

# Assessment of effectiveness of improved fisheries management techniques

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## ABSTRACT

The main objective of this research is to review Korean fisheries structural adjustment policy and to evaluate the resource status and fishing capacity in the Yellow Sea. The Korean authorities have for some time followed a structural adjustment policy in fisheries, largely focusing on buyback of fishing vessels. This policy appears to have a significant contribution to reducing the rate of fisheries resource decline and some fish species, such as squid, Spanish mackerel and Jack mackerel, show signs of recovery. Nevertheless, even though a large number of fishing vessels has been retired for the last 15 years, the effective fishing capacity(i.e. engine power) has tended to increase. Thus, increased engine power has to a certain extent replaced decommissioned vessels. This trade-off, often observed under buyback programs, has occurred because of lack of effective institutional arrangements.

In order to make the buyback policy more effective, the central and provincial governments need to develop an integrated policy including buyback, resource enhancement, off-fisheries income promotion, fuel subsidy reorientation and self (or co)-management programs. Also, the package program should be supported by a new R&D system that is focused on enhancing and maintaining the Yellow Sea's environment and ecosystem. This will require far closer cooperative work among South/North Korea, China, and related international bodies.

**Key words:** structural adjustment policy, fishing capacity, engine power, subsidy, ecosystem and the Yellow Sea.

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## 1. Introduction

Fishing communities in the west coast has been long involved in fisheries of the Yellow Sea and there have been keen competitions for fish stocks among Korea, China and Japan. Now, this Far Eastern region including these coastal states is the largest producer as well as the largest consumer of fish in the world(FAO FISHSTAT). However, they have never agreed upon creating any forms of joint Yellow Sea fisheries resource management.

Recently, bilateral fishery agreements were concluded among three states, based on the UN Convention on the Law of the Sea(Choi, 2000). Contracting the bilateral treaties, since the late 1990s Korea began to facilitate its fisheries structural adjustment policy, focusing on fisheries resource restoration and conservation. The primary instrument is buyback programs of reducing fishing capacity(Shin *et al.*, 2001). Many fisheries experts agree that so far the buyback programs have made a significant contribution to lowering the rate of resource decline in the entire Korean waters but the programs are not yet sufficient to allow full recovery of resource stocks to the optimal levels(i.e. MSY). Thus, many fishing communities/fisheries(especially fisheries dependent on bottom fishery resources) are facing serious economic hardship.

The entire Yellow Sea of the Korean peninsula is a single vast continental shelf and one of the most productive fishing grounds in the world. Since however the Yellow Sea is a semi-closed sea, its ocean ecosystems are known to be very sensitive and vulnerable to external shocks such as overexploitation, pollution and climate change(Park, 2009). For the last three decades the Yellow Sea has suffered from severe overexploitation and pollution problems. Overexploitation has been much more intensified by fishing capacity expansion of Korean and China(Hong, 2007). Ocean pollution also has been getting worse than ever before and in recent years. And climate change seems to add much more to such problems than any other factors(Park, 2009).

In this context, the main objectives of this research are to review Korean fisheries structural adjustment policy, to develop and estimate an analytical model for evaluating the fishery resource status and fishing capacity of the Yellow Sea and to draw some policy implications based on the research results.

## 2. Structural adjustment policy: Buyback programs

### 2.1. Goal and background

The main goal of Korean fisheries structural adjustment policy is to promote their productivity, competitiveness and sustainability by reducing the current fishing capacity to a level that is appropriate to fishery resource stocks. There are by and large three reasons that Korean government started the fisheries structural adjustment policy(Kim *et al.*, 2006). First, there has been a continuous decline of fisheries resources over time since the mid 1970s in entire Korean waters. Such problem began to get much more serious since early 1990s.

Second, Korean fisheries have begun to face the trade liberalization since 1984. Starting of World Trade Organization(WTO) and expansion of free trade agreements provided a momentum for facilitating to open Korean fish market to the international community. Third, the bilateral fisheries agreements among Korea, Japan and China made narrow Korean adjacent fishing grounds and limited much Korean fishing freedom in the Far East region. This resulted in overcapacity and thus keener competition among on-and off-shore fishing vessels on the entire Korean waters and led to beginning buyback programs.

### 2.2. Process

A research on fisheries resource stock assessment showed that fishing capacity exceeded the optimal level by 23~53%(Korea Rural Economic Institute, 1992). The first general buyback program was launched in 1993, based on a survey & research for fisheries structural adjustment (buyback programs) and the buyback programs started with a legal base in 1994(i.e. Special Law of Dealing with Agricultural and Fishing Village Problems, 1990).

There are two types of buyback programs: one is the general buyback program and the other is the international buyback program. The general buyback priority in 1994~2007 was placed on on-shore fishing boats(i.e. on-shore stow net on anchors, gape net with wings, etc : 1,175 boats) which use very small mesh nets and the off-shore fishing vessels(i.e. large purse seine, large otter trawl, etc) which most affect fishery resources. The international buyback program started to alleviate off-shore fisheries' economic hardship due to Korea-Japan(1999) and Korea-China Fisheries(2001) Agreements. In order to deal with such fishermen's difficulty, the government has legislated "Special Law for Fishermen's Aid and Fisheries Development Due to the Bilateral Fisheries Agreements (Choi, 1999, 2002)."

### 2.3. Implementation/delivery system/main bodies

The main bodies of the program are comprised of i) Ministry for Food, Agriculture, Forestry and Fisheries(MIFAFF), ii) metropolitan city mayor/province governor (non-metropolitan city/county/guchung chief), iii) fisherman, iv) legal persons of appraisal and evaluation and v) fisheries-loss-evaluation organization (designated universities, etc.). Implementation and delivery system is as follows (Fig. 1).

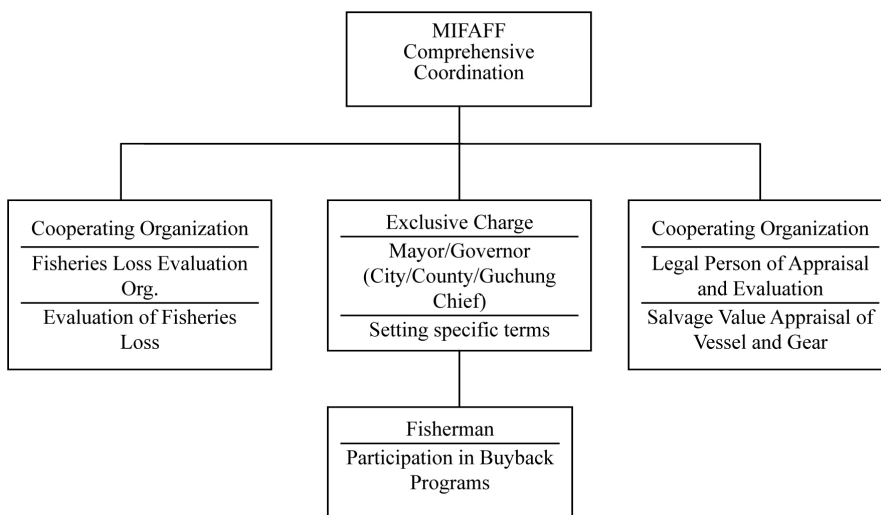


Figure 1. Implementation/delivery system/main bodies

### 2.4. Target fisheries and interest groups

The buyback program targeted the on-and off-shore fishing vessels, which have relatively large impact on fishery resources and low competitiveness due to change in domestic/international environment or lowered average productivity(or catch (mt) per vessel). During the period from 1995 to 1997, the number of off-shore fisheries vessels was reduced to 59,176 from 42,331. However, horse power(HP) per vessel increased to 481 from 381.

Policy target fisheries include eight on-shore fisheries. Priority is placed on the order of purse seine, gill net, trap, composite fisheries and stow net on boat/on anchor. Lift net is possible to apply to the buyback program as subsidiary fisheries. During the period from, 2005 to 2006, the buyback program was not applied to off-shore fishing vessels (Kim *et al.*, 2006). However, in 2007, 84 vessels of off-shore fisheries were retired because of foreign regulation, fishing disputes and overexploitation nature. Now, the government has a plan to reduce 30%(1,050 vessels) of the entire off-shore fishing capacity(Kim *et al.*, 2006).

There are indirect targets and other interest groups in relation to the buyback program. They include the fishermen who did not participate in the fisheries structural adjustment programs: fishermen who engage in fisheries with license, except for fishermen with on- and off-shore fishing permits(articles 27 and 28 of enforcement regulations of fishery law), fishermen who engage in report fisheries and the crews who are discharged from the retired fishing vessels.

### 2.5. Fishing vessel reduction through the buyback programs

During the period from 1994 to 2007 the buyback programs have been implemented in two ways: one was a general buyback program and the other was an international one. In the first year(1994) of the program 54 vessels were decommissioned and 730 boats in 1999 were reduced in a large scale under both of the general and the international buyback programs.

Since, however, the law regarding the international buyback program was legislated to deal with the fisheries problems dictated by the Korea-Japan(1999) and the Korea-China (2001) fisheries agreement, the international buyback program was placed for the limited period from 1999 to 2002. The total number of fishing vessels reduced in 1994~2007 was 8,324(on-shore 6,357 and off-shore 1,967) and the public fund of 1,067 billion Korean won was used for decommissioning the boats(Department of Fisheries Policy).

## 3. Assessments of resource stocks and fishing efforts

### 3.1 Assessment model: Surplus production model

Surplus production models are relatively simple and most widely used for resource evaluation. There are three models(i.e. Schaefer, 1954, Fox, 1970, Pella-Tomlinson, 1969) that require minimum data set. The concept of surplus production is as follows:

$$S_{t+1} = S_t + R_t + G_t - FM_t - NM_t$$

Where  $S_{t+1}$ =next year stock,  $S_t$ =current year stock,  $R_t$ =recruitment,  $G_t$ =body growth,  $FM_t$ =fishing mortality,  $NM_t$ =natural mortality.

If there is no catch in current year,  $S_{t+1} = S_t + R_t + G_t - NM_t - NM_t$ . Here, an increase in stock is  $R_t + G_t$ . Surplus production is  $R_t + G_t - NM_t$ . Thus, next year stock is current year stock + surplus production-natural mortality. That is,  $S_{t+1} = S_t + R_t + G_t - NM_t$ .

The simplest and perhaps the most useful example is obtained when  $r(B) \ r(1 - \frac{B}{K})$

( $r$ =net proportional growth rate of the population,  $B$ =population size (kg or M/T),  $K$ = environmental carrying capacity), so that  $\frac{dB}{dt}=r(B) \cdot B$  becomes  $\frac{dB}{dt}=r(B) \left(1 - \frac{B}{K}\right)$ . This is the famous logistic equation, first proposed as population model by P. F. Verhulst (1983). Expressing this equation as a discrete function, the following is obtained.

$$B_{t+1} = B_t + rB_t \left(1 - \frac{B_t}{K}\right)$$

Adding catch element to the equation above, the standard biomass-dynamic model, that is, Schaefer surplus production model is obtained where  $Y_t$ =harvest,  $q$ =catchability coefficient and  $f$ =fishing effort

$$B_{t+1} = B_t + rB_t \left(1 - \frac{B_t}{K}\right) - Y_t$$

$$Y_t = qfB_t$$

Denoting that  $F(B)=rB_t \left(1 - \frac{B_t}{K}\right)$ , if  $F(B) > Y_t$ , the population size would increase. In case  $F(B) < Y_t$ , the population size would decline. The reference point necessary for resource management can be derived from the Schaefer model where  $MSY$  is maximum sustainable yield,  $B_{MSY}$  is biomass(e.g. M/T) at  $MSY$  and  $E_{MSY}$  is fishing effort at  $MSY$ .

$$MSY = rK/4$$

$$B_{MSY} = K/2$$

$$E_{MSY} = r/2q$$

With two time series data of catch and fishing effort, the Schaefer model parameters and the reference points are obtained.

$$U = (a + b \cdot E), \quad Y = (a + b \cdot E) \cdot E,$$

$$MSY = -\frac{a^2}{4b},$$

$$E_{MSY} = -\frac{a}{2b}$$

where  $a$  and  $b$  are parameters,  $U$  is catch per unit effort,  $E$  is fishing effort and  $Y$  is catch or production.

Another surplus production model is Fox model(1970), developed based on Gompertz growth model.∴  $B_{t+1} = B_t + rB_t \left(1 - \frac{\ln B_t}{\ln k}\right) - Y_t$ . The following reference points for resource management are derived from the Fox model.

With two time series data of catch and fishing effort, the Fox model parameters and the reference points are obtained as follows.

$$U = (ae(b \cdot E)), Y = (a \cdot \exp(b \cdot E)) \cdot E,$$

$$MSY = -\frac{\exp(a-1)}{b}, \text{ and}$$

$$E_{MSY} = -\frac{1}{b}.$$

### 3.2 Management reference points

There are several management reference points(i.e. reference point RP, target reference point TRP and limit reference point LRP) as indices. Management reference points that can be estimated by using the models above include  $MSY$ ,  $F_{MSY}$ ,  $2/3 MSY$ ,  $2/3 F_{MSY}$ ,  $F_{0.1}$ , etc. Because the reference point( $2/3 F_{MSY}$ ), that Doubleday(1976) suggested, may add much to reducing risk and uncertainty that are accompanied by inaccuracy or lack of data,  $F_{MSY}$ (or  $F_{MSY}$ ) and  $2/3 F_{MSY}$ (or  $2/3 F_{MSY}$ ) were used in this research.

### 3.3 Presentation of the resource status

Recently, traffic light display methods are used to visualize the fisheries resource status(Caddy, 1999, Caddy, 2002, ICCAT, 2008). The display method classifies the resource status into three stages and colors: green is safe, yellow is middle and red is risky. This method is to visually evaluate the resource status by the traffic light colors. This research employed the display method that ICCAT uses widely: from the resource stock’s perspective, “red is overexploited” and “green is non-overexploited”; from the fishing effort’s perspective, “red is overcapacity” and “green is non-overcapacity.” For both of the relative stock and the relative fishing effort, “upper yellow is non-overexploited/non-overcapacity” and “lower yellow is overexploited/non-overcapacity.”

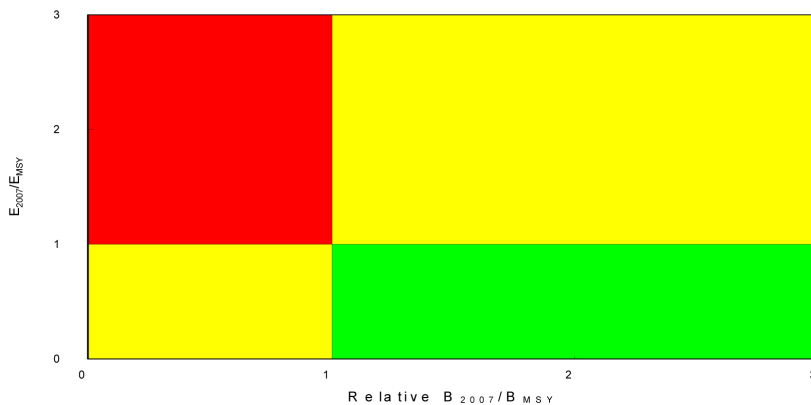


Figure 2. Distribution of relationship between B-ratio and E-ratio

### 3.4 Estimation of relative fishing efforts by species and estimation of management reference points by region and by species

Assessment of resource management reference points is made, including all marine zones and all kinds of fisheries. In this case were chosen the typical fisheries of exploiting major target species and the CPUE(catch per unit effort) by species were calculated, based on their horse power. Relative total fishing efforts necessary for estimating the model parameters for each species were calculated, dividing the total catch of each species by the CPUEs of the typical fisheries. Overall *MSY*(maximum sustainable yield) and *RP* are estimated by the following formulas where *RP* is the reference point of species  $r_i$ ,  $cr_i$  is the contribution ratio of species or fishery to total catch and  $w_i$  is the by-species catch ratio of marine zone or fishery.

$$\begin{aligned} \text{Overall } MSY &= \sum cr_i \cdot MSY_i \\ \text{Overall } RP &= \sum w_i \cdot RP_i \end{aligned}$$

### 3.5 Data sources and geography of the Yellow Sea

The assessment and analysis used the data that collected from several government sources: National Statistical Office(catch volume), National Fisheries R&D Institute(catch by region and by marine zone) and Ministry of Food, Agriculture, Fisheries and Forestry (fishing efforts by fishery: horse power).

The Yellow Sea area is defined in this research as follows: the sea area north of the line connecting west edge of Jindo, west edge of Jeju and the mouth of Yangtze river(excluding Bohai and Korea bays). Since catch data in the Yellow Sea is not available, the catch volumes by region and by fishery were estimated based on the catch data of Korea National Statistical Office(NSO) and the data(by fishery/marine zone) of National R&D Institute(NFRDI). Since, however, the catch data by marine zone for off-shore fisheries is not available and neither is the catch data of some on-shore fisheries, the NSO catch volumes of Incheon city, Kyonggi-do, Chungnam-do, Jeonbuk-do and Jeonnam-do were included in the analysis. In case of Jeonnam, it is presumed that 50% of its production is exploited in the Yellow Sea.

Regarding the off-shore fisheries(i.e. large purse seine, squid angling, large pair trawl, large Danish seine, large otter trawl and west southern pair trawl) that operate over the entire fishing grounds, their catches in the Yellow Sea were separated from their total catches and the Yellow Sea catch proportions were calculated, based on the catch data (by marine zone) of NFRDI. Then the total catch by species in the Yellow Sea was recalculated, based on the estimated marine zone catch data.



### 3.6 Stock assessments by major species in the Yellow Sea

#### 3.6.1 Hair tail (or Ribbon fish)

Stock assessment in this research covers ten major fish species that have been caught in the Yellow Sea. In 2007 the Yellow Sea's contribution to total Korean hair tail catch in the entire Korea waters(*cr*) accounted for 8.1% and its relative weight of total Yellow Sea's catch of all species(*w*) was 1.82%. Hair tail stock status, based on the resource management criterion( $B_{2007}/B_{MSY}$ ) was estimated 0.7 that show overexploitation. In terms of fishing effort or capacity, the ratio of  $B_{2007}/B_{MSY}$  was estimated 0.9 which is not in overcapacity but in risk(Fig. 3).

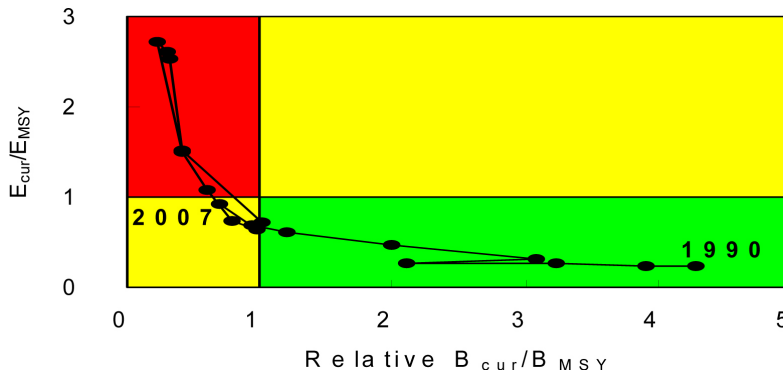


Figure 3. Stock status of hair tail in the Yellow Sea

#### 3.6.2 Yellow croaker

The Yellow Sea's relative share of yellow croaker catch (*cr*) in 2007 held 27.0% and its relative weight of total Yellow Sea's catch of all species(*w*) was 3.2%. The yellow

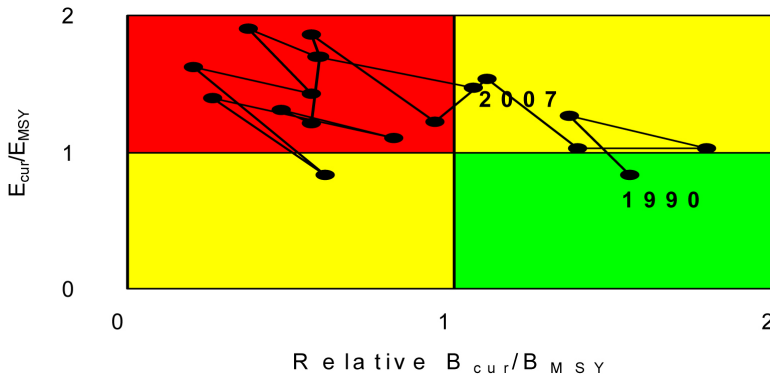


Figure 4. Stock of catch for yellow croaker in the Yellow Sea

croaker stock status, based on the resource management criterion( $B_{2007}/B_{MSY}$ ) was estimated 1.07 that implies non-overexploitation. In terms of fishing effort or capacity, the ratio of was estimated at 1.47 which implies overcapacity(Fig. 4).

### 3.6.3 Chub mackerel

The Yellow Sea’s relative contribution( $cr$ ) was 52.2% in 2007 and its relative weight of total Yellow Sea’s catch of all species( $w$ ) was 25.6%. Korean chub mackerel stock status, based on the resource management criterion( $B_{2007}/B_{MSY}$ ) was estimated 1.06 that implies a good resource status. In terms of fishing effort or capacity, the ratio of  $B_{2007}/B_{MSY}$  was 0.92 which is not in overcapacity(Fig. 5).

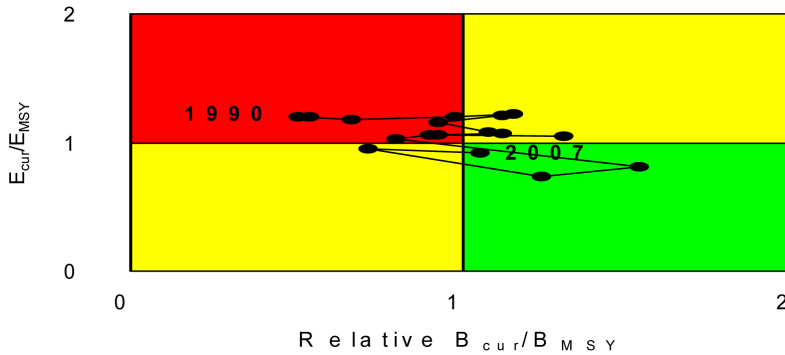


Figure 5. Stock of catch for chub mackerel in the Yellow Sea

### 3.6.4 Anchovy

The anchovy production in the Yellow Sea has been maintained at a high level for the last two decades. The Yellow Sea’s relative contribution anchovy( $cr$ ) in 2007 occu

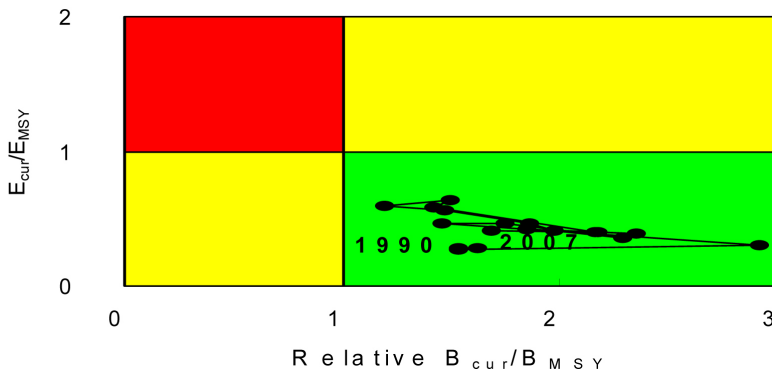


Figure 6. Stock of catch for anchovy in the Yellow Sea

ped 16.3% and its relative weight of total Yellow Sea's catch of all species( $w$ ) took 12.3%. The anchovy stock status, based on the resource management criterion( $B_{2007}/B_{MSY}$ ) was estimated 1.85 that implies a good resource status. In terms of fishing effort or capacity, the ratio of  $B_{2007}/B_{MSY}$  was 0.42 which is not in overcapacity(Fig. 6).

### 3.6.7 Blue crab

Blue crab catch has shown an increasing trend. The Yellow Sea's relative share of blue crab catch( $cr$ ) was 91.4% in 2007 and its relative weight of total Yellow Sea's catch of all species( $w$ ) accounted for 4.24%. The blue crab stock status, based on the resource management criterion( $B_{2007}/B_{MSY}$ ) was estimated 0.32 that implies overexploitation. In terms of fishing effort or capacity, the ratio of  $B_{2007}/B_{MSY}$  was 2.75 which indicate overcapacity(Fig. 7).

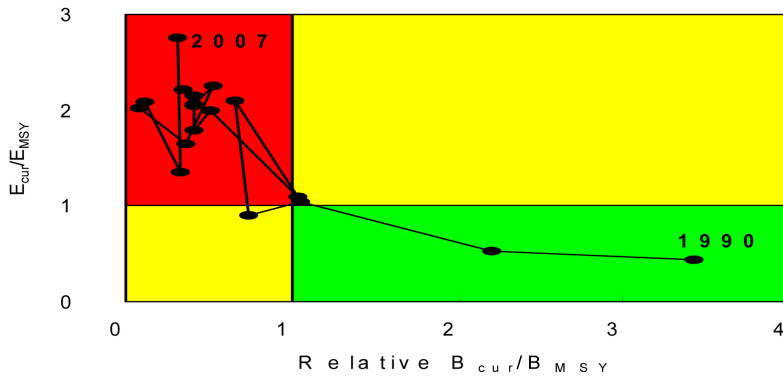


Figure 7. Stock of catch for common squid in the Yellow Sea

### 3.6.8 Common squid

Common squid production has shown an increasing trend since 2005.

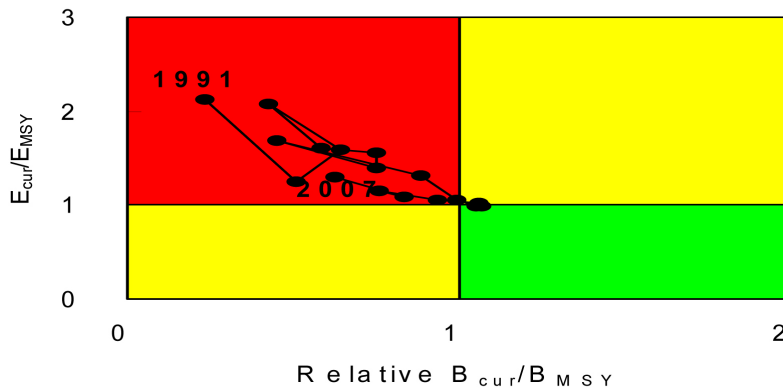


Figure 8. Stock of catch for common squid in the Yellow Sea

In 2007 Common squid catch in the Yellow Sea contributed 5.58%(*cr*) to total Korean squid production and its relative weight of total Yellow Sea’s catch of all species(*w*) was 3.48%. The common squid stock status, based on the resource management criterion ( $B_{2007}/B_{MSY}$ ) was estimated 0.63 that implies overexploitation. In terms of fishing effort or capacity, the ratio of  $B_{2007}/B_{MSY}$  was 1.29 which indicate overcapacity(Fig. 8).

**3.6.9 Sea bass**

Sea bass catch has shown a decreasing trend since 2007. The Yellow Sea’s contribution(*cr*) in 2007 accounted for 28.5% and its relative weight of total Yellow Sea’s catch of all species(*w*) was 1.21%. The sea bass stock status, based on the resource management criterion( $B_{2007}/B_{MSY}$ ) was estimated 1.71 that implies non-overexploitation. In terms of fishing effort or capacity, the ratio of  $B_{2007}/B_{MSY}$  was 0.15 which indicate non-over-capacity(Fig. 9).

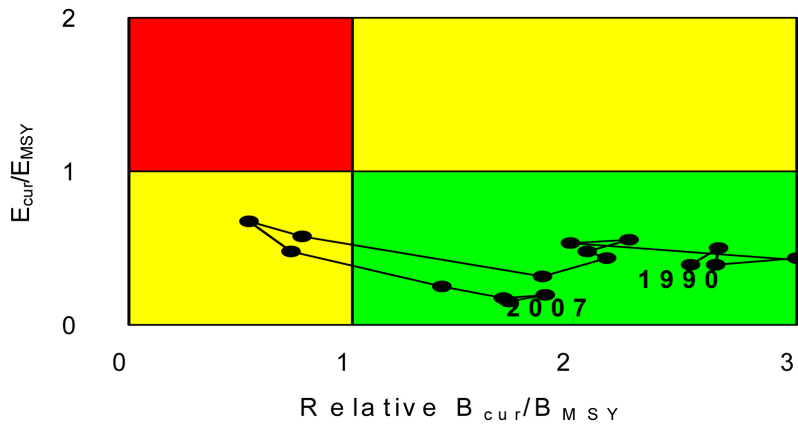


Figure 9. Stock of catch for sea bass in the Yellow Sea

**3.6.10 Pomfrets**

The Yellow Sea’s relative share of pomfrets catch(*cr*) in 2007 held 0.93% and its relative weight of total Yellow Sea’s catch of all species(*w*) was 28.9%. The pomfret stock status, based on the resource management criterion( $B_{2007}/B_{MSY}$ ) was estimated 0.73 that implies non-overexploitation. In terms of fishing effort or capacity, the ratio of  $B_{2007}/B_{MSY}$  was 1.25 which indicate a good status of the stock(Fig. 10).

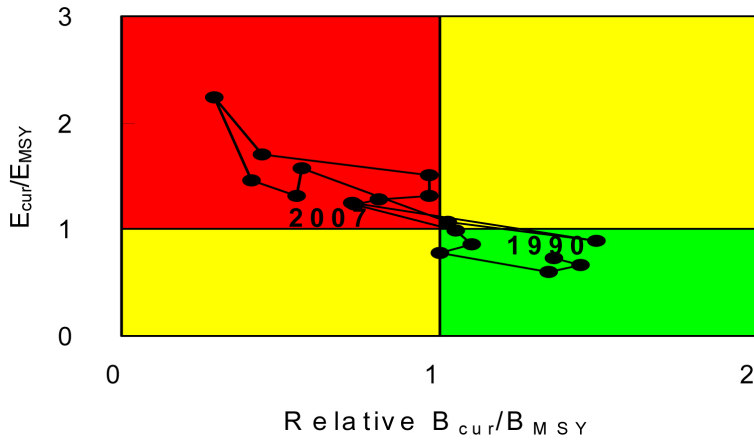


Figure 10. Stock of catch for pomfrets in the Yellow Sea

### 3.6.11 Monkfish

The Yellow Sea’s relative catch of monkfish( $cr$ ) in 2007 occupied 16.5% and its relative weight of total Yellow Sea’s catch of all species( $w$ ) was 0.81%. The monkfish status, based on the resource management criterion( $B_{2007}/B_{MSY}$ ) was estimated 2.53 that implies non-overexploitation. In terms of fishing effort or capacity, the ratio of  $B_{2007}/B_{MSY}$  was 0.73 which indicate non-overcapacity(Fig. 11).

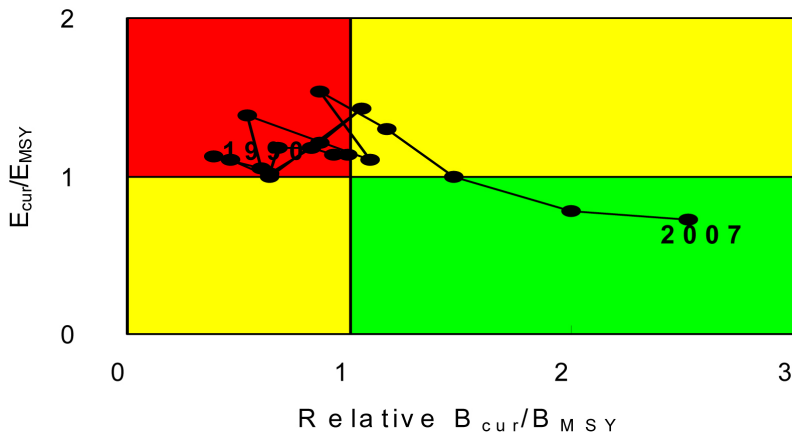


Figure 11. Stock of catch for monkfish in the Yellow Sea

### 3.6.12 Brown croaker

The Yellow Sea’s contribution to total brown croaker catch( $cr$ ) accounted for 28.4% in 2007 and its relative weight of total Yellow Sea’s catch of all species( $w$ ) was

0.29%. The brown croaker status, based on the resource management criterion ( $B_{2007}/B_{MSY}$ ) was estimated 0.64 that implies overexploitation. Regarding fishing effort or capacity, the ratio of  $B_{2007}/B_{MSY}$  was 1.27 which indicate overcapacity(Fig. 12).

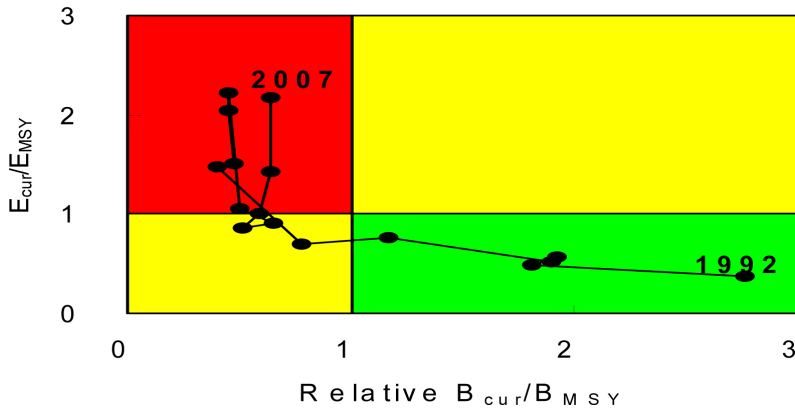


Figure 12. Stock of catch for brown croaker in the Yellow Sea

### 3.7 Resource utilization assessment by major fisheries in the Yellow Sea

#### 3.7.1 Large pair trawl (LPT)

Major target species of the LPT are Spanish mackerels, sea bass, hair tail, anchovy and pomfrets. Evaluating the resource status of these species by the multi-species approach, the relative fishing effort  $E_{2007}/E_{MSY}$  was 0.63, implying that large pair trawls in the Yellow Sea do not has yet overcapacity problem(Fig. 13, Table 1).

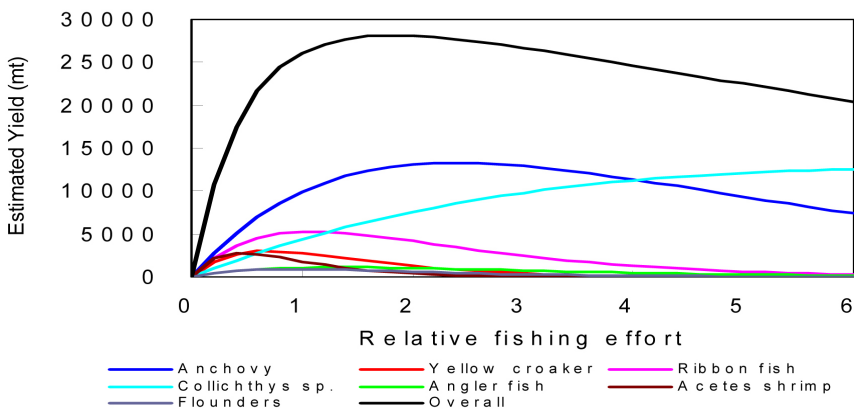


Figure 13. Multi-species equilibrium yield obtained from Fox's surplus production model for LPT in the Yellow Sea from 1990 to 2007.

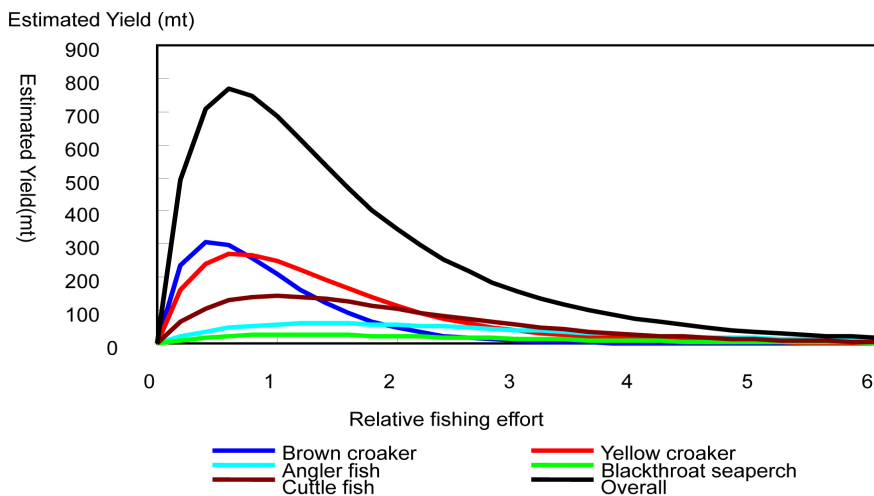
**Table 1.** Status of stock utilization of LPT in the Yellow Sea

Species	Catch in 2007 (mt)	Percentage of species (wi, %)	Contribution rate (cr, %)	$E_{07}/E_{MSY}$	$2/3E_{MSY}/E_{05-07}$ (%)	$E_{MSY}/E_{05-07}$ (%)
Overall	16,505	100.00	1.43	0.63	80.4	94.3
Spanish mackerel	4,037	24.46	9.57	0.99	77.0	100.0
Sea bass	2,575	15.60	18.63	0.15	100.0	100.0
Hair tail	2,130	12.91	3.23	0.92	86.6	100.0
Yellow croaker	1,644	9.96	4.80	1.47	39.4	59.1
Anchovy	1,522	9.22	0.69	0.42	100.0	100.0
Pomfrets	683	4.14	7.19	1.25	62.5	93.7

However, considering resource fluctuations and uncertainty of stock status assessment, the optimal average fishing effort over the recent three years(2005~2007), based on the and criteria is estimated at 80.4~94.3%, implying that LPT fishing capacity should be reduced by 5.7~19.6%(Table 1).

### 3.7.2 Large danish seine (LDS)

LDS production has decline over time since 1995. Major target species are brown croaker, yellow croaker, sea bass, monkfish, red fish, cuttle fish, etc. Evaluating the resource status of these species by multi-species approach, the relative fishing effort  $E_{2007}/E_{MSY}$  was 1.67, implying that its fishing effort in the Yellow Sea exceeds the reference point( $E_{current}/E_{MSY}$ )(Fig. 14, Table 2).



**Figure 14.** Multi-species equilibrium yield obtained from Fox's surplus production model for LDS in the Yellow Sea from 1990 to 2007.

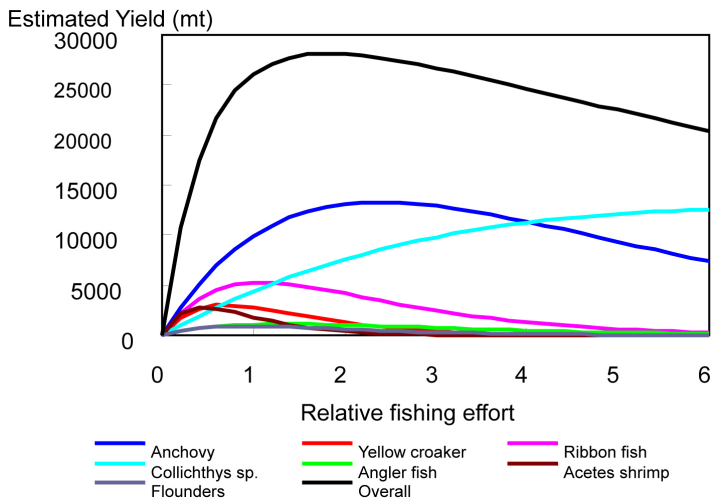
**Table 2.** Status of stock utilization of LDS in the Yellow Sea

Species	Catch in 2007 (mt)	Percentage of species (wi, %)	Contribution rate(cr, %)	$E_{07}/E_{MSY}$	$2/3E_{MSY}/E_{05-07}$ (%)	$E_{MSY}/E_{05-07}$ (%)
Overall	1,583	100.0	0.14	1.67	57.4	74.8
Brown croaker	432	27.3	14.25	2.17	43.4	65.1
Yellow croaker	427	27.0	1.25	1.47	39.4	59.1
Sea bass.	264	16.7	1.91	0.15	100.0	100.0
Angler fish	112	7.1	0.78	0.73	79.9	100.0
Blackthroat seaperch	91	5.7	3.15	0.87	69.9	100.0
Cuttle fish	76	4.8	3.90	1.02	42.3	63.4

Considering resource fluctuations and uncertainty of stock assessment, the optimal average fishing effort over the recent three years (2005~2007) on the  $E_{MSY}$  and  $2/3E_{MSY}$  criteria is estimated at the level of 57.4~74.8%, indicating that LDS fishing capacity should be reduced by 25.2~42.8% (Table 2).

**3.7.3 Off-shore stow net (OSSN)**

OSSN production has declined over time since 1990 but it has shown a stable trend at the low level. Major target species are brown croaker, yellow croaker, sea bass, monkfish, red fish, cuttle fish, etc. Evaluating the resource status of these species by using the multi-species approach, the relative fishing effort  $E_{2007}/E_{MSY}$  was 1.67, implying that its fishing effort in the Yellow Sea exceeds the reference point(Fig. 15, Table 3).



**Figure 15.** Multi-species equilibrium yield obtained from Fox’s surplus production model for OSSN in the Yellow Sea from 1990 to 2007.



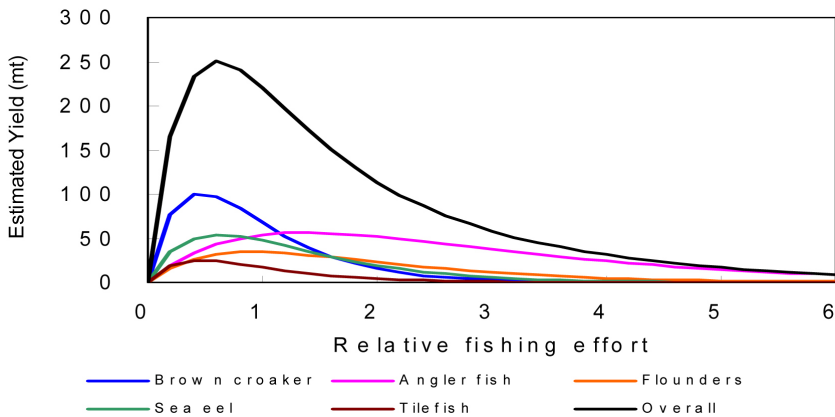
Taking into account resource fluctuations and uncertainty of stock status assessment, the optimal average fishing effort over the recent three years(2005~2007) on the  $E_{MSY}$  and  $2/3E_{MSY}$  criteria is estimated at 79.5~89.1%, indicating that OSSN fishing capacity should be reduced by 10.9~20.5%(Table 3).

**Table 3.** Status of stock utilization of OSSN in the Yellow Sea

Species	Catch in 2007(mt)	Percentage of species (wi, %)	Contribution rate(cr, %)	$E_{07}/E_{MSY}$	$2/3E_{MSY}/E_{05-07}$ (%)	$E_{MSY}/E_{05-07}$ (%)
Overall	34,024	100.00	2.95	1.67	79.5	89.1
Anchovy	10,225	30.05	4.62	0.42	100.0	100.0
Yellow croaker	4,754	13.97	13.89	1.47	39.4	59.1
Hair tail	3,391	9.97	5.14	0.92	86.6	100.0
Sea bass	3,208	9.43	23.22	0.15	100.0	100.0
Angler fish	2,061	6.06	14.30	0.73	79.9	100.0
Acetes shrimp	1,962	5.77	15.63	2.23	38.3	57.4
Floundrs	1,451	4.27	5.96	1.11	58.8	88.1

### 3.7.4 Medium danish seine (MDS)

MDS production has declined rapidly over time since 1995 but currently it shows a stable trend at a very low level. Major target species are brown croaker, monkfish, flounders, sea eel, red horsehead, etc. Evaluating the resource status of these species by the multi-species approach, the relative fishing effort  $E_{2007}/E_{MSY}$  was 1.67, implying that its fishing effort in the Yellow Sea exceeds the reference point(Fig. 15, Table 4).



**Figure 16.** Multi-species equilibrium yield obtained from Fox’s surplus production model for MDS in the Yellow Sea from 1990 to 2007.

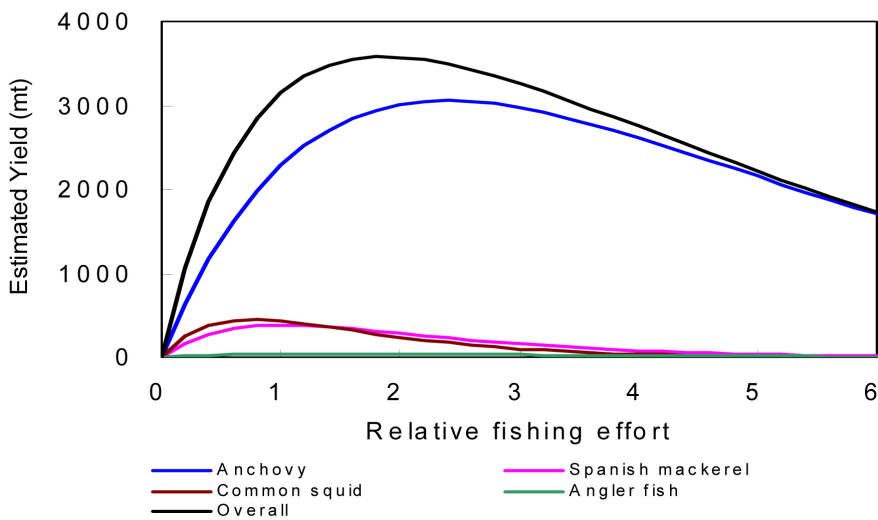
Considering resource fluctuations and uncertainty of stock status assessment, the optimal average fishing effort over the recent three years(2005~2007) on the  $E_{MSY}$  and  $2/3 E_{MSY}$  criteria is estimated at 53.8~75.2%, indicating that MDS fishing capacity should be reduced by 19.9~24.8%(Table 4).

**Table 4.** Status of stock utilization of MDS in the Yellow Sea

Species	Catch in 2007(mt)	Percentage of species (wi, %)	Contribution rate(cr, %)	$E_{07}/E_{MSY}$	$2/3E_{MSY}/E_{05-07}$ (%)	$E_{MSY}/E_{05-07}$ (%)
Overall	697	100.00	0.06	1.67	53.8	75.20
Brown croaker	140	20.09	4.62	2.17	43.37	65.06
Angler fish	104	14.92	0.72	0.73	79.89	100.00
Flounders	54	7.68	0.22	1.11	58.75	88.13
Sea eel	53	7.53	0.27	1.60	33.80	50.70
Tile fish	21	3.01	1.34	2.10	32.07	48.10

### 3.7.5 Medium pair trawl(MPT)

MPT catch has increased rapidly over time since 2000. Major target species are anchovy, Spanish mackerel, squid and monkfish. Evaluating the resource status of these species by multi-species approach indicated the relative fishing effort  $E_{2007}/E_{MSY}$  was 0.56, implying that its fishing effort in the Yellow Sea exceeds the management reference point (Fig. 17, Table 5).



**Figure 17.** Multi-species equilibrium yield obtained from Fox's surplus production model for MPT in the Yellow Sea from 1990 to 2007.

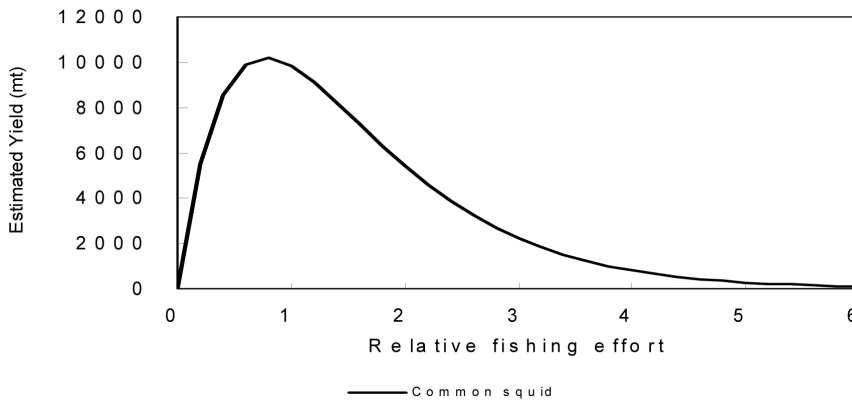
Considering stock fluctuations and uncertainty of stock assessment, the optimal average fishing effort over the recent three years(2005~2007) on the  $E_{MSY}$  and  $2/3E_{MSY}$  criteria is estimated at 91.0~98.3%, indicating that MPT fishing capacity should be reduced by 1.7~9.0%(Table 5).

**Table 5.** Status of stock utilization of MPT in the Yellow Sea

Species	Catch in 2007(mt)	Percentage of species (wi, %)	Contribution rate(cr, %)	$E_{07}/E_{MSY}$	$2/3E_{MSY}/E_{05-07}$ (%)	$E_{MSY}/E_{05-07}$ (%)
Overall	3,894	100.0	0.34	0.56	91.0	98.3
Anchovy	2,357	60.5	1.07	0.42	100.00	100.00
Spanish mackerel	536	13.8	1.27	0.99	76.96	100.00
Common squid	367	9.4	0.21	1.29	56.55	84.82
Angler fish	80	2.1	0.56	0.73	79.89	100.00

### 3.7.6 Squid angling (SA)

SA catch began to increase rapidly over time since 2000. Major target species is common squid, one of the pelagic species abundant in Korean waters. Evaluating the resource status of the species, the relative fishing effort  $E_{2007}/E_{MSY}$  was 1.25, implying that its fishing effort in the Yellow Sea exceeds the management reference point (Fig. 18, Table 6).



**Figure 18.** Multi-species equilibrium yield obtained from Fox’s surplus production model for SA in the Yellow Sea from 1990 to 2007.

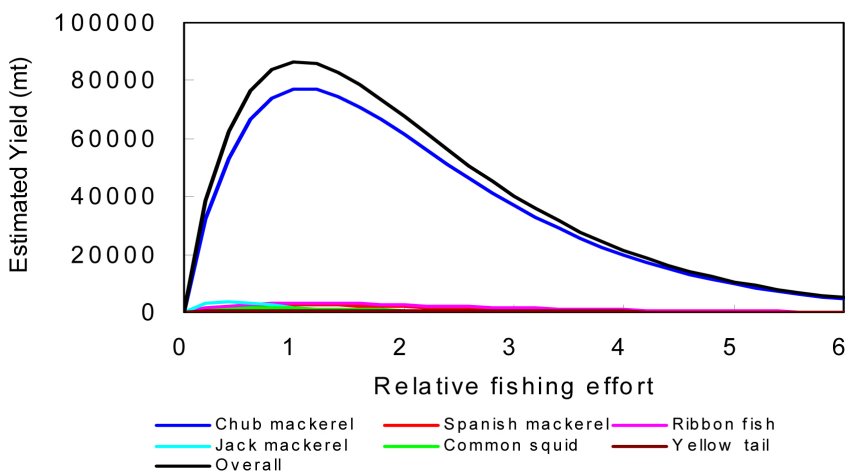
Taking into account stock fluctuations and uncertainty of stock assessment, the optimal average fishing effort over the recent three years(2005~2007) on the  $E_{MSY}$  and  $2/3E_{MSY}$  criteria is estimated at 56.5~84.5%, indicating that AS fishing capacity should be reduced by 15.5~43.5%(Table 6).

**Table 6.** Status of stock utilization of SA in the Yellow Sea

Species	Catch in 2007(mt)	Percentage of species(wi, %)	Contribution rate(cr, %)	$E_{07}/E_{MSY}$	$2/3E_{MSY}/E_{05-07}$ (%)	$E_{MSY}/E_{05-07}$ (%)
Common squid	8,269	100.0	4.74	1.25	56.5	84.8

**3.7.7 Large purse seine (LPS)**

LPS production began to increase gradually over time since 2000. Major target species are mackerel, Spanish mackerel, hair tail, Jack mackerel, squid and yellow tail. Evaluating the resource status of these species by the multi-species approach, the relative fishing effort  $E_{2007}/E_{MSY}$  was 1.0, implying that it’s fishing effort in the Yellow Sea does not exceed the management reference point(Fig. 19, Table 7).



**Figure 19.** Multi-species equilibrium yield obtained from Fox’s surplus production model LPS in the Yellow Sea from 1990 to 2007.

**Table 7.** Status of stock utilization of LPS in the Yellow Sea

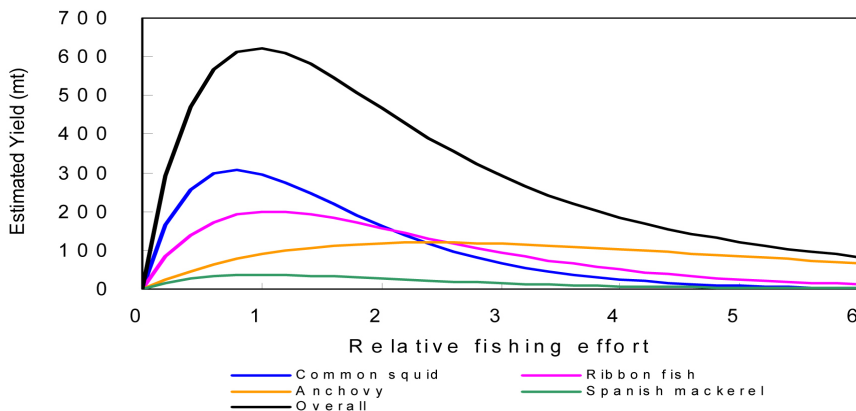
Species	Catch in 2007(mt)	Percentage of species(wi, %)	Contribution rate(cr, %)	$E_{07}/E_{MSY}$	$2/3E_{MSY}/E_{05-07}$ (%)	$E_{MSY}/E_{05-07}$ (%)
Overall	85,405	100.00	7.41	1.0	75.8	98.6
Chub mackerel	74,752	87.53	51.99	0.92	76.85	100.00
Spanish mackerel	3,689	4.32	8.74	0.99	76.96	100.00
Hair tail	2,049	2.40	3.10	0.92	86.62	100.00
Jack mackerel	1,910	2.24	10.00	2.68	29.82	44.73
Common squid	1,130	1.32	0.65	1.29	56.55	84.82
Yellowtail	1,030	1.21	15.79	0.78	80.56	100.00

Considering stock fluctuations and uncertainty of stock assessment, the optimal average fishing effort over the recent three years(2005~2007) on the and criteria is estimated at 75.8~98.6%, suggesting that LPS fishing capacity should be reduced by 1.4~24.2% (Table 7).

### 3.7.8 Large otter trawl (LOT)

LOT production began to increase gradually over time since 2000. Major target species are squid, hair tail, anchovy and Spanish mackerel. Evaluating the resource status of these species by the multi-species approach indicated the relative fishing effort  $E_{2007}/E_{MSY}$  was 1.0 implying that its fishing effort in the Yellow Sea does not exceed the management reference point(Fig. 20, Table 8).

Taking into account stock fluctuations and uncertainty of stock assessment, the optimal average fishing effort over the recent three years(2005~2007) on the  $E_{MSY}$  and  $2/3E_{MSY}$  criteria is estimated at 73.7~92.7%, suggesting that the LOT fishing capacity should be reduced by 7.3~26.3%(Table 8).



**Figure 20.** Multi-species equilibrium yield obtained from Fox's surplus production model LOT in the Yellow Sea from 1990 to 2007

**Table 8.** Status of stock utilization LOT in the Yellow Sea

Species	Catch in 2007(mt)	Percentage of species (wi, %)	Contribution rate(cr,%)	$E_{07}/E_{MSY}$	$2/3E_{MSY}/E_{05-07}$ (%)	$E_{MSY}/E_{05-07}$ (%)
Overall	563	100.00	0.05	1.00	73.7	92.7
Common squid	250	44.36	0.14	1.29	56.55	84.82
Hair tail	129	22.94	0.20	0.92	86.62	100.00
Anchovy	92	16.39	0.04	0.42	100.00	100.00
Spanish mackerel	52	9.15	0.12	0.99	76.96	100.00

### 3.8 Overall assessment of resource utilization in the Yellow Sea

Annual production in the Yellow Sea was 307,135 mt in 1990, 406,110 mt in 1995, 293,794 mt in 2000, 269,821 mt in 2005 and 293,239 mt in 2007. The catch in 2000s decreased in comparison with that in 1990s. The catch composition in 2007 by species with catches greater than 5,000 mt shows that mackerel accounted for 25.6%, anchovy 12.3%, blue crab 4.2%, common squid 3.5%, yellow croaker 3.2%, Spanish mackerel 3.0%, small shrimp 2.6%, pen shell 2.5%, mullets 2.1%, hair tail 1.8%. The Yellow Sea' contribution ( $cr_i$ ) to total Korean catch by species appeared that pen shell held 92.9%, blue crab 91.4%, small shrimp 61.9%, mullets 55.1%, mackerel 52.2% and yellow croaker 27.0% (Fig. 21, Fig. 22).

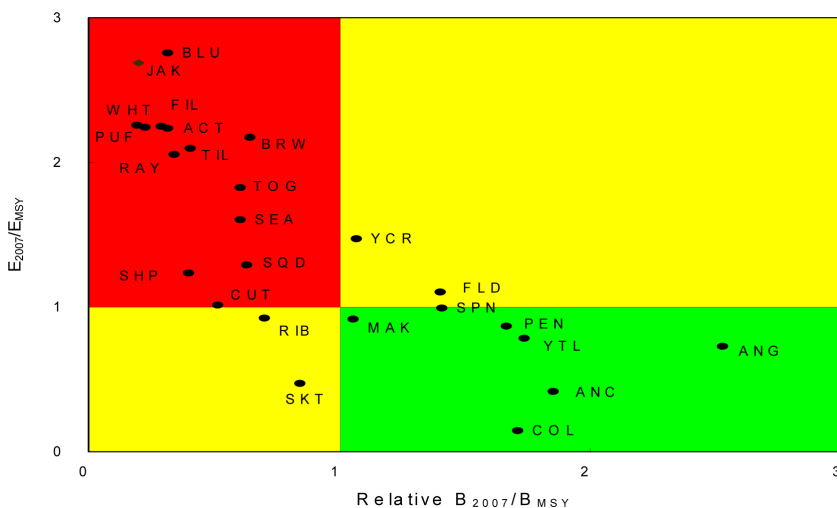
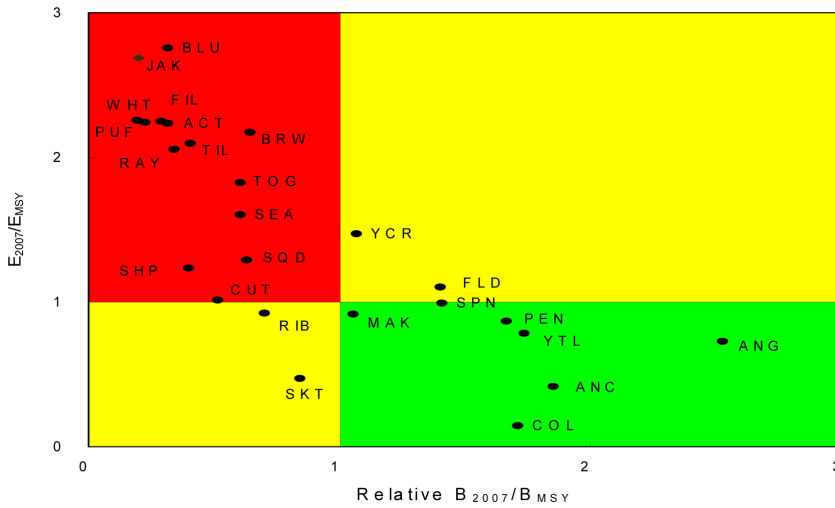


Figure 21. Change of total catch in the Yellow Sea from 1990 to 2007.

Regarding the stock status by species, the assessment results suggest that i) red fish, monkfish, anchovy, sea bass, yellow tail, pen shell and Spanish mackerel are not in overexploitation/overcapacity, ii) hair tail and skate ray are in overexploitation but in non-overcapacity and iii) yellow croaker is in non-overexploitation but in overcapacity. However, considering stock fluctuations and assessment uncertainties, the average optimal fishing effort over the last three years(2005~2007) on and criteria was evaluated at 73.4~90.2. This result suggests that the current level of total fishing capacity in the Yellow Sea need to be reduced by 9.8~26.6%.



**Notes :** Hair tail, RIB; Rays, RAY; Flounders, FLD; Cuttle fish, CTL; Sea bass., COL; Sharp toothed eel, SHP; Chub mackerel, MAK; Blue crab, BLU; File fish, FIL; Anchovy, ANC; Brown croaker, BRW; Yellow tail, YTL; Pomfrets, POM; White croaker, WHT; Puffers, PUF; Sea eel, SEA; Spanish mackerel, SPN; Tongue fish, TOG; Angler fish, ANG; Common squid, SQD; Tile fish, TIL; Jack mackerel, JAK; Acetes shrimp, ACT; Yellow croaker, YCR; Pen shell, PEN; Skate ray, SKT.

**Figure 21.**  $B_{2007}/B_{MSY}$  and  $E_{2007}/E_{MSY}$  in 2007.

## 4. Marine resources and ecosystem impacts

### 4.1 Objectives of the fisheries structural adjustment (FSA)

The ultimate long-term goal of FSA policy is ecosystem-based, environmentally-sustainable management and use of Korean marine ecosystem by reducing fisheries development stress and promoting sustainable exploitation of the ecosystem from a densely populated, heavily urbanized and industrialized semi-enclosed shelf sea.

The focus of FSA on sustainable fisheries management and reducing stress to the ecosystem provides an opportunity for exploring how the FSA can further national and regional commitments to certain international conventions and agreements, such as the United Nations Convention on the Law of the Sea, the FAO Code of Conduct for Responsible Fisheries, the Global Program of Action for the Protection of the Marine Environment from Land-based Activities and the bilateral fisheries agreements among Korea, China and Japan.

Its mid-term objectives are i) to enhance national capacities in protection of marine environment and sustainable use of marine and coastal resources, through the buyback programs and the resource enhancement projects, ii) to strengthen fishermen-government part-

nership in marine environment protection and management through establishment of regional fisheries coordination/cooperation mechanisms and iii) facilitate self-management practices dealing with marine environmental/living resource management (Ministry of Maritime Affairs and Fisheries 2007).

#### *4.2 Impacts of the fisheries structural adjustment (FSA) policy*

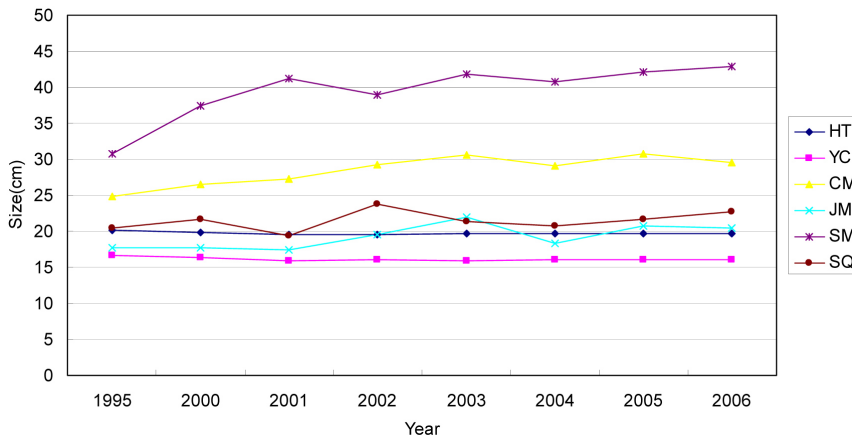
In practice, it is extremely difficult to distinguish the FSA's impacts on the Yellow Sea ecosystem from those of other drivers such as climate change and land-based pollution. At this moment it is only possible to draw some conclusions as to what are the probable implications of the FSA on the Yellow Sea ecosystem from other scientific research results on the Yellow Sea.

Lee *et al.* (2007) developed fish reproduction potential indices in the coastal and offshore ecosystem in Korea. The research results showed that i) the average annual catch from the Yellow Sea ecosystem in 1975~2004 was 130 thousand mt with coefficient of variation (CV) of 16.8, which was 4.5~6.5 times less than that of the southern sea, ii) the fishing effort increased gradually over time from 1990s, iii) the ratio of adult to small fish has tended to increase since 1997 mainly due to an increase in the ratio of adult to small anchovy in the Yellow Sea and iv) the fish reproduction potential index in the Yellow Sea is still in a low level of 1.22 because of ever-increasing overcapacity.

Another data source that may suggest the ecosystem change is the observation data on the mean capture sizes of major fish species (i.e. hair tail, yellow croaker, chub mackerel, Spanish mackerel and common squid) caught in the Yellow sea. The size (length) of hair tail and yellow croaker after 1995 have tended to be shorter more or less than those in 1995, but since 1995 their size appears to be pretty much stable at 19.7cm and 16.1cm, respectively (Fig. 23). The other three fish species have tended to increase in size.

The study by Lee *et al.* (2007) and the increase in the size at capture of most fish species seem to suggest that the food web and ecosystem of the Yellow Sea in part of Korea have been getting healthier after the introduction of the buyback programs. However, until more and longer scientific observations and analyses, it would be difficult to come up with any meaningful objective conclusion about comprehensive impacts of Korean fisheries structural adjustment policies on the Yellow Sea's fishery resources and ecosystem.





**Source :** Internal Data Base of Department of Fishery Resource Research, Division of Fishery Resources and Ocean Environment, NFRDI.

**Figure 23.** Size change in fish species over time (hair tail (HT), yellow croaker (YC), cub mackerel (CM), Spanish mackerel (SM) and common squid (SQ))

However, fishermen on the west coast are aware of the benefits that have been generated by the FSA. They recognize that the fish species on which the buyback programs have had the largest positive effect are in order of bottom, middle-layer and pelagic fish. In spite of such positive effects of the FSA, they tend to believe that further substantial reduction of fishing capacity(5.7-19.6%) needs to be made. Their belief is consistent with the scientific assessment results of stock status and fishing effort in the Yellow Sea.

#### 4.3 Comparison with buyback activities in other countries: China, Japan and Australia

Many countries in the world have adopted and implemented buyback programs for sustainable fisheries development. All of the fishing states(e.g. Korea, China and Japan) that operate in the Yellow Sea and the East China Sea have implemented buyback schemes. Korea started the programs in 1994, Japan in 1981 and China in 2002.

**Korean** buyback programs have been operated under the individual vessel-catch permit system with input controls and the TAC(total allowable catch) system. Between 1994 and 2007 the buyback programs have been implemented in two ways: one was a general buyback program and the other was an international one. In the first year(1994) of the program 54 vessels were decommissioned and 730 boats in 1999 were reduced in a large scale under both of the general and the international buyback program

Since, however, the law regarding the international buyback program was legislated to deal with the fisheries problems dictated by the Korea-Japan(1999) and the Korea-China (2001) fisheries agreement, the international buyback program was placed for the limited

period from 1999 to 2002. The total number of fishing vessels reduced in 1994~2007 was 8,324(in-shore 6,357 and off-shore 1,967) and the public fund of 1,067 billion Korean won was used for decommissioning the boats.

The results of a study(Lee *et al.*, 2003) showed that the buyback programs did not make a positive net contribution to resources recovery, but it helped the declining rate of resource stocks be reduced and forecasted that resources status and fishing household's management performance would be improved significantly in the long run where the buy-back programs with input controls, resource enhancements and TACs goes together.

**Chinese** ocean fisheries faced new fisheries problems because the existing fishing grounds were much squeezed due to the China-Japan, Korea-China and China-Vietnam bilateral-fisheries agreement. Since the fisheries agreements, more than 30 thousand vessels that operated in the off-shore were out of business. 300 thousand fishermen and more than 3 million fisheries population were affected. A variety of fisheries-related industries such as distribution, processing, transportation, fishing gear manufacturers and fishing port services were influenced directly and/or indirectly. Under such circumstances, fishing intensity of the off-shore fisheries have increased and safety problems on the seas have been getting serious. Thus, the Chinese government began to realize that vessel reduction and fisheries structural adjustments are imperative. Major goals of vessel reduction policy are placed in fisheries resource conservation and fishing-community's economic vitalization and structural adjustment. Ministry of Agriculture and National Management Bureau of Safety, Production and Overseas announced a tentative code for fishing vessel disuse(Cho *et al.*, 2003).

In 1999 Chinese government put a moratorium on the southern sea. At the same time it extended the moratorium period over the Yellow Sea so that fishing time at the Sea was significantly reduced. Also, in 1999 it established a zero-growth goal for quantity harvested. This policy was a practical step to resource conservation and fisheries sustainable development. In addition, China strengthened the regulations for limiting new boat construction. The government increased the number of ocean-administrative officials and strengthened the rules of implementing vessel reduction policy in a unified manner. The policy package has helped Chinese capture fisheries production with resource stabilization increase by 9.5 thousand mt between 1998 and 1999(Cho *et al.*, 2003).

**Japanese** buyback programs were divided into two stages: stage 1(1989~2000) was focused on vessel reduction that management performance got worse and stage 2(2001~) aimed at active fishing effort adjustment to the optimal level of stocks for domestic/international resources restoration, following 『The Resources Recovery Plan』(Cho *et al.*, 2003). Because of excessive fishing effort against target fish species and/or deterioration of natural aquatic environments on which reproduction of species depends, the stock statuses of certain species are worsened. The necessity to rebuild important marine living resources by reducing excessive fishing effort and restoring fishing grounds and nursery areas, are increasingly

recognized.

In accordance with the Basic Plan of Japanese Fishery, which was adopted in 2002, a framework for “Resource Recovery Plan” to implement the necessary measures for rebuilding resources in a comprehensive and planned manner was established. Under the framework, either national or prefecture governments assume a role of formulating specific resource recovery plan according to the nature of the stock or fishery in question. The plan will be developed and implemented in cooperation with stakeholders including fishermen utilizing such resources. In order to implement the plan, various measures such as the reduction of fishing efforts(e.g., decrease in the number of boats, suspension of operations, modification of fishing gear), active resource enhancement(e.g., release of fry) and preservation and rehabilitation of the environment of fishing grounds(e.g., maintain of sea grass beds or tidal flats) are employed. As of February 2008, 51 plans for specific fish species and 20 comprehensive plans in area and fishing type are already developed or under development either by central or prefecture governments. Total number of the plan is increasing over years and the area in which plan was developed has been widely extended throughout Japan(OECD, 2009).

**Australian** buyback scheme was unique in the sense that the buyback was implemented in a fishery managed by individual vessel tradeable harvesting rights rather than input controls. Profits for all vessel classes rose over the period 1997~2000 following the 1997 buyback of 27 fishing licenses, but some of the gains were due to a rise in output prices that were independent of the adjustment program (Fox *et al.*, 2003). All vessel classes (small and large) also experienced substantial productivity gains immediately following the 1997 license buyback with an average increase over all vessels of 39%. This increase, coincident with a decline in catch per unit of effort for key species, provides strong support that the buyback was successful at improving economic performance. Ongoing productivity improvements for small vessels over the period 1998~2000 following the buyback is attributed to the existence of individual tradeable harvesting rights in the fishery(Fox *et al.*, 2003, OECD, 2009).

The comparison of Korean buyback programs with those of other three states(e.g. China, Japan and Australia) implies that the common denominator of buyback programs is effectiveness for resource conservation and restoration and would be more effective where they are implemented with input and/or output controls, resource enhancement programs and in some cases space and/or time moratorium. In addition, decommissioned vessels need to be thoroughly monitored not to reenter and the states of adopting buyback schemes do not allow new vessels to be constructed.

## 5. Conclusions and policy implications

The Korean fisheries authorities have for some time followed a structural adjustment policy in fisheries, largely focusing on buyback of fishing vessels. This policy appears to have a significant contribution to reducing the rate of fisheries resource decline. Some fish species, such as squid, Spanish mackerel and Jack mackerel, showed signs of recovery. Even though a large number of fishing vessels has been reduced for the last 15 years, the effective fishing capacity (i.e. engine power) has tended to increase. Thus, increased engine power has to a certain extent replaced decommissioned vessels. This trade-off, often observed under buyback programs has occurred because of lack of institutional arrangements.<sup>1</sup> Now, the ministry of food, agriculture, fisheries and forestry(MFAFF) began to search for a way of effectively controlling vessel engine power.

In addition, it is known that fisheries resource management problems are compounded by land-based pollution and climate change. Korean government has begun to much actively manage land-based pollution through the intergovernmental cooperative mechanism. To respond to climate change, the government declared low carbon/green growth strategy as a new national policy toward six decades ahead. In particular, dealing with land-based pollution problems in the Yellow Sea is much more important than other seas in Korean peninsular since most of large industrial complexes and metropolitan cities are located in the east coast of China and in the west coast of Korea

Following such national initiative, the central and provincial governments should be able to develop integrated green policy package including buyback, resource enhancement, off-fisheries income promotion, fuel subsidy reorientation and self (or co)-management programs.<sup>2</sup> Also, the package program should be supported by new R&D system that is focused on enhancing and maintaining the Yellow Sea's environment and ecosystem. This will require far closer cooperative work among South/North Korea, China and related international bodies.

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1 During the buyback period there is no additional new-boat construction. Since however higher engine power was allowed where two existing boats were put together into one, engine power has much increased without construction of extra new boats. Most of the decommissioned boats were scraped or used for artificial reef establishment. Small number of boats was given to the few Asian developing coastal states.

2 Fuel subsidy(tax exemption) is a type of cost-saving support, which amounted to about 754 billion won in 2007(Ministry of Food, Agriculture, fisheries and Forestry, Fisheries Annual Report, 2008). Green policy package needs to include reorientation schemes for fuel subsidy so as to provide fishermen with some incentives to save fuel consumption.

## References

- Caddy, J. F. 1999. Deciding on precautionary management measures for a stock based on a suit of limit reference points(LRPs) as a basis for a multi-LRP harvest law. *NAFO Scientific Council Studies* 32. pp.55-68.
- Caddy, J. F. 2002. Limit reference points, traffic lights and holistic approaches to fisheries management with minimal stock assessment input. *Fisheries Research* 56. pp.133-137.
- Cho, J. H., J. G. Ryu, S. M. Lee and J. H. Ahn. 2003. *International Comparison and Policy Implication*. Korean Maritime Institute. pp.75-86(Korean).
- Choi, J. H. 1999. *Modern International Ocean Law*. Sejong Publishing Co. Ltd. pp.336-356(Korean).
- Choi, J. H. 2000. *History of Koran-Japan Fisheries Relationship*. Sejong Publishing Co. Ltd. pp.473-506(Korean).
- Choi, J. H. 2002. *A Study on Korea-China Fisheries Agreement*. Ministry of Maritime and Fisheries. pp.105-113(Korean).
- Doubleday, W. G. 1976. Environmental fluctuations and fisheries management. *ICNAF Special Publication* 1, pp.141-150.
- Fox, K. J., R. Q. Grafton, T. Kompas and T. N. Che. 2003. Capacity reduction and productivity: The case of fishery. *Economics and Environment Network Working Paper EEN0303*. pp.1-25. (<http://een.anu.edu.au>).
- Fox, W. W. 1970. An exponential surplus yield model for optimizing fish populations. *Transactions of the American Fisheries Society*, 99. pp.80-88.
- Hong, H. P. 2007. *A Study on Fisheries Status of Korea, China and Japan and Fishery Policy Directions*. Korea Maritime and Fisheries Institute. pp.45-96(Korean)
- ICCAT. 2008. Report of the 2007 ICCAT big-eye tuna stock assessment session. *Collect. Vol. Scientific Paper. ICCAT* 62(1). pp.97-239.
- Kim, J. H., S. J. Jo, D. W. Lee and S. K. Park. 2006. *A Deep Evaluation Report of Financial Projects: Fisheries Structural Adjustment*. Korea Development Institute. pp.1-49 (Korean).
- Korea Rural Economic Institute. 1992. *A Survey and Research for In- and Off-shore Fisheries Structural Adjustment*. pp.3-25 (English summary pp.27-30).
- Lee, K. N., Y. T. Shin, H. D. Pyo and Y. S. Kim. 2003. *An Analysis on Effects of the Buyback Programs of In- and Off-shore Fishing Vessels*. Ministry of Maritime Affairs and Fisheries. pp.1-21(Korean)
- Lee, S. K., J. B. Lee, C. I. Zhang and D. W. Lee. 2007. Fish reproduction potential indices in the coastal and off-shore ecosystem in Korea. *Journal of Korean Fisheries Society* 40(1), pp.24-30 (English abstract p.24).
- Ministry of Maritime Affairs and Fisheries. 2007. *Future National Ocean Strategy*.

- pp.89-101(Korean).
- Ministry of Food, Agriculture, Fisheries and Forestry, 2008. *Fisheries Annual Report*. pp.189-190(Korean).
- National Fisheries Research & Development Institute. 2007. *Climate Change! Threat? or Opportunity?*, pp.21-23(Korean).
- National Fisheries Development & Research Institute. 2005. *Ecology and Fishing Grounds of Major Adjacent Fish Species*. pp.9-370(Korean).
- OECD. 2009. Country Note: Australia (2006~2008). pp.1-25.
- \_\_\_\_\_. 2009. Country Note: Japan (2006~2008). pp.1-14.
- Park, S. K. 2009. The effect of climate change on fishing industry. In *Proceedings of 2007 to 2008 Annual Scientific Meeting between Pukyong National University (Korea) and National Fisheries University (Japan)*. Pukyong National University and National Fisheries University. pp.119-154(Japanese).
- Pella, J. J. and P. K. Tomlinson. 1969. A generalized stock production model. Bulletin. *IATTC* 13. pp.419-496.
- Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of the commercial marine fisheries. Bulletin. *IATTC* 1. pp.27-56.
- Shin, Y. T., Y. H. Jeo, C. I. Pak and E. C. Jeong. 2001. *A Study on the Comprehensive Restructuring of Off-shore Fisheries*. Korean Maritime Institute/Ministry of Maritime Affairs and Fisheries. pp.9-25(Korean).