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Marine Stock Enhancement, Restocking, and Sea Ranching in Korea

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Additional information is available at the end of the chapter

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Abstract

The Fish Stock Enhancement Programs (FSEPs)-based Fish Stock Rebuilding Plan (FSRP) have been established and operated from 2006 and is expanded to 16 species in 2016. While the current FSEPs-based FSRP is operated by species if the FSEPs-based FSRP be expanded to encompass the whole coastal ecosystem, it will greatly contribute to more effective FSEPs-based FSRP for all overfished species in coastal and offshore fisheries in Korea. This study is intended to introduce the processes and the contents of the Korea's FSEPs-based FSRP and its fisheries resources management policies in more details. It is also to reveal any current issues in the socio-bioeconomics to achieve the effectiveness of the FSEPs-based FSRP. Objective recovery amounts of catch for each step were configured and a 10-year FSEPs-based FSRP was simply analyzed by catch data. The 10 year results of the FSEPs-based FSRP show that the amount of catch was increased in 8 species among 10 species.

Keywords: Fish Stock Enhancement Programs (FSEPs), Fish Stock Rebuilding Plan (FSRP), fish catch recovery

1. Introduction

The world's fishing has contributed to human welfare, income, augmenting employment and meeting raised food demand. On the other hand, it has also imposed a firm threat on fishery resources and marine ecosystems by diminishing stock abundance and biodiversity, and compromising the economic viability of the fishing industry [1, 2]. The present situation compels the United Nations to draw attention toward sustainable resource management in the oceans [3]. In this regard, a reduction in only fishing effort should counteract the increase in global per

capita fish intake registered over the last five decades [4, 5]. South Korea has increased the fishing pressure on many marine resources in a sustainable way in a short period [6, 7]. This situation compelled the whole nation and experts to think about exploited stock rebuilding to make sound marine ecosystem. Though conditions vary from species to species, stock assessment carried out in coastal and offshore areas in Korea revealed that the total fish harvest dropped consistently from 1.7 million tons in 1986 to 1.0 million tons in 2004 [8]. Remained fishing pressure can be one of the potential causes to deplete fish stocks by 3.5 million tons in a decade [6]. In addition, in the 2000s, the proportion of adult fish in the catches was lower than 20% [8]. This highlights that the reproductive capacity of fish stocks has been sharply decreased, which not only resulted in the decline of fishery resources but also increased the percentage of immature fish.

Besides fishing pressure, climatic variations, unbalanced catch composition, environmental contamination, and habitat destruction are other factors contributing to the decline in the biomass of marine resources [7]. Moreover, co-management of fishing grounds with neighboring countries has not been effectively carried out due to territorial conflicts. Some of the fishing management strategies conventionally adopted by the Korean Government include closures in fishing time, area closures, mesh size regulations, and mesh as well as input control. Conventional fisheries management strategies had solely focused on arbitrating within fisheries and maintaining fishing industry rather than on rebuilding stocks. Besides, management policies also were implemented ineffectively in accordance with stock data. In particular, the characteristics of coastal and offshore multi-species fisheries put the ultimate challenges in implementing management policies for each fish species. Likewise, another potential reason of depletion in fisheries resources is the failure of effectively refrain fishers from overfishing of juvenile fishes due to mix fishing [6]. As a result, the Korean government has taken step to rebuild fish stocks as the core objective of fisheries policy. The government launched the Fish Stock Rebuilding Plan (FSRP) including traditional management measures and Fish Stock Enhancement Programs (FSEP) in 2005 to effectively achieve this objective.

This study introduces the methods and insights of the Korean eco-friendly FSEP-based FSRP and its 10-year fisheries management policy. It presents different strategies proposed to overcome any issues related to the implementation of the FSRP plan.

2. FSEP-based FSRP's legislative policy and scientific structure

2.1. FSRP's legal framework

Understanding fisheries law is not easy to Korean fishermen due to its complex structure with 3 presidential decrees and 15 ministerial ordinances. Still, the 1960s law standards are applied even though some measures are contradictory to current fisheries management plans.

In this context, the "Fisheries Resources Management Act" was announced and established by the government on April 22, 2009, to conduct "broad and methodical fisheries resource management and to establish and implement fisheries resources recovery plan" [6]. The sole goal/

purpose of this law is to enhance fish stocks by conserving and managing marine resources through strengthening research and assessment. Some key features of the law are as follows:

1. Fisheries resources research and assessment shall be conducted each year.
2. Plan to recover fisheries resources shall be established every 5 years.
3. Institutional ground for co-management to settlement of dispute was established.
4. International rules like promoting international cooperation, eco-friendly fishing method, sharing data on resources management, and precautionary approach are also incorporated into the law.

Then, the Ministry for Food, Agriculture, Forest and Fisheries initiated the Fishery Resources and Environment Division to develop and implement FSRP. In addition, the Fishery Resource Recovery Team (FRCT) was established to conduct research, implement resource enhancement programs, and management. For working effectively with FRCT, fishermen, academics, governmental officers, and researchers were encouraged to participate in developing, implementing, and assessing FSRP. A newly organized Science Committee (SC) and the Fishery Resource Management Committee (FRMC) will also take part in decision making for FSRP implementation [9].

2.2. FSRP's scientific background

Depending upon the status of the fish species, efforts are directed toward the recovery and management of the target fish under specific ecosystem-based FSRP. A Fish Stock Rebuilding plan was set up for drastically depleted species. By contrast, fisheries management plan was taken into consideration for overexploited species. Intensive management on total allowable catch (TAC) was provided where TAC target species were key staples. To understand the situation of selected target species in offshore and coastal seas, the decision was made on the basis of three steps such as (1) investigating applicable materials and recovery of target fish; (2) classifying fish to manage and recover target species; and (3) setting target quantity at each stage for recovery.

In most cases, the only data available to assess the state of fish stocks were the annual catch data, except for a few species. Based on the method used by Garibaldi and Caddy [10], 3-year moving average fishery data were analyzed to evaluate the condition of fish stocks by using the species catch data. When catch level was less than 20% of the maximum moving average value, it was grouped as depleted stock. From an analysis at the beginning, 30% catch reduction of some fish species were targeted to recover.

By 1990s, several stocks had depleted significantly; therefore, data could not depict absolute state of stock by species. To include species for recovery, fluctuation trends of catch by species were analyzed. Hence, considering the features of fluctuation trends of catch, they were grouped into (1) very low, (2) low, (3) decreasing, (4) decreasing trend after increasing, (5) fluctuation, (6) stable, and (7) increasing. Then, the species that were within (1), (2), and (3)

conditions were grouped as recovery targeted species at last. The rest of the fish species were considered as management target species.

Meanwhile, stock biomass and maximum sustainable yield, MSY, for 10 targeted species was estimated. Among those species are Sand Fish (*Arctoscopus japonicus*), Blue Crab/Swimming Crab (*Portunus pelagicus*), Octopus (*Octopus vulgaris*), Tokobushi Abalone (*Haliotis discus*), Skate/Ray (*Hongo koreana*), Cod (*Gadus macrocephalus*), Yellow Croaker (*Larimichthys polyactis*), File Fish (*Stephanolepis cirrhifer*), Korean flounder (*Paralichthys olivaceus*), and Purplish Washington Clam (*Saxidomus purpuratus* Sowerby). On the basis of the results of assessment, recovery target for every phase and recovery tenures were set.

In addition, fishery resources that required systematic and broad management were found through conducting research and assessment. FSRP, TAC, and Marine Protected Areas were also implemented after the assessment plans. A “total fishery resources information database” was created and then operated to manage systematically for implementing FSRP. Fishery resources information like fishing status, habitat, and ecological information were collected under the “total fishery resources information database.” A useful scientific research assessment system was built on the basis of this database.

Furthermore, the central and local governments divided the role in research and assessment considering features of every species and strengthening human resources on stock assessment and research. It was aimed to construct a more effective scientific research and assessment system for better management and improvement of FSRP. Thus, research, assessment manuals, and model fully based on the characteristics of each species were made. Moreover, ecological changes including climate change were taken into consideration when stock assessment by species was done. To develop and implement the FSRP, the stock assessment by species was supplied as basic data [6].

3. FSEP-based Fish Stock Rebuilding Plan

3.1. Fish Stock Enhancement Programs

Fish Stock Enhancement Program (FSEP) is one of the major tools of rebuilding fishery stocks carried out by the Korean Fisheries Resources Agency (FIRA). FIRA is involved in Fish Stock Enhancement Programs including the construction and installation of artificial reefs, production and release of fish seeds, and building and managing marine ranches and marine forest (marine reforestation) to restore and recover fish stocks in Korea’s coastal and offshore fisheries. In Korea, the main goal of Fish Stock Enhancement Programs is to increase fish stocks and fishermen’s income by improving the marine environment and restoring productivity for natural population of fish [11]. The artificial reef program was implemented in 1971 to increase fisheries resources by creating habitats and spawning grounds. The fry stocking program has been operating since 1976 in order to complement and enhance the recruitment of fishery resources by directional fry releases of Jumbo Shrimp, Blue Crab, Flat Fish, Kuruma Prawns, Jacopevers, and Abalone. The marine ranching program was conducted in four main coastal

areas since 1998 (**Figure 1**). This program is conducted by using multiple networks, based on the industry-university-institute model, to establish optimum technical and model development. Since 2009, the marine seaweeds forest program has been playing an important role in the spawning, breeding, and feeding grounds for many kinds of marine organisms including fishes. The program focuses on the reestablishment of marine seaweed forests destroyed by some factors such as sea temperature rise, marine pollution, and algae-eating animals.

3.1.1. Artificial reefs program

Artificial reefs are man-made structures placed in the sea to attract, protect, and cultivate marine organisms. It is one of the main methods of creating and enhancing marine resources, utilizing the environment of marine life. Selective artificial coral reefs have been used to enhance specific fish populations. Improved rugged-type reef and round reefs were used for

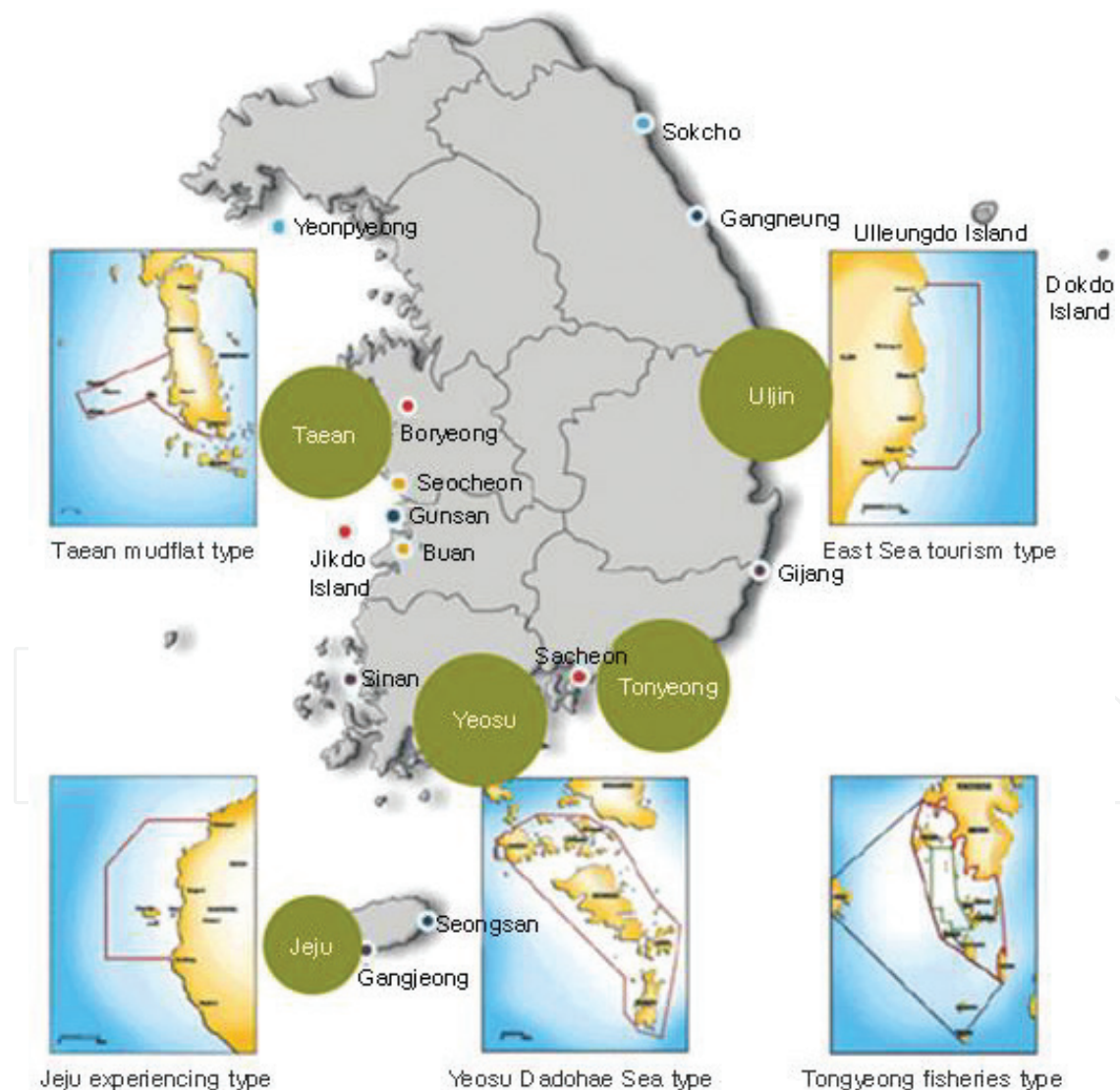


Figure 1. Map of coastal marine ranches in 2014. Source: Fisheries resources agency (FIRA), homepage, business FIRA, 2015.

shellfish and algae while large octagonal dams and cube and box shape reefs were used for small and medium fishes. In addition, for large fishes, composite steel fishing vessel reefs and large octagonal dome-shaped reefs were used. The installing process of artificial reefs is related to site suitability assessment, structure of reefs, and follow-up management.

3.1.2. Fish seed-releasing program

Young healthy artificially produced fish and shellfish are selected and released in a suitable environment with the purpose of increasing marine resource abundances. Afterwards, continuous research is conducted in order to determine releasing efficiency and investigate any effect associated to seedling releases, including monitoring the genetic diversity and the preservation of a healthy environment after the releases. The total seedling released accounted for 4.85 billion, including government (1.58 billion), laboratories (2.5 billion), and local government (770 million) [12]. Ninety percent of the total quantity is from major species including jumbo shrimps, Blue Crabs, Flat Fish, Kuruma Prawns, Jacopevers, and Abalones. Eighty-one percent of the total expenses are from major species including Abalones, Flatfish, Blue Crabs, Sea Cucumbers, and Jacopevers. By continuing disease screening and genetic diversity evaluation, healthy fish seed was produced for fruitful operation of fish seed-releasing program.

3.1.3. Marine ranching program

The marine ranching programs were conducted in the coastal and sea areas of Tongyeong, followed by Jeonnam (Yeosu) Dadohae Sea in 2001, and East Sea (Uljin), Yellow Sea (Taeon), and Jeju starting from 2002 (**Figure 1**). The Jeonnam marine ranching was completed in 2011, and the marine ranches of the East Sea, Yellow Sea, and Jeju were completed by the end of 2014. With the purpose of increasing stock biomass of fish stocks in coastal fisheries in a short period of time, the technology and experience attained from the marine ranching were applied throughout the entire program. The technology and experience acquired through the marine ranching program can also be used to develop marine ranching models that suit each specific sea environment. In order to maximize the effects of the resource enhancement, the program was implemented by a marine ranching utilization management system through mutual cooperation with research institutes and academic regional organizations and established in an efficient model for the local government and local organizations, bringing direct impacts to the fish stock rebuilding.

3.1.4. Marine seaweeds forest program

Destruction of spawning grounds and nursery habitats often lead to the reduction in fish stock biomass and productivity of the marine ecosystem. Marine forest creation programs were intended to restore the fish stock biomass and the ecological functioning. A total of 47 marine forests were created between 2009 and 2013 (3334 ha, KRW 72.2 billion). Fisheries authorities have raised awareness of the importance of promoting sea forest for enhancing fish stock biomass and the necessity of building a national rebuilding program to restore the fisheries stocks and ocean ecosystem in the territorial waters of Korea (approximately 8 million ha).

3.2. Fish Stock Rebuilding Plan

Korean Government established the fundamental plan for the FSRP in 2005. Its fisheries management strategies aim to mitigate the challenges of the existing fisheries management policies and to attain an expected recovery of fishery resources across EEZ territory. At national level, this ecosystem-based FSRP has been established as a comprehensive plan to enhance fish stock from the current level to a target level within a rebuilding period by choosing appropriate FSEPs.

Korea's FSRP was primarily aimed to marine fish stock recovery by eliminating the challenges from traditional management strategies with a view to improving conventional policies in the following ways:

1. FSRP focuses on specific fish stock for recovering. It contrasts to the lack of goals found in traditional fisheries management policies.
2. Conventional fisheries management policy was implemented without scientific research and estimation. By contrast, FSRP took into consideration the condition of fish stocks and required time of recovery with pragmatic goals.
3. Conventional fisheries management policies were established on the initiative of central government. On the other hand, FSRP ensures voluntary fishermen participation to execute plans and making them responsible for the results.
4. An analysis neither before application of fisheries management measure nor after its execution regarding conventional fisheries management policies was performed. However, FSRP ensures an analysis on fisheries management measures by fishery types, sea area and species before and after operation for effective utilization.

The main objective of FSRP and its policy was to enhance the total fish stock to 8 million tons by 2017 in order to maintain a consistent catch level at 1.3 million tons annually within coastal and offshore fisheries. Hence, it is anticipated that to reach fishery resources at an optimum quantity level, Korea's coastal and offshore sea ecosystem should break a vicious cycle chain of resource exploitation and aggravated fishery business condition and to keep a stable fishery production.

FSRP was performed by dividing the operational plan into three potential phases with mid-term and long-term plans. To establish system for operating FSRP, at first, the mid-term goals will get preference to achieve, and then long-term objectives will be attained by settling and spreading the management plans nationwide. To promote and operate each phase of FSRP, strategies and objectives were constructed as Phase 1—Institutional update and basic mid- and long-term FSRP's foundation (2005); Phase 2—FSRP implementation by species (2006–2012); Phase 3—FSRP-based fisheries management system settlement (2013–2017) (**Table 1**).

Traditionally, Korean fisheries were managed by considering input control depend on licensing system of fishing vessels and some technical measures like gear mesh size regulation, area closure, and time closures. Besides, since 1994, vessel buyback plan has been implemented.

Phase	Objectives	Policy enforcement
Phase 1 (2005)	Institutional update and basic mid- and long-term FSRP's foundation	(Master Plan Establishment) <ul style="list-style-type: none"> • Update Institution to implement FSRP • Mid- and long-term FSRP Establishment on yearly basis • New "Fisheries Resource Management Act" enactment • Set up Teams for Fish Stock Rebuilding to implement FSRPs fully • Species Selection for pilot projects to establish FSRPs in 2006
Phase 2 (2006–2012)	FSRP implementation by species	(Plans for Mid-term) <ul style="list-style-type: none"> • Fixed targets to maintain a total catch at 1.2 million tons • Pilot projects execution for 7 species by 2007 • FSRPs execution and establishment for 20 species by 2012 • Basic and bio-ecological research implementation on yearly basis
Phase 3 (2013–2017)	FSRP-based fisheries management system settlement	(Plans for Long-term) <ul style="list-style-type: none"> • Achievement of sustainable target at a total catch of 1.3 million tons • FSRPs execution annually to recover target species • Shift species-based FSRPs to establish ecosystem-based FSRPs • Review FSRPs for revising

Table 1. Phases to operate FSRP plans.

Thereafter, the total allowable catch (TAC) as an output control measure has been implemented since 1999 to reduce excess catch of fish.

In addition, FSEP plans such as artificial reef installation, fry releasing, and seaweed forest programs also have been implemented to enhance fish stocks for coastal and offshore fisheries. Moreover, to trigger participation and encourage playing a vital role of the fisheries personnel, both Science Committee (SC) and Fishery Resource Management Committee (FRMC) were formed. Experts from various disciplines (ecology, fisheries stock assessment, statistics, etc.) were included in the Science Committee to create and improve a fish stock recovery plan exclusively relying on Fish Stock Enhancement Programs and to make pragmatic advice for considering measures to rebuild fish stocks by analyzing data from scientific researches and critical reviews. Likewise, a scientific research on fish stock is conducted by NFRDI to recover desired species and subsequently FFRMC makes action plans to rebuild fish stock. FFRMC determines the measures to manage fishery effectively by judging

the comments made by academics, governmental, and nongovernmental participants. Basically, resources are managed by applying measures not only giving importance on individual species but also for refraining from using unbalanced fishing efforts and techniques. Accordingly, management took steps to install artificial coral reef and release fish fry to increase the overall fish stock in the coastal zone of Korea. In light of recovering individual fish stock, many policies and programs were taken into consideration to enforce them for the durability of fishery resources through FSEP. However, Korea's entire fishery was not shut down for a faster fish stock recovery as in other nations [13]. Hence, ecosystem-based fisheries management was implemented though some restriction was present on individual fisheries resource exploitation for effective and quick recovery of stocks. Consequently, the minimization of overall compromised revenue due to stop fish harvest could be possible to overcome undesirable situation. Besides, Korean fishery sector also could maintain stable business during the resource recovery period [14].

One interesting attribute of FSEP-based FSRP is promising the voluntary participation of fishermen to promote community-based fisheries management. In this manner, fishermen can make decision to manage resources as efficiently as possible and take part in developing plans for FSRP. In addition, voluntary self-control management can be implemented by fishermen to avoid unregulated fishing to promote efficient FSRP for rebuilding fish stocks effectively.

4. Classic and sustainable dimensions in FSEP-based FSRP

4.1. Environmental friendliness of FSEP-based FSRP

Although it is difficult to evaluate a comprehensive fisheries management policy FSRP based on FSEP within only 10 years, some vivid emerging improvements were depicted at the level of biodiversity. Vital FSEP tools not only enhanced biological components in the marine ecosystem but also encouraged physical and biological manipulation to make sound habitat for lifting up the stock size.

Until now, a total of 16 FSRPs have been established, including the special programs on sandfish, swimming crab, octopus (East Sea), skate ray (Yellow Sea), cod, yellow croaker, filefish, Korean flounder (East Sea) but rest FSRPs were considered for nationwide. In 2008, 10 species were considered to reach a target level of recovery based on their stock biomass from catch data. Fish Stock Enhancement Programs were acted in supporting with stock rebuilding plans to progress fish stock level. The amount of gained biomass was computed on a yearly basis by subtracting harvested amounts in 2005 from the total harvest in each subsequent year up to 2016. Once the gain in stock biomass of each targeted species is calculated for 10 consecutive years, from 2005 to 2016, the total recovery amount was estimated by adding all values of recovered stock amount of each targeted fish. As a result, the estimated 10 targeted fish stocks recovery amounts accounted for 469,827 million tons (Table 2).

Year	Sandfish	Blue Crab*	Octopus	Tokobushi Abalone	Skate ray	Cod	Yellow Croaker	File fish	Korean Flounder	Purplish W-Clam**
2004	2472	2683	5953	19	259	2641	17,570	1267	5345	5380
2005	2401	3714	7637	66	255	4272	15,272	1055	5472	6534
2006	2647	6894	7894	54	392	6810	21,428	1071	5218	3399
2007	3769	13,606	12,033	62	375	7533	34,221	2998	7326	3422
2008	2720	17,596	11,838	102	1343	5395	33,200	2631	5175	2672
2009	3939	31,302	15,386	34	3254	6870	34,033	8280	5107	1918
2010	4236	33,193	10,813	27	4131	7289	31,931	3475	6671	1950
2011	3834	26,608	10,421	3	2925	8585	59,226	1606	6709	2314
2012	5836	26,861	10,080	5	2123	8682	36,840	1419	6488	2037
2013	6306	30,448	9109	5	1651	9133	35,280	1295	18,171	2199
2014	4678	25,310	9881	10	1889	13,402	27,638	2418	18,804	2335
2015	4762	16,374	8753	4	2349	7820	33,254	2040	17,753	1828
2016	7593	13,558	9683	5	2000	4994	19,271	1805	15,977	1741
Total increase catch amount (M/T)	23,909	200,896	31,884	36	18,137	14,834	132,771	5959	41,401	0
Price (2016) (\$/MT)	1241	11,954	14,113	55,706	5350	5015	8022	6163	7460	4956
Increase revenue (million US\$)	29.7	2329.2	450.1	2.0	97.0	74.4	1065.1	36.7	308.9	0

Source: 2017 Korean Fisheries Yearbook, www.fips.go.kr*Swimming Crab.

**Purplish Washington Clam, Butter Clam.

Table 2. FSEP-based FSRP's economic effectiveness by target species.

4.2. Economic viability of FSEP-based FSRP

FSRP has contributed to rebuild fishery stocks in a relatively short period. Observations indicate a positive change in fish stock biomass during FSRP project operation. Likewise, an increment of catches triggered more revenues from targeted individual fisheries. The total revenue was computed by multiplying market price with the total recovery amount of fish over a 10-year period to evaluate the economic contribution of FSRP. Between 2005 and 2016, fishing earning increased by 4393.1 million USD (**Table 2**). Besides, an average yearly basis increment was seen in the fishing income of million USD 206.3 million amid FSRP operation [15]. In

10 years, the total increased 0.55 million tones fish contributed to the domestic fish market. This is an important fact taking into consideration that 70% of the food supply is imported from overseas, with the value of imported fish and seafood estimated in 3.8 billion USD [16].

A bioeconomic analysis was conducted to predict the economic impact for each species. In particular, biological and economical uncertainties were considered fully during analyzing the bioeconomic modeling. After performing this analysis, the results were used to make best policies for effectively maintaining FSEP-based Fisheries Stock Rebuilding Plans.

4.3. Social acceptability of FSEP-based FSRP

Effective and voluntary participation of fishermen community in promoting self-regulatory fishery is one of the main objectives of FSRP. As a novel concept in Korean fisheries management, community-based fishery allows fishermen to deliver unique ideas to manage resources as effectively as possible through improving awareness and understanding on current situation to implement FSRP. Effectiveness of community-based FSRP can be maximized by ensuring active participation of fishermen.

Before selecting the stock of a target species for enhancing, an agreement was made between the fishery resource management committee and the fishermen's organizations. The purpose of this agreement was to stimulate voluntary and active participation of fishermen to maximize the effectiveness of FSRP in connection with community-based management associations. Tasks were made voluntarily by fishermen to refrain themselves from roaming for fishing beyond limits, using excess gears by vessels and disturbing in spawning grounds. The Science Committee arranged conferences to make a fruitful avenue to ensure active participation of fishermen. Eventually, many fisheries restrictions were watched and found limited unlawful fishing.

Korean fisheries rebuilding relies on the voluntary participation of fishermen community for effective stock enhancement through notable stock enhancement programs. Besides, many strategies were taken to ensure better participation in providing opinion, managing resources, and stopping illegal fishing. Accordingly, strengthen community-based fisheries management imposes losses upon fishermen during rebuilding stock for accepting to reduce the amount of catch from fishermen organizations.

During the entire FSRP period, the government supported fishermen by taking some fruitful steps to stabilize the market for ensuring active participation. For example, some specific support was made to fix losses such as support on reducing fishing days, improvement of habitat for small fish, and also avoidance of by-catches. Expenditure to displace fishing gear and training of fishermen was aided for minimizing losses [17].

Socially accepted FSRP also provided time-demanding education and counseling to fishermen by experts having in-depth knowledge on fisheries. In addition, a fisheries management committee was set up as a system to manage and operate FSRP. To build up awareness of fishermen, the fisheries management committee worked on strengthening public relations on rebuilding stocks of targeted fish [18].

5. Limitations of FSEP-based FSRP

The Science Committee, the regional fishery management committee, and the fishermen have a significant contribution to the overall monitoring of ecosystem-based stock rebuilding. There have been fruitful opinions regarding fish stock enhancement to complete the goals for recovering fisheries resources. Fisheries rebuilding operations that run for 10 years have brought positive results on several ecological, economical, and social aspects; however, there are some challenges to be considered to get the best output to continue a comprehensive national stock rebuilding approach in Korea. These are some specific factors to be taken into consideration as follows:

1. The first challenge involves the preservation of the genetic resources. In order to succeed, all programs must ensure a high genetic variation for the offspring of targeted species for stocking in wild environments. In Jeju, Abalone showed a reduction of its genetic diversity, probably due to intensive breeding within the same hatchery brood stock [19]. Thus, Tokobushi Abalone could not establish their population like among other targeted species in FSRP since a genetic drift also observed due to breeding practices among limited brood stocks in the same hatchery without having enough facilities to exchange broods between hatcheries to get verity of genetic characteristics in produced fish seedlings [20].
2. Rebuilding plans focused on maximizing stocks but did not pay attention to the reduction of unwanted by-catch species. Annual catches of Butter Clam, one of the 10 targeted species for FSRP, declined sharply due to mixed catching.
3. There are inherited limitations to assess the efficiency of the enhancement strategies due to the lack of data available and the fact that only few species are examined well enough to drive definite conclusions. For better result, some aspects such as environmental, production, migration, and resources may be taken into account to collect effective data and expand them to evaluate data in an appropriate way [19].
4. Korean coastal fisheries comprise multispecies harvesting for small-scale and commercial fishing industry. Thus, conventional fisheries management could not fulfill sole target for single species through FSRP. Accordingly, related species must be taken into consideration for carrying out ecosystem-based FSRP gradually for achieving goals to enhance stock [21]. Community-based fisheries management tools are aimed for fisheries resources utilization sustainably through FSRP. Fishermen are encouraged to involve actively to both gain knowledge about their concerns and to reduce overexploitation. In order to compensate the loss in fishermen's profitability [12] and ensure a successful rebuilding plan, market stabilization and some form of compensation support may need to be provided to the fishermen community.
5. Operation of FSRP in Korea will not bring fruitful result unless cooperative action can be taken to continue large marine FSRP among adjacent nations, for example, China and Japan [22].

6. Conclusion

A decade ago, Korea implemented an eco-friendly community-based national stock rebuilding approach in coastal and seashore areas within exclusive economic zone. The aim of this study is to uphold the scenarios of rebuilding fishery stocks which depleted mainly due to an excess in fishing pressure during the last 40 years. Despite the efforts of traditional fisheries management policies against unlawful fishing, unwanted trends were observed with marine fisheries resources. Based on the 10 years experience, FSEP-based FSRP in Korea has proven to be helpful for governing fishery resources for next generations. The fisheries rebuilding plan increased the fishermen's annual income by 95%. From a social perspective, fisheries enhancement has brought a secured livelihood for increasing income in a consistent manner. Despite having many praiseworthy reasons to continue ecosystem-based fisheries management, fisheries enhancement rebuilding plans have been moving with some risks of dwelling unavoidable challenges in main policy to achieve rapid effective results. Therefore, systematic research on the biology of species, mixed catches effects, pollution management, and net income loss recovery by stabilizing market for fishermen will be helpful to carryout Korean permanent fisheries rebuilding in the future. At the bottom line, cooperative fisheries resources management by adjacent nations may be a benchmark for rebuilding marine resources not only within EEZ but also between neighboring states.

Korean fisheries have been struggling to enhance depleted stocks at sustainable level with their conventional management policies for a couple of decades. Usually, input and output control policies, for instance, vessel buyback, total allowable catch, and restriction on breeding season, were applied by government agencies to keep resources at an optimum level. Despite immense endeavor to limit fishing pressure for meeting seafood demand sustainably in the near future, a significant proportion of stocks were dropped below sustainable level. Artificial reefs, marine ranching, fry releasing, and marine gardening programs were selected in an effort to recover environmental degradation and provide a friendly ecosystem to marine communities. Awareness of fishermen was built throughout FSRP programs for a better understanding of the existing stock abundance and evaluation of risk factors.

To sum up, FSRP has brought positive results in most of the targeted species. These rebuilding plans helped fishermen to increase catches noticeably for generating additional income. Sustainable fishery has been achieved due to voluntary participation of fishermen community to restrict unlawful fishing. In addition, they were provided government-supported training to develop core strategies to keep stocks at a sustainable level in the long term. Such self-governance program was a proof to rebuild stocks effectively even though some limiting factors should have been addressed to raise effectiveness of FSRP.

Possible rebuilding of stock may be triggered by correcting bio-ecological shortfalls in comprehensive national Korean FSEP-based FSRP. Moreover, scientific analysis on stock estimation is also an important parameter to determine the exact required period of rebuilding and to select species for improving stock status. Multinational stock rebuilding is recommended to extend targeted species number from sea shore to common boundaries of neighboring

countries. For instance, Japan has been running stock rebuilding programs since 2001 [6]. Likewise, in 2016, China started the 13th 5-year mega plan to restore their exclusive economic zone to get at a higher rate of fish catch [23]. Besides commercial species, other species may be taken into account for enhancing their stocks in developing a friendly marine ecosystem to improve ecosystem status.

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