Report on assessment and management advice for 2002 of the anchovy fishery in the Yellow Sea and the East China Sea

The Bei Dou Fisheries Management Project 2001-2005

Yellow Sea Fisheries Research Institute

Qingdao 22-24.04.2002

INTRODUCTION

According to the Project Document for the “Bei Dou Fisheries Management Project 2001-2005” a small workshop was arranged 22-25 April 2002 at the Yellow Sea Fisheries Research Institute (YSFRI) in Qingdao. The workshop was arranged within the sub project “Fishery Management based on Scientific Investigations” to evaluate the present state of the anchovy stock and setting and advicing on a TAC for 2002. All the input data for the workshop were provided by YSFRI.

Participants: Prof. Johannes Hamre, Institute of Marine Research, Bergen
Dr. Jin Xianshi, YSFRI, Qingdao
Mr. Zhao Xianyong, YSFRI, Qingdao
Mr. Li Fuguo, YSFRI, Qingdao

The same workshop met in Quingdao in March last year and a report on its work is available at YSFRI.

MATERIALS AND METHODS

Data

Data on acoustic measurements of number and biomass by age of anchovy were available for the years 1985 - 2002, except for the years 1997-1998 (Table 1). The surveys were carried out in the winter season from November to early February, the measurements done in November-December one year were however considered as stock estimates at 1 January the following year for obtaining consistency in the data treatment. The total catch by year from the start of the anchovy fishery in 1989, was also recorded (Table 1), but samples of the catches for converting the data to catches by age were not available. In addition reports on the general biology of the stock and the development of the fishery were used in the processing of the data and in the evaluation of the assessment results. The data were processed and the calculations were made on spreadsheet (Excel).

Basic Methods

The basic methods used in estimating stock parameters are by comparing stock estimates in number by age in subsequent years. The yearly mortality (Z) is thus obtained by input of acoustic measurements to the formula:

$$N_{t+1} = N_t * e^{-zt}$$

where N_t is the estimated number of a year class in year t and N_{t+1} is the corresponding estimate of the year class in the subsequent year.
The abundance of the year classes as recruits of the first year (R_1) have been back calculated by the VPA method using the Pope's approximation formula:

$$N_t = N_{t+1} * e^M + C * e^{M/2} \quad ,$$

where M is the natural mortality and C is the catch by age in number in the year t.

The catch in number (the sustained yield) is estimated by the conventional catch equation:

$$C_t = N_t * E*(1-e^{-zt})$$

where C is the catch in number by age and E the exploitation rate F/(F+M). F is the fishing mortality.
The M-output (M_{out}) is calculated by a similar formula:

$$M_{out} = N_t * M/(F+M)*(1-e^{-zt})$$

The corresponding output biomasses of the stock are obtained by multiplying the number by the mean weight by age and summarizing the age groups.
The M-output is the biomass production corresponding to the natural mortality (Hamre and Tjelmeland 1982).
A stock recruitment relationship was estimated by fitting the Beverton and Holt's stock- recruitment model to an estimated number of age group one (R_1) and a corresponding spawning stock estimate (SSB), using the least sum of square method. The Beverton and Holt's model used is of the form:

$$R_1 = R_{MAX} *SSB/(H+SSB)$$

where R_{max} is the asymptotic R, and H is the SSB which yields half of the R_{max} value.

The calculations were executed on spread sheet (Excel) and the tuning of the parameters Rmax and H against SSB was performed by using the Excel's solver function.

RESULTS AND DISCUSSIONS

Natural mortality.

The total mortality (Z) was estimated by comparing abundant estimates of year classes in subsequent years. Since there is a break in the data series in 1997-98, only data from the years 1987-95 were used for the mortality estimate. The 1986 data was excluded because this was the beginning year of the data series and the distribution area of anchovy was grossly under covered by the survey. In the period from 1987 to 1995, there was an insignificant fishery on the stock, and the total mortality Z was considered equal to the natural mortality (M) .The average natural mortality (M) in age group (t) was obtained by tuning back-calculated number of age groups (t) from age groups (t+1) against the corresponding acoustic measurements, using the solver function in Excel to identify the M-value giving the best fit. The catches were subtracted by converting the total catch to catch in number by age using the age composition in the stock from the survey data as basis for the calculation (Table 2). Since the catches prior to 1996 are rather small it is assumed that the possible error introduced by this approach is insignificant. The back calculation of cohorts by ages was done by Pope's approximation formula. The estimated number of age 3 was used as the terminal stock in the VPA run. This is because the lager individuals tend to congregate in the southeastern part of the wintering ground, extending into the Korean water; and it is likely that these individuals are inadequately covered by the surveys. The estimates of the age 4 anchovy are therefore doubtful and considered improper as the terminal stock in the VPA run.. The back-calculated stock numbers, using the age 3 as the terminal stock, are shown in Table 3. (NB: *1) I deliberately avoid using the word 'emigration' because inadequate coverage into the Korean water was a general problem and emigration might be true specifically only for some years. 2) I added the above sentences in blue as you requested, but frankly, I am not quite sure about the significance of my above-added statements as a justification for not using age 4 as the terminal stock. The inadequate coverage is actually a general problem for all age groups, what might be true is that the age 4 and age 1 fishes were affected more seriously than the other two age groups. Should this be agreed upon, then the biomass of age 4 forward-predicated from age 3 would be used to replace the observed age 4 in the adjusted SSB for stock-recruitment estimation, a point which can be deferred to a later report. 3) I feel that your statement in a later paragraph, 'the very low and fluctuating number left as four years old', could be good justification for not using age 4 as the terminal stock,*

The mortality from age 2 to age 3 in the years 1987 to 1995 was calculated by comparing the measured 2 years old to the back-calculated 2 years old derived from the measured 3 years old in the subsequent year. The differences in the estimates were squared and the M-value corresponding to the least sum of squares was selected as the average yearly M_2 for the period. The best fit was obtained when M_2 equalled 0.45 and the corresponding estimates are illustrated in Figure 1.The estimates obtained in the years after1996 are included in this Figure but not used in the M_2 estimates. This is because the catches make a considerable part of the mortality in this period and since the age structure of the catches are not sampled but assumed on the basis of the survey data, these data are considered to be inadequate for natural mortality estimates. Figure 1 shows that the survey data for these two age groups are consistent and that the estimated M_2 is fairly accurate.

Judging from Tables 2 and 3, the M-value of age group 3 (M_3) is probably higher than M_2, but due to the very low and fluctuating number left as four years old, the present method of estimating M_3 is not applicable. The M_3 and M_4 have therefore been set equal to M_2 in the assessment. The error introduced is however probably small, due to the low number left in the older age groups (Table 2).

Comparing the measured number of the 1-groups to the back-calculated number from the 2-groups in the subsequent years (Table 3), it is seen that the sum of the former figures is about 20 % lower then that of the latter ones. This indicates that M_1 is smaller than M_2. However, if the 1-group fish is not fully recruited to the measurable stock, the difference may also be explained as a measure of incomplete recruitment. Judging from the general knowledge of biology and distribution of the smallest fish, the latter is a more likely explanation to the difference in the two estimates, and M_1 is therefore set equal to M_2 assuming that some 80% of the 1- group is recruited to the measurable stock at the 1st. of January each year.

Stock - recruitment relationship.

Since the 1-group fish are considered to be incomplete recruited to the surveyed stock, the R_1 parameter of the stock- recruitment formula was back calculated from the number of 2 years old fish in the subsequent year, where $M_1 = M_2$. The corresponding SSB was estimated as the total stock biomass, including the back calculated 1-group fish, minus half the catch of the previous year. This was considered as a reasonable estimate of SSB since the fishing activity is more or less continues throughout the year, and the spawning activity of anchovy is more or less continues from April through October with a peak in June and July.

In 1997 and 1998, when no survey was done, the age groups 4 were chosen roughly to be 0.1 billion individuals. The 2-group in 1997 and the 3-group in 1998 were back calculated from the observed 4-group in 1999 using an average M of 0.45, and the 2-group in 1998 from the observed 3-group in1999. Finally the age group 3 in 1997 was projected forward from the 2-group estimate in 1996, and an estimate of the state of stock and recruitment for the to years without survey data could thus be establish.

The resulting stock- recruitment scatter-plot is shown in Figure 2, and the following stock- recruitment relationship was obtained:

$$R_1 = 2.487 \times \mathrm{SSB}/(1.174 + \mathrm{SSB})$$

where R_1 is given in billions individuals and SSB in million tonnes. For a stock size of 1.5 million tonnes at the beginning of one year will yield a recruitment of about 140 billion individuals as one years old fish at the beginning of the subsequent year. The average R_1 in the years 1987-96 is estimated to 182 billion ind., corresponding to a SSB of about 3.2 million tonnes.

Sustainable yield.

Based on an average R_1 of 180 billion ind and a M of .48 , sustainable yield (Y) and corresponding stock biomass (BSS) versus fishing mortality (F) was calculated and presented in the last year report as shown in Figure 3. In this calculation the catchability of the 1-group was set to 0.8 when the two years old and older fish is 1. This was considered as the best choice of fishing pattern as long as catch by age data is lacking. The new data included in the present report do not justify to recalculate the long term yield and M-output or change the findings which were as follows:

The virgin stock (F=0) is estimated at about 3.5 mill. tonnes, which is in accordance with the survey measurements. The sustainable yield (Y) is approaching 850 000 tonnes (Y_{max}) which may reduce the stock to 1.5 mill. tonnes. This is the stock level where the recruitment is supposed to be affected (Figure 2). This means that fishing more then 850 000 tonnes a year for several years, as has been the case in this fishery, the stock is bound for a collapse according to this assessment. The optimum sustainable yield (Y_{opt}) is estimated at 775 000 tonnes, corresponding to F_{opt} or $F_{.1}$ of 0.7. The corresponding stock biomass is estimated at 2.0 mill. tonnes.

Anchovy is important as prey species for other fish stocks in this area. Therefore when managing the anchovy stock, multispecies aspects also have to be taken into consideration (YSFRI, 1999). In order to quantify this statement the biomass production corresponding to the natural mortality, the M-output (Hamre and Tjelmeland 1982), was calculated and is shown in Figure 3. The M-output is considered as the food potential for the predators, and is estimated at 1.4 mill. tonnes in the virgin state (F=0). The M-output is reduced to 0.6 mill. tonnes when the stock is exploited at the optimal level ($F_{.1}$) and below 0.3 mill. tonnes if F is increased above F_{max}. These findings clearly demonstrate that anchovy is a very important prey species in the area and that a stock collapse will have serious impact on the food supply for other important commercial stocks in this ecosystem.

State of stock and fishery.

The development of stock and fishery is shown in Figure 4.

The abundance of anchovy has been measured annually since 1986, except for the years 1997- 1998. The surveys have been carried out in the winter season from November to early February with R/V “Bei Dou, applying acoustic method. For the years 1997-98, the Figure shows the VPA-calculated stock sizes, as described by ages under the section of stock-recruitment relationships.

The catches prior to 1989 were low and anchovy was only taken as by-catch in the trawl fisheries. From 1990 onwards the catches increased to 0.45 mill. tonnes in 1995 and to a record catch of 1.2 mill. tonnes in 1998. The catch levelled off since then and declined to 0.95 mill. tonnes in 2000 and further to a preliminary estimate of 0.48 mill. tonnes in 2001.

The catch-stock development in1995-2002 confirms the conclusion drawn in the last years report. When the catches approach the $F_{.1}$ level (0.7 mill. tonnes), the stock is reduced to about 2 mill. tonnes, and is depleted when the yearly catches result in F-values above F_{max} (catches > 0.85 mill. tonnes). The stock is at present fished down to some 5 % of the estimated virgin stock (3.5 mill. tonnes) and is considered to be at a point of collapsing.

Fishery management and prediction.

A work shop for giving scientific management advice for 2000 (YSFRI, 1999) valued the average potential yield of anchovy in the Yellow Sea and East China Sea at 500 000 tons a year (Iversen et al.1993). The estimate was considered conservative and regarded as a precautionary catch level. The work shop concluded that since 1996 the catches had been far above the 500 000 tonnes level and warned that if the present fishing effort was carried on in the coming years the risk for stock collapse would be high.

The catch taken in 2000 was far above the recommended precautionary catch level, and the stock continued to decline. In order to turn this stock development, the last year work shop recommended to limit the fishing mortality in 2001 to below 0.7 or to a catch below 100 thousand tonnes. This was not acted upon and the catch in 2001 amounted to about 4 times that level. The measurable stock in 2002 is reduced to below 0.2 mill.tonnes, but it is difficult to predict a future equilibrium stock level and the corresponding catches in unregulated anchovies fishery. This is because data on the age composition of the catches are lacking, and such data are needed to determine the fishing pattern and the recruitment curve, which are essential input parameters in forecasting stock development as a function of the catch on such low stock levels. However, since the anchovy is a fast growing fish which mature at a low age, and the fishery on immature fish is limited, it is possible that the stock will survive on this low level without any direct restriction on the fishery, yielding yearly catches of some few hundred thousand tonnes. The consequences of such a management policy is obvious for the anchovy fishery, but an unregulated anchovy fishery may also affect seriously the obtainable yield of other fisheries in the region.

As pointed out by Johannessen et. Al. (2001), anchovy is important as food for several other fish species in the area, such as small yellow croaker, flounder, white croaker, hairtail, Spanish mackerel etc. A stock collapse of anchovy may therefore have serious implications also for these stocks, and managing the anchovy fishery multispecies aspects should thus be taken into account. Sustained high fishing pressure on anchovy may impose increased competition and other species may boost and replace the position of anchovy as a dominant species in the Yellow Sea. Reducing the fishing pressure on anchovy may improve the condition not only for anchovy but also for the predator stocks.

Although other plankton feders, such as sandeel which has increased in later years, may replace the role of anchovy in the food chain, it seems fair to conclude that this will reduce considerably the potential of the total fish production in the Yellow Sea. In order to avoid this as a permanent state of overexploitation, the workshop is of the opinion that, with the present state of stock, nothing but a total band on the anchovy fishery for some years can turn the trend and rebuild the anchovy stock to a higher sustainable level. It is further recommended that future investigations should include monitoring of other stocks which may interact with the state of the the anchovy stock such as sandeel, croaker, hairtail, Spanish mackerel etc as well as the anchovy stock during its collapsing and rebuilding processes. It is felt that the present case of overexploiting the key species in this rather limited and surveyable ecosystem provides a unique opportunity to study and assess the vital parameters of stock interaction in an exploited ecosystem. Such knowledge will be of grate value in general, both for management purposes and for scientific insight into the dynamic of an ecosystem as well.

References

Hamre, J. and S. Tjelmeland 1982. Sustainable yield estimates of the Barents Sea capelin stock. ICES C.M. 1982/H:45: 1-24. (Mimeo).

Iversen, S., A., Zhu, D., Johannessen, A. and Toresen, R. 1993. Stock size, distribution and biology of anchovy in the Yellow Sea and East China Sea. Fisheries Research, 16, 147-163.

YSFRI, 1998. Workshop on evaluation of the state of selected fish stocks and respective scientific management advices and processing of hydrographic data.The Bei Dou research and Fisheries management Project. Yellow Sea Fisheries Research Institute, Qingdao 12-18.11.1998. (Mimeo)

YSFRI, 1999. Evaluation of the state of selected fish stocks and respective scientific management advices for 2000. The Bei Dou research and Fisheries management Project. Yellow Sea Fisheries Research Institute, Qingdao 12-17.11.1999. (Mimeo)

Tables

Table 1. Stock size and yearly catches in mill.tonnes in 1986-2002.

Year	Stock	Catch
1986	0.68	
1987	2.16	
1988	2.82	
1989	2.82	0.04
1990	2.51	0.06
1991	2.46	0.11
1992	2.78	0.19
1993	4.12	0.25
1994	3.74	0.35
1995	3.85	0.45
1996	2.55	0.60
1997		1.10
1998		1.20
1999	0.79	1.10
2000	1.75	0.95

2001	0.42	0.48
2002	0.18	

Table 2. Stock measurements in number and weight by age.

	Stock in number (billion ind.)				Mean weight in gram			
age:	**1**	**2**	**3**	**4**	**1**	**2**	**3**	**4**
1986	139	121.2	34.7	0.3	6.0	10.8	13.5	15.7
1987	102	84.1	32.8	1.4	6.8	12.0	13.0	16.4
1988	210.1	98.9	30.3	0.1	6.8	10.1	12.9	15.7
1989	136.5	105.9	74.6	8.5	3.3	11.1	14.2	15.3
1990	72.9	106.6	67	4.4	5.3	11.0	13.2	15.7
1991	163	94.9	58	17.3	4.8	8.3	11.2	13.5
1992	104.2	161.6	19.9	2.2	6.1	11.3	14.4	15.9
1993	185.6	168.7	80.4	24.1	5.0	10.1	14.1	14.6
1994	122.8	66.4	114.7	43	6.8	11.4	13.0	15.2
1995	198	133.3	58.6	0.6	6.6	12.7	14.6	15.7
1996	113.3	69.1	66.5	5.7	7.3	10.1	13.8	18.8
1997								
1998								
1999	30.1	38.4	14	0.9	4.0	12.0	20.0	24.0
2000	56.6	58.8	36.5	2.4	3.8	11.9	19.6	23.5
2001	18.733	23.238	4.413	0.134	3.2	10.9	20.6	27.3
2002	7.87	7.50	1.65	0.21	3.9	12.2	20.9	25.2

Table 3. Back calculated stock number (billion ind.) by age from age 3 (terminal stock)

Age:	**0**	**1**	**2**	**3**
1986				
1987	263	184	48	33
1988	235	168	117	30
1989	162	150	107	75
1990	359	104	94	67
1991	488	229	65	58
1992	267	311	140	38
1993	327	170	193	80
1994	232	209	100	115
1995	249	148	124	59
1996	409	159	76	67
1997	250	261	80	35
1998	192	159	128	28
1999	153	122	66	37
2000	62	98	48	4

2001	16	39	37	4
2002		10	8	2

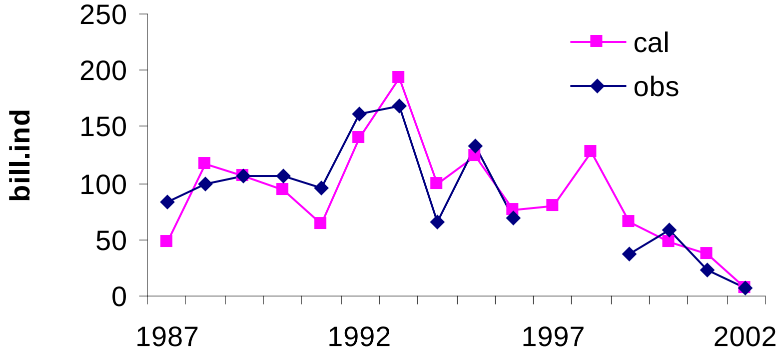

Figure 1. Number of 2 years old anchovies measured (obs), compared to back-calculated (cal) number from measured 3 years old the subsequent year. The 1991 figure is back calculated from the corresponding 4 years old (see Table 2).

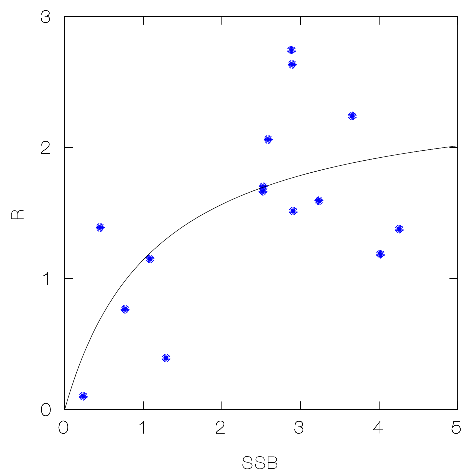

Figure 2. Recruits R_1 in 100 billions individuals versus adjusted stock size in million tonnes. Superimposed is the estimated stock-recruitment curve based on Beverton-Holt's model.

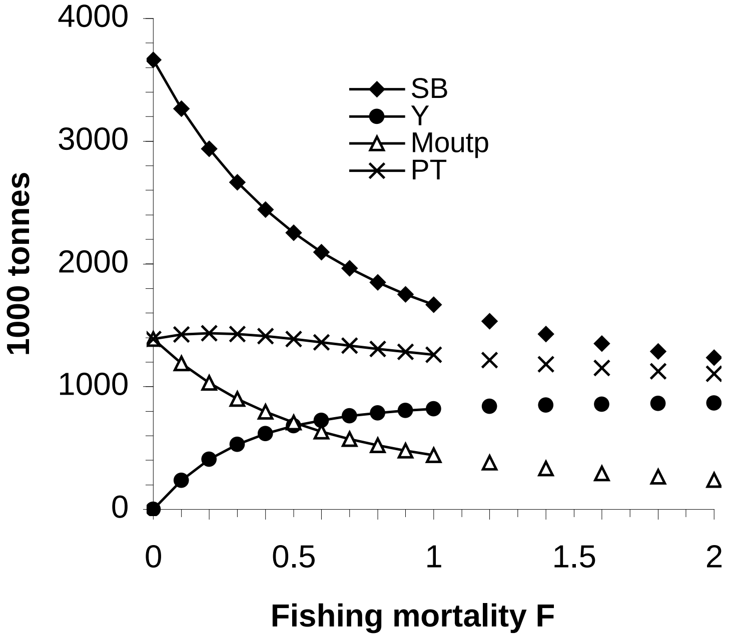

Figure 3. Stock biomass (SB), Sustainable yield (Y), M-output (M_{outp}) and total biomass production (PT) of anchovy versus fishing mortality.

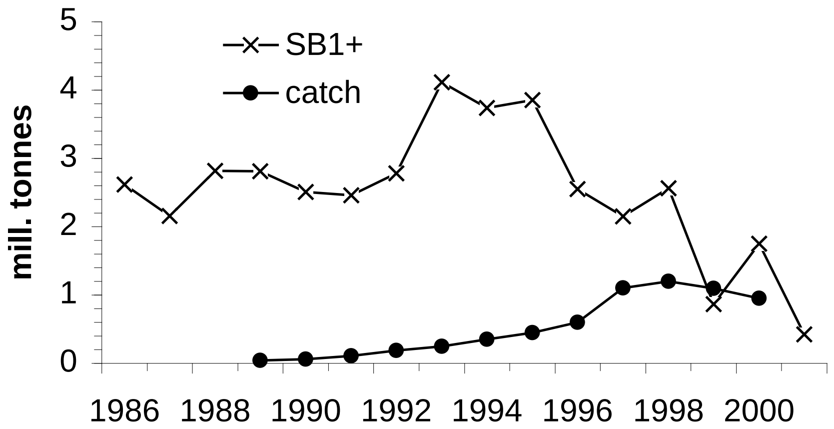

Figure 4. Measured stock biomass of 1-group and older anchovies (SB_{1+}) and yearly catches. For the years 1997-98 the stock biomass is back-calculated from the 1999-2001 stock measurements and 1997-2000 catches.