production due to increase of 'cantrang' fisheries was 257 624 Kg per year during 2014 to 2017 that equal to IDR. 18 557 416 577 per year.
Key Words: bioeconomic, 'cantrang', gill net, multi-gears fisheries, Pati regency.

Introduction. Fish resource management is a multi-dimensional problem, that takes into account human activities, fish resources, aquatic environment, and technological progress. Therefore, fisheries resources management should pay attention to social interest, cultural, legal, economic, technological and natural resources (Wijayanto et al 2016). Fisheries business have high risk and uncertainty. This uncertainties are related to the fish populations dynamics, inaccuracies of fish stock size estimates, and inaccuracy of implementation in harvest quotas (Sethi et al 2005). Therefore, fisheries resource management is one of the most complex human activities. This is exacerbated by multi-species and multi-gears problem, so that interaction and conflicts of interest in fisheries is very high, including artisanal fisheries cases. Interaction between fishing gear cause problem of externalities and tragedy of the commons. Therefore, research in a multi-disciplinary approach is important, including biological and economic research, i.e by bioeconomic approaches (Padilla & Charles 1994; Brasão 2000; Pelletier et al 2009; Ulrich et al 2001; Cissé et al 2013; Guillen et al 2013; Evora 2016).

Through 'Permen KP No 2/2015', the Indonesian government has ban the use of 'cantrang' in the territorial waters of Indonesia. 'Cantrang' is a fishing gear type of boat seines or vessel seines. Conflicts of interest related to 'cantrang' ban regulation have become national issues, both technical, social, economic and political issues. The stakeholders who pro the prohibition of 'cantrang' argue that 'cantrang' is not an environmentally friendly tool, that has low selectivity of fishing gear. While another stakeholders argue that the ban of 'cantrang' will harm not only 'cantrang' fishermen (both owners and crews), but also cause decrease the supply of fish processing industry and others implications (Adhawati et al 2017a; Adhawati et al 2017b). There were several moment demonstrated the rejection of the 'cantrang' ban regulation, both in regency, provincial and national level.

Artisanal fishermen are part of stakeholders who tend to agree on the ban of 'cantrang'. Artisanal fishermen have an opinion that an enhancement in the number of 'cantrang' fishing gear has caused a reduction in artisanal fisheries production. Pati regency is one of regencies in Central Java Province and is a fishing base of 'cantrang'. Pati regency is also fishing base of artisanal fisheries, including fishermen who use gill nets. Therefore, research on fisheries interdependence needs to be done in Pati regency, including interrelated betwen 'cantrang' and gill nets fisheries. Based on the description above, it can be seen that the 'cantrang' problem is a crucial issue and needs to be studied, including in Pati regency. The bioeconomic approach can be used to analyze the relationship between 'cantrang' fisheries and gill nets fisheries. The purpose of this research was to analyze the effect of 'cantrang' to gill nets fisheries in Pati regency.

Material and Method

Research location. Location of this research was in Pati regency. Fishermen villages can be found along the coastal of Pati regency. This research was carried out in March to May 2018 on several fishing bases, including in PPP (coastal fishing port) Bajomulyo, PPI (fish landing place) Alasdowo, PPI Banyutowo, PPI Margomulyo, PPI Pecangaan, PPI Puncel and PPI Sambiroto. Location of Pati regency could be seen on the map in Figure 1.

Figure 1. Map of Pati regency.

Data collection. Our research object is fisheries of 'cantrang' and gill net in Pati regency. We used survey to collect data of cost and price. We also used data of production and fishing effort that were published by DKP Kabupaten Pati (government agency). Interviews were conducted on 90 fishermen of gill net. We observed 7 fishing ports in Pati regency.

Research model. The bioeconomic model can be grouped into two types, i.e. behavioral model and optimization model (Padilla & Charles 1994). The bioeconomic model can also be used to analyze technical interactions of multi-gears fisheries (Ulrich et al 2001). The bioeconomic model basis used in this study is a model of Gordon-Schaefer (Sobers 2010; Wijayanto et al 2016). The Gordon-Schaefer model was modified to analyze the interdepency of two types of capture fisheries, namely industrial fisheries ('cantrang') and gill net fisheries. This study used some of the following equations:

$$C_G = a.E_G - b.E_G^2 \tag{1}$$

$$E_{G.MSY} = \frac{a}{2.b} \tag{2}$$

$$C_{G.MSY} = \frac{a^2}{4.b} \quad (3)$$

$$E_{G.MEY} = \frac{p.a - c}{2.p.b} \quad (4)$$

$$E_{G.OAE} = \frac{p.a - c}{p.b} \quad (5)$$

$$TR_G = p.C_G \quad (6)$$

$$TC_G = c.E_G \quad (7)$$

$$\Pi_G = TR_G - TC_G \quad (8)$$

$$C_{GC} = C_G(1 - d.E_C) \quad (9)$$

where: C_G is the production of gill net fisheries (kg per year) before ‘cantrang’ increase;
E_G is the amount of gill net that operates (unit of fishing effort);
$C_{G.MSY}$ is gill net production (kg per year) before ‘cantrang’ increase on maximum sustainable yield (MSY) condition;
$E_{G.MSY}$ is the amount of gill net (unit of fishing effort) on MSY conditions;
$E_{G.MEY}$ is the amount of gill net (unit of fishing effort) on maximum economic yield (MEY);
$E_{G.OAE}$ is the amount of gill net (unit of fishing effort) on open access equilibrium (OAE);
TR_G is total gill net revenue (IDR per year);
TC_G is total gill net cost (IDR per year);
π_G is gill net profit (IDR per year);
C_{GC} is the production of gill net (kg per year) which is influenced by increased intensity of ‘cantrang’ use;
E_C is the number of ‘cantrang’ that operate (unit);
a, b and d are constants;
p is fish price of gill net catch (IDR per Kg);
c is the cost per unit of gill net fishing effort (IDR per year).

By performing a regression of $CPUE_G$ (ie C_G/E_G) and E_G, then value of a (intercept) and b (slope) are obtained. The slope of the C_{GC}/C_G and E_C regression can be used to estimate the value of d. C_{GC} is obtained by reducing actual gill net production (at the moment of ‘cantrang’ increase) with estimation of C_G value using equation (1). To estimate an amount of gill net in unit on minimum gill net production, minimization process could be done through the first derivative of equation (9) to E_G equal to zero, or to E_C equal to zero. The minimization process produces the following equations:

$$E_{GM} = \frac{a}{b} \quad (10)$$

$$E_{CM} = \frac{1}{d} \quad (11)$$

where: E_{GM} is E_G when C_G is equal to zero;
E_{CM} is E_C when C_{GC} is equal to zero.

If the revenue equation of the gill net fisheries after ‘cantrang’ increase is formulated using combination of equations (9) and (6) so generate the following equation:

$$TR_{GC} = p.C_{GC} \quad (12)$$

where: TR_{GC} is the total revenue of gill net fisheries after increase of ‘cantrang’ fisheries operation.

Furthermore, the equation (12) be combined in equation (8) will generate an equation (13), ie the profit of gill net fisheries after 'cantrang' increase (Π_{GC}):

$$\Pi_{GC} = TR_{GC} - TC_G \quad (13)$$

If equation (13) is maximized by both constraint to E_C equal to zero and also E_G equal to zero, it will be obtained that the maximum profit of gill net fisheries occurs when E_C is equal to zero. The loss value of gill net fisheries production that be caused of increasing usage of 'cantrang' can be estimated with the following equations:

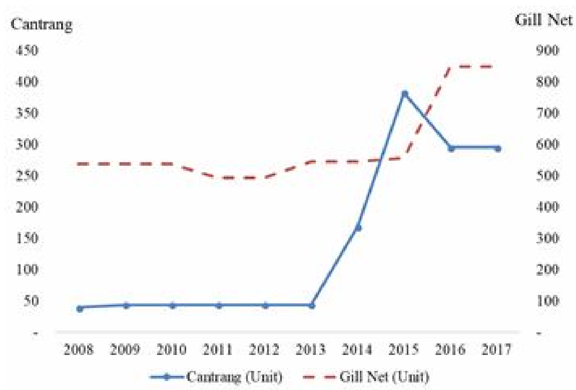
$$LC_G = C_G.d.E_C \quad (14)$$

$$LTR_G = LC_G.p \quad (15)$$

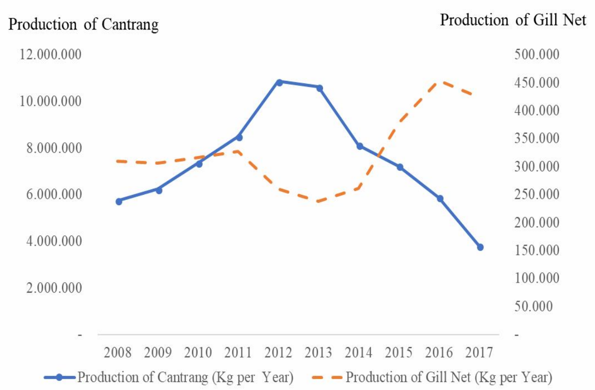
where: L_{CG} is loss of gill net production due to 'cantrang' operation (kg per year);
LTR_G is loss revenue from gill net fisheries due to 'cantrang' operation (IDR per year).

Results and Discussion. Pati regency has 7 fishing ports, namely PPP Bajomulyo, PPI Pecangaan, PPI Margomulyo, PPI Sambiroto, PPI Banyutowo, PPI Puncel, and PPI Alasdowo. Of the seven ports, only PPP Bajomulyo and PPI of Banyutowo are fishing base of industrial fisheries, that is purse seine, 'cantrang' and long-line. PPI Banyutowo is a fishing base of industrial fisheries and artisanal fisheries. While PPI Pecangaan, PPI Margomulyo, PPI Sambiroto, PPI Puncel, and PPI Alasdowo are fishing base for artisanal fisheries.

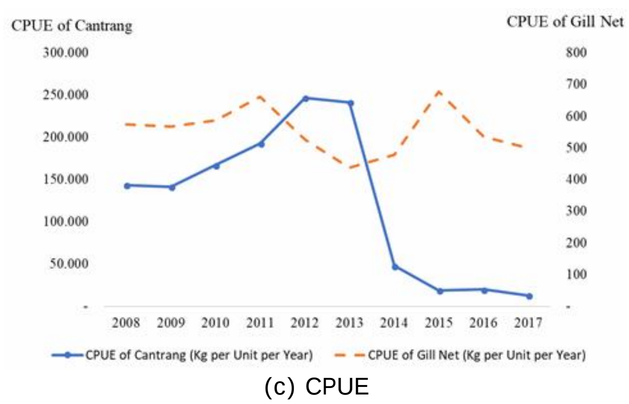
The progress of gill net and 'cantrang' fisheries. The progress of 'cantrang' in Pati regency has increased significantly since 2014. The relationship between 'cantrang' production and gill net production is relatively opposite. At the time of production 'cantrang' rise, then the gill net production tends to go down, and vice versa. While catch per unit effort (CPUE) of 'cantrang' tend to decrease drastically, especially starting in 2014 (Figure 2).



(a) Number of unit



(b) Production



(c) CPUE

Figure 2. Number of gill net and 'cantrang', production and cpue.

Multi-gears fisheries have a vulnerability to conflict of interest, including the relation between industrial and artisanal fisheries. 'Cantrang' is an active fishing gear that operates until touch the bottom of the seawaters. The catch of 'cantrang' is not selective. The various types of fish and various sizes are caught by 'cantrang'. Therefore ‘cantrang’ fisheries is considered as a non-selective fishing gear and cause of decreasing the production of artisanal fishermen. Moreover, ‘cantrang’ operated on the north coast of Java has been modified and not in accordance with national standards, i.e SNI No 01-7236-2006 (Badan Standarisasi Nasional 2006; Riyanto et al 2011; Sasmita 2013), so that the fishing power increase, including in Pati regency. Fishermen of ‘cantrang’ extended the length of the net, and reduced the mesh size. Fishing operation of ‘cantrang’ is similar to trawl operation that pulled by vessel. Therefore, Adhawati et al (2017b) mentioned cantrang with the term 'Danish trawl'. At the present, a length of the warp rope of ‘cantrang’ on the north coast of Java can reach 1000 m (Sasmita 2013).

Trawl is indeed a fishing gear that has a big catch, but not selective. The trawl operation has relatively large by-catch. The part of the trawl catches are under-size fish, similar to 'cantrang'. Some countries have banned the trading of under-sized fish, and push the fishermen to modify trawl, including enlarging a mesh size (Ulrich et al 2001; Prellezo et al 2017).

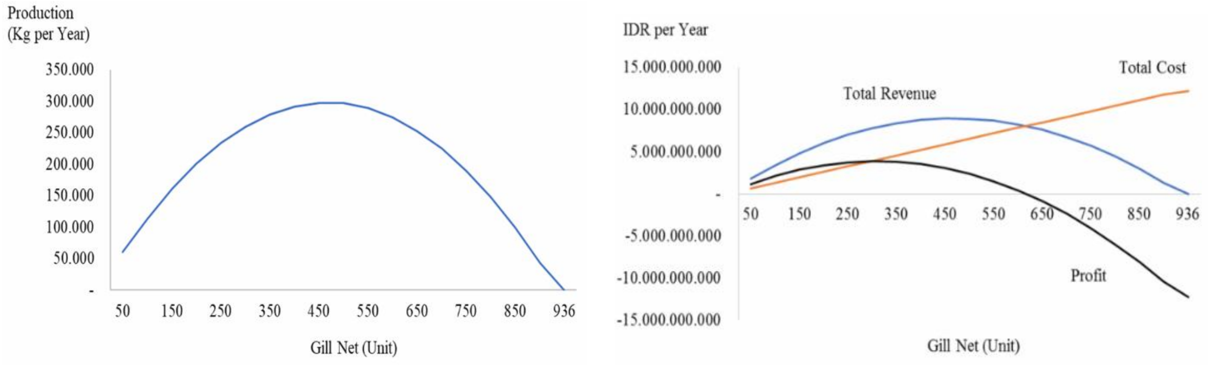
Fisheries of gill nets before increasing number of ‘cantrang’. Indonesia is the largest archipelagic country in the world, with 2/3 of Indonesia is seawaters. Indonesia has more than 17,000 islands and located in tropic area (BPS-Statistics Indonesia 2016). These natural conditions caused Indonesian waters to be rich in fish resources. However, the management of fish resources in Indonesia still needs to be improved. The exploitation of fish resources in Indonesia is still open access. As a result, the phenomenon of overfishing occurs in some types of fish resources in certain areas (Wijayanto et al 2016). Restrictions on fishing activities are vulnerable to rejection by fishermen. But most nations in the world have implemented input/effort control (restricting access, fishing gear, times of fishing, or fishing ground) as total allowable effort (TAE) and output controls, i.e total allowable catch (TAC), and individual transferable quota (ITQ) (Edvardsson et al 2011).

This research analysis shows that the MSY level for fisheries of gill net is 468 units. But that number has been exceeded, even when the number of 'cantrang' has not increased significantly yet. While the MEY level for fisheries of gill net is 228 units (Table 1). The reduction in the number of gill net fisheries at both on the MEY and MSY levels is not easy, mainly due to social factor considerations. The curve that describes the relationship between production, revenue, cost and fishing effort in the gillnet fisheries can be seen in Figure 3.

Table 1

MSY, MEY and OAE for fisheries of gill net

	MSY	*MEY*	*OAE*
Production (kg per year)	298 255	220 165	298 092
Gill net (unit)	468	228	457
Total revenue (IDR per year)	21 484 166 749	17 652 129 150	20 965 790 644
Total cost (IDR per year)	18 146 970 519	10 482 895 322	20 965 790 644
Profit (IDR per year)	3 337 196 230	7 169 233 828	-
Equation of $C_G(E_G)$	$C_G = 1275\ E_G - 1.36\ E_G^2$		
p (IDR per kg)	72 033		
c (IDR per unit gill net per year)	38 793 914		



a. Production and fishing effort. b. TR, TC, profit and fishing effort.

Figure 3. Production, TR, TC, profit and fishing effort of gill net.

Relationships between 'cantrang' fisheries and gill net fisheries. Fisheries of 'cantrang' significantly increased in Pati regency starting with 2014. At the time of fish resource conditions overexploited and CPUE decreased, pushed the fishermen to make modifications of fishing gear to increase the catching power of fishing gear, including increasing the length of net and reducing the mesh size. Our research shows the relationship between a gill net production after 'cantrang' increase (C_{GC}) and the number of 'cantrang' (fishing effort) following the equation:

$$C_{GC} = C_G(1 - 0.00472E_C) \quad (16)$$

Increasing the number of 'cantrang' fishing gear pushes the production of gill net to decrease. 'Cantrang' has a bigger fishing power than gill net. 'Cantrang' also captures various types of fish sizes, including fish that become fish targets for gill net, therefore the production of gill net will be affected. Artisanal fisheries in tropical seawaters is usually a multi-species and multi-gears, including in Pati regency. Therefore, the complexity of artisanal fisheries is relatively high because of the conflict of interest. There is complex interaction, both inter-species, between species and between fishing gears (Padilla & Charles 1994). However in this research, we focused on the relationship between 'cantrang' fisheries and gill net fisheries (multi-gears).

Given that 'cantrang' increase is proven to decrease gill net production, therefore it is necessary to develop a win-win solution. Such management may be either license restrictions or total allowable catch (TAC). However, the application of fish resources management will experience social challenges because fishermen in Pati regency are already familiar with the present management pattern. In principle, there is a decline in fish stocks and decreased productivity on the open access equilibrium that results in a decrease in profits of fisheries (Brasão 2000; Wijayanto et al 2016).

The loss value of gill net fisheries. An enhancement 'cantrang' fisheries units push more loss, both on production and income for gill net fisheries. Our research shows that the production of gill net fisheries is theoretically down to zero if the number of business actors of 'cantrang' reaches 212 units. The curve in Figure 4 shows the relationship between the number of 'cantrang' fishing gear and gill net production and the loss of gill net production. This simulation uses scenario of gill net production amount under MSY condition.

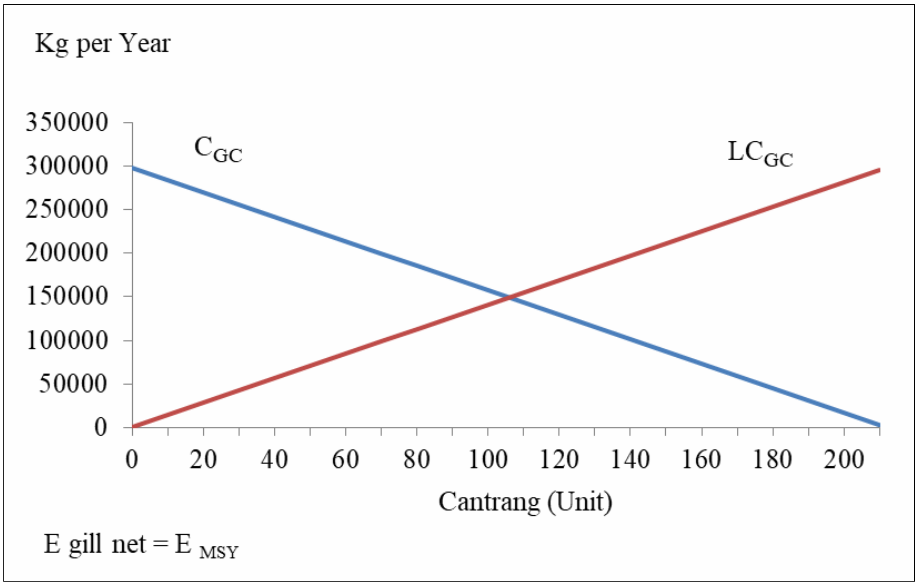


Figure 4. Number of 'cantrang', production of gill net and production loss of gill net (C_{GC} = gill net production that is influenced by cantrang fishing effort; LC_{GC} = loss of gill net production that is influenced by cantrang fishing effort).

Table 2 shows estimates of decreased gill net production and decreased revenues of gill net. If averaged, then in the period 2014 to 2017, production loss of gill net was 257 624 kg per year or equivalent to IDR 18 557 416 577 per year.

Table 2

Estimation of production and income loss of gill net fisheries

Years	*Production loss estimation (kg per year)*	*Income loss estimation (IDR per year)*
2014	231 312	16 662 068 556
2015	519 233	37 401 935 574
2016	139 975	10 082 831 088
2017	139 975	10 082 831 088

Fisheries of gill net should be protected. Several research have shown that gill net fishing gear is selective (Hay et al 2008; Li et al 2017). The gill net is also a main fishing gear for artisanal fishermen. Therefore, the Indonesian government needs to regulate the management of artisanal fisheries and industry so that industrial fisheries do not push artisanal fisheries. According to Blankenhorn (2007), artisanal fisheries in Indonesia is very important, because 75% of fishing vessels are not motor-driven in 1977-1995. The majority of fishermen depend on coastal resources close to the beach. Artisanal fisheries involve skilled but non-industrialized operators.

Conclusions. Based on the research result, it can be concluded that the relationship between 'cantrang' production and gill net production is opposite. At the time of production 'cantrang' rise, then the gill net production tends to go down. The relationship between 'cantrang' and gill net fisheries in Pati regency follow the equation: $C_{GC} = C_G\ (1-0.00472\ E_C)$. It is estimated that the average loss of gill net fisheries due to 'cantrang' operation was 257 624 Kg per year and equivalent to IDR. 18 557 416 577 per year.

Acknowlegedments. Our research team would like to thank for FPIK - Diponegoro University who has funded this research. We also thank to Nur Arif Setiawan for his support in data collection process.

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Received: 21 August 2018. Accepted: 26 November 2018. Published online: 17 January 2019.
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How to cite this article:
Wijayanto D., Sardiyatmo, Setyanto I., Kurohman F., 2019 Bioeconomic analysis of the impact of ‘cantrang’ (Danish seine) toward gill net in Pati regency, Indonesia. AACL Bioflux 12(1):25-33.