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Enhancement of Chinese shrimp in northern Yellow Sea, China

Ye Changchen Li Peijun Liu Haiying Wang Wenbo Dong Jing Chen Tan※
(Marine Fisheries Reaearch Institute of Liaoning, Dalian 116023)
(※ Dalian Worker's University)

Abstract Based on the abundance index of young Chinese shrimp pre- and post-releasing in northern Yellow Sea during 1985~1992, the percentage of released amount in mixed stock (wild and released) was estimated as 92% in average, and the mean recapture rate was 9.2%. The relationship between the postreleased abundance index (Y) and released amount (X) can be presented as $Y=24.01X-1.00\ 3X^2$, $R=0.898$. The significance of correlation is significant when examined by using of F test. The best effect of enhancement can be obtained with a medium released amount. The optimum released amount corresponding with the maximum yield was 1.6 billion ins, and that with the maximum abundance index was about 1.2 billion ins. The death character of the released shrimp was described and the mortalities under different conditions were estimated. Up to opening date (August 15) the survival amount with Cohort Analysis was about 10.5% of the released. The fishing mortality was 0.82 and the natural mortality was 0.11 during the fishing season. The rest 0.07 of the released amount migrated to the wintering ground out of northern Yellow Sea.

Key words *Penaeus orientalis*, releasing enhancement, reasonable released amount, Yellow Sea

Enhancement of fisheries resources is defined as different kinds of young individuals (or inseminated eggs and their parents) released into natural waters to increase their stock. In China, there are 3 kinds of enhancements: releasing enhancement, meaning releasing in original habitat; transplanting enhancement, meaning releasing in nonhabitat; sowing enhancement, that is enhancement for bottom living shellfish in coastal area. Based on the abundance of young Chinese shrimp pre- and post-released in northern Yellow Sea of China during 1985~1992, the effect of enhancement was determined.

1 Natural and released shrimp

In northern Yellow Sea, young Chinese shrimp occur along the coast from Dalian to Dandong City for 400km distant, where the depth is less than 5m. The releasing phase of Chinese shrimp there is arranged between 20 June~10 July annually when the released body length is about 3 cm, similar to the natural one. The young shrimp released into the sea immediately mixed with the natural ones, constituting a part of the mixed stock. The percentage of released young shrimp in the mixed stock was estimated with the abundance index from pre- and post-releasing surveys. Thirteen sections in the habitat of young shrimp, each 1 having 5 stations of depth(5 m, 3 m, 2 m, 1 m, <1 m), were set up. A small haul as a test net was hauled 10 min for the abundance index data. If there were young shrimp at 5 m station, the additional stations (7 m, 10 m)should be added to meet the condition of closed population. An average yield per voyage and

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net was regarded as abundance index (Table 1). The recapture number and rate were estimated on the basis of the yield statistics of every 5 d(Table 2).

2 Result and discussion

2.1 Relationship between released amount and abundance index

Table 1 Abundance index of young Chinese shrimp in northern Yellow Sea

year	abundance index		% *	released amount
	before releasing	after releasing		
1985	lack	lack	-92.2	1.62
1986	0.9	153.6	99.4	7.17
1987	17.7	93.2	81.0	7.74
1988	1.0	117.9	99.2	14.00
1989	12.9	111.0	88.4	15.81
1990	lack	lack	92.2	11.90
1991	8.4	94.1	91.1	18.24
1992	1.6	75.2	97.8	21.04

* average value % means ratio of released shrimp to mixed stock.

The released shrimp constituted about 92% of the mixed stock and there were only a few natural shrimp. Based on the data presented in table 1, the relationship between abundance index after releasing and released amount can be described as a parabola. The expression is:

$Y = aX - bX^2$ $(a = 24.10 \quad b = 1.003 \quad R = 0.898)$

Where Y is abundance index; X is released amount/$\times 10^8$ ins

The correlation coefficient was examined with F - test, $F = 16.62 > F_{0.05}(1, 4) = 7.71$, meaning the control level of released amount over the abundance index is about 80% ($R^2 = 0.806$). Therefore it was sure that the effect of releasing enhancement of Chinese shrimp in northern Yellow Sea was remarkable. The optimum released amount was presented as $X_{opt} = a/2b$ to match the maximum abundance index based on the derived expression when $dy/dx = 0$. The optimum released amount of Chinese shrimp in northern Yellow Sea was about 1.17 billion ins.

Table 2 Enhancement data of Chinese shrimp in northern Yellow Sea

items	1985	1986	1987	1988	1989	1990	1991	1992	total mean
A released amount/$\times 10^8$ ins	1.62	7.17	7.47	14.00	15.81	11.90	18.24	21.02	12.16
B survival number of 15 Aug/$\times 10^6$ ins	31.95	92.46	73.58	165.84	85.34	111.90	163.24	125.56	106.23
C catches /t	884	2094	1702	3741	1605	2562	3450	2313	2294
C catches /$\times 10^6$ ins	25.92	80.86	65.98	146.15	79.84	98.90	147.42	117.99	95.83
D average body weight/g	34.1	25.9	25.8	25.6	20.1	25.9	23.4	19.6	25.1
E (B/A)/%	19.7	12.9	9.9	11.8	5.4	9.4	8.9	6.0	10.5
F recapture rate/%	16.0	11.3	8.8	10.4	5.0	8.3	8.1	5.6	9.2

2.2 Recapture rate

The average recapture rate between 1985～1992 was 9.2%, and the maximum and minimum rates were 16% in 1985 and 5% in 1989.

Variation in recapture rate of enhancement fishery is a normal phenomenon. Except for variations between years, the recapture rate of enhancement fishery for Chinese shrimp in northern Yellow Sea can be divided into 2 stages. The average recapture rate during the first period (1985～1988) was 11.6% with fluctuations between 16%～8.8%, and the second period (1989～1992) was 6.7% with fluctuations between 8.3%～5.0%. The recapture rate decreased due to the increasing damage of unlawful fishing before opening date.

2.3 Decrease in released amount

The released numbers decreased after the shrimp were released into the sea for various factors. If these factors and mortalities could be estimated, the whole developmental process from the beginning of releasing to the end of fisning season can be learned. It was very important for determining appropriate measures to improve the effect of enhancement.

2.3.1 Estimation of mortality Mortalities of the released young shrimp under different conditions were shown in Fig. 1.

depth	time	number	mortality
	beginning	N_0	
<5m	25 Jun.	↓	M_1(handling mortality)
	5 Jul.	N_1	
		↓	M_2(abrupt mortality after releasing)
>5m	5 Jul.	$R_1 = N_2 + R_0$	
			F_1(unlawful fishing mortality)
		↓	M_3(mortality in channel sea water)
	15 Aug.	R_2	M(natural mortality)
	(opening date)		F(fishing mortality)
		↓	M(natural mortality)
	the end Oct.	$Y = Y_1 + Y_2$	S

Fig. 1 Mortality character

N_0, released amount(in number).
N_1 and N_2, number of released shrimp surviving at different stages.
R_0, natural shrimp stock.
R_1, mixed stock composed of released shrimp and natural shrimp.
Y, total yield caught in autumn($= Y_1 + Y_2$).
Y_1, catch of natural shrimp.
Y_2, catch of released shrimp.
S, survivors migrating from Yellow sea to wintering ground.

(1) Handling mortality

Handling mortality, which can be easily estimated, is caused in the period when the shrimp were calculated with balance before released. According to the releasing data of 1992 and 1993 in northern Yellow Sea, the handling mortalities were 8.5% in 1992 and 7.2% in 1993, averaging 7.8%, when the ratio of dead shrimps numbers to the totle sampled numbers expressed handling mortality.

(2) Abrupt mortality

During 2～3 d after the cultured young shrimp were released into the sea, a large amount of death was caused by a sudden change of environment and preys etc. This mortality is defined as abrupt mortality which is very difficult to estimate. According to the mortality data of 1992 and 1993 in northern Yellow Sea, the average values were 17.2% in 1992 and 16.4% in 1993.

Li[1] found, when examining 225 stomaches of 45 fishes distributing along the coast of this area, there was only 1 young shrimp in the stomch of an eroaker (*Corvina belengerii*, Cuvier). Therefore, in northern Yellow Sea, the mortality from predators can be neglected.

(3) Other mortalities

Water－chnneling mortality　There are shrimp pools of 17×10^3 hm^2 and a saltworks along the coast of northern Yellow Sea. When sea water was channeled into these places from late June to late July, the released young shrimp were damaged. In terms of sampling research, the damaged number was up to 1 575 ins /hm^2 during this period, constituting about 7.7% of the released amount of that year(1990).

Unlawful fishing mortality　Death, caused by fishing with various kinds of nets before opening date, is defined as unlawful fishing mortality, which is very difficult to estimate. The only research was made for hand push net. In northern Yellow Sea, there are 30 releasing sites and 1 500 hand push nets from Dalian to Dandong city. In July, the young shrimp inhabiting there were captured at an average of 5 kg/tide (1 200 ins/kg), and in terms of 15 tides, the total captures were 0.135 billion ins, making up about 11.3% of the released amount of 1990.

Natural mortality　The releasing was performed during the 40 d from 5 July to the opening date (15 August). The instantaneous natural moratality coefficient every 5 d was 0.025[2]①, corresponding to the natural mortality rate of 0.18.

2.3.2 Stock abundance　According to the fishery statistics and biological data, the mixed stock abundance at opening date was estimated using Cohort Analysis[3](Table 2). The survival rate during the 8 years was 10.5%.

Based on the result with Cohort Analysis, the average instantaneous fishing mortality coefficient during the fishing season was estimated as about 2.34(1985～1992), and the natural mortality coefficient was 0.32. The rates of fishing mortality and natural mortality were 0.82 and 0.11, respectively.

2.3.3 Decrease character in number　Figure 2 illustrates the decrease character of released shrimp and the different results estimated from 2 directions. Estimated from the regular derection the survival rate of the released was 42.5% and 10.5% from the opposite direction. Therefore, where the rest (about 32%) had gone was unknown. Considering the method error of 15%～20% for measuring before releasing there

were 17% ~ 22% of the released shrimp nowhere to be found.

In addition, according to the total morality coefficient 2.66(2.34 + 0.32) in fishing season, some released shrimp, equivalent to 7% of the released amount at opening date, had migrated to wintering ground out of northern Yellow Sea. So the spawning individuals occuring in the spawning ground next year was scarce. As a result, the shrimp releasing has to be conducted every year to maintain the abundance.

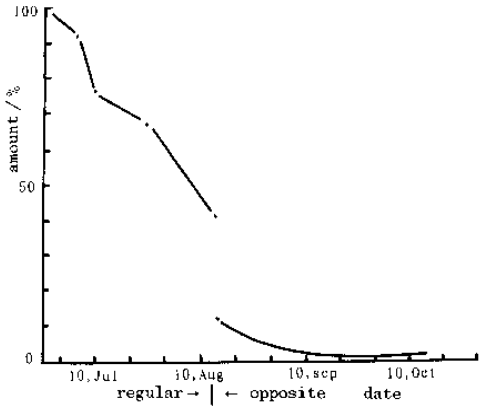

Fig. 2 Decrease in number of released shrimp in northern Yellow Sea

2.4 Reasonable released amount

2.4.1 Maximum yield Maximum yield is a standard for reasonableness judging. The reasonable (optimum) released amount (Xopt) may be defined as the released amount to match the maximum yield(Fig. 3).

The relationship between recapture and released amount (Fig. 3) was similar to that between abundance index and released amount in section 2.1.

$Y = aX - bX^2$ $(a = 14.7, b = 0.453, R = 0.840)$

Where Y is recaptured shrimp/$\times 10^8$ ins; X is released amount/$\times 10^{10}$ ins. The significance of correlation was examined by using F - test; $F = 14.38 > F_{0.05}(1,6) = 5.99$. The correlation was quite significant. The control level of released amount on recapture was about 70% and the best effect of enhancement can be obtained only with the medium level of released amount.

After derivation of the expression with respect to X, the X_{opt} was obtained with $dy/dx = 0$. When $X_{opt} = a/2b = 1.62 \times 10^8$ ins and $Y_{max} = a^2/4b = 1.2 \times 10^8$ ins, the yield in weight is about 3 000 t, and the average body weight was 25 g.

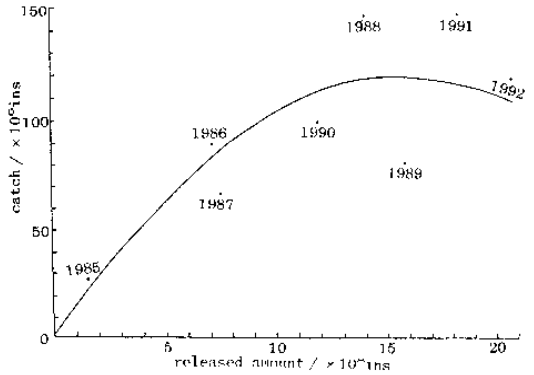

Fig. 3 Relationship between recoptured and released amount of shrimp in northern Yellow Sea

2.4.2 Maximum economic effect The profit of enhancement fishery is expressed as follows[4]:

$$u = p(aX - bX^2)W - (cX + d)$$

Where u is fishery profit/$\times 10^6$ Yuans(RMB); p is unit price of the shrimp/$\times 10^4$ Yuans$\cdot t^{-1}$; W is mean body weight/g; c is unit price of released shrimp/($\times 10^6$ Yuans$\cdot 10^{-9}$ ins^{-1}) and d is fishing cost/$\times 10^6$ Yuans which was assumed constant. Meanwhile the average fishing cost of the preceding 3 years was recognized as the fishing cost this year; X is released amount/$\times 10^8$ ins. The item $p(aX - bX^2)W$ in the expression is an output and $(cX + d)$ is an input. The input - output cruves of enhancement fishery of Chinese shrimp in northern Yellow Sea was shown in figure 4.

When $du/dx = 0$, there are $X_{eop} = (apW - c)/2pwb$ and $U_{max} = (apW - c)^2/4pwb$, where X_{eop} is optimum released amount to match the maximum profit, about 1.5×10^9 ins for the enhancement of Chinese shrimp in northern Yellow Sea and U_{max} is maximum profit of the fishery, about ¥86×10^6.

This paper provides released amount with some

scientific data and optimum released amount for different goals. The policy－makers may balance verious factors to decide the yearly released amount, for example, 0.9 billion shrimp were released in 1995.

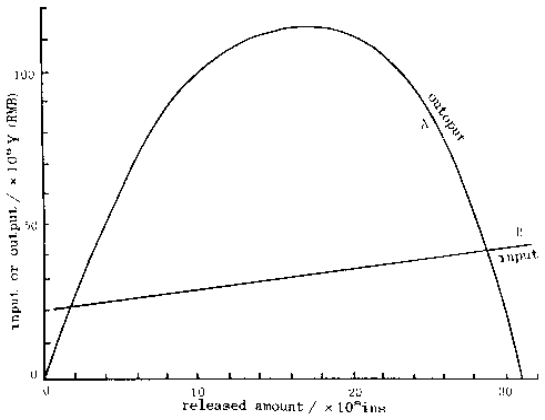

Fig.4　Input－output cruves of enhancement fishery of Chinese shrimp in northern Yellow Sea

2.5　Evaluation in result

2.5.1　Increase in stock number　Figure 5 is a yield and fishing effort cruve of Chinese shrimp fishery in northern Yellow Sea, showing the dynamics after and before enhancement. Before enhancement the stock size fluctuated at low level with an annual yield of 200 t, and after enhancement it increased largely with an annual mean yield of 2 300 t. The total released amount during the 8 years(1985～1992) was 1.216×10^9 ins. The enhancement yield amounts to 18 352 t; the annual mean yield was 2 300 t, which increased by about 10 times compared with the yield before enhancement. The enhancement effect is very large.

2.5.2　Economic result　The total value of the first sale was ¥0.586 billion during 1985～1992 when the total cost was ¥0.195 billion including fishing cost(¥0.132 billion) and the cost for purchasing young shrimp (¥0.063 billion). The total economic result, composed of fishermen profit and social economic result, was ¥0.741 billion. The fishermen got ¥0.455 billion during the 8 years, accounting for about 60% the total economic result. The ratio of the input (cost of young shrimp for releasing)to the output(value of the first sale)was about 1∶10. The economic result of Chinese shrimp enhancement in northern Yellow Sea was very remarkable.

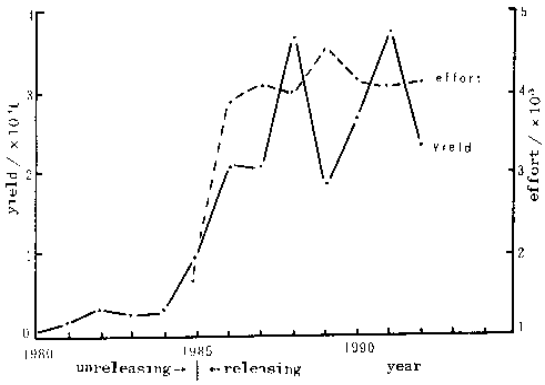

Fig.5　A yield curve of Chinese shrimp fishery in northern Yellow Sea

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黄海北部中国对虾增殖

叶昌臣 李培军 刘海映 王文波 董婧
(辽宁省海洋水产研究所,大连 116023)
陈 檀
(大连工人大学,116001)

摘 要 根据1985～1992年黄海北部中国对虾幼虾放流前后相对资源量资料,估算放流虾在混合虾群中占的平均比例约为92%,平均回捕率9.2%。放流量(X)与放流后相对资源量(Y)的关系为 $Y=24.10X-1.003X^2$,R=0.898。经F—检验相关显著。结果表明:中等放流量才能获最好增殖效果;与最大渔获量相应的放流量约16亿尾;与最大相对资源量相应的放流量约12亿尾。描述了放流虾的死亡特征,并估算了各类死亡值。用Cohort分析方法估算了放流虾到开捕时(8月15日)的存活数量,平均占放流量的10.5%。渔汛的捕捞死亡率约0.82,自然死亡率0.11,其余0.07游出黄海北部去越冬场。

关键词 中国对虾,放流增殖,合理放流数量,黄海北部