

〈Article〉

# Resource Constraints in the Development of the Australian Southern Bluefin Tuna Industry

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## 1. Purpose

Demand for tuna has been increasing due to a global sushi boom, changes in diet patterns toward health consciousness in Western countries and the economic development of emerging countries such as China. In addition, there will be new uses for tuna stakes in Europe, if the price of tuna goes down (Mylonas et al (2010)). This trend is an opportunity for the Australian southern bluefin tuna (SBT) farming industry. However, the industry faces serious SBT resource constraints, and the catch quota on juvenile tuna for fattening is strictly limited by the Conservation Committee of Southern Bluefin Tuna (CCSBT). At present, only Japan has a full-cycle farming technology that does not depend on the catching of wild juveniles. Transfer of this technology might be one solution to the resource constraint. However, the full-cycle farming technology is not explicit; instead it is a group of implicit practices that depend on the experience of technicians. Therefore, the possibility of transferring this technology to Australia in the near future is not guaranteed. Another solution might be a resource recovery acceleration of SBT and an expansion of the future production capacity for fattening farming.

This paper aims to answer this question concerning the resource recovery strategy by applying a surplus production model that represents the reproductive relations of marine resources. We will then project future resource trends based on the estimated range of the carrying capacity and the intrinsic growth rate of SBT resources.

## 2. Southern Bluefin Tuna for Australia and Japan

SBT is one of important commodities within Australian fishery exports, and is a major fishery product especially in South Australia (SA). For example, the export value of SBT exceeds 10% of Australian fishery exports, including processed goods. Aquaculture has a half share in SA fisheries, and although the tuna sector formerly occupied a dominant position in the aquaculture there, it is declining due to the development of other products such as oysters. In terms of production value, the share of tuna in SA fisheries is nearly one-thirds (ABARE (2010 a, b)). Tuna's contribution to employment in the aquaculture sector is also nearly one-thirds (Econsearch (2008)).

SBT fisheries were exploited in the late 1950s by Japanese longline fleets, as the catch amount expanded drastically after the installation of an ultra-low temperature freezer to the fleets (Figure 1). However, the catch amount decreased during the 1960s due to resource limitations. The entry of Australian purse seine fleets followed the Japanese fleets' entry, and the catch amount increased in the 1970s. Both countries caught equivalent quantities in the 1980s, and the resource depletion

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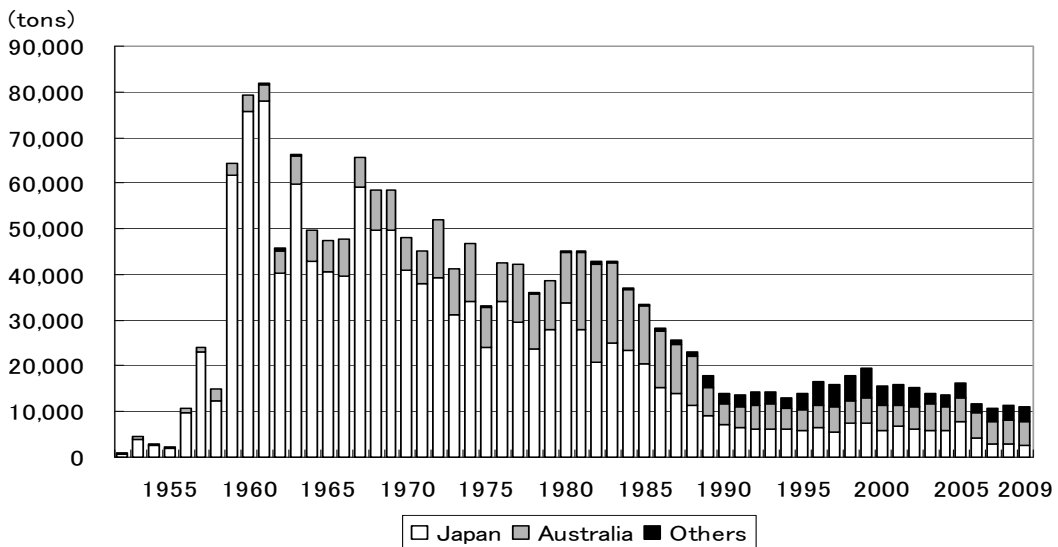
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became a serious issue during this period.

Because the Australian purse seine fleets targeted small SBT used for cheap tuna canning, in 1994 the Overseas Fishery Cooperation Foundation (OFCF) of Japan began cooperatively transferring farming technology to Australia to improve the economic efficiency of the tuna industry. In the same year, the CCSBT was established with Japan, Australia and New Zealand as its initial members.

These three countries introduced a catch quota system in 1985, and the quota of each country has since decreased. For example, the countries' total catch quota was 38,650 tons as of 1985, but it was reduced to 11,750 tons in 1989, and it remained at the same level until the year 1997. Despite the efforts by these three countries to conserve SBT, the catches of non-member countries such as Korea, Taiwan and Indonesia increased in the 1990s. The issue of non-member involvement is discussed by Pintassilgo and Duarte (2001), who address how cooperative agreements may be undermined over time due to the emergence of new entrants. This problem has now been alleviated, as Korea and Indonesia became members of the CCSBT in 2001 and 2008, respectively, and Taiwan became a member of the Extended Commission as a Fishing Entity in 2002.

In addition to the issue of non-member over-fishing, there was conflict between member countries regarding an estimation of the SBT resource level. Japan had a relatively optimistic perspective on the resource recovery, while Australia and New Zealand insisted on keeping a strict quota. The government of Japan then proposed to implement experiment fishery plans (EFP) to test the hypothesis of increasing resources, while Australia and New Zealand refused claiming that implementing the EFP would reduce resources. As a result, this issue was brought to the International Tribunal for the Law of the Sea (ITLOS) and to the Arbitral Tribunal (AT) constituted under Annex VII of the United Nations Convention on the Law of the Sea (UNCLOS) in 1999-2000. Since the dispute ended, the CCSBT has continued to reduce the quota, but the resources have never been recovered. The latest quota as of 2010-11 is 9,449 tons, which equals one-fourth of the quota in 1985. Of this quota, 2,261 and 4,015 tons are allocated to Japan and Australia, respectively.



Data: CCSBT data base

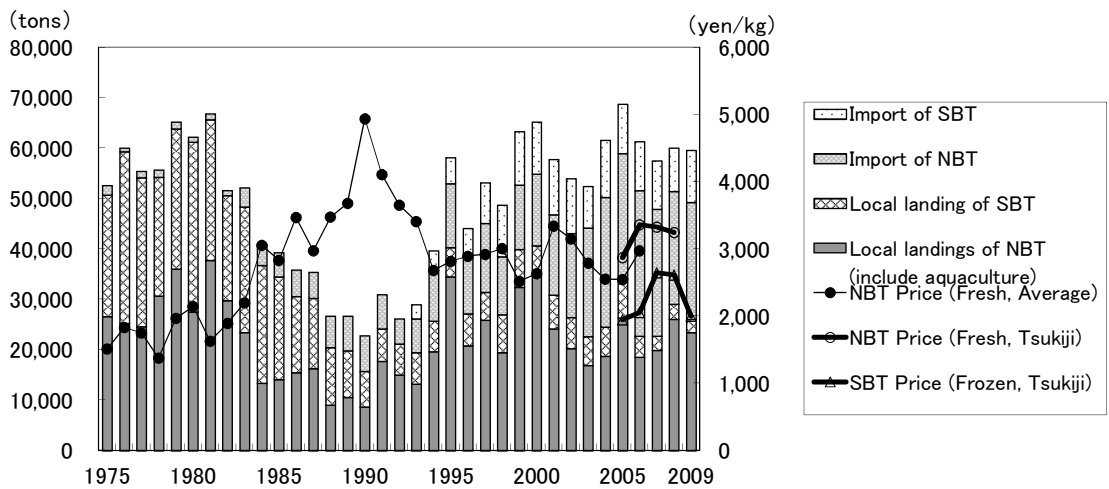
Figure 1 Catch amount of southern bluefin tuna by country

Under the severe resource constraints, the Australian Commonwealth government introduced the Individual Transferable Quota (ITQ) system for SBT fishery management in 1984, which provided transferrable catch quotas to Australian fishing bodies. After its introduction, the number of vessels and fishing bodies became concentrated in SA. According to Campbell et al. (2000) and Kuronuma (1992), two-thirds of the operators left their fisheries within two years, taxable income per vessel was estimated to have increased by an average of 13% in the states of New South Wales and Western Australia, quotas per vessel increased from 226 tons to 550 tons in SA, and the distribution of SBT quota ownership for SA was concentrated from 65% in 1984–85 to 87% in 1994–95. The ITQ system has contributed to the improved economic efficiency of Australian SBT fisheries.

After the establishment of ITQ system, Australian SBT fisheries were converted from wild catch fisheries to more profitable aquaculture entities. The catch quota price has risen from A\$600–1,000 per ton in 1984 to A\$6,000–7,000 in 1987, and it is currently at A\$17,500 (Kuronuma (1993) and Clean Seas (2008)). In addition, the farmed production increased drastically with the introduction of offshore farming in the middle of the 1990s. It exceeded 5,000 and 9,000 tons in 1997 and 2000, respectively, and has remained at 7,000–10,000 tons each year since 2002 due to resource constraints.

Most SBT is exported to Japan now, where SBT has the second highest market valuation after northern bluefin tuna for sashimi and sushi usage. The SBT price in the wholesale markets of heavy consumption areas, including Tokyo’s biggest market *Tsukiji*, is around 2,000 yen/kg (Figure 2), which is two thirds the price of northern bluefin tuna and twice the price of bigeye tuna. Bigeye tuna is a substitutive species of bluefin tuna, and is considered the standard tuna for sashimi.

In the Japanese market, northern bluefin tuna comprises both domestic wild and farmed fish, along with imported fish mostly farmed in Mediterranean countries such as Spain, Italy and Croatia. Before 1980, almost all bluefin tunas were domestically landed as shown in Figure 2. However, domestic landings began to decrease in the latter half of the 1980s, while the demand for tuna increased due to the economic bubble. The reason for the decreased domestic landings was resource reduction caused by over-catching and/or climate changes. Subsequently, the price of northern bluefin tuna rose sharply from 3,000 yen/kg to more than 4,000 yen/kg, and it accelerated imports of bluefin



Note) SBT: Southern bluefin tuna, NBT: Northern bluefin tuna

Figure 2 Supply of bluefin tunas and prices in Japanese markets

and bigeye tuna. Imports of SBT began in 1991, after success in applying fattening technology. At the same time, imports of northern bluefin tuna also increased, and the proportion of fattened tuna has been increasing ever since.

However, both SBT and Atlantic bluefin tuna face serious resource constraints, and production has recently become stagnant. In Japan, the production of farmed tuna has been increasing steadily, reaching 10,000 tons as of 2010, thus exceeding the production of farmed SBT and Atlantic bluefin tuna. Furthermore, Kinki University succeeded in developing a full-cycle farming technology in 2002, and farmed tuna production based on the technology accounts for 10% of total farmed tuna production in Japan. After that, some private firms have succeeded in the technological development, which is considered diffused in Japan in the near future.

### 3. Advantages and Disadvantages of the Australian Tuna Farming Industry

Most of the Australian tuna farming industry is concentrated in Port Lincoln, SA, which is near the juvenile fishing area in the Big Australian Bight. The juveniles migrate from spawning areas near Java Islands, Indonesia along the west coast of Australia. They are transferred to offshore cages after being caught alive by purse seine fleets. After the process of fattening in the cages for 3–6 months, they are shipped fresh or frozen. The ratio of frozen fish to fresh fish has been increasing and is currently more than 80%. This avoids price falls caused by shipping concentration of fresh fish, and allows for opportunities to take advantage of price rebounds.

The advantages and disadvantages of SBT farming, including technological issues, are summarized by Hidaka (2010) and Hidaka and Torii (2005), using Michael Porter's five forces theory:

#### <Advantages>

- Few threats from local and foreign new entrants due to the huge sunk costs of farming operations.
- Stable supply of juvenile tuna and feeds.

#### <Disadvantages>

- Severe international competition with the Mediterranean and Mexican northern bluefin tunas in the Japanese market.
- Substitutive goods such as salmon for sashimi.
- Monopolistic buying powers by the Japanese importers.

In addition to these five forces, they assert that the agglomeration of the industry to Port Lincoln was an advantage that enabled both efficient information diffusion within the industry as well as effective R&D activities by the Federal and SA governments and related private sectors such as the Tuna Boat Owners Association (TBOA). This collaborative aquaculture development program was named the Aquafinn Cooperative Research Center (CRC), which began in 1997 and ended in 2005. It was succeeded by the Australia Seafood CRC.

We also interviewed the Australian Southern Bluefin Tuna Industry Association (ASBTIA), which succeeded the TBOA, and related companies in 2009. As a result, it was found that R&D activities for developing artificial feeds are ongoing. The activities focus on machinery feeding to enhance the feed conversion ratio and to reduce the cost of production. However, the small amount of public

relations expenditures, due to the small size of the SBT industry, is a disadvantage. This contrasts with the beef industry of Australia, for example.

The status of resources is a crucial but uncertain factor in designing the industry's strategy. For example, the SBT catch quota was reduced by the CCSBT again in 2009, just after we interviewed the ASBTIA and got feedbacks that new SBT resources had appeared in the Tasman Sea. Indeed, the Australian SBT industry is protected from local and foreign new entrants by a strict catch quota (Hidaka and Torii (2005)). However, the resource status embodies two sides of the same coin. The industry cannot take advantage of the emerging opportunities of global expansion of tuna markets.

In order to revitalize the industry, there are two paths: one is to develop or to introduce a full-cycle farming technology, and the other is to accelerate a recovery of SBT resources to expand the catch quota of juveniles for fattening farming. In order to consider the feasibility of the latter path, we must analyze the resource trends of SBT.

#### 4. Method for Analyzing Reproductive Relations of SBT

Fishing effort is a concept meaning "aggregated inputs into fishing" such as vessels, fishing gears and labor days. Catch per unit effort (CPUE) data are generally used for resource estimations. In case of SBT, time series data of the catch per hook of longline vessels as proxy of resource trends are reported by the CCSBT (2010) and show downward trends for fish over 4 years old. However, the data is generally collected in high-density resource areas where fisheries are operated, rather than in randomly sampled areas (Ishii (1996)). This was the central issue in the Australia-Japan dispute concerning the Japanese experimental fishery plans for SBT (Polacheck (2002) and Komatsu and Endo (2002)). In addition, the standardization of CPUE between different fishing gears, such as longline and purse seine, is one of the constraints of using CPUE data (FRA (2010)).

Therefore, we attempt to estimate resources by applying the surplus production model developed by Schaefer (1954) and Clark (1985), by which resources can be estimated using catch data.

Based on the model, resources at the end of each period are represented as:

$$S_t = S_{t-1} + r S_{t-1} (1 - S_{t-1} / k) - Q_t \quad (\text{Eq. 1}),$$

where  $K$  is the maximum carrying capacity of the species,  $r$  is the intrinsic growth rate,  $Q$  is the catch amount, and  $t$  is the year. On the right of Eq.1, if the catch is equal to the second term which is the growth of the resources ( $dS/dt$ ), then the resource is stable as  $S_t = S_{t-1}$ , and the catch is termed a sustainable yield (SY). In addition, if  $S=K/2$ , then  $dS/dt$  is maximized, and the catch is termed a maximum sustainable yield (MSY).

If the resource data are available, we can estimate the parameters  $K$  and  $r$  by applying the least squares method. For example, Grafton (2000) estimated the intrinsic growth rate to be 0.3 by providing an exogenous  $K$  for the Canadian cod.

It is widely accepted that SBT resources have been facing a serious crisis of depletion. In 2009, the CCSBT (2010) estimated the spawning stock biomass at around 5% of pre-exploited levels. As this estimate was around 10% in 2006 (CCSBT(2008)), the estimated results are not yet robust, but they are still far below an MSY.

In our analysis, therefore, we attempted to select appropriate combinations of  $K$  and  $r$  so that the

two parameters acquired normal resource trend features. More concretely, we assigned various values to  $K$  that changed with every 100 thousand tons, and assigned values to  $r$  that changed with every 0.01. We selected combinations of  $K$  and  $r$  when the resource levels fall between zero and  $K/2$  as of 2010. We set the initial value of  $S$  equal to  $K$  in 1950, because SBT was unexploited before the 1950s, and resources were considered be full in that year (Figure 3).

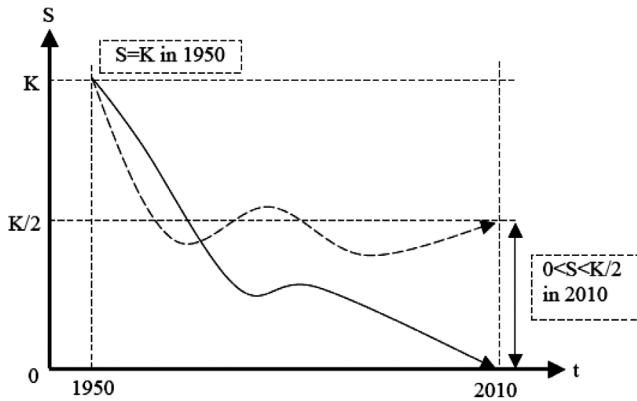


Figure 3 Estimating the ranges of  $K$  and  $r$  that satisfy  $0 < S < K/2$  as of 2010

### 5. Estimated Results of Carrying Capacity and Intrinsic Growth Rate

Based on the analysis outlined in the last section, the ranges of  $K$  and  $r$  satisfying realistic resource trend conditions are found in the gray cells of Figure 4. This figure presents the negative correlation of the two parameters meaning that a marginal increase in  $K$  and  $r$  has a similar influence

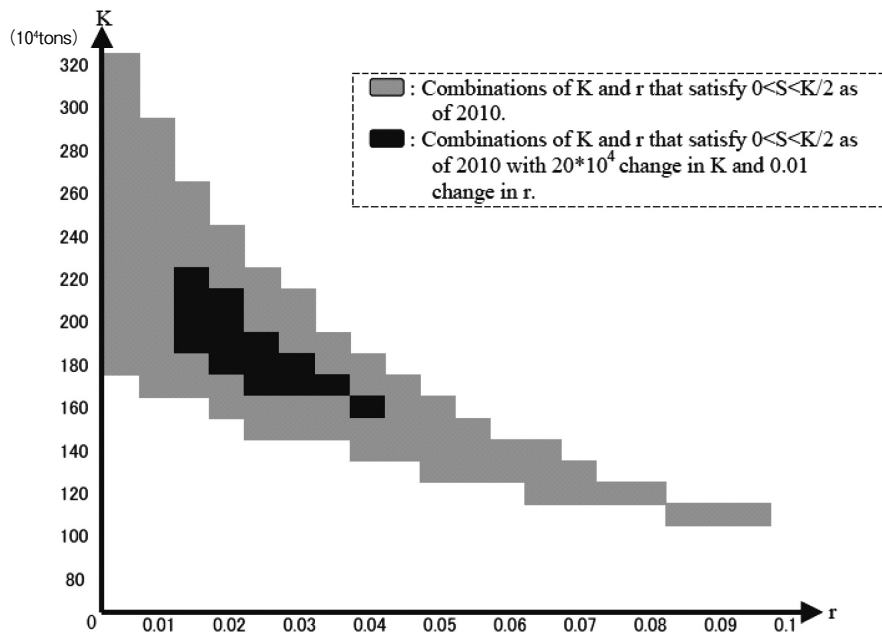


Figure 4 Distribution range of  $K$  and  $r$

on the resource trend. Therefore, there are infinite combinations of the two parameters that can reproduce the resource trends that might have actually taken place before 2010.

Though the surplus production model assumes a constant  $K$  and  $r$ , they might change due to environmental changes. These phenomena are named regime shifts, and they are common in pelagic species such as sardine and herring. In the case of tuna, Kawasaki (2005) presented a drastic change in CPUE (kg/day) for the North-West Pacific bluefin tuna caught by Japanese longline fleets before and after 1990. Additionally, Ravier and Fromentin (2001) presented a long-term synchronized fluctuation of Atlantic bluefin tuna caught in set nets in the Mediterranean Sea. Therefore, we selected combinations of  $K$  and  $r$  that provided robust results even if they change within a certain range. The black cells of Figure 4 are applicable under the conditions, in which  $K$  changes by 200,000 tons and  $r$  changes by 0.01, which are equivalent to 10% and 12% changes at the median of  $K$  and  $r$ , respectively.

Among these more realistic combinations of  $K$  and  $r$ , we selected some representative combinations and calculated resource trends in the past, which are presented in Figure 5. For all cases, the estimated resources have decreased drastically since 1960, when catch amounts increased sharply, and show low stable levels after 1990 in spite of the strict catch quota imposed. As of 2010, the estimated resource levels were between one-third and one-fourth compared with the pre-exploitation level.

In order to project future resource trends, we prepared three catch quota scenarios for the years 2011–2050: a) 14,925 tons, b) 11,810 tons and c) 9,449 tons, which were implemented in 2006, 2007–09

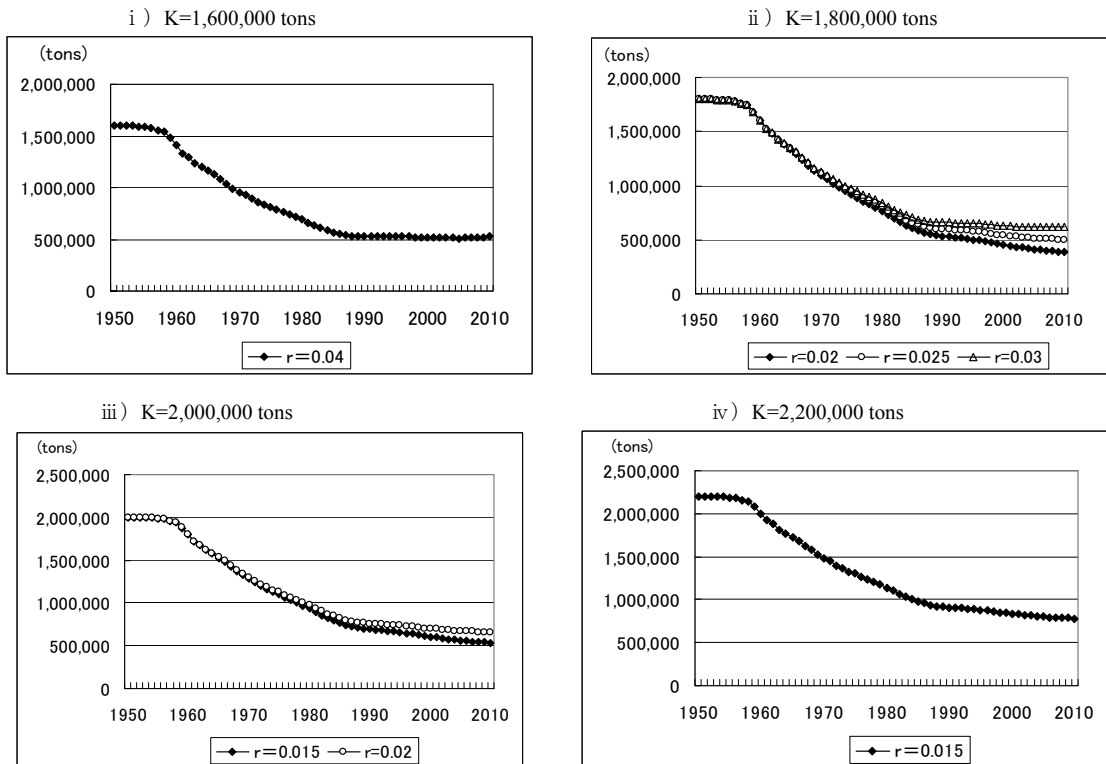


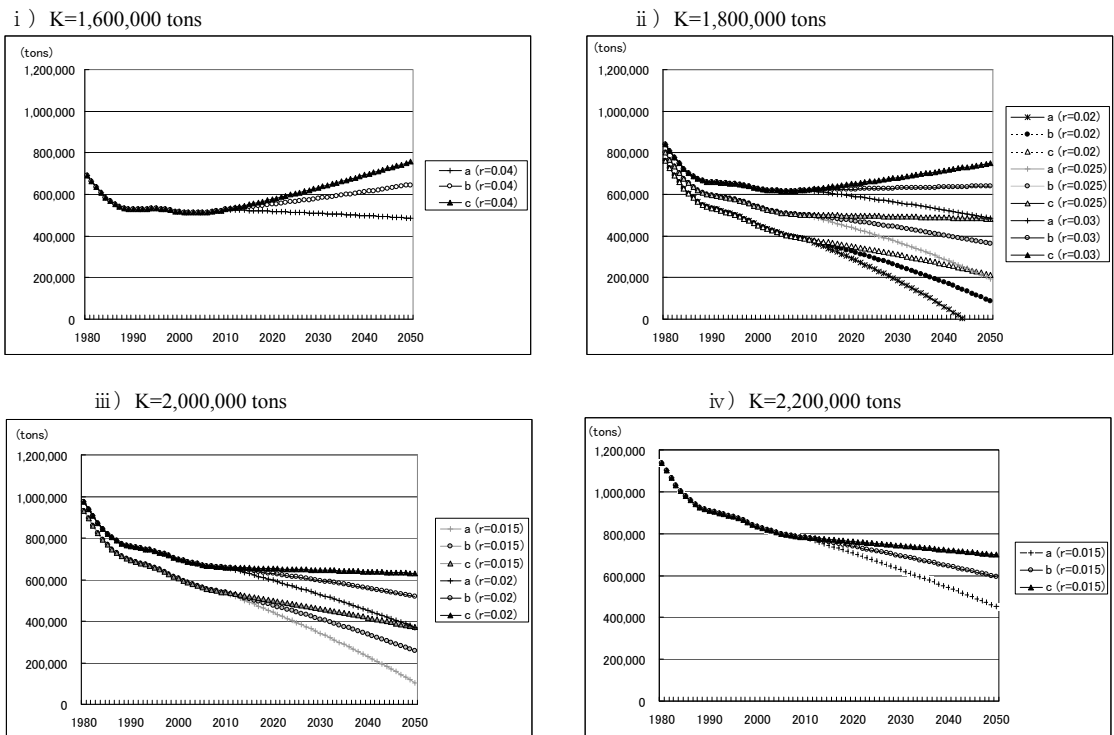
Figure 5 Resource estimates depending on  $K$  and  $r$  (1950–2010)

and 2010-11, respectively, and we ran simulations from 2011 to 2050.

The results of the representative cases are presented in Figure 6. For case *i*, in which  $K=1.6 \times 10^6$  tons, resources would begin increasing under the catch quota scenarios a and b. For case *ii*, in which  $K=1.8 \times 10^6$  tons, resources would continue decreasing if  $r$  were lower than 0.025, and the combination of  $r=0.03$  and scenario a would increase resources. For cases *iii* and *iv*, no combination of  $r$  and a catch quota scenario results in resource growth. Therefore, the possibility of resource recovery is considered very limited, especially in the case of catch quota expansion at the same level that was implemented in 2006-09. Even if the current catch quota, historically the most strict, were maintained, the resource levels would be lower than  $k/2$  as of 2050, while the resources would trend upwards for the cases of  $(K, r)=(1.6 \times 10^6, 0.04)$  and  $(1.8 \times 10^6, 0.03)$ .

Then to what extent the catch quota should be reduced to enhance the resource levels over  $k/2$  as of 2050? The answer is presented in Table 1, in which catch quotas satisfying this aim for each combination of  $K$  and  $r$  are presented. In the table, each cell corresponds to a black cell of Figure 4, that shows realistic combinations of the two parameters. The table indicates that even if the quota would be reduced to 5,000 tons, which is nearly a half of the current quota, only the three favorable cases among the fifteen cases can satisfy the aim. The resource depletion is so severe that the quota reduction does not work well for many cases.

This simulation assumes constant  $K$  and  $r$  in the surplus production model. However, we must pay attention to climate changes, especially to downward risk in the resource trends. Therefore, we repeated similar simulations that allow decreases in  $K$  or  $r$  after 2030, that is the halfway point of the



Note) Catch quota scenarios after 2011: a) 14,925 tons, b) 11,810 tons, c) 9,449 tons

Figure 6 Resource projections depending on  $K$ ,  $r$  and catch quotas (2011-2050)



simulation period 2011-2050. As a result, we found that  $(K, r)$  could be reduced to  $(1.1 \cdot 10^6, 0.04)$  and  $(1.6 \cdot 10^6, 0.025)$  for the case of  $(K, r) = (1.6 \cdot 10^6, 0.04)$ , to  $(1.3 \cdot 10^6, 0.035)$  and  $(1.7 \cdot 10^6, 0.025)$  for the case of  $(K, r) = (1.7 \cdot 10^6, 0.035)$ , and to  $(1.5 \cdot 10^6, 0.03)$  and  $(1.8 \cdot 10^6, 0.025)$  for the case of  $(K, r) = (1.8 \cdot 10^6, 0.03)$ , respectively, to attain the same aim. This means that  $K$  and  $r$  can be decreased at least by 17% after 2030 as far as the three favorable cases are concerned, but the resources would not exceed  $K/2$  for other twelve cases even if without unfavorable climate changes.

Table 1 Catch quotas satisfying  $S > K/2$  as of 2050

(Unit: tons)

		Intrinsic growth rate (r)					
		0.015	0.02	0.025	0.03	0.035	0.04
Carrying capacity (K) (10,000 tons)	220	0					
	210	...	3,000				
	200	...	1,000				
	190	...	...	3,000			
	180		...	0	6,000		
	170			...	2,000	7,000	
	160						8,000

Note) The cell with ... mark means that resources would not exceed  $K/2$  as of 2050 even if the catch quota is zero after 2011.

## 6. Conclusion

The Australian SBT industry faces the opportunities of a growing global tuna demand, but it cannot take advantage of them due to the very limited tuna resources used for farming at present. This paper analyzed whether the resource level could be recovered by the continuation of the current strict catch quota by applying a surplus production model and by projecting future resource trends that depend on the carrying capacity, the intrinsic growth rate, and three SBT catch quota scenarios. We found that resource recovery would likely not take place even if the current quota were maintained, especially in cases of relatively large carrying capacities and low intrinsic growth rates. In addition, it was found that the resources would likely not exceed the  $K/2$  as of 2050, that could provide MSY, even if the catch quota would be reduced to a half of the current quota.

Therefore, it is urgent for the industry to promote the technological development of a full-cycle farming method that does not depend on wild resources. Otherwise, the other appropriate option might be licensing technology from Japan, where considerable spaces is already allocated to the farming of other species such as sea bream and yellowtail, but space for tuna farming is not sufficient in spite of its full-cycle farming technology.

We analyzed the trends of SBT resources by applying the surplus production model, in which parameters such as carrying capacity and intrinsic growth rate are held constant. However, these parameters might change, as suggested by the regime shift theory, which addresses resource fluctuation due to climate changes. We approached this issue by selecting parameters that provide robust results despite marginal parameter changes. Some remaining issues to explore include the adoption of stochastic models and the explicit consideration of climate factors.

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## SUMMARY

# Resource Constraints in the Development of the Australian Southern Bluefin Tuna Industry

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Demand for tuna has been increasing due to a global sushi boom, changes in diet patterns toward health consciousness in Western countries and the economic development of emerging countries such as China. This trend is an opportunity for the Australian southern bluefin tuna (SBT) farming industry. However, the industry faces serious SBT resource constraints, and the catch quota on juvenile tuna for fattening is strictly limited by the Conservation Committee of Southern Bluefin Tuna (CCSBT).

Solutions might include an acceleration of SBT resource recovery, and an expansion of the future production capacity for fattening farming. This paper aims to answer this question concerning the resource recovery strategy by applying a surplus production model that represents the reproductive relations of marine resources, and by projecting the future resource trends based on the estimated range of the carrying capacity and the intrinsic growth rate of SBT resources.

It was found that resource recovery is unlikely to take place even if the current quota, historically the most strict, is maintained, especially in the cases of relatively large carrying capacities and low intrinsic growth rates. This finding was supported by alternative simulations that assumed further strict catch quotas. Therefore, it is urgent that the industry promotes the development or licensing of full-cycle farming technology that does not depend on wild resources.