A MANAGEMENT POLICY FOR NORTH JAPAN SEA SAILFIN SANDFISH *Arctoscopus japonicus* STOCK

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ABSTRACT

The fishery cooperative association of Akita Prefecture closed the sailfin sandfish *Arctoscopus japonicus* fisheries from 1992 to 1994 to rehabilitate the stock. Following the temporary closure, the total allowable catch (TAC) has gradually increased. The aim of this study is to evaluate the effects of the fishery moratorium and other restrictions for this stock using several scenarios involving age-structured models and ocean environmental factors. The following results were obtained:1) stock biomass (SB) did increase during the fishing moratorium; 2) if more prefectures, including Aomori, Akita, Yamagata and Niigata had also implemented the moratorium, a greater increases in SB would have been realized; 3) if a 30% reduction in fish harvest had been implemented from 1980 to 1982 when the ocean environmental condition was relatively good, SB would have recovered; 4) SB would not have recovered if the moratorium had not been implemented; 5) if exploitation rates E_t could be tightly controlled, a constant exploitation rate policy of E_t = 0.4 would be a better policy compared to other policies based on Monte-Carlo simulation tests; and 6) if E_t can not be controlled at a constant level, a short-term reduction policy of Et, for example, a 30% reduction during the 3 years when stock size was very low, would be very effective. In particular, when the ocean environmental condition is good, this policy works effectively.

Keywords: sailfin sandfish, *Arctoscopus japonicus*, fishing moratorium, management policy, age-structured model, environmental factor

INTRODUCTION

Sandfish catches in Akita Prefecture, where the main spawning grounds of the North Japan Sea sandfish stock are located (Fig. 1.), have been largely fluctuating from the 1960s to the 1980s (Fig. 2.). In the late 1980s, the catch had collapsed. The fishery society of Akita Prefecture conducted a fishing moratorium from 1 September, 1992 to 30 September, 1995, in order to rehabilitate the stock. This was the first time that a fishing moratorium was implemented in large-scale fisheries in Japan. When the fisheries were reopened on 1 October, 1995, the fishing effort in Akita Prefecture was substantially reduced and the total allowable catch (TAC) system was introduced [1]. It was observed that since 1995, the TAC has gradually increased each year. However, fishermen of other prefectures (Aomori, Yamagata and Niigata) harvesting this stock did not take part in the moratorium and TAC system. Evaluating the effects of the moratorium on stock recovery is a very interesting issue.

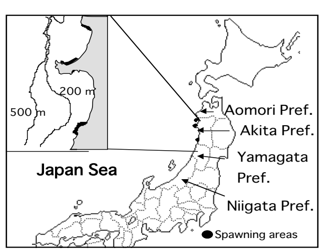

Figure 1. Location of the spawning grounds of North Japan Sea sandfish stock (dark areas)

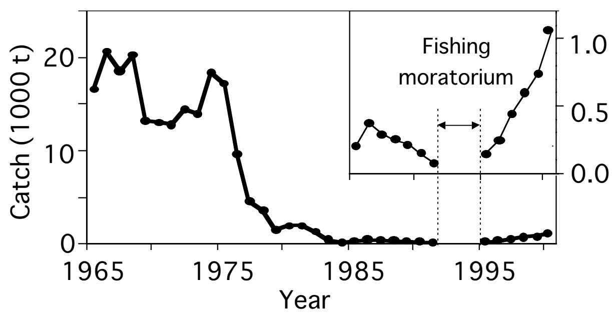

Figure 2. The annual sandfish catch in Akita Prefecture

The North Japan Sea stock is harvested by two methods: the first method is that employed by coastal fisheries, which uses fixed gears, such as set and gill nets; the other is the method employed by offshore fisheries, which uses trawl gears, such as Danish seine boats and small-scale Danish seine boats. The coastal fisheries operate in the spawning grounds off Akita and Aomori Prefectures and target spawners in December. The offshore fisheries catch North Japan Sea stock throughout the year in the offshore waters off Aomori, Akita, Yamagata, and Niigata Prefectures (Fig. 1.). The offshore fisheries of Aomori, Yamagata, and Niigata Prefectures caused critical damage to this stock in the 1980s, when the stock size was very small [2]. However, the fishermen of these prefectures, who harvest this stock, did not participate in the moratorium and the TAC system.

Some studies have pointed out that the fluctuation in this stock is affected by ocean environmental conditions [2, 3]. Watanabe (2003) constructed the stock-recruitment model, which reproduced the fluctuation in the recruitment of the stock, using spawner abundance and water temperatures. Therefore, based on this model, we can simulate the dynamics of this stock.

In this study, the fishing moratorium in Akita Prefecture and other management policies on this stock were evaluated using simulations, involving age-structured models and ocean environmental factors. Additionally, management policies, constant exploitation rates, and feedback control were examined for the proposal of future plans.

MATERIALS AND METHODS

Dynamic model of stock size

The dynamic model of stock size in number was assumed as

$$TN_t = R_t + \sum_{a=2}^{4+} [N_{a-1,t-1} \exp(-M) - TC_{a-1,t-1}], \qquad \text{(Eq. 1)}$$

where TN_t is the total stock size in number in year t, R_t is the recruitment in number, and $N_{a,t}$ is the stock size in number at age a (a = 1, 2, 3, and 4, and greater than 4 years (4+)). R_t is the stock size in number at age 1 and was obtained as follows [2]:

$$R_t = S_{t-2} \exp(-M_{1,t} - 2.0 \cdot 10^{-12} \cdot S_{t-2}), \qquad \text{(Eq. 2)}$$

where S_t is the egg production and $M_{1,t}$ is the natural mortality coefficient determined by water temperatures [2].

Simulation tests to evaluate fishing moratorium and other management policies

In order to evaluate the effects of the fishing moratorium and other management policies on stock abundance, we tested the dynamics of the North Japan Sea stock under different scenarios, as follows:

Scenario 1: From 1992, the fishermen of these four prefectures did not conduct the fishing moratorium and harvested with the mean exploitation rates from 1980 to 1991.;

Scenario 2: The fishermen of Akita Prefecture conducted a fishing moratorium from 1992 to 1994, which corresponds to the actual case;

Scenario 3: The fishermen of Aomori, Akita, Yamagata, and Niigata Prefectures conducted a fishing moratorium from 1992 to 1994;

Scenario 4: From 1985 to 1987, when the ocean environmental condition was relatively bad, the exploitation rates of these four prefectures were forcefully reduced to $E_t \times 2/3$;

Scenario 5: From 1980 to 1982, when the ocean environmental condition was relatively good, the exploitation rates of these four prefectures were forcefully reduced to $E_t \times 2/3$, where E_t is the mean exploitation rate from 1965 to 1979;

In these scenarios, the following are assumed: (1) The estimated total stock size in number $\tilde{N}_t$ does not have a measurement error, (2) In scenario 2, after the fishing moratorium, the exploitation rate employs the value obtained in scenario 1.

Simulation tests using the Monte-Carlo method

Simulation tests using the Monte-Carlo method were performed to compare stock dynamics and catches when management policies were implemented. The simulation tests were conducted from 1966 to 1999 and were repeated 100 times. These were performed using the following management policies: policy 1, $E_t = 0.3$; policy 2, $E_t = 0.4$; policy 3, $E_t = 0.5$; policy 4, $E_t = 0.6$; and policy 5, feedback control system.

In the case of constant exploitation rates (policies 1, 2, 3, and 4), the total quota was obtained based on stock size estimation. The total quota $\tilde{Q}_t$ was determined as follows:

$$\tilde{Q}_t = \tilde{N}_t \cdot \exp(-M) \cdot E_t, \qquad \text{(Eq. 3)}$$

where M is the constant natural mortality coefficient that was estimated using Pauly's (1980) method (M = 0.14/year).

In the case of feedback control (policy 5), $\tilde{Q}_t$ was determined as follows [5, 6]:

$$\tilde{Q}_t = \tilde{Q}_{t-1} + [\lambda \cdot \frac{(\tilde{N}_t - TG)}{TG} + \rho \cdot \frac{(\tilde{N}_t - \overline{N})}{\overline{N}}] \cdot \tilde{Q}_{t-1}, \qquad \text{(Eq. 4)}$$

where TG is the target level of stock size, λ and ρ are control variables, and $\overline{N}$ is the mean of $\tilde{N}_{t-1}$ and $\tilde{N}_{t-2}$. The values of TG, λ and ρ were obtained by trial and error to prevent the $\tilde{Q}_t$ value from tending to 0. Likewise, three values were assigned to λ and ρ depending on the stock size levels, as follows:

$$\begin{cases} \lambda_1, \rho_1, & \tilde{N}_t \geq TN_{1979} \\ \lambda_2, \rho_2, & \tilde{N}_t \leq TN_{1979} \quad and \quad \tilde{N}_t \geq \tilde{N}_{t-1} \\ \lambda_3, \rho_3, & \tilde{N}_t \leq TN_{1979} \quad and \quad \tilde{N}_t \leq \tilde{N}_{t-1} \end{cases} . \qquad \text{(Eq. 5)}$$

In these Monte-Carlo simulations, we assumed the measurement error, $\varepsilon_{o,t}$ as follows:

$$\tilde{N}_t = TN_t \cdot \varepsilon_{o,t} . \qquad \text{(Eq. 6)}$$

The $\varepsilon_{o,t}$ was obtained as two cases, upon consideration of the residuals between the reproduced values and the observed recruitment [2]:

Case 1: When we can accurately forecast the stock size using a model, such as the recruitment model, taking into consideration the ocean environmental conditions [2], $\varepsilon_{o,t} \sim L_N(1, 0.4)$;

Case 2: When we cannot accurately forecast the stock size using a model, such as the Ricker model [2], $\varepsilon_{o,t} \sim L_N(1, 0.8)$.

Likewise, the actual catches C_t were obtained as follows:

$$C_t = \alpha \cdot \tilde{Q}_t, \qquad \text{(Eq. 7)}$$

where α is the error and lognormal distribution $L_N(1, 0.2)$ with mean 1 and standard deviation 0.2. Therefore, the actual catches at age a $TC_{a,t}$ were

$$TC_{a,t} = C_t \cdot \frac{N_{a,t}}{TN_t}. \qquad \text{(Eq. 8)}$$

We evaluated the performance of each management policy based on the following three points:

(1) Mean stock biomass B_{mean} (ton) as

$$B_{mean} = \frac{1}{100}\sum_{d=1}^{100} \overline{SB}, \qquad \text{(Eq. 9)}$$

where $\overline{SB}$ is the mean value of stock biomass between 1966 and 1999 in one trial of the simulation;

(2) Mean catch C_{mean} (ton) as

$$C_{mean} = \frac{1}{100}\sum_{d=1}^{100} \overline{C}, \qquad \text{(Eq. 10)}$$

where $\overline{C}$ is the mean value of the actual catch between 1966 and 1999 in one trial of the simulation;

(3) EX denotes the number of extinction, i.e., the number when the stock biomass reaches 0 in 100 repetitions of the simulation test.

RESULTS

Evaluation of fishing moratorium and other management policies

In scenario 1, the stock biomass was 430 ton in 1995 and this was half that in scenario 2. The stock biomass in 1999 was 840 ton and was 1/10 that in scenario 2. In scenario 2, the stock biomass reached approximately 790 ton in 1995 and then marked approximately 7000 ton in 1999. In scenario 3, the stock biomass was approximately 2280 ton in 1995 and then marked approximately 10000 ton in 1999. In 1995, the stock biomass was three times that in scenario 2. In scenario 4, the stock biomass increased gradually from 1985 and reached approximately 6500 ton in 1995. In scenario 5, the stock biomass increased markedly from 1982 and reached approximately 11500 ton in 1995. Subsequently, the stock biomass was constant until 1999.

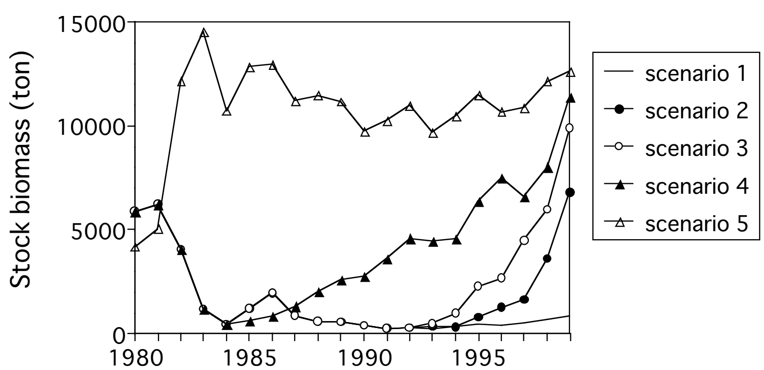

Figure 3. The stock biomass in each scenario

Comparison of management policies using the Monte-Carlo simulations

In case 1, C_{mean} was not different in all policies and was highest in $E_t = 0.4$. However, B_{mean} decreased corresponding to an increase in E_t. The EX was 0 when $E_t = 0.3$, 0.4, and 0.5; however, extinction occurred when $E_t = 0.6$ (Fig. 4.).

In case 2, C_{mean} was similar in all policies. However, B_{mean} decreased corresponding to an increase in E_t. The EX value was 0 when $E_t = 0.3$ and 0.4. Note that the value of EX markedly increased when $E_t = 0.5$ and 0.6.

In case 1 of feedback control, (λ_1, ρ_1), (λ_2, ρ_2), and (λ_3, ρ_3) were (0.001, 1.0), (1, 1), and (0.1, 2.5), respectively. The B_{mean} value was at the same level as that of $E_t = 0.3$. The C_{mean} value was lower when compared with that of other policies. In case 2, (λ_1, ρ_1), (λ_2, ρ_2), and (λ_3, ρ_3) were (0.001, 1.0), (0.001, 1.0), and (0.01, 3), respectively. The B_{mean} value was at the same level as that of $E_t = 0.3$. However, the C_{mean} value was similar among all policies. Figure 4 shows the mean stock biomass B_{mean}, the mean catch C_{mean}, and the number of extinction EX in each policy and each case of error distribution.

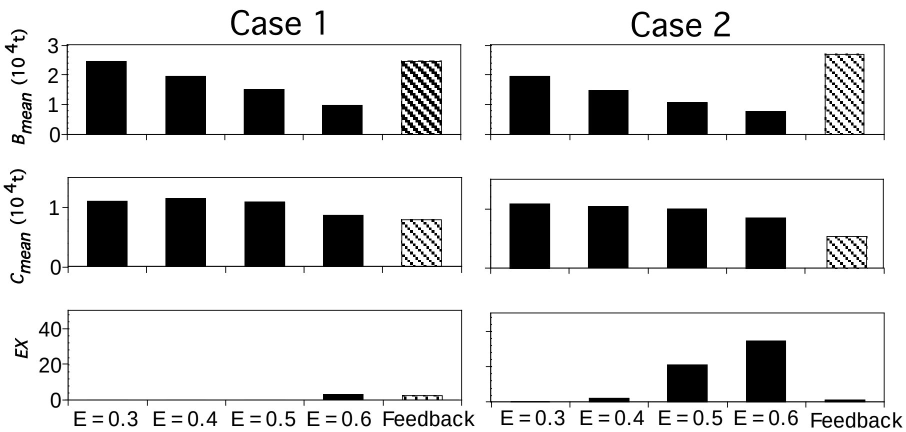

Figure 4. The mean stock biomass B_{mean}, the mean catch C_{mean}, and the number of extinction EX in each policy and each case of error distribution

DISCUSSION

This study has shown that the stock biomass can increase when the fisheries of Akita Prefecture conduct a fishing moratorium (scenario 2) and it would not have recovered if the moratorium had not been implemented (scenario 1) (Fig. 3.). These results are consistent with those obtained by Sakuramoto *et al* (2001), whose simulations were based on the forecasting model of the coastal catch in Akita Prefecture. The results of this study suggest that the implementation of a fishing moratorium is important to increase stock size.

Mizuguchi and Shibata (1992) pointed out that the fishing restrictions on the North Japan Sea stock should be applied not only to the fisheries of Akita Prefecture but also to those of Aomori, Niigata, and Yamagata Prefectures, where large amounts of fish are harvested in the offshore areas. A greater increase in the stock biomass would have been realized if more prefectures, including Aomori, Akita, Yamagata, and Niigata, had also implemented the moratorium (scenario 3) (Fig. 3.).

If the fishing restriction had been conducted from 1980 to 1982 (scenario 5), the stock biomass would have increased markedly from 1982. However, in scenario 4, the stock biomass would not have increased markedly. These results imply that the fishing restriction works effectively for stock sizes when ocean environmental conditions are relatively good. Likewise, they suggest that the fisheries in Akita Prefecture could have avoided the 3-year fishing moratorium if the restriction had been conducted earlier, in the 1980s.

When the exploitation rates E_t in case 2 were 0.5 and 0.6, the mean stock biomass B_{mean} was low. The number of extinction markedly increased compared with that when E_t was 0.3 and 0.4 (Fig. 4.). If the policy continues to permit a high exploitation rate, then improvement of the stock forecast analysis will be required. This can be carried out using the ocean environmental conditions.

The Monte-Carlo simulation tests for the North Japan Sea stock showed that a constant exploitation rate policy (E_t = 0.4) exhibits a better performance compared with other policies. If the exploitation rate can be controlled at a certain level, E_t = 0.4 would be a better policy. However, if the exploitation rate cannot be controlled, the stock should be managed by implementing a tentative reduction of exploitation rates, for instance, a 30% reduction during the 3 years when stock size was very low. This approach worked effectively to increase stock size, particularly when the ocean environmental conditions were good (Fig. 4.).

The actual mean E_t (E_t = 0.59) was very high when the stock size was very low due to the intensive harvesting of offshore fisheries in the four prefectures mentioned above. We conclude that a constant exploitation rate policy (E_t = 0.4) and the reduction of exploitation rates in short term should be implemented by all fisheries that harvest the North Japan Sea stock.

REFERENCES

1. Sugiyama H, 1998, Fishery management for sandfish in Akita. *J. North Jpn. Fish. Econom*, 26, pp. 9-14 (in Japanese).
2. Watanebe K, 2003, A study on dynamics and management of sandfish stocks *Arctoscopus japonicus* in the waters around Japan, PhD Thesis, Tokyo University of Fisheries, Tokyo.
3. Sakuramoto K, Sugiyama H and Suzuki N, 2001, Models for forecasting sandfish catch in the coastal waters off Akita Prefecture and the evaluation of the effect of a 3-year fishery closure, *Fisheries Sci.*, 67, pp. 203-213.
4. Pauly D, 1980, On the interrelationships between natural mortality, growth parameters, and mean environmental temperature in 175 fish stocks, *J. Cous. Int. Explo. Mer.*, 39, pp. 175-192.
5. Tanaka S, 1980, A theoretical consideration on the management of a stock-fishery system by catch quota and on its dynamical properties. *Bull. Japan. Soc. Sci. Fish.*, 46, pp. 1477-1482.
6. Sakuramoto K and Tanaka S, 1989, A simulation study on management of whale stocks considering feedback systems, *Rep. Int. Whal. Commn* (Special Issue II), pp. 199-210.
7. Mizuguchi K and Shibata R, 1992, Methodology of studies on sandfish, *Report of Sandfish Research Council*, Japan Sea National Fisheries Research Institute, 5, pp. 30 (in Japanese).