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Suitability of Marine Seeds Release as a Climate Change Adaptation Policy: A Bridge between Aquaculture and Capture Fisheries

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ABSTRACT

Due to climate change, marine fish resources are decreasing or fluctuating. Countries around the world are making efforts to reduce overfishing and create fish habitats to respond to this crisis. In particular, each country has traditionally responded by reducing fisheries production through output control. However, this approach is not enough to achieve the Maximum Sustainable Yield. Efforts are needed to increase inputs through new approaches. Marine seeds release is being focused on as a bridge connecting capture fisheries and aquaculture. Marine seeds release is a way to restore fish stocks by releasing fry or fingerling (marine seeds) raised in tanks on land into the sea. Here, I will examine the case of marine seeds release policy in Korea and examine which species of fish seeds release policy can be more effective in the era of climate change. Marine seeds release can be a bridge between capture fisheries and aquaculture.

Key words : marine seeds release, climate change, aquaculture, capture fisheries

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1. Introduction

1.1 Climate Change as a Global Phenomenon and Its Impacts

Climate change is affecting almost every aspect of the Earth's environment. In terms of the marine environment, it is causing an increase in ocean temperatures, sea level rise, ocean acidification, and a decrease in marine biodiversity. It is also affecting the ability of marine species to reproduce, spawn, nurture, and grow (Hoegh-Guldberg & Bruno, 2010). In the Intergovernmental Panels on Climate Change (IPCC)'s Special Report on "Global Warming of 1.5℃", adopted in 2018, the IPCC compares the difference between limiting the global temperature increase to 1.5℃ and 2.0℃ above pre-industrial levels in 2100. Specifically, the report estimates that limiting temperature increase to 1.5℃ could reduce the number of people at risk in coastal areas by 10 million and reduce fish catches by 1.5 million tonnes compared to a 2.0℃ increase (decreasing 3 million tonnes for a 2.0℃ increase and decreasing 1.5 million tonnes for a 1.5℃ increase).

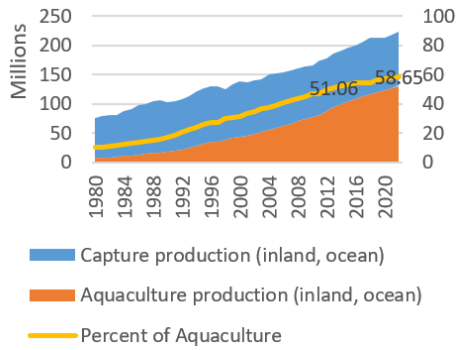
The effects of climate change can also be seen in Korean seas. Based on the observations of the National Institute of Fisheries Science (NIFS)'s seas survey, the average annual surface seas water temperature increase in Korean waters over the past 55 years (1968–2022) was 0.025℃/yr, an increase of about 1.36℃, while the global average surface seas water temperature increase over the same period was 0.0094℃/yr, an increase of 0.52℃. The average annual surface seas water temperature increase in Korea's nearshore waters was 0.0094℃/yr, which was 0.52 ℃ higher than the global average.

Some studies show that rising ocean temperatures are causing many marine species to shift upward in their latitudinal distribution or to move to deeper, cooler waters (Saba et al., 2023). Of course, there are many factors that can contribute to changes in the catch of marine species, such as changes in water temperature, overfishing, reproductive collapse, changes in the food chain, and changes in habitat due to ocean acidification. But there's no denying that climate change is certainly playing a role.

1.2 Shifts in Fisheries Production: Capture Fisheries vs. Aquaculture

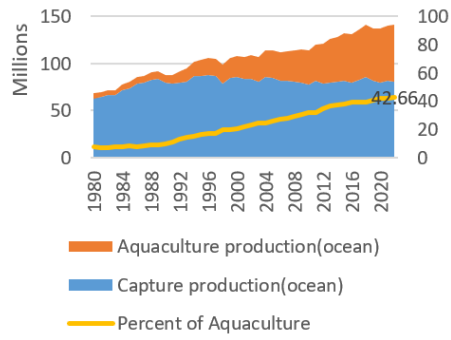
Climate change is reducing fisheries production, and changing fish species (Brander, 2007; IPCC, 2018). As a result, aquaculture, which can partially control changes in the environment, is becoming increasingly important. Globally, aquaculture's share of production continues to rise. When including both ocean and inland waters, aquaculture accounted for 58.65% in 2022 (Figure 1). In 2022, aquaculture accounted for less than half of the ocean fisheries production at 42.66 % (Figure 2). There is no doubt that aquaculture will continue to grow in importance and become a vital part of food security.

Figure 1. Capture fisheries and aquaculture production (ocean and inland).



Source: FAO (ocean, 2024a).

Figure 2. Capture fisheries and aquaculture production (Ocean).



Source: FAO (2024b).

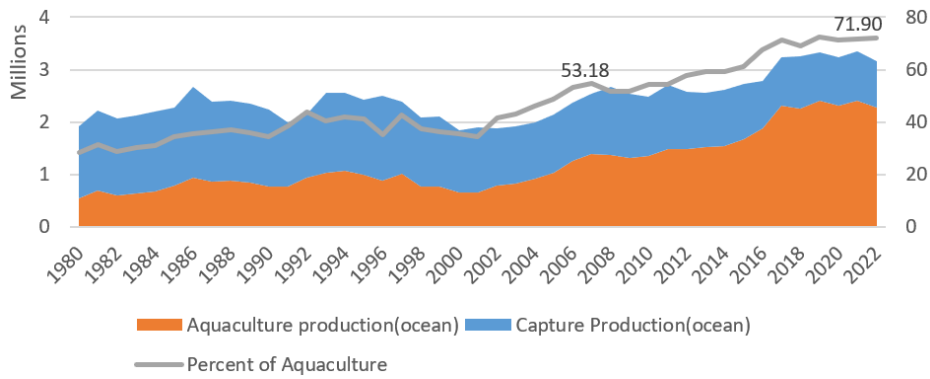
Korea's aquaculture production has grown rapidly from 119,211 tonnes in the 1970s to 2,250,567 tonnes in 2018, and aquaculture production has overtaken fisheries production in total seafood production (Figure 3).

1.3 Importance of Capture Fisheries

Despite these trends, capture fisheries will continue to be important. There are ecological and environmental benefits to capture fisheries that are not found in aquaculture.

First, capture fisheries can maintain ecosystem balance. Capture fisheries take place in environments where different species naturally reproduce and grow. If managed in a sustainable way, capture fisheries can avoid over-concentration on

Figure 3. Capture fisheries and aquaculture production of South Korea (ocean).



Source: KOSIS (2024).

certain species and contribute to maintaining the natural species diversity of marine ecosystems.

Second, capture fisheries can reduce environmental pollution. Aquaculture can often cause problems that pollute water. For example, feed, chemicals, and antibiotics from fish farms can pollute the surrounding environment. Because capture fisheries take place in natural ecosystems, there is relatively little of these kinds of pollution.

Third, wild-caught fish may have a higher nutritional value. Some research suggests that wild-caught fish may have a higher nutritional value than farmed fish. For example, wild-caught fish may have a higher omega-3 fatty acid content and a healthier fat distribution.

Fourth, capture fisheries can contribute to a sustainable economy. When managed sustainably, capture fisheries are an important source of income for local economies and traditional fishing communities. It can provide livelihoods in many coastal and island communities.

1.4 Challenges and Solutions for Capture Fisheries

Although capture fisheries are important, they are always vulnerable to illegal, unregulated, unreported (IUU) fishing and overfishing. Due to government support and the short-term profit motive of fishermen, capture fisheries have been catching more fish than they should. Based on FAO's assessment, the fraction of fishery stocks within biologically sustainable levels decreased to 62.3% in 2021, that is 2.3% lower than in 2019. This fraction was 90% in 1974. In contrast, the per centage of stocks fished at unsustainable levels has been increasing since the mid-1970s, from 10% in 1974 to 37.7% in 2021 (FAO, 2024c). Overfishing - fishing that causes the reduction of stock abundance to below the level that can produce Maximum Sustainable Yield (MSY) - not only causes negative impacts on biodiversity and ecosystem functioning, but also reduces fish production, which subsequently leads to negative social and economic consequences. Rebuilding overfished stocks to the biomass that enables them to deliver MSY could increase fisheries production by 16.5 million tonnes and annual rent by USD 32 billion (FAO, 2024b; Ye et al., 2013). Sustainable Development Goal (SDG) 14 (Conserve and sustainably use the oceans, seas and marine resources for sustainable development) set Target 14.4: to end overfishing by 2020. Unfortunately, world fisheries have diverged from this target, with overfishing increasing from 35.4% in 2019 to 37.7% in 2021 (FAO, 2024a).

The options for maintaining adequate fish stocks are clear. Either we increase inputs (stimulate reproduction) or reduce outputs (catch). The traditional response has been to reduce fishing intensity. This will naturally stimulate reproduction. This is the least intrusive and most effective way to reduce human interference with natural ecosystems. On the other hand, governments and fishermen can also actively intervene to promote reproduction, which means

reducing environmental pollution and protecting or creating spawning grounds. Marine seeds release can also stimulate reproduction.

2. Marine Seeds Release in South Korea: Current Status and Effectiveness

2.1 Basic Concepts of Marine Seeds Release

Marine seeds release is a way to restore fish stocks by releasing fry or fingerling (marine seeds) raised in tanks on land into the sea. While aquaculture is compartmentalised and isolated from the outside, marine seeds release targets the commons.

2.2 General Status of Marine Seeds Release in South Korea

As of 2023 in South Korea, a total of 69 species (53 marine species, and 16 inland species) are managed for release. In particular, in 2007, the Fisheries Resources Management Act (FRMA) made it mandatory to conduct a release effectiveness survey to review the effectiveness of the release project. In 2011, the Korea Fisheries Resources Agency (FIRA) was established to take over the management of seeds releases from the NIFS. In 2016, a marine seeds certification system was introduced to ensure more thorough management of the released varieties. In 2016, a marine seeds certification system was introduced to ensure more thorough management of the released Varieties (FIRA, 2024a).

To improve the effectiveness of marine seeds release, FRMA specifies the place and time of release, the variety, and the size of the seeds. In particular, to enhance the effectiveness of the marine seeds release programme, a consultative committee is formed, and the opinions of fishermen are taken into consideration when selecting the seeds to be released. This process often involves the selection of local specialty varieties or species that are commonly caught in the area but have become overfished. Measures are also taken to ensure genetic diversity and prevent the spread of infectious diseases. In particular, a four-year research plan has been established to investigate the effectiveness of the releases, including marking and tracking surveys, recovery rate surveys, genetic research, and economic analysis. The budget for aquatic seeds release in 2022 was 41.3 million USD.

2.3 Effectiveness of Marine Seeds Release

We will look at the effectiveness of marine seeds release by focusing on the

varieties that have global statistics among the projects that are released as the main marine species in South Korea. To analyse the effectiveness of marine seeds release, South Korea uses recapture rates of fish stocks caught in marine seeds release areas. To identify the released marine seeds, tracking is done using methods such as building a genetic[1] database of the released individuals or tagging them.

2.3.1 Production and marine seed release of aquatic species

Among a total of 69 species of aquatic seeds release projects, I will select 10 species for which the characteristics of climate change and marine seeds can be well understood, and examine their production trends, seeds release effects, etc. Among a total of 69 species of aquatic seeds release projects, I will select 10 species for which the characteristics of climate change and marine seeds can be well understood, and examine their production trends, seeds release effects, etc (NIFS, 2024a ; 2024b). The species selected for this purpose are pacific cod, bastard halibut, stone flounder, fleshy prawn, swimming crab, blackhead seabream[2], black rockfish[3], Alaska pollock, spotted sea bass, and barred knifejaw. For the convenience of discussion, detailed statistics on the production and seed release of each species are attached in Appendix separately and omitted from the main text, and only general trends are examined. The current status and trends of production and seeds release for these species are schematically shown in Figures 4 to 13. For stone flounder, spotted sea bass, and barred knifejaw, for which global production statistics are unknown, only Korean statistics were used. The current status and trends of production and seeds release for these species are schematically shown in Figures 4 to 13 (FIRA, 2024b).

2.3.2 Effects of marine seed release

The effects of marine seeds release vary for each species. Although no statistical method was used here, the seeds release that can clearly estimate its effectiveness on the graph when compared to the global production is swimming crab. Blackhead seabream shows a certain degree of correlation that the seeds release may have an effect. In the case of barred knifejaw, it is difficult to compare because there are no global production statistics, but the correlation between seeds release and domestic statistics is clearly visible. For other seeds, it is difficult to observe the effectiveness on the graph.

However, looking at the recapture rate performed by FIRA in the seeds release areas, the figures range from 3.2% to 63.4% (Table 1). Pacific cod is 3.2%, bastard halibut is 63.4%, stone flounder is 13.0%, fleshy prawn is 23%, swimming

1 When seeds are released, paternity between the mother and the released individuals is estimated through genetic markers or population genetic analysis.
2 There are some errors in this data, as Korean production statistics are larger than global production statistics, so only general trends should be viewed.
3 It's the same as the error in footnote 2.

Figure 4. Pacific cod production and seed release.

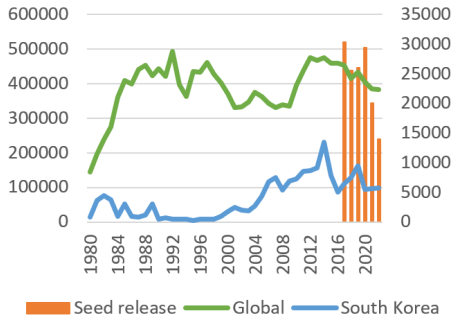


Figure 5. Bastard halibut production and seed release.

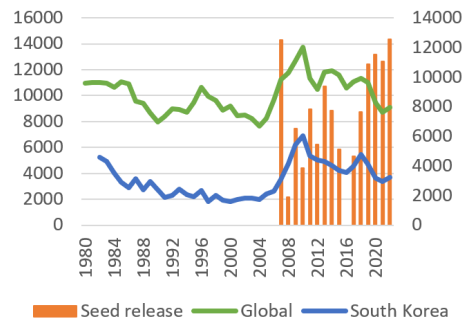


Figure 6. Stone flounder production and seed release.

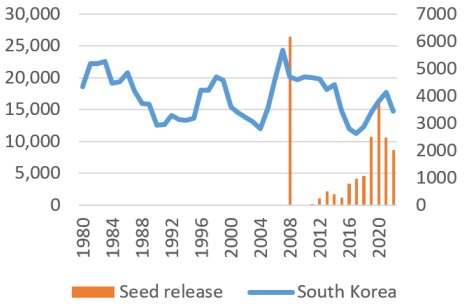


Figure 7. Fleshy prawn production and seed release.

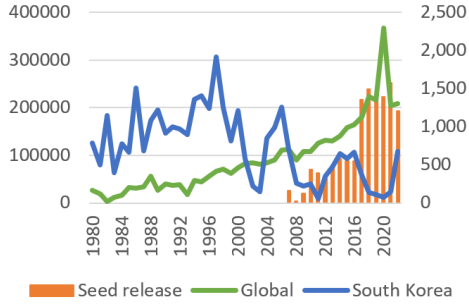


Figure 8. Swimming crab production and seed release.

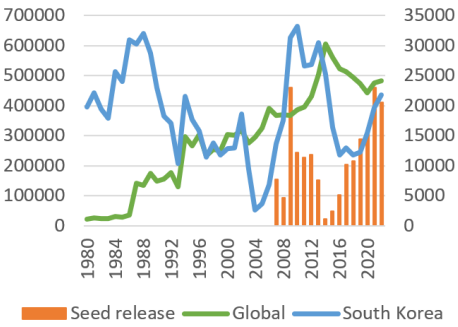


Figure 9. Blackhead seabream production and seed release.

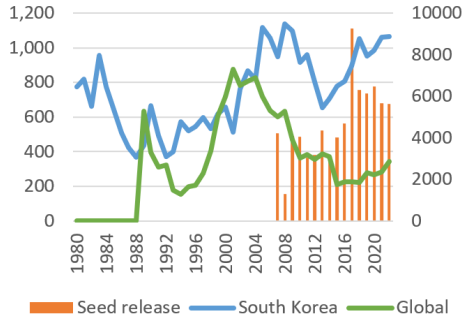


Figure 10. Black rockfish production and seed release.

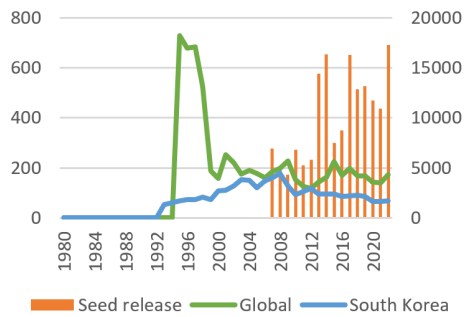


Figure 11. Alaska pollock production and seed release.

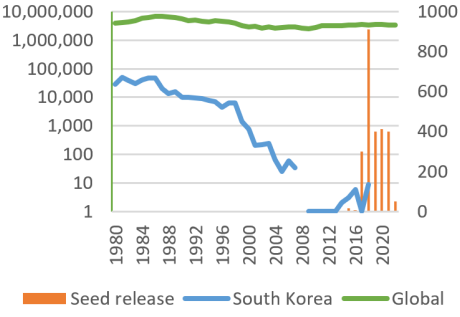


Figure 12. Spotted sea bass production and seed release.

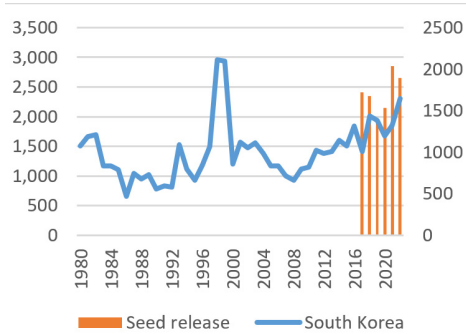


Figure 13. Barred knifejaw production and seed release.

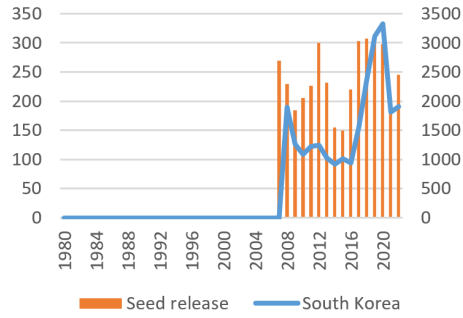


Table 1. Fish species characteristics and the effectiveness of marine seeds release

Fish species	Habitat water temperature[4]	Migration characteristics	Recapture rate (%)	B/C
Pacific cod (*Gadus macrocephalus*)	Cold/temperate (0.8℃–14℃)	Wide-area migratory (300 to 500 km)	3.2	2.62
Bastard halibut (*Olive flounder, Paralichthys olivaceus*)	Temperate/warm (8.6℃–25℃)	Demersal sedentary	63.4	5.56

4 In this paper, for convenience, cold-water species are classified as mainly living below 10°C, temperate-

Table 1. Continued

Fish species	Habitat water temperature[4]	Migration characteristics	Recapture rate (%)	B/C
Stone flounder (*Platichthys bicoloratus*)	–	Demersal sedentary	13	1.27
Fleshy prawn (*Fenneropenaeus chinensis*)	Warm	Migratory	23	3.57
Swimming crab (*Portunus trituberculatus*)	4℃–30℃	Migratory	4.8	4.21
Blackhead seabream (*Acanthopagrus schlegelii*)	Temperate/warm (13.1℃–25.4℃)	Sedentary	31.6	3.47
Black rockfish (*Sebastes schlegelii*)	Temperate/warm (8℃–21.3℃)	Migratory	32.2	2.01
Alaska pollock (Walleye pollock, *Gadus chalcogrammus*)	Cold (2℃–10℃)	Wide-area Migratory	–	–
Spotted sea bass (*Lateolabrax maculatus*)	Temperate/warm (12.7℃–26.3℃)	Coastal migratory	49.2	1.95
Barred knifejaw (*Oplegnathus fasciatus*)	Temperate/warm (16.1℃–25.2℃)	Coastal sedentary	13.2	1.05
Haliotis discus	–	Sedentary	55.0	2.59
Apostichopus japonicus	–	Sedentary	43.1	1.84

crab is 4.8%, blackhead seabream is 31.6%, black rockfish is 32.2%, spotted sea bass is 49.2%, and barred knifejaw is 13.2%.

In addition, B/C analysis was performed to analyse the feasibility of seeds release for each of these species[5], and the results were 1.05 to 5.56, indicating that all are economically feasible.

water species are classified as mainly living between 10°C and 15°C, and warm-water species are classified as mainly living above 15°C.

5 Alaska pollack is excluded because there is no relevant data.

2.3.3. The suitability of marine seeds release as a climate change adaptation policy

The most important thing in marine seeds release projects is that the released marine seeds grow to adulthood and contribute to the reproduction of the stock. In the end, the effectiveness can only be seen in the recapture rate. Of course, if we also consider the B/C, we can check the efficiency of the project and decide whether to continue the project in the future.

Given the unique nature of the ocean environment, a recapture rate of 20% or more may be considered a very successful outcome. In the Table 1, the species with a recapture rate of more than 20% are bastard halibut, fleshy prawn, blackhead seabream, black rockfish, spotted sea bass, Haliotis discus and Apostichopus japonicus.

Species with high recapture rates are predominantly temperate and/or warm-water species. In terms of migration characteristics, they are either (demersal) sedentary or local migratory species. In particular, all species with recapture rates above 50% are sedentary species. It can be concluded that it is the migration characteristics that have more influence on the recapture rate than the water temperature.

On the other hand, species that are cold-water species and have a wide range of migration can be considered to have significantly lower recapture rates. In particular, the recapture rate for Pacific cod was 3.2%, and for Alaska pollock it was difficult to determine the recapture rate. Of course, despite the low recapture rate for Pacific cod, the B/C was 2.62, which is a positive aspect that it is economically beneficial to continue the marine seeds release.

Rising ocean temperatures do not necessarily translate into an increase in warm-water fish species (NIFS, 2023). Fish and other aquatic organisms depend on many variables, including habitat, spawning grounds, prey, salinity, and oxygen levels, to affect their reproduction and migration, not just ocean temperature.

However, there are factors that seem to affect the effectiveness of marine seeds release in the context of climate change. In particular, the environment of the sea must be favourable for the particular species and the range of the species must be not as wide as possible. For cold-water, wide-ranging fish species such as Alaska pollock, it is difficult to see the effects of seeds release within a short period of time.

If similar marine seeds release projects are pursued in the future by South Korea or other countries, it would be advantageous to assess the suitability of the respective habitats for the specific species in advance and, if possible, to select species with narrower migratory ranges. In this regard, specific release procedures and preliminary impact studies in accordance with the FRMA will help to improve the effectiveness of the project.

Finally, there are limitations to this analysis. The effectiveness of marine seed release was mainly based on the recapture rate and B/C analysis results.

However, the factors affecting the effectiveness of marine seed release depend on many variables, including habitat, spawning grounds, prey, salinity, and oxygen levels, as mentioned above. This analysis has limitations in that it does not take these factors into account. These limitations should be supplemented in future studies.

3. Conclusion

As the ocean environment changes, the species of fish caught in South Korean Sea are also changing. As sea temperatures rise, the catch of some warm-water fish species has been steadily increasing, but this is not the case for all warm-water fish species.

One way to make fishing more sustainable is to release marine seeds. And what is even more important after discharge is to manage them in an appropriate way. Releasing marine seeds can promote the regeneration of marine ecosystems. Marine seeds release can be an important policy tool to overcome the difficulties of capture fisheries by leveraging advanced aquaculture technologies and can serve as a bridge to connect the strengths of aquaculture and capture fisheries. In other words, the marine seeds release is a good instrument for climate change adaptation policy that effectively combines the advantages of aquaculture and capture fisheries.

A review of South Korea's marine seeds release programme shows that mainly sedentary marine species and temperate and/or warm-water marine species are effective in Korean waters. While it is unlikely that the South Korea example can be replicated in other countries, it can at least help countries explore one alternative way to build fish stocks.

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Appendix 1. Annual production and seed release by fish species (unit: tons [production], thousand [seed release])

Fish species	Pacific cod			Bastard halibut			Stone flounder		Fleshy prawn			Swimming crab			Blackhead seabream			Black rockfish			Alaska pollock			Spotted sea bass		Barred knifejaw	
Production, seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Seed release	South Korea	Seed release
1980	844	144,587	–	3,862	10,976	–	18,644	–	783	27,340	–	19,734	22,541	–	776	–	–	–	–	–	28,112	4,020,814	–	1,502	–	–	–
1981	3,646	195,356	–	4,706	11,028	–	22,242	–	502	19,211	–	22,181	26,321	–	818	–	–	–	–	–	50,283	4,176,828	–	1,667	–	–	–
1982	4,462	239,236	–	4,596	10,983	–	22,239	–	1,145	2,749	–	19,393	24,107	–	663	–	–	–	–	–	38,413	4,478,217	–	1,695	–	–	–
1983	3,784	274,962	–	4,312	10,973	–	22,549	–	396	12,288	–	17,854	23,456	–	956	–	–	–	–	–	29,642	4,858,086	–	1,176	–	–	–
1984	902	361,410	–	3,528	10,623	–	19,184	–	773	16,308	–	25,643	30,281	–	774	–	–	–	–	–	39,906	5,986,318	–	1,168	–	–	–
1985	2,996	409,593	–	2,883	11,067	–	19,432	–	667	33,191	–	23,960	29,188	–	642	–	–	–	–	–	46,496	6,132,334	–	1,104	–	–	–
1986	919	399,437	–	2,534	10,891	–	20,790	–	1,503	30,908	–	30,897	36,225	–	510	–	–	–	–	–	46,890	6,758,944	–	660	–	–	–
1987	839	441,778	–	3,150	9,540	–	17,982	–	683	34,469	–	30,273	142,780	–	423	–	–	–	–	–	20,162	6,723,969	–	1,043	–	–	–
1988	1,200	453,109	–	2,393	9,381	–	15,999	–	1,080	55,557	–	31,968	134,518	–	369	–	–	–	–	–	13,348	6,658,607	–	954	–	–	–
1989	3,020	423,451	–	2,945	8,663	–	15,856	–	1,220	26,430	–	28,753	174,885	–	435	634	–	–	–	–	15,786	6,320,979	–	1,022	–	–	–
1990	487	442,132	–	2,380	7,979	–	12,594	–	912	39,480	–	23,004	148,221	–	666	396	–	–	–	–	9,798	5,736,171	–	780	–	–	–
1991	663	419,905	–	1,885	8,370	–	12,706	–	998	37,117	–	18,300	154,765	–	494	311	–	–	–	–	10,104	4,893,484	–	831	–	–	–
1992	438	493,795	–	2,022	8,997	–	14,111	–	968	38,980	–	17,087	176,135	–	370	323	–	–	–	–	9,504	4,992,406	–	818	–	–	–
1993	481	397,054	–	2,454	8,922	–	13,466	–	897	17,479	–	10,419	130,641	–	399	178	–	1,340	–	–	9,043	4,619,008	–	1,523	–	–	–
1994	473	363,480	–	2,035	8,702	–	13,337	–	1,363	47,133	–	21,483	297,149	–	574	153	–	1,540	–	–	7,605	4,374,765	–	1,119	–	–	–
1995	273	433,855	–	1,914	9,472	–	13,674	–	1,406	44,449	–	17,651	265,295	–	521	197	–	1,695	728	–	6,903	4,774,848	–	925	–	–	–

Appendix 1. Continued

Fish species	Pacific cod			Bastard halibut			Stone flounder		Fleshy prawn			Swimming crab			Blackhead seabream			Black rockfish			Alaska pollock			Spotted sea bass		Barred knifejaw	
Production, seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Seed release	South Korea	Seed release
1996	472	433,310	–	2,317	10,628	–	18,066	–	1,242	56,534	–	15,754	303,170	–	545	207	–	1,854	679	–	4,445	4,510,003	–	1,178	–	–	–
1997	481	460,550	–	1,592	9,953	–	18,079	–	1,911	66,056	–	11,430	234,466	–	596	277	–	1,813	684	–	6,373	4,480,871	–	1,501	–	–	–
1998	476	426,625	–	2,002	9,617	–	20,135	–	1,245	70,687	–	13,813	253,657	–	534	404	–	2,092	524	–	6,232	4,048,878	–	2,957	–	–	–
1999	894	402,246	–	1,679	8,877	–	19,569	–	814	61,452	–	11,819	249,000	–	619	604	–	1,813	187	–	1,392	3,268,728	–	2,933	–	–	–
2000	1,766	370,912	–	1,607	9,179	–	15,423	–	1,211	73,560	–	12,842	303,431	–	658	717	–	2,682	159	–	766	2,929,654	–	1,201	–	–	–
2001	2,458	330,884	–	1,707	8,436	–	14,503	–	582	83,338	–	13,016	301,184	–	512	878	–	2,765	252	–	207	3,138,640	–	1,566	–	–	–
2002	1,968	332,692	–	1,822	8,502	–	13,816	–	222	84,847	–	18,659	317,451	–	764	784	–	3,227	220	–	215	2,653,209	–	1,479	–	–	–
2003	1,826	347,397	–	1,801	8,247	–	13,107	–	148	81,045	–	9,478	275,599	–	866	806	–	3,811	175	–	242	2,887,962	–	1,564	–	–	–
2004	2,641	375,426	–	1,737	7,654	–	12,038	–	848	84,699	–	2,683	295,500	–	820	826	–	3,774	189	–	64	2,693,091	–	1,382	–	–	–
2005	4,272	362,093	–	2,112	8,207	–	15,319	–	989	90,392	–	3,714	324,437	–	1,117	717	–	3,000	177	–	25	2,790,974	–	1,173	–	–	–
2006	6,810	342,299	–	2,298	9,686	–	19,879	–	1,261	110,203	–	6,894	391,090	–	1,055	637	–	3,713	160	–	60	2,860,487	–	1,173	–	–	–
2007	7,533	331,246	–	3,074	11,210	12,508	24,340	–	704	112,003	25,701	13,606	367,223	7,687	947	602	4,214	4,037	184	6,946	35	2,909,418	–	1,007	–	–	2,694
2008	5,395	339,015	–	4,184	11,763	1,884	20,162	6,172	259	89,953	3,781	17,596	370,847	4,718	1,140	632	1,308	4,477	198	5,183	–	2,649,155	–	934	–	190	2,295
2009	6,870	333,730	–	5,439	12,657	6,543	19,687	–	219	107,837	19,977	31,302	366,446	23,009	1,097	469	4,093	3,178	228	4,298	1	2,503,247	–	1,114	–	127	1,846
2010	7,289	394,344	–	6,035	13,736	3,859	20,107	–	252	107,774	69,872	33,193	385,346	12,217	916	365	4,053	2,351	152	6,830	1	2,833,091	–	1,154	–	109	2,056
2011	8,585	437,444	–	4,675	11,328	7,827	20,017	17	52	125,697	62,562	26,608	395,495	11,326	962	383	3,058	2,657	125	5,232	1	3,210,504	–	1,437	–	122	2,259
2012	8,682	474,128	–	4,392	10,449	5,453	19,868	259	352	131,721	51,069	26,861	429,959	11,785	803	357	3,183	2,922	119	5,840	1	3,271,726	–	1,381	–	124	3,004
2013	9,133	467,184	–	4,295	11,804	9,379	18,171	499	472	130,805	75,675	30,448	503,868	7,570	654	386	4,353	2,411	142	14,415	1	3,247,753	–	1,408	–	102	2,317

Appendix 1. Continued

Fish species	Pacific cod			Bastard halibut			Stone flounder		Fleshy prawn			Swimming crab			Blackhead seabream			Black rockfish			Alaska pollock			Spotted sea bass		Barred knifejaw	
Production, seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Global	Seed release	South Korea	Seed release	South Korea	Seed release
2014	13,402	474,978	–	4,008	11,919	7,723	18,905	407	650	140,936	92,342	25,242	605,561	1,166	706	372	2,990	2,362	164	16,381	2	3,245,082	–	1,600	–	92	1,554
2015	7,820	458,696	–	3,705	11,611	5,116	14,925	275	581	158,973	88,082	16,374	560,831	2,402	780	211	4,036	2,399	225	7,498	3	3,372,735	15	1,511	–	101	1,499
2016	4,975	458,930	–	3,555	10,598	–	12,023	787	665	163,514	87,850	11,751	522,735	5,123	809	228	4,704	2,121	171	8,738	6	3,476,397	1	1,841	–	94	2,198
2017	6,479	452,232	30,300	3,989	11,073	4,670	11,212	958	359	181,055	216,233	12,941	512,936	10,228	896	228	9,264	2,179	198	16,305	1	3,488,651	300	1,410	1,725	156	3,035
2018	7,511	415,156	25,500	4,762	11,326	7,662	12,292	1,068	143	223,225	238,903	11,770	493,145	10,739	1,053	224	6,304	2,259	168	12,839	9	3,395,722	910	2,012	1,680	238	3,072
2019	9,520	432,851	26,010	4,107	11,030	10,892	14,672	2,497	115	215,550	219,143	12,306	472,902	14,403	952	281	6,146	2,136	167	13,167	–	3,494,660	400	1,941	1,357	312	3,020
2020	5,507	405,095	29,400	3,182	9,467	11,504	16,360	3,751	77	367,431	222,020	15,417	442,138	15,799	983	266	6,465	1,643	143	11,709	–	3,544,256	411	1,675	1,531	333	2,976
2021	5,629	385,212	20,000	2,923	8,713	11,077	17,683	2,485	144	204,255	252,737	19,715	476,019	22,961	1,062	282	5,669	1,617	140	10,936	–	3,484,189	400	1,856	2,035	181	1,825
2022	5,734	382,635	14,000	3,208	9,107	12,577	14,739	2,009	674	208,193	193,191	21,809	481,505	20,543	1,064	343	5,621	1,725	173	17,303	–	3,358,618	50	2,306	1,893	191	2,457