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Yield per Recruit of Shrimp (*Pandalus borealis*) at Flemish Cap

by

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Abstract

A length based model written by Seaver was used for calculating yield and spawning biomass per recruit for northern shrimp at Flemish Cap. The model uses fishing pattern by length, Von Bertalanffy growth equation, maturity of females by length and finally natural mortality (*M*). The three different values of *M* were tried as inputs. As the value of *M* is unknown it was difficult to evaluate the status of the stock. The fishing pattern was obtained from a virtual population analysis for the years 1993-2000 using the XSA method. As the ageing and therefore the XSA analysis was not considered very reliable in 2001 the value of this exercise is perhaps meagre.

The calculated effort or corresponding F_{3-5} was 0.48 in year 2003. The calculated value of F_{3-5} corresponding to the nominal effort of 2004 is about 0.46, if catch becomes 48 000 tons in 2004 (as projected). When using M = 0.3, the $F_{0.1}$ is 0.33 and thus the effort is too much. If M is 0.5 the $F_{0.1}$ is at 0.46 which is about the same as expected in 2004. For M = 0.7 on the other hand $F_{0.1}$ is at 0.66 which is much higher than the present F_{3-5}. The female (spawning) biomass is for the last four years 9-15% of the virgin female biomass. So far such a small spawning biomass appears to be sufficient to sustain the stock.

Introduction

The fishery for northern shrimp has been carried out since 1993. In 1995 there appeared to be a reduction in the female part of the stock and NAFO recommended that fishing should be kept at the lowest level possible. The effort was however increased greatly in 1996. There was a decline in stock size if judged by standardized CPUE in the years 1997 and 1998. As the cod stock declined in the Flemish Cap area around mid nineties the decreasing predation gave way to an increased shrimp stock.

Methods

The model used for calculating yield per recruit was a length based approach that is part of the Northeast Fisheries Science Center's Stock assessment toolbox.[1]. The calculations are stepwise and similar to the calculations for the conventional Thompson and Bell model (1934) although here based on length instead of age. The animals are all supposed to be dead at the end of the time period. Here the last age was assumed to be 10 years.

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[1] Contact Alan Seaver (Alan.Seaver @noaa.gov), National Marine Fisheries Service, Northeast Fisheries Science Center, Woods Hole, MA, 02543 for information about the Stock Assessment Toolbox.

The cohort starts with an arbitrary number N_1 at the beginning of the first time step. The numbers alive at the beginning of each time step after the first (t >1) are:

$$N_t = N_{t-1} e^{-z} T$$

where $Z_t = F_t + M$ is the instantaneous mortality rate due to the natural mortality (M) and fishery mortality (F) as obtained from the fishery pattern (selectivity) of northern shrimp at Flemish Cap in the years 1993-2000 (Skuladottir *et al.,* MS 2001). The F at age was there determined by using extended survivor analysis (XSA). The fishery pattern was fitted from average F for ages 2-6. The age was turned into average length at age for the same years over the period 1993-2000, as this is a length based model and the fishery selectivity (S) was fitted to a logistic curve:

$$.S_L = 1/1 + e^{a+bL}$$

Alpha and Beta were used as inputs in the model (Table 1, Fig. 2). The growth constants of the von Bertalanffy growth curve like L infinite and K (coefficient of growth) were calculated for year-classes 1993-1999 (von Bertalanffy, 1938; Skuladottir *et al*., MS 2004). Other inputs were the length weight relation ship fitted as a logarithmic line for all sex stages using data from March through December obtained in 1996 (Fig. 1). Finally a maturity ogive was needed where proportion of female maturity per length could be calculated. All the Icelandic samples from year 1998 and the proportions females (including transitionals) in each 0.5 mm length class were fitted to a logistic curve (Fig. 3). Alpha and Beta from the curve were used as inputs (Table 1).

Results

The model was run using three values of M, namely 0.3, 0.5 and 0.7. All other inputs were kept the same as presented in Table 1. The results are presented in Table 2 and Fig. 4-6. To see where we are at present in relation to catch and nominal effort, a regression was fitted between mean $F_{3\text{-}5yrs}$ every year against nominal effort in the years 1993-2000 (Fig. 7).

For M = 0.3 the F at maximum sustainable yield (F_{max}) is 0.49. The nominal effort of year 2004 if nominal catch becomes 48 000 tons (as projected to the end of the year) will be 142 900 hours. This corresponds to the $F_{3\text{-}5}$ of 0.46 which is below the F_{max} but above $F_{0.1}$ of 0.33 (Table 3). So the effort is too much at present. F is 0.25 at 30% spawning stock biomass per recruit (MSP). When M = 0.5 the results for $F_{0.1}$ were 0.46 and then the effort is just on the safe side. The F at 30% MSP is 0.26. In 2003 the nominal effort was 148 200 and the calculated $F_{3\text{-}5}$ from the regression in Fig. 7 was 0.48 (Table 3) or slightly above $F_{0.1}$.

Finally a run was made with the very high M of 0.7 giving $F_{0.1}$ of 0.657 which is far above the present F of 0.46. If M was as high as 0.7 it would be wise to increase the fishing pressure on shrimp, but then one would have to think about the risk of recruitment failure as the F at 30% MSP is still only 0.26. In this exercise it is assumed that the female biomass should be at 30% of the virgin stock (Table 2), whereas is in fact at the present level of effort of $F_{3\text{-}5}$ = 0.46, MSP is 11% of virgin stock when M = 0.3, 14% at M = 0.5 and 13% at M = 0.7.

Discussion

When thinking about precautionary status one runs into great difficulties with this exercise. Firstly the M is unknown and secondly the results of the XSA analysis that was carried out in 2001 and also compared to the ADAPT analysis (Skúladóttir *et al* 2001) were not found to be convincing. That was probably tied up with the difficulty in ageing shrimp from which catch in numbers was derived (Skuladottir and Orr, MS 2001). Thus the fishing pattern was may be not well estimated.

It is known that the value of M is low when there are few predators present but high when predation is heavy. For Flemish Cap one would think that M is low in the later years or since cod disappeared in the mid nineties, perhaps M is between 0.3 and 0.5. The results for $F_{0.1}$ in year 2004 appear to be below the mean $F_{3\text{-}5yrs}$ when M = 0.3 and above the mean $F_{3\text{-}5yrs}$ when M = 0.5 as assessed from the regression in Fig. 7. So provided M is as high as 0.5 the effort can be increased a little bit. M of 0.7 is not likely to be true as there are few predators at present.

The female (spawning) stock biomass per recruit is rather curious at Flemish Cap as it is not known what size of female biomass is desireable for maintainance of the stock. In this exercise it is assumed that the female biomass should be at 30% of the virgin stock whereas it is in fact much lower for the last couple of years. The mean $F_{3\text{-}5yrs}$ in the years 2001-2002 about 0.5 and 0.43 (Table 3) gives rise to some 9-15% of female stock size and it appears to be able to sustain the stock in the last four years as judged by the present status of the stock (Skúladóttir and Gudmundsdóttir, MS 2004).

Acknowledgements

Special thanks are due to Alan Seaver for granting the permission to use the length based yield per recruit model he has written. The author is grateful to Gudrún Thórarinsdóttir who introduced the model to her. Gunnar Pétursson is also thanked for the various necessary calculations carried out while preparing the data for the inputs in the model.

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Table 1. Inputs into the length based yield per recruit model (Alan Seaver).

Length at start		1
Last age		10
Von Bertalanffy growth curve		
L infinite		35.8
K		0.1916
Length weight relationship		
all year all stages	Alpha	-8.2038
logarithmic line (Fig. 1)	Beta	3.202
Fishing selectivity		
Logistic (Fig. 2)	Alpha	-3.17479
	Beta	0.10563
Natural mortality		0.3; 0.5; 0.7
selectivity		1
Maturity		
Logistic(Fig. 3)	Alpha	-30.23111
	Beta	1.34421

Table 2. Reference point summary. Output from the model.

M = 0.3	F	Yield per recruit	SSB per recruit	Total biomass per recruit
F zero	0	0	0.6563	10.112
F 01	0.3261	0.9374	0.1370	4.9560
F Max	0.4894	0.9847	0.6421	3.7344
Fat 30% MSP	0.2493	0.8623	0.1969	5.7499

M = 0.5	F	Yield per recruit	SSB per recruit	Total biomass per recruit
F zero	0	0	0.1095	3.3696
F 01	0.4571	0.3612	0.0134	1.6774
F Max	0.7504	0.3844	0.0038	1.2067
Fat 30% MSP	0.2571	0.2902	0.0329	2.2017

M = 0.7	F	Yield per recruit	SSB per recruit	Total biomass per recruit
F zero	0	0	0.0189	1.369
F 01	0.657	0.1714	0.0011	0.6788
F Max	N/A			
Fat 30% MSP	0.2671	0.1152	0.0056	0.9861

Table 3. Average F of 3 to 5 years old in the XSA run made by Skuladottir *et al* (MS 2001) and nominal effort (nominal Catch divided by standardised CPUE from (Skuladottir and Guðmundsdottir, MS 2004)

Year	Effort	F3-5yrs	Assessed F3-5yrs
1993	69573	0.184	
1994	109915	0.315	
1995	124428	0.450	
1996	201418	0.709	
1997	98700	0.277	
1998	98403	0.244	
1999	135659	0.337	
2000	142564	0.389	
2001	156250		0.509
2002	136877		0.432
2003	148224		0.477
2004	142860*		0.456

*projected to end of year 2004

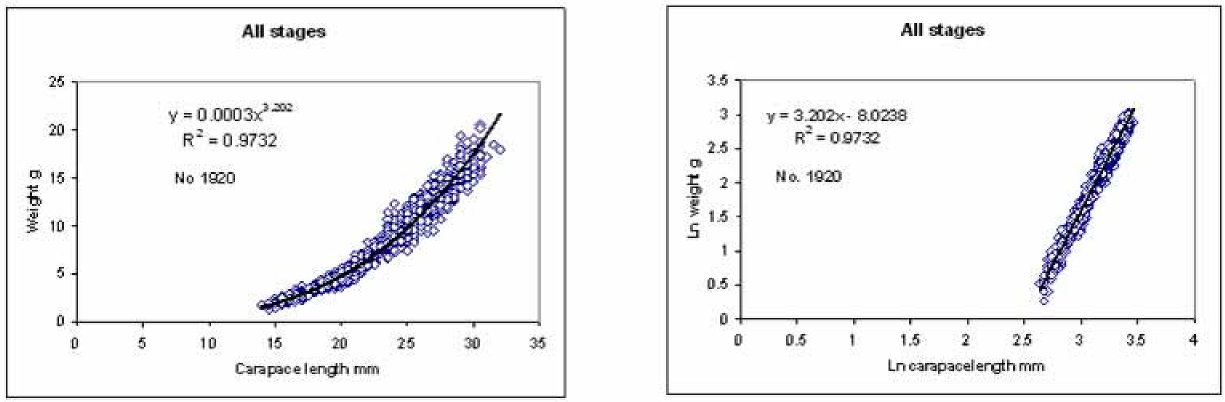

Figure 1. Shrimp. The length weight relationship of northern shrimp. All sexual stages combined for the months March to December.

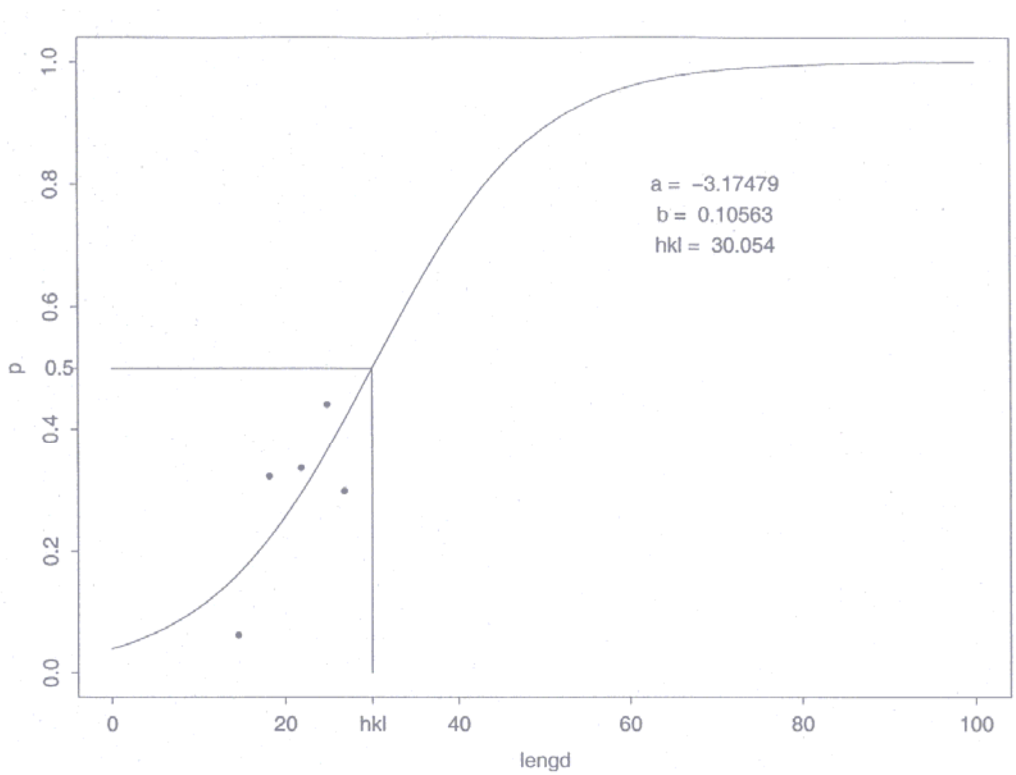

Figure 2. Shrimp in Div. 3M. Fishing selectivity. The ogive was fitted to average Fs of the ages 2-6 year olds converted into lengths, obtained from the XSA calculations (Skúladottir et al. 2001). The fishing pattern was the average of the years 1993-2000.

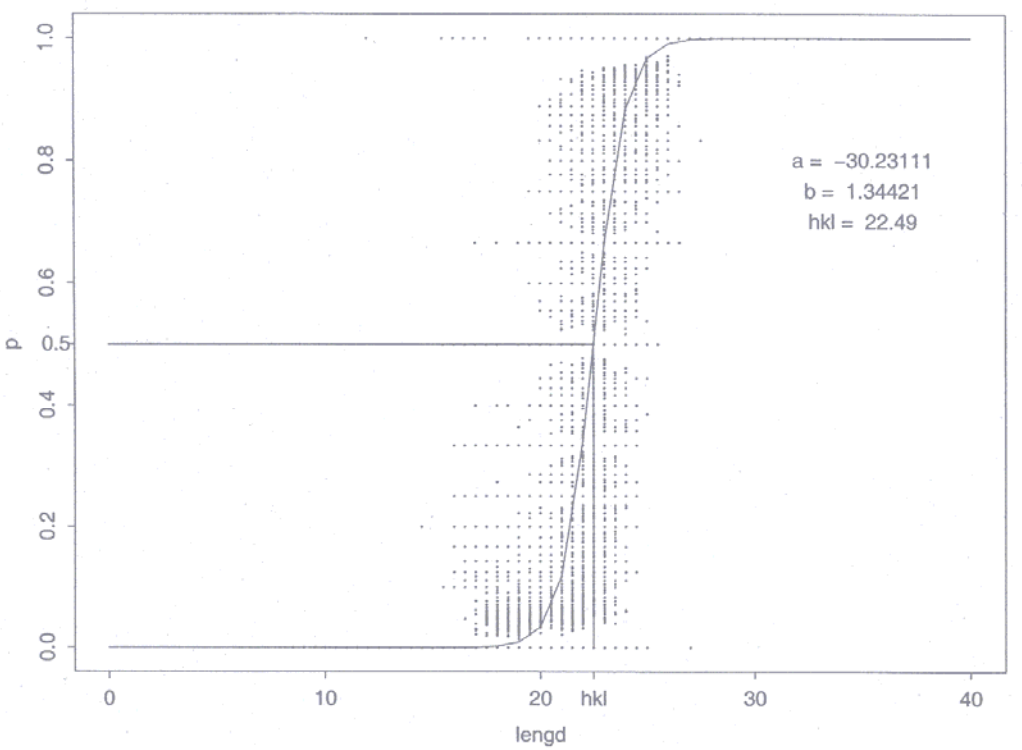

Figure 3. Shrimp in Div. 3M. Female maturity ogive of the whole year of 1998.

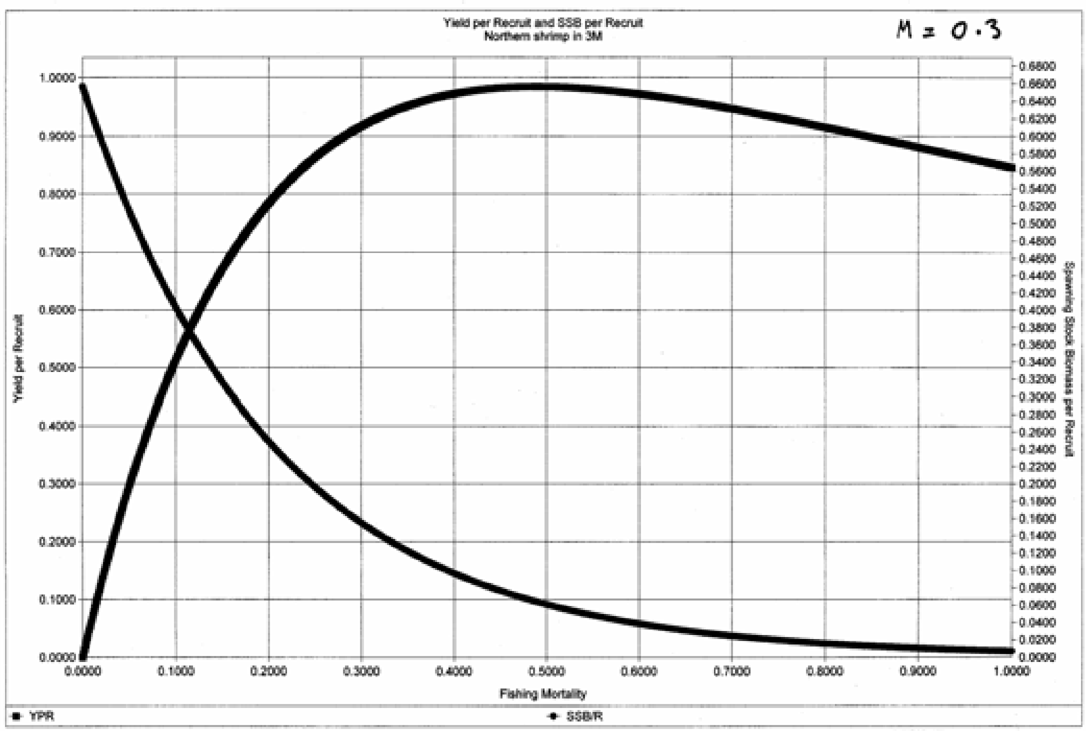

Figure 4. Shrimp in Div. 3M. Yield per recruit of shrimp using the inputs of Table 1 and M = 0,3.

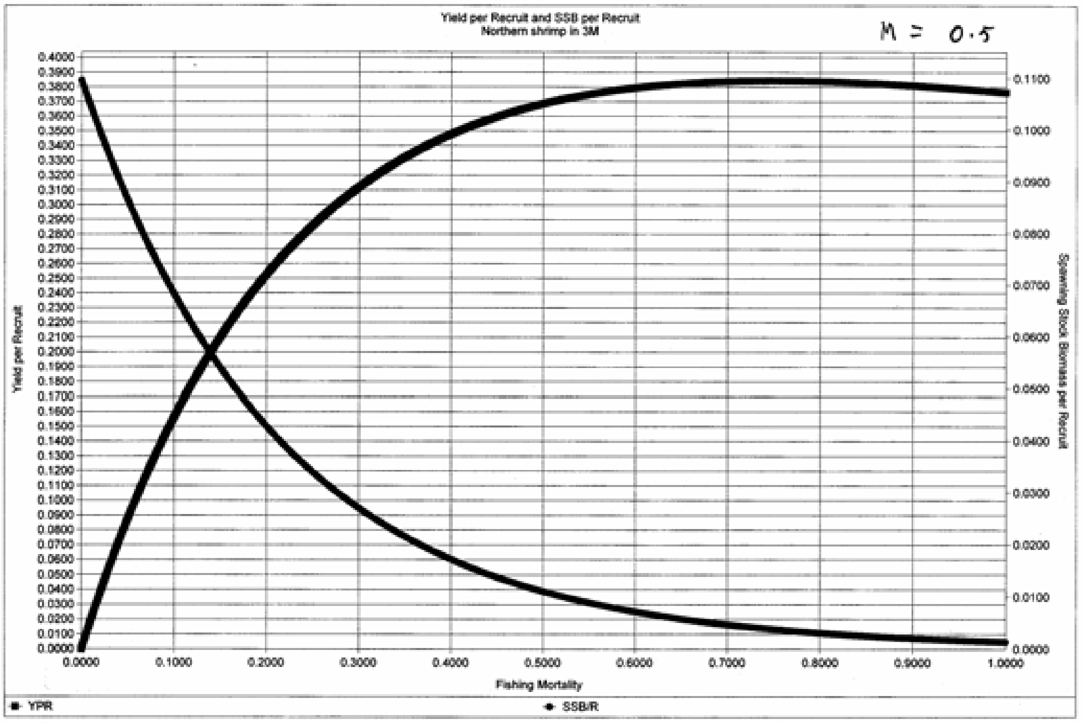

Figure 5. Shrimp in Div. 3M. Yield per recruit of shrimp using the inputs of Table 1 and M = 0.5.

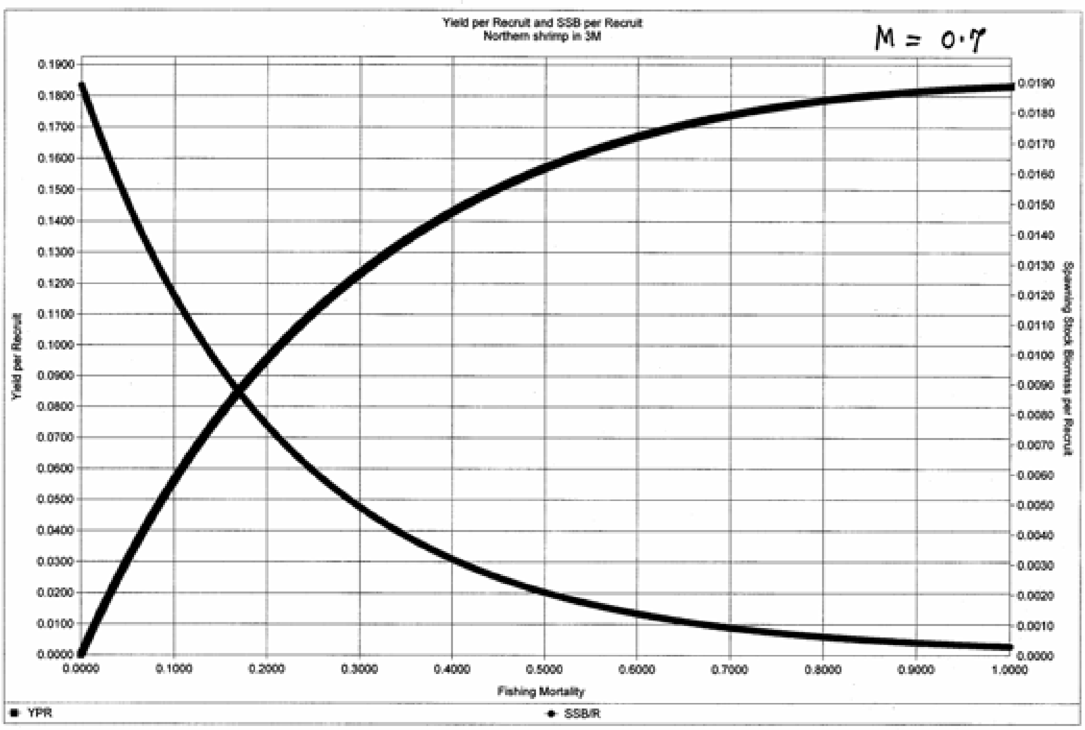

Figure 6. Shrimp in Div. 3M. Yield per recruit of shrimp using the inputs of Table 1 and M = 0.7.

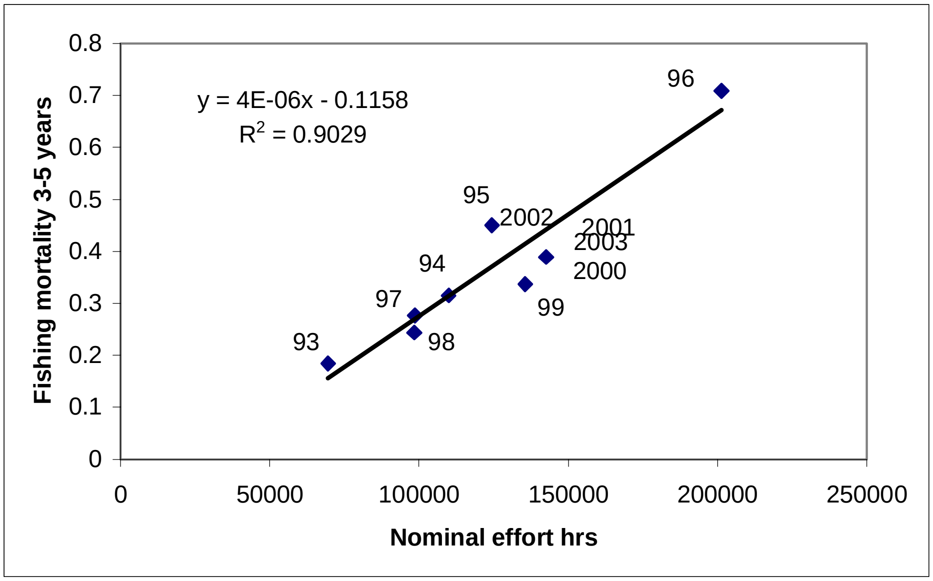

Figure 7. Shrimp in Div. 3M. Nominal effort (calculated by dividing Nominal catch by standardized CPUE) against average fishing mortality of 3-5 year olds from Skúladóttir et al (2001).