BIODIVERSITAS
Volume 19, Number 3, May 2018
Pages: 927-935

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d190323

An analysis of capture fisheries resource depletion in Cirata Reservoir, West Java, Indonesia

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Manuscript received: 14 May 2017. Revision accepted: 29 April 2018.

Abstract. *Anna Z. 2018. An analysis of capture fisheries resource depletion in Cirata Reservoir, West Java, Indonesia. Biodiversitas 19: 927-935.* Fisheries in public waters such as the Cirata Reservoir in West Java, Indonesia are potential economic resources that should not be ignored. They play an important role in food security for the surrounding communities. Unfortunately, natural capture fisheries in Cirata Reservoir have received less attention in the past than aquaculture which dominates economic activity in the waters. Recently, the condition of the dam has deteriorated as a result of major aquaculture activity with extensive use of artificial feedstock; an increase in industrial and domestic waste entering the waters; and open access fisheries management that has allegedly caused depletion of the natural fish resources of the waters. From time to time there have been observed declines in the natural capture fisheries production. The research reported in this paper aimed to estimate the extent of this depletion and associated economic depreciation of capture fish resources in the Cirata Reservoir. Bio-economic methods were used to calculate the potential sustainable utilization of the resources. The analytical model of Logistic Gordon-Schaefer (GS) and Fox models provided the framework for the analysis. The fish depletion was calculated by comparing the potential sustainable utilization and the value of the actual utilization, based on quarterly data for the years 2011 up to 2016. Depreciation was calculated in terms of unit rent loss as a result of the depletion. The analysis showed that depletion of fish resources occurred in certain quarters between years of 2011 to 2016. The value of the total depletion over this period for the GS model amounted to 835.13 tons with an estimated value for depreciation of IDR 5.93 Billion, or IDR 84.71 Billion in Present Value term. For Fox Model, the depletion reaches 1421.35 Ton, with a value of IDR 10.09 Billion, or 144.17 Billion in Present Value term. This value represents the economic loss due to depletion of the fisheries resource in Cirata Reservoir. The policy implication of this fish depletion is that there is a need for better management of the aquatic habitat, by reducing water pollution load, and by regulation of capture fisheries through input/output restrictions based on the conceptual tools of Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY).

Keywords: Bio-economy, Cirata Reservoir fisheries, CYP, depletion, depreciation, Fox, Gompertz, Gordon-Schaefer, MEY, MSY

INTRODUCTION

Among the wide variety of aquatic habitats sustaining fish resources in Indonesia, artificial lakes and dams have particularly important economic potential for communities in West Java. Although the original construction of these reservoirs was for diverse socio-economic purposes such as generation of electricity, irrigation of agricultural lands, recreation, etc., the subsequent use of reservoirs, especially in West Jawa, has often been for the development of fisheries; natural capture fisheries, as well as aquaculture. The Cirata Reservoir in West Java, Indonesia is a particular example of this.

In general, it is rather uncommon for dam fisheries to provide a high economic contribution to local economics and to become the foundation of livelihoods for surrounding communities. This is more clearly observed in the case of natural capture fisheries rather than in aquaculture (Dirican 2014). Aquaculture, involving a fairly expensive investment, is a less desirable option for local communities, who have limited financial capacity. Rather, aquaculture is a more attractive option for investors from big cities who view the surrounding communities only as sources of labor in their aquaculture ventures. The natural capture fishery is often the preferred option for communities around lakes/dams, because, in addition to representing a more modest financial investment, natural fisheries can also be a foundation for food security in the communities who often cannot afford to buy other foodstuffs. Thus, natural fishery activities are not only carried out for commercial purposes, but also for subsistence (Kyomuhendo 2002; Petr 2003; Trasande et al. 2010).

Fisheries such as in Cirata do not usually receive the attention and management care that aquaculture receives, because it is often perceived not to contribute as much to the wider economy as does aquaculture. Often local fisheries have to face negative externalities from various activities both on water and on land. This includes habitat destruction arising from pollution: by feedstock residues from the aquaculture industry; by wastes from industry in the vicinity; and by domestic waste. Another aspect that receives less attention than it deserves, is the management of the natural fishery activity itself. The unregulated management of the fishery often results in the waters being over-fished, and the fish-stock in the reservoirs being depleted beyond sustainable self-replacement levels.

To overcome these problems, structured research is needed regarding the condition of fishery resources in the

Cirata Reservoir. There needs to be an analysis of the extent of depletion of the fishery resource arising from uncontrolled exploitation as well as from other other causes. Oosten (1949) defined the depletion of fish resources as a condition where a decline, due to overfishing on a segment of the stock abundance, lowers the maximum productive capacity of the resources. The study reported in this paper was carried out to accurately assess the condition of the Cirata Reservoir fishery and to measure the extent to which the natural fishery potential has been depleted and to determine what this implies in terms of economic depreciation of the resource.

MATERIALS AND METHODS

There has not been a lot of research on resource depletion and depreciation of fisheries in man-made lakes and reservoirs in Indonesia. For marine fisheries, Tai et al. (2000), carried out research into resource depletion and depreciation using the net present value method to calculate the value of changes in a fishery resources over an interval of one year. However, in our study, we used a model developed by Amman and Durraipah (2001) for land resources and by Anna (2003) for fisheries, which assumes that the degradation will follow a logistic function.

For applications in fishery resources, the formula for degradation rate of Amman and Durraipah (2001) is used with the adjustment, as follows:

$$D_t\% = \frac{hs_t - ha_t}{hs_t} \quad (1)$$

Where:
D_t : Degradation percentage at t
hs_t : Sustainable production at t
ha_t : Actual production at t

While the depletion rate coefficient is calculated based on the following equation:

$$f\,D_t = \frac{1}{1 + e^{\frac{hs_t}{ha_t}}} \quad (2)$$

As for the depreciation rate, it is basically similar to the degradation rate, except that it uses economic parameters as follows:

$$f\,R_t = \frac{1}{1 + e^{\frac{ps_t}{pa_t}}} \quad (3)$$

Where:
fR_t : Depreciation rate
ps_t : Sustainable rent
pa_t : Actual rent

The depletion value itself is the difference between sustainable production and actual production. Meanwhile the depreciation can be calculated by multiplying the unit of rent which is the ratio of rents and the amount of production in t, to the depletion in ton. Depreciation also can be calculated by using the difference between sustainable rent and actual rent. The calculation of present value is used to determine the present depreciation value, using the market discount rate on average throughout the year 2011 to 2016, that was 7%.

To obtain the value of sustainable production, we first carried out a standard bio-economic analysis, using both Logistic and Gompertz models, as follows: to

Logistic form:

$$\frac{\partial x_t}{\partial t} = r x_t \left(1 - \frac{x_t}{K}\right) - h_t \quad (4)$$

Gompertz form:

$$\frac{\partial x_t}{\partial t} = r x_t \ln\left[\frac{K}{x_t}\right] - h_t \quad (5)$$

Where: x_t is biomass at t (time), h is the harvest or production, r is the intrinsic growth rate, K is the environment carrying capacity. The logistic functional form is symmetrical, while Gompertz is not. Furthermore, it is assumed that the harvest rate is linear to the biomass and effort, as written below:

$$h_t = qE_t x_t \quad (6)$$

Where q is a coefficient of catching ability and E_t is the effort in unit of trip. Trip is defined as frequency of travel for fishing yearly. By assuming the equilibrium condition, the sustainable yield-effort curve from the two functions above could be written as:

$$\text{Logistic: } h_t = qKE_t - \left[\frac{q^2 K}{r}\right] E^2$$
$$\text{Gompertz:: } h_t = qKE_t \exp^{\left[\frac{-qE}{r}\right]} \quad (7)$$

The estimation of parameters r, K and q for the yield effort equation from both models above (Logistic and Gompertz) involves non-linear techniques. However, by writing $U_t = h_t/E_t$, (catch per unit effort), equation (10) could be transformed into a linear equation so that ordinary regression methods can be used to estimate the biological parameters of the above functions. In this study, the parameter estimation technique developed by Clarke et al. (1992) (commonly known as the CYP method) and the Fox algorithm (Fox 1970), were used to estimate the parameters r, q, and K through the following equation:

CYP:

$$\ln(U_{t+1}) = \frac{2r}{2+r)}\ln(qK) + \frac{(2-r)}{(2+r)}\ln(U_t) - \frac{q}{(2+r)}(E_t + E_{t+1}) \quad (8)$$

Fox:

$$\frac{U_{t+1} - U_{t-1}}{2U_t} = rLn(qK) - r\ln(U_t) - q\ln(E_t) \quad (9)$$

Quarterly production and effort time series data (catch and effort) for 5 years (2011-2015) were collected from Fish Landing Centre in the study areas. This data was used as the basis for the calculation of the yield-effort curve using Stata® and Excel® software. Three types of fishing gear are used in the area of study: gillnets, cast nets and fishnets. To obtain the correct value of the unit effort, the entire unit effort had to be standardized using King (1995) formula, based on the Gill net. Market information regarding the cost per unit effort and the price per unit of the fish landed were obtained from survey data. The entire financial data was converted into real values, by adjusting nominal values to the consumer price index. Given that time series data is not available for cost per unit of effort, the calculation technique of Tai et al. (2000) was used to convert cross-section data to time series costs, by aligning the values according to the consumer price index. Primary data for costs in 2015 were obtained from interviews with 40 respondents from the population of 4580 fishermen in the area, experienced in using the three existing types of fishing gear. The number of respondents is calculated using the formula of Fauzi (2001), as follows:

$$s = \frac{NZ^2(0.25)}{\{d^2(N-1)\} + \{Z^2(0.25)\}} \tag{10}$$

Where:
s : Taken samples
N: Total population
Z: standard of deviation
d : Level of precision (5 or 10%)

The calculation of production and effort optimal values and of economic rents was carried out numerically using the MAPLE 17.0 $_{(R)}$ software.

RESULTS AND DISCUSSION

Bio-economic analysis of Cirata Fisheries

Bio-economic analysis was used to understand the dynamics of utilization of the fishery resource in Cirata Reservoir. As described above in the Methods section, the bio-economic analysis used Logistic and Gompertz models, with parameters estimated by the Clark, Yoshimoto, and Pooley algorithm (CYP) (Clarke et al. 1992) and the Fox algorithm (Fox 1970).

Cirata fisheries production per quarter for the period 2011 to 2015 can be seen in Figure 1. Fisheries production in Cirata decreased from year to year with the lowest production occurring in the 3rd quarter of 2013 when the total production was only 128.32 tons. Figure 2 presents similar quarterly data for the standardized catch per unit effort (CPUE), using gillnet as a standard. As can be seen from the graphs, the CPUE tends to decrease quarterly, this is due to the decrease in production, while the effort tends to increase from year to year, causing the productivity of fisheries in this region to be decreased.

To obtain the biological parameters, calculations using various models including those of Schaefer (Schaefer 1954), CYP (Clarke et al. 1992), Fox (1970), Walter Hilborn (1971), Schnute (Schnute 1977), and Pella Tomlinson (Pella and Tomlinson 1969) were initially performed using Stata and Excel. However, CYP and Fox models were the only two that had robustness with good statistical performance (i.e., that met the criterion for a Best Linear Unbiased Estimator).□

From Table 1, above, it appears that the values for intrinsic growth (r) determined by Fox and CYP algorithms did not differ much. On the other hand, the value for environmental carrying capacity (K) determined by the Fox algorithm was somewhat larger than the value determined by the CYP algorithm, while the reverse was the case for the estimation of catchability coefficient (q).

Among the variable costs and prices needed to calculate the optimal values for sustainable fisheries in Cirata, the fishing costs per trip, including for gasoline consumption, amounted to an average of Rp. 22.500 per trip of fishing. In the case of fish prices, the average nominal prices for captured fish of all species traded in Cirata was adjusted to real values using the Consumer Price Index based on the year 2007 (Table 2). The average Real Price for traded Cirata fish, across the six years from 2011 to 2016 was 13.6 million rupiah per ton.

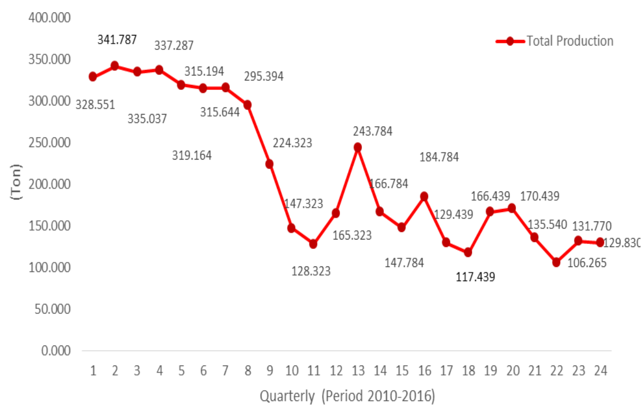

Figure 1. Production per quarter of the Cirata fishery, West Java, Indonesia

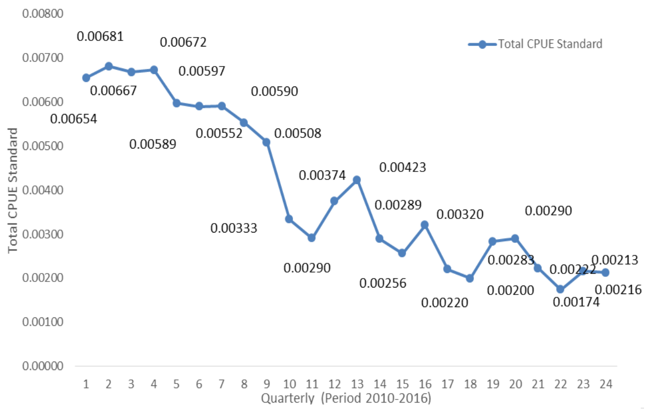

Figure 2. Total catch per unit effort (standardized CPUE) per quarter for the Cirata fishery, West Java, Indonesia

Table 1. Estimation of biological productivity parameters for the Cirata fishery, West Java, Indonesia using Fox and CYP algorithms

Parameters	Fox algorithm	CYP algorithm
Intrinsic growth (r)	0.231474	0.173348
Carrying capacity (K) ton	4138.53	2673.83
Catchability coefficient (q)	0.00000258	0.000004

Table 2. Real price (thousand rupiahs/ ton) of caught fish traded in the Cirata districts, West Java, Indonesia across the years 2011 to 2016 inclusive

Year	Nominal price	Real price
2011	7816.92	11612.58
2012	11648.70	12022.52
2013	9143.60	12885.26
2014	10726.32	13795.52
2015	13513.15	15575.05
2016	11250.00	15476.63
Total	64098.69	81367.56
Average	10683.1151	13561.26

Depletion and depreciation analysis of Cirata Fisheries

To measure the extent of depletion and financial depreciation of fisheries in Cirata, a comparison was first made between the actual and the estimated sustainable fisheries in the research site. To estimate the values for sustainable production, following Anna et al. (2017), the two following model scenarios were used: (i) the Logistic Model, by using parameters estimated from the Fox algorithm; (ii) the Fox/Gompertz model using parameters estimated from the CYP algorithm.

For the Logistic Model, the results are presented in the time series graph in Figure 3. From Figure 3, it can be seen that the actual catch exceeded the estimated sustainable catch in 2011 and 2012, and in the first quarter of 2014. Furthermore, the actual capture fell below the estimated sustainable catch in 2013, and a little below the estimated sustainable catch from the second quarter of 2014 through to the last quarter of 2016.

The shape of the time series curve for sustainable catch based on a Gompertz model was not much different from the curve based on the Logistic model. However, the absolute values for estimated sustainable catch in every quarter obtained with the Gompertz model were well below the estimates obtained using the Logistic model. Thus, it can be seen that the sustainable catch in 2011-2012 and the first quarter of 2014 estimated by the Gompertz model was below the estimates obtained from the Logistic mode, and far below the actual catch taken in the Cirata waters in those quarters. The Gompertz model estimates suggested that there was considerably greater likelihood of overfishing than suggested by the Logistic model. In accordance with the precautionary principle, it would appear that the Gompertz model might be a safer guide than the logistic model for use in directing fisheries policy in the Cirata waters.

For the Gompertz model, the comparison between sustainable catch and actual catch is presented in Table 4.

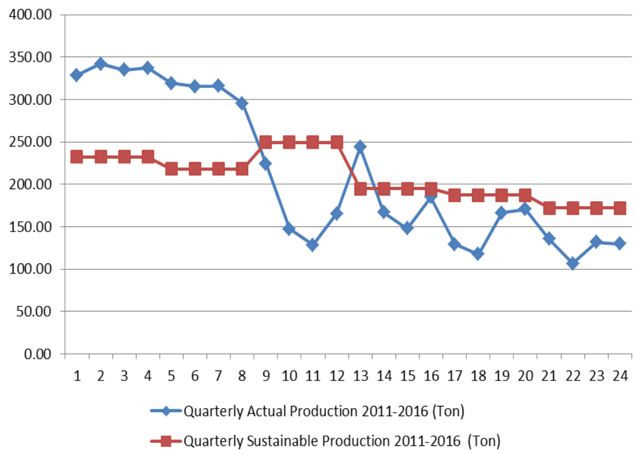

Figure 3. Comparison between the actual quarterly fish catch values from the Cirata Reservoir waters, West Java, Indonesia and the estimated sustainable catch values based on a Logistic model

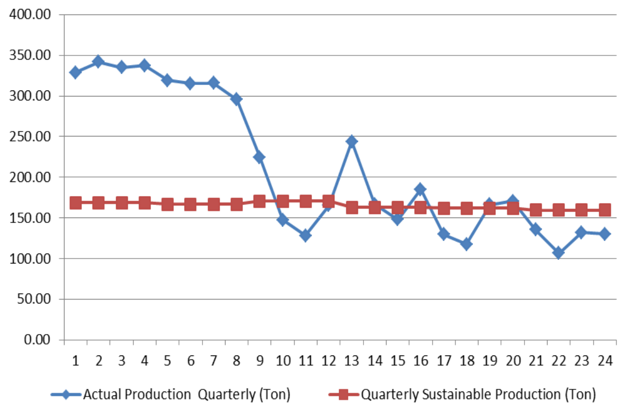

Figure 4. Comparison between the actual quarterly fish catch values from the Cirata Reservoir waters, West Java, Indonesia, and the estimated sustainable catch values based on a Gompertz model

Our study then went on to estimate depletion and depreciation values for the Cirata fisheries by first calculating the quarterly values of unit rent in the industry. Table 3 summarises the results of the calculation of unit rent values.

As shown in Table 3, along with the decrease in actual production from year to year, the economic rent of fish resources in the region also decreased from year to year, as did the unit rent. In considering the issue of sustainable yields, it is important to note that the lowest values for these parameters were obtained in the quarters of the last two years, 2015 and 2016. This suggests that, indeed, overfishing had occurred particularly in the early years of the period 2011-2016.

The average unit rent value across the six years of observation was 7.1 million IDR/ton, which was then used for the calculation of depreciation in the fishery resources of Cirata waters. Table 4 summarises the results of the calculation of resource depletion and depreciation per quarter over the six years, based on the Logistic model estimation of sustainable catch.

Table 3. Calculated financial values for rent and unit rent in each quarter over the years 2011-16 for the Cirata's fisheries, West Java, Indonesia

Year	Quarter	Actual production (ton)	Effort (trip)	Total Revenue (million IDR)	Total Cost (million IDR)	Rent (million IDR)	Unit rent (million IDR/Ton)
2011	1	328.55	50215.87	4468.29	1129.86	3338.43	10.16
	2	341.79	50215.87	4648.30	1129.86	3518.44	10.29
	3	335.04	50215.87	4556.50	1129.86	3426.64	10.23
	4	337.29	50215.87	4587.10	1129.86	3457.24	10.25
2012	5	319.16	53476.47	4340.64	1203.22	3137.41	9.83
	6	315.19	53476.47	4286.64	1203.22	3083.42	9.78
	7	315.64	53476.47	4292.76	1203.22	3089.54	9.79
	8	295.39	53476.47	4017.36	1203.22	2814.14	9.53
2013	9	224.32	44176.47	3050.79	993.97	2056.82	9.17
	10	147.32	44176.47	2003.59	993.97	1009.62	6.85
	11	128.32	44176.47	1745.19	993.97	751.22	5.85
	12	165.32	44176.47	2248.39	993.97	1254.42	7.59
2014	13	243.78	57661.22	3315.46	1297.38	2018.08	8.28
	14	166.78	57661.22	2268.26	1297.38	970.88	5.82
	15	147.78	57661.22	2009.86	1297.38	712.48	4.82
	16	184.78	57661.22	2513.06	1297.38	1215.68	6.58
2015	17	129.44	58840.93	1760.38	1323.92	436.45	3.37
	18	117.44	58840.93	1597.18	1323.92	273.25	2.33
	19	166.44	58840.93	2263.58	1323.92	939.65	5.65
	20	170.44	58840.93	2317.98	1323.92	994.05	5.83
2016	21	135.54	60984.94	1843.34	1372.16	471.18	3.48
	22	106.27	60984.94	1445.27	1372.16	73.11	0.69
	23	131.77	60984.94	1792.07	1372.16	419.91	3.19
	24	129.83	60984.94	1765.69	1372.16	393.53	3.03

Table 4. Fishery resources depletion and depreciation in the Cirata waters, West Java, Indonesia based on the Logistic model estimation of sustainable catch

Year	Quarter	Actual production (ton)	Sustainable production (ton)	Depletion (ton)	Depreciation (million IDR)	PV depreciation million IDR (δ=7%)
2011	1	328.55	232.33	-96.22	-683.15	-9759.26
	2	341.79	232.33	-109.45	-777.12	-11101.78
	3	335.04	232.33	-102.70	-729.20	-10417.13
	4	337.29	232.33	-104.95	-745.17	-10645.35
2012	5	319.16	218.16	-101.00	-717.13	-10244.74
	6	315.19	218.16	-97.03	-688.94	-9842.07
	7	315.64	218.16	-97.48	-692.14	-9887.71
	8	295.39	218.16	-77.23	-548.36	-7833.78
2013	9	224.32	249.16	24.84	176.34	2519.07
	10	147.32	249.16	101.84	723.04	10329.07
	11	128.32	249.16	120.84	857.94	12256.22
	12	165.32	249.16	83.84	595.24	8503.36
2014	13	243.78	194.74	-49.04	-348.20	-4974.22
	14	166.78	194.74	27.96	198.50	2835.78
	15	147.78	194.74	46.96	333.40	4762.92
	16	184.78	194.74	9.96	70.70	1010.07
2015	17	129.44	187.08	57.64	409.24	5846.26
	18	117.44	187.08	69.64	494.44	7063.41
	19	166.44	187.08	20.64	146.54	2093.41
	20	170.44	187.08	16.64	118.14	1687.69
2016	21	135.54	171.96	36.42	258.55	3693.53
	22	106.27	171.96	65.69	466.36	6662.34
	23	131.77	171.96	40.19	285.31	4075.91
	24	129.83	171.96	42.13	299.09	4272.68

From Table 4 based on the Logistic estimation of sustainable catch, it appears that there was depletion of the Cirata fishery resource in some quarters of observation, with the highest depletion occurring in the second quarter of 2011, equivalent to a quarterly depreciation of 777.12 million IDR, and a present value depreciation of 11.10 billion IDR. The total depleted fisheries during 2011 to 2016 are 835.13 Tons, and the depreciation total is IDR 5.93 Billion, while the total Present Value is IDR 84.71 Billion. This represented the monetary value lost due to depletion of the fish resources. This estimated depletion was likely caused by various impacts; not just overfishing, but also deterioration in the water quality arising from aquaculture and waste disposal by domestic and industrial activities. However, the relative impacts of these likely causes of depletion have yet to be definitively confirmed by in-depth empirical research.

The amount of depletion in the Cirata fisheries according to the Logistic model, reveal fluctuations from year to year, with an average of depletion of 25% across the quarters of observation. As shown in Figure 5 below, the depletion was high in the initial observations and decreased substantially in the four quarters of 2013, then after it fluctuated through to the end of 2016. At the end of 2016, the depletion was estimated to be 21%.

Based on the Gompertz model's estimation of sustainable catch, the results presented in Table 5 below suggest that the number of quarters in which resource depletion occurred was greater than was indicated by the Logistic model (see Table 4 for comparison). From Table 5, it appears that significant depletion of the fisheries resource continued from the first quarter of 2011 through to the first quarter of 2013, after which there were only occasional quarters of depletion through until the end of 2016. The total depletion of the resource across the period of 2011 to 2016 was estimated to be to 1421.35 Tons, while the total monetary value of the depreciation across this period was estimated to be IDR 10.1 Billion IDR, equivalent to IDR. 144.17 Billion IDR in Present Value (PV) terms.

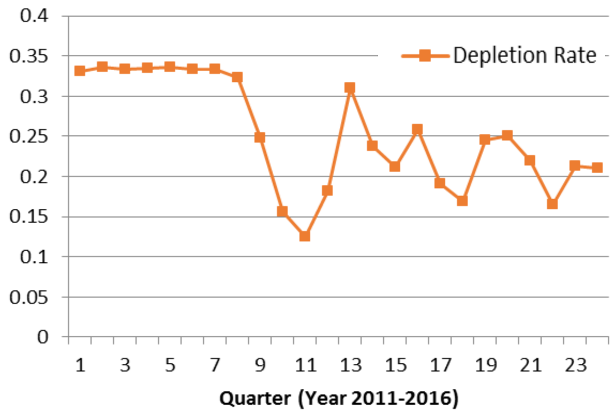

Figure 5. Cirata, West Java, Indonesia fishery resource depletion estimated each quarter since the beginning of observations in 2011 based on the Logistic model estimation of sustainable catch

Table 5. Fishery resources depletion and depreciation in the Cirata waters, West Java, Indonesia based on the Gompertz model estimation of sustainable catch

Year	Quarter	Total standard effort (trip)	Actual production (ton)	Sustainable production (ton)	Depletion (ton)	Depreciation (million IDR)	PV Depreciation million IDR (δ=7%)
2011	1	50216	328.55	168.559	-159.99	-1135.94	-16227.73
	2	50216	341.79	168.559	-173.23	-1229.92	-17570.25
	3	50216	335.04	168.559	-166.48	-1181.99	-16885.60
	4	50216	337.29	168.559	-168.73	-1197.97	-17113.82
2012	5	53476	319.16	166.484	-152.68	-1084.03	-15486.17
	6	53476	315.19	166.484	-148.71	-1055.84	-15083.50
	7	53476	315.64	166.484	-149.16	-1059.04	-15129.14
	8	53476	295.39	166.484	-128.91	-915.26	-13075.21
2013	9	44176	224.32	170.480	-53.84	-382.29	-5461.27
	10	44176	147.32	170.480	23.16	164.41	2348.73
	11	44176	128.32	170.480	42.16	299.31	4275.88
	12	44176	165.32	170.480	5.16	36.61	523.02
2014	13	57661	243.78	162.976	-80.81	-573.74	-8196.23
	14	57661	166.78	162.976	-3.81	-27.04	-386.23
	15	57661	147.78	162.976	15.19	107.86	1540.91
	16	57661	184.78	162.976	-21.81	-154.84	-2211.94
2015	17	58841	129.44	161.841	32.40	230.05	3286.40
	18	58841	117.44	161.841	44.40	315.25	4503.55
	19	58841	166.44	161.841	-4.60	-32.65	-466.45
	20	58841	170.44	161.841	-8.60	-61.05	-872.17
2016	21	60985	135.54	159.635	24.09	171.07	2443.90
	22	60985	106.27	159.635	53.37	378.92	5413.19
	23	60985	131.77	159.635	27.86	197.84	2826.29
	24	60985	129.83	159.635	29.80	211.61	3023.06

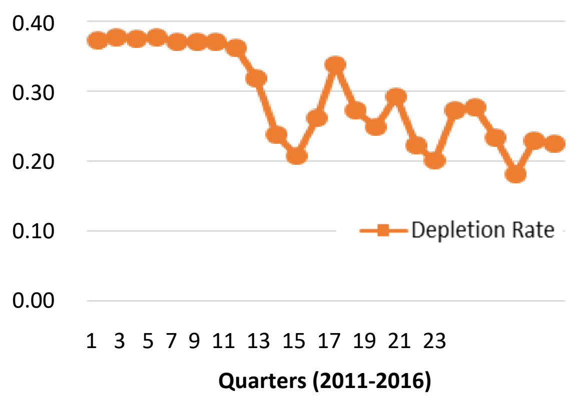

Figure 6. Cirata, West Java, Indonesia fishery resource depletion estimated each quarter since the beginning of observations in 2011 based on the Gompertz model estimation of sustainable catch

Fisheries depletion in the Cirata fisheries according to the Gompertz model, reveal fluctuations from year to year, with an average depletion of 29% across the years of observation, much higher than estimated by the Logistic model (Figure 6). However, the pattern of depletion estimates from quarter to quarter was much the same with the Gompertz model as with the Logistic model: there was high depletion in the first eight quarters (2011-2012), less depletion in the four quarters of 2013, and then fluctuation in estimated depletion through until the end of 2016. At the end of 2016, the overall of depletion since the beginning of 2011 was estimated at 23%.

Discussion

A consideration of depletion and depreciation of fishery resources in the waters of Cirata Reservoir is inseparable from a concern for the condition of the aquatic habitat and the proper management of the natural fish stock. Until now there have been no special rules governing the utilization of the fishery in Cirata, other than the Code of Conduct for responsible fisheries mandated by general Fisheries legislation. Under the Law, the utilization of fisheries in any waters must be in accordance with the carrying capacity and the ability of the resources to regenerate. Thus fisheries in waters like Cirata are supposed to be managed in such a way that access is not left entirely open to all comers. Hardin (1968) states that tragedy of depletion or degradation of natural resources occurs when property rights are communal (common property right), and access to the resource is left open (open access). In closed waters like those of the Cirata Reservoir, such open access without regulation will result in a decline in the fish resources to a level approaching extinction.

Thus the policy implication associated with the depletion and depreciation of fish resources in Cirata is that the management of the inputs and outputs must follow a sustainable trajectory, both in terms of yield and the effort required to harvest it. Such considerations of trajectory management lead to the concepts of Maximum Sustainable Yield (MSY) and Maximum Economic Yield (MEY). In following an MSY regime, for example, output quotas (termed Total Allowable Catch, JTB) can be enforced amounting to 80% of the MSY value for the fishery.

Another policy implication is in regard to the input side of the sustainability; for example by implementation of fish restocking within the Cirata waters. However, such restocking activities would be meaningless if they were not accompanied by management of the outputs as well as management of other inputs needed to support the productivity of the restocking regime. Restocking activities carried out continuously throughout the year is part of a management tool aimed at providing for community food security; however, such a strategy becomes void if harvesting the fishery resource is left on an open access basis.

Other aspects proposed for the management of the natural resources of the Cirata fisheries include the notion of Community-based Fisheries Management. A general objective of fisheries management is to establish policies and strategies that protect the fish resources from overexploitation but also protect the economic livelihood of the society dependent on the resources. These considerations are mandated by the FAO Code of Conduct for responsible fisheries (FAO 1995) which has established the principles for all nations of the world as to proper fisheries management for long-term sustainable use.

Arnason (2006) has stated that in general the optimum form of fisheries management occurs when it is possible to push the fishing industry to produce maximum sustainable rents. On the other hand, fisheries management regimes based on property rights have been a hallmark of fisheries in developed countries and have provided good performance for those fisheries. In contrast, for the majority of developing countries, the issue of ownership remains a dilemma, because of the traditional practice of joint ownership or communal property rights. The concept of right of ownership must provide incentives for preventing overcapitalization of fisheries and for avoiding economic inefficiency.

One of the management tools that can reduce the negative effects of collective ownership rights is by providing for public cooperation in fisheries management, a practice known as community-based management, which has become one of the recommended management options for developing countries like Indonesia (Douglas 2001). Community-based management is a system in which the authority and responsibility for local resources are divided between government and local resource-users and/or their community (Brown 1998). Brown (1998) notes that the term community-based management is often used interchangeably with other terms, such as co-management, collaborative management and joint management. According to Pomeroy (1995, 1998) these strategies have much in common with regard to general approach, but may differ in the relative participation by government and end-users in the management of the resources.

Basically, community-based fisheries management is a joint responsibility of government and society. The government provides a number of important functions in such management regimes, including drafting support policy and legislation. Sajise (1995) stated that community-based management is a strategy in which the local community has the opportunity/ responsibility to control their own resources; define their own needs, goals, and aspirations; and make decisions that affect their own socio-economic welfare. Under this form of management, the government only plays a minor role, thus their costs of management are low.

In the Cirata fisheries, for example, the local community and other groups would be granted certain exclusive rights, and based on a calculation of sustainable and economically optimal inputs and outputs, the people decide by consensus on appropriate entitlements such as catch quotas. The advantage of this system is that the joint decision-making has an ethical basis and is socially acceptable. This encourages the people themselves to be the ones who facilitate effective law enforcement on the basis of social pressure and physical constraints.

From the research reported in this paper, the following conclusions can be drawn: (i) The actual production in terms of the Gordon Schaefer (Logistic) model, revealed that the actual fish capture of Cirata fishery in 2011, 2012 and the first quarter of 2013 exceeded the estimated sustainable catch for the waters. From then on, except for the first quarter of 2014, the actual catch fell below or close to the sustainable catch levels (ii) The shape of the time series curve obtained in the Gompertz model did not differ much from the Logistic model. However, the overall height of the Gompertz curve was lower than the Logistic curve, suggesting greater caution would be required to avoid overfishing than would be recommended by the logistic model. (iii) On the basis of both models, there was indication of depletion of the fishery resource in some quarters. According to the Logistic model, the estimate of the financial depreciation across the six years of observation from 2011-2016, in Present Value (PV) terms, was IDR 84.71 billion. The average depletion was 25% across the years of observation. (iv) For the Gompertz model, the number of quarters in which the fishery resources were depleted was greater than estimated under the Logistic model. The value of the Present Value depreciation under the Gompertz model was IDR 144. 17 billion based on an average depletion of 29% cross the six years of observation, a much higher depletion than estimated by the logistic model. (v) The implication for policies, relating to the depletion/depreciation of the fishery resource in the Cirata waters, is that there needs to be a rationalization of input and output levels for the fishery, and that control of the resource should be based on community-based management, in which government supports communities in forming evidence-based management policy and the communities' implementation of policy for long-term food security.

Suggestions arising from this research are that there needs to be: (i) further research regarding the impact of habitat water quality on the production dynamics and resource depletion in the Cirata fishery; (ii) an analysis of the relationship between aquaculture activities and the resource depletion of the natural catch fishery; (iii) implementaion of a sustainable fishery management approach involving regulation of the fishery's inputs and output; (iv) improvements in water quality management to enable sustainable increases in carrying capacity without negative impacts leading to fisheries depletion and depreciation; (v) and an approach to fish-restocking of the Cirata waters that is balanced by regulation of other inputs and of catch levels.

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