THE BIOECONOMICS OF THE TIGER SHRIMP BROODSTOCK FISHERY OF KUALA BARAM, SARAWAK.

By
Hadil Bin Rajali

Fisheries Research Institute
Sarawak Branch
Kuching, Sarawak

Abstract

The length-based Thomson and Bell yield analysis is used to assess the bioeconomics of the tiger shrimp trawl fishery of Kuala Baram. The application is extended to include the analysis of financial performance by iteration. The outputs from the analysis include estimates of yield, catch rate, mean individual weight, fishery cost and profit. About 18 tonnes of spawners can be harvested annually. The projected optimum annual returns (profits) to 67 local trawlers would be about ***RM 1.4 millions*** or a monthly profit per vessel of about *RM 2,000.* With 22 trawlers actively targeting for tiger shrimp since the year 1997, the profit will be about *RM 6,195,500* or a profit of about *RM 28,161* per month per vessel. The maximum profit of about *RM 7 millions* could be attained if the effort level is at 8 vessels.

Keywords: bioeconomics, tiger shrimp broodstock, fishery

Abstrak

Penganalisaan-hasil Thomson dan Bell berasas kepada sukatan panjang adalah digunakan bagi mentaksir bioekomik perikanan udang harimau Kuala Baram. Penganalisaan ini juga melibatkan taksiran kos dan keuntungan secara iterasi. Hasil penganalisaan merangkumi anggaran hasil, kadar tangkapan, berat purata individu udang, kos dan keuntungan perikanan. Adalah dijangka kira-kira 18 tan induk udang boleh didaratkan setahun. Bagi 67 buah pukat tunda yang beroperasi, unjuran optima keuntungan ialah kira-kira ***RM 1.4 juta*** ataupun keuntungan bulanan sebanyak *RM 2,000* bagi setiap buah bot. Sejak tahun 1997, hanya 22 buah pukat tunda saja yang aktif menangkap induk udang, jadi dengan itu unjuran keuntungan ialah kira-kira *RM 6,195,500* setahun ataupun *RM 28,161* sebulan bagi setiap buah bot. Keuntungan maksimum dapat diperolehi jika bilangan pukat tunda dikurangkan kepada hanya 8 buah.
Kata kunci: bioekonomik, induk udang harimau , perikanan

1 INTRODUCTION

Tiger shrimp, *Penaeus monodon* belongs to the *Penaeus* genus typically spawned at sea and enters the inshore waters at an age of about three weeks or one month as a post larva. It grows there for about three months before migrating back to sea where maturation of females can start (maturation of males also start in the inshore waters).

In an average environmental condition, the recruitment is a direct function of spawning stock levels. However, the vagaries of environment and the spatial and temporal conditions can affect recruitment patterns. The recruitment of a natural fish population does not generally represent (even in the tropics) a continuous introduction of young fishes into the exploitable stock, but rather corresponds to a seasonal pattern with one or more (usually two) pulses during an annual cycle (*Longhurst and Pauly 1987*). As *Browder and Moore* (1981) pointed out, juvenile shrimp require the matching of two sets of variables for good survival: a static set related to the benthic environment and a dynamic set related to water conditions. Match or mismatch (*Cushing 1975*) of the two sets can determine survival or failure of estuarine juvenile stocks.

Penaeus monodon was found to be substantially abundance in the northern coastal waters of Sarawak from Kuala Suai to Kuala Baram, Miri in water depths ranging from 10 to 60m with mud-sandy bottom *(Hadil 1994).* The stock assessment survey carried out in 1999 *(Hadil and Albert 2001)* off Kuala Baram, Miri showed that about 62.5% of the tiger shrimp resources were found in the area 11 to 50m deep with the rest caught in the shallower waters.

The catching of the live tiger shrimp by local trawlers was carried out at night targetting gravid spawners non-moonlighted night. Trawling is concentrated in waters between 30-60m deep in areas from Kuala Baram to Tanjong Batu, Miri. The tiger shrimp fishing ground is about 5-7 nm off the coast *(Hadil and Albert 2001).*

Sarawak has utilized the state own brood stock resource of Kuala Baram for the fast growing tiger shrimp aquaculture industry since mid 90's. In order to sustain the industry, the resource should be protected and managed to benefit the spawner collectors, the fishermen and the entrepreneurs: hatcheries and grow-out operators. The aim of this paper is to assess the bioeconomics of catching tiger shrimp spawners using a spreadsheet-based Thomson and Bell yield analysis model.

2 MATERIAL AND METHODS

There were 67 trawlers ***[25-(10-24.99 GRT), 8-(25-39.99 GRT), 21-(40-69.99 GRT) and 13->70GRT]*** operating in the waters of Kuala Baram in 2000. Catch and effort data of trawlers were collected monthly at Miri and Baram landing ports *(Hadil and Albert 2001).* The number and size of vessels sampled during a month varies. The fishing power or effort was only based on the number of vessel and not on the characteristics of the vessel; there was no standardization of effort. The other data collected were fuel, repair and labour cost. Catch data which include all quantities of fish caught were recorded in terms of weight. The present wholesale price was used in the analysis.

Tiger shrimps caught were weighed and measured using a vernier caliper for total and carapace length. The female shrimp egg maturity stage was determined based on criteria mentioned by *Motoh (1981)*. In Miri, the catch was landed in boxes and each box contains 20-30 kg of shrimps. Since the average monthly catch per vessel is 100kg *(Anon. 2000)*, sampling one box (approximately 250 tails of tiger shrimp) a month was considered sufficient for proper estimates of the length distribution for the annual landings, assuming the size distribution of all the boxes is similar. To estimate the length composition of the total catch in year 2000, the monthly length frequencies were raised to the monthly catch and then summed up over all months to get the annual length composition (Table 1). In the present assessment, only total length-frequency data of female tiger shrimp and effort data were utilized in the analysis.

The length based-Thomson and Bell yield analysis followed the method introduced by *Sanders (1995)* using Microsoft Excel spreadsheet. The inputs data (Table 2) required include fishing efforts; trawl catchability coefficient, q; natural mortality, M; asymptotic length, L_{00}; curvature (growth) coefficient, K and trawl selection ogive (Table 2). These inputs were obtained from the analysis of the length-frequency data series using FAO-ICLARM Stock Assessment Tools, FiSAT software *(Gayanilo and Pauly 2001).*

Since the smallest size of female tiger shrimp recruited into the trawl fishery was 10cm in total length, the figure for early natural mortality, was not available. Therefore, the number of tiger shrimp recruits, R (annually), was calculated based upon the population fecundity (number of spawners at maximum sustainable yield, MSY x the individual fecundity), recruitment rate (*Ye 1981*) and the percentage of females in the population *(Hadil and Albert 2001).*

The price of tiger shrimp spawner was based on the present wholesale price of RM50 per tail for broodstock weighing more than 110 gm or 24 cm in total length *(Hadil* *and Albert 2001).* The total fishing cost was estimated using the catch and effort data collected.

3 RESULTS AND DISCUSSION

The size range of tiger shrimps caught by trawlers was from 10 to 34 cm total length (Table 1). The length-weight relationship;

$$\text{Weight} = 0.0266\ \text{Length}^{2.6566}$$

was calculated from 185 tails of tiger shrimps covering the whole size range caught by trawlers. The relationship is similar (Weight = $0.0216\text{Length}^{2.6531}$) to the study reported by *Prasad (2001)* in Kerala, India.

Table 2 showed the input data required for the analysis. There were 67 trawlers in operation in 2000 *(Anon. 2000).* The effort specified in this analysis was in term of numbers and not on the size of vessels. The average total fishing cost estimated was *RM 102,000.00* per vessel per year (for 10 months fishing period in a year) calculated from the monthly labour cost of *RM 3,000* and *RM 7,200* per month for fuel and repair.

The catchability coefficient, q=0.6 was obtained from *Hadil and Albert (2001);* subsequently the fishing mortality, F (Table 3) was derived from this figure. In the fishing ground the estimate of fishing mortality, F at age remains very sensitive to catchability coefficient, q and number of effort inputs. The natural mortality, M=2.6 generated was similar to the value recommended by *Garcia* (1985). *Hadil and Albert (2001)* in their earlier tiger shrimp resource stock assessment have used the value of M at 2.5. The asymptotic length, L_{00} and curvature (growth) coefficient, K, calculated were 41cm and 1.2yr^{-1} respectively. The results obtained were comparable to the growth estimates of the slightly smaller banana shrimp, *Penaeus merguiensis* of Santubong-Salak estuary (*Hadil 2000*). *Garcia* (1985) suggested that the K values for *Penaeus* spp. to be in a range of 0.8 to 2.0 yr^{-1}. The L_{00} and K values were used to calculate the time interval (Table 2) between different shrimp sizes.

The number of recruits per year, R=570,960 was based on MSY=52000 tails of female tiger shrimp *(Hadil and Albert 2001)* and 0.0036% recruitment rate (*Ye 1981*) for every parent stock of which 61% are female *(Hadil and Albert 2001).* It was assumed that constant recruitment prevailed in the case of Kuala Baram fishery. *Garcia* (1985) pointed out that the normal generation interval, the period between reproductions of parent to reproduction of progeny generation, is one year in *Penaeus*. Therefore, the annual yield is equal to the generation yield and would approach the recruitment, and may serve as a relative abundance of recruitment. Based on that assumption *Ye (1981)* was able to estimate the parent stock size of *Penaeus orientalis* and the corresponding recruit abundance for 16-generation years (1961-1976) using the models of Beverton and Holt (1957) and Ricker (1958). The recruitment rate obtained by *Ye* (1981) was in the range 0.002 to 0.007% per annum taking into consideration only 500,000eggs were spawned.

The number of eggs spawned varies with the condition and the size of the female. For wild tiger shrimp each spawner produced 250,000 to 1,000,000 eggs/spawn (*Motoh,1981*; *Chen, 1990*). *Penaeus orientalis* produces between 500,000 to 1 million eggs per spawning period *(Ye 1981)*. Both *P. monodon* and *P. orientalis* were exploited by trawl, and thus followed similar selection ogive. *Ye* (1981) stock-recruitment relationship was adopted by inputting the weighted average for recruitment rate at 0.0036% in the calculation for the number of tiger shrimp recruits, R. Landings of tiger shrimp for Kuala Baram, Miri was only seriously monitored since 2000 (*Anon. 2000*) and that the data was insufficient for stock-recruitment relationship analysis.

Taking the precautionary approach in fishery, it is safe to accept the estimate that 0.0036% (*Ye 1981*) of the tiger shrimp progenies was recruited into the trawl fishery from approximately 500,000 eggs spawned. According to Mohd Fariduddin (1989), in the hatchery, between 30-48% of the tiger shrimp eggs spawned will hatch. In control pond conditions, the survival rate of post larvae was 70% as reported by *Apud* (1988). Sexual maturity is defined as the minimum size at which spermatozoa are found inside the thelycum in the females. Wild *Penaeus monodon* female possess spermatozoa at 47mm carapace length or about 67.7g body weight (*Motoh 1981*). Since the size adopted by *Hadil and Albert (2001*) for the MSY calculation was 110g, it was imperative that the fecundity figure should be between 248,000-811,000 eggs/spawn (*Motoh 1981*) and it is reasonable to choose an average figure of 500,000eggs/spawn for this analysis. Accordingly, the fecundity for spawner more than 130g was between 700,000 to 1,100,000 eggs as reported by Mohd Fariduddin (1989).

The trawl selection ogive obtained through FiSAT software *(Gayanilo and Pauly 2001)* is shown in Table 3, giving the output figures for catch weight based on length class. This analysis (Tables 3 and 4) estimated that about 18.34 tonnes of spawners were harvested in year 2000 with a catch rate of 273.79 kg per vessel. However, about 32.06 tonnes of female tiger shrimp was landed in Miri in 2000 (*Anon. 2000*). The difference in the yield estimates and the actual catch was probably due to the fact that trawlers were harvesting tiger shrimp well beyond the boundary of Kuala Baram, which they usually do in order to increase their catch. However, this analysis was based on the MSY figure derived from Kuala Baram tiger shrimp survey by *Hadil and Albert* (2001) in 1999. The other possibility was that the recruitment rate adopted, 0.0036% was low. The stock recruitment relationship for shrimps is very unclear as pointed out by Garcia and Le Reste (1981).

It was assumed that minimal mortality occurred at harvest, which was possible taking into account the hardiness of tiger shrimps trapped inside the net for about 30 minutes of trawling (*Hadil and Albert, 2001*-personal observation). If the estimated 18.34 tonnes of female shrimps were to be harvested alive for hatcheries, the optimum annual returns (profits) to the local fishermen would be about ***RM 1,420,630*** (Table 4). The number of trawlers in operation was 67 units *(Anon. 2000).* So the projected monthly profit per vessel per month is about *RM 2,120* (10 months of fishing per year). In an earlier report by *Hadil* (2001), only 22 trawlers were actively targeting tiger shrimp. Table 5 shows that with 22 trawlers, the profit will be about *RM 6,195,500* or a profit of about *RM 28,161* per month per vessel, which is by far more lucrative. Earlier estimates by *Hadil (2001)* put the income per vessel to be about *RM 20,000* a month that did not take into account the expenses incurred.

By iteration and changing effort level, it was shown (Table 5 and Figures 1 & 2) that the maximum profit (*RM 7,007,772*) could be attained at the effort level of 8 vessels. As the effort level increased, catch rate declined, subsequently profit also decreased. In other words, to maximize yield per recruit, the effort level should be minimal. The market price of spawners sold by middlemen to hatchery operators and breeders were between RM165 to RM180 per tail *(Hadil 2001)* compared with the wholesale price of RM50 per tail they bought from the fishermen. In this case, the middlemen get the highest profit margin.

The present assessment has shown that the coastal waters of Kuala Baram (0-12NM), has the commercial potential for the harvest of tiger shrimp broodstock. It will be of greater benefits if these shrimps were to be harvested alive for the ever-growing aquaculture industry. This finding confirmed the earlier suggestion by *Hadil and Albert (2001)* that spawners could fetch better price than dead shrimp. The lucrative nature of this tiger shrimp fishery should pave the way for the Department of Marine Fisheries Sarawak in regulating the harvest of the spawning stock. The setting up and the proper implementation of the guidelines for the tiger shrimp protected area of Kuala Baram should be given utmost importance because it is the spawning stock which can be controlled through management decisions.

4 ACKNOWLEDGMENT

Highest appreciation goes to Director-General of Fisheries Departrment Malaysia, Director of Marine Fisheries Sarawak and Director of Research for their supports and far sightedness in providing Development fund: 23500036 in achieving this discovery. I am also grateful to IRPA for providing the grant JISK 01-03-07-0025 for the initiate part of the study. My sincere gratitude goes to Mr. Syed Abdullah, Mr. Richard Rumpet, Mr. Ibrahim Johari and Dr. Ahamad Sade for their excellent ideas and encouragements in preparing for this paper.

5 REFERENCE

Anon. (2000). Annual Fisheries Statistics. Department of Marine Fisheries Sarawak.

Apud, F.D. (1988). Prawn grow-out practices in the Philipines. Chapter 4 Pp.89-119 I n: Biology and culture of *Penaeus monodon.* SEAFDEC Aquaculture Department, Tigbauan, Iloilo Philipines.

Beverton, R.J.H. and Holt, S.J. (1957). On the dynamics of exploited fish populations. *Fish. Invest. Minist. Agric. Fish Food G. B. (2 Sea Fish)* 19:533p.

Browder, J. and Moore, D. (1981). A new approach to determinng the qualitative relationship between fishing production and flow of freshwater to estuaries. In "Freshwater Inflow to estuaries" (R.Cross and D. Williams, eds.), FSW/OBS-81/04;pp.403-430. USFW Office Biol. Serv., Washington D.C.

Chen, L.C. (1990). Aquaculture in Taiwan. Fishing News Books, Blackwells Scientific Publications, Oxford.

Cushing, D.H. (1975). Marine ecology and fisheries. Cambridge University Press, Cambridge, 278pp.

Garcia, S. and L. Le Reste (1981). Life cycles, dynamics, exploitation and management of coastal penaeid shrimp stocks. *FAO Fish.Tech. Pap.*,(203):215p.

Garcia, S. (1985). Reproduction, stock assessment models and population parameters in exploited penaeid prawn populations. In Rothlisberg, P.C., Hill, B.J. and Staples, D.J. (Eds), *Second Australian National Prawn Seminar,* pp. 139-58, NPS2, Cleveland, Queensland, Australia.

Gayanilo, F.C.Jr. and D. Pauly (2001). The FAO-ICLARM Stock Assessment Tools (FiSAT) User's Guide. ICLARM Contribution. FAO Rome, 2001.

Hadil, R. (1994). Penaeid prawn distribution and abundance in the coastal waters of Sarawak, Malaysia. *Fisheries Bulletin* No. 95.

Hadil, R. (2000). Growth and mortality estimates of the juveniles and adolescent banana shrimps, *Penaeus merguiensis* of Santubong-Salak estuary. *Malaysian Fisheries Journal* 1 *(2)**: 119-138** (December 2000).*

Hadil, R. (2001). The exploitation pattern of the tiger shrimp, *Penaeus monodon* resource of Kuala Baram. *FRI Newsletter **Vol. 6 No: 2 December 2001***

Hadil, R. and Albert C.G. (2001). Resource assessment of the tiger shrimp, *Penaeus monodon* of Kuala Baram, Miri-Sarawak. *Malaysian Fisheries Journal 2 (1)**:** 221-237 (June 2001).*

Longhurst, A.R. and Pauly, D. (1987). Ecology of tropical oceans. ICLARM Contribution No. 389. Academic Press, Inc. 407p.

Mohd Fariduddin Othman. (1989). Teknik-teknik mematangkan induk udang harimau (*Penaeus monodon*). Risalah Perikanan Bil. 39. Jabatan Perikanan. Kementerian Pertanian Malaysia.

Motoh, H. (1981). Studies on the fisheries biology of the giant tiger prawn, *Penaeus monodon* in the Philippine. *Technical report, No. 7*. Tigbauan, Iloilo: SEAFDEC Aquaculture Department, 128pp.

Prasad, G. (2001). Length-weight relationships of *Penaeus monodon* reared in semi-intensive culture systems of Kerala, India. *Naga, The ICLARM Quarterly* (Vol. 24, Nos. 1&2) January-June 2001.

Ricker, W.E. (1958). Handbook of computations for biological statistics of fish populations. *Bull. Fish. Res. Board Can. (119):300p.*

Sanders, M.J. (1995). Introduction to Thomson and Bell yield analysis using Excel spreadsheets. FAO Fisheries Circular No. 895. FAO Rome, October 1995.

Ye, C.C. (1981). The prawn (*Penaeus orientalis* Kishinouye) in Pohai sea and their fishery. *In* "Penaeid shrimps-their biology and management". Gulland, J.A. and Rothschild, B.J. (eds.). pp 49-59. Fishing News Books Limited.

Table 1: Length frequency of tiger shrimp caught by trawlers off Kuala Baram, Sarawak in 2000.

Total length (cm)	**Catch numbers (frequencies)**
10.0-12.0	1000
12.1-14.0	2000
14.1-16.0	5000
16.1-18.0	21000
18.1-20.0	20000
20.1-22.0	42000
22.1-24.0	87000
24.1-26.0	115000
26.1-28.0	83000
28.1-30.0	35000
30.1-32.0	12000
32.1-34.0	1000
Total	**424000**

Table 2: Input data needed for the Thomson and Bell yield analysis

Parameters	***Values***
Fishing effort (annual), x vessel	67*
Catchability coefficient, q	0.60
Natural mortality (per year), M	2.6
Recruit number (annual), R	570,960
Asymptotic length (cm), Loo	41
Curvature (growth) coefficient, K	1.2
Length / weight constants, a	0.0266
(when w in gm and l in cm), b	2.6566
Shrimp price, Pr (RM/kg)	RM 450**
Total fishing cost, C (RM/ vessel/year)	RM 102,000***

**vessels [25-(10-24.99GRT), 8-(25-39.99), 21-(40-69.99) & 13->70GRT]*
***mature female, 110g-RM50 per tail*
****RM3,600-fuel and repair, RM1,500-labour for 7 days trip, 2 trips per month for 10 months fishing*

Table 3: Trawl catch weight (tonnes) of tiger shrimp spawner based on length class. Kuala Baram.

length class (cm)		Time	Selection ogive	Fishing Mortality coef	Natural Mortality coef	Start Population No.	End Population No.	Mean Population No.	Catch Number	Natural Death	Mean Weight (g)	Catch Weight (t)
L1	**L2**		**S**	**F**	**M'**	**N1**	**N2**	**N'**	**CN**	**D**	**w**	**Cw**
10	12	0.06	0.00	0.00	0.15	570,960	491456	530215	2036	77468	16	0.03
12	14	0.06	0.01	0.01	0.16	491456	414926	452112	5695	70835	24	0.14
14	16	0.06	0.03	0.07	0.17	414926	325481	368395	27225	62220	36	0.97
16	18	0.07	0.04	0.10	0.18	325481	244246	282922	29408	51826	50	1.46
18	20	0.08	0.11	0.35	0.20	244246	141217	188051	65398	37631	67	4.35
20	22	0.08	0.37	1.27	0.22	141217	31825	73415	93205	16187	87	8.08
22	24	0.09	1.00	3.80	0.25	31825	559	7736	29366	1899	110	3.24
24	26	0.11	1.00	4.28	0.28	559	6	121	520	34	138	0.07
26	28	0.12	1.00	4.91	0.32	6	0	1	5	0	169	0.00
28	30	0.14	1.00	5.76	0.37	0	0	0	0	0	204	0.00
30	32	0.17	1.00	6.95	0.45	0	0	0	0	0	244	0.00
32	34	0.22	1.00	8.79	0.57	0	0	0	0	0	288	0.00
34	36	0.30	1.00	11.94	0.77	0	0	0	0	0	337	0.00
									252859.15	318100.85		18.34

Table 4: Results of the Thomson and Bell yield analysis

Parameters		*Values*
Catch number,	CN	252859 tails
Catch weight,	CW	18.34 tonnes
Mean Individual	w	72.54 gram
Catch rate,	Cw / x	273.79 kg/ trawler
Gross revenue,	Gr	RM 8,254,630
Fishery cost,	Fc	RM 6,834,000
Fishery profit,	Pr	RM 1,420,630

Table 5: Fishery profit at different fishing effort.

Fishing effort (trawlers)	Catch weight (t) Cw	Catch rate (kg/boat)	Mean individual weight (gm)	Gross revenue RM (000)	Fishery Cost RM (000)	Fishery profit RM (000)
	18.34	274.284	72.545	8254.6251	6834	1420.6251
0	0	0	0	0	0	0
4	15	3,646	134	6551.219266	408	6143.2193
8	17	2,177	116	7823.771616	816	7007.7716
12	18	1,524	106	8213.707337	1224	6989.7073
16	19	1,164	100	8,365	1,632	6,733
20	19	938	95	8,428	2,040	6,388
24	19	784	91	8,451	2,448	6,003
28	19	672	88	8,454	2,856	5,598
32	19	588	86	8,446	3,264	5,182
36	19	521	83	8,432	3,672	4,760
40	19	468	82	8,413	4,080	4,333
44	19	425	80	8,392	4,488	3,904
48	19	388	78	8,370	4,896	3,474
52	19	357	77	8,346	5,304	3,042
56	19	331	76	8,322	5,712	2,610
60	18	308	74	8,297	6,120	2,177
64	18	288	73	8,273	6,528	1,745
68	18	270	72	8,249	6,936	1,313

Figure 1: Catch versus Fishing effort.

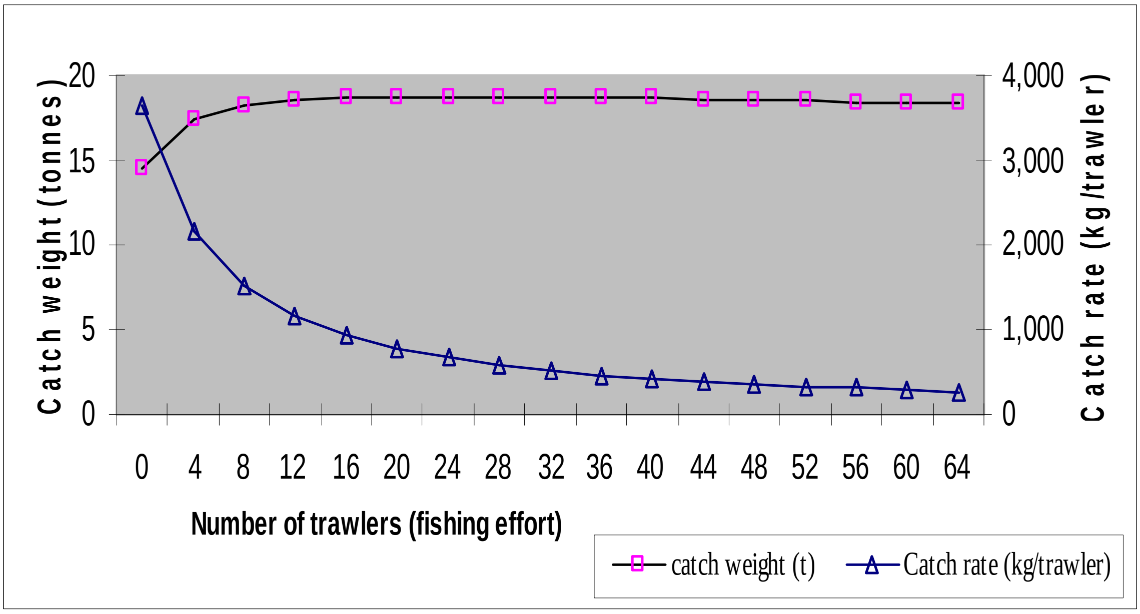

Figure 2: Fishery profits and revenues versus fishing efforts.