Improvement of Stocking Efficiencies

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Introduction

This paper focuses on the principal idea or theory of stock enhancement, and the future prospect of "how to continue the actual activity of stock enhancement in rural areas," based on the concept of "Area-Capability". It should be recalled that an excellent article of Beverton and Holt (1957) on the Dynamics of Exploited Fish Population Dynamics, is the most important reference to be able to understand the effect of fisheries activity of humankind on the fishery resource species. The catch equation of Beverton and Holt (1957) is therefore the principal guiding idea for exploited fishery resources dynamics.

The main parameters of the equation are, ***F*** as the fisheries mortality, ***M*** natural mortality, a_c age of first caught, and ***K*** growth coefficient of von Bertalannffy's growth curve. ***M*** and ***K*** are determined by natural conditions and apart from human activity. However, ***F*** and a_c are decided by fisheries activities. So, the measuring tool for fisheries management is by controlling fishing effort and gear. Also, it is easy to understand that ***Y*** yield is dependent on fluctuation of ***R*** recruitment. Nevertheless, studying the basic biology and distribution of resource species is also an essential effort to clarify the dynamics of target species. In reality, yield (***Y***) is fluctuating from year to year and could suffer from recruitment fluctuation. It is therefore necessary to find the way of getting more stable yield. To get the effect of fluctuation of ***R***, **Y/R** is used for developing fisheries management practice.

$$Y = FW_{\infty} R \exp\{-M(a_c - a_r)\} \sum_{n=0}^{3} \frac{\Omega_n \exp\{-nK(a_c - a_0)\}}{F + M + nK}$$

$$\times [1 - \exp\{-(F + M + nK)(a_d - a_c)\}]$$

Where, $(a_c \leq a < a_d)$

$$\Omega_0 = -\Omega_3 = 1, \quad -\Omega_1 = \Omega_2 = 3$$

Life Cycle of Coastal Fishery Resources

Fig. 1 shows the schematic explanation of the life cycle of fishery resources organisms, such as giant clam, sea cucumber, penaeid shrimp, and spiny lobster. There are common pattern in the life cycle. In general, the life cycle of fishery resources organisms consists of benthic phase and pelagic phase.

Usually, larval period has pelagic phase as planktonic life and at the end of pelagic life, larvae attain metamorphose stage and settle to the bottom. So, larval migration or transportation success affects the individual number of settlement and recruitment.

In other words, survival in pelagic phase and success of settlement would affect the abundance of the fishery resource organisms. Thus, settlement success which is a bottleneck of the population dynamics of fishery resources should be addressed and/or enhanced.

As a researcher at the stock enhancement center, *Prof. H. Fushimi* was in-charge of the *kuruma* prawn release activity

Prof. Fushimi cited that:

After everything was finished, fishers knew how and what to do for Kuruma prawn intermediate culture. There was no need to explain everything to them.

Working together is the key to improve confidence of scientific data.

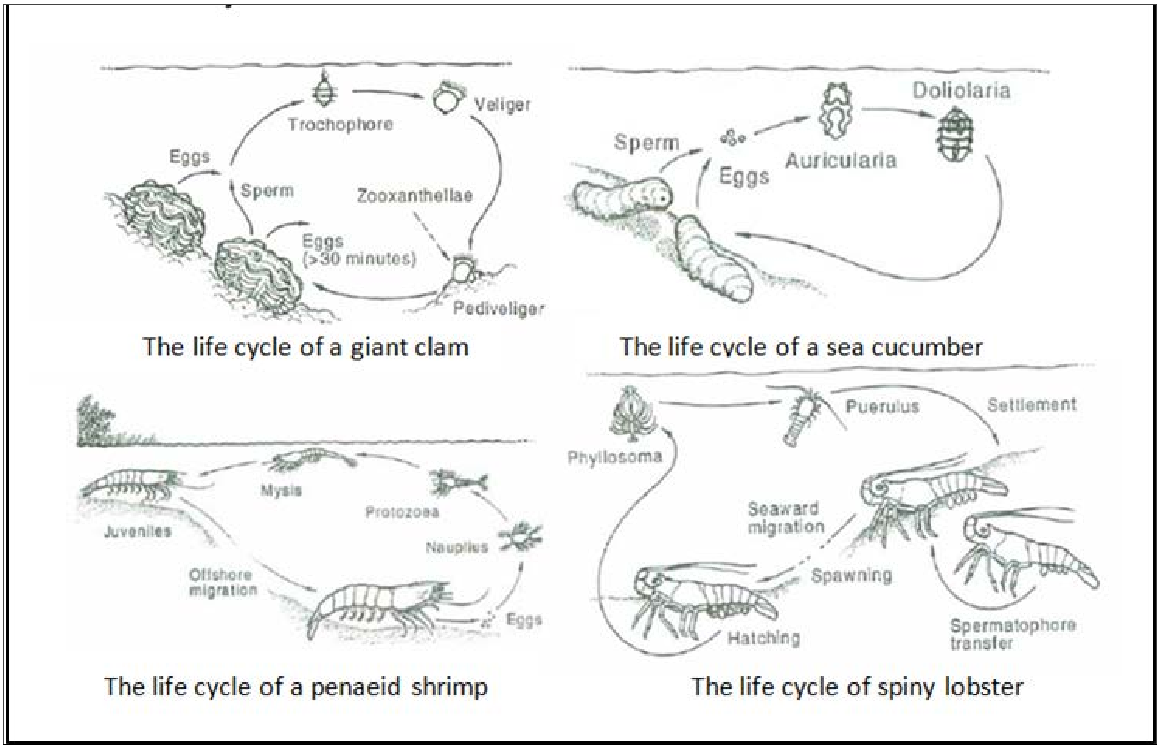

Fig.1. Schematic diagram of life cycles of some organisms

Fig. 2 shows a schematic explanation of the life cycle of *kuruma* prawn. In the early spawning season, April to May, old broodstocks spawn in deep open sea areas, and the hatched-out larvae spend planktonic life and are transported by water current. The postlarvae migrate to immediate coastal zones, and then settle in tidal flats. These areas are very important as nursery ground of larval *kuruma* prawn. After attaining 3 cm in body length (BL), the larvae move to shallow areas, 4-6 m in depth connecting the coastal zones. Here, the adult *kuruma* prawn become sexually mature and start to mate. After mating, the adult migrate to shallow open sea connecting the shallow areas, and then spawn in shallow open sea during July to August, *i.e*. late spawning season. Hatched-out larvae also spend planktonic life and settle during August to November. After first spawning, young broodstock migrate to open sea. From this schematic explanation of the life cycle, it is easy to understand the importance of habitat sequences. Without habitat sequences, *kuruma* prawn could not complete their life cycle.

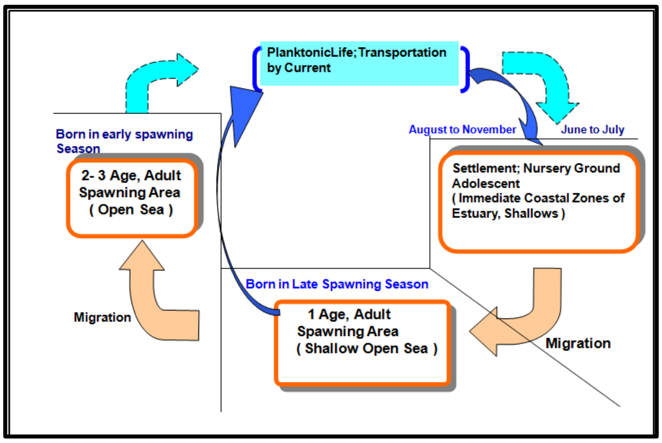

Fig. 2. Schema of the life cycle of *kuruma* prawn (Adapted from Kurata (1986))

Reclamation of Coastal Areas in Japan

In Japan, severe land reclamation occurred during the era of industrial areas construction and development in 1960s. As a result, the yield of coastal fishery resources markedly declined from 1960s to 1970s. Moreover, as large beach and seagrass habitats had been reclaimed, costal fishery resources lost their habitats and deteriorated. Habitat sequence is an essential condition of completing the life cycle of coastal resources destroyed by severe land reclamation. The Federal Government therefore conducted a public project on stock enhancement of fishery resources, as compensation for fishermen (**Fig. 3**). Known as *Tsukuru Gyogyo* in Japanese, stock enhancement centers were established in each Prefecture under this project.

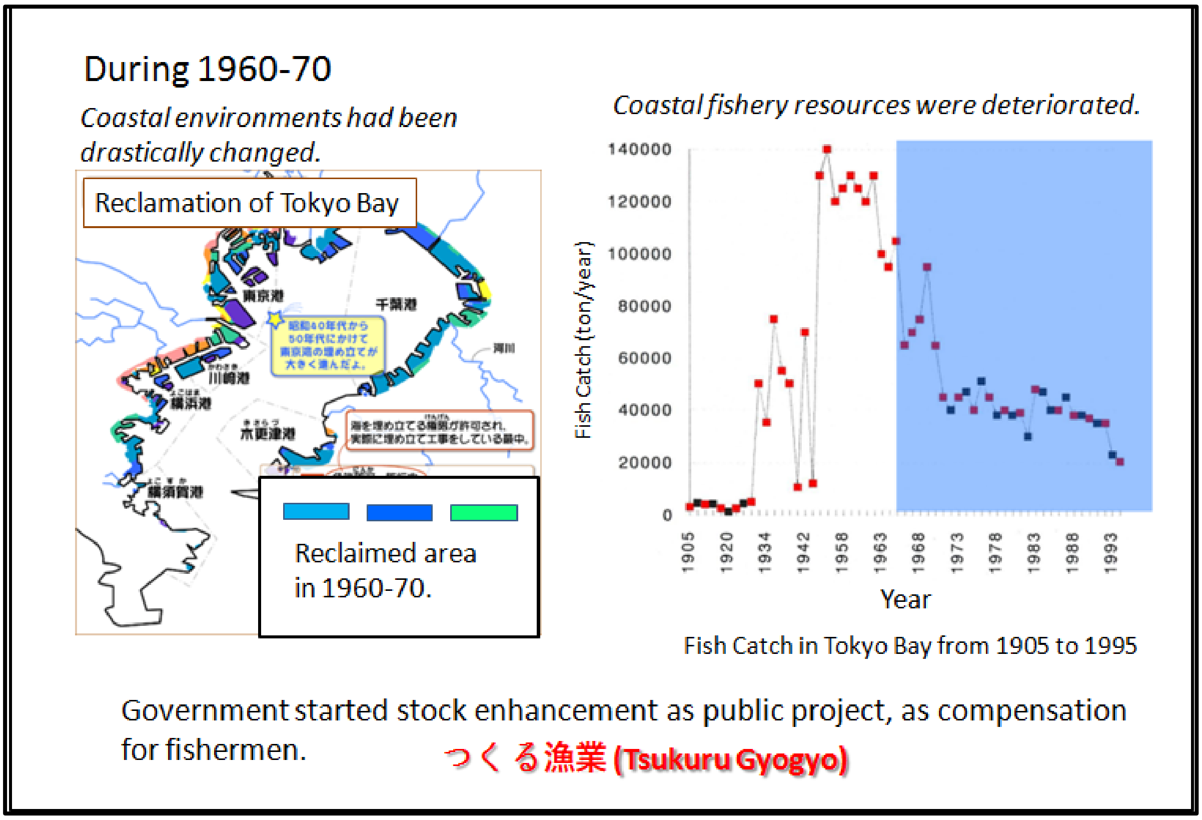

Fig. 3. Reclamation of Coastal Area in 1960s to 1970s

Case Study of Good Practice of Stock Enhancement: Hamana Lake

Stock enhancement of *kuruma* prawn in Hamana Lake in Japan has been successful (**Fig. 4**). Hamana Lake is located in Shizuoka Prefecture, central Pacific area of mainland Japan. Fishermen's association of 7 villages around Hamana Lake had been conducting larval prawn releases as stock enhancement for more than 20 years by themselves. The fishermen also conduct environmental monitoring and conservation activities.

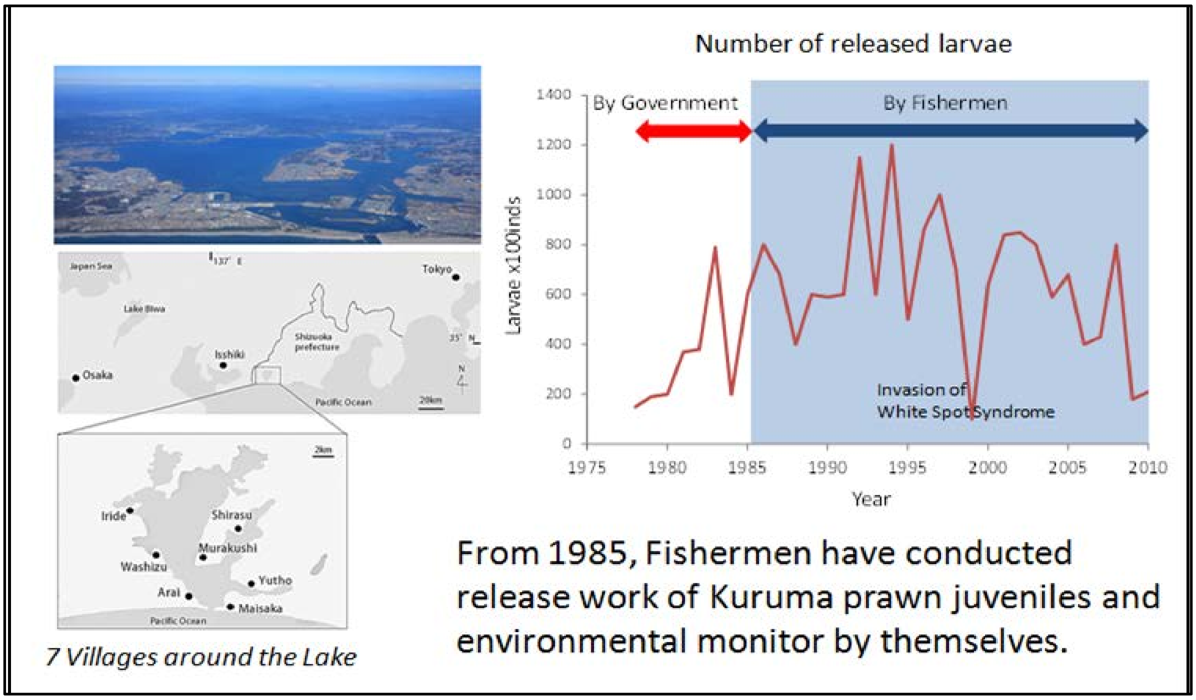

Fig. 4. Good stock enhancement practice in Hamana Lake, Japan

Model of Recapture Process for Hatchery-raised *Kuruma* Prawn Postlarvae in Shonai-ko, Lake Hamana

Fig. 5 shows the plan for detecting stock enhancement efficiency and the driven model to determine the recovery of released juveniles. The yield of each cohort is determined using the model. The Kuruma Prawn Stock Enhancement Technology at Hamana Lake, and mathematical model for evaluation of stocking effectiveness had been established. The stock enhancement of *kuruma* prawn by releasing hatchery-raised juveniles had improved the recruitment. Thus, the yield had increased corresponding to the amount of juveniles released. Fruitful results of many research studies are published as scientific papers. But, scientific papers were not the only driving power for continuing stock enhancement activities. What is the driver of continuing stock enhancement activity by fishermen themselves? This could be gleaned from the life of fishermen in local communities. Why fishermen wanted to continue stock enhancement activity by themselves? This leads to the history of Kuruma Prawn Stock Enhancement Project with special reference to the relationship among fishermen and researchers or local government staff.

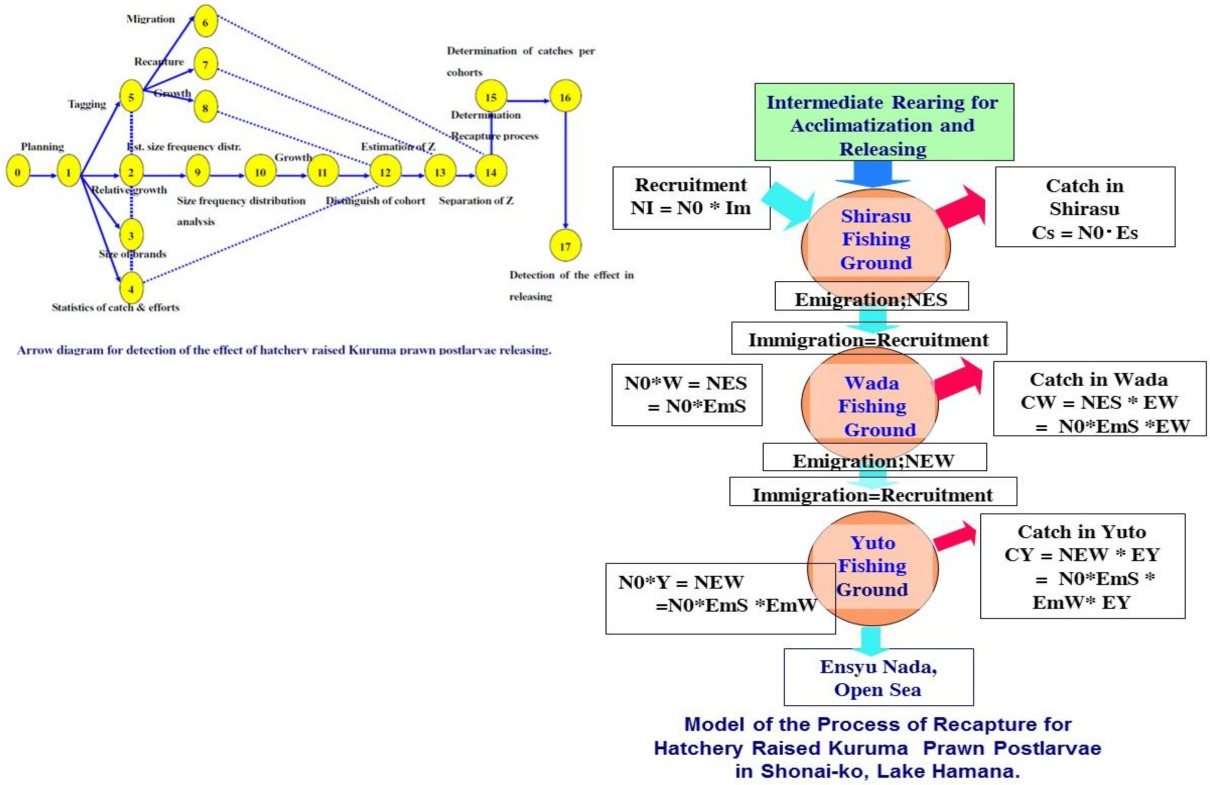

Fig. 5. Recapture for hatchery-raised *kuruma* prawn postlarvae in Shonai-ko, Lake Hamana

What Changes Had Occurred?

In the case of Hamana Lake, *kuruma* prawn was selected as target species for stock enhancement because *kuruma* prawn is the area's most economically-important species. In the initial stage of the project, there were no appropriate aquaculture technology of prawn, and environmental information was quite limited, even if it was necessary to come up with release schedule and sites. Researchers working for the stock enhancement center carried out several environmental studies and technology improvement on their own. Any kind of collaboration and trusts could not be extended by the fishermen around lake. However, two years later, researchers and young fishermen living in Shirasu Village (**Fig. 6**) started collaborating with the center, and succeeded in releasing 3 million larvae and 10 million larvae in the following year. As a result, catch of small prawn drastically increased. Then, other villagers also participated in the stock enhancement project, and released 14 million larvae. Results had indicated that in the beginning, population of the small prawns increased around the mouth of the Lake. Some fishermen living at the mouth of the Lake caught much small prawn, except those from Shirasu. Two years later, and on their own initiative, such fishermen terminated their activity of catching small prawn, and joined the stock enhancement project.

All activities including intermediate aquaculture, environmental assessment, catch statistics and post-harvest were conducted with the collaboration between fishers and researchers. Although this public project was terminated after 5 years, the fishermen from 7 villages took over the release work as their own activity, after the project. The evidence of impacts from conservation activity on the life of fishermen is necessary to change their minds and attitude. Although data could be used as evidence, working together is the key to improve the coinfidence of scientific data and conservation activities. Therefore, "after everything was finished, fishers knew how and what to do about *kuruma* prawn intermediate culture. There was no need to explain anything to them."

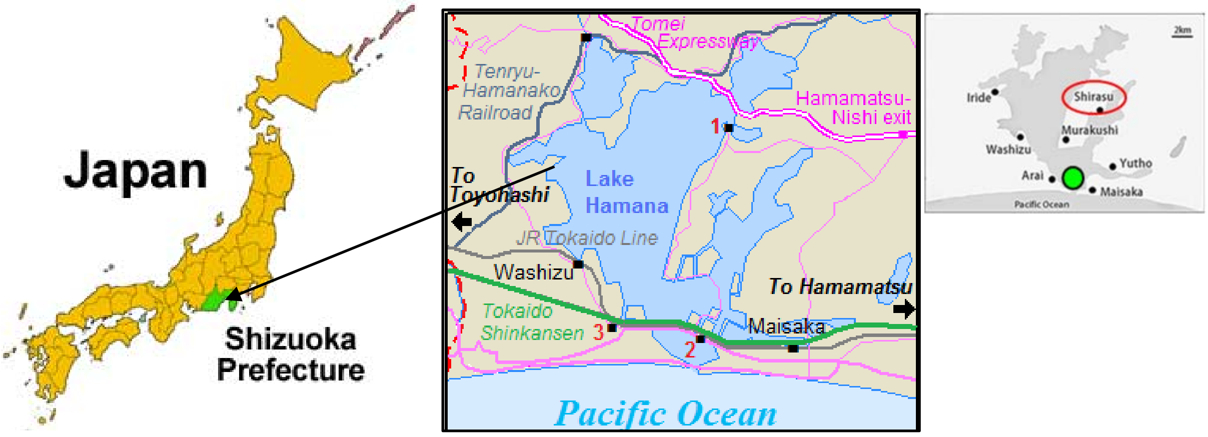

Fig. 6. Map of Japan showing Shirasu Village near Lake Hamana in Shizuoka Prefecture, Japan

Lessons Learned

From several case studies on stock enhancement project, many important aspects have been suggested. These include the following:

- New technology is key for establishment of communities
- Community activities make scientific data collection possible
- Scientific data improve community's understanding of nature
- Evaluation from other stakeholders sustains community activities
- Data on important resources can attract users' interests
- Collaboration between users and researchers enhances users' understanding of scientific data and information
- Improvement of livelihoods could foster conservation ideas and actions
- Evidence of resource improvement sustains community conservation activities

These aspects are very important to cultivate users' interests on nature, promote conservation activities, and for decision-making that could change daily actions. The aforementioned factors are closely related and when carried out could promote technology-led communities, community activities to improve data collection, and awareness-raising and users' interest enhancement on nature.

A good example on how scientific data contribute to decision-making process at local community towards the sustainable use of ecosystem services is shown in **Fig. 7**. The stock enhancement of *kuruma* prawn in Hamana Lake demonstrated how scientists can collaborate with local communities.

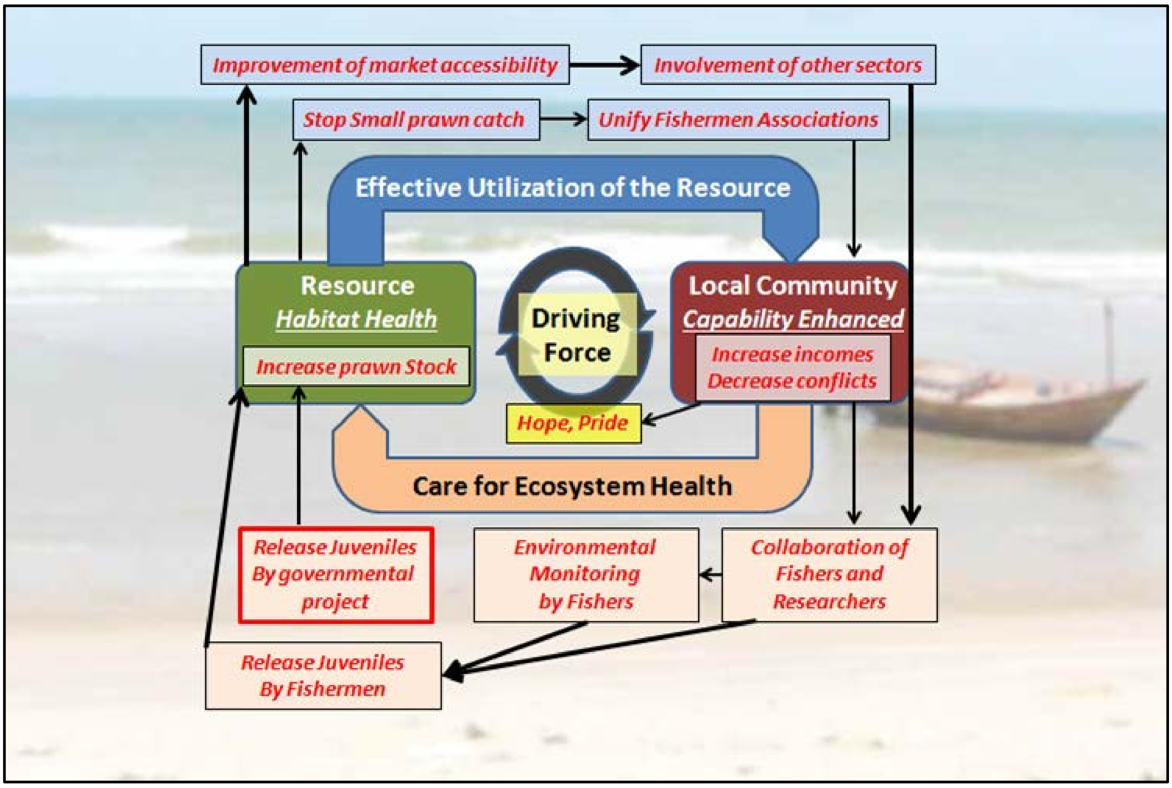

Fig. 7. Area-Capability cycle of stock-enhancement of Kuruma prawn in Hamana Lake, Japan

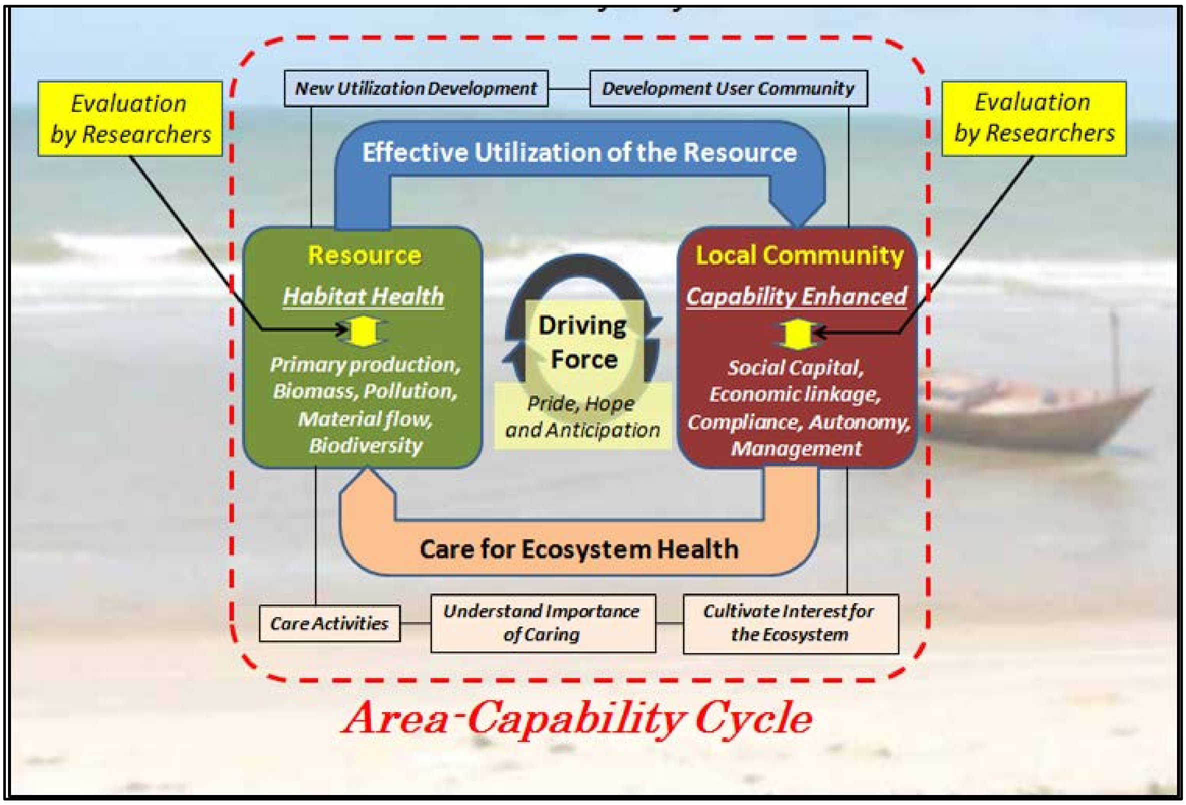

Fig. 8. Area-Capability cycle model for decision-making process at local community based on scientific information

Model for Decision-making Process at Local Communities Based on Scientific Information

Based on the findings from the aforementioned case study, a hypothetical model could be developed for *decision-making process at local coastal communities based on scientific information*. This model is known as Area-Capability Cycle. Using this cycle, eight (8) elements could be laid down as important aspects toward transformation of users' minds and attitudes. These elements are:

(1) existence of natural resources at sites is necessary to rediscover natural resources around

(2) technological or system improvement of utilization of the resources

(3) community development of users

(4) realization of improvement of livelihoods by natural resource utilization

(5) interest cultivation on nature supporting the resources

(6) understanding and realization of the importance of care on nature (in other words, ecosystem)

(7) activation of care of nature

(8) improvement of resource situation through such care

Scientists should contribute to the proof that leads towards the improvements of both livelihoods and resources. The concept of "Area-Capability Cycle" could provide the future prospect of "improvement of stocking efficiency" as shown in **Fig. 8**.

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