

RESOURCE RENT ESTIMATE FOR THE BALI STRAIT SARDINE FISHERY

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ABSTRACT

This paper briefly describes the past development of the Bali Strait small pelagic fishery, and presents the impact of increasing fishing pressure and climatic variable on the quantity of catch. This paper then presents an estimate of its rent potential and the impact of increasing fishing pressure on rent at different climatic conditions.

Keywords: resource rent, bioeconomic, sardine fishery, climate change.

INTRODUCTION

Bali Strait is situated between Java and Bali islands, and connecting the Flores Sea with the Indian Ocean. Fishing in this area has been largely conducted by fishers from coastal areas bordering the strait located in Pengambengan (Bali Province) and Muncar (East Java Province). The main target species of fishery in this area is Bali sardine (*Sardinella lemuru* Bleeker, 1853), locally named “lemuru”, although small quantities of other small pelagic species are also found. Budihardjo *et al.* (1990) reported that 80% of the catch from Bali Strait consisted of lemuru, while Wudianto (2001) reported higher figure, that was 98% of the total catch. This species concentrates in a relatively narrow area in that Strait. Purse seiners is the main fishing gear to catch this species. Contribution of this fishing fleet is about 93% of the total catch of Bali strait fishery (Merta *et al.*, 2000).

The small pelagic fishery in the Bali strait developed rapidly after the introduction of the purse seine in 1974. The catch increased rapidly, resulting in greater quantity of raw material for processing industry, which also increased in the processing capacity. Canneries and fishmeal processing units were built in the coastal area on both sides of the strait. Currently, there are 18 fish canneries processing the catch of the Bali strait fishery. A rapid increase in the number of purseseine vessels has led to the overexploitation of the sardine stock in the Bali strait. Results of the studies conducted by Sujastani and Nurhakim (1982), Salim (1986), Merta (1992), and Merta and Eidman (1994) confirm such situation. Overexploitation not only threatens the sustainability of sardine stock but also dissipates resource rent, as reported by Purwanto (1992) from a bioeconomic study on sardine fishery in that area.

Timeseries data on fishing effort and catch in the Bali fishery indicate that catches have largely fluctuated even though relatively small changes in the numbers of boats operated. This phenomenon reflects high fluctuations in abundance and/or catchability of the fish population as an impact of environmental conditions rather than being a direct impact of fishing intensity only (Anonymous, 1999). Consequently, the result of analysis using the traditional production model, which considers fishing effort variation only, would be bias. Furthermore, resource rent estimated on the basis of such model would also be misleading. Therefore, environmental

phenomena should also be taken into account in the analysis (Freon, 1986). Unfortunately, those studies did not take into account environmental variation in the analysis.

In this paper, a bio-economic model accommodating environmental variation is formulated for the Bali strait sardine fishery and its application to estimate catch and resource rent is demonstrated. The result of this analysis then is used to evaluate management policy.

MATERIAL AND METHODS

The bioeconomic model used in this study is developed on the basis of the Schaefer (1957) production model. Basic equations of the bioeconomic model are as follows:

- (1) $P(x) = TR(x) - TC(x)$ (Resource rent function)
- (2) $TR(x) = p.G(x)$ (Total revenue function)
- (3) $TC(x) = c.[r/q - (r/q.K).x]$ (Total cost function)
- (4) $G(x) = r.x.(1 - x/K)$ (Natural population growth function)
- (5) $x = K - (q.K/r).E$ (Biomass function)
- (6) $Y = (q.K).E - (q^2.K/r).E^2$ (Production function)

Where:

x = the stock biomass;

p = price of fish;

c = cost of fishing per unit effort;

r = the natural growth rate of population;

q = catchability coefficient;

K = the environmentally limited maximum biomass or carrying capacity;

E = fishing effort;

Y = Yield.

The environmental conditions may affect the yield on parameters K , r and/or q (Freon, 1986). Considering the data available, the bioeconomic model is modified to take into account the effects of environmental variations by modifying the K and the r parameters. Southern oscillation index (S_t) is used as a proxy for environmental conditions. The r parameter is modified as follows:

$$(7) \quad r_t = a_0 - a_1.S_t$$

A method of analysis developed by Schnute (1977) was used to estimate parameters of the model:

$$(8) \quad \ln(U_{t+1}/U_t) = (a_0 - a_1.S_{t+1}) - b.(U_t + U_{t+1})/2 - q.(E_t + E_{t+1})/2$$

$$(9) \quad K = (a_0 - a_1.S_{t+1})/(qb)$$

Where:

U_t and U_{t+1} = catch per unit effort in year t and $t + 1$, respectively;
 a_0 , a_1 , b and q = coefficients.

The coefficients of equations (8) were estimated by ordinary least square on the basis of the catch and effort data from Merta *et al.* (2000) and Marita (2004), and the southern oscillation index (SOI) from the Australia Bureau of Meteorology (2008). Meanwhile, the cost of fishing and the price of sardine were resulting from a field study in 2005.

RESOURCE EXPLOITATION

The following equation is the result of the statistical analysis:

$$(10) \quad \ln(U_{t+1}/U_t) = (4.52484 - 0.08396 S_{t+1}) - 0.00748 (U_t + U_{t+1})/2 - 0.01432 (E_t + E_{t+1})/2$$

$$(3.524)** \quad (-4.856)** \quad (-3.469)** \quad (-3.289)**$$

$R^2 = 0.71$; $n=14$; ** t -statistics in the parentheses are significant at $P < 0.01$.

On the basis of equations (8) and (10), the catchability coefficient was 0.01432. Meanwhile, the natural growth rate and the carrying capacity were represented by the following equations:

$$(11) \quad r_t = 4.52484 - 0.08396 S_t$$

$$(12) \quad K_t = 42208.9 - 783.188 S_t$$

Based on equations (11) and (12), the natural growth rate and the carrying capacity were greater during El Niño episodes, as indicated by sustained negative values of the SOI. Consequently, the natural logistic growth rate was also greater (equation (13)). The natural logistic growth rate function of the sardine stock in the Bali strait accommodating climatic variable was formulated on the basis of equations (4), (11) and (12) as follows:

$$(13) \quad G_t(x) = (4.52484 - 0.08396 S_t) x_t - 1.07201 * 10^{-4} x_t^2$$

The natural growth rate increased, to the maximum rate, with increasing stock size. After reaching the maximum rate, increasing stock resulted in lower growth rate (Fig.1). The natural growth rate during the El Niño was greater than that during La Niña episode, as indicated by sustained positive values of the SOI.

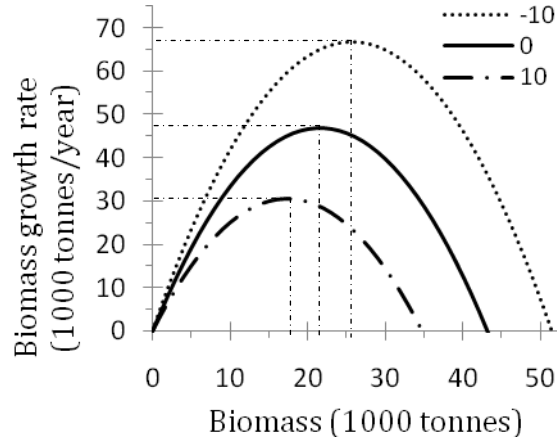


Figure 1. The relationship between the growth and biomass of the sardine stocks in the Bali strait at different SOI, namely -10, 0 and 10.

The development of fishing effort in the Bali strait small pelagic fishery decreased the sardine biomass. The sardine biomass also decreased with increasing SOI. The following equation represented a relationship between the sardine biomass and fishing effort,

$$(14) \quad x_t = (42208.9 - 783.188 S_t) - 133.626 E_t$$

In early development of the fishery, increasing fishing effort decreased the sardine biomass, which in turn, increased the natural growth rate. The quantity of catch of sardine (h_t), therefore, also increased to the maximum sustainable yield (MSY) with increasing fishing effort. After attaining MSY, increasing fishing effort resulted in lower catch (Fig. 2). The relationship between the quantity of catch of sardine and fishing effort in the Bali strait small pelagic fishery was as follows:

$$(15) \quad h_t = (604.639 - 11.2191 S_t) E_t - 1.91419 E_t^2$$

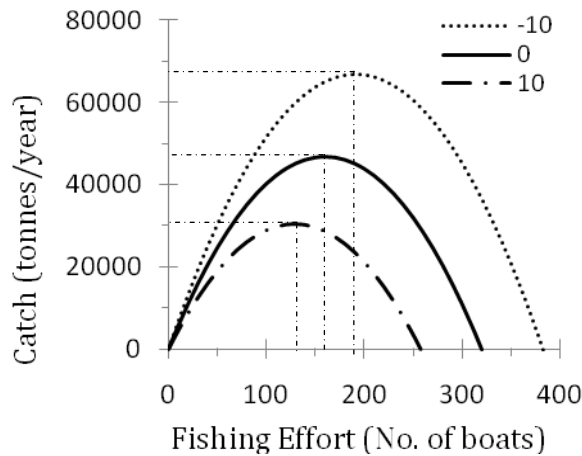


Figure 2. The relationships between the catch of sardine and fishing effort in the Bali small pelagic fishery at different SOI, namely -10, 0 and 10.

During El Niño episodes, the quantity of catch of sardine was greater, as an impact of greater natural growth rate and greater carrying capacity of the sardine biomass. The optimum yield and optimum fishing effort were greater during the El Niño (Fig. 2). The MSY and the optimum effort at MSY, that is the effort required to achieve the MSY, at different climatic conditions could be estimated by the following equations:

$$(16) \quad MSY = 2332.07 (4.52484 - 0.08396 S_t)^2$$

$$(17) \quad E_{msy} = 157.936 - 2.93051 S_t$$

The result of analysis shows that the level of fishing effort at MSY also varied with climatic conditions (Fig. 2). In El Niño episodes, the effort required to achieve MSY is greater, vessel productivity is higher and the MSY resulting is larger. On the contrary, during La Niña episode, the effort required to achieve the MSY should be reduced (Fig. 2).

Comparing between the level of fishing effort at MSY and the actual fishing effort during 1990-2004, the actual effort was higher than the biologically optimal effort (Effort at MSY) (Fig. 3). Consequently, the yield are lower than the MSY, and the CPUE are also lower than the CPUE at MSY (Fig. 4). The Bali sardine fishery is more productive in El Niño episodes. The CPUE and the MSY in El Niño episodes are higher than those in La Niña episode.

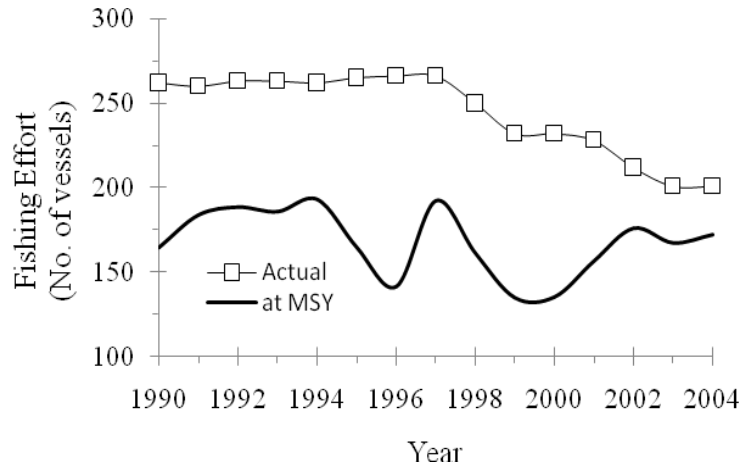


Figure 3. Fluctuation of fishing effort for the Bali strait small pelagic fishery and the biologically optimal level of fishing effort for sardine, 1990 – 2004.

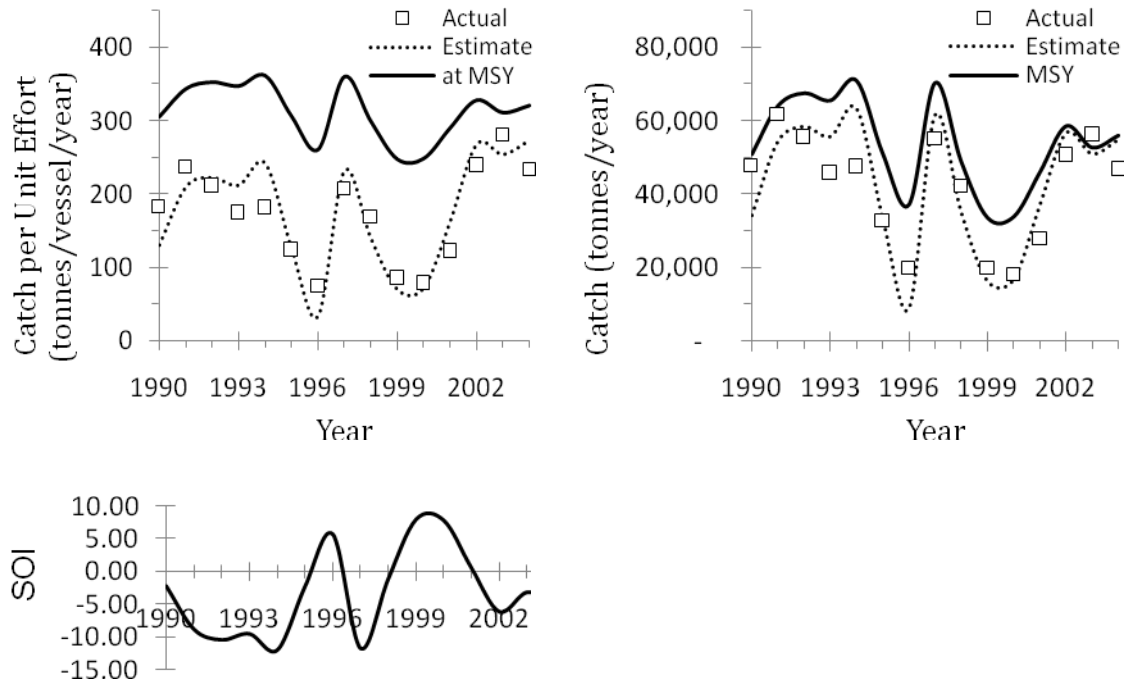


Figure 4. Fluctuation of the catch per unit effort and the catch of sardine in the Bali strait small pelagic fishery and SOI, 1990 – 2004.

ECONOMIC OF FISHERY AND RESOURCE RENT

The average price of the catch was about Rp. 2100/kilogram. Meanwhile the cost of fishing was about Rp. 257 million/vessel/year. Therefore, the value of production from the Bali strait sardine stock and the cost to harvest at different level of biomass could be estimated by the following equations:

$$(18) \quad TR(x) = 2.1 [(4.52484 - 0.08396 S_t) x - (1.07201 * 10^{-4}) x^2]$$

$$(19) \quad TC(x) = 257 [(315.873 - 5.86103 S_t) - (7.48355 * 10^{-3}) x]$$

The value of sardine production increases with increasing biomass up to a maximum level, then decreases with further increases in biomass (Fig. 5). The total value of production from sardine biomass in the Bali strait also varies with climatic variation. The sardine biomass produced higher revenue during the El Niño. Meanwhile, the cost of fishing decreases with increasing biomass (fig. 5). Therefore, the same revenue from the Bali strait fishery may be produced with the lower fishing cost, and gain higher rent, at the higher biomass (Fig. 5).

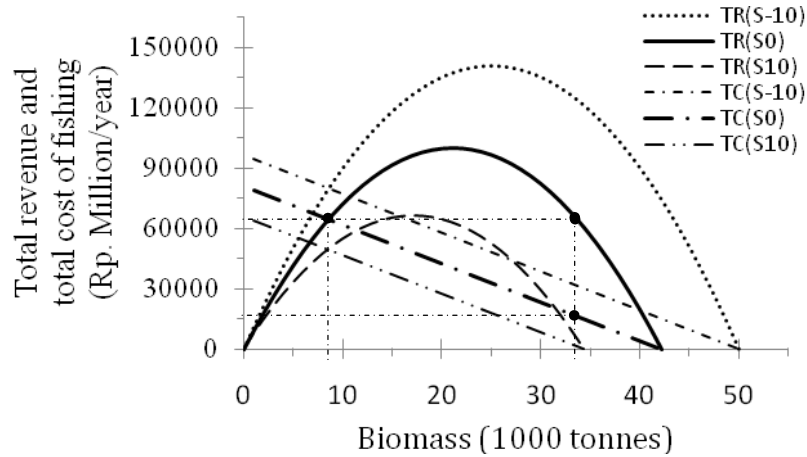


Figure 5. The relationships between the value of sardine production, and the cost of fishing, and sardine biomass in the Bali strait at different SOI. (TR(S10) and TC(S10) are total revenue and total cost of fishing when SOI is 10).

The relationship between fishery rent and biomass of sardine at different climatic conditions was represented by the following equation:

$$(20) \quad R(x) = (2100x - 179434)[(4.52484 - 0.08396 S_t) - (1.07201 \cdot 10^{-4})x]$$

Fishery rent is negative at very low biomass. The rent increases with increasing biomass up to a maximum level, then decreases with further increases in biomass (Fig. 6). The rent generated in the Bali strait sardine fishery also varies with climatic variation. The sardine biomass produced higher fishery rent during the El Niño.

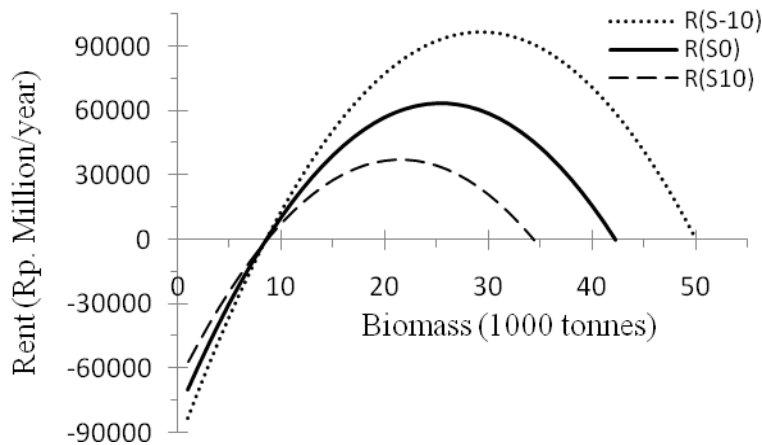


Figure 6. The relationships between fishery rent and sardine biomass in the Bali strait at different SOI. (R(S10) is fishery rent gained at SOI of 10).

The effort required to achieve optimum rent (E_{MEY}), as presented in Fig 6, and the economically optimum production (MEY) at different climatic conditions can be estimated by the following equations:

$$(21) \quad E_{MEY} = (157.936 - 2.93051 S_t) - 31.9715$$

$$(22) \quad MEY = 2332.07 (4.52484 - 0.08396 S_t)^2 - 1956.63$$

In year 2007, the average southern oscillation index is 1.45, the intrinsic growth rate and the carrying capacity of the Bali strait sardine stock are 4.403 and 41,073 tonnes/year, respectively. The level of fishing effort are 230 vessels with catchability coefficient of 0.0143. The estimates of the optimal levels of fishing effort, biomass, harvest, catch per unit effort, total revenue, total cost and rent generated in the Bali strait sardine fishery are presented in Table 1.

Table 1. Estimates of fishing effort, biomass, harvest, catch per unit effort, total revenue, total cost and rent generated in the Bali strait sardine fishery

	Units	Optimal	year 2007	Difference
Fishing effort	vessels	122	230	-108
Biomass	tonnes	24,809	10,339	14,470
Harvest	tonnes	43,256	34,065	9,191
Catch per unit effort	tonnes/vessel	355	148	207
Total revenue	Rp. Million/year	90,837	71,536	19,301
Total cost	Rp. Million/year	31,285	59,119	-27,833
Rent	Rp. Million/year	59,552	12,418	47,134

The fishing effort in year 2007 were higher than the economically optimal level, indicating that the sardine stock in the Bali strait were economically overexploited. The resource rent loss was about 79 % of the potential rent.

The estimates of the economically optimal fishing effort (E_{MEY}) in 1990 – 2004 are presented in Fig. 7. This figure shows that the actual effort during 1990-2004 exceeded the economically optimal effort. Consequently, the rents were not optimal (Fig. 8). The overexploitation of sardine stock and climatic condition in the Bali strait during La Niña episode in 1996 and 1999-2000 have resulted in negative rent.

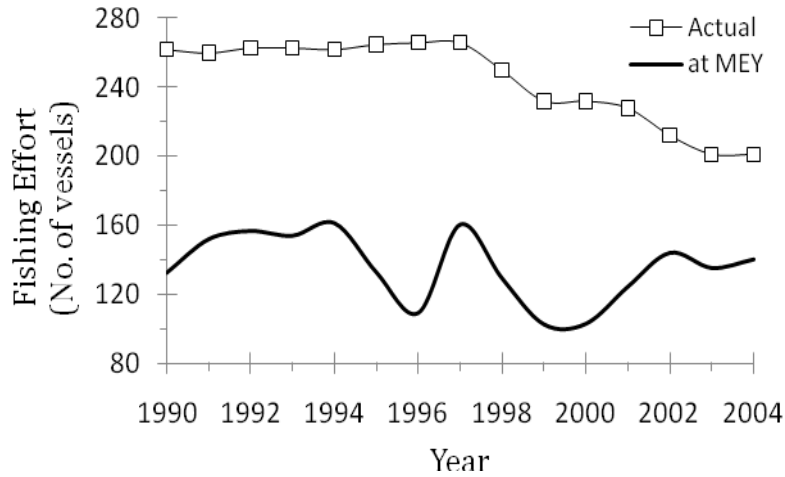


Figure 7. Fluctuation of fishing effort for the Bali strait small pelagic fishery and the economically optimal level of fishing effort for sardine, 1990 – 2004.

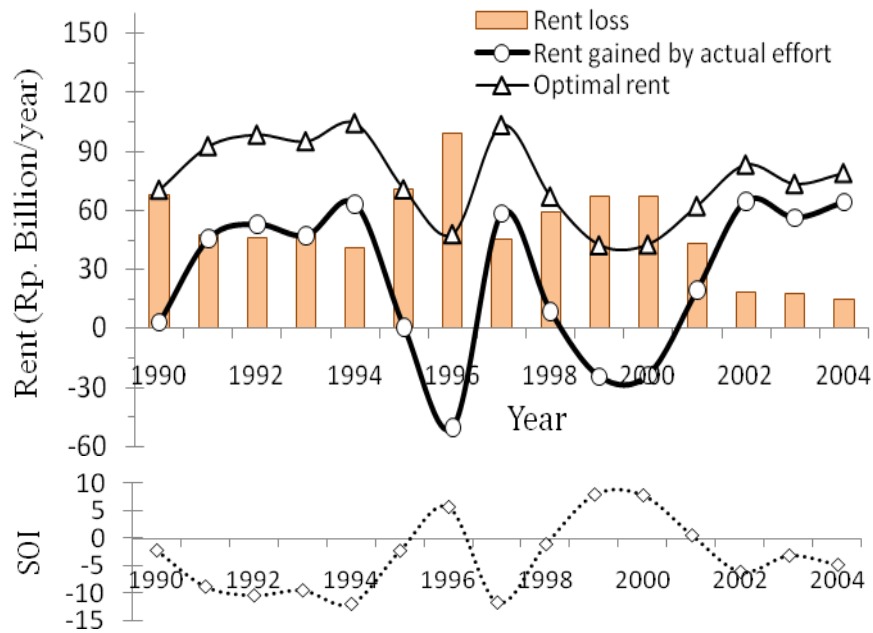


Figure 8. Fluctuation of fishery rent and rent loss in the Bali strait sardine fishery and SOI, 1990 – 2004.

DISCUSSION AND CONCLUSIONS

The sardine fishery in the Bali strait is jointly managed by the Provincial Governments of East Java and Bali. The earliest initiative to manage fishery in the Bali strait took place in 1977 when the small pelagic fish stocks in this area was overexploited as a result of the development of the fishing capacity of purse seine fleet beyond the capacity of fish stocks to sustain. Those two

Provinces had agreed in 1977 to only allowed 100 vessels to fish in the Bali Strait. This agreement, however, was not complied as the number of purse seiners continuously increased, the number of fishing boats operated in the Bali strait were more than the number of boats allowed (Fig. 9). Therefore, those two Provinces changed this allocation to 133 vessels in 1978, and further changed to 273 vessels in 1985. The situation was completely reversed in 1986 and after, for which the number of boats in operation was always less than the number of licences granted. The allocation agreed in 1985 was reviewed in 1992, but no change was made in the number of vessels allowed to fish.

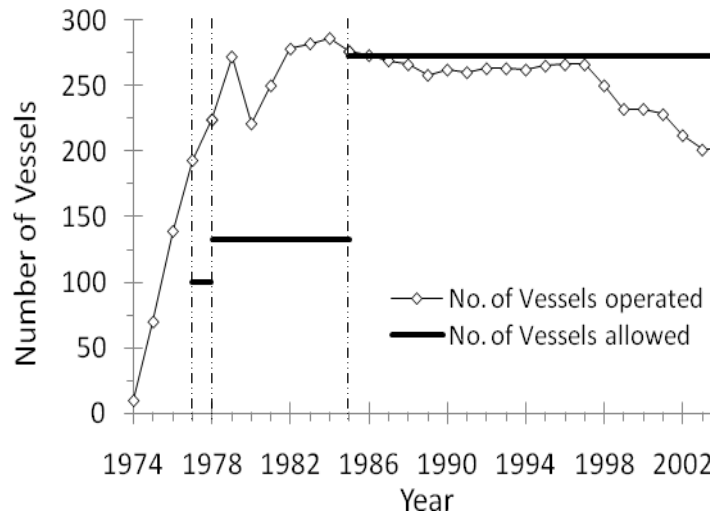


Figure 9. The number of vessels allowed to fish and the number of purse seiners operated in the Bali Strait, 1974 – 2004.

The results of the analyses clearly show that the total allowable fishing effort for the Bali strait pelagic fishery targeting sardine stock (TAFE) agreed by both the Provincial Governments in year 1986, amounting of 273 vessels, however, was higher than the optimal level required to catch at the MSY level. As the optimal fishing effort needed to generate the optimal rent is lower than the effort associated with MSY, therefore the TAFE was also higher than the optimal fishing effort needed to generate the optimal rent.

Meanwhile, the actual fishing effort for the Bali strait pelagic fishery targeting sardine, even though lower than the TAFE, was higher than the optimal level required to generate the optimal rent. Therefore, the Bali sardine stock was biologically and economically over-exploited during 1990 – 2004. To optimise resource rent, the fishing effort targeting sardine stock in the Bali strait should be decreased.

The result of the analysis clearly show that the economically optimal level of fishing effort varied with southern oscillation. Therefore, the TAFE should be adjusted periodically on the basis of, at least, the climatic condition in order to achieve the economically optimal level of yield and rent.

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