USING REAL OPTIONS TO ESTIMATE A BENEFIT OF THE ADAPTIVE RESOURCE MANAGEMENT

Mitsutaku Makino, Yokohama National University, m-makino@ynu.ac.jp

ABSTRACT

In the institutional framework of fishery management in Japan, which can be seen as a Co-Management system, fishermen's agreements are prerequisites for implementation of resource management measures. However, because of uncertainties in the effect of management measures, fishermen's agreements are difficult to obtain. This study applied a decision-making method under uncertainty, i.e., Real Options Analysis, to the implementation process occurring in Kyoto, which is known as a successful example of Japanese co-management. There are two management measures in place here; voluntary restraint of fishery operations (reversible), and shelter constructions by public expenditure (irreversible). In both cases, a small-scale trial was implemented before full expansion. Based upon information from daily fishery operations during the trial period, expansion of each measure was agreed upon by local fishermen. This implementation process can be seen as an Adaptive Management Strategy, and can be modeled as a Compound Rainbow Option. The optimal decision-making strategy is derived, where not only short-term benefits for fishermen, but also long-term profits for the administration are taken into account. In addition, the benefits of this adaptive strategy compared to a hypothetical, non-flexible (top down) policy are estimated. In this model, fishermen participate independently in the decision making process, which reflects the actual institutional features of the Japanese co-management system.

Keywords: Real Options; Adaptive Management; Co-Management; Institutional Features; Japan

INSTITUTIONAL FEATURES OF JAPAN

Backgrownd

The fundamental concept of the fishery management in Japan is “the holistic utilization of sea surfaces”, provided in Section 1 of the current Fishery Law (for detail on the institutional features of Japanese fisheries co-management, see [1]). Under this idea, various fishing operations within an area are arranged/coordinated from an overall point of view, not simply from the viewpoint of each economic unit. As an institutional instrument for this coordination, various levels and scales of coordinating organization have been instituted to facilitate holistic fisheries coordination, i.e. the Fishery Policy Council (for national level), Wide-Area Fisheries Coordinating Committees (WFCCs; for multijurisdictional level), Area Fishery Coordinating Committees (AFCCs; for Prefectural level), and local Fisheries Cooperative Associations (FCAs; for local level).

In addition to these formal coordinating organizations, a number of new operational ideas have been developed since the late 1970s, largely on the initiative of the fishermen. These developments include what is known as “Shigen Kanri-gata Gyogyo” or Resource Management-type Fishery. In order to maintain and improve incomes, as well as sustain resources, various management measures have been initiated by autonomous bodies of fishermen, called Fishery Management Organizations (FMOs). FMOs are often formed by a group of fishermen within a FCA. Sometimes, FMOs are organized by members from several neighboring FCAs or even from FCAs of several prefectures.

In the Japanese institutional framework, the principal decision-makers of management are local fishermen. The Fishery Law simply provides a framework for fishery management, through a system of fishing rights and licenses. In order to achieve holistic utilization of sea surfaces, coordinating organizations have wide-ranging authority and power. For example, AFCCs, composed mainly of local fishermen, can decide on allocation and restrict the applications of fishing rights/licenses using the Fishery Ground Plan and Committee Directions. In addition, a variety of fishing restrictions have been stipulated in prefectural fishery coordinating regulations, FCA regulations and FMO rules. Prefectural fishing regulations broadly stipulate fishing restrictions, in order that the regulations may be applicable throughout the prefecture. FCA regulations stipulate more detailed fishing restrictions, applicable to local conditions. These FCA regulations take into account the restrictions set out in the Prefectural Fishery Coordinating Regulation but include, in addition, some restrictions that have not been stipulated in the prefectural regulations. In the same manner, the FMO rules are even more detailed and yet stricter than the FCA regulations.

On the other hand, the government also plays a vital role in fishery resource management. Co-management literature makes it clear that local fishermen or fishermen's organizations cannot function efficiently without government co-operation or intervention [2]. It is much the same for the Japanese institutional framework. For example, the prefectural fisheries division is responsible for the issue and renewal of fishing rights and prefectural licenses, based on advice from the AFCC. Furthermore, in many cases, scientific information or administrative guidelines presented by the prefecture forms a basis for regulations and rules devised by local fishermen.

Implementation process of management measures in Japan

As explained above, the principal decision makers of the management are local fishermen themselves. For example, even when the government plans to construct shelters by public expenditure, the agreement from the local fishermen is the prerequisite. Therefore, in many cases, short-term improvement in expected fishery profit is one of the most important factors in decision-making processes. Taking into account the high rate of depreciation for fishing gears, the term of the decision-making for each fisherman is relatively short (3-5 years at the longest).

In addition to the high rate of the depreciation, the uncertainty in the effect of measures makes local fishermen reluctant to agree with a large-scale implementation at one time. Lump implementation of large-scale measures would bring them high economic risk. Therefore, the implementation process of the management measures inevitably becomes an incremental process (start with small scale trials). As a result, the management plan can be changed according to the information gained during the process, i.e., there exists a flexibility in decision-making. Flexibility in decision-making means that the management plan can be optimally changed in response to the information gained after a project started. To sum up, fishery management in Japan must be modeled as successive decision-making series composed of short-term phases with the flexibility in decision-making. Also, it should be modeled as co-management between fishermen and government, not as compulsory regulation on fishermen by the government.

RESOURCE MANAGEMENT OFF KYOTO PREFECTURE

The trawl fishery off Kyoto Prefecture is known as one of the most successful cases of Resource Management-type Fishery in Japan. They capture various kinds of fish living in the depth between about 200 and 350 m under the licenses of the Minister of Agriculture, Forestry and Fisheries. The most important target is the Snow Crabs, *Chionoecetes opilio*, which occupies about 50 % of the yield (yen).

The main legal regulations are set out in the Prefectural fishing regulations on limitation about vessel size, fishing instruments, fishing period, minimum size and so on. In order to conduct the

Snow Crab fishery, boat owners need approval from the Minister of Agriculture, Forestry and Fisheries[a]. However, the catch had showed a downward trend since 1960's. In order to deal with the decrease in catch, autonomous body of trawl fishermen (called a Fishery Management Organization; FMO), local government officials, and researchers in Prefectural research stations cooperatively engaged in resource management since 1983. Presumably as a result of those measures, total yield and the net benefit have been greatly increased in recent years. (Figure 1)

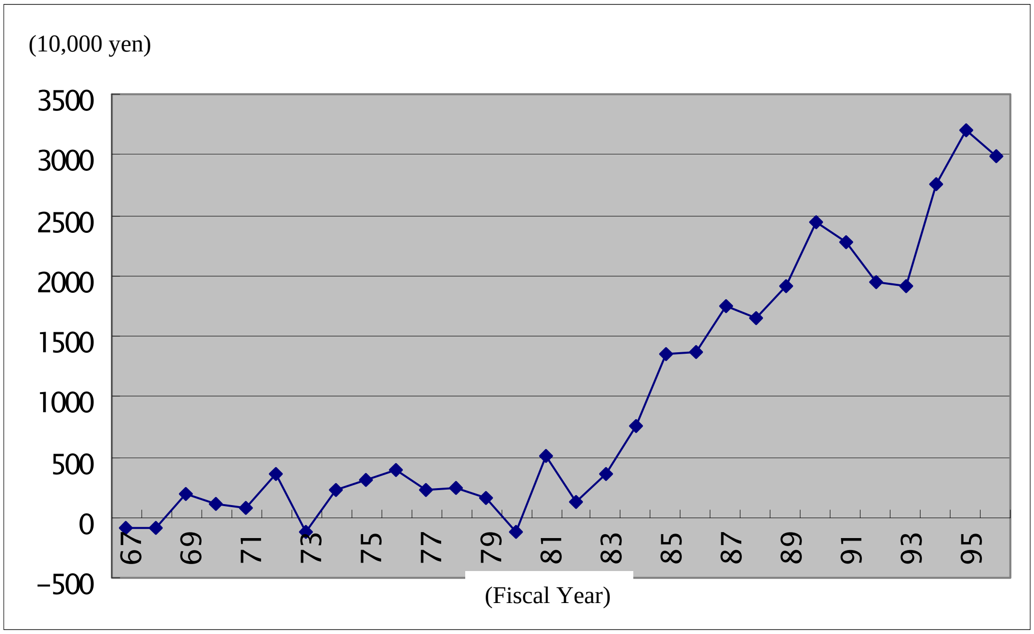

Figure 1. Changes in Estimated Profits for an average fisherman

There are two main measures adopted here, i.e., shelter constructions by public expenditure (irreversible) and voluntary restraint of fishery operations (reversible). The main target resource of the measures was the Snow Crabs. The shelter construction was firstly proposed by researchers in Kyoto Prefectural research station, and started in 1983, mainly in order to protect the breeding ground of the crab. Then voluntary restraints of fishery operations were greatly expanded in order to prevent the over fishing of Snow Crabs. The over fishing observed here was mixed catching, i.e., the catch of young individuals, and soft shell individuals (just after casting off the skin).

REINTERPRETATION AS AN ADAPTIVE MANAGEMENT

Adaptive management is a type of natural resource management that implies making decisions as part of an on-going learning process [3 – 7]. It begins with the recognition that we have only imperfect knowledge of interdependencies existing within and among natural and social systems. Monitoring the results of management actions will provide a flow of information that may indicate the need to change a course of action. Scientific findings and the changes in societal needs may also indicate the need to adapt resource management to new information. Therefore, under this approach, management actions are regarded as experiments and management decisions are made adaptively by wide ranges of stakeholders such as resource users, government officials, academics, and so on. An adaptive management system has two elements;

a monitoring system to measure key indicators and the current status of things, and a response system that enables modifying key indicators [8].

In short, the adaptive management utilizes the information gained after the implementation of the management measures, and then, optimal decisions are made successively and flexibly subject to the information available at each decision node. Key concepts for the modeling are flexibility in decision-making and stakeholder-involvement.

Adaptive management has been most notably used in the past to describe the setting of catch quotas in fisheries management. More recently, the term describes the incorporation of scientific research into the management process to create a tool for ecosystem management [9]. Preceding studies based on adaptive management was, for example, on the Gulf Island Recreation Land Simulation [10], Everglades restoration Plan [11], Great Barriar Reef in Australia [12], sika deer management in Hokkaido Island, Japan [13], etc.

The implementation process of the resource management measures in this case is showed in Figure 2 and it can be understood as an adaptive management process. X shows the total area of shelter construction, and R shows the rate of voluntary restrained area compared to the total fishing ground. This process can be abstructed as follows. Between 1983 and 1987 (Phase 1), X is implemented at small scale as an experimental management. As it were, Phase 1 is a trial period of X. Then, in 1988, R is increased at small amount, and Phase 2 is the trial period for R. Then, after recognizing the effectiveness of these measures, i.e., after monitoring the key indicators of the project, both measures were fully expanded in Phase 3, and enjoyed the outcome in Phase 4. All the possible options at each decision-making point (called "decision node") are showed in Figure 3.

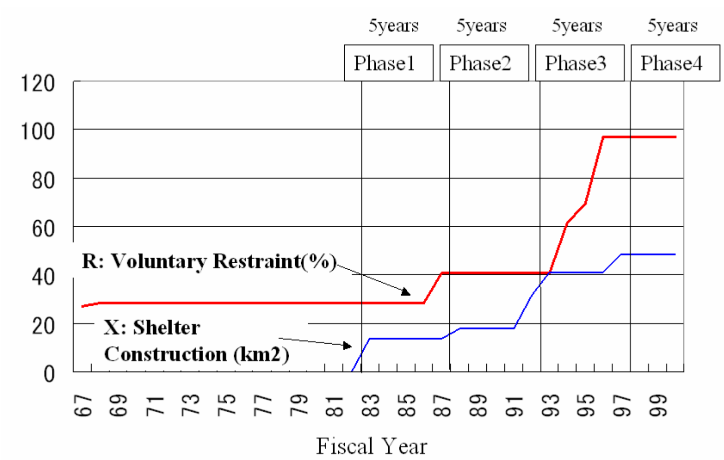

Figure 2. Implementation process of management measures revealed off Kyoto Prefecture

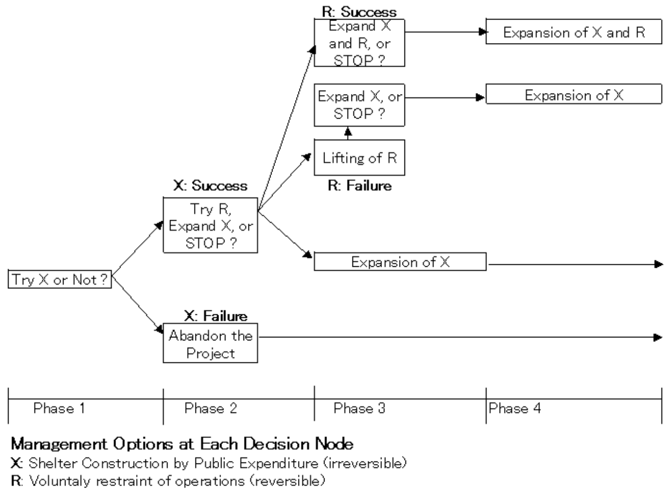

Figure 3. Management options at each decision node

REAL OPTIONS AS A TOOL TO QUANTIFY THE BENEFIT OF ADAPTIVE MANAGEMENT

The conventional approach for evaluation of the value of a project is Net Present Value (NPV) approach, in which uncertainty of cash flow is not explicitly considered, and merely discounted expected cash flows are added up. Also, the NPV approach is constrained to precommitting today to a go or no go decision [14]. It uses only information that is available today, and allows no changes of plan once it started. In other word, there is no flexibility in decision-making in the NPV method.

In order to model and quantify the flexibility in decision-making during the process, a methodology called real options analysis, or contingent claims analysis, is used in this study [15,16]. The Real option analysis builds on ideas from financial economics (the Options theory). Begin by observing that an investment project is defined by a stream of costs and benefits that vary through time and depend on the unfolding of uncertain events [17]. Using the option pricing theory the flexibility of decision-making process can be quantified as an ex ante evaluation.

Using this real options approach, the flexibility on decision-making is quantified. Another key concept of the adaptive management is the stakeholder-involvement, and it is modeled in the next section.

MODEL

Decision-making rules and stakeholder-involvement

The project period is defined as 4 phases (each 5 years) from 1983, i.e., from 1983 to 2002. The index for fishermen’s agreement to the implementation, F, is defined as the present value of the expected profit during one phase (5 years). At the beginning of each phase, fishermen decide the implementation, expansion, or stopping of the project if F increases. In addition, as the index for the accountability for public expenditure, the present value of the expected net benefit during the project period evaluated at 1983 is defined (P). The government is assumed to invest on this project only if P is not negative.

Therefore, both P and Fs of each phase, representing the long-term net benefit for the government and short-term profit for local fishermen, are the constraint for the implementation of the measures. This expresses the stakeholder-involvement in this model.

Uncertaintiy-1

There are two kinds of uncertainties in this case; one is the fluctuation of the profit that exists before the implementation of the measures (Uncertainty-1). Figure 4 shows the fluctuation from 1967 to 1982. It is derived from environmental fluctuations, stock changes, market conditions, and so on, and is basically non-manageable. Using the time series analysis techniques, it can be modeled as white noise of mean 158.84 and standard deviation 189.97[b]. Based on this result, Figure 5 shows the binominal lattice of the Uncertainty-1[c].

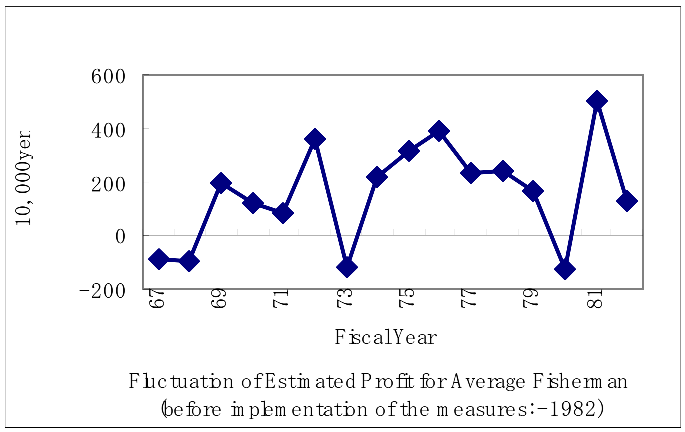

Figure 4. Fluctuation of estimated profit for average fisherman before the implementation of measures.

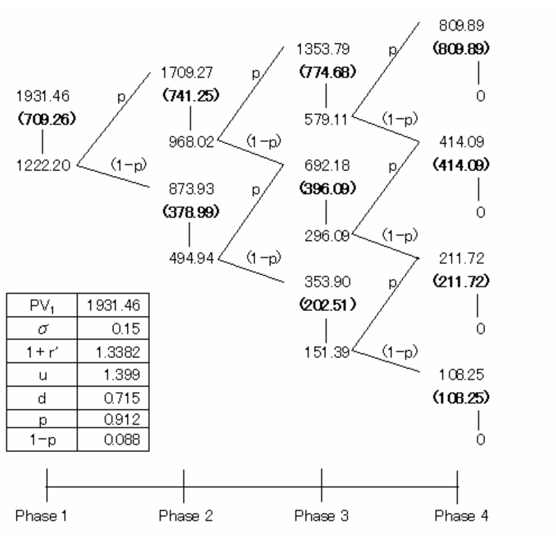

Figure 5. Binominal lattice of the uncertainty-1

Uncertainty-2

Then, to this lattice, we add the effects of two management measures with uncertainty of their effectiveness (Uncertainty-2). In this study, we assume a linear function with diminishing returns[d]. If the small scale trial of X is successful, the change in P is assumed to be α. If R trial is successful, change in P is β. If the trials failed, -γ, and – δ, for X and R, respectively. Here, α, β, γ, δ > 0.

The rate of diminishing return of full expansion was v for great success and w for success (1> v > w > 0).

The probability of the success in trials and the great success in full expansion, termed "objective probabilities" in Real Options literatures, should be assumed based on other similar case studies in the past. However, we have no information available for this case, thus we assume them to be 0.5.[e]

This kind of model can be analyzed as "Compound (Rainbow) Option", which means that each stage gives an option to the next stage. In this case, it is composed of learning options, stop options, and expansion options.

RESULTS

In this case, the key indicators to be measured at the trial period are α and β, i.e., the effectiveness of the measures X and R. Figure 6 shows the optimal decision-making strategy in α - β space (where $\gamma = \delta = 0.3$, v = 1/2, w = 1/3 is assumed). If both α and β are considered to be very small, the trial of X at Phase 1 is not rational. In other words, resource management does not pay enough. If α is large enough and β is relatively small, the full expansion of only X at as early as Phase 2 is optimal, rather than trying R.

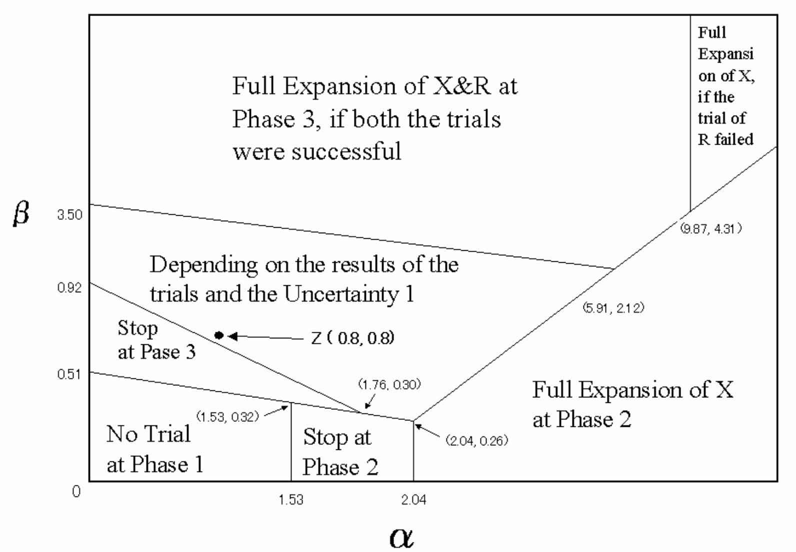

Figure 6. Optimal action in α - β space

A numerical example at point Z (α = β ; one of the least values necessary for the full expansion at Phase 3) is shown in Figure 7. Calculations are conducted backwardly just as in

Dynamic Programming. Figure 8 showed the estimated benefit of the adaptive management compared to the conventional management. The difference in the value of the project between this model (evaluated by real options methodology and stakeholder-involvement model) and conventional model (evaluated by Net Present Value method) at point Z is 117.8 million yen[f].

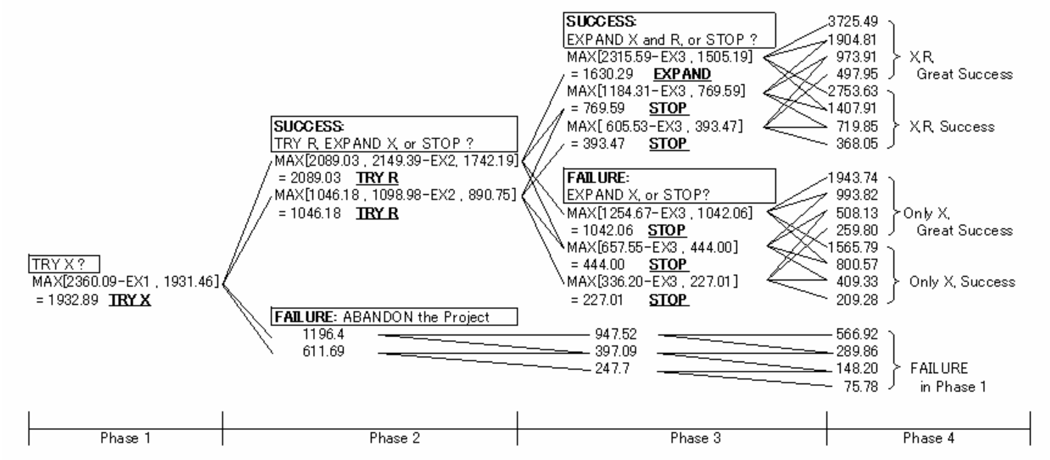

Figure 7. Numerical example at point Z

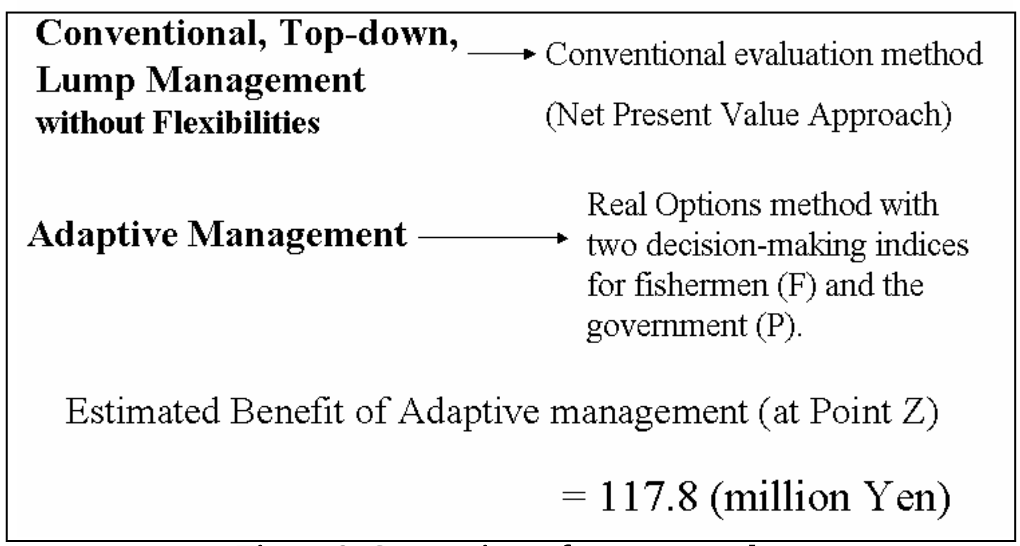

Figure 8. Comparison of two approaches

Finally, Figure 9 and 10 show the actual results observed at Kyoto Prefecture. At the beginning of Phase 2, estimated 95% confidence interval of the value of α by simple regression analysis using the data obtained during Phase 1 is 3.09 – 7.00. In the same way, at the beginning of Phase 3, 95% CI of α and β are 3.11 – 7.06, and 2.67 – 8.10, respectively. Therefore, in this model, the implementation processes revealed in Figure 2 proved to be rational.

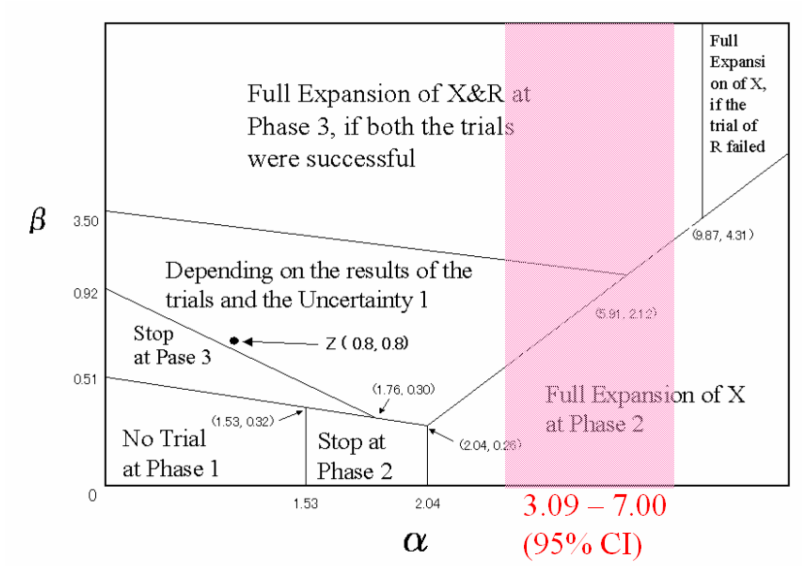

Figure 9. Actual result estimated from data of Phase 1

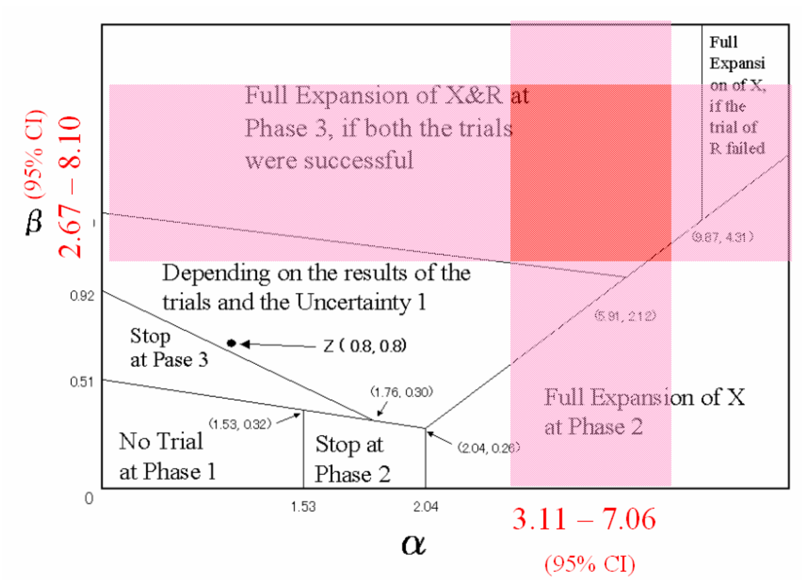

Figure 10. Actual results estimated from data of Phase 1 & 2

FUTURE PLANS

In this study, simple linear function was used. If ecological information of species or the ecosystems is available, one can incorporate the ecological modeling, and show more realistic and detailed results that would directly contribute to the management plan of the interested cases.

In recent years, Bayesian approach is increasingly incorporated to the financial options theory. Therefore, incorporating Bayesian theory into real options approach would have large potential to contribute to the adaptive management in the near future.

REFERENCES

[1] Makino, M. (2004) Using Real Options to Estimate a Benefit of the Adaptive Resource Management, *Proceedings of IIFET 2004 Japan.*
[2] Pomeroy R.S. and Berks F. (1997) Two to tango: the role of government in fisheries co-management, *Marine Policy* 21(5), 465-480.
[3] Holling, C. S. (ed) (1978) *Adaptive Environmental Assessment and Management*, John Wiley, New York.
[4] Halbert, C. L. (1993) How Adaptive is Adaptive Management? Implementing Adaptive Management in Washington State and British Columbia, *Reviews in Fish Biology and Fisheries,* 1, 261-283.
[5] Walters, C. J. (1986) *Adaptive Management of Renewable Resources*, McMillan, New York.
[6] Costantza, R., Mageau, M., Norton, B. & Pattern B. C. (1997) Social Decision Making, In: *Ecosysem Health*, (eds Rapport D., Costanza R., Epstein P.R., Gaudet C. & Levins R.), Blackwell Science, Inc. London.
[7] Parma, A. M. & NCEAS working group on population management (1998) What can Adaptive Management do for our fish, forests, food, and biodiversity? *Integrative Biology Issues, News, and Reviews*, 1, 16-26.
[8] Hilborn, R & Silbert, J. (1988) Adaptive Management of Developing Fisheries, *Marine Policy*, 12(2), 112-121.
[9] Zedler, J. (1997) Adaptive Management of Coastal Ecosystems Designed to Support Endangered Species, *Ecology Law Quarterly*, 24(4), 735-744.
[10] Gunderson, L. H., Holling, C. S., & Light, S. S. (1995) *Barriers and Bridges to the Renewal of Ecosystems and Institutions*, Columbia University Press, New York.
[11] Ogden, J. C. & Davis, S. M. (eds.) (1994) *Everglades: the Ecosystem and its Restoration,* St. Lucie Press, Del Ray, Florida.
[12] Mapstone, B. D., Campbell, R. A. & Smith, A. D. M. (1996) Design of Experimental Investigations of the Effects of Line and Spear Fishing on the Great Barrier Reef, *CRC Reef Research Technical Report Number 7,* CRC Reef Research Center, James Cook University, Townsville, Queensland, Australia.
[13] Matsuda, H., Uno, H., Kaji, K., Tamada, K., Saitoh, T., & Hirakawa, H. (2002) A Population Estimation Method by Reconstructing the Population Size from Harvest Data: A Case Study of Sika Deer in Hokkaido Island, Japan, *Wildlife Society Bulletin*, 30(4), 1160-1171.
[14] Copeland, T. and Antikarov, V. (2001) "Real Options", TEXERE, NY.
[15] Amram, M. and Kulatilaka, N. (1999) "Real Options", Harvard Business School Press, Boston.
[16] Razgaitis, R. (2003) *Dealmaking Using Real Options and Monte Carlo Analysis,* John Wiley & Sons, Inc. Hoboken, New Jersey.
[17] Dixit, A. K. and Pindyck, R. S. (1994) "Investment Under Uncertainty", Princeton University Press, New Jersey.
[18] Young, L. C. (1941) On Randomness in Ordered Sequences, *Annals of Mathematical Statistics*, 12, 293-300.
[19] Jarque, C. M. & Bera, A. K. (1987) A Test for Normality of Observations and Regression Residuals, *International Statistical Review,* 55, 163-172.

ENDNOTES

[a] Total allowable catch (TAC) has also been set for Snow Crab since 1996, but it does not seems binding level for the moment.

[b] It is estimated by Maximum Likelihood method, using Mathematica "Time Series" version 10. Catch data are obtained by author at the field investigation. This estimation result passed the Dickey-Fuller Test (unit-root test), mean square successive difference (MSSD) test of Young [18], and Jarque-Bera test [19].

[c] For details of the binominal lattice, see, for example, chapter 9 of [14]. In this study, Crystal Ball 200.2 (Professional Edition) was used in estimating the volatility.

[d] We chose as simple function as statistically meaningful, mainly in order to make a universal and versatile model. Other forms, such as CES, Cobb-Douglas, Leontief, etc., could be applied if appropriate natural scientific knowledge is available.

[e] In order not to use objective probabilities, one can set α and β ranging from negative to positive values.

[f] As noted earlier, Z is one of the least points necessary for the full expansion of X and R. So, the larger α and β, (and the larger the uncertainty), the larger the benefit of the adaptive management is.