바다숲사업 프로세스

The Process for the Marine Forest Project

2019. 12.

FIRA | 한국수산자원공단

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KOREA FISHERIES RESOURCES AGENCY

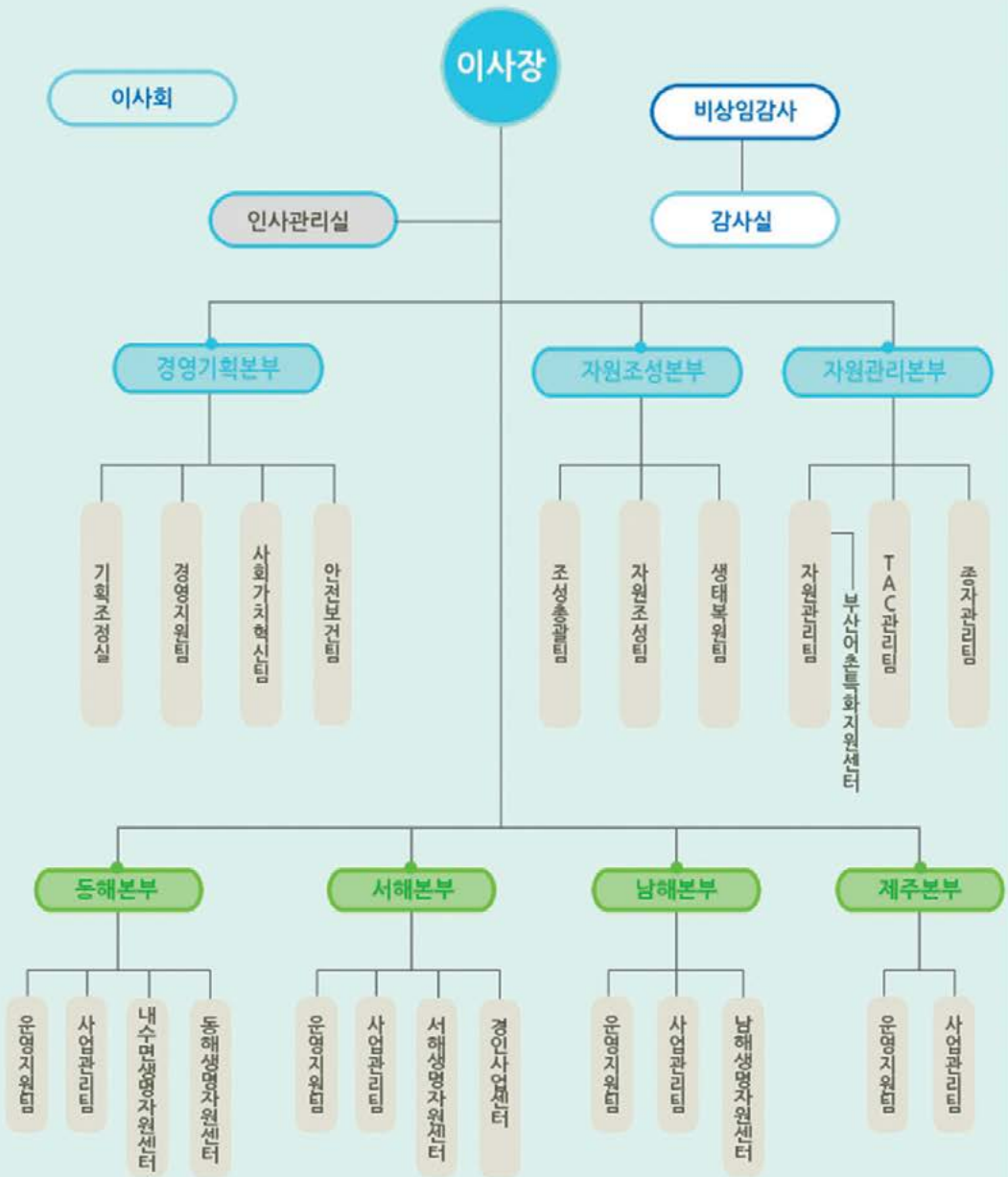
FIRA 경영전략체계도

미 션	수산자원의 지속적 이용기반 구축으로 국가경제에 기여
비전	깨끗하고 풍요로운 어장, 어촌경제 활성화, 국민에게 신뢰받는 FIRA

경영목표 2030	연근해 자원량 회복 (503만톤 달성)	어가소득 증대 (80백만원/년 달성)	국민평가 최고등급 (S등급 달성)
핵심가치	전문성	공공성	고객지향성

전략목표	생태계 기반 수산자원 증대	지속가능 수산 자원 관리 강화	미래 성장 동력 강화	사회적 가치 창출	국민공감경영 신뢰 구현
전략과제	• 수산자원 조성 확대 • 수산자원 서식환경 개선	• 체계적 어업 생산 관리 • 방류 수산자원 관리	• 성장동력 발굴 및 실용화 • 혁신기술 개발 강화	• 일자리·사회적책임 강화 • 혁신성장·상생경영 지원	• 윤리·인권 경영 강화 • 경영혁신 내재화

한국수산자원공단 조직도



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Chapter I
Marine Forest Project Outline

1. What is a marine forest?

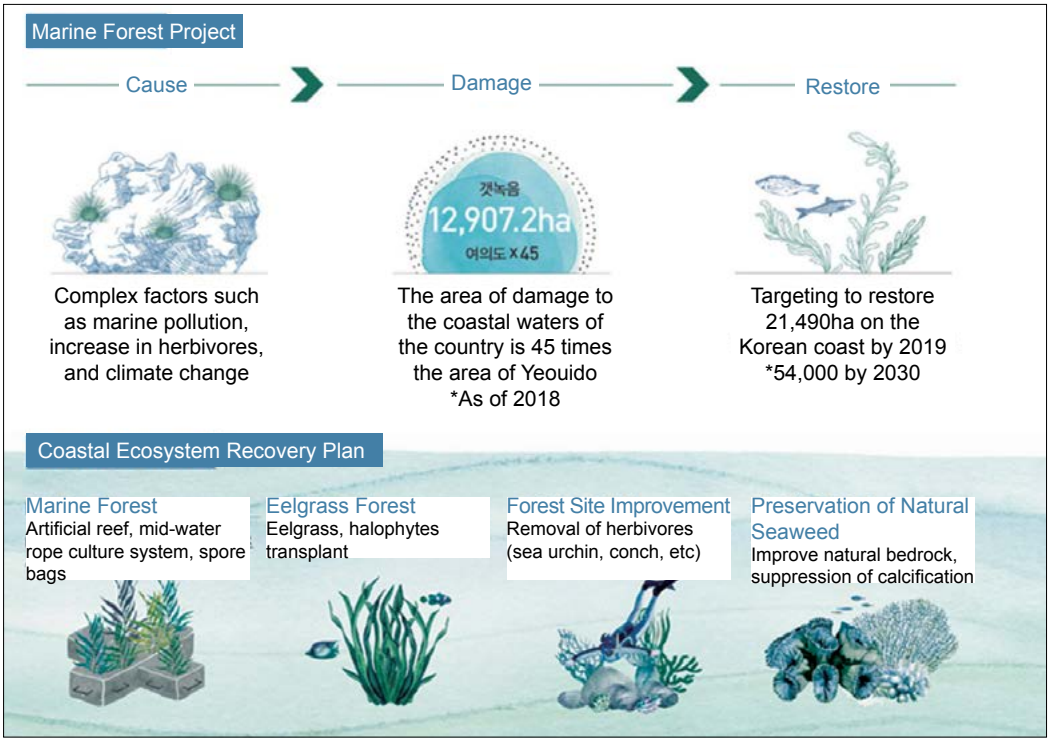
A forest is defined as an area filled with trees, but are there forests in the sea? The answer is yes, there are. A marine forest generally refers to a colony of various seaweeds or seagrasses formed in coastal waters, and the concept includes submarine forests, seaweed beds, seagrass beds.

These marine forests are important environmental resources of coastal ecosystems, providing various tangible and intangible services (including goods) to our human society. They provide us with well-being foods rich in dietary fibre and minerals for blood sugar control and arteriosclerosis prevention, as well as pharmaceuticals composed of functional substances such as alginic acid, beta-carotene, and laminarin. In addition, a marine forest forms the centre of the cycling of matters as an important primary producer of coastal ecosystems. Also as a habitat for various living organisms, including fish or invertebrates, it plays a vital role in maintaining the lifecycle and biodiversity for the recovery of coastal ecosystems by increasing the secondary productivity of the colonies. A marine forest purifies the environment of contaminated sea areas by absorbing not only Carbon Dioxide (CO_2), but also Nitrogen, Phosphorus, heavy metals, etc. to restore and maintain the balance of degraded fishery resources ecosystem. It also prevents coastal erosion by maintaining sand dunes, and plays a role as a bioenergy source. In recent years, the marine forest has been proving a place for marine leisure activities such as fishing and scuba diving, and marine education activities, so it has been highly regarded for contributing to the increase in demand for marine experience tourism and education.

However, recently calcification has been occurring in the coastal waters of Korea, from the Jeju island coastal area to the south coast and east coast, and the beneficial tangible and intangible services that the marine forests provide to our society are disappearing. In response, the national government and local governments are trying to improve the marine environment by artificially transplanting and attaching useful seaweeds to cope with the calcification. In Article 2 (1) 6 of the Fisheries Resource Management Act, marine forests are to be restored at a national level by identifying marine forest project area as “a place where fisheries seeds such as seaweeds are transplanted for the restoration of coastal ecosystems and the

improvement of fishery productivity in waters where seaweeds have disappeared or are likely to disappear by calcification (whitening event)".

The importance of the biological, physical, and economic value of marine forests are also recognised internationally, and strong protection and restoration policies have been introduced. The United States is committed to preventing overfishing of seafood and strongly protect fishery resources under the Magnuson-Stevens Fishery Conservation and Management Act 1976 and Article 404 of the Federal Clean Water Act, a regulation on dredging and landfill in US waters to ensure a stable and sustainable supply of seafood and to increase socio-economic benefits in the long run (NOAA, 2014).



<Image 1-1> Marine forest creation and coastal ecosystem recovery

2. Background of the Marine Forest Project

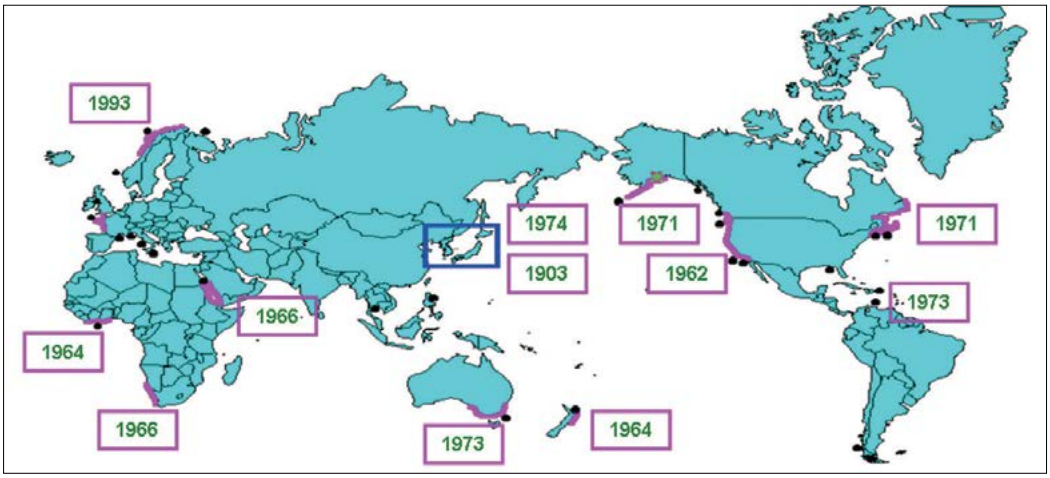
A. Definition and causes of calcification

Calcification can be defined as "a phenomenon which a part of coastal sea area where some or all of the seaweeds growing there, for some reason, are killed or lost and the seabed becomes barren. So, not only useful seaweed but also herbivorous benthic animals such as sea urchin, abalone and conch, which feed on the seaweeds are decreased in numbers, along with a decrease in the production of sedentary fish live in seaweed bed", thereby, it can be called a "sea desertification," in which fishing villages eventually suffer from famine (Kim, 1991).

The physical factors of calcification include 1) rising seawater temperature due to global warming, 2) loss of habitat caused by typhoons and storms, 3) destruction of habitats due to industrialisation, landfill or reclamation, or 4) the occurrence of floating matter due to large-scale port construction. Chemical factors include low and high salinity in seawater, increased pollution of the coastal environment, and lack of nutrients. Biological factors can include increased grazing pressure from the increased number of seaweed-feeding animals, inhibiting the growth of other seaweeds by non-articulated coralline algae, and reckless over-exploitation of seaweed resources.

B. Current status of calcification in Korea

Since the 1960s, calcification has occurred on a large scale in the northwestern part of Norway, the Baja California peninsula, western and eastern Canada, the South Pacific coast of Australia, the Red Sea coast, and Japan.



<Image 1-2> Current status of calcification around the world (□: year occurred)

In Korea, calcification began to occur after the 1980s in some of the seas along Jeju island and the south coast, and spread to the east coast in the 1990s.

According to a study by the National Institute of Fisheries Science, in 2004, calcification occurred in 6,954ha, which accounts for about 20% of 35,101ha of the local fishing grounds, and in 2010, out of the 53,838 ha of rock mass surveyed in the east coast, west coast, south coast, and Jeju Sea, calcification occurred in 14,317ha (26.6%). It is estimated that about 1,200ha of calcification spreads every year. This indicates that the sea desertification of the coast of Korea is progressing rapidly, and it is feared that there will be serious damage to the coastal ecosystem and the fishery industry as a result of the calcification.

Since 2013, hyperspectral aerial imaging has been conducted to survey calcification on the coast of the country except for the west coast, and the current status of calcification by the coastal areas in Korea is as shown in <Image 1-3>.

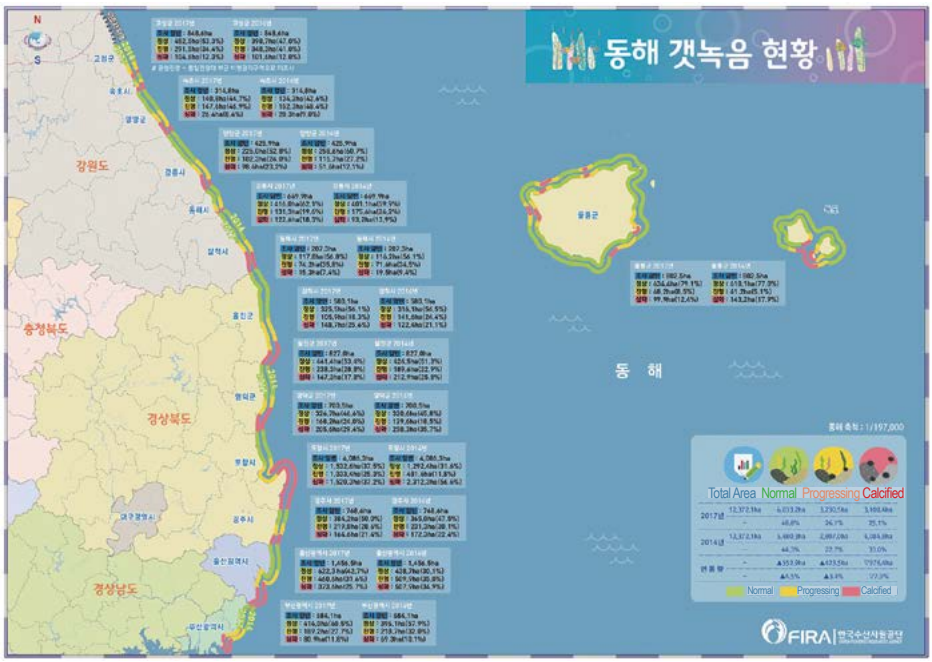
On the east coast, as of 2017, calcification occurred in 6,338.9ha of rock mass, which is approximately 51.2% of the total bedrock area of 12,372ha. On the south coast, calcification is occurring in 961ha of bedrock, which is 13.4% of the total bedrock area of 7,170.9ha as of 2018. In Jeju island sea, as of 2016, 35.2% of the total bedrock area of 5,574.3ha, or 5,574.3ha of rock mass, showed calcification. It is observed that seaweeds are disappearing due to the calcification in all over the Korean coastline.

<Image 1-3> Current status of calcification in Korean coastal areas

A detailed look at calcification by coastal areas of Korea is as follows.

The current status of calcification on the east coast is shown in <Image 1-4>. Calcification on the east coast appears in various forms over almost all sea areas

from the northernmost part of Goseong, Gangwon-do to the southern part of the East Sea, and it is believed that excessive grazing behaviour by herbivorous animals such as sea urchins is the main cause. As the grazing pressure by herbivores increases, non-articulated coralline algae that coexisted underneath it die due to photooxidation, resulting in a typical calcification that turns the bedrock white. When this phenomenon is visually expressed, it is also called a 'whitening event'.



<Image 1-4> Current status of calcification in Korean east coast

Calcification on the west coast is caused by the sedimentation and deposition of suspended solid on rocks that are covered with non-articulated coralline algae, thereby physically hindering the growth and spread of large brown algae. As a result, large algae colonies centred on brown algae decline, and only small red algae and turf algae such as Gracilaria textorii, Gigartina tenella, and Grateloupia, which indicates poor vegetation in the sea area. It can also be observed throughout the calcification in which invertebrates such as sponges, hydras, and moss animals competing for space on rocks, where there is an important habitat for epiphytic seaweeds, preempting the attachment of seaweeds, thereby gradually decreasing the density and biomass of seaweeds. This calcification on the west coast has a

different ecological background to the East Sea, Jeju island and the South Sea. In the Yellow Sea, the feeding activity of herbivores such as sea urchins with a very high grazing pressure causes seaweed colonies to decline and be lost. Whereas, in the East Sea, Jeju island and the South Sea, the bedrock is bleached due to the death of articulated and non-articulated coralline algae.

The current status of calcification on the southern coast is shown in <Image 1-5>. The calcification on the south coast is not only caused by grazing activities of herbivores like sea urchins, but also by the increase in the coverage of coralline algae and sedimentation of suspended substances (off the Wan-do coast), similar to the Yellow Sea. The combination of these factors is believed to be contributing to the increase of sessile invertebrates, such as Mediterranean mussels, sponges, sea squirts and moss animals (Geumo-do, Yeosu), as well as the increase of opportunistic annual algae and coverage of turf algae (Mokdo, Busan) on the bedrock.

<Image 1-5> Current status of calcification in Korean south coast

The current status of calcification on Jeju island is as shown in <Image 1-6>. Calcification in Jeju island is mainly caused by a biological factor such as an increase in the habitat density of sea urchins, which are generally known to have the biggest appetite among marine herbivores. Also, an increase in the coverage of articulated and non-articulated coralline algae is the main factor. Moreover, physical factors such

as frequent typhoons and strong swelling waves are intensifying the phenomena. Of course, it is undeniable that global warming, such as increased water temperature, is also acting as a factor for the synergistic effect of calcification. However, in addition to biological and physical natural phenomena, government management policies such as insufficient marine forest resource management policies of some fishing villages that exclusively exercise fishing rights in coastal local fishing grounds and inadequate control measures for herbivores are also affecting the spread of calcification.

In particular, in Jeju Island waters, the structure of its subtidal rock is so large that herbivores can easily hide in the face of strong typhoons. It also consists of various types of grooves, which makes it hard to get rid of herbivores such as sea urchins. Since the grazing pressure is further increased by herbivores making patches in the dozens between stones and rocks, it is necessary to propose systematically organised citizen-participatory marine forest management program and policies to suppress the spread of calcification.

<Image 1-6> Current status of calcification around Jeju island

3. Necessity of the Marine Forest Project

The calcification in coastal waters is accelerating the eutrophication of coastal areas by damaging marine forests, which play a role in purifying the ocean environment by absorbing nitrogen, phosphorus and heavy metals. In addition, calcification causes a decrease in invertebrates such as abalone, conch, and sea urchin which feed on seaweeds, as well as useful fish resources such as black rabbitfish, Japanese sawtail, largescale blackfish, and greenlings. It also causes the destruction of fishery habitats such as spawning grounds, shelter, and breeding grounds. The decrease in seaweeds reduces the primary productivity in coastal waters as they are primary producers of marine ecosystems. As seaweeds fail to absorb CO_2, the cause of global warming, this accelerates climate warming and the decrease of oxygen suppliers caused by photosynthesis, which leads to a decline in the primary productivity in the ocean, resulting in the destruction of the ecosystem.

Accordingly, systematic management is required, along with the creation of a large-scale marine forest that restores coastal ecosystems damaged by calcification and provides a stable habitat for fisheries resources such as spawning, nursery, breeding and feeding grounds.

Meanwhile, in response to climate change, a greenhouse gas reduction project has been implemented. Based on Article 55 (2) of the Framework Act on Low Carbon and Green Growth, leading the low carbon industry by expanding carbon sinks through the creation of marine forests and utilising them as renewable energy sources by mass production of biomass. In January 2014, by announcing the National Roadmap for Greenhouse Gas Reductions, policy tools and sector-wide goals are being proposed and implementation of GHG reduction efforts are being reinforced.

As a universal participation project in greenhouse gas reduction negotiations on the new climate regime, the Government will submit the Intended Nationally Determined Contribution (INDC) after 2020 in time agreed in Warsaw. Since the sea rehabilitation project is being promoted as an INDC strategic project set by Korea as well as an international cooperation project, the necessity of the marine reforestation project is further enhanced.

4. How we carry out the Marine Forest Project

In the past, excessive use of fishery resources, marine pollution, and reckless coastal development in Korea have resulted in a decrease in the productivity of the fishing industry. In response, the government implemented fishery stock enhancement programs from the early 1970s as part of the fishery resource management policy to enhance the productivity of coastal fishing grounds and increase the income of fishermen.

The first stock enhancement program in Korea was the artificial reef facility project, which started in 1971 with the dropping of square concrete in the waters of Gangwon-do. And later, the fishery seedling discharge project was started in 1976. In the early days, the stock enhancement programs mainly consisted of the artificial reef facility and the fishery seedling release projects. Starting with the Tongyeong pilot marine ranch construction project in 1998, five pilot marine ranches were placed, and later the marine ranch construction project has been officially added to the stock enhancement programs. Since then, the seaweed bed construction project has been started in 2002 and the construction of coastal marine ranches since 2006.

The seaweed bed construction was a project to improve the marine environment by artificially transplanting and attaching seaweeds to artificial reefs on the coast, thereby creating a spawning and habitat for coastal fisheries resources to enhance overall resources. It can be considered the beginning of the Marine Forest Project. The seaweed farm construction project started in 2002, and since 2009 has been converted into the Marine Forest Project and is being carried out.

In 2009, the National Institute of Fisheries Science conducted a nationwide survey on geographical targeting for the Marine Forest Project, creating a foundation for a large-scale marine forest development project. And in 2011, the Fisheries Resources Corporation (now the Korea Fisheries Resources Agency FIRA) was launched as an independent organisation under the Ministry of Oceans and Fisheries, and started to proceed the Marine Forest Project further methodically and professionally.

Based on Article 55 (2) of the Fisheries Resource Management Act, the government has established and operates the Korea Fisheries Resources Agency to carry out fishery resource management projects, such as protecting and nurturing fishery resources, and researching, developing, and distributing new technology.

The Korea Fisheries Resources Agency is promoting fishery resources development projects such as the building of marine forests and marine ranches and fishery seed resource management. Among them, the Marine Forest Project aims to create 54,000ha of the entire coast of Korea.

5. Current status of the Marine Forest Project

Marine forests began to be developed on the coast of Korea in 2009. As of 2019, new marine forest creation, marine forests management, natural seaweed plant protection and preservation, technology development and consensus are being carried out as part of the Marine Forest Project.

As of 2019, 173 sea forests have been created on the coast of the country, with 21,490ha of the construction area and KRW 280.8 billion of project costs have been invested.

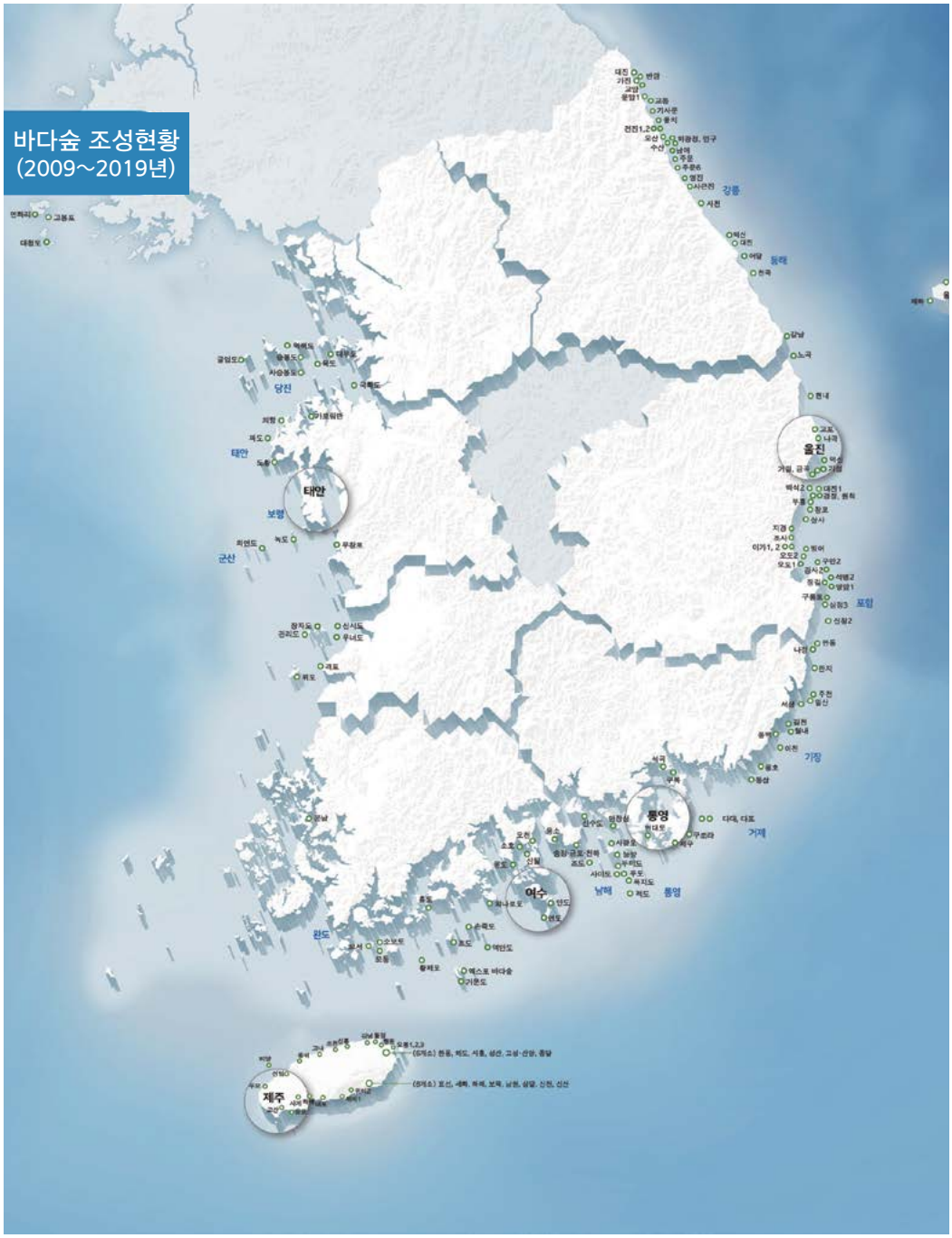
<Table 1-1> Current status of the Marine Forest Project

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Development Site (number)	7	10	11	10	9	19	21	24	18	20	24	173
Development Area (ha)	121	250	715	860	1,388	2,575	3,236	3,064	3,043	3,108	3,130	21,490
Development Fund (hundred million KRW)	100	150	130	159	183	327	357	347	352	352	352	2,809

Looking at the marine forest creation status by sea area from 2009 to 2019, there are 69 marine forest development sites, 8,300.91ha in the East Sea, 28 sites, 1,571.35ha in the West Sea, 36 sites, 3,928ha in the South Sea, and in the Jeju sea area, there are 40 sites, 7,689.47ha.

<Table 1-2> Current status of the Marine Forest Project by area

		East Sea	West Sea	South Sea	Jeju	Total
2009	Site (number)	2	2	2	1	7
	Area (ha)	75	1	25	20	121
2010	Site (number)	2	2	4	2	10
	Area (ha)	60	10.2	130	50	250.2
2011	Site (number)	4	3	2	2	11
	Area (ha)	282	15	106	312	715
2012	Site (number)	4	2	2	2	10
	Area (ha)	416	70	112	262	860
2013	Site (number)	4	1	2	2	9
	Area (ha)	491	101	300	496	1,388
2014	Site (number)	7	2	5	5	19
	Area (ha)	725	200	529	1,120.6	2,574.6
2015	Site (number)	8	4	5	4	21
	Area (ha)	1,126	350	672	1,088	3,236
2016	Site (number)	15	1	3	5	24
	Area (ha)	1,634	50	294	1,086	3,064
2017	Site (number)	7	2	4	5	18
	Area (ha)	1,050	165	640	1,188.2	3,043.2
2018	Site (number)	9	1	4	6	20
	Area (ha)	1,360	10	640	1,097.6	3,107.6
2019	Site (number)	7	8	3	6	24
	Area (ha)	1,081.91	599.15	480	969.07	3,130.13
계	Site (number)	69	28	36	40	173
	Area (ha)	8,300.91	1,571.35	3,928	7,689.47	21,489.73



<Image 1-7> Current status of marine forests in Korea (2009~2019)

<Table 1-3> Progress of marine forests by year and area

Sea / Year	East Sea	West Sea	South Sea	Jeju
2009	[강원도] 1개소 강릉시 안현동 사근진 40.0 [경상북도] 1개소 포항시 남구 신창2리 35.0	[충청남도] 2개소 태안군 소원면 파도리 1.0 태안군 소원면 의항리	[경상남도] 2개소 거제시 남부면 다대리 2.0 거제시 남부면 다포리 23.0	[제주도] 1개소 서귀포시 안덕면 사계리 20.0
2010	[강원도] 1개소 동해시 천곡동 30.0 [경상북도] 1개소 영덕군 영덕읍 창포리 30.0	[경기도] 1개소 화성시 우정읍 국화도 10.0 [충청남도] 1개소 보령시 웅천읍 무창포 0.2	[경상남도] 1개소 남해군 미조면 조도 20.0 [전라남도] 3개소 여수시 신월 20.0 여수시 소호 20.0 여수시 삼산면 거문도 70.0	[제주도] 2개소 서귀포시 남원읍 신흥리 25.0 서귀포시 대정읍 상모리 25.0
2011	[강원도] 2개소 양양군 현북면 기사문리 87.0 삼척시 원덕읍 신남 69.0 [경상북도] 1개소 울진군 울진읍 현내리 76.0 [부산광역시] 1개소 영도구 동삼동 50.0	[인천광역시] 1개소 옹진군 백령면 고봉포 8.0 [충청남도] 1개소 보령시 웅천읍 무창포 2.0 [전라북도] 1개소 군산시 옥도면 장자도 5.0	[경상남도] 1개소 통영시 사량면 사량도 91.0 [전라남도] 1개소 여수시 삼산면 거문도 15.0	[제주도] 2개소 제주시 애월읍 동귀리 104.0 서귀포시 하예동 208.0
2012	[강원도] 2개소 강릉시 주문진읍 주문리 140.0 삼척시 원덕읍 갈남리 51.0 [경상북도] 1개소 포항시 남구 구룡포 56.0 [울산광역시] 1개소 동구 주전동 169.0	[전라북도] 2개소 군산시 옥도면 무녀도 10.0 부안군 변산면 격포리 60.0	[경상남도] 1개소 통영시 욕지면 초도 62.0 [전라남도] 1개소 완도군 청산면 모서리 50.0	[제주도] 2개소 제주시 조천읍 북촌리 126.0 서귀포시 대포동 136.0
2013	[강원도] 2개소 강릉시 사천면 사천진리 225.0 동해시 어달동 114.0 [경상북도] 2개소 포항시 남구 구만2리 89.0 영덕군 강구면 삼사리 63.0	[충청남도] 1개소 서산시 대산읍 가로림만 101.0	[경상남도] 1개소 통영시 욕지면 두미도 200.0 [전라남도] 1개소 완도군 청산면 모동리 100.0	[제주도] 2개소 제주시 애월읍 고내리 154.0 서귀포시 성산읍 고성·신양리 342.0
2014	[강원도] 2개소 양양군 강현면 물치리 202.0 강릉시 주문진읍 주문리 88.0 [경상북도] 4개소 포항시 남구 삼정3리 37.0 포항시 북구 방어리 91.0 울릉군 서면 태하리 45.0 영덕군 원척리·경정리 200.0 [부산광역시] 1개소 남구 용호동 62.0	[경기도] 1개소 안산시 단원구 육도 100.0 [인천광역시] 1개소 옹진군 덕적면 덕적도 100.0	[경상남도] 2개소 남해군 이동면 용소리 146.0 통영시 욕지면 적도 62.0 [전라남도] 3개소 무안군 운남면 성내리 21.0 완도군 청산면 소모도 100.0 여수시 삼산면 초도 200.0	[제주도] 5개소 제주시 조천읍 신흥리 153.8 제주시 구좌읍 행원리 248.4 서귀포시 보목동 211.6 서귀포시 남원읍 남원리 140.0 서귀포시 표선면 표선리 366.8

<Table 1-3> Continued

Sea / Year	East Sea	West Sea	South Sea	Jeju
2015	[강원도] 2개소 강릉시 연곡면 영진리 380.0 동해시 대진동 328.0 [경상북도] 3개소 영덕군 병곡면 백석2리 75.0 포항시 남구 강사2리 97.0 울릉군 북면 천부3·4리 70.0 [울산광역시] 1개소 동구 일산동 76.0 [부산광역시] 2개소 기장군 장안읍 월내리 42.0 기장군 장안읍 길천리 58.0	[인천광역시] 2개소 옹진군 자월면 사승봉도 50.0 옹진군 대청면 대청도 100.0 [충청남도] 1개소 보령시 오천면 녹도리 100.0 [전라북도] 1개소 부안군 위도면 위도 100.0	[경상남도] 3개소 거제시 남부면 저구리 200.0 사천시 신수동 신수도 100.0 고성군 회화면 당황리 12.0 [전라남도] 2개소 여수시 남면 연도 180.0 고흥군 봉래면 외나로도B 180.0	[제주도] 4개소 제주시 구좌읍 김녕리 332.3 제주시 한림읍 비양리 453.1 서귀포시 표선면 세화리 155.6 서귀포시 남원읍 하례리 147.0
2016	[강원도] 4개소 고성군 토성면 교암리 142.0 속초시 교동 185.0 양양군 현남면 남애1·2리 292.0 양양군 강현면 전진2리 152.0 [경상북도] 8개소 포항시 북구 오도1리 43.7 포항시 북구 오도2리 35.0 포항시 남구 석병2리 73.8 경주시 감포읍 연동리 53.0 울진군 매화면 덕신리 260.0 울진군 기성면 기성리 118.0 울진군 북면 고포리 44.0 울진군 북면 나곡리 85.0 [울산광역시] 1개소 북구 구유동 판지 37.0 [부산광역시] 2개소 기장군 일광면 이천리 50.0 기장군 일광면 동백리 63.5	[충청남도] 1개소 보령시 오천면 횡견도 50.0	[경상남도] 1개소 통영시 산양면 연대도 100.0 [전라남도] 2개소 완도군 금일읍 충도 128.0 여수시 오천동 66.0	[제주도] 5개소 제주시 조천읍 조천리 84.2 제주시 구좌읍 하도리 579.2 제주시 애월읍 신엄리 101.8 제주시 구좌읍 한동리 217.4 서귀포시 남원읍 위미1리 103.4
2017	[강원도] 3개소 고성군 거진읍 반암리 150.0 양양군 손양면 오산리 150.0 양양군 손양면 수산리 150.0 [경상북도] 4개소 영덕군 남정면 부흥리 150.0 포항시 남구 영암1리 150.0 포항시 남구 장길리 150.0 경주시 감포읍 나정2리 150.0	[인천광역시] 1개소 옹진군 백령면 백령도(연화리) 160.0 [충청남도] 1개소 태안군 근흥면 도황리 5.0	[경상남도] 2개소 거제시 일운면 구조라·망치리 160.0 남해군 미조면 송정·금포·천하 160.0 [전라남도] 2개소 여수시 삼산면 손죽도 160.0 여수시 남면 안도리 160.0	[제주도] 5개소 제주시 한경면 두모리 161.3 제주시 구좌읍 월정리 322.0 서귀포시 남원읍 위미2리 320.0 서귀포시 성산읍 성산리 138.9 서귀포시 성산읍 시흥리 246.0

<Table 1-3> Continued

Sea / Year	East Sea	West Sea	South Sea	Jeju
2018	[강원도] 5개소 양양군 인구리 150.0 양양군 하광정리 150.0 삼척시 덕산리 150.0 고성군 가진리 150.0 고성군 대진리 150.0 [경상북도] 3개소 영덕군 금곡리 150.0 울진군 거일2리 150.0 영덕군 대진1리 150.0 [울산광역시] 1개소 울주군 서생면 대송리(평동) 160.0	[전라북도] 1개소 군산시 옥도면 신시도 10.0	[경상남도] 3개소 통영시 사이도 160.0 통영시 능양 160.0 통영시 우도 160.0 [전라남도] 1개소 여수시 동도리 160.0	[제주도] 6개소 제주시 오봉리1 138.0 제주시 오봉리2 160.0 제주시 오봉리3 160.0 제주시 종달리 160.0 서귀포시 삼달·신산리 157.0 서귀포시 신천리 322.6
2019	[강원도] 2개소 고성군 문암1리 151.59 양양군 전진1리 151.94 [경상북도] 5개소 영덕군 경정리 155.26 포항시 지경리 155.68 포항시 조사리 155.77 포항시 이가리1 155.82 포항시 이가리2 155.85	[경기도] 1개소 안산시 대부도 5.0 [인천광역시] 6개소 옹진군 대청면 대청도(선진동) 153.1 옹진군 대청면 대청도 10.0 옹진군 덕적면 굴업도 154.14 옹진군 덕적면 굴업도 10.0 옹진군 자월면 승봉도 10.0 옹진군 백령면 백령도(남3리) 152.91 [전라북도] 1개소 군산시 옥도면 관리도 104.0	[경상남도] 1개소 고성군 춘암리(안장섬) 160.0 [전라남도] 2개소 여수시 역만도 160.0 완도군 황제도 160.0	[제주도] 6개소 제주시 고산리1 161.52 제주시 고산리2 161.54 제주시 고산리3 161.56 제주시 고산리4 161.59 제주시 고산리5 161.58 서귀포시 신산리 161.28

6. Long-term direction for the Marine Forest Project

The direction of policy of the Marine Forest Project is suggested as one of the five detailed tasks in the area of focus of the fishery resource management implementation plan, 4. the habitat of fishery resources and the management of the ecological environment. However, there is a limit to the project that deals with the entire coastal ecosystem.

Therefore, we propose a long-term direction that considers domestic and international environmental changes and fishery resource management policies for the efficient and successful implementation of the Marine Forest Project. It is also necessary to derive strategic directions to secure the feasibility of sustainable budget investment.

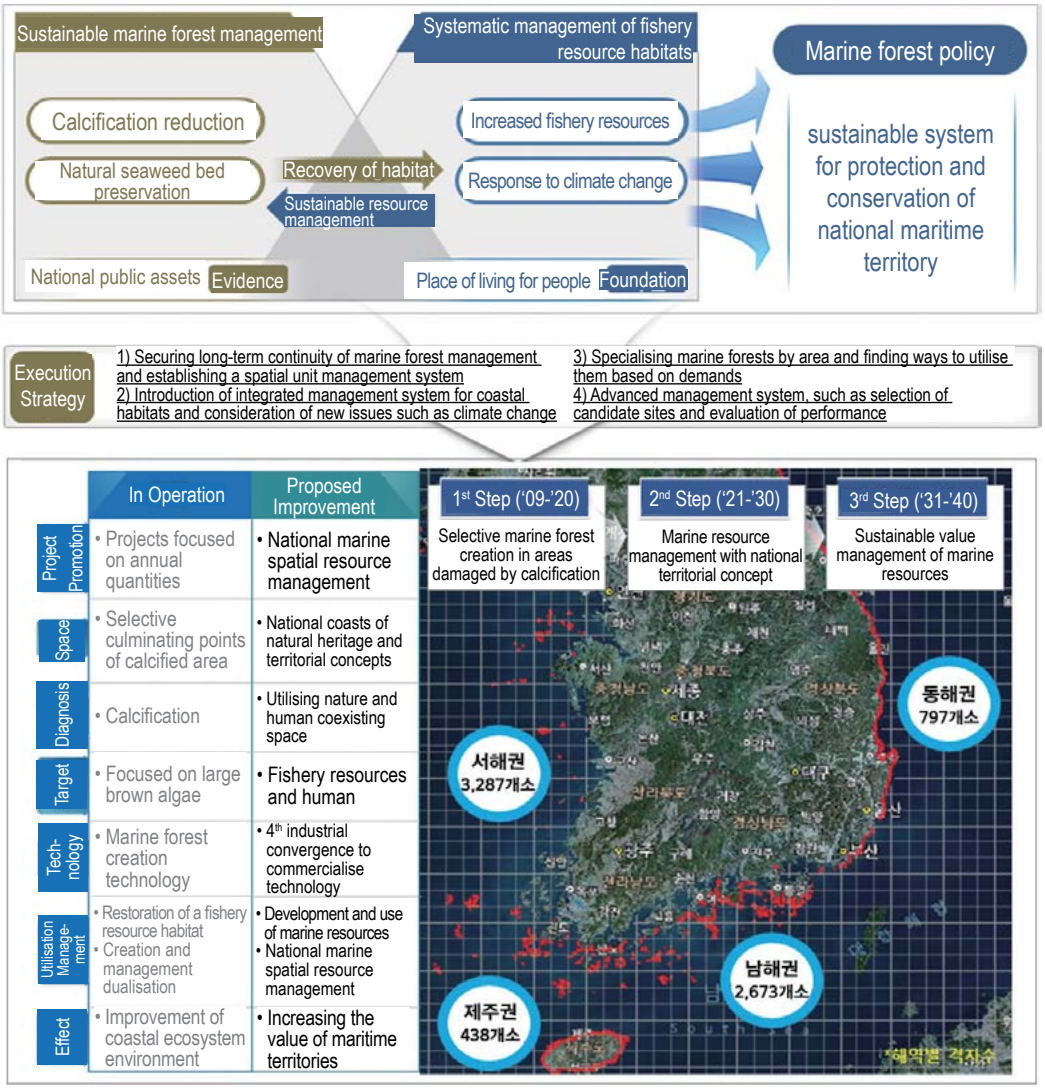
<Table 1-4> Long-term vision, goals and strategies

Vision	Spreading the value of marine forests as a place of national territory and people's lives and leisure - Realisation of national maritime territory, people's marine forests, and healthy coastal ecosystems -
Goal	▷ (Management) National territorial concept marine forests' integrated management and continuous expansion ▷ (Response) Proactive response to natural and artificial long-term fluctuation factors and realisation of value of service ▷ (Target) 54,000ha of marine forest on the coast of Korea by 2030

4 Strategic Objectives and Key Tasks	
1. Establishment of national core value marine forest per unit management system	① Securing the spatio-temporal continuity of the national marine forest - Transition of grid unit management for integrated management of national core space - Strengthening of coastal sea forest ecosystem diagnosis and evaluation system ② Creating marine forests based on ecosystem - Expansion of marine forest development sites and diversification of target species - Specialisation of target sea areas in consideration of ecological, social and economic conditions
2. Enhancement of national marine forest management efficiency	① Improving the resilience and health of national marine forests. - Maintaining natural seaweeds and securing sustainable productivity - Maximising calcification improvement and strengthening natural resilience. ② Advancement of applied technology and enhanced on-site performance - Specialisation of applied technology in consideration of target site environment and target species characteristics - Strengthening the applied technology verification system and establishing Test-Bed
3. Securing technology to predict, reduce, and adapt to long-term fluctuation factors	① Response to natural and artificial long-term fluctuation factors - Development of reduction and adaptation technologies according to the impact of climate change - Operation of the Kuroshio impact area monitoring system. ② Establishment of a comprehensive information system for coastal ecosystems from the fisheries resource management perspective - Establishment of comprehensive information on marine forests linked to fisheries resources information system - Prediction of factors influencing marine forests and derivation of response scenarios
4. The 6th industrialisation of marine forest and expansion of autonomous management system	① Realising the value of marine forest services - Increased production of fishery resources in the target area and contributing regional specialisation - Linking to revitalisation of the 6th regional industry such as tourism ② Establishment of a citizen-participating autonomous management network - Establishment of a cooperative system for stakeholders and the general public (volunteers, etc.) - Linking to regional job creation and response to aging population

☐ Basic Direction

(Paradigm) utilising marine space for use, protection and production based on marine forests
(Operational direction) Increasing the value of coastal marine territories through three-dimensional management of marine forests
(Strategy) Coastal grid-based marine ecological space resource management roadmap



<Image 1-8> Long-term road map of Marine Forest Project

제 II 장 바다숲 사업 추진 절차

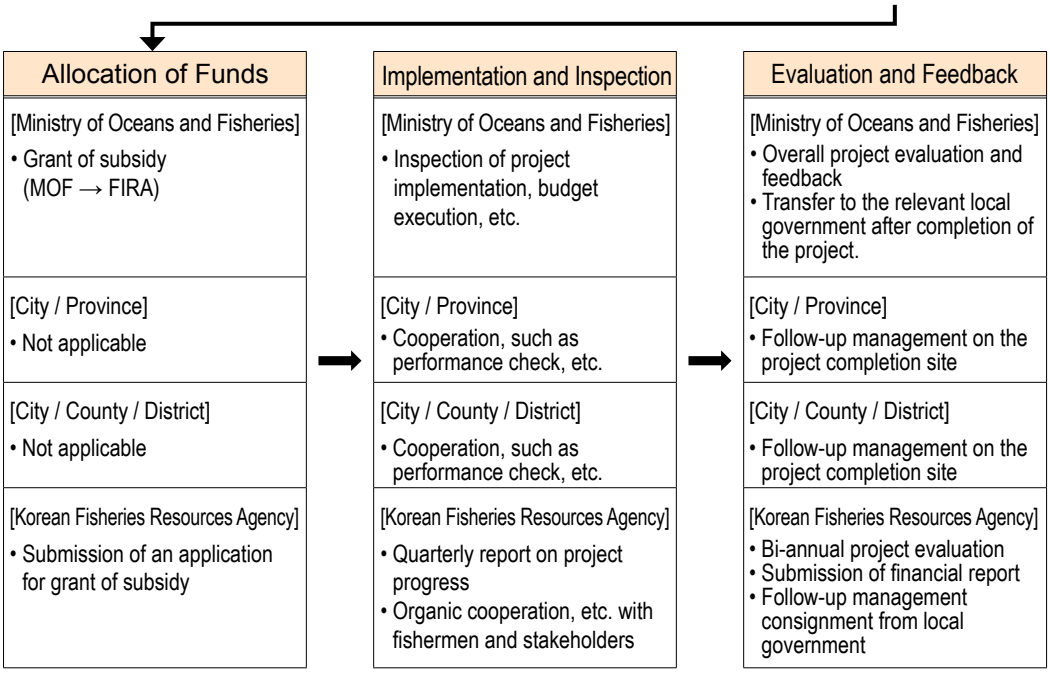
1. 사업신청 단계
2. 사업선정 단계
3. 계획수립 및 시행 단계
4. 자금배정 단계
5. 사업이행 및 점검 단계
6. 사업평가 및 환류 단계

Chapter II
Marine Forest Project Procedure

The Marine Forest Project is carried out by the Ministry of Oceans and Fisheries' guidelines for marine and fisheries projects (marine forest development management). The project consists of a project application stage, selection stage, planning and implementation stage, funding allocation stage, project implementation and inspection stage, and evaluation and feedback. The roles of the agencies in charge under the standard process (SP) are as follows.

<Table 2-1> Marine Forest Project procedure

Project Application	Project Selection	Planning and Implementation
[Ministry of Oceans and Fisheries] • Announcement of project guidelines	[Ministry of Oceans and Fisheries] • Formation of the Marine Forest Selection Committee to select the project site	[Ministry of Oceans and Fisheries] • Approval of the Marine Forest Project Plan • Approval of detailed plans for the Marine Forest Project by FIRA
[City / Province] • Prioritise among the waters recommended by city/provincial government and recommend to FIRA	[City / Province] • Not applicable	[City / Province] • Not applicable
[City / County / District] • Recommend areas for the project from the list of candidate sites for the Marine Forest Project to the city/ provincial government	[City / County / District] • Not applicable	[City / County / District] • Not applicable
[Korean Fisheries Resources Agency] • City/province recommended list and required documents are collected and submitted to the Ministry of Oceans and Fisheries	[Korean Fisheries Resources Agency] • Presenting the survey result and evaluation of project candidate sites, etc.	[Korean Fisheries Resources Agency] • Establishment of detailed plans for Marine Forest Project



1. Project application stage

□ Ministry of Oceans and Fisheries (MOF)

○ MOF annually announces the project promotion plan, including financial investment plans and project requirements for marine forest development projects.

○ MOF comprehensively analyses project performance, financial conditions, and marine environment by sea area and announces the size of the project.

□ City/Province and City/County/District

○ A city/county/district selects the desired area from the candidate site list of Marine Forest Project prepared by the Korea Fisheries Resources (FIRA) and recommends it to the city/province along with a list of recommended sites for the Marine Forest Project and the consent form for the designation of fishery resource management area from the local fishing community.

○ Cities and provinces determine the priority among the waters recommended by the cities, counties, and districts and recommend them to FIRA.

○ Required documents

– 1 copy of recommendation for candidate site for the Marine Forest Project

– 1 copy of the agreement on the designation of fishery resource management area and consent form from fishermen (including signature)

☐ Korea Fisheries Resources Agency (FIRA)

○ FIRA collects the results of the survey and evaluation of project candidates for each sea area and submits the recommendation list from cities and provinces and other documents to the Ministry of Oceans and Fisheries.

2. Project selection stage

☐ Ministry of Oceans and Fisheries (MOF)

○ MOF comprehensively inspects the result of the survey and evaluation of the candidate sites, the list of recommendations from cities and provinces and other documents submitted by FIRA and selects water areas with optimal conditions as a project site.

○ Selection method

– The "Marine Forest Selection Committee" is formed with up to 10 experts from MOF, FIRA, academia, and research institutes, and the committee selects the sites referring to the results of the investigation and evaluation of candidate sites for the project, the recommendation list, and other documents.

○ Selection priority

– Water areas that require government policy consideration for calcification

– Water areas where marine forests can be developed by utilising and improving natural bedrocks rather than artificial reef installation, etc.

– Areas where cooperation is active, such as participation of fishing villages and/or designated as fishery resource management area by the local government.

– Areas requested by the local government where the site is in the designated fishery resource management area, and the follow-up management of the site is excellent.

– Water areas with high utilisation as a water-friendly space such as easy accessibility and ecological experience.
– Water areas that can be reselected from among the recommended areas in the previous year.
– Local governments that do not properly perform follow-up management of Stock Enhancement Program-related projects (artificial reef projects, fishery seed discharge projects, etc.) are excluded from the project funding.

❊ Be sure to comply with the management expenses of artificial reefs, such as securing at least 15% of artificial reef project expenses for the relevant year and at least 10% of release project expenses for the relevant year.

☐ Korea Fisheries Resources Agency (FIRA)

○ In the "Marine Forest Selection Committee" held by the MOF, FIRA presents the results of the investigation and evaluation of project candidate sites, recommendations from cities and provinces, and related information such as required documents.

3. Planning and implementation stage

☐ Ministry of Oceans and Fisheries (MOF)

○ When Marine Forest Project sites are selected, a "marine forest development management project plan" is established within the scope of the secured budget.
– The project plan includes a project outline, business plan and investment plan for each sector (marine forest creation management, natural seaweed bed protection and conservation, technology development project, consensus formation, etc.)

○ To ensure the smooth implementation of the project, occasionally the project sites are inspected, and various business consultations are held, etc be held.

☐ Korea Fisheries Resources Agency (FIRA)

○ Establishment of a detailed project plan for the relevant year under MOF's "Marine Forest Project Plan".
– When a detailed project plan for the relevant year is established, it will be finalised with approval from the MOF

- Detailed project plans for the relevant year include the scope of the development area, facility area, construction method, management method, monitoring and survey of efficacy, technology development and consensus formation, all based on basic surveys such as the seabed topography, marine environment, and ecological characteristics of the target water area.
- Each year, FIRA establishes detailed action plans for each sea area following the "detailed project plans" for the relevant year, and carries out projects according to the characteristics of each sea area, such as the purity, ecology, and marine environment of the creatures in the marine forest.

○ Notes for establishing detailed project plans

- Detailed project plans to be formulated in an optimal way for the main development method suitable for the characteristics of each sea area, and for the stable maintenance of the marine forest and the expansion of its effects.
- To establish management plans such as target sites, diagnosis and evaluation survey, and completion standards and procedures for finalising the development and management of marine forests.
- To establish the project plan with the preference of utilising and improving natural bedrock and eco-friendly methods (using eco-friendly materials, etc.)
- To establish a disaster (crisis) management system, such as systematic dissemination of current situation in the event of a disaster, countermeasures and damage response.

4. Funding allocation stage

□ Subsidy application and issuance

○ FIRA submits an application for a grant of subsidies to MOF.

○ A project plan must be attached to the application, and the plan must include specific matters necessary for project execution, such as project outline, project execution plan, budget execution plan.

□ Settlement and subsidy payment procedure

○ Upon completion of the subsidiary project or the end of the financial year, the FIRA submits the subsidy settlement to the project department of MOF within two months, along with a report on the performance of the subsidiary project for the relevant year and the budget statement detailing costs classified by items and details.

○ The project expenses are executed by budgetary accounting-related statutes, relevant regulations, and government budget compilation standards.

○ The subsidy grant application, decision (including cancellation and change), confirmation, grant conditions and subsidy execution procedures are subject to the 'Act on the Grants-in-aid Management' and 'Ministry of Oceans and Fisheries National Subsidy Management Regulations'.

○ When submitting the subsidiary project performance report, submit a financial report verified by an accounting firm, etc.

5. Project implementation and inspection stage

(OVERALL)

□ Ministry of Oceans and Fisheries (MOF)

○ MOF occasionally hold business councils, advisory meetings, etc. to guide and inspect marine forests so that the project can smoothly proceed.

○ MOF reviews the details of the project completion reported by FIRA (diagnosis/evaluation survey results and committee meeting results) and makes a final decision on the completion of the Marine Forest Project (confirmed).

○ MOF transfers the completion of the project to the relevant local government for the stable maintenance and spread of the effects of marine forests.

○ In response to issues and crises (disasters) arising in the process of the project, according to the response system, identify the situation and instruct FIRA for solutions, or directly respond if necessary.

(PROJECT IMPLEMENTATION)

□ Korea Fisheries Resources Agency (FIRA)

○ FIRA conducts development and management for 4 years for the individual project area.

❊ Management can be terminated early if the marine forest formation is stabilised within 4 years through monitoring, and the management period can be extended if additional management is needed (advance consultation with MOF)

○ After a Marine Forest Project is completed, FIRA reports to MOF the results

of diagnosis and evaluation survey, project history, completion reports, etc. of waters where the project has been finalised through the evaluation process.

❊ If it is deemed necessary to conduct follow-up management (monitoring, herbivore removal, seaweed transplantation, etc.) to maintain and expand the efficacy of the marine forest, FIRA will consult with the local government and actively cooperate with them.

○ FIRA holds project briefings, business councils, and discussions with MOF, local governments, relevant agencies, and fishermen in the process of the Marine Forest Project.

○ FIRA carries out the creation of marine forests in consideration of the characteristics of the sea area and conditions of marine algae, etc. under the marine forest development plan.

– Marine forest development is a project to restore coastal ecosystems and habitats of fishery resources. Marine forests are created according to the characteristics of the sea area, including seaweed forests, algae forests, and coral forests.

– The seaweed forest development methods include restoring calcified bedrock and expanding seaweed-covered bedrock area (rock cleaning, installing seaweed seedling plates, replanting and reserving seaweeds, installing artificial reefs, natural stones), and creating seaweed spore releasing grounds (mid-water rope culture system and spore bags, etc.), herbivore density control, environment improvement, etc. These methods are to be performed in consideration of the reproduction and spread of target organisms according to the characteristics of the sea.

– To prioritise the method of utilising and improving natural bedrock, when developing a marine forest.

– Among perennial (Ecklonia cava, Ecklonia stolonifera, gulfweed, kelp, etc.) and annual (sea mustard, five-ribbed kelp, etc.), target seaweeds are selected to have the greatest effect according to the characteristics of the sea.

– To secure algae and seaweed seeds, preparation is necessary with detailed action plans, such as private contract cultivation, self-production, and approval of collection by the local authority.

– Artificial reefs for marine forest development is selected after deliberation of the "Artificial Reef Selection Committee for Marine Forest Project" in consideration of factors such as efficiency, stability, and economic feasibility.

❊ Selection can be carried out under MOF ordinance 'Artificial Reef Installation Project Execution and Management Regulations', and can request a specialised agency to supervise the production, design and installation.

○ Regular and frequent monitoring to increase the efficacy of marine forest development.
  – Monitoring: survey of calcification resolution rate, seaweed succession and biota change, growth and survival rate of transplanted seaweed, stability of planted artificial reefs and epiphytes biota, etc.

○ Protecting and spreading the formed marine forest by maintaining the habitat density of herbivores (sea urchins, snails, sea hares, etc.) below a certain level.
  – In particular, removal efforts are carried out frequently in the year when marine forests are created to enhance the seaweeds' survival.
    ❊ Encourage active participation of the fishing community ('haenyo' female divers for shallow water and professional divers and self-managed fishing boat for deep water herbivore removal)

○ Supplemental plantation if the growth and survival rate of transplanted seaweeds is poor.
  – Supplemental plantation, if the growth is significantly lower than other seaweeds or the survival rate is less than 50% compared to the time of formation, due to external environment such as natural disasters.

○ A seaweed breeding facility (authorised by local governments as a research centre) can be served as a seed bank, such as preserving the established marine forest and supplying food for herbivores.
  – The facility may be entrusted to the local fishing village for continuous and efficient management.

○ Efforts to reduce waste such as plastic by collecting and disposing of derelict fishing gear and wastes that hinder the growth of seaweeds in marine forests and expanding the use of eco-friendly materials.

○ Securing facility stability by maintaining and repairing facilities to be prepared for natural disasters (typhoon, etc.).

□ City/Province and City/County/District

○ The relevant local government for the development of marine forests, the staff in charge is designated to actively cooperate at each stage of the project and establish an organic cooperation system with fishing villages, etc.
  – The relevant local government to attend various project briefings, business councils, and advisory meetings according to the guideline and to actively support the Marine Forest Projects.

○ To smoothly secure seaweed and seagrass seedlings in the development of marine forests, the administrative authority to actively cooperate with the approval for collection, etc.

○ The relevant local government to organise budgets for stable maintenance and expansion of marine forests and carry out active follow-up management according to MOF to the project completion transfer.

(INSPECTION)

☐ Ministry of Oceans and Fisheries (MOF)

○ MOF checks whether the installation of artificial reefs for marine forests, seaweed transplantation, and other development are carried out promptly and requests for corrective actions when problems arise.

○ Each quarter, project performance, results, and budget execution are checked.

☐ Korea Fisheries Resources Agency (FIRA)

○ FIRA reports the results of project implementation, performance, budget execution, etc. to MOF on a quarterly basis.

(SANCTIONS)

☐ Ministry of Oceans and Fisheries (MOF)

○ In the event of illegal activity or illegal execution of the project budget, the related project is suspended and the project budget is recovered.

○ Penalties are given if selected project sites for the following year, had a history of insufficient corrective action and follow-up management for water areas in which there are project delays and poor performance.

6. Project evaluation and feedback stage

(PROJECT EVALUATION)

☐ Ministry of Oceans and Fisheries (MOF)

○ According to the detailed project plan, MOF participates in or checks the evaluation so that FIRA conducts interim and final evaluations and project performance evaluation on time and analyses the results.

☐ Korea Fisheries Resources Agency (FIRA)

○ FIRA assesses the entire process of the project twice a year (interim, final).
– Interim evaluation (July) and final evaluation (December)

- At least 7 evaluation committee members, consisting of external evaluation committee members.
- The details of the evaluation are comprehensively assessed on project promotion plan establishment, project performance and results, budget execution performance, etc.

○ Report interim and final assessments to MOF.

(PERFORMANCE MEASUREMENT)

☐ Ministry of Oceans and Fisheries (MOF)

○ As of the end of the year, MOF measures the achievement of the performance target against the project plan and the achievement of the target value of the performance indicator.

(FEEDBACK)

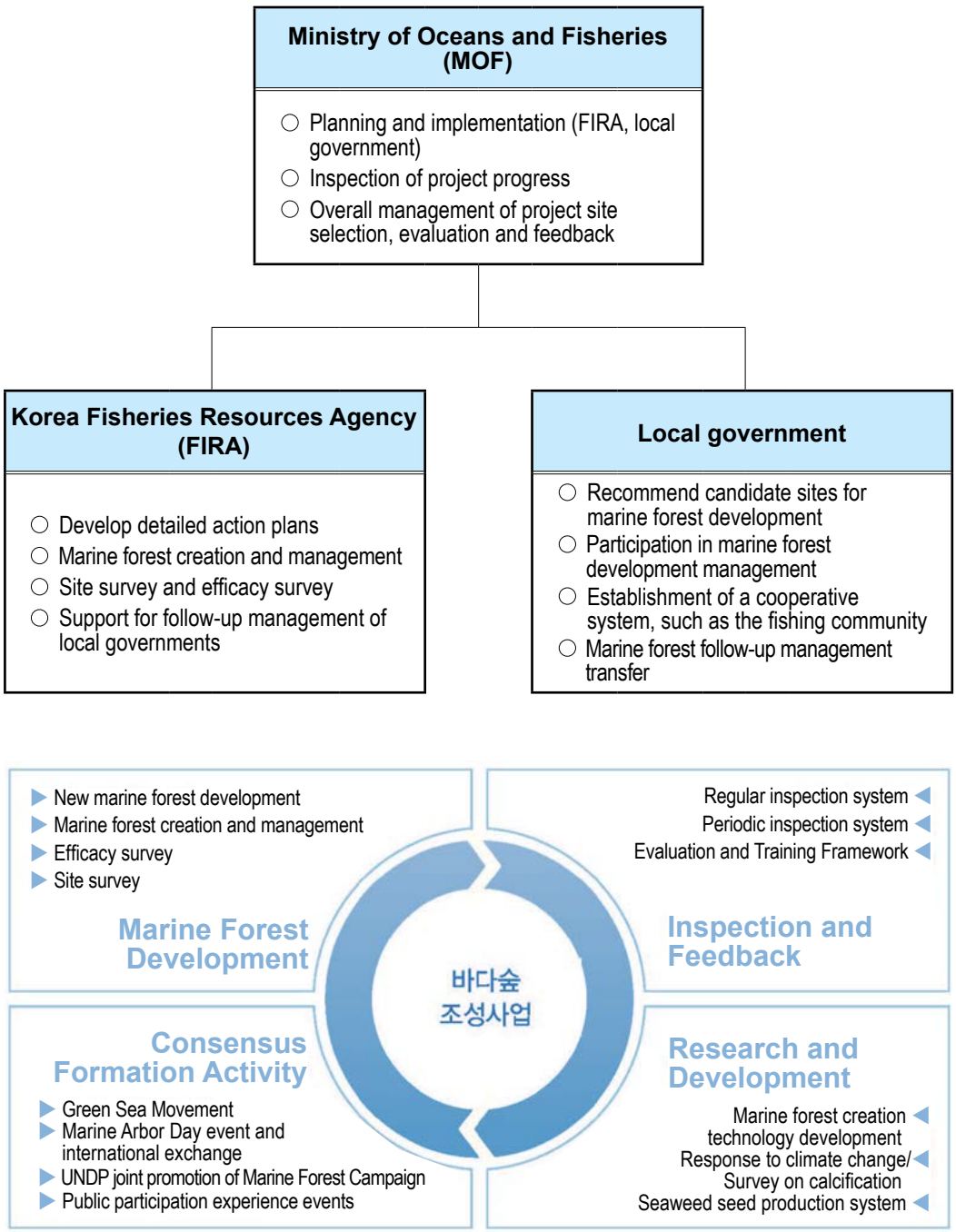
☐ Ministry of Oceans and Fisheries (MOF)

○ Corrective measures such as strengthening marine forest management etc. through cause analysis for water areas with project delays and poor performance.

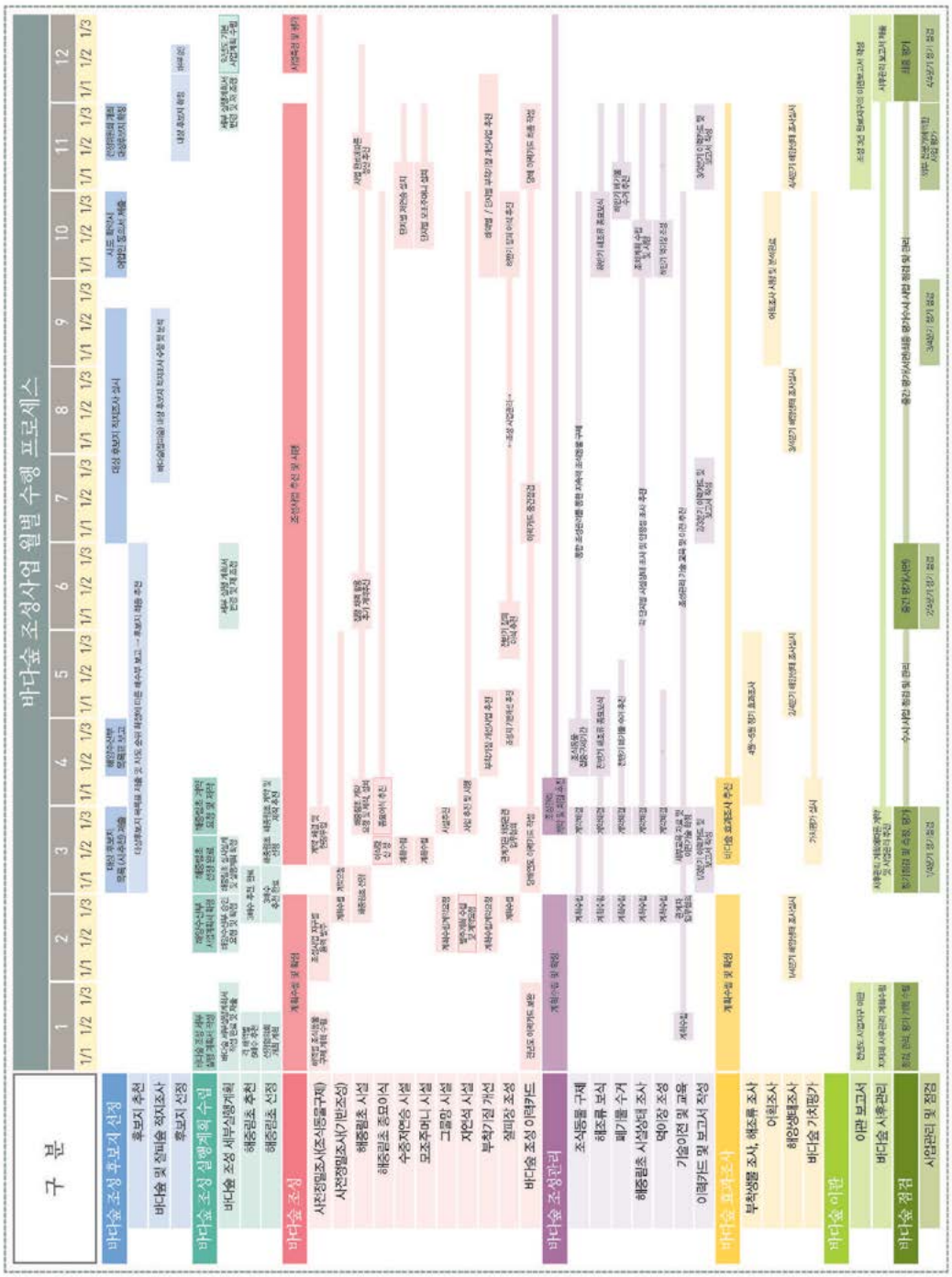
○ Reflecting improvement measures in the next year's project plan through analysis of evaluation results.

☐ Korea Fisheries Resources Agency (FIRA)

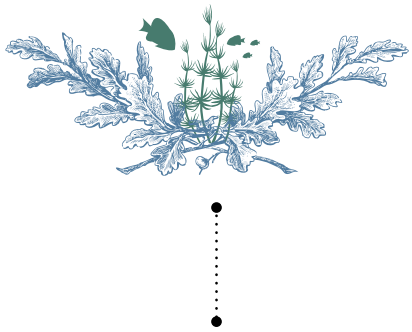
○ Project plan revision and improvement plans are reflected in the next year's project plan through analysis of evaluation results.



<Image 2-1> Project system diagram



<Image 2-2> Monthly project process



제Ⅲ장 바다숲 조성지 선정

1. 바다숲 적지조사 대상지 선정
2. 적지조사 및 기본계획 수립
3. 바다숲 조성 후보지 추천 및 조성지 선정

Chapter III
Selection of Marine Forest Sites

In order to restore coastal ecosystems and habitats for fishery resources through the development of marine forests, marine forests are created on a large scale in the coastal areas across the country. Marine forests development sites are selected every year targeting areas that are calcified and require marine forests.

As shown in the table below, the procedure for selecting a sea area for the marine forest development consists of the process of selecting appropriate sites, site survey and basic planning, recommending candidate sites, and marine forest development site selection.

<Table 3-1> Marine forest sites selection procedure

Classification	Note
Submission of candidate sites for survey (Mar-Apr)	■ FIRA (HQ): Site selection based on survey results of calcification. ■ FIRA (Sea Branch): Submit candidate sites for site survey to the head office based on hyperspectral aerial image data, water depth data (chart, etc.), marine environment data (national marine environmental monitoring system, etc.), and ideas from local governments.
⇩	
Review of the candidate sites for survey (Apr-May)	■ FIRA (HQ): Review of the feasibility of candidate sites for site survey (project conditions, exclude local governments that did not perform follow-up management, etc.) and consultation with MOF. * When selecting a site, HQ consults with the sea branches.
⇩	
Selection of sites for survey (May)	■ FIRA (HQ): Select sites for survey and report it to the relevant sea branches.
⇩	
Site survey and basic planning (Jun-Sep*following year)	■ Survey Items: Meteorological characteristics, social factors, marine environment, habitat, seabed topography, seabed quality, calcification progress, etc. ■ Four season surveys (spring, summer, autumn, winter) ■ Analysis of site survey results and drafting of basic plan
⇩	
Recommendation of candidate sites for Marine Forest Project (Sep-Oct)	■ FIRA (Sea Branch): Request for candidate site recommendation from the list of candidate sites derived from the site survey results to the local government ■ Local government: Review the list of candidate sites of the FIRA and recommend candidate sites for marine forest development (including required documents such as confirmation of management water area designation, fishermen consent, etc.) ■ FIRA (HQ): Survey result of marine forest development candidate sites and the list of local government recommendations is reported to MOF ■ MOF: Comprehensive review of project candidate site survey results and recommendation list
⇩	
Selecting Marine Forest Project sites (Nov)	■ MOF: Final selection of the site via Marine Forest Selection Committee. ■ FIRA: Present the results of the site survey and the plan for the development.

1. Marine forest candidate sites survey and site selection

A. Submission of candidate sites for survey

○ FIRA Headquarters (Ecological Restoration Team) requests submission of candidate sites to conduct site surveys to develop marine forests two years later, to the FIRA sea branches.

– According to the survey result on the actual conditions of calcification, areas are selected in the order of the highest calcified area (progress rate).

– Provides hyperspectral aerial imaging data on the actual condition (surveyed annually since 2013) to the sea branches to determine the area of rock mass and calcification, etc.

○ The FIRA sea branches select candidate sites for site surveys and submit them to the head office after reviewing possible conditions based on the hyperspectral aerial imaging data, water depth data (charts, etc.), marine environment data (national marine environmental monitoring system, etc.) and suggestions from local governments.

– Conducts preliminary surveys such as grid number and area, water depth, calcification distribution map, environmental characteristics, area of calcification, distribution of bottom sediments, pollutant source, construction progress, urban development plan, distribution of seaweed in the past and change patterns, and the public's compliance rate on the Marine Forest Project.

– Submission of data on marine forest candidate site survey <Table 3-2>.

B. Review of candidate sites for the survey and site selection

○ FIRA Headquarters conducts a feasibility review for candidate sites for site investigation submitted by the sea branches.

– Current status of target sites such as calcification and environment, also project implementation conditions, etc.

– Whether or not a municipality (city/county/district) with a history of poor follow-up management of marine forest site is included.

❊ Excluded from candidate sites for site survey if the local government has a poor follow-up management history.

○ After reviewing the candidate sites, prepare a target site (plan) for the site survey (selection of the site for the site survey to be 1.5 to 2 times the marine forest development plan).

○ Consultation with MOF on the site survey.

○ Notifying the result of the selection of sites for the marine forest site survey.

<Table 3-2> Marine forest sites survey data

○○ Candidate Site for Marine Forest Project (year0000)					
(○○ Province, ○○ City / County, ○○ Town Water Area)					
Grid Number		Grid Area	ha		
Current status of water depth and calcification distribution in candidate sites					
(Bathymetric Map)		(Calcification Distribution Plot)			
Environmental characteristics (average data for the last three years)					
Water Temp(°C)	Salinity(psu)	pH	DO(mg/L)	Transparency(m)	Suspended Solids (mg/L)
DIN(μg/L)	DIP(μg/L)	Current(m/s)	Rainfall(mm)	Sunlight(hr/yr)	Water Quality (WQI)
Distribution of Bottom Sediments (refer to hyperspectral data/ if none, leave it blank)	Water Area: ha(%)		Rock Mass: ha(%)		Non-rock: ha(%)
Calcification Area (refer to hyperspectral data/ if none, leave it blank)	Normal		In Progress		Intensified
	ha(%)		ha(%)		ha(%)
Pollution Source					
Development progress (finished within 3 years or ongoing development and sand excavation, etc)					
Urban Development (long-term) Plan					
Past seaweed distribution and change patterns					
Reaction to Marine Forest Project					

2. Site survey and basic planning

A. Site survey period

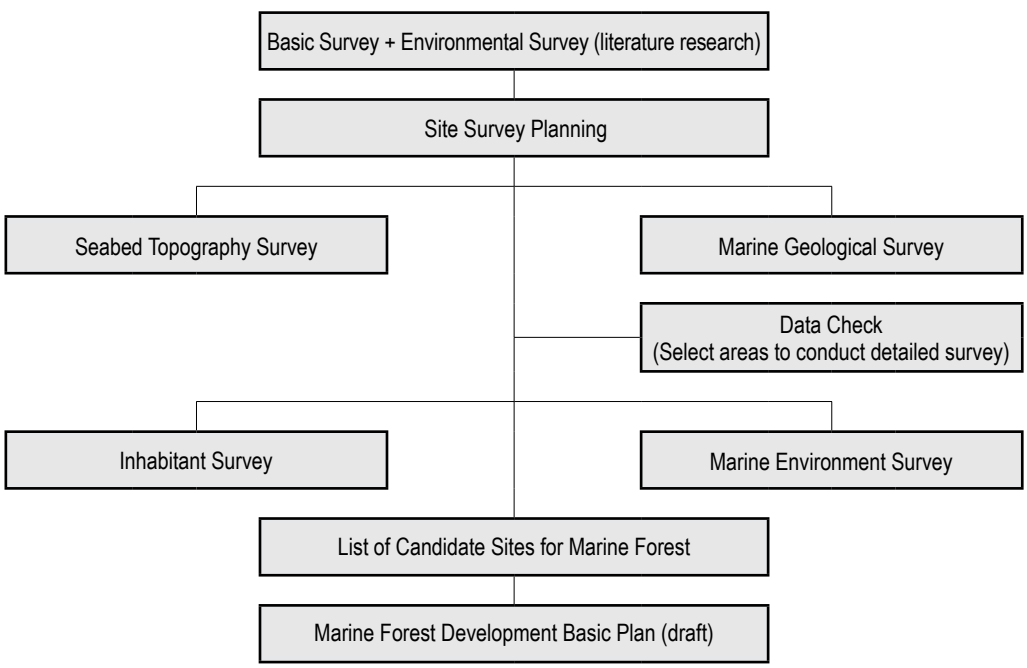
○ Until September of the following year after the site selection.

B. Survey area

○ Survey area: Water surface area (10 to 165ha) of each grid subject to survey.
○ Specialised marine forests such as eelgrass forests and halophytes are separately calculated for the survey area.

C. Order of site survey and basic planning

○ Site survey planning (fishing community opinion research, literature research, etc.)
○ Site survey (seabed topography, sediment, inhabitant, marine environment, etc)
○ Preparation of a list of marine forest candidate sites and a basic plan.



<Image 3-1> Marine forest site survey and basic planning flowchart

D. Marine forest site survey

○ Meteorological survey (literature research)
- Research the data for the last 5 years in the sea area to be surveyed.
- Average temperature, average rainfall, sunlight, typhoon occurrence frequency, solar insolation, waves, and wave height are investigated.

○ Social factor survey (literature research)
- The current status of fishing rights and fishing population in the waters subject to the survey is researched.
- Research past and present algae (seaweed) habitat status.
- Research whether fisheries resource development projects such as marine forests, marine ranches, and seaweed forests are carried out.
- Research urban development plans and pollution sources in the sea area to be surveyed.

○ Marine environment survey
- By using the marine environmental monitoring system provided by the Marine Environment Information System (MEIS), data (quarterly) for the last five years of the survey target sea area are investigated.

  ❊ Transparency, Water Temperature, Salinity, Chemical Oxygen Demand, Hydrogen Ion Potential, Dissolved Oxygen, Dissolved Inorganic Nitrogen, Dissolved Inorganic Phosphate, Silicate Silicon, Suspended Solids, Chlorophyll-a, Water Quality (WQI).

<Table 3-3> Marine environment survey results (last 5 years)

Point	Year	Month	Transparency (m)	Water Temp (°C)		Salinity		Hydrogen Ion Potential		Dissolved Oxygen (mg/L)		Chemical Oxygen Demend (mg/L)		Dissolved Inorganic Nitrogen (μg/L)		Dissolved Inorganic Phosphate (μg/L)		Silicate Silicon (μg/L)		Suspended Soilds (mg/L)		Chlorophyll-a (mg/L)		Water Quality Index (WQI)
				Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	

– The physical characteristics (flow velocity and direction of flow) of the sea area are investigated using the digital tidal current map of the Korea Hydrographic and Oceanographic Agency.

– On-site surveys are conducted by setting two points in the sea area on a quarterly basis (Feb, May, Aug & Oct)
– Water temperature, salinity, Hydrogen Ion potential, dissolved Oxygen (mg/L), and transparency of the surface layer and the bottom layer are measured using a device such as YSI and a Secchi disc.

❊ Calculation of the amount of light from the transparency measurement

– Seawater in the surface and bottom layers is collected and analysed for dissolved inorganic nitrogen, dissolved inorganic phosphorus, suspended solids, and chlorophyll-a using the Korean Standard Method for Marine Environment.
– Calculate the water quality index (WQI) based on the field survey results.

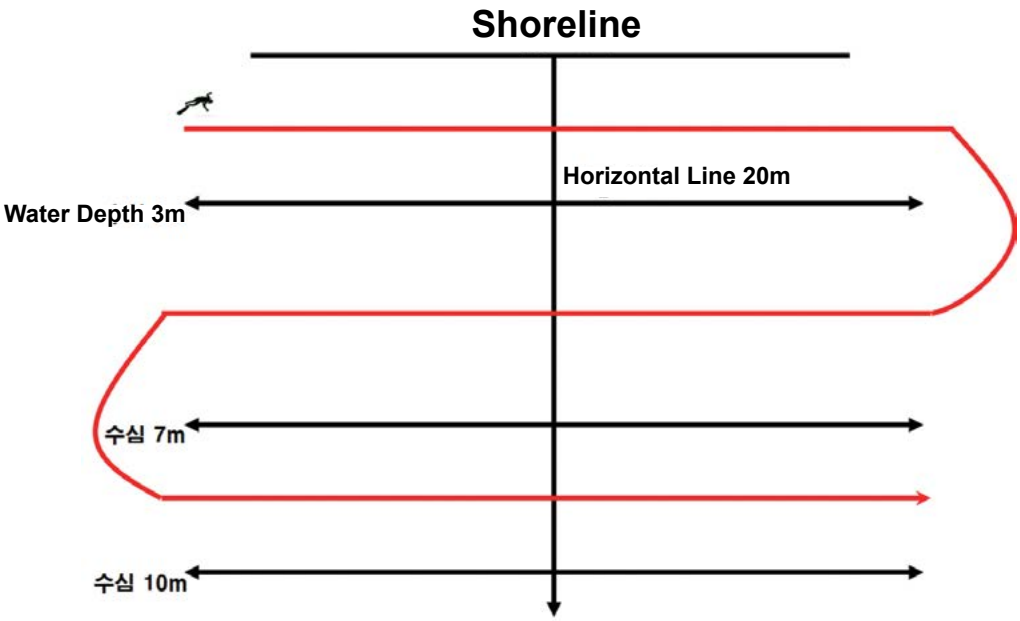
<Table 3-4> Marine environment survey results (field survey results)

Survey Period (Month)	Point	Trans-parency (m)	Water Temp (°C)		Salinity		Hydro-gen Ion Potential		Dissolved Oxygen (mg/L)		Dissolved Inorganic Nitrogen (μg/L)		Dissolved Inorganic Phosphate (μg/L)		Suspend-ed Soilds (mg/L)		Chloro-phyll-a (mg/L)		Water Quality Index (WQI)
			Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	Surface	Bottom	

○ Inhabitant survey (seaweeds and macrozoobenthos)

– On-site surveys are conducted in the target sea areas on a quarterly basis (Feb, May, Aug & Oct)
– Three vertical lines are set based on the shoreline following the Line Transect Method, and three horizontal lines 20m long are installed on each vertical line (water depth 3, 7 and 10m).

❊ The surveyed water depth is based on the approximate lowest low water, and horizontal line water depth can be changed considering the characteristics of each sea area.



<Image 3-2> Line installation and survey method (Line Transect Method)

- Underwater video footage is taken for more than 20 minutes along the vertical and horizontal lines.
- Still images should be wide-angle and captured images from a video are prohibited. A close-up photograph should portrait an identifiable inhabitant.
- Photographs/videos are taken using a diving computer or a fathometer to check the depth of the water.
- Quadrat (50×50cm) are installed at 3 fixed points for each vertical line (1 point per depth zone), and after underwater videography of the quadrats, all samples in the quadrats are collected using the destructive sampling method.
- For the analysis of coverage, the whole (50×50cm) and section (25×25cm) close-up shots are fixed for several seconds for each quadrat, and still images are also photographed in parallel (shooting from the vertical direction of the quadrat, no side shooting).
  ❊ If it is impossible to check the algae (seaweed) form due to sediments, remove them before shooting.
- When collecting samples, use a net with a mesh size no larger than 1 mm.
  ❊ Prevent small and light creatures from being lost underwater.
- The nine collection nets (seaweeds + zoobenthos) that have been collected for each area of the survey are separated and placed in a 3L plastic sample container and fixed with 10% formalin (10 formalin + 90 seawater), and the collection information is clearly displayed.

<Table 3-5> Marine organism sampling information form

Classification	Description	Note
Business Name	000	Seaweeds, macrozoobenthos With or without fixing agent Formalin (00%)
Date	00 / 00 / 0000	
Location	00 city 00 county 00 town sea area	
Collection Point	Line No. 00 / 0m	
	N00°00.000′, E00°00.000′	
Collector	Company : 0000000 / Collector: 000	

❊ Width 10cm × Length 7cm (Insert one inside of the sample bottle & attach one outside)

– Collected samples are identified by species by collection point, and the population size and biomass are measured (up to the second decimal place) and converted into units of $1m^2$.
– Calculate ecological status (species diversity, species evenness, abundance, dominance).
– Calculate the coverage, frequency, relative coverage, relative frequency, and important value of seaweeds and articulated/non-articulated coralline algae, and display as a percentage (%) of coverage per unit area ($1m^2$).

○ Inhabitant survey (herbivores)

– On-site surveys are conducted in the target sea areas on a quarterly basis (Feb, May, Aug & Oct)
– Select one point that can represent the distribution of herbivores by water depth (same as the above line-transect survey location), and survey the types and population of herbivores at each point in a 100×100cm quadrat, a total of 9 points survey).
❊ The survey targets are sea urchins, sea snails, abalone, and sea hares.
– Herbivorous fish (black rabbitfish, Japanese sawtail, largescale blackfish, thread-sail filefish and greenlings etc.) are visually observed to determine their species and population.

○ Multibeam echo sounder survey

– Water depth survey should be carried out in continuous echogram, preferably in calm weather, and the surveying ship should maintain a constant sailing speed.
– For the survey pitch, carefully establish the survey plan route by referring to the application criteria of the distance between soundings for each depth.

<Table 3-6> Application criteria of the distance between soundings by depth

Classification	Description	Note
Under 5m	(2.5m+Mean Sea Level)x3	For the mean sea level, the reference surface of the reference tide station nearby the local port is applied.
5m~10m미만	(7.5m+Mean Sea Level)x3	
10m~20m미만	(15m+Mean Sea Level)x3	
20m~30m미만	(25m+Mean Sea Level)x3	
30m~40m미만	(35m+Mean Sea Level)x3	
Over 40m	(Average Depth+Mean Sea Level)x3	

※ The average depth is applied according to the depth range (for seas over 40m, the sounding period is calculated separately depending on the equipment performance and the sea area environment conditions)

- Depth surveying should be investigated so that the mean sea level for each region is applied to ensure that the survey (swath) is conducted without any missing data within the task section.
  ※ Consult with the supervisor if swath bathymetry is unavailable.
- When underwater structures or facilities for fisheries resources such as artificial reefs are found during water depth surveying, the location, form, and specifications should be checked in detail.
- The measurement for sound velocity for the sound velocity correction should be conducted frequently according to the change in the local situation or profile.
- For the location of the sounding, the Differential Global Positioning System (DGPS) is used, and the error range should be accurately calibrated within ±1m.
- When processing the bathymetry survey data, corrections on water depth, sound speed, and tide, etc. must be made.
- Based on the survey results, the survey area map, bathymetric map, gradient, sediment distribution map, submarine topography map, and comprehensive information map are prepared.

○ Side-scan sonar image survey

- Using side-scan sonar, the seabed topography, underwater structures, etc. are identified.
- When underwater structures such as artificial reefs are discovered, the type and format must be clearly identified.
- When surveying, the appropriate swath width for each depth should be set so that the submarine terrain can be clearly identified when producing mosaic images.
- When surveying, the height of the sensor of the equipment and the speed of the survey vessel to be adjusted constantly in order to accurately identify

the survey object.

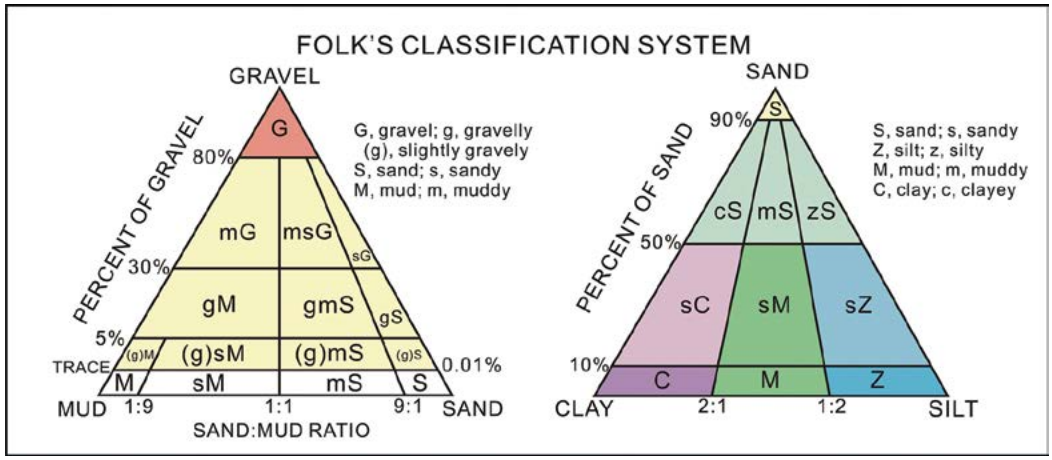
- In order to process seabed image data, correction of towing distance and gradient distance of location data and filtering (TVG, SF) correction should be performed.
- Mosaic processing of the seafloor image and comparison with the results of the depth survey are required, before submitting the results.
- Based on the survey results, the seafloor image map (mosaic) and a map of obstacles are prepared.

○ Marine obstacle survey

- In the sea area to be surveyed, marine structures (fish farms, fishing grounds, etc.) and distribution of rocks which do not cover/cover and uncover are identified.
- DGPS should be used to identify the exact location of the obstacles to produce a map of the obstacles.
- If offshore construction is being carried out, check the construction status, etc.

○ Seafloor sediment survey

- In order to identify the sediment grain size and distribution in each survey sea area, sediments are collected and analysed from 8 selected points.
- More than 600g of sediments per point is collected by bottom samplers (Grab), and the collected samples are sent to a specialised institution for analysis.
- The average grain size, degree of sorting, skewness, and sediment type, etc. are analysed using the "Folk & Ward" method. And areas with at least 70% mud are re-analysed by the unified classification method to calculate ground bearing capacity (see Chapter V, Technology No. 2017-01).



<Image 3-3> Triangular diagram for classification of surface sediments

○ Sediment quality survey
- On-site surveys are conducted in the targeted sea areas on a quarterly basis (Feb, May, Aug & Oct)
- The sediment conditions are recorded by survey depth (same as the location of the above line transect inhabitant survey).
- Depth of sediment is measured at four points per irradiation depth at each vertical line.

○ Calcification status survey
- On-site surveys are conducted to analyse calcification status in the target sea areas on a quarterly basis (Feb, May, Aug & Oct)
- When investigating the above inhabitants, the coverage percentage (%) per unit area ($1m^2$) of articulated/non-articulated coralline algae is identified by analysing images taken from quadrats at nine points for each surveyed sea area.
- The conditions of calcification are determined according to the criteria below.

<Table 3-7> Criteria for reporting current status of calcification

Calcification Stage	Reporting Criteria	Environmental Characteristics and Conditions
Normal	Less than 40% articulated/ non-articulated coralline algae coverage	■ Seaweed intake of herbivores: 30g/m^2/day ■ Number of herbivores (sea urchin): 5-10/m^2 ■ Marine algal flora – Decrease in large brown algae and perennial algae – Increase of small red algae
Progressing	40-80% articulated/ non-articulated coralline algae coverage	■ Seaweed intake of herbivores: 40-60g/m^2/day ■ Number of herbivores (sea urchin): 10-20/m^2 ■ Marine algal flora – Signs of large brown algae population loss – Small perennial red algae habitats formed
Calcified	Over 80% articulated/ non-articulated coralline algae coverage	■ Seaweed intake of herbivores: 70g/m^2/day ■ Number of herbivores (sea urchin): over 20 /m^2 ■ Marine algal flora – Loss of large brown algae population – Small perennial red algae habitats formed ❊ Excluding commercial resource factor

E. Eelgrass forest site survey

○ Survey for meteorological characteristics, social factors, marine environment, and seabed sediment quality.

→ Same as D. Marine forest site survey

○ Multibeam echo sounder survey, seafloor image, and marine obstacles survey

→ Same as D. Marine forest site survey. However, the water depth is low in eelgrass habitats (within 5m depth), so the survey method can be changed, such as skipping certain survey subjects or using drones, according to the survey conditions in each sea area.

○ Inhabitant survey (eelgrass habitat status)

– On-site surveys are conducted in the target sea areas on a quarterly basis (Feb, May, Aug & Oct).

❊ Pre-administrative processing such as permission is required in relation to the collection of eelgrass (endangered marine species).

– The area, density, and ecological characteristics of eelgrass colonies are surveyed. Both land and underwater surveys are conducted, and if necessary, a spectrography survey is done using a drone, etc.

– Underwater video footage should be at least 20 minutes per sea area.

– Still images should be wide-angle and captured images from a video are prohibited. A close-up photograph should portrait an identifiable inhabitant.

– Photographs/videos are taken using a diving computer or a fathometer to check the depth of water.

– The eelgrass distribution area is determined by calculating the internal area of the connecting line between each coordinate after finding the coordinates of the edge of the colony (this also can use spectroscopy).

– As for the density of the eelgrass habitat, the survey area that includes the eelgrass colony is divided into 9 zones. A quadrat (50×50cm) is installed at every point 10cm apart in each zone. And the positional coordinates of each quadrat are recorded.

❊ It is arranged considering the range where the eelgrass colony is exposed at low tide.

❊ The location is selected considering the centre and edges (north, east, south, and west) of the eelgrass colony.

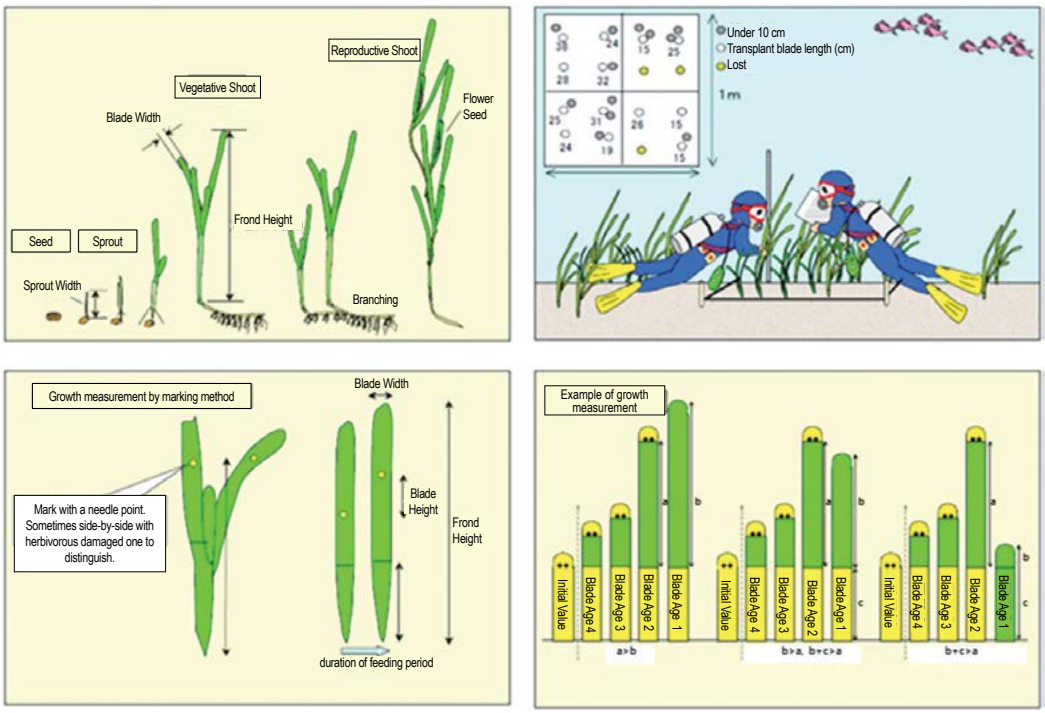
– The eelgrass population within quadrat in each zone is counted and converted to density (number/m^2).

– To understand the ecological characteristics of eelgrass, eelgrass is collected from each quadrat for 10 weeks and the number of blades (n), the length of the blade (cm), the length of the above-ground part (cm), the length of the below-ground part (cm), the length of frond (cm), the width of frond (mm), number of rootstock nodes (n) are measured.

– The wet weight and dry weight are measured by dividing the eelgrass samples into above-ground and below-ground sections. The wet weight (gwwt/m^2) is

measured after removing adherent matters and moisture as much as possible. For the dry weight (gDW/m^2), the samples without damage are cleaned and dried at 60°C for more than 24 hours before weighing them.

– The population per unit area is calculated by counting the vegetative shoots and reproductive shoots (flowering stocks).



<Image 3-4> Eelgrass habitat status survey method

○ Inhabitant survey (benthos & nekton)

– On-site surveys are conducted in the target sea areas on a quarterly basis (Feb, May, Aug & Oct).

– Benthos (zoobenthos, algae) and fish living in the sea area are surveyed.

– For collecting benthos, one point for each zone is set in the above-mentioned eelgrass habitat survey area (9 total) and samples are collected using Can Core (20×12.5×20cm) or Grab.

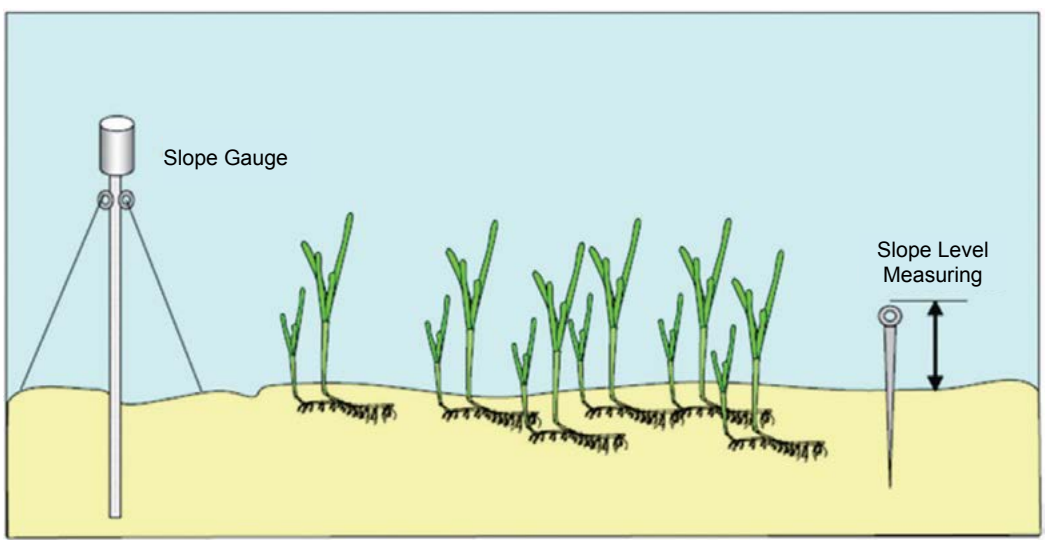
– After covering the blade part of eelgrasses with a collection net in the Core applied area, the growing point is cut with scissors to collect all the blades. The Can Core covers the cut part and the rootstocks and sediment inside the Can Core are collected.

❊ Fill in the collection information according to the above <Table 3-5> sampling information form.

– Collected samples are identified by species and collection point, and the population size and biomass are measured (up to the second decimal place) and converted into units of $1m^2$.
– Calculate ecological status (species diversity, species evenness, abundance, dominance).
– Species and populations of nekton (fish) and herbivores (snapping shrimps and swimming crabs, etc.) observed in each quadrat are identified.

○ Seafloor sediment survey

– On-site surveys are conducted in the target sea areas on a quarterly basis (Feb, May, Aug & Oct).
– The sediment conditions are recorded for each survey area (a total of 9, the same as the above-mentioned inhabitant survey location), and the depth of sediment is measured at 4 points per area.
– To ascertain the change in the slope of the seabed, the movement of sediment is monitored by using a slope gauge or a slope level measuring system (can use stainless steel ruler, etc.).



<Image 3-5> Measuring eelgrass habitat slope change

F. Halophyte site survey

○ Precise surveying using the unmanned aerial vehicle (UAV)
- A spatial survey of the sea area to be conducted using UAV surveying equipment.
- A drone equipped with an RTK function is used to obtain spatial images and digital elevation model (DEM) data.
- Generate spatial sequence DEM and film the current habitat situation.
- The scale of the AV aerial photograph is 1:5,000 or less, the shooting altitude is 100m or less. Colour images are taken to study halophyte colonies.
- Analyse halophyte colonies and topographic conditions for halophyte formation.
- Analyse topographic conditions such as altitude suitable for the survival/growth of each species.
- The habitat situation of halophytes is filmed targeting the entire halophyte habitat. The distribution, area, and location of each species are indicated and calculated into an electronic map.

○ Main survey lines and points surveying
- At least three major survey lines reflecting the characteristics of the survey area are set, and the topographical profile is created using VRS (Virtual Reference Station) GPS.
- The tidal benchmark of the Korea Hydrographic and Oceanographic Agency (KHOA) is used for inspection and correction of the values observed in the field.
- Ground control points (GCP) are 3/km or more, and used for calibration after being installed evenly on land and mud flats using a VRS-RTK measuring instrument.
- The topographical profile of the main survey line is used for the analysis of the habitat of major halophytes.

○ Calculation of exposure time
- For the exposure time of the halophyte colony, the data obtained by measuring the altitude using VRS-RTK GPS in the survey area and the value of the harmonic constant derived from the tide level measurement data from the KHOA are used.
- The tide level data observed in the area near the survey area are used to minimise the local deviation.
- Reflecting the characteristics of year-round inconsistent tide level, after producing the tide data for 1 year for each area, average exposure time during one tidal cycle (about 12h) is calculated by comparing to the altitude of the survey point.

○ Sedimentary environment survey
  – The survey point is divided into a halophyte colony and a non-halophyte colony. Colony samples are collected according to the species of halophytes, and non-halophyte colony samples are collected from the upper, middle and lower sides of the survey line.
  – Grain size and general sediment constituents (TOC, AVS) are analysed.
  – The standard grain size analysis method of Ingram (1971) was applied for the analysis and the statistical analysis was processed by the graphic method. The statistical constants such as average grain size, classification, skewness, and kurtosis were calculated using the formula of Folk and Ward (1957). A logarithmic ∅ scale is used for grades of the grain size.
  – The analysis of general sediment constituents is carried out by the Korean Marine Environmental Test Methods (KMTM).

○ Zoobenthos survey
  – The benthos survey point is set in order to compare between halophyte colonies and non-halophyte colonies, and also to compare between before and after the formation of halophyte habitats. The survey point is selected from the sediment points after consulting with the client.
  – Collect 0.1m^2 using Can Core and convert it to 1m^2 for analysis. Species composition, density, biomass, dominant species, ecology indices (diversity index, abundance index, evenness index) and health are analysed.

○ Marine endangered species survey
  – Check the presence and distribution of protected species in the area.
  – Using a video and a camera to film videos, survey for at least 1 hour. Use a quadrat (1 × 1m) and calculate the spatial range and density based on the photographing information.

<Image 3-6> Surveying suitable sites for halophytes development

○ Halophyte colony survey
- Qualitative and quantitative surveys are conducted at the same time for a representative colony in the survey area.
- The qualitative survey records the species that have appeared while on foot, and some unidentified plant species are identified and classified by taking photos and collecting and transporting them to the laboratory. The quantitative survey is carried out by installing a quadrat (1m×1m) marked by small quadrats at a spot with good vegetation and identifying the species that appear in the area. And take pictures with a digital camera, and record the survey location in the report.
- VRS-RTK GPS is used to measure the altitude and boundary of the colony.
- When recording a halophyte colony, the dominant species representing the colony is used to name it as a ooo colony, and in the case of a mixed colony, the dominant colony is recorded first.
- For surveyed and identified vegetative plants, a plant list is prepared in the order of pteridophytes and gymnosperms, Archichlamydeae (dicots), Sympetalae (dicots), monocots according to Engler's classification system (Melchior and Werdeman 1954, Melchior 1964). The list of halophytes is prepared based on the list of halophytes in Korea suggested by MOF.

○ Halophyte habitat density survey
- The density of halophytes by species is measured by an appropriate collection method using a quadrat (1 × 1m) and converted into the population size (n) per $1m^2$ and the biomass (g).
- Create a distribution map (vegetation map) by species and measure the total habitat area (m^2).
- Ecological indices are produced by examining dominant species, population size, biomass, and frequency.
- Survey surrounding flora habitat other than halophytes.

○ Actual vegetation map
- The actual vegetation map is a map of halophyte colonies distributed within the survey area. Using satellite image maps, the surveyed colony data is digitised based on coordinates and altitude to mark the boundaries of each colony and applied to an electronic map.
- The minimum area of a colony is at least $5m^2$ to be recorded and small colonies are also marked if necessary.

○ Halophyte species for the project and impair possibilities survey
- Halophyte species for transplantation is selected by using the geographic data of the area and the data on the status of the inhabitants.
- Calculate the area where halophytes can be transplanted and the maximum habitat formation area by using the environmental characteristics data of the area.

– Species of halophyte for development sites are marked on an electronic map according to topographical survey results.
– Through interview surveys, the actual state of harvesting in the area, the status and plans of large-scale construction, pollutants, fish farms, and tourism infrastructure are researched.
– Investigate the accessibility of project stakeholders to the candidate site for development.
– Various matters required for long-term maintenance and management are surveyed during development, such as the compliance rate from local fishermen.

<Image 3-7> Proposal of suitable habitat for halophytes (draft)

G. List of candidate sites for marine forest and basic planning (draft)

○ Based on the data from the site survey results, candidate sites for the marine forest development are determined by using ecosystem evaluation techniques such as HEP (refer to Chapter V, Technology No. 2018-02).

○ Based on the site survey results, a list of candidate sites for marine forests is prepared.

○ A basic plan (draft) for the Marine Forest Project is drawn up for the waters selected as candidate sites.

○ The basic plan (draft) includes the site survey results of each sea area, marine forest development plan, method, and budget.

<Table 3-8> Marine forest candidate site list

List of candidate sites for Marine Forest Project

Sea Area	City/ Province	Recommended candidate site	Area (ha)	Note
East Sea	Gangwon			
	Gyeong-buk			
	Ulsan			
	Busan			
West Sea	Incheon			
	Gyeonggi			
	Chung-nam			
	Jeonbuk			
South Sea	Jeonnam			
	Gyeong-nam			
Jeju	Jeju			

3. Marine forest sites recommendation and selection

A. Marine forest sites recommendation

○ Based on the site survey results, a list of candidate marine forest sites prepared by the FIRA sea branches is provided to the local government.

○ City/county/district selects the water area desired for the project from the list of candidate sites, and collate a recommendation list for the candidate sites, a letter of recommendation, and a Consent Form for the designation of fishery resource management area (including the signatures of local fishermen) and submits them to the relevant city/province.

○ In cities and provinces, priorities are set among the waters recommended by local governments, and an agreement on the designation of fishery resource management area is attached and recommended to the FIRA sea branches (until October).

○ FIRA HQ puts together and submits reports of the site survey results, local government recommendation list, and documents to MOF.

○ MOF reviews the site survey results and the recommendation list and establishes a plan for selecting new marine forest sites.

B. Marine forest sites selection

○ MOF organises and holds a Marine Forest Selection Committee to select new sites for the following year (November).

– Marine Forest Selection Committee: no more than 10 experts from MOF, FIRA, academia, and research institutes, etc.

○ FIRA attends the committee and presents the site survey results for candidate sites, a list of local government recommendations, other supporting documents and the marine forest development plan.

○ The committee evaluates the candidate sites by referring to the site survey results, the recommendation list and other documents, and considers the following priorities.

– Water areas that require government policy consideration for the progressing calcification.

– Water areas where marine forests can be developed by utilising and

improving natural bedrocks rather than artificial reef installation, etc.

- Areas where cooperation is active, such as participation of fishing villages and/or designated as fishery resource management area by the local government.
- Areas requested by the local government where the site is in the designated fishery resource management area, and the follow-up management of the site is excellent.
- Water areas with high utilisation as a water-friendly space such as easy accessibility and ecological experience.
- Water areas that can be reselected from among the recommended areas in the previous year.
- Local governments that do not properly perform follow-up management of stock enhancement program-related projects (artificial reef projects, fishery seed discharge projects, etc.) are excluded from the project funding.

※ Be sure to comply with the management expenses of artificial reefs, such as securing at least 15% of artificial reef project expenses for the relevant year and at least 10% of release project expenses for the relevant year.

○ The suitability of the marine environment, ecological and topographic adequacy, obstacles and management conditions for the formation of marine forests, and the connection with other projects are evaluated, and new sites are selected in order of high score.

<Table 3-9> Marine forest site recommendation list

List of candidate sites for Marine Forest Project each sea area

Sea Area	City/Province/ District	Recommended Site	Area (ha)	Ranking	Note

. . (Date)

Applicant: Mayor/Governor (Signature)

<Table 3-10> Marine forest site letter of recommendation

Letter of Recommendation for 00 Marine Forest Project Site

«General Outline»
o Location:
o Marine forest water area:000km (00,000ha)
o Name of fishing village and number of fishing village officials:

«Conditions and characteristics of fisheries in the water areas»
o Fishery status:
– Number of fishermen:
– Coastal fisheries:
– Stationary fisheries:
– Local fisheries:
o Fishery characteristics
–
–

«Characteristics of the water area»
o
o

«Sea map»

«Management plan, such as designation of fishery resource management area»
o Organisation of autonomous management community
–
–
o Plan for designation of fishery resource management area
–
–

«Benefit»
o
o

※ Project Manager: Officer 000, Department 000, Bureau 000 (Telephone:)

<Table 3-11> Consent form for the designation of fishery resource management area in local fishing community

Consent Form

Title: Consent for designation of fishery resource management area in the marine forest development waters

000 fishing community agrees to the access restriction of the water area after designating the fishery resource management area pursuant to Article 48 of the Fisheries Resource Management Act with respect to the sea area of the marine forest development and management project implemented by the Ministry of Oceans and Fisheries and the Korea Fisheries Resources Agency. We agree to actively cooperate and support administrative guidance for the successful development and efficient management of marine forests.

Attachment: fishermen's consent signatures

0000.00

000 fishing village cooperatives representative chief 000 (signature)

<Table 3-11> Signature list of the fishermen for the designation of fishery resource management area in local fishing community

Signature List

Title: Consent for designation of fishery resource management area in the marine forest development waters

All 000 fishing village cooperatives members agree to the contents of the agreement, and sign as follows.

0000.00

Name	ID Number	Address	Signature	Note
	123456-1XXXXXX			

<Table 3-13> Letter of commitment for the designation of fishery resource management area and follow-up management

Letter of Commitment

Title: Designation of fishery resource management and follow-up management for the marine forest development water area

In accordance with Article 48 of the Fisheries Resource Management Act, as the follow-up management entity of marine forests, 000 Province and 000 city/district shall designate the water area for the marine forest development project implemented by the Ministry of Oceans and Fisheries and the Korea Fisheries Resources Agency as a fishery resource management area. We are committed to faithfully carrying out our follow-up management duties so the marine forests are protected and managed with our best efforts.

Attachment: fishermen's agreement on the designation of Fisheries Resource Management area and consent signatures

0000.00

000 Mayor/Governor (signature)

<Table 3-14> Marine forest nomination evaluation table

Evaluation Items	Value	Rating					Score
		A	B	C	D	E	
		5	4	3	2	1	
□ Marine environment suitability for marine forest development – Whether the water quality environment and water environment of the sea area are suitable	4						/20
□ Ecological adequacy for the development of marine forests – The condition of calcification, the density of herbivores, and presence of natural algae and seaweed in the surrounding waters in the past or present	4						/20
□ Topographical adequacy for marine forests – Sediments condition, slopes, rock mass distribution, etc.	4						/20
□ Factors that hinder the development of marine forests – Presence of pollutant sources in the surrounding sea area, development activities in progress or long-term development plans	3						/15
□ Management conditions for marine forest development waters – Fishing community's positive attitude (a consent form), local government's willingness to designate the management area and follow-up management	3						/15
□ Linkage with other stock enhancement projects – Whether it is linked to marine ranches, artificial reefs, and other stock enhancement projects	2						/10
Total	Points						

제IV장 바다숲 조성관리

1. 조식동물 구제
2. 해중림초(인공어초) 시설
3. 자연석 시설
4. 종자부착판 시설
5. 해조류 이식(보식)
6. 수중저연승 시설
7. 해조 먹이장 시설
8. 모조주머니 시설
9. 유주자 살포
10. 그물망 시설
11. 부착기질 개선(갯닦기)
12. 폐기물 수거·처리
13. 잘피숲 조성
14. 천연해조장 관리

Chapter IV
Marine Forest Project Management

The Marine Forest Project is carried out for four years, conducted on the sea area which is selected as a new site for the development of marine forests. The primary development methods include restoration of calcified rock mass and expansion of seaweed attached to bedrock (rock cleaning, installing seaweed seedling attachment panels, seaweed transplant/preservation, installing artificial reefs and natural stones), seaweed spore spreading grounds (mid-water rope culture system and spore bags, etc.), controlling herbivore density and improving the environment. The reproduction and spread of the target organisms are planned according to the characteristics of each sea area.

Details of the main methods of development of marine forests are as follows.

1. Marine herbivore removal

- ○ When the destruction of marine forest is noticeable due to the increase in the number of herbivores being greater than the existing amount of sea algae, the marine forest must be maintained continuously by reducing the grazing pressure.
- ○ Marine herbivores are animals that feed on algae and are classified into crawling animals (arthropods, echinoderms, gastropods and sea urchins) and swimming animals (nekton; fish).
- ○ In subtropical regions, the damage to seaweeds by fish remains an important task to resolve.
- ○ The grazing pressure of herbivores should be lowered in order to maintain the existing amount of algae in consideration of the habitat density of herbivores

– Measures to reduce the grazing pressure of herbivores: removing herbivores, increasing the amount of seaweeds, feeding facilities for herbivores, and transferring herbivores.

○ The most efficient way to lower the grazing pressure of herbivores is to directly remove the most common herbivores such as sea urchin and conch.

○ The target species for herbivore removal are sea urchins, shellfish (conch), and sea hares.

○ In principle, all herbivores must be removed, and the remained density should be maintained at a maximum of 1 n/m^2 or less.

○ Removal work is carried out underwater by fishermen or divers, and where there is a marine forest-forming structure (artificial reefs, natural stones, etc.), the relevant structure shall be worked on first and move on to the surrounding natural bedrock.

○ The removed herbivores are carried on board, weighed by each taxonomic group every working day, and transported to a place designated by the supervisor.

○ The number of herbivores per unit area to be calculated at the time of the removal, and where additional work is required after the removal work, the additional herbivore population should be calculated.

○ Underwater filming, photos and videos are taken on the entire working process of the removal of herbivores in each work area.

○ The measures to reduce the sea urchin population, a common herbivore, are as follows.

– Direct removal of sea urchins in the most efficient way.

– Removing sea urchins by installing a feeding facility with kelp, etc.

– Moving sea urchins to a place rich in algae for feeding, nuturing them into high-quality resources and harvesting them.

– A chemical substance, Diterpene, is found in seaweeds other than marine forest-forming species such as Rugulopteryx okamurae and Dictyota dichotoma, and this substance is reported to inhibit abalone larval settlement and metamorphosis, as well as grazing of sea urchins. Solidifying Diterpene and spraying it in the marine forest area to induce herbivores to avoid or clear away from the area.


<Image 4-1> Removal of Marine herbivores

2. Marine forest reefs (artificial reefs)

○ When developing a marine forest, marine forest reefs (artificial reefs for shellfish and seaweed) are installed to transplant seaweeds and provide habitat for seaweeds and benthic animals.

○ Marine forest reefs are based on a ground area of 500m^2 per complex, and 1-3 complexes can be installed in the marine forest site. Usually, seaweed plant facilities development and seaweed seed transplantation are carried out at the same time.

○ In order to increase the growth and survival rate of seaweed, the marine forest must be easy for seaweed to attach, and its structure must be easy to remove herbivores.

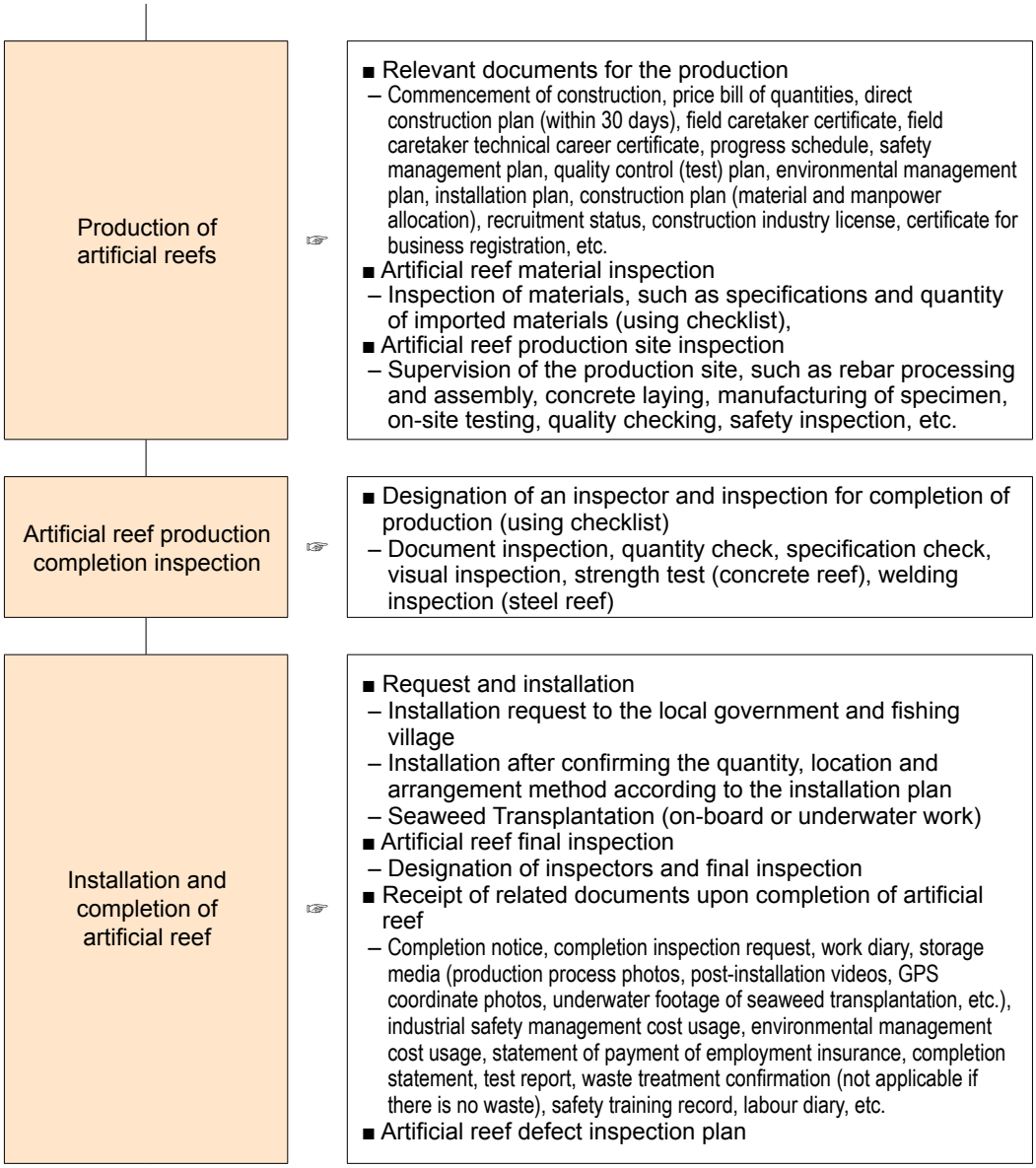
○ The marine forest reef should have a stable shape and adequate weight, so it doesn't move or fall over during typhoons, storms, swelling waves and strong ocean currents.

○ Marine forest reefs should be arranged to maximise stability considering size, durability, water depth, and waves.

<Image 4-2> Marine forest artificial reefs

<Table 4-1> Artificial reef project system

Recommendation of 3 artificial reefs	☞	■ 5 artificial reefs recommended (internal) ■ Recommendation committee for 3 artificial reefs. – Selection of committee members (supervised by the audit office, 5 - 10 people) – Based on the evaluation table for recommendation, 3 artificial reefs are selected in the order of the highest score. ※ Refer to <Table 4-2>
Artificial reef selection (priority)	☞	■ Artificial reef selection committee meeting – Selection of committee members (supervised by the audit office, 5 - 10 people) – Based on the evaluation table for selection, the priority is determined in the order of highest score ※ Refer to <Table 4-3>
Artificial reef contract	☞	■ Sign a use of technology contract with the right holder of the 1st priority artificial reef (patented reef) ■ Open Bidding bidding for construction (supply contract) – Design details and specifications


Production of artificial reefs
■ Relevant documents for the production
– Commencement of construction, price bill of quantities, direct construction plan (within 30 days), field caretaker certificate, field caretaker technical career certificate, progress schedule, safety management plan, quality control (test) plan, environmental management plan, installation plan, construction plan (material and manpower allocation), recruitment status, construction industry license, certificate for business registration, etc.
■ Artificial reef material inspection
– Inspection of materials, such as specifications and quantity of imported materials (using checklist),
■ Artificial reef production site inspection
– Supervision of the production site, such as rebar processing and assembly, concrete laying, manufacturing of specimen, on-site testing, quality checking, safety inspection, etc.
Artificial reef production completion inspection
■ Designation of an inspector and inspection for completion of production (using checklist)
– Document inspection, quantity check, specification check, visual inspection, strength test (concrete reef), welding inspection (steel reef)
Installation and completion of artificial reef
■ Request and installation
– Installation request to the local government and fishing village
– Installation after confirming the quantity, location and arrangement method according to the installation plan
– Seaweed Transplantation (on-board or underwater work)
■ Artificial reef final inspection
– Designation of inspectors and final inspection
■ Receipt of related documents upon completion of artificial reef
– Completion notice, completion inspection request, work diary, storage media (production process photos, post-installation videos, GPS coordinate photos, underwater footage of seaweed transplantation, etc.), industrial safety management cost usage, environmental management cost usage, statement of payment of employment insurance, completion statement, test report, waste treatment confirmation (not applicable if there is no waste), safety training record, labour diary, etc.
■ Artificial reef defect inspection plan

<Table 4-2> Evaluation table for the recommendation of 3 artificial reefs for Marine Forest Project

OO Marine Forest Project Artificial Reef Evaluation Table

Sea Area

o Installation use: Marine forest development

(Standard installation quantity, installation unit price, seaweed transplant quantity: per unit)

Classification	Installation plan (draft 1)					Installation plan (draft 2)					Installation plan (draft 3)					Installation plan (draft 4)					Installation plan (draft 5)				
Installation Overview	Reef name: Standard installation quantity: Area installation quantity: Unit price: million won Seaweed transplant quantity: m standard: m(t)					Reef name: Standard installation quantity: Area installation quantity: Unit price: million won Seaweed transplant quantity: m standard: m(t)					Reef name: Standard installation quantity: Area installation quantity: Unit price: million won Seaweed transplant quantity: m standard: m(t)					Reef name: Standard installation quantity: Area installation quantity: Unit price: million won Seaweed transplant quantity: m standard: m(t)					Reef name: Standard installation quantity: Area installation quantity: Unit price: million won Seaweed transplant quantity: m standard: m(t)				
Evaluation Criteria																									
Suitability(25)	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5
Economic(25)	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5
Manageability(25)	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5
Stability(25)	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5	25	20	15	10	5
Total																									
Ranking	위					위					위					위					위				
Final Score	점					점					점					점					점				

<General Opinion>

Committee Member (Signature)

※ By referring to the evaluation criteria for artificial reef installation project, 5 points for each installation plan (proposal) are given sequentially (no tie).
※ Ranking by adding up the evaluation scores of the members by installation plan (proposal)
※ The final score is given by rank, 5 points for the 1st, 4 points for the 2nd, 3 points for the 3rd, 2 points for the 4th, and 1 point for the 5th.
※ In the case of a tie, the average value is applied to the final score (ex. 2 reefs of the joint 1st place, 4.5 points and/or of the 4th, 1.5 points)
※ If the final scores are tied, the reef selected by the majority of the members as the first preference is given priority, and the sum of the total scores is applied as a subordinate priority. If this is also a tie, it will be re-evaluated only for the relevant reefs.

<Table 4-3> Evaluation table for selecting artificial reefs for Marine Forest Project

OO Marine Forest Project Artificial Reef Evaluation Table

Sea Area

o Installation use: Marine forest development

(Standard installation quantity, installation unit price, seaweed transplant quantity: per unit)

Classification	Installation plan (draft 1)			Installation plan (draft 2)			Installation plan (draft 3)		
Installation Overview	Reef name: Standard installation quantity: Area installation quantity: Unit price: million won Seaweed transplant quantity: m standard: m(t)			Reef name: Standard installation quantity: Area installation quantity: Unit price: million won Seaweed transplant quantity: m standard: m(t)			Reef name: Standard installation quantity: Area installation quantity: Unit price: million won Seaweed transplant quantity: m standard: m(t)		
Evaluation Criteria									
Suitability(25)	25	20	15	25	20	15	25	20	15
Economic(25)	25	20	15	25	20	15	25	20	15
Manageability(25)	25	20	15	25	20	15	25	20	15
Stability(25)	25	20	15	25	20	15	25	20	15
Total									
Ranking	위			위			위		
Final Score	점			점			점		
<General Opinion>									

Committee Member (Signature)

※ By referring to the evaluation criteria for artificial reef installation project, 5 points for each installation plan (proposal) are given sequentially (no tie).
※ Ranking by adding up the evaluation scores of the members by installation plan (proposal)
※ The final score is given by rank, 3 points for the 1st, 2 points for the 2nd, 1 points for the 3rd.
※ In the case of a tie, the average value is applied to the final score (ex. 2 reefs of the joint 1st place, 2.5 points and/or of the 2nd, 1.5 points)
※ If the final scores are tied, the reef selected by the majority of the members as the first preference is given priority, and the sum of the total scores is applied as a subordinate priority. If this is also a tie, it will be re-evaluated only for the relevant reefs.

<Table 4-4> Artificial reef material inspection checklist

Artificial Reef Material Inspection Checklist

□ Business Name:
□ Reef Name:
□ Contracted Quantity:
□ Production Site (Company):

Steel Artificial Reef	Check	Concrete Artificial Reef	Check
1. Design Drawing		1. Design Drawing	
2. Design Quantity (KS standard)		2. Design Quantity (KS standard)	
3. Material Specifications (H-BEAM, ANGLE, PIPE, PLATE, etc)		3. Material Specifications (Deformed bar, etc)	
4. Material Quantity (H-BEAM, ANGLE, PIPE, PLATE, etc)		4. Material Quantity (Deformed bar, etc)	
5. Test Report		5. Test Report	
6. Receiving Statement		6. Receiving Statement	
7. Welder Safety Status		7. Formwork Status (if necessary)	
8. Workshop Inspection (Notice board, precautions, safety rules)		8. Workshop Inspection (Notice board, precautions, safety rules)	
❉ Specific information		❉ Specific information	

❉ Attached documents (material inspection photo book)

Date: . .

Inspector: (Signature)

<Table 4-5> Artificial reef production completion inspection checklist

□ Concrete Reef Production Completion Inspection Checklist

Inspection Items	Details	Classification	Check
Material receipt confirmation	■ Contract document (design drawing, design document, specifications) matches the standard and quantity (check various materials receipt documents)	Material Inspection	
Confirmation of specimen production	■ Is the same material used for making the specimen? (Check the compressive strength test result)		
Certified test report results	■ Confirmation of the result of the quality test report by a nationally recognised testing labouratory		
Slump test	■ The slump (flow) test results conform to the design specifications?		
Production quantity	■ Is the same quantity produced as the contract quantity?	Production Condition	
Dimension check	■ Is it made in the same dimensions as the design drawing?		
Appearance check	■ Are there any cracks, breaks, or deformations? ■ Is the surface cured condition of concrete (bubble marks) good?		
Compressive strength test	■ Does the compressive strength meet the standard when tested with Schmidt hammer? ■ Is it made of uniform strength (between upper and lower strength)?		
On-site documents	■ Contract details, safety management plan, quality control (test) plan, environmental management plan, test report, safety training log, design drawings, photos, etc.	Other	
Covering depth	■ Does the concrete covering depth of the rebar match the design drawing?		
Final pouring date and curing period	■ Confirmation of securing concrete curing period.		

□ Steel Reef Production Completion Inspection Checklist

Inspection Items	Details	Classification	Check
Material Check	■ Contract document (design drawing, design document, specifications) matches the standard and quantity (check various materials receipt documents).	Material Inspection	
Material test report results	■ Check if the material specifications and tensile test results are consistent with the design drawings and specifications.		
Metalwork condition	■ Does the metalwork condition of materials meet the guidelines?		
Production Quantity	■ Is the same quantity produced as the contract quantity?	Production Completion	
Dimension Check	■ Is it made in the same dimensions as the design drawing?		
Appearance Check	■ Does it look the same as the design drawing? ■ Are there any cracks, breaks, or deformations?		
Welding condition check	■ Are there any problems with welding, levelling, and finishing? ■ Are welding defects (weld beads, undercuts, overlaps, etc.) satisfactory with the instructions?		
On-site Documents	■ Contract details, safety management plan, quality control (test) plan, environmental management plan, test report, safety training log, design drawings, photos, etc.	Other	

3. Natural stones

A. Natural stone specifications and materials

○ Natural stones are installed to expand the bedrock that seaweed can adhere to in the marine forest formation area.

○ Natural stone specifications generally use around 1.0m^2, but may vary depending on the purpose and the depth of water.

○ The natural stone should not be flat and elongated in shape, and the material should be solid and dense, free from weathering or freezing.

○ The type, specific gravity, weight, dimensions, etc. of natural stones are specified in the design and specifications. The specifications are inspected and confirmed before transporting the stones to the site.

○ The shape and appearance of natural stones are visually inspected. a sample test or a previously issued quality test report is checked to confirm the quality standard in the design document.

○ Check the sample test or previously issued quality test report to confirm the quality standard in the design document.

○ If a natural stone is deemed not suitable for the project after the inspection, it cannot be brought into the site.

○ Natural stones must be from an approved place. To use a stone type other than the ones specified in the design document, a sample of the stone is tested, and the quality test results must be submitted to seek approval from the client before using them.

○ Where stones are purchased separately or intended to be brought in from outside the approved place due to the site conditions, approval is needed by submitting the results of quality tests, the quantity of use, stone permits, etc. after sampling and testing.

<Table 4-6> Quality standard for different type of rocks

Classification	Weight		Absorption (%)		Compression strength (kg/cm²)	
	Capstone	Rubble stone	Capstone	Rubble stone	Capstone	Rubble stone
Granite	2.6or over	2.5or over	Less than 5%	Less than 5%	over 10,000	over 500
Andesite	2.4or over	2.3or over	Less than 5%	Less than 5%	over 10,000	over 500
Basalt	2.6or over	2.5or over	Less than 5%	Less than 5%	over 10,000	over 500
Sandstone	2.5or over	2.4or over	Less than 5%	Less than 5%	over 10,000	over 500

B. Natural stone facility

- ○ Review the natural stone supply source and site conditions, and establish a facility plan, such as loading and transporting, as well as the work schedule. When loading natural stones on the deck barge (barge), request an external agency to check the loading quantity.
- ○ Where it is likely to affect traffic (roads), due to the transportation of a large number of natural stones, to obtain necessary permissions in advance by consulting with relevant agencies on the transportation route.
- ○ The contractor establishes sufficient measures to prevent adverse effects on traffic or the environment, such as dropping natural stones or generating dust on the road during transporting natural stones.
- ○ Before the underwater installation, mark the planned facility location and check the obstacles around the facility area.
- ○ When the natural stone carrier arrives at the designated location, the location of the facility is checked using the WGS-84 coordinate system, and anchors are lowered in all directions of the carrier so that the carrier does not move due to wind, wave break, or tide.
- ○ The natural stone is arranged in 1-3 levels on a flat surface, and the natural stone is installed on the sandy (sanded) ground away from the natural rock mass.
- ○ If subsidence is expected after the installation, the contractor consults with the client in advance.
- ○ During the installation, contaminants such as soil spreading should not occur, affecting the surrounding ecosystem, and be careful about safety accidents.
- ○ When working on a natural stone facility, you can check the progress and the condition of the seafloor through diving work if needed.
- ○ During the installation, a small vessel other than the tugboat should be on-site for an emergency.


<Image 4-3> Natural stone facilities

시 험 결 과
(박편현미경분석)

성적서번호 : 2016-G-083

페이지 (3) / (총3)

지오메카닉스

Project Name	인천 중구 연안 바다목장 자연석 시설사업		
Specimen ID	암석	Depth	m
Test Date	2016-10-24		

Geologic Description		Qualitative Description	
Rock Name		Texture	None
Gneiss	(편마암)	Fracturing	None
Petro Classified		Alteration	None
Metamorphic rock	(변성암)	Matrix	None

Microscope Observations

Mineral Composition (Modal Analysis)

Major Comp		Vol%	Minor Comp		Vol%	Accessories	Vol%
Quartz	(Qtz)	35.3	Biotite	(Bi)	5.7	Opaque mineral	3.3
Plagioclase	(Pl)	25.9	Sericite	(Ser)	3.5		
Microcline	(Mi)	9.6	Chlorite	(Chl)	16.7		
						Total	100

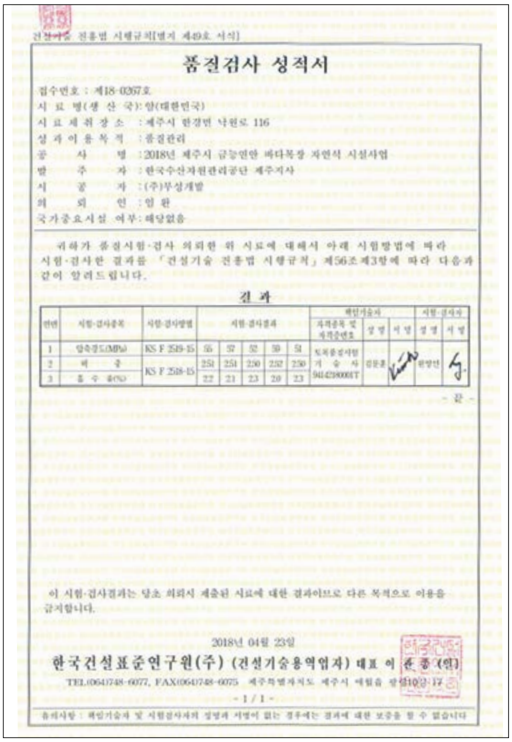
Photo-Micrograph of Typical Features of Thin Section

Photomicrograph for sample, PPL, x40

Photomicrograph for sample, XPL, x40

확 인 이학박사 양 주 석

GeoMc-QPF-26-02



건설기술 진흥법 시행규칙[별지 제49호 서식]

품질검사 성적서

접수번호 : 제18-0267호

시 료 명(생 산 국): 암(대한민국)

시 료 채 취 장 소 : 제주시 한경면 낙원로 116

성 과 이 용 목 적 : 품질관리

공 사 명 : 2018년 제주시 금능연안 바다목장 자연석 시설사업

발 주 자 : 한국수산자원관리공단 제주지사

시 공 자 : (주)부성개발

의 뢰 인 : 임 환

국가중요시설 여부: 해당없음

귀하가 품질시험·검사 의뢰한 위 시료에 대해서 아래 시험방법에 따라 시험·검사한 결과를 「건설기술 진흥법 시행규칙」 제56조제3항에 따라 다음과 같이 알려드립니다.

결 과

연번	시험·검사종목	시험·검사방법	시험·검사결과					확인기술자 자격종목 및 자격증번호	성명	서명	시험·검사자 성명	서명
1	압축강도(MPa)	KS F 2519-15	55	57	52	59	51	토목품질시험 기술사 9414210001T	김문호		원영민	
2	비 중	KS F 2518-15	2.51	2.51	2.50	2.52	2.50					
3	흡 수 율(%)		2.2	2.1	2.3	2.0	2.3					

- 끝 -

이 시험·검사결과는 당초 의뢰시 제출된 시료에 대한 결과이므로 다른 목적으로 이용을 금지합니다.

2018년 04월 23일

한국건설표준연구원(주) (건설기술용역업자) 대표 이 준 종 (인)

TEL.(064)748-6077, FAX(064)748-6075 제주특별자치도 제주시 애월읍 광령10길 17

- 1 / 1 -

유의사항 : 확인기술자 및 시험검사자의 성명과 서명이 없는 경우에는 결과에 대한 보증을 할 수 없습니다

SHIN HAN INSPECTION CO., LTD
(LICENSED BY KOREAN GOVERNMENT)

SHINSCO

(株) 新 韓 檢 定

Report No. IP-1701-029

Date: Jan. 04. 2017

ORIGINAL

SURVEY REPORT

(부선 적재 용적)

본 보고서는 (주)호성건설의 요청에 의거하여 2017년 01월 04일 하기 부선에 입회하여 현재 적재된 실제 자연암석(연암석괴) 용적에 대한 검정을 시행하고 그 결과를 하기와 같이 보고합니다.

부선의 명세

부 선 명 : 남광2호

선 박 번 호 : ICB-952243

선 적 항 : 인천광역시

총 톤 수 : 1,090.00 Tons

부 선 제 원 : 길이 - 66.72 미터
폭 - 20.00 미터
깊이 - 3.70 미터

진 수 일 : 1995년 6월 01일

적재 용적

상기 부선에 적재된 자연암석(연암석괴)는 갑판상(Coaming 내부 및 상부)에 적재 되었으며 그 용적은 아래와 같이 산출되었음.

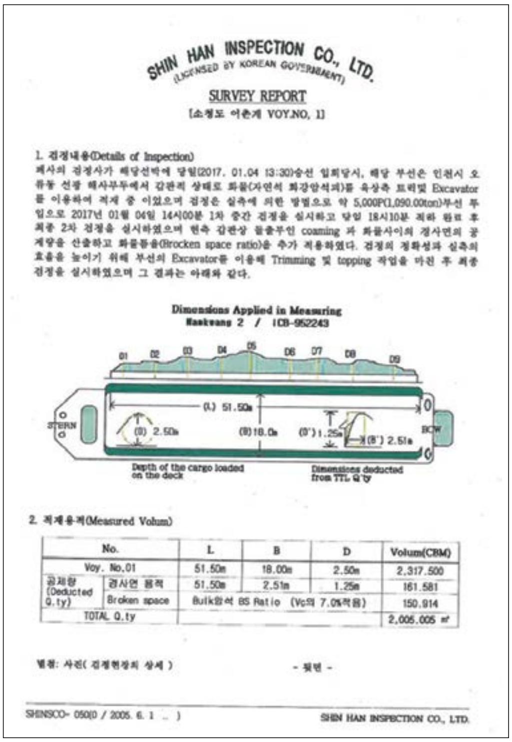
총 적재된 용적 : 2,005.005㎥

본 보고서는 당사의 양식과 최선의 능력으로 어느쪽에도 편견없이 발행함.

Surveyor Y. S Park

주식회사 신한검정 (SHINSCO)

인천사무소장 이 용 남



SHIN HAN INSPECTION CO., LTD.
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SURVEY REPORT

[소청도 어촌계 VOY.NO. 1]

1. 검정내용(Details of Inspection)

폐사의 검정사가 해당선박에 당일(2017. 01.04 13:30)승선 입회당시, 해당 부선은 인천시 오류동 선광 해사부두에서 갑판적 상태로 화물(자연석 최강암석괴)를 육상측 트럭및 Excavator를 이용하여 적재 중 이었으며 검정은 실측에 의한 방법으로 약 5,000P(1,090.00ton)부선 투입으로 2017년 01월 04일 14시00분 1차 중간 검정을 실시하고 당일 18시10분 적하 완료 후 최종 2차 검정을 실시하였으며 현측 갑판상 돌출부인 coaming 과 화물사이의 경사면의 공제량을 산출하고 화물틈율(Brocken space ratio)을 추가 적용하였다. 검정의 정확성과 실측의 효율을 높이기 위해 부선의 Excavator를 이용해 Trimming 및 topping 작업을 마친 후 최종 검정을 실시하였으며 그 결과는 아래와 같다.

Dimensions Applied in Measuring
Namkwang 2 / ICB-952243

2. 적재용적(Measured Volum)

No.		L	B	D	Volum(CBM)
Voy. No.01		51.50m	18.00m	2.50m	2,317.500
공제량 (Deducted Q.ty)	경사면 용적	51.50m	2.51m	1.25m	161.581
	Broken space	Bulk암석 BS Ratio (Vc의 7.0%적용)			150.914
TOTAL Q.ty					2,005.005 ㎥

별첨: 사진(검정현장의 상세)

- 뒷면 -

SHINSCO- 050(0 / 2005. 6. 1 ...)

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<Image 4-4> Natural stone quality survey reports and calibration reports (example)

4. Seedling attachment panels

A. Natural stone specifications and materials

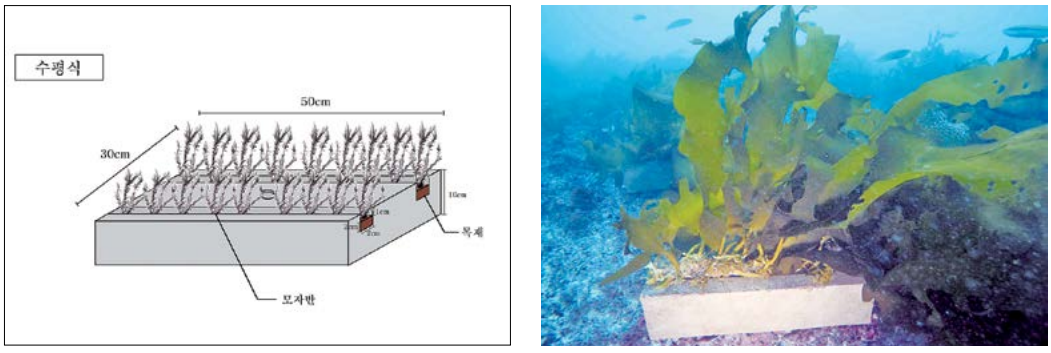
○ It is a method that can directly transplant seaweed seedlings by using concrete panels that are made to attach seaweed seedling ropes to existing facilities in seaweed reefs or natural bedrocks where calcification is progressing.

○ Seedling attachment panels vary in size depending on their shape but they are usually in a rectangular box shape of around 40cm(w) × 30cm(l) × 10cm(h). They are made so that seaweed can be transplanted by planting wood materials with grooves cut in the concrete.

○ This method is especially useful in shallow areas as it is designed to install on natural rocks to transplant seaweed seedlings, different from the usual method of transplanting seeds only in designated seaweed reefs.

○ It is easy to attach and detach seedling panels using anchor bolts, so it is easy to manage the seedlings like re-transplanting and expanding. Also, when the transplanted seedlings are grown, they can be moved to other sea areas, so by controlling the density of the transplanted seaweed colonies, it is possible to expand the seaweed fields to nearby sea areas.

○ However, as it is easy for herbivores such as sea urchins to access, it may be more effective if the facility is located in a sea area with a low density of herbivores or where herbivores are removed.



<Image 4-5> Diagram of seedling panel and facility picture

5. Seaweed transplantation (supplementary plantation)

A. Selection of seaweeds for the formation of marine forests

○ The prerequisites for selecting seaweeds for marine forest development is that the species capable of producing and cultivating large amounts of artificial seeds, and which seeds can be stably supplied through mass cultivation must be selected.

○ Seaweeds that live in the target sea area, or have inhabited a lot in the past but have disappeared now and that are judged to have good growth in the target sea area are selected.

○ For target seaweeds, perennial seaweeds and large seaweeds are given priority, but other seaweeds such as red algae are possible to secure biodiversity in the marine forest sea area.

○ Among the target seaweeds, it is recommended to use perennial seaweeds rather than annual seaweeds, as it takes a lot of manpower and expenses to rebuild once the seaweed is transplanted into marine forests.

B. Transplantation (supplementary plantation) timing by major seaweed species

○ The seaweed transplantation (supplementary plantation) period is carried out by selecting the most active period by reflecting the life cycle of the target seaweed.

○ Kelp

– The maturity period is late autumn, October to November.

– The seedling collection is in November and transplanted and grown from December to January of the following year.

– Seedling transplantation is suitable during the period when the blade grows by 5 to 10cm (early February)

– For mid-water rope culturing, April to May is the suitable period when the length of the blade grows about 50 cm.

○ Ecklonia cava, Ecklonia stolonifera, sea oak

– The maturity period is late autumn, October to November.

- The seedling collection is in November and cultured indoors are transplanted and grown in mid-January to early February.
- Cultivated seedlings grow up to 10 cm in April at the earliest, but usually 5-10 cm in April to May, so transplanting at this time.
- Considering the fall-off rate immediately after transplantation, it can be carried out in the fall, the maturity period.

○ Gulfweed

- The maturity period is April to May.
- Carry out provisional transplantation when the frond grows about 3-4cm in indoor culture.
- Avoid direct waves, adapt to the waves for about 1 to 2 days, and carry out a transplanting at a depth of 5 m after provisional transplantation.
- Instead of newly cultured seedlings, use collected ones that are already grown.
- After the main cultivation is started, seedlings are collected once around November in the same year, and again around April of the following year. So, it is recommended to use them after collecting them in November or April.

C. Seaweed seedling transplantation into artificial structures

○ The method of transplanting seaweed is as follows.

- Method of growing by attaching zoospores or spores to artificial structures
- A method of collecting seaweed that has grown to a certain extent with its roots and attaching it to artificial structures or natural rock mass using a fixing material.
- A method of cultivating zoospores or spores on a rope to make them grow to some extent, and then binding the rope to artificial structures or natural rock masses to let seaweeds grow and root down.

○ Seaweed transplants are mainly carried out in seaweed forests, and sea oak, Ecklonia cava, Ecklonia stolonifera, gulfweed, and kelp can be used for seedling transplantation.

○ Seaweeds transplant in seaweed forests mainly uses the above transplant method by binding ropes with young seaweeds (seedlings around 5 to 30cm) to make seaweeds grow and take root.

○ When the cultivated seedlings grow by 5 to 10cm, nail the cultivating rope in wood (processed to fit the size of the grooves of seaweed reef), put it in the grooves of the seaweed reef, and secure the wood with bolts (using air tools).

○ When fixing seaweed ropes in the seaweed reef, you can directly fix only the grown ropes on the seaweed reef without using wood. This method has no problem when the seaweed is young, but when the seaweed grows and begins to be affected by the current, the rope gap between the bolts fixing the rope increases, which can lead to seaweed falling out of the roots.

○ When using wood material, if ordinary wood is used, the wood can be corroded before seaweed takes root, so hardwood must be used. The use of Delenia (also known as Abidon) wood, which is used for ships or trappings, is suitable because it is sufficient to withstand the length of time the roots of seaweeds inhabit in the seaweed reefs.

○ There are two methods of transplanting seaweed seedlings in the seaweed reefs, onboard or in water, and the appropriate method is selected according to the characteristics of the sea area and the size of the facility.

○ Working onboard has the advantage of reducing expenses as large quantities can be transplanted in a short period of time, while it has the disadvantage of not being able to transplant if the correct timing is missed depending on the seaweed species. In addition, if the land temperature is high during the seaweed reef installation, the heat damage of seaweeds is feared, so it is necessary to consider a solution or an underwater transplantation method.

○ In order to work on sea oak, Ecklonia cava, and Ecklonia stolonifera on board, the work must be completed by the latest June, and transplantation of gulfweeds can be done by autumn.

○ Underwater seedling transplantation is a method that divers perform underwater transplants after the seaweed reef installation. This is a method of fixing the ropes with seaweed seedlings grown underwater with flat bar or cable ties.

D. Seaweed supplementary planting

○ On-land seaweed supplementary plantation: this is a method of taking underwater artificial structures (seaweed reefs, etc.) out of the water and then planting seaweeds. It is suitable when there is a large amount of transplantation due to a large amount of fell-off seaweeds, but a lot of expenses and difficulties arise in re-installation after the structure is lifted out of water.

○ Underwater seaweed supplementary plantation: as a general supplementary plantation method, divers perform plantation directly in the water. It is suitable if the seaweed fall-off rate is low, and if the amount of plantation is large, it takes a lot of time and budget.

<Image 4-6> Seaweed transplantation (left: on-board, right: underwater)

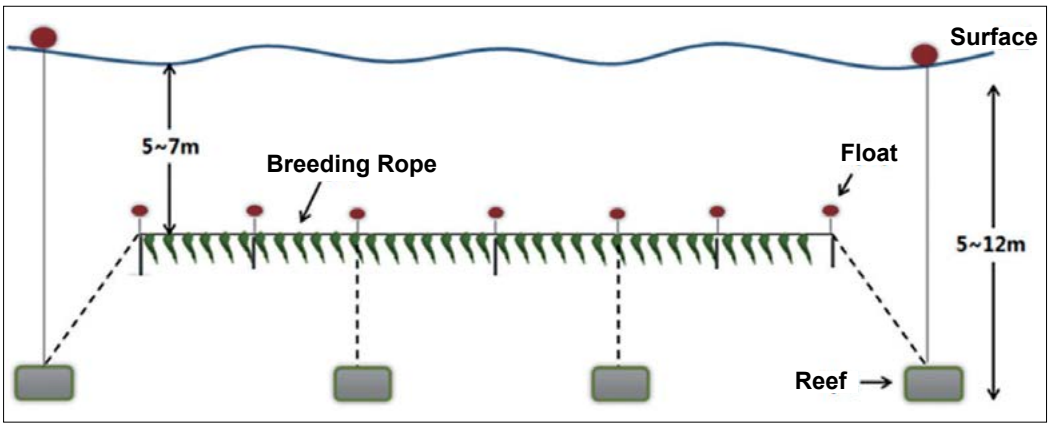
6. Mid-water rope culture system

○ Mid-water rope culturing is a method of creating a marine forest in which seaweed seedling ropes are floated in the water on a structure for anchoring, seaweed reefs for sea forest, and natural bedrock using ropes and floats.

○ It is not a method of direct transplantation of seaweeds to form a seaweed field, but a method used to cultivate large seaweeds such as kelp and sea mustard in the sea. It is a line-suspended system, with the concept that it descends to the seafloor and installed. It is mainly installed in waters with high transparency.

○ It is a method that is useful in releasing spores and attracting herbivores, it also has the additional effect of restraining the growth and expansion of non-articulated algae due to light blocking as it floats on the water. A seaweed field can be built in a large area with little cost and effort with this method.

○ When installing on anchor structures or seaweed reefs, ropes are tied to hooks installed in the structures, and underwater buoys are floated above them, and the length of the ropes are adjusted according to the depth of water. Then it is installed by connecting the anchor rope with the upper body line, and then tying the rope of cultured seaweed to the body line. When installing on natural rock, the underwater rock is drilled and anchor bolts are installed to fix the support rope.



<Image 4-7> Diagram of mid-water rope culture facility

7. Seaweed feeding grounds

○ As one of the measures to reduce the grazing pressure of herbivores, a feeding ground for herbivores is provided to control the access of herbivores to seaweeds transplanted to seaweed reefs, etc. It is also can be used to remove sea urchins, etc. gathered for feeding of seaweeds in the feeding ground.

○ The seaweed feeding ground is installed based on the artificial structure of the marine forest site. A support rope is installed on the bottom by using the distance between the seaweed reefs, and a buoy is installed to prevent the sagging of the support rope and maintain a certain depth.

○ The connection part of the support rope and the artificial structure is tightly bonded, and after the installation, there should be no floatage caused by the sagging of the suspended line and positive buoyancy.

○ To transplant seaweeds, attach a seaweed cultivation line (φ16mm) to the support rope with cable ties, etc. Select a suitable seaweed species according to the characteristics of the sea area such as kelp.

<Image 4-8> Seaweed feeding facilities

8. Spore bags

○ Spore bags are installed underwater when the seaweeds are mature. Then a large number of zoospores are released, which will grow by inhibiting natural bedrock or artificial structures in the vicinity.

○ In general, it is a method that can artificially encourage the release of spores at the right time to obtain the effect of generating seaweeds. If the facility is installed in a sea area where the density of herbivores such as sea urchins is low, or where herbivores are removed, it can have good efficacy.

○ The method of making the spore bag is as follows.

– Cut off the blade parts of mature seaweeds and use them after drying in the shade for 12 hours in a well-ventilated place.

– To keep seaweeds moist and not too dry, spread a plastic sheet on the floor to prevent the seaweeds from directly touching the concrete floor, and cover them with newspapers wet with seawater.

– Note that using too much seawater may cause the stimulated seaweeds to release the zoospores.

○ The dried parent algae are placed in a net (natural material such as coir) and hung on natural bedrock or artificial structures. For a large number of zoospores and spores to be released, a buoy is hung above the net to prevent sinking to the seafloor.

○ If the spores released from the bag spread further to the surrounding sea areas, the efficacy can be greatly affected by herbivores. So, it is appropriate to install the facility in an environment where there are smaller waves and the current flows slowly.

<Image 4-9> Making spore bags and installation

9. Seaweed zoospores scattering

○ Zoospore scattering is a method of releasing the zoospores from the mature parent algae on board and then scattering them into the sea, which can be distributed in large quantities to the desired depth of water.

○ Cut the blade part of the mature seaweeds, dry them in the shade for 12 hours in a well-ventilated place, and place them in a large container on board to fill with seawater and stir well to release the zoospores.

○ The density and movement of the zoospores to be closely monitored, and if significant time elapses, the previously released zoospores may die. It is, therefore, better to judge after examining through a microscope. Normally, after 30 minutes of adding seawater to the dried parent algae, the density and movement of the zoospores are optimal.

○ As with the spore bags, the zoospore scattering is suitable for an environment where there are smaller waves and the current flows as slowly as possible.

<Image 4-10> Seaweed zoospores scattering

10. Seaweed cultivation nets

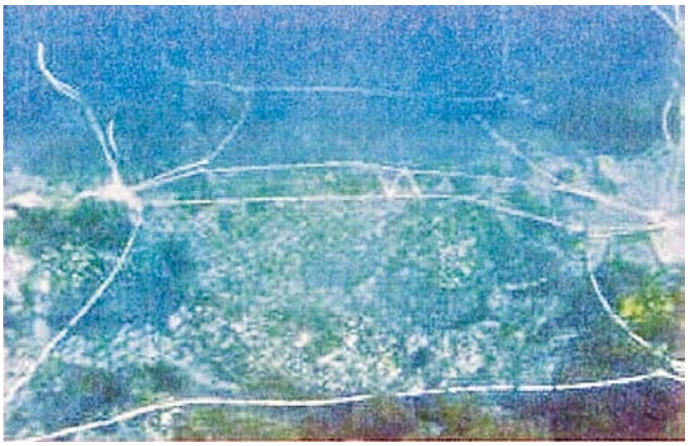
○ The seaweed cultivation net is a method that can create a marine forest relatively simply by collecting zoospores and spores on a net and installing it on natural bedrock, and by transplanting or binding the cultivated seedlings to the net.

○ The net facilities are more suitable for the cultivation of small seaweeds, such as agar, sea lettuce, and sea staghorn, rather than large seaweed varieties.

○ There are various types of nets, but usually, the mesh size is 5×5cm, and the thickness of the mesh is about 2~5mm.

○ The total net size varies depending on the size of the natural rock mass, and sandbags (40kg 4 pcs per set) or concrete anchors (50kg 4 pcs per set) are used for the rock binding.

○ There are disadvantages as the roots of seaweed cannot adhere to bedrocks due to the buoyancy of nets, and also, the nets must be removed later.



<Image 4-11> Seaweed cultivation nets

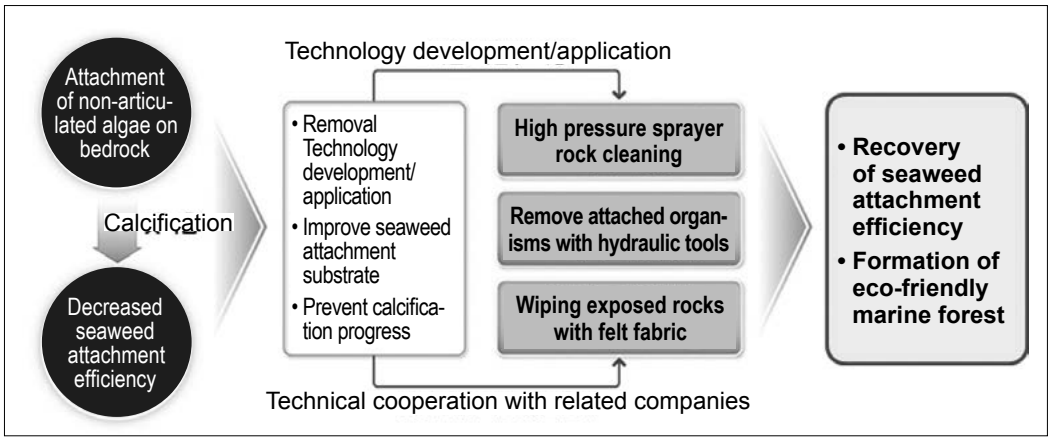
11. Improving attachment substrate (rock cleaning)

○ In the areas where seaweeds used to flourish in the past, but are now difficult to develop because calcareous algae and other attached organisms are covering the area, the rock cleaning method is used to improve the seaweed attaching substrate by removing those organisms.

○ There are ways that operators can use chisels, etc. and for divers to use equipment such as high-pressure sprayers or grinders.

○ Usually, the intertidal zone rock cleaning is done by local fishermen using chisels, etc. Under the tidal area, divers perform rock cleaning using a high-pressure sprayer.

○ It is carried out so that opportunistic attached organisms cannot re-dominate by removing them. The efficacy is even higher if it is carried out at the same time as the release of seaweed spores.



<Image 4-12> Diagram of attachment substrate improvement

<Image 4-13> Improving attachment substrate

12. Waste collection and disposal

○ Where discarded fishing gear or garbage such as waste nets, waste traps, ropes, etc. is deposited in the marine forest development area, waste is collected and disposed of for cleaning.

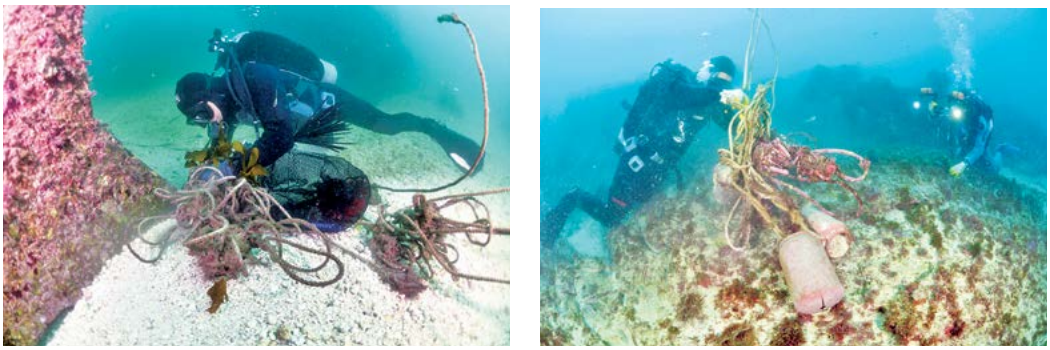
○ When wastes are found underwater through monitoring, etc., the location, types, and quantity are identified, and the weight is calculated based on the derelict fishing gear calculation table. During the process, small-sized wastes are immediately collected by divers.

○ Regarding the lifting and disposal capacity of underwater waste, equipment such as working ships and cranes must be appropriately mobilised. The lifting of waste deposited in the water is carried out by the work ship and divers.

○ For waste that could not be lifted among the burried waste, the quantity and reason must be recorded on the field note and reported to the supervisor.

○ Waste to be weighed onboard or nearby after lifting, and record the weight in the field note along with the amount of waste identified in the water by the diver, and the weight and the total waste amount after drying are compared.

○ The recovered waste is thoroughly sorted and separated by type after unloading, moved to the measuring station after moisture is removed. The amount of waste is measured and handed over to the waste disposal company.



<Image 4-14> Collecting waste

<Table 4-7> Derelict fishing gear measurement table

Type	Size	Weight (kg)
Rope	Φ 16 ㎜, 1 m	0.5
Rope	Φ 7 ㎜, 30 m	4
Rope	Φ 7 ㎜, 1 m	0.1
Rope	Φ 20 ㎜, 50 m	15
Rope	Φ 6 ㎜, 200 m	30
Rope	Φ 6 ㎜, 100 m	13
Rope	Φ 20 ㎜, 100 m	30
Gill net	Width 90 ㎝, 7 Width	4
Waste fish net	-	11
Buoy	Large (plastic sphere)	3
Buoy	Medium-large (plastic sphere)	1
Buoy	Medium (plastic sphere)	0.7
Buoy	Small (plastic sphere)	0.5
Buoy	Φ0.45 m × 0.8 m (styrofoam)	2
Buoy	Φ0.45 m × 0.5 m (styrofoam)	2
Anchor	Small (metal)	10
Fish trap	Spring	1
Fish trap	For swimming crab	3
Fish trap	For crab (Φ0.4 m×0.3 m)	1.2
Fish trap	For eel fishing	0.5
Fish trap	Square(60 ㎝×130 ㎝×83 ㎝)	13
Container	Plastic container 1	1.5
Container	Plastic container 2	2
Container	Plastic container 3	3
Seaweed rope	Plastic	2
Cloth	2 m × 3 m	2
Seaweed dryer	0.7 m × 2 m (Wood)	4.5

13. Eelgrass forest

○ As part of the Marine Forest Project in the West Sea and South Sea of Korea, eelgrass forests are developed.

○ Eelgrass is a perennial seaweed that provides a habitat for marine organisms and plays the role of absorbing and removing pollutants flowing from the coast. However, its habitat is gradually decreasing due to environmental pollution, so it is necessary to develop eelgrass beds.

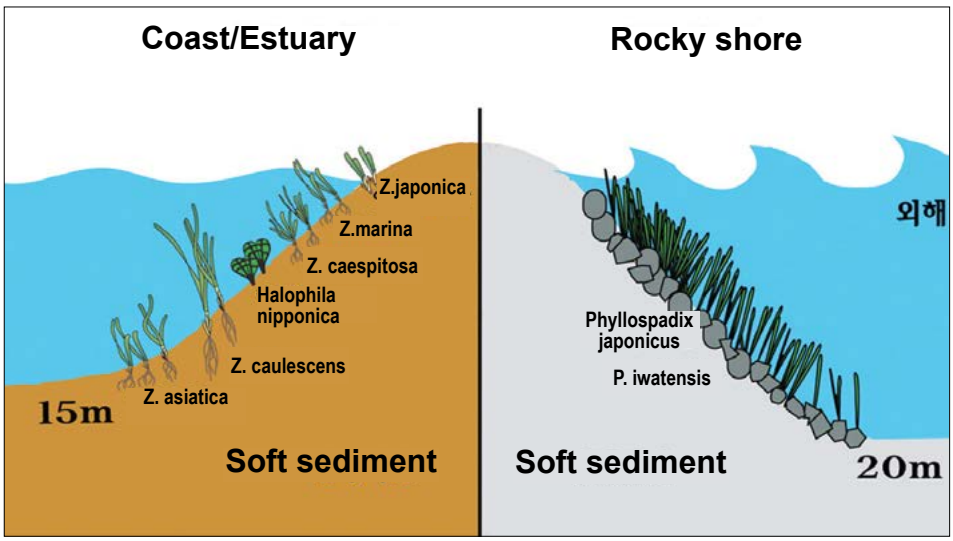
○ The method of forming an eelgrass bed is mainly undertaken through eelgrass collection and transplantation, and the appropriate transplant method is selected depending on the target species and the environment of the transplant site. Typical transplant methods include a staple method, a TERFS method, a shell method, an anchor method, and a transplant method using clay and Korean paper.

○ Eelgrasses are collected by divers or at low tide in a sea area where eelgrasses are widely distributed. Eelgrasses should be transplanted at low tide. For safety, the transplantation is done within a short time by a large number of people after sufficient transplantation techniques training.

○ After forming the eelgrass bed, the composition and survival rate of the transplanted eelgrasses are monitored. Until the transplanted eelgrasses adapt to the new environment, they must be protected from fishing activities such as net work and fishing.

<Image 4-15> Eelgrass forest in Korean coastal areas

<Image 4-16> Eelgrass transplantation



<Image 4-16> Diagram of development of Eelgrass in soft sediment and on hard rocks

14. Natural seaweed bed management

○ It is necessary to respond to calcification by preserving and spreading naturally formed seaweed colonies along with the development of marine forests in coastal ecosystems damaged by the calcification.

○ In order to protect and preserve natural seaweeds, it is necessary to first identify the current status of seaweed colonies and then analyse the damage status and sea areas that require management through detailed survey. Subsequently, based on the survey results, a management plan for each grade is derived through the rating of the natural seaweed bed, and the status of the seaweed bed is continuously monitored while executing the management.

○ In order to calculate the grade of a natural seaweed bed, the seaweed species diversity, the biomass ratio of the species from the marine forest, the calcification rate, and the herbivore density are used as evaluation criteria.

<Table 4-8> Evaluation table for grading natural seaweed bed

Survey sea area	Evaluation criteria				Score	Grade (I~V)
	Seaweed diversity	Biomass ratio	Calcification rate	Herbivore density		
OOO	1.3	5.0	5.0	5.0	16.3	I
OOO	0.7	1.0	1.0	3.0	5.7	IV

○ Seaweed diversity: the value is obtained by calculating the diversity index based on the seaweeds that present. The values calculated at the survey points of the seaweed bed are averaged (up to the first decimal place).

○ Biomass ratio: based on the biometric results of seaweeds present at each point, the biomass ratio is calculated by dividing the biomass of the major seaweeds that make up the marine forest (table below) by the total biomass. It is evaluated using the average biomass ratio calculated at each survey point of the seaweed bed.

– 5.0: Marine forest composition ratio over 80%

– 4.0: Marine forest composition ratio over 60% - less than 80%

– 3.0: Marine forest composition ratio over 40% - less than 60%
– 2.0: Marine forest composition ratio over 20% - less than 40%
– 1.0: Marine forest composition ratio less than 20%

<Table 4-9> Major seaweed list in marine forest

Species	Scientific name
Sargassaceae	Sargassum confusum, S. coreanum, S. horneri, S. macrocarpum, S. nipponicum, S. patens, S. serratifolium, S. yezoense, Hizikia fusiforme, Sargassum
Costariaceae	Agarum cribosum, Costaria costata
Alariaceae	Undariopsis peterseniana, Undaria pinnatifida
Laminariaceae	Laminaria japonica
Lessoniaceae	Ecklonia cava, Ecklonia stolonifera, Eisenia bicyclis
Gelidiaceae	Gelidium amansii
Gracilariaceae	Gracilaria verrucosa

○ Calcification rate: calculate the percentage(%) of calcification indicator organisms (coralline algae) per unit area ($1m^2$) per each point. The rate calculated at each point of the seaweed bed is evaluated using the average value.
– 5.0: Calcification rate under 20%
– 4.0: Calcification rate over 20% - less than 40%
– 3.0: Calcification rate over 40% - less than 60%
– 2.0: Calcification rate over 60% - less than 80%
– 1.0: Calcification rate over 80%

○ Herbivore density: calculate the number of herbivores per unit area ($1m^2$) per point. It is evaluated using the average of the population calculated at each survey point of the seaweed bed.
– 5.0: Herbivore population under $3/m^2$
– 4.0: Herbivore population over $3/m^2$ - less than $6/m^2$
– 3.0: Herbivore population over $6/m^2$ - less than $9/m^2$
– 2.0: Herbivore population over $9/m^2$ - less than $12/m^2$
– 1.0: Herbivore population over $12/m^2$

○ Natural seaweed bed grade: calculate the grade of the surveyed sea area by summing the scores for each evaluation criterion.

– Grade I 16.0 points or higher, Grade II 12.0~15.9 points, Grade III 8.0~11.9 points, Grade IV 4.0~7.9 points, Grade V less than 4.0 points

○ Natural seaweed bed management plan by grade: based on the grade by sea area above, refer to the table below to prepare a management plan for the next year. However, a management plan can be planned separately according to the budget and site conditions.

<Table 4-10> Management plan by natural seaweed bed grade

Grade	Management Plan
Ⅰ, Ⅱ (Good)	■ Natural seaweed bed is maintained healthy ■ Continuous monitoring of the natural seaweed bed conservation area ■ Sea area management by focusing on conservation and management of natural seaweed beds ■ Monitoring, herbivore removal, seaweed transplantation, etc.
Ⅲ (Average)	■ Areas in need of restoration at the initial stage of reduction of natural seaweeds ■ Active protection and preservation projects for natural seaweed beds ■ Ecological restoration project of natural seaweed beds ■ Monitoring, herbivore removal, seaweed transplantation, natural bedrock improvement, spore bags, etc.
Ⅳ, Ⅴ (Poor)	■ Areas in need of restoration due to the reduction of natural seaweeds – Areas where seaweeds are heavily damaged by the spread of calcification or by herbivores. ■ Need for restoration projects linked to marine forest and seaweed forest development projects, etc. ■ Monitoring, herbivore removal, seaweed transplantation, natural bedrock improvement, spore bags, seedling attachment panels, natural stones, mid-water rope culture system etc.

■ Monitoring: calcification rate, herbivore density, benthic organisms, marine environment, etc.
■ Ecological restoration: herbivore removal, seaweed transplantation, natural bedrock improvement (rock cleaning), spore bags, etc.
■ Artificial restoration: seedling attachment panels, natural stones, mid-water rope culture system, etc.

제Ⅴ장 바다숲 조성 기술개발

1. 인공어초 침하 방지를 위한 지반지지력 산정
2. 초분광 항공 영상을 활용한 수심 보정
3. 생태계를 고려한 수산자원 산란·서식장 적지선정
4. 바다숲 적지선정
5. 인공어초 안정성 산정
6. 종사 이식체를 활용한 바다숲 조성
7. 칼블럭을 이용한 자연암반 해조류 이식
8. 풍태를 이용한 해조성체 암반 직접이식
9. 생분해성 천연소재를 활용한 모조주머니 제작
10. 바다숲 조성 지식재산권 현황

Chapter V
Marine Forest Technology Development

1. Calculation of ground bearing capacity to prevent subsidence of artificial reefs (Technology No. 2017-01)

○ Before the technology was developed there were no existing standards for calculating the ground bearing capacity for installing an artificial reef.

○ The technology can utilise the sediment sampling method used in the existing site survey, and it can estimate the ground strength using disturbed samples.

○ Since the clay grains in seawater exist beyond the range that the cohesion can exert, this technology is developed with the assumption that they are governed by the internal friction angle. The strength parameters (internal friction angle) of marine clay is calculated within a practical range by using the plasticity index that identifies the basic components of the clay.

<Table 5-1> Ground bearing capacity calculation procedure

Sediment sampling	■ Sediment is collected by a Grab or Piston corer (disturbed sample)
↓	
Atterberg Limits test	■ Calculation of plasticity index
↓	
Classification of samples	■ Existing methods simply classifies the grain size, so the properties of the soil are unknown. ■ Classify samples using the “Unified Soil Classification System”
↓	
Strength parameters	■ Calculating the internal friction angle to find out the strength of the soil and determine the strength of the ground
↓	
Ground bearing capacity	■ Application of shallow foundation bearing capacity formula in civil engineering (Meyerhof, 1963)

○ The plasticity index depends on the degree of water contained in the soil. This refers to the difference between the “liquid limit”, which behaves the same as water due to the higher content of water in the soil, and the “plastic limit”, which behaves like a solid due to the lower content of water.

○ Prior to the development of this technology, all ground with more than 70% mud content had been deemed inadequate for artificial reef installation. However, with this technology, it is possible to determine a place with sufficient bearing capacity as a suitable site by calculating the ground bearing capacity.

※ For technical details, refer to the discussion materials of the Technology Evaluation Board.

2. Water column correction using airborne hyperspectral image (Technology No. 2017-02)

○ This technology is a method of producing a bathymetric map and submarine topography using hyperspectral aerial images. Its process includes the aerial image acquisition stage, the preprocessing stage, the calibration stage of aerial image data.

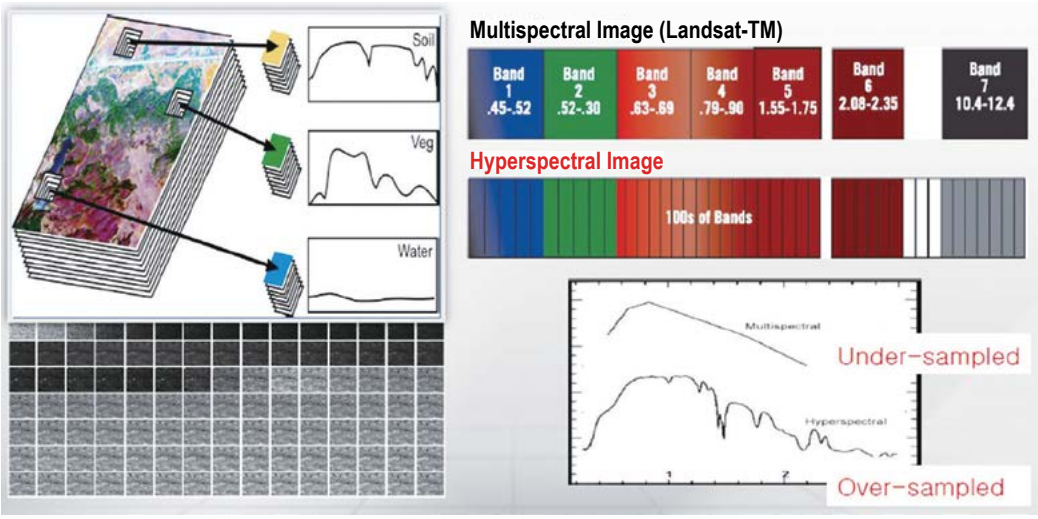
○ The procedure for depth surveying and correction using hyperspectral aerial images proceeds as follows.

<Table 5-2> Water depth survey and calibration method

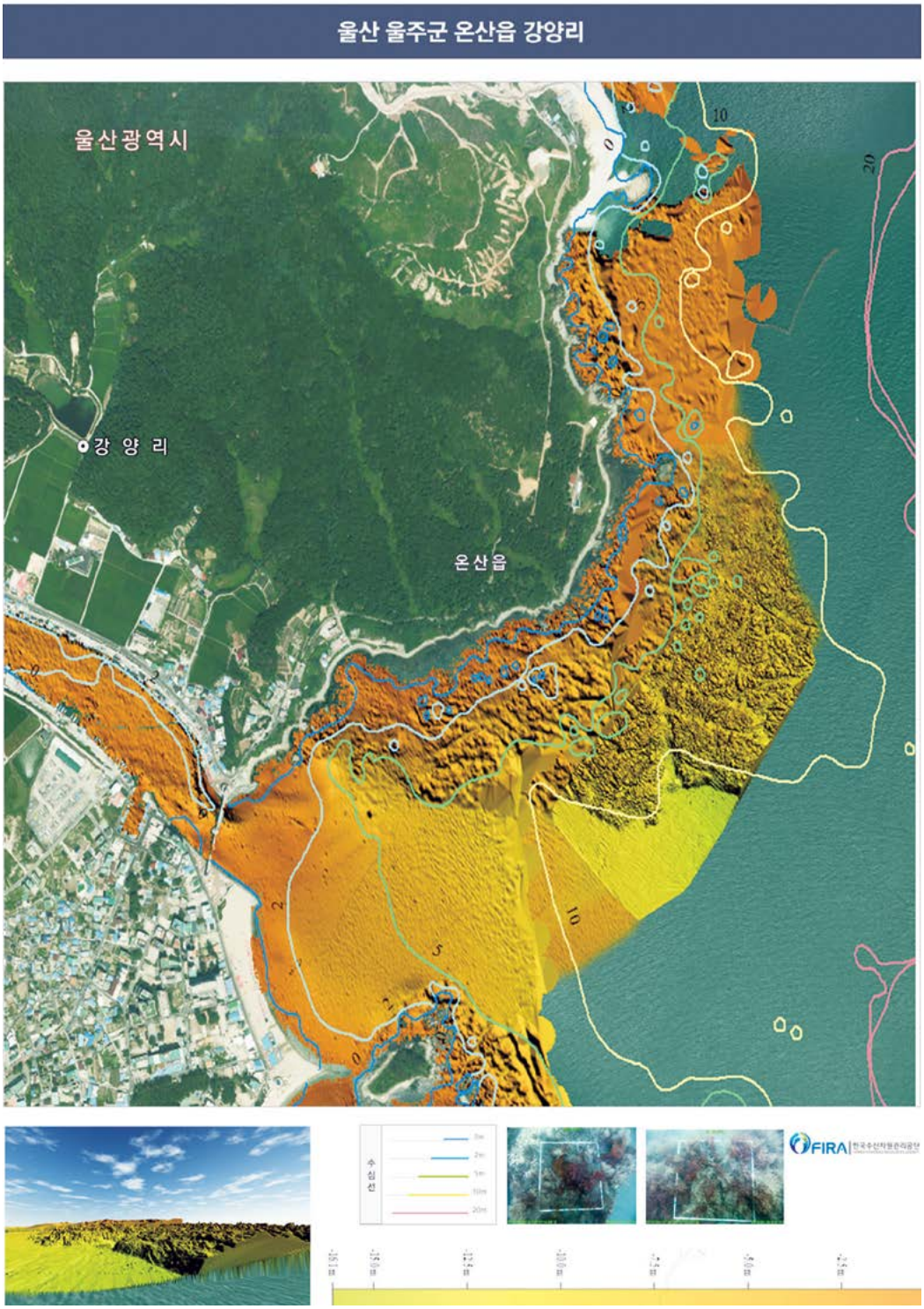
Acquisition of hyperspectral aerial images	■ Hyperspectral aerial images are taken as CASI-1500 images. ■ Filming altitude of 2,000 meters, spatial resolution of 1.5 meters. ■ Spectral resolution is filmed in 96 bands with a width of 7.2 nm in the range of 366.6 nm to 1,048.5 nm wavelength.
↓	
Preprocessing Stage	■ Preprocessing stage for hyperspectral aerial images includes bolometric correction, atmospheric correction, and geometric correction.
↓	
Water Depth Correction Stage	■ Water depth data used for depth correction is obtained from CZMIL (Optech Inc. Canada). ■ The filming altitude is 400~600m, the point density of the laser pulse is 1.5point/m^2, and the depth data with the spatial resolution 1.5m is obtained through gridding.

○ A hyperspectral aerial image is composed of tens to hundreds of consecutive bands with a narrower bandwidth compared to a multispectral image having less than 10 bands.

❊ For technical details, refer to the discussion materials of the Technology Evaluation Board.



<Image 5-1> Hyperspectral aerial imagery mechanism (reflectance spectroscopy)



<Image 5-2> Production of water depth distribution map and seabed topography map using hyperspectral aerial imagery (example)

3. Selection of spawning and habitat sites for fishery resources considering the ecosystem (Technology No. 2018-01)

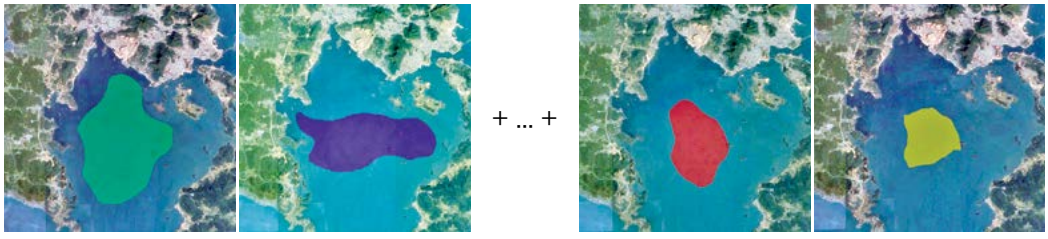
○ The existing method of selecting a suitable site did not incorporate the concept of targeting fish species or organisms. Previously appropriate sites were selected based on the stability of artificial reefs. However, it is very important to identify the main target species by sea area and provide a habitat suitable for that target species for efficient resource development.

○ Accordingly, quantized appropriate site determination techniques have been developed through the introduction of evaluation methods considering the ecosystem, enabling the selection of an ecological-centred site for major habitats in each sea area.

○ The technology allows the calculation of pros and cons of suitable sites by quantization (scoring, numerical), and enables experts to select the best, next best, etc., based on the score.

○ The Habitat Evaluation Procedure (HEP) for selecting an appropriate site can be expressed as an intersection of various environmental factors required for the survival of the target fish (or organism).

○ For example, the optimal habitat water temperature of adult black sea bream is 16~20°C, with the salinity over 31‰, and the water depth between 40 to 60m. There are many other environmental conditions necessary for the survival of black sea bream, and a site that satisfies all of these conditions (environmental intersection) becomes the optimal site.



<Image 5-3> Basic conceptual diagram for selecting a suitable site (example)

○ In this way, the area of the intersection (optimal site) of the environmental survival conditions of the target species can be identified easily. In addition, the second-best site can also be derived by the score distribution.

※ For technical details, refer to the discussion materials of the Technology Evaluation Board.

<Table 5-3> Habitat assessment method procedure

Selection of suitable ecological site	Selection of target species	■ Selection of target sea areas and fish species (or seaweed) ■ Understanding the life cycle of the target organism – Investigate the ecological environment of habitats, such as suitable temperature and spawning
	Target species environment factors	■ Environmental factors affecting the habitat of target organisms – Water quality, sediment, prey, natural enemies, water depth, flow intensity, etc.
	Data analysis	■ Create a spatial distribution plot for the environment factors – Using spatial interpolation methods such as kriging and trigonometric network method – Statistically processed data of over 10 years are used as marine environment data – Determines to what extent the target sea area to be gridded(finely subdividing the space) to create a spatial distribution
	Spatial gridding by factors of target species habitat environment	■ Grid target waters so that each formatting factor can be input (Gridded Spatial Distribution Map, GSDM) ■ Each habitat factor is converted into a suitable index (SI)
Technological site selection	Field survey	■ Site survey by item of artificial reef facility project regulation – Artificial reef stability survey, marine environment survey, flow velocity measurement, slope, sediment distribution, light quantity calculation, questionnaire, etc.
	Data analysis and spatial gridding	■ After analysing the data for each item, to make spatial gridding – Artificial reef stability survey: wave stability analysis by water depth – Marine environment survey: in addition to field surveys, also use long-term observations for at least 10 years data from the Marine Environment Information System (MEIS) – Flow velocity measurement: field survey or reliable numerical experiment analysis – Gradient: analysis by water depth measurement such as multi-beam, etc. – Sediment distribution: analysis using the unified soil classification system in addition to oceanographic grain size analysis. Calculate the bearing capacity after the analysis – Light quantity calculation: compensation depth calculation using a Secchi disc and the amount of sunlight ■ Overlay all analysed spatial grids into a single plot
Final selection	Site selection	■ Determining the optimal site through the final overlapping of the above spatial gridding results

4. Marine forest site selection (Technology No. 2018-02)

○ Previously, after surveying the natural seaweed colonies in a specific sea area, sites were selected by focusing on the restoration of the dominant species in that sea area or species that inhabited in the past but disappeared.

○ However, there is a need for a new method of selecting a site to find the most suitable site for the ecological environment for the target species in a specific sea area. A Habitat Evaluation Procedure (HEP) was introduced that satisfies both the ecological and technical viewpoints at the same time and quantize the suitable site.

○ Taking Ecklonia cava for example, for them to survive, the condition of water temperature of 10°C or higher, salt of 31‰ or higher, and COD of 1.3mg/ℓ or lower is required. In addition, many other environmental conditions are necessary for the survival of Ecklonia cava, and a site that satisfies all of these conditions becomes the optimal site.

○ The marine forest site selection method is a quantized site selection technique centred on the target species, which is shown in the following table.

<Table 5-4> Flowchart of marine forest site selection methodology

Selection of target species and ecological data survey	■ Spatial distribution of target seaweed ■ Major ecology and life cycle of target seaweed ■ Ecological environment of major habitats such as the suitable water temperature
↓	
Suitability Index (SI)	■ The best ecological environment values desired by target species such as water temperature, salinity, and transparency analysis
↓	
Spatial gridding	■ Grid the target sea area ■ Gridding 10m for narrow area and 100m for wide area.
↓	
Gridded Spatial Distribution Map (GSDM)	■ Enter ecological environment values for each grid in the gridded sea area ■ Apply the suitability index (SI) to the ecological environment value
↓	
Habitat Suitability Index (overlay geometric means)	■ The final habitat suitability index by geometrically averaging the GSDM to which SI applied such as water temperature and salinity (the HSI is calculated as a geometric average; geometric average is overlayed)
↓	
Decision on suitable sites	■ The sea area with the highest score among the sea areas overlapping the geometric mean is selected as a suitable site.

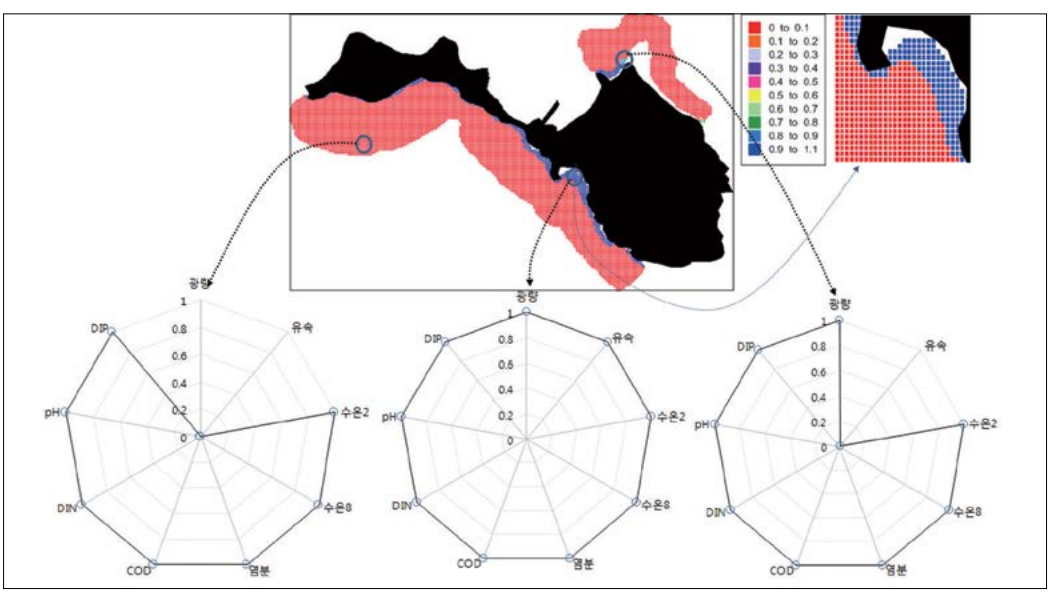
○ The most important thing for selecting a site is the selection of the target species. The lower limit of the habitat of the target seaweed is identified through field survey or literature researches.

<Table 5-5> Ecological environmental requirements of the target species (example)

Target species	Marine environment primary factors								
	Feb water temp (℃)	Aug water temp (℃)	Salinity	pH	COD (mg/L)	DIN (μ mol/L)	DIP (μ mol/L)	Flow speed (m/s)	Sunlight (mol/d)
Ecklonia cava	10~16	23~27	Over 30.9	Below 8.9	Below 1.3	0.07 ~9.31	0.36 ~13.20	Over 0.3	Over 1.4
Sargas-sum	4~19	20~28	Over 26.6	Below 8.9	Below 2.2	0.17 ~4.57	0.30 ~7.85	Below 0.5	Over 2.6

○ In order to calculate the suitable index (SI) according to the habitat limit of the target seaweed, each SI value is calculated against all factors that will be considered in the habitat assessment (water temperature, salinity, pH, COD, NH4-N, DIN, wave height, amount of sunlight, etc.). The sea area is gridded to create a spatial distribution map (GSDM) to apply SI values to the sea area. After that, the best site can be determined by overlapping the geometric mean as shown in the following figure.

※ For technical details, refer to the discussion materials of the Technology Evaluation Board.



<Image 5-4> Results of Ecklonia cava site selection through HSI analysis in waters off Yeondae island, Tongyeong

5. Stability evaluation of artificial reefs (Technology No. 2018-03)

○ Structures such as artificial reefs installed on the seabed of the coast are mainly active or inverted by the power of waves. Therefore, the most important underlying factors in the stability analysis of structures using waves are wavelength and wave height, based on which stability analysis of artificial reefs is performed.

○ In order for the fishery resource facilities to function properly, it is necessary to examine the external force. For fishery resource facilities, including artificial reefs, the endurance period is set at 30 years, so it is necessary to analyse physical external forces of at least 30 years. Due to climate change, extreme weather changes such as unexpectedly large typhoons are frequent, so external forces need to be calculated for design waves with a frequency of at least 50 years.

○ When waves approach, the flow velocity is generated inside the water mass due to the movement of particles, which is used for stability analysis of the structure. Normally, a wave's water particle velocity can be obtained theoretically. However, when the wave transitions to the breaking state, it is very difficult to theoretically find the speed of particles, so it is obtained by numerical method or experimental method using a water tank.

○ Artificial reefs that are currently used as general reefs are said to have proven stability against waves through hydraulic model tests. However, the hydraulic model test has limitations in the reproduction of high crests and long cycles, and there are many physical and spatial constraints in the setting of gradients that greatly affect the deformation of waves.

○ As an alternative to overcoming this, numerical experiments have the advantage of responding to any wave and depth as long as the computer's capacity allows, so the stability of artificial reefs is analysed using numerical experiments.

○ The basic concept of stability analysis of artificial reefs depends on how much the artificial reef's weight can withstand the hydrodynamic force generated by waves. In other words, if the artificial reef's own weight is heavier than the hydrodynamic force, it would not move.

○ The hydrodynamic force applied on an artificial reef can be calculated by the following equation.

$$F = C_D A \rho \frac{V_w^2}{2g}$$

※ C_D =Drag coefficient of the reef, A =Projected cross-sectional area of the reef against vertical flow, ρ = Fluid density, V_ω=Water particle velocity of waves in the ocean

○ After calculating the hydrodynamic force using the above equation, the final stability of the artificial reef is obtained using the following two equations. Structures in water are evaluated for stability in the forms of sliding and overturning. Generally, sliding of structures occurs first, followed by overturning. Therefore, structures with the potential for sliding to occur also pose a risk of overturning.

❋ For technical details, refer to the discussion materials of the Technology Evaluation Board.

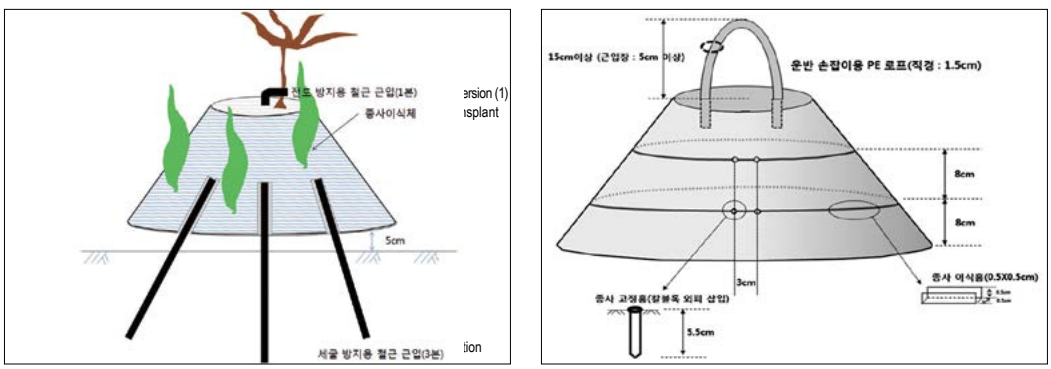
$W > \frac{0.5\,(C_D A W_O (U_W + U_T)^2/g)}{\mu\,(\frac{\sigma}{\rho})}$	$W > \frac{0.5\,(C_D A W_O (U_W + U_T)^2/g)}{\mu\,(\frac{\sigma}{\rho})} \cdot \frac{l_A}{l_V}$

※ C_D =Drag coefficient, A =Shadow effect area of the vertical surface perpendicular to the wave propagation direction (m^2), W_O =Unit weight of seawater(t/m^3), μ =Coefficient of friction between the reef and the foundation ground, I_A =Height of the orthogonal projection area of the reef to centre on the vertical surface perpendicular to the flow(m), I_V =Distance from the projection point to the nearest edge with respect to the bottom direction of the reef centre (m), U_W =Water particle velocity on the reef, U_1 =Flow speed on the reef, g =Gravitational acceleration

6. Marine forest development using seaweed seedling transplant structure (Technology No. 2019-01)

○ In response to the need for a variety of marine forest development techniques at low depths and a way to generate income for fishermen in the nearby sea, the seedling transplant structure has been developed. A pilot marine forest was constructed using idle fishing ports.

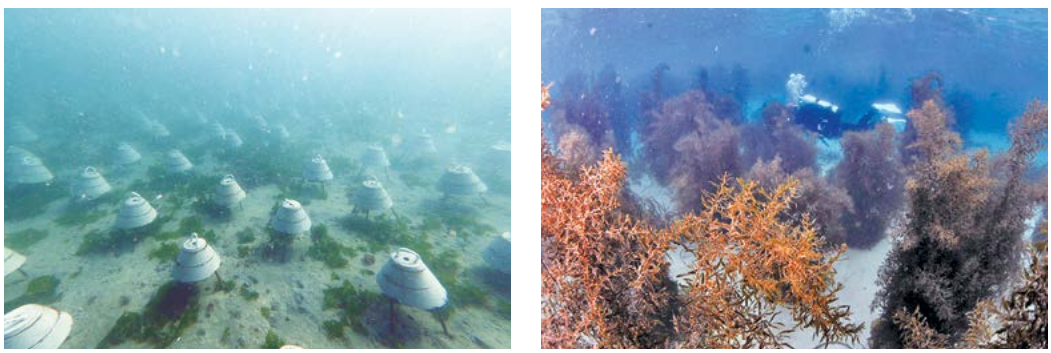
○ The seedling transplant structure was developed to prevent burying due to sand movement and provide scour protection in idle fishing ports, and also make it easier for fishermen to harvest seaweeds.



<Image 5-5> Diagram of seaweed seed transplant structure

○ The developed seaweed seedling transplant structures were installed on a trial basis in idle fishing ports of Uljin and Gijang county, etc. The attachment, regrowth, and stability of transplanting seaweeds, such as sea mustard, sargassum, and kelp were checked.

❊ For technical details, refer to the discussion materials of the Technology Evaluation Board.



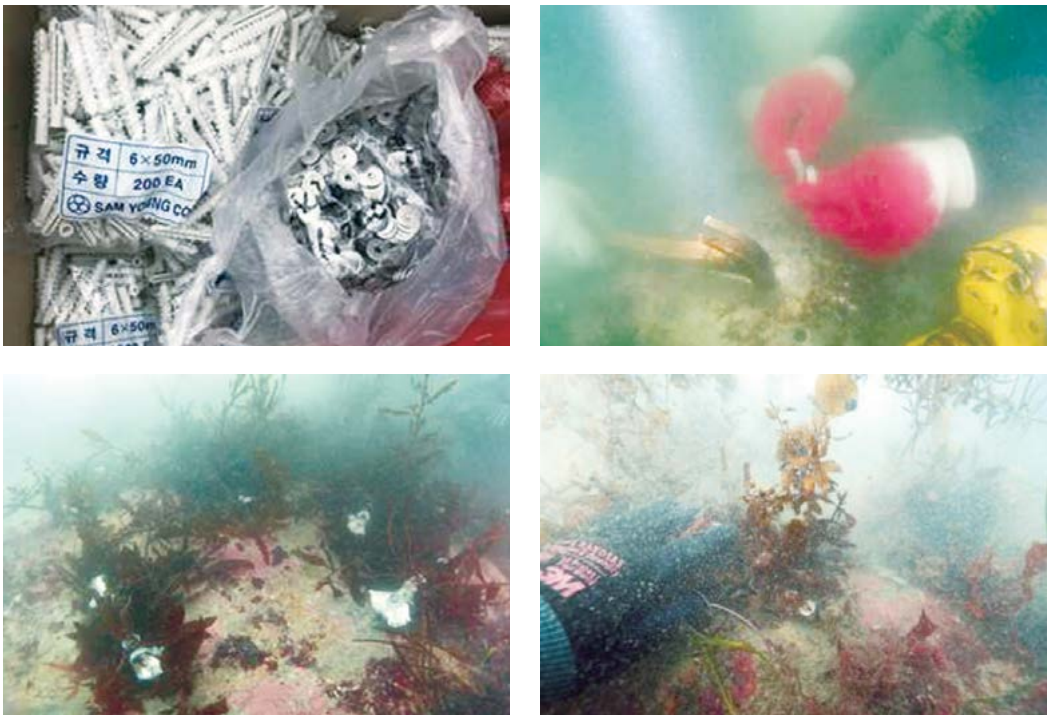
<Image 5-6> Installation of seaweed seed transplant structure

7. Natural stone seaweed transplant using wall plugs (Technology No. 2019-02)

○ Staple guns, which are usually used on land, have been often used to transplant and replanting seaweeds underwater. However, as safety problems such as worker injuries occur underwater, it became necessary to develop construction techniques using equipment that can be used for underwater operations without safety issues.

○ Therefore, a technique was developed to transplant seaweeds by using wall plugs after drilling 5cm holes to natural rocks and artificial structures using an underwater hydraulic drill. This was tested in the waters of Gijang county to check whether it could be used to create marine forests in the future.

※ For technical details, refer to the discussion materials of the Technology Evaluation Board.



<Image 5-7> Transplanting seaweeds on a natural stone using wall plugs

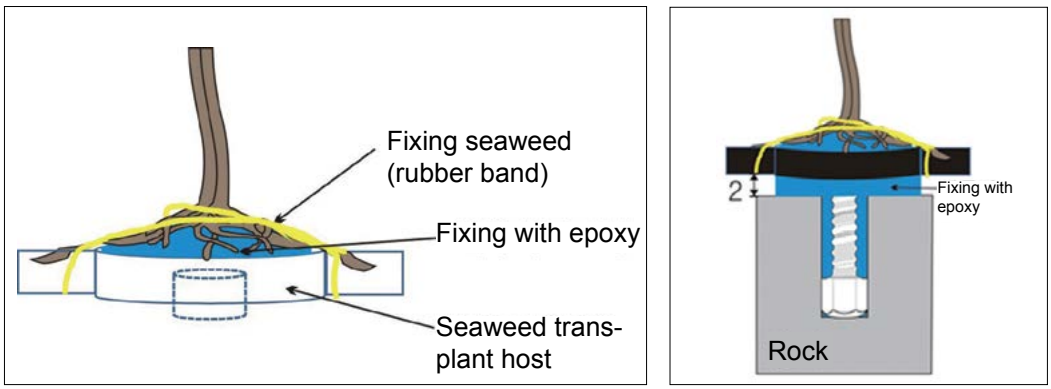
8. Direct seaweed plantation on rocks using washed-up seaweeds (Technology No. 2019-03)

○ Washed up seaweeds refer to seaweeds such as Ecklonia and Sargassum that have been eliminated from bedrock due to external forces such as typhoons. These washed up seaweeds can be collected and used for seaweed transplantation. Especially, the survival rate after transplantation is high as seaweeds are grown in the relevant sea area.

○ Washed up seaweeds for bedrock transplant are selected as seaweeds in good condition with no damage to the rhizoids(growing point) and blades. A place to store collected washed up seaweeds (such as a port near a transplant site or a nearby indoor fish farm) is secured to carry out the preliminary work in the shade that is not affected by the sun.

○ The preliminary work is to remove foreign substances from the roots of seaweed (washed up) and trim the roots so they stick well to epoxy. After that, apply epoxy on the lower part of the root, attach it to the seaweed transplant host, and fix them with a rubber band.

○ Seaweeds that have completed the preliminary work are placed in a container box and placed in seawater for about a day in a place where there is no wave or flow of water, such as in a port or an indoor water tank.



<Image 5-8> Diagram of seaweed transplantation on rock using washed up seaweed

○ One day after the preliminary work on the land, the washed up seaweeds are moved to the transplant site and stored underwater, and epoxy is applied to the bottom of the seaweed transplant host and bonded with a bolt. When applying epoxy to the bottom of the host, make sure not to smear on the nut part, and the part with epoxy must be completely fixed into the rock.

※ For technical details, refer to the discussion materials of the Technology Evaluation Board.

<Image 5-9> Transplanting washed up seaweeds in Biyang waters in Jeju

9. Making spore bags using biodegradable natural material (Technology No. 2019-04)

○ Spore bags, one of the methods for creating marine forests, are used to spread seaweed spores. However, the existing spore bag material is likely to generate microplastics by using PE materials such as PP ropes. Spore bags that have lost their function must be recovered by divers, and if they are lost due to waves, they can generate marine wastes.

○ Therefore, the use of natural materials is required, and spore bags made of coir, a fibre that forms the hard skin of palm fruit (coconut), was developed.

○ To make a coir spore bag, fix two pieces of timber (50×50×200mm) into an X-shape and put it in the upper part of the coir net (300×650mm/ mesh 3mm or more) pocket to have buoyancy when installed. And add 2-3kg dried parent algae per pouch. The mouth of the spore bag is sealed with a coir rope. Two to three spore bags are connected with each rope and fixed to artificial reefs, natural rocks, etc.

○ The coir material naturally decomposes after about 3 months, so no separate recovery work is required.

※ For technical details, refer to the discussion materials of the Technology Evaluation Board.

《그림 5-10》 천연소재를 활용한 모조주머니 시설 모습

10. Intellectual property rights for the Marine Forest Project (FIRA)

○ While working on the Marine Forest Project, technology development was continuously encouraged to advance the project, and until now (2019) 25 patents were registered and two patent applications were obtained.

<Table 5-6> Status of intellectual property rights related to Marine Forest Project

Technology	Summary	Intellectual property right	Note
Method for calculating the area of bedrock and non-bedrock for survey on the actual condition of calcification	After depth survey, seafloor image survey, and sub-bottom profiling survey for the target marine area, it is possible to calculate the area of submarine bedrock and non-bedrock through 3D modelling and modelling image analysis of the seafloor.	Patent registered	Registration No. 10-1339678 (2013.12.04.)
Device for fixing the suspension rope of seaweed farms	A fixing device that can safely and conveniently fix and release the suspension and reinforcement ropes in seaweed farms.	Patent registered	Registration No. 10-1347302 (2013.12.26.)
Amidoxime-rich nano-fibres for recovery of uranium ions and the manufacturing method	Better adsorption capacity for uranium recovery by amidoximating nanofibres which contain a large amount of cyanides to include more amidoximes compared to conventional polyacrylonitrile fibres.	Patent registered	Registration No. 10-1408773 (2014.06.11.)
Seaweed farm and seaweed collection method from the seaweed farm	It is about seaweed farms and aquaculture vessels capable of multi-cultivation of seaweeds and capable of mass production. The effect of improving work performance by reducing the working time for collecting seaweeds in aquaculture farms.	Patent registered	Registration No. 10-1412024 (2014.06.19.)
Stapler type seaweed automatic transplantation device and method	Mass production is possible by automating the seed line transplantation in seaweed farming, and thus improving work performance.	Patent registered	Registration No. 10-1412027 (2014.06.19.)
Open-guided automatic seaweed transplantation device and method	Reducing seed line transplantation labour hours in seaweed farming, thereby improving economic efficiency and work performance by mass production	Patent registered	Registration No. 10-1412021 (2014.06.19.)
Seaweed farm mooring device	Mooring device for strengthening mooring and maintaining the form of mooring in seaweed farms	Patent registered	Registration No. 10-1412023 (2014.06.19.)

<Table 5-6> Continued

Technology	Summary	Intellectual property right	Note
Automatic seaweed transplantation device and method	Mass production is possible by automating the seed line transplantation in seaweed farming, and thus improving work performance.	Patent registered	Registration No. 10-1412026 (2014.06.19.)
Mid-water rope culture system for marine forest creation and marine forest creation method using the facilities	By forming a cluster through the installation of multiple mid-water rope culture facilities, and use the structure for various purposes such as a fish and shellfish habitat, a seed bank feeding ground, etc.	Patent registered	Registration No. 10-1415493 (2014.06.27.)
Fish incubator for spawning and nurturing sandfish	The hexahedral body formed with the combination of the upper and lower horizontal parts and the solid part that can connect the parent algae is installed with seaweed nurturing lines to serve as a sandfish spawning site and create protection for juvenile fish.	Patent registered	Registration No. 10-1427538 (2014.07.31.)
Triangular tunnel type artificial reef	Minimising physical collision between seaweeds and waves to maximise structural stability and marine forest efficacy. Sectionalisation of internal space allows coexistence of various kinds of fish and shellfish and form a natural food chain.	Patent registered	Registration No. 10-1475227 (2014.12.16.)
Herbivore capturing device	Easily capture herbivores by luring and preventing their escapes with its luring and trapping parts and the device is made of materials that can be installed in various shapes of the seabed.	Patent registered	Registration No. 10-1540423 (2015.07.23.)
Water depth correction method using aerial hyperspectral images	Water depth correction for aerial hyperspectral images allows effective classification of coastal seafloor cover and to improve the analysis range and accuracy as noise effects are reduced by minimising effects from water depth.	Patent registered	Registration No. 10-1621354 (2016.05.10.)
Calcification detection technique using aerial hyperspectral images	As the effect of noise is reduced by minimising the effect of water depth through depth correction for aerial hyperspectral images, it is possible to effectively classify the coastal seafloor cover and to accurately detect the calcification.	Patent registered	Registration No. 10-1672291 (2016.10.28.)
H-shape seaweed transplant plate	Easy to install and dismantle on natural bedrock, artificial reefs, etc. With the minimisation of unnecessary contact surfaces, it restores calcified sea area with severe curvature, and reduces damage by herbivores in the early stage of seaweed transplantation.	Patent registered	Registration No. 10-1722386 (2017.03.28.)

<Table 5-6> Continued

Technology	Summary	Intellectual property right	Note
Method of transplanting eelgrass of subtidal zone using clay, Korean paper, and eelgrass implant container	During transplantation, the outside of the clay attached to the eelgrass is wrapped with Korean paper to inhibit the drying of the clay and prevent the separation or collapse of the clay, thereby improving the survival rate of the eelgrass after transplantation.	Patent registered	Registration No. 10-1739342 (2017.05.18.)
Halophyte classification system through hyperspectral imaging technique	Accurate and systematic classification of halophyte character species and prevention of damage to halophytes by drones when acquiring images as well as drone abnormality and fall by eliminating indirect contact completely.	Patent registered	Registration No. 10-1744662 (2017.06.01.)
Underwater herbivore removal device	As a device using suction power by air pressure, it is harmless to the marine environment, and it is effective for the removal of various herbivores which previously performed by hand.	Patent registered	Registration No. 10-1803773 (2017.11.27.)
Method of transplanting eelgrass of subtidal zone using clay and Korean paper	During transplantation, the outside of the clay attached to the eelgrass is wrapped with Korean paper to inhibit the drying of the clay and prevent the separation or collapse of the clay, thereby improving the survival rate of the eelgrass after transplantation.	Patent registered	Registration No. 10-1812733 (2017.12.20.)
Droppings for eelgrass transplantation using industrial by-products and the method of eelgrass transplantation using them	As a sustainable technology that can recycle industrial by-products, it is a simple method of dropping it into the coastal area, contributing to the high efficiency of transplanting eelgrasses in the water, building a healthy ecosystem on the coast, and increasing the of fisheries production.	Patent registered	Registration No. 10-1943465 (2019.01.23.)
Method of collecting sea urchins using electric stimulation	The effect of attracting sea urchins without destroying the aquatic ecosystem by using electric stimulation by applying low voltage and low current in the water.	Patent registered	Registration No. 10-195125 (2019.02.18.)
Method of surveying the distribution of eelgrass colonies using unmanned aerial vehicles	A method of surveying the actual conditions and status of eelgrass colonies by acquiring colour images or multispectral images of the target area using drones and classifying and analysing eelgrass colonies.	Patent registered	Registration No. 10-1965235 (2019.03.28.)
Seaweed transplantation method for the creation and expansion of natural seaweed beds	A method of installing the seedling rope in the seaweed colonies, collecting the spores of seaweed, and then installing the seedling rope in the transplanting sea area.	Patent registered	Registration No. 10-1974404 (2019.04.25.)

<Table 5-6> Continued

Technology	Summary	Intellectual property right	Note
Seaweed seedling collecting device and method for collecting seaweed using the device	A seedling collection device that can be installed in a seaweed colony to effectively collect spores released from seaweeds, and a method for harvesting seedlings using the device.	Patent registered	Registration No. 10-1974403 (2019.04.25.)
Structure for transplanting adult seaweed directly on rock mass	It is easy to install and is suitable for the marine environment. Reduction of fall-off rate and improvement of survival rate through direct transplantation of individual seaweeds into underwater rock mass.	Patent registered	Registration No. 10-2045689 (2019.11.11.)
Rope fixture for seaweed transplantation and supplementary plantation	As a rope fixing tool for seaweed transplantation and supplementary plantation, fast and easy fixing of seaweed-attached ropes to underwater artificial reefs or natural bedrock without using mechanical tools such as stapler.	Patent applied	Application No. 10-2019-0126129 (2019.10.11.)
Nurturing rope binding device to create natural seaweed beds	Fast and easy fixing of seaweed-attached ropes to natural rock in the water without using a machine tool such as stapler.	Patent applied	Application No. 10-2019-0126130 (2019.10.11.)

제VI장 바다숲 효과조사

1. 바다숲 조성지 효과조사
2. 잘피숲 조성지 효과조사
3. 염생식물 조성지 효과조사

Chapter VI
Survey on Efficacy of Marine Forests

1. Survey on the efficacy of the marine forest sites

A. Application criteria

○ It targets the sea area of the Marine Forest Project (1 to 4 years).

○ As for the efficacy survey period, a survey per season (February, May, August, and October) is conducted for the first and fourth-year sea areas, and only the May survey is conducted for the second and third-year sea areas.

❊ Winter (Dec - Feb), Spring (Mar - May), Summer (Jun - Aug) & Fall (Sep - Nov)

○ Marine environment surveys are conducted seasonally only in sea areas in the first and fourth years of the project.

○ The customer satisfaction survey (questionnaire) is conducted once a year only in the sea area of the fourth year.

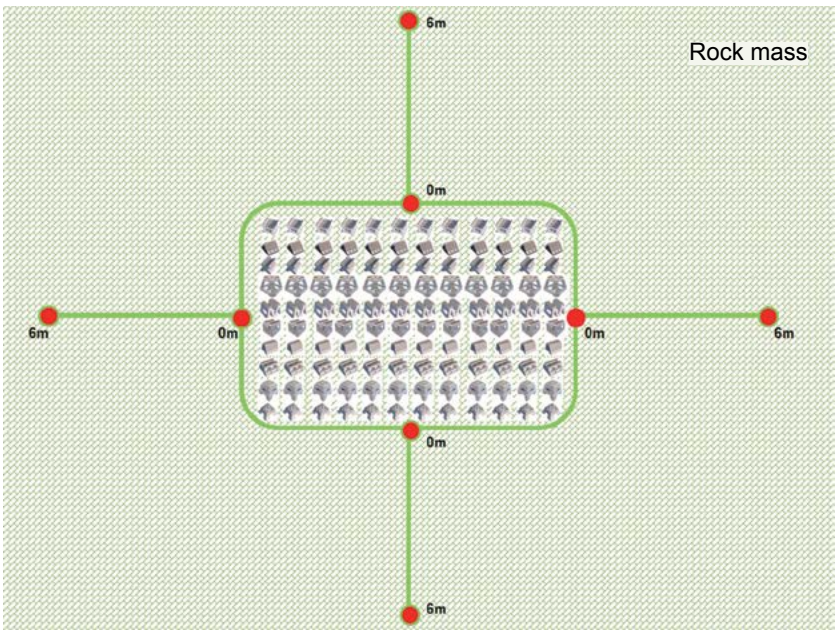
<Table 6-1> Marine forest efficacy survey schedule by item

Classification	Item	Survey period				Note
		Feb	May	Aug	Nov	
Habitat survey	Seaweeds	○	○	○	○	
	Macrozoobenthos	○	○	○	○	
	Meiobenthos		○			
	Zooplankton	○	○	○	○	
	Roe & larva	○	○	○	○	
	Calcification reduction rate		○			Use underwater film data
	Epizoites	○	○	○	○	
Marine environment	Marine environment	○	○	○	○	Sea area of the 1st and 4th year
Nekton survey	Nekton	○	○	○	○	
Customer satisfaction	Fishermen Survey	Once a year				Sea area of the 4th year

B. Seaweeds and macrozoobenthos survey

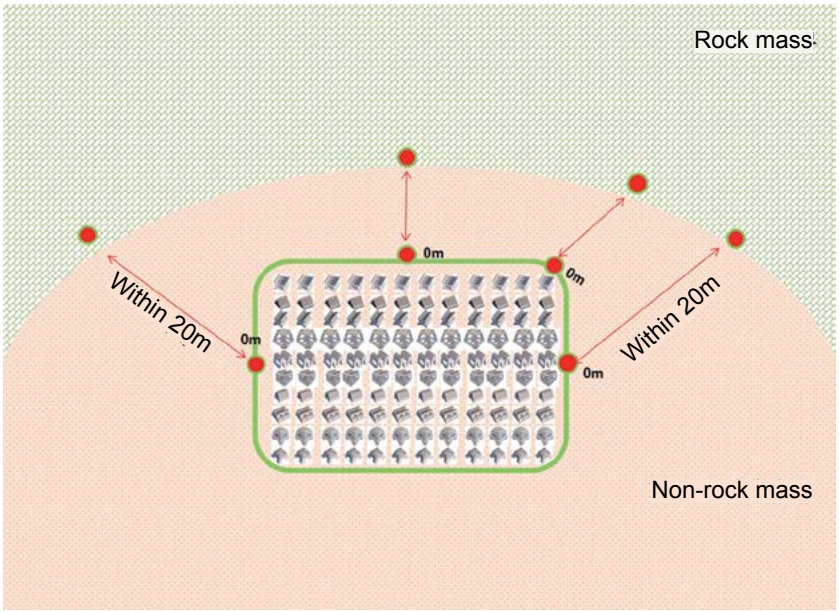
○ For the collection of benthos, a diver fixes a reference point at the site that can represent the survey area within the distribution area of the organism. It is carried out using the quadrat method for quantitative analysis and the line transect method for qualitative analysis.

○ If there are one or two or more extension facilities such as artificial fish reefs in the marine forest area, select straight lines from the boundary (reef) to the north, east, south, and west, also select 8 points of 0m (reef) and 6m from each direction. Samples are collected at each point using the quadrat method.



<Image 6-1> Reference map for survey station (1)

○ Where it is difficult to set up four lines north, east, south, and west due to the nature of sediments in the surrounding area (non-rock mass), a rock mass where seaweeds inhabit within 20m is selected as the survey point, and the reef section on the horizontal extension line from the survey point as a point at 0m, 8 points are selected. At each point, samples are collected with the quadrat method and a location plot is created.



<Image 6-1> Reference map for survey station (1)

○ For the collection of seaweeds and macrozoobenthos, the whole quantity is collected in the quadrat (50×50cm) using the 1-time destructive sampling method at each of 8 points of the quadrat. The mesh of the collecting net used should not exceed 1mm, and for the coverage analysis, after installing the quadrat, filmed vertically using a Full-HD underwater camera.

※ The attached organism collection nets are utilised to prevent the loss of small and light organisms in the water as much as possible.

○ Eight (seaweeds + macrozoobenthos) nets that finished collecting for each sea area are brought up on board. Seaweeds are dried as much as possible and kept frozen (dry ice can be used) or fixed in 5-10% formalin (GR formalin 10 + seawater 90). Zoobenthos are placed in a 3L plastic sample container and fixed with 10% formalin. Sample collection information must be clearly marked on the sample container.

<Table 6-2> Sampling information (label)

Classification	Survey details		Note
Business name	000		
Date and time	YYYY MM DD, HH MM		
Location	00 city 00 county 00 town sea area		
Collection area	Line No. 00 / 0m, 6m		N00°00.000′, E00°00.000′
Collected item	Depth : 00m	Animal, Seaweed, Environment	With or without fixing agent Formalin (00%)
Collector	Company : 0000000 / Collector: 000		

❊ Width 10cm × Length 7cm (Insert one inside of the sample bottle & attach one outside)

○ Collected samples are identified by species and collection point, and the population size (n/m^2) and biomass are measured (wet weight, minimum 0.01g/m^2) and converted into units of 1m^2.

○ Conduct calculation of ecological index (species diversity, evenness and abundance), comparison of colony structures and similarity analysis, and the status of herbivores is identified.

C. Meiobenthos survey

○ Meiobenthos generally pass through a 1mm sieve and remain in a 42μm sieve.

○ For sampling meiobenthos, one point is selected for each sea area and is conducted only during the survey in May.

○ Samples are collected using an acrylic core (3.6cm in internal diameter and 10cm in depth) within 3m of the project site (marine forest reefs). Samples are put in a sampling container of 100ml or bigger, fixed with formalin (5-10%) and sealed, and clearly display the sample collection information (see Table 6-2 above).

○ Collected samples are identified to the species level, and the population size (n/m2) is measured (including foraminifera).

○ Conduct calculation of ecological index (species diversity, evenness and abundance), comparison of colony structures and similarity analysis.

D. Zooplankton survey

○ A conical shaped net with a collection tube (net entry: 45cm, length: 70cm, mesh: 330μm) is used, and a flow meter is attached to the 2/3 height of the net's ring inlet.

○ The boat speed at the initial stage of net deployment for sample collection to be maintained at a minimum of 0.5m/sec. The net towing speed is maintained at about 1m/sec. In principle, the surface collection method is used if the depth of water is within 5m, and if it's deeper than 5m, use oblique towing between 1m above the seabed and the surface. The net towing is carried out for 10 minutes, and such oblique towing is continuously and repeatedly performed by adjusting the towing speed within the 10 minutes.

○ When the net clogging occurs due to the high density of zooplankton, the towing time can be adjusted according to the site conditions.

○ After the towing is completed, use seawater to collect all the specimens that may be attached to the inside of the net, into a bucket under the net. Transfer the samples from the bucket to a separate storage 1L container (polyethene material) without seawater overflowing. The seawater cleaning and transferring from the net to the bucket are repeated several times to ensure that no collected sample residues remain in the net.

○ In the case of excessive collection of small jellyfish during surveys in spring, summer, and autumn, the situation should be recorded separately, and the towing time should be shortened to 1/2 (5 minutes).

○ Record the type of flowmeter (manufacturer & model name) and rotation number (value at the start point and end point) (The filtration is calculated according to the calculation method of the flowmeter used).

❊ Caution) after collecting samples, separate the net and bucket and wash them thoroughly with seawater to prevent mixing of the samples collected at the previous point when collecting at the next point.

○ Fix the storage container with 5% formalin and seal, and clearly display the sample collection information (see Table 6-2 above).

○ Collected samples are identified down to the species level, and the population size (n/m^2) is measured.

○ Conduct calculation of ecological index (species diversity, evenness and abundance), comparison of colony structures and similarity analysis.

E. Fish roe & larva survey

○ RN80 net (net entry diameter: 80cm, mesh: 500μm) is used to collect fish roe and larva samples, and a flowmeter is attached to the net's inlet, on the edge that is 1/3 of the diameter.

○ The boat speed at the initial stage of net deployment for sample collection to be maintained at a minimum of 0.5m/sec. The net towing speed is maintained at about 1m/sec. In principle, the surface collection method is used if the depth of water is within 5m, and if it's deeper than 5m, use oblique towing between 1m above the seabed and the surface. The net towing is carried out for 10 minutes, and such oblique towing is continuously and repeatedly performed by adjusting the towing speed within the 10 minutes.

○ When the net clogging occurs due to the high density of zooplankton, the towing time can be adjusted according to the site conditions.

○ After the towing is completed, use seawater to collect all the specimens that may be attached to the inside of the net, into a bucket under the net. Transfer the samples from the bucket to a separate storage 1L container (polyethene material) without seawater overflowing. The seawater cleaning and transferring from the net to the bucket are repeated several times to ensure that no collected sample residues remain in the net.

○ In the case of excessive collection of small jellyfish during surveys in spring, summer, and autumn, the situation should be recorded separately and the towing time should be shortened to 1/2 (5 minutes).

○ Record the type of flowmeter (manufacturer & model name) and rotation number (value at the start point and end point) (The filtration is calculated according to the calculation method of the flowmeter used).

○ For the sampling time, day, night or tidal cycles are not considered.

○ Fix the storage container with ethanol (over 70% concentration) and seal, and clearly display the sample collection information (see Table 6-2 above).

○ If the species with genetic analysis data, the collected samples are identified by species by genetic analysis, and the population size (n/1,000m^2) is measured.

○ Conduct calculation of ecological index (species diversity, evenness and abundance), comparison of colony structures and similarity analysis.

F. Calcification reduction rate survey

○ When collecting seaweed and macrozoobenthos samples from 8 points for each survey sea area, a quadrat (50×50cm) is installed, and a Full-HD underwater camera is used to film vertically so the coverage of coralline algae can be analysed.

○ Divide the quadrat into 10cm × 10cm sections, if the image quality is poor (it is impossible to distinguish between coralline algae and seaweeds, etc.) because of marine weather and environment.

○ Coverage by species of seaweed within the quadrat is calculated using Image Analyzer software that allows precise analysis of the coverage.

○ Check for the presence of coralline algae (articulated & non-articulated coralline algae).

○ Calculate coverage, relative coverage, and relative frequency for each point/species.

○ Repeat coverage analysis so that errors can be minimised, and calculate the rate of calcification of coralline algae per unit area.

G. Epizoite survey

○ For seaweeds, large brown algae (Ecklonia cava) are targeted for the survey.
❊ In the case of the sea area without Ecklonia cava, it is selected from large brown algae such as sargassum, sea oak, Ecklonia stolonifera, sea mustard, and kelp.

○ Seaweeds are collected three times separately, one at a time.

○ For the collection of seaweed-attached epizoites, use a 100×50cm-sized collection net (less than 1mm of mesh) to prevent the loss of samples during the collection process. Completely wrap the target seaweed from the top to the base with the net and collect the whole body, including the base.

○ The collected sample is fixed with a 10% formalin solution still in the collection net, and the sample collection information (see Table 6-2 above) is clearly displayed.

○ Collected samples are classified into types of macrozoobenthos such as crustaceans, molluscs, polychaetes, etc., and identified down to the species

level, and the population size (number) and biomass (minimum 0.01g) are measured.

○ Conduct calculation of ecological index (species diversity, evenness and abundance), comparison of colony structures and similarity analysis.

H. Marine environment survey

○ The survey can be carried out from time to time, if there is a change in the environment of the Marine Forest Project sea area and it is necessary to understand the characteristics of the marine environment.

○ The water temperature, salinity(psu), pH, DO(mg/L), oxygen saturation(%), and transparency, etc. of the surface layer and the bottom layer at one representative point in each area of the survey, are measured using devices such as YSI and a Secchi disc.

○ Data on chemical oxygen demand(COD), dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus(DIP), and chlorophyll-a(Chl-a) are used to calculate water quality index(WQI) by reflecting the measurements of similar points from the National Marine Environment Information System.

I. Nekton survey

○ For each fishing section, one point in the project site (the nearest outer corner of artificial reef installation (planned)) and one point in the nearby control section (non-facility site) are surveyed.

○ Gill net: 2 points for each sea area (1 point in the project site, 1 point in the control site)

– 4 gill nets (width 50m × length 2m) are used at each point.

○ Drum net fish trap: 2 points for each sea area (1 point in the project site, 1 point in the control site)

– 30 drum net fish traps (width 60cm × length 35cm) are used at each point.

○ Hauling of both gill nets and drum traps are set for more than 12 hours and less than 24 hours based on the timing of casting, and the duration can be adjusted in consideration of variables such as weather conditions.

<Table 6-2> Fishing gear for Nekton survey

Classification		Gill net	Drum net trap (retractable spring)
Number by sea area		4 x 2 points = 8 (400m)	30 x 2 points = 60 (400m)
Size		50m width x 2m length	60cm width x 35cm length
Part	Mesh	81-85mm	Mesh 20mm (Td210, plaited thread 9)
	Buoy	High density buoy No.3 x 60(n)	
	Underlay	No.13(20g) x 120(n)	
	Strop	H 2m x 101(n) (top-to-bottom connection 50m apart)	
Deposition time		12-24 hours	12-24 hours
CPUE (conversion)		g/per ea/24h	g/per ea/24h

○ The total population and weight are measured for each fish species caught during the survey.

○ If there are a large number of organisms collected, measure up to 30 per point for each species of fish, and measure the total weight by counting the rest.

○ The length and weight are measured to the first decimal place.

○ Fish species should be written in Korean names (distinguished dialects).

○ Measure the standard traits for each fish species and describe the traits using symbols L1, L2, etc.

ex) black sea bream(L1: the whole length, L2: fork length), small yellow croaker(L1: total length, L2: body length), eel(L1: total length, L2: length to the anus), skate ray(L1: body-disc length, L2: body-disc width), prawn(L1: carapace length-CL) and cephalopod(L1: mantle length)

○ Fish measurement traits (TL+FL, TL+BL, TL+AL, BdL+BdW)

– TL (Total length): The straight length from the front end of the snout of the upper jaw to the back end of the tail fin. If one of the upper and lower jaws of the snout is long or short, measure from the end of the short one.

ex) All fish species except skates, stingrays and cephalopods.

○ Fish measurement traits (TL+FL, TL+BL, TL+AL, BdL+BdW)

– FL (Fork length): The straight length from the front end of the snout of the upper jaw to the concave inner end of the tail fin.

ex) horse mackerels, common mackerels, yellowtails, black sea breams, red seabreams, sea basses, tunas, etc.

– BL (Body length): The straight length from the front end of the muzzle of the upper jaw to the base end of the tail fin. That is the straight length of the joint point between the hypural and the tail fin stem.

ex) small yellow croaker, white croaker, brown croaker, flatfish, spotty belly greenling etc.

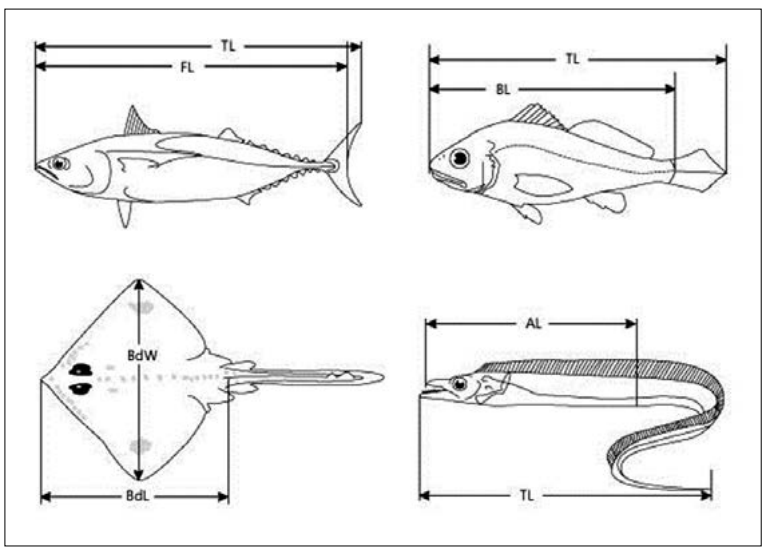
– AL (Anal length): Length from the end of the snout of the upper jaw to the anus.

ex) conger eel, sharp-toothed eel, hairtail, tidepool gunnel, etc.

– BdL (Body disc length): Length from the front end of the snout to the rear end of the pectoral fin.

ex) mottled skate, skate ray, ray, etc.

– BdW (Body disc width): Length between the left and right edge extrusion of the pectoral fin.



<Image 6-3> Measurement for type of fish

○ Crustacea measurement traits (CL: prawn, CL+CW: crab)

– CL (Carapace length): Length from the back edge of the eye socket to the far back edge of the carapace.

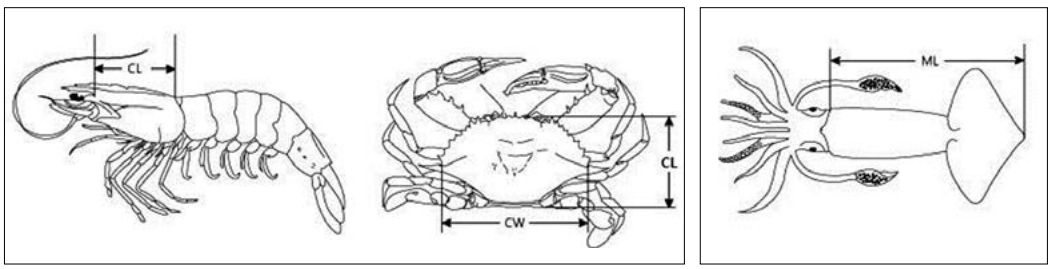
ex) prawn, etc.

– CW (Carapace width): Length of the maximum width not including the outer spines of the cranial breastplate.

ex) crab, etc.

○ Cephalopoda measurement traits (ML: cuttlefish, giant octopus, webfoot octopus, Longarm octopus, etc)

– ML (Mantle length): Length from the ventral end of the torso to the end of the mantle.



<Image 6-4> Measurement for crustacea and cephalopoda

<Table 6-4> Field note for Nekton survey

Survey location				Survey date	YYYY MM DD	
Survey point		Coordinates (WGS-84)	Start of casting	° . ′ N, ° . ′ E		
			End of casting	° . ′ N, ° . ′ E		
Collecting equipment	Net Trap	Number of equipment		Standard	Size : m	
					Mesh : mm	
Casting time	MM DD HH MM			Hauling time	MM DD HH MM	
Depth	m	Surveyor			Weather	Clear, Cloudy, Rain
Special note						

<Table 6-5> Field note for Nekton survey

Field note for fish measurement

Survey sea area		Survey date	YYYY MM DD
Survey point			
Survey equipment	Net, Trap	Surveyor	

No.	Fish species	Mea-surement	L1(cm)	L2(cm)	BW(g)	population	
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
17							
18							
19							
20							

1. TL+FL: sea bass, black sea bream, other breams, common mackerel, horse mackerel, tunas, etc.
2. TL+BL: goosefish, snailfish, croakers, flat fish, greenlings, etc.
3. TL+AL: conger eel, sharp-toothed eel, hairtail, gunnels, etc.
4. BdL+BdW: mottled skate, skate ray, other rays, etc.
5. CL+CW: swimming crab, Asian paddle crab, other crabs, etc.
6. CL: prawns, etc.
7. ML: cuttlefish, common cuttlefish, giant octopus, webfoot octopus, long arm octopus, etc.

❇ All fish species are measured in total

❇ Crabs (swimming crab, Asian paddle crab), prawns, cephalopods are measured from commercial catches

J. Customer satisfaction survey

○ In order to reach a consensus on the Marine Forest Project and use for basic policy data, the satisfaction level (perception level) of the customer in the region is investigated.

– Survey target: Fishermen affiliated with fishing villages in the target sea area in its 4th year of Marine Forest Project

– Survey method: Customer satisfaction survey on the Marine Forest Project

<Table 6-6> Customer satisfaction survey

000 Marine Forest Project customer satisfaction (perception) survey

Hello, this is the Korea Fisheries Resources Agency.

Our agency is conducting the "000 Marine Forest Project Customer Satisfaction (Perception) Survey" for fishermen from 000 area fishing villages.

This survey is intended to collect opinions of fishermen on the 000 Marine Forest Project, and the findings of the survey will be used as basic data to establish the direction of policy development related to the Stock Enhancement Program in 000 (city/province) in the future.

We would like to actively reflect the opinions of fishermen of 000 fishing villages through this survey, so we would appreciate your active cooperation in the survey.

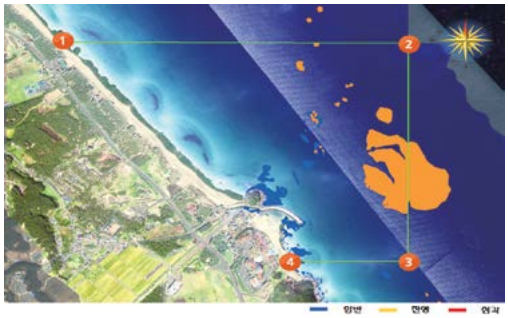
※ This investigation is strictly confidential in accordance with Articles 33 and 34 of the Statistics Act, and all responses are used for statistical analysis purposes only.

YYYY MM

□ **Marine Forest Project Outline**

o Project to restore coastal ecosystem by transplanting seaweeds, installing natural stones or seaweed reefs, etc. in the sea area where calcification (sea desertification) has progressed

o Total project cost: KRW 000 million (government expense)
o Total project period: 0000~0000 (4 years)
o Location and area: 000 Gangyang ~ East coast of Pyeongdong Sea area 000ha
o Details: 000 fishery plants, 000m^3 of natural stone installation, seaweed transplantation, mid-water rope culture system, spore bag installation



(Sea area diagram example)

Organisation: FIRA 00 Branch Project Management Team 000 (position) ☎: 000-000-0000
Survey agency: Efficacy survey company and surveyor in charge ☎: 000-000-0000

I. Respondent details

1) Gender	① Male ② Female
2) Age	① 20's ② 30's ③ 40's ④ 50's ⑤ over 60
3) fishing communities belong to	① 00 ② 00 ③ 00 ※ If there are multiple fishing communities
4) How long have you been fishing	① less than 10 years ② 10-19 years ③ 20-29 years ④ over 30 years
5) Main trade	① net/trap fishery ② fishing ③ skin diving fishery ④ leisure fishing tourism ⑤ set net fishery ⑥ other( )
6) Annual income	❉ The sum of annual fishing income, agricultural income, and other income. ① less than KRW 15 million ② KRW 15-30million ③ KRW 30-45 million ④ KRW 45-60 million ⑤ over KRW 60 million
6) Annual fishery income	❉ Annual income generated from fishing activities. ① less than KRW 10 million ② KRW 10-20million ③ KRW 20-30 million ④ KRW 30-40 million ⑤ over KRW 40 million

II. Marine Forest Project

1. How much do you know about the national Marine Forest Project?
   ① very well ② know a little ③ have heard of it ④ not at all

1-1. (Question for respondents ①, ②, ③ from Q1) How did you learn about the Marine Forest Project(multiple choices available)?
   ① FIRA project stakeholder ② local government official ③ project partner
   ④ mass media(TV, radio, newspaper etc.) ⑤ Internet
   ⑥ promotional material(poster/brochure etc.) ⑦ friend or family
   ⑧ other ( )

2. 000 (Dong, Myeon, Ri, Fishing Village) has carried out the Marine Forest Project for 4 years from 2015 to 2019. Are you currently aware of this project?
   ① very well ② know a little ③ have heard of it ④ not at all

2-1. (Question for respondents ③,④ from Q2) If the project is not well known, which part do you think should be strengthened?
① expand promotion ② active briefing session
③ installation of the project sea area indication signs ④ other( )

3. Do you think 000 (Dong, Myeon, Ri, Fishing Village) Marine Forest Project helps increase fishing income?
① very helpful ② mostly helpful ③ average ④ not so much ⑤ not at all

3-1. (Question for respondents ①, ②, ③ from Q3) If it helped increase your fishing income, what contributed to it(multiple choices available)?
① seaweeds ② fish ③ leisure and tourism ④ other( )

3-2. (Question for respondents ①, ② from Q3-1) If it helped increase your fishing income, what are the main species that contributed to it?
(species: mutliple answers available)

4. What kind of seaweed do you think is suitable for 000 (Dong, Myeon, Ri, Fishing Village)?
① sea mustard ② Ecklonia cava ③ sargassum ④ kelp ⑤ five-ribbed kelp
⑥ other ( )

5. What do you think is the most important point to consider when pursuing the Marine Forest Project in 000 (Dong, Myeon, Ri, Fishing Village)?
① coastal ecosystem recovery ② increase fishery resources
③ link to marine experience tourism ④ increase income for local fishermen
⑤ other ( )

6. 000 (City/Do municipalities) plans for follow-up management for the 000 (Dong, Myeon, Ri, and fishing village) marine forest. Do you agree it is necessary to continue follow-up management of the marine forest area?
① strongly agree ② somewhat agree ③ neither agree nor disagree
④ disagree somewhat ⑤ strongly disagree

7. The Korean government designates May 10 every year as Sea Arbor Day (National Day), the 'day to plant seaweeds in the sea'. Have you heard or know about Sea Arbor Day?

   ① strongly agree ② somewhat agree ③ neither agree nor disagree
   ④ disagree somewhat ⑤ strongly disagree

7-1. As a fisherman belongs to 000 (city/province), are you willing to host an event to celebrate Sea Arbor Day?

   ① strongly agree ② somewhat agree ③ neither agree nor disagree
   ④ disagree somewhat ⑤ strongly disagree

8. If you have any improvements and additional comments for future marine forest projects, we will actively reflect on them.

Additional comments and improvements

✻ Thank you for your sincere response to the survey ✻

Respondent's Name	
Signature	

2. Survey on the efficacy of eelgrass forest sites

A. Application criteria

○ It targets the sea area of the eelgrass development management (1 to 4 years).

○ The efficacy surveys are conducted in four seasons (February, May, August, and October).

○ Marine environment surveys are conducted seasonally only in sea areas in their first and fourth years into the project.

○ To determine the effectiveness of the eelgrass forest, the diffusion area, density, growth status, benthos, nekton and marine environment are surveyed.

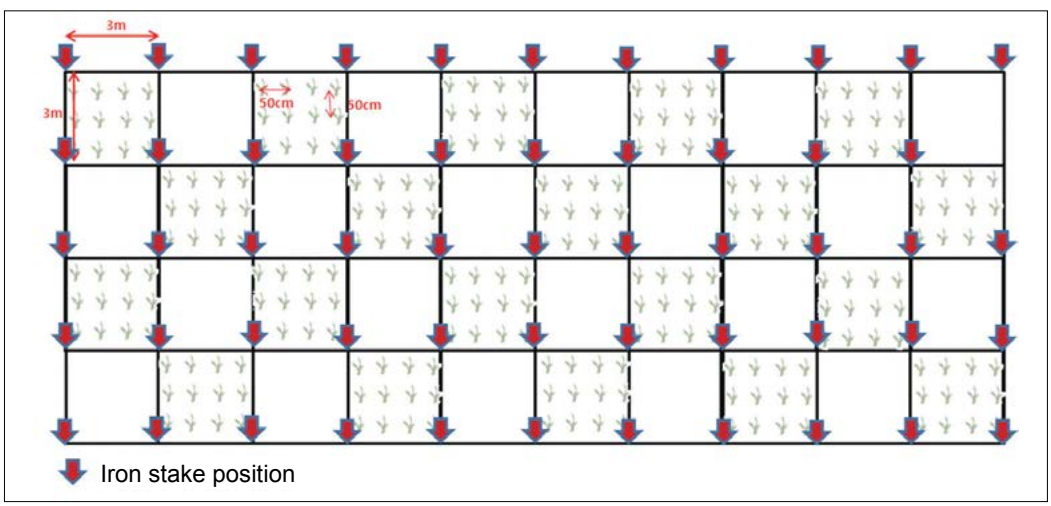
B. Survey of the diffusion area of eelgrass

○ When constructing an eelgrass bed, a 3×3m grid is installed using ropes and iron stakes.

○ The marking of the transplant site should be firmly fixed to withstand the waves, and if it is lost or damaged while monitoring, refurbish immediately.

※ Iron stake: 50cm or more, PE rope 5mm white or fluorescent colour used.

○ The number of sections is determined and installation is made according to the area of construction, referring to the diagram below.



<Image 6-5> Diagram for eelgrass development site indication

○ After marking the eelgrass forest development site, install buoys at the four corners, and then record the coordinates and create a diagram.

○ During monitoring, 10 grids are selected at random, and the population in the grid is counted to calculate the survival rate (%). Calculate the number of populations settled in the empty grid to calculate the spread(settlement) rate (%).

C. Survey of the density of eelgrass

○ There are a total of 4 survey points, and 2 points are set on each of the transplant and settlement sites.

○ The eelgrass density is indicated by the growth density(n/m^2) by counting the population in the quadrat four times after installing quadrats(50×50 cm).

○ Identify the seasonal survival rate of transplant and settlement sites.

❊ Conduct the survey at the same survey point quadrat.

D. Survey of the growth condition of eelgrass

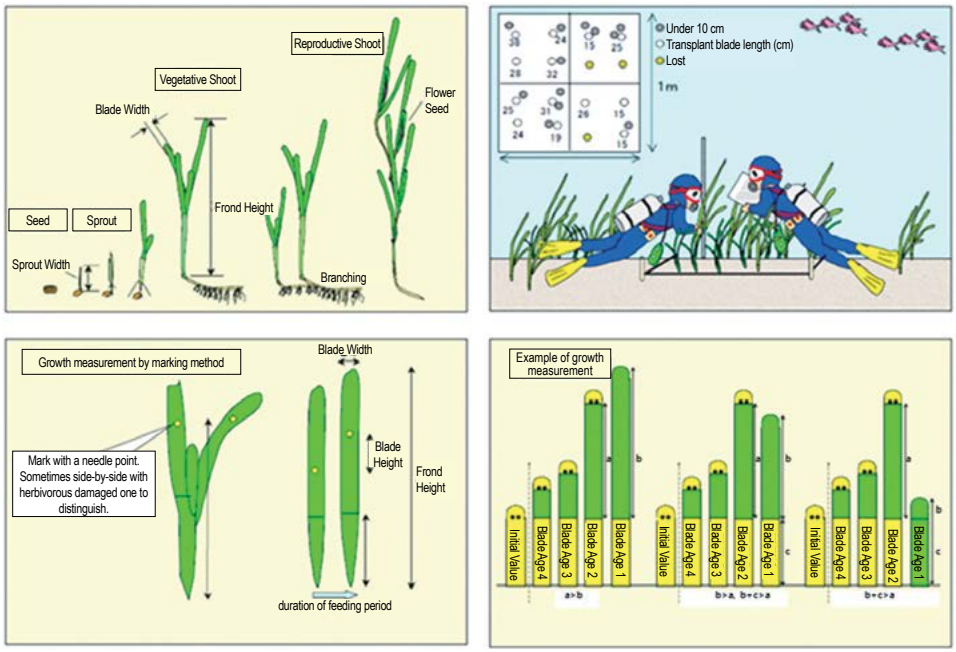
○ The survey point is carried out at the eelgrass transplant and settlement sites, and about 20 eelgrasses per point are randomly collected including the rootstocks.

○ Measure the morphological characteristics of eelgrasses.

– Number of blades (n), length of blade (cm), above-ground part (cm), below-ground part (cm), blade sheath length(cm), blade sheath width(mm), number of rootstock nodes(n)

○ Samples are divided into above-ground and underground to measure wet and dry weights. The wet weight(gWWt/m^2) is measured by removing adherent substances and moisture as much as possible. For the dry weight(gDW/m^2), the samples that are not damaged, are washed and dried at 60°C for more than 24 hours before weighing them.

○ Count the vegetative shoots and reproductive shoots (flowering stocks) and calculate the population per unit area. When measuring the population per unit area, the method shown below is applied.



<Image 6-6> Measuring eelgrass growth

E. Benthos survey

○ Can Core (20×12.5×20cm) is used for collecting samples for benthos. After covering the blade part of eelgrasses with a collection net in the Core applied area, the growing point is cut with scissors to collect all the blades.

○ The Can Core is covered on the cut part and the rootstocks and sediment inside the Can Core are collected 3 times (n=3).

○ The collected samples transported to the laboratory are classified into benthos inhabiting rootstocks and sediments within a sieve of 1 mm mesh, and then the attached substances are removed.

○ Identify collected samples by species and collection point, and the population size (n/m^2) and biomass are measured (wet weight, minimum 0.01g/m^2) and converted into units of 1m^2.

○ Conduct calculation of ecological index (species diversity, evenness and abundance), comparison of colony structures and similarity analysis.

F. Nekton survey

○ Surveys are conducted at high tide to identify the nekton that uses the eelgrasses as their habitat.

○ The survey of nekton uses a beach seine (50m×2m) and gill net (50m×2m×4(n)), and each survey point sets at 1 development site and 1 non-development site.

❊ In sea areas where beach seines cannot be used, only use gill nets.

○ The beach seine is used repeatedly three times at low tide at the development site (eelgrass transplant site) and analyse the collected fish.

○ The gill net is used to analyse fish collected after casting for between 12 to 24 hours at the development site (eelgrass transplant site) and non-development site (more than 500 meters away from the development site).

○ Record the sample collection process (start and end time, coordinates, etc.) in the field note.

○ The total population and weight are measured for each fish species caught during the survey.

○ If a large number of organisms are collected, measure up to 30 per point for each species of fish, and measure the total weight by counting the rest.

○ The length and weight are measured to the first decimal place.

○ Fish species should be written in Korean names (distinguished dialects).

○ Measure the standard traits for each fish species and describe the traits using symbols L1, L2, etc.

ex) black sea bream(L1: the whole length, L2: fork length), small yellow croaker(L1: total length, L2: body length), eel(L1: total length, L2: length to the anus), skate ray(L1: body-disc length, L2: body-disc width), prawn(L1: carapace length-CL) and cephalopod(L1: mantle length)

❊ For the measurement traits by species, refer to the nekton survey in the above 1. Survey on the efficacy of marine forest sites.

G. Marine environment survey

○ The marine environment survey is conducted at high tide.

○ There are 4 survey points for each sea area, and 2 development sites and 2 non-development sites (500m or more away from the development site toward the open sea) are set.

○ The sampling method of seawater and sediments in accordance with the Korean Standard Methods for Marine Environment (MOF) and the analysis of the samples is conducted by the certified body for measuring and analysing capabilities.

○ Water environment

– To survey the basic environment of seawater (water temperature, salinity, pH, DO, transparency), chlorophyll-a (Chl-a), chemical oxygen demand (COD), dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP) and dissolved inorganic silicon concentration (DIS).

– The basic environment survey and seawater collection are conducted at the bottom of each point (water level 1m from the seafloor).

– The basic environment survey is conducted using a water quality meter and a Secchi disc, and for other nutritive salts, more than 2 L of seawater is collected and analysed using a Niskin water sampler.

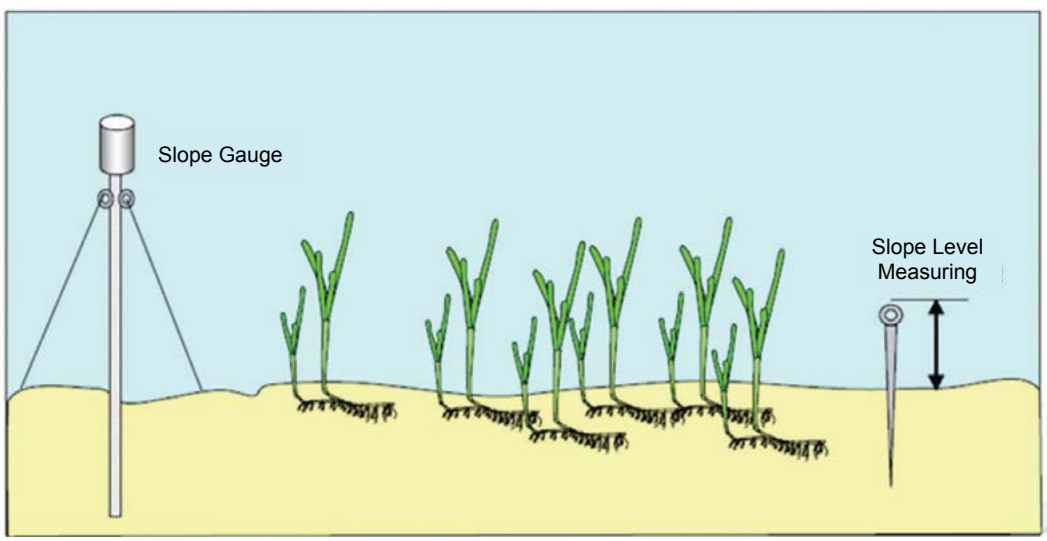
– Using the transparency of the sea area measured with a Secchi disc, the limiting depth of growth is calculated (refer to Table 6-7 below), and it is determined whether the transparency falls below a certain level.

○ Sedimentary environment

– To collect at least 1,200g of sediments per sample by the Grab. The collected samples are sent to a specialised analysis institution to perform grain size or proportions analysis and construct a grain-size accumulative curve.

– Using the "Folk & Ward" method, calculate the average grain size, degree of sorting and skewness, etc., and create a substratum distribution chart for each classification (see Table 6-8 below).

– Analyse sedimentary properties (grain size distribution), organic matter content (including moisture content), and acid volatile sulphide analysis.



<Image 6-7> Measuring Eelgrass habitat slope change

– Since the maintenance of the eelgrass forest is very closely related to the change of the slope of the seafloor, a slope gauge or a slope level measuring system (stainless ruler, etc. can be used) are used to monitor the movement of sediments. In particular, it should be surveyed carefully where the slope change is more than ±10cm per month is unsuitable for the eelgrass forest.

<Table 6-7> Determining water depth for the limit of eelgrass growth using transparency

□ Outline

○ Since seaweed is a plant, it needs an absolute amount of light for photosynthesis.

○ There are two methods of measuring the amount of sunlight in water, using a photometer measurement and a Secchi disc.

○ Using a photometer is suitable for short-term observation of the sea area, and the Secchi disc is suitable for predicting the amount of sunlight over a long period of time.

○ Since the Korea Ocean Observing Network (KOON) measures the transmittance with a Secchi disc, we developed a method for measuring the amount of underwater light using a Secchi disc that is easy to use data.

□ How to calculate the amount of light in water using a Secchi disc

○ The Secchi disc uses a 30cm white disk to measure the depth down into the water until it is invisible.

○ The underwater light attenuation uses the Lambert-Beer formula:

$$A = B \cdot \exp(-kz) \qquad (1)$$

Here, A = the amount of light at depth z, B = the amount of light just below the water surface, k = attenuation coefficient

○ In order to find the attenuation coefficient k, formula (1) is summarised for k:

$$k = -\frac{1}{z} ln(A/B) \qquad (2)$$

○ k can be expressed in the form of a correlation with transparency in the form of the Poole and Atkins formula.

$$Tr = D/k \qquad (3)$$

Here, D=integer, Tr=transparency

○ B, the amount of light just below the surface of the water is determined by the following procedure.

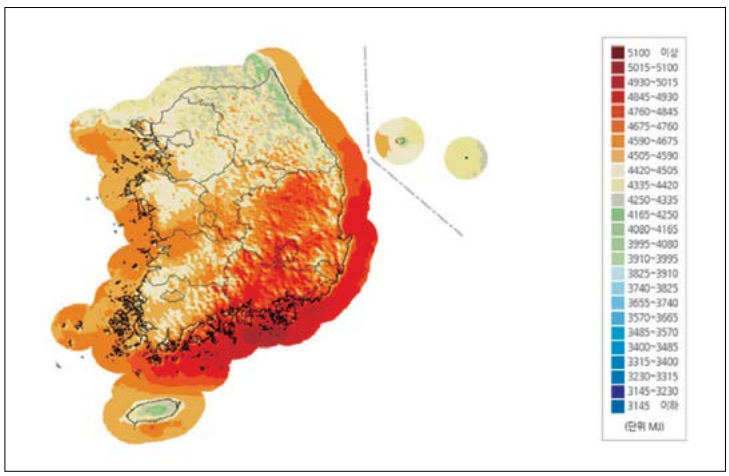
– The amount of sunlight incident on the surface is calculated by taking into account sea surface reflection, energy loss due to absorption, and shear wave radiation.

– According to Ishikawa (1988), energy loss due to sea surface reflection and absorption is 79%.

– Photosynthetically active radiation (PAR) by shear wave radiation is 42% according to Hurukawa (1961).

– Therefore, the amount of light directly underwater can be expressed as Equation (4).

$$B = \text{total solar radiation } (MJ/M^2/day) \times 0.42 \times 0.79 \qquad (4)$$



※ 출처 : http://www.greenmap.go.kr

○ Using Equation (1), the amount of light directly underwater can be calculated as follows.

– The total solar radiation in Yeosu is 4,760MJ/m^2, so converting it into a daily unit becomes 13.04MJ/m^2/day. Converting this into mol units and substituting it into Equation (4), it is calculated as 19.67mol/m^2/day (1MJ = 1/0.22mol)

– Transparency correlation integers D can be obtained as follows. In this study, Hiroshima Bay, which has a similar environment to Gamak Bay, uses 1.6 and therefore adopts 1.6 as a D value.

Relation	Target sea area	Source
Tr = 1.6/k	Tokyo Bay	Location surveying
Tr = 1.6/k	Seto-inland Sea (Hiroshima Bay)	Hashimoto(1997)
Tr = 1.45/k	Chesapeake Bay	U.S. EPA
Tr = 1.7/k	– Poole and Atkins (1929) and Idso and Gilbert (1974) empirically suggest that 1.7 is appropriate	Takahashi(1996)

□ The minimum amount of light required for eelgrass growth

○ The necessary amount of light to grow eelgrass according to field survey, water tank experiment, and photosynthesis experiment

– In this study, the most conservative value, 3.3 mol/m^2/day, is applied as the minimum required amount of light as a result of the field survey.

Survey method	Required amount of light	Source
Field survey	Annual average daily light integral required for growth: 3.3mol/m^2/day	Hiraoka(2005)
Water tank experiment	Aug-Oct (Water temp 21-26°C) : 2.1mol/m^2/day	Kawasaki(1988)
Photosynthesis test	Daily compensation light integral at the growth limit water temp: 1.7mol/m^2/day(28°C)	Morita(2003)

□ Example of the actual calculation

Ex) As a result of measuring transparency using a Secchi disc in Gamak Bay, Yeosu, the annual average was 2.3m. The total amount of sunlight in Yeosu sea area was 4,760 MJ/m^2 as a result of the analysis of data from the Korea Meteorological Administration (KMA). At this time, what is the marginal depth of growth of eelgrass?

① Calculate the amount of light directly under the water (B) from the daily light integral.

→ (4,760/365/0.22) × 0.42 × 0.79 = 19.67mol/m^2/day

② The attenuation coefficient k is obtained from the transparency.

→ 2.3=1.6/k, thus k = 0.696 (here, the integer D is the Hiroshima Bay value)

③ Finally find the growth limit depth z.

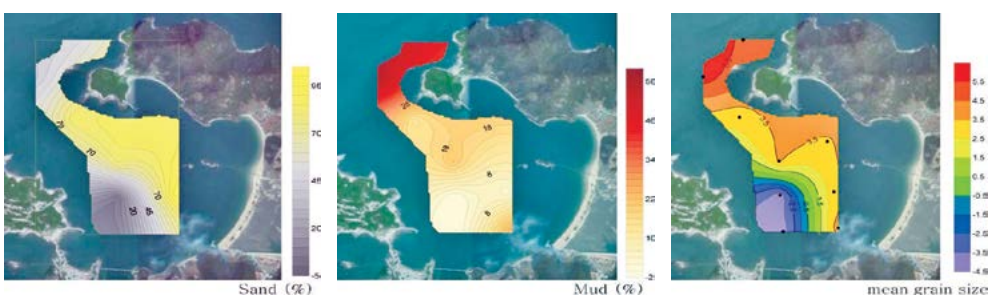
→ 0.696 = -1/z×ln(3.3/19.67), therefore, z=2.6m.

④ Finally, when applying Si value, it is reasonable to apply 0 for water depths deeper than 2.6m.

<Table 6-8> Sedimentary environment grain size analysis result

Grain size analysis result									
Sample No.	Average grain size (ϕ)	Degree of sorting (ϕ)	Skew-ness	Kurtosis	Content (%)				Sediment type
					Gravel	Sand	Silt	Clay	

Sand (%) Mud (%) Mean grain size (Mz)



3. Survey on the efficacy of halophyte development sites

A. Application criteria

○ It targets the sea area of the halophyte development management(1 to 4 years).

○ Conduct the survey at any time within the period of the efficacy survey period for the Marine Forest Project (February to October).

– Plants change throughout the year, and the survey is carried out several times during the project, and also prior to the project commencement to track their seed dispersal, germination, survival, and growth. The terrain also shows different patterns seasonally, it is necessary to survey the effects of plant survival and seed distribution several times throughout the year.

○ In order to identify the efficacy of halophyte development sites, seed density, halophyte species and density, growth, sedimentary environment, zoobenthos, monitoring imaging, and topographical surveys are conducted.

B. Survey of seed density in sediment

○ The density of seeds distributed in sediments is surveyed within the quadrats in the sown development site to confirm the change in the density of seeds.

○ The number of seeds remaining in the sediment is secured so that can significantly represent the density of seeds. The sediment is collected using a box-shaped Grab or a cylindrical Core, and the density of seeds distributed therein is surveyed.

<Image 6-8> Seed density survey in sediment

○ The sediment sample is collected at 2cm depth in the initial survey and the number of seeds is obtained. If the number of seeds is not secured, the appropriate depth is determined and surveyed, and further survey is conducted accordingly.

C. Survey of halophyte species number and density

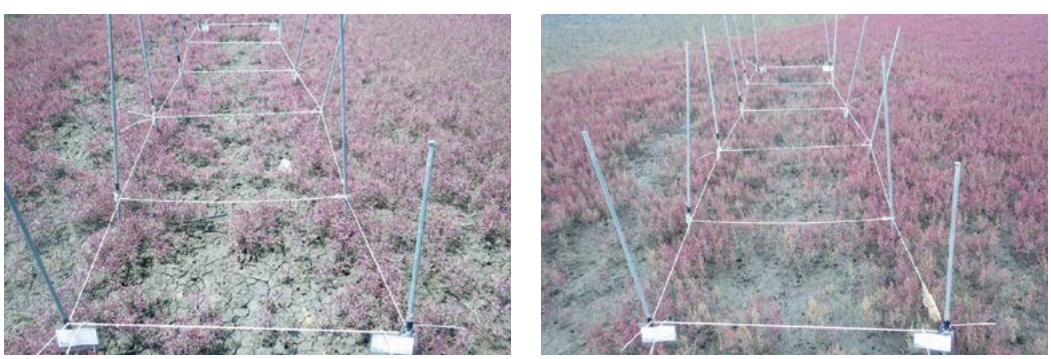
○ A fixed quadrat (1×1m) is set where a halophyte colony can be represented. The number of species and density are surveyed for germinating halophytes, and the density of all halophytes is calculated by the size of population (n)/ m^2.

○ When the species of halophytes have grown to the extent that it is possible to identify them, the number of species and coverage of each area are surveyed.

○ For classification and identification, refer to Illustrated Flora of Korea by Chang-bok Lee (2003), Standard Illustrations of Korean Plants by Woo-cheol Lee (1996), Flora of Korea by Young-no Lee (2000), Ferns and Fern Allies of Korea (2005), and Naturalized Plants in Korea (1995,2001).

○ A plant list is prepared for the surveyed and identified plants following the order of ferns and gymnosperms, polypetalous(dicotyledons), sympetalous (dicotyledons), and monocotyledons according to Engler's classification system (Melchior and Werdeman 1954, Melchior 1964).

○ The list of halophytes is prepared based on the list of halophytes in Korea presented by the Ministry of Oceans and Fisheries (2012).



<Image 6-9> Halophyte species and density survey

D. Survey of halophyte growth

○ The growth survey is conducted on halophytes living in fixed quadrats at the same time as the species number and density survey of halophytes. The survey is conducted after germination, and the growth rate and coverage change are surveyed by measuring the lengths of the above-ground and underground parts.

<Image 6-10> Halophytes growth survey

E. Sedimentary environment survey

○ The salinity concentration of sediments is determined depending on whether freshwater is introduced and the distance from the shoreline, etc. This is known as an environmental factor to be considered in the selection of halophyte species. Grain size, water content, organic matter content, pH and electrical conductivity, available phosphorus, and total nitrogen are also usually determined by the distance from the shoreline, and in some cases, related to the distribution area of the halophyte species.

○ The measurement method for each item of sediment environment is carried out in accordance with the Korean Standard Methods for Marine Environment (MOF).

○ The sedimentary environment survey is mainly conducted before the development to determine whether the target site has the environmental factors suitable for halophyte growth. However, if it is necessary to survey the efficacy of the formed halophytes on the sedimentary environment, the survey should be carried out during and after the development.

○ Moisture content

– Immediately after transferring 10g of soil collected at the site to the laboratory, put it in a weighing bottle and weigh it before drying. After 48 hours of drying in a 105°C dryer, measure the weight, and the moisture content is converted into a percentage by the difference in soil moisture content.

○ Grain-size distribution

– A sample is collected from the surface layer of a halophyte community using a Spatula, and the analysis is performed according to the standard grain size analysis method of Ingram (1971).

– Add 10% hydrogen peroxide (H_2O_2) and 0.1N hydrochloric acid (HCl) to the collected sediment sample to completely remove organic matter and carbonate. In the process of removing organic matter and carbonate in the dissolved salt in sediment, repeat the pouring distilled water process five to seven times or more, to remove residual hydrogen peroxide and hydrochloric acid.

– After the pretreatment process is completed, the clastic sediment is separated into a coarse-grained sample and a fine-grained sample by wet sieving using a 4Ø(0.064mm) sieve. The coarse-grained sample is dried in an oven and then sieved for 15 minutes using a ro-tap sieve shaker to obtain the weight by grain size. And the weight of the fine-grained sample is calculated by pipetting in consideration of the sedimentation rate, and the weights of the coarse-grain sample and the fine-grained sample are summed to obtain the weight percentage in each section.

– At this stage, Calgon is used as a diffusion agent to prevent grain coagulation.

– Organic matter: 10g of soil dried in a dust-free shade is put in a pot and dried at 105°C, and the weight is measured. Then it is heated for 12 hours in an electric furnace at 550°C, after that, weighed and the difference is calculated to obtain the ignition loss.

– Soil acidity (pH) and salinity: Mix 10g of sample dried in a dust-free shade with distilled water at 1:5(w/w), shake for 30 minutes, and then filter through a filter paper (Whatman No.44) and measure the pH, E.C, and salinity of the filtrate using YSI Model 63.

– Available phosphorous: Place 2.85g of dried soil in a triangular flask, in which the extract (0.01N NH4F + 0.025N HCl) is added and shaken for 10 minutes. After filtering it with Whatman No. 44, the filtrate is coloured according to the ascorbic acid method, and then colourimetrically quantified at 880nm using a spectrophotometer (Ultrospec 2000, Pharmacia) (APHA 1989).

– Total nitrogen: Put 1g of dried soil in a micro-Kjeldahl flask, add 6g of decomposition catalyst (K_2SO_4: $CuSO_4$ = 9:1) and 5ml of concentrated H_2SO_4, and heat to decompose. After transferring the decomposed solution to a 50ml volumetric flask, 10ml is taken and mixed with 40% NaOH 10ml, distilled with a micro Kjeldahl apparatus, and titrated with 1/14 N H_2SO_4 standard solution for quantification (Jackson, 1967).

<Image 6-11> Sedimentary environment survey

F. Sedimentary environment survey

○ Obtain comparative data before and after the efficacy survey on the function, or diversity provided by the halophyte colony to the habitat of the benthic animal community. It is also determined whether the process of creating a halophyte colony can be affected by burrowing animals.

○ It is also identified whether the development of the halophytes changes the making of the dominant benthic animal community.

○ Survey of zoobenthos colonies in sediments

– Select a line transect and collect sediments twice by using a Can Core.

– Remove the mud by sieving the collected sediments using a sieve with 1mm mesh. After sieving, the remaining residue is placed in a sample bottle, fixed with a 10% neutral-formalin solution, and transported to the laboratory.

– After washing the transported remnants with fresh water, all animals appearing with the naked eye or with a magnifying glass are screened to

the level of phylum, and the selected organisms are identified to the level of species.

– For each of the identified species, the population is measured and the biomass (wet weight) is measured by higher classification. The measured values are converted into the number of population and biomass per unit area(m^2) and then applied to the ecological analysis.

○ Sight survey of gastropods and crabs

– The distribution of organisms larger than those in sediments, such as gastropods and crabs is primarily determined by observation.

– Although not particularly standardised, the reliability of data is secured through the replicated plot of selecting a number of representative points.

– For close investigation, observe the active organisms within the unit area using a telescope, etc. from a distance that does not interfere with the crab activity.

<Image 6-12> Zoobenthos survey

G. Monitoring imaging survey

○ In order to show the temporal and spatial effect on the change of the halophyte colony, an imaging survey using drones is conducted.

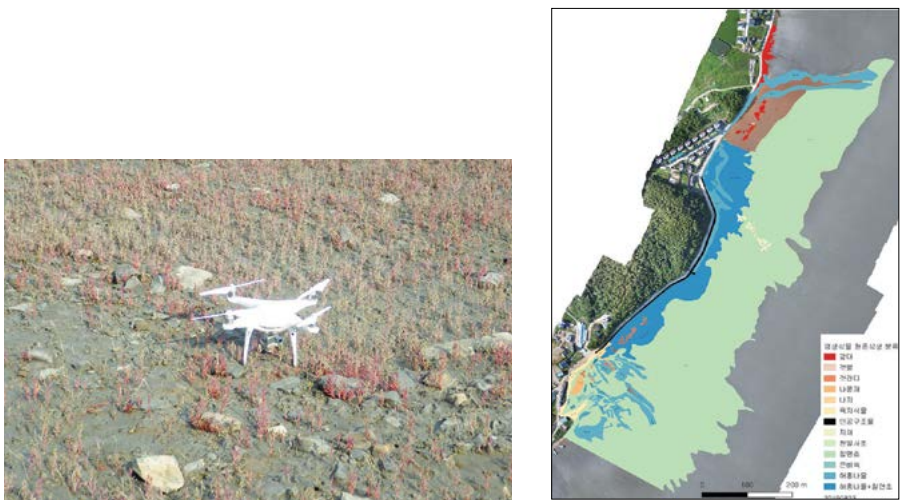
○ Drone filming is conducted in time for high solar altitudes during low tide when the bottom of the intertidal zone is exposed and the terrain is not shaded by features. The filming is conducted by setting the average of 4 rows parallel to the coastline, 80% of overlap, 70% of sidelap, 90° camera angle, and within 100m flight altitude. From the data, the changes in the halophyte colony are

compared overall, and the result of quantitative analysis of the distribution of halophytes and the growth survey is analysed by linking the data.

○ The filming range is for the entire habitat of halophytes, and the distribution and location of each species are displayed on an electronic map every month.

○ With the result of the survey, the vegetation map of halophytes and the vegetation distribution area are obtained.

○ A base map is created using a digital topographic map (1/5,000) and artificial satellite images on the filmed aerial images. A grid is set on the basic map, and the current vegetation map is created through field surveys and the area is calculated.



<Image 6-13> Survey imaging monitoring

H. Topographic survey

○ Topographic survey using terrestrial LiDAR is a spatial range of a continuous space including all areas including quadrats, halophyte formation regions, sediment environment investigation, halophyte growth survey, and zoobenthos monitoring survey regions, as well as some areas of natural communities.

○ Analyse topographic conditions related to the formation of halophytes, as well as topographic conditions such as altitude, etc. suitable for seed retention, germination and survival/growth of each plant species in sediments.

○ Using a geodimeter, important lateral lines and topographic sections from the coastline to the required distance, including the quadrats installed in the development of halophyte sites, are obtained.

○ Using RTK-DGNSS (Real Time Kinematic-Differential GNSS), the control point of the survey area is measured using the surrounding benchmark, and the surveying is repeated to correct the height error.

○ By analysing the accumulated tidal subersion time, etc., and the altitude distribution of halophytes is linked to the tide level.

○ When monitoring is required for spatial information (exact area, etc.) and changes (expansion/reduction, etc.) of halophyte colonies, spatial information of the boundary interface of each plant colony is obtained using RTK-DGNSS.

<Image 6-12> Topographic Survey

<Table 6-9> List of halophytes in Korea

순번	국명(Local name)	학명(Scientific name)
44	갯마디풀	*Polygonum arenastrum*
45	갯질경	*Limonium tetragonum*
46	갯까치수염	*Lysimachia mauritiana*
47	털갯완두	*Lathyrus japonicus var. aleuticus*
48	해녀콩	*Canavalia lineata*
49	갯강활	*Angelica japonica*
50	갯사상자	*Cnidium japonicum*
51	갯기름나물	*Peucedanum japonicum*
52	참골무꽃	*Scutellaria strigillosa*
53	개질경이	*Plantago camtschatica*
54	갯쑥부쟁이	*Aster hispidus*
55	갯금불초	*Wedelia prostrata*
56	푸른갯골풀	*Juncus setchuensis var. effusoides*
57	새섬매자기(좀매자기)	*Scirpus planiculmis*
58	모래사초	*Carex drymophila var. pilifera*
59	갯쇠돌피	*Polypogon monspeliensis*
60	갯조풀	*Calamagrostis pseudo-phragmites*
61	갯개미취	*Aster tripolium*
62	쇠보리	*Ischaemum crassipes*
63	우산잔디	*Cynodon dactylon*
64	좀보리사초	*Carex pumila*
65	바다지기	*Fimbristylis cymosa*
66	버들명아주(가는명아주)	*Chenopodium virgatum*
해초1	거머리말	*Zostera marina*
해초2	포기거머리말(가는거머리말)	*Zostera caespitosa*
해초3	수거머리말	*Zostera caulescens*
해초4	애기거머리말	*Zostera nana*
해초5	왕거머리말	*Zostera asiatica*
해초6	새우말	*Phyllospadix iwatensis*
해초7	게바다말	*Phyllospadix japonicus*
해초8	줄말	*Ruppia maritima*
해초9	해호말	*Haloplila nipponica*
암벽1	땅채송화	*Sedum oryzifolium*
암벽2	해국(왕해국)	*Aster sphathulifolius*
암벽3	암대극	*Euphorbia jolkini*
암벽4	대나물	*Gypsophila oldhamiana*
기타1	갯고들빼기	*Crepidiastrum lanceolatum*
기타2	섬기린초	*Sedum takesimense*
기타3	갯대추	*Paliurus ramosissimus*
기타4	돌가시나무	*Rosa wichuraiana*
기타5	곰솔(해송)	*Pinus thunbergii*

제VII장 바다숲 이관 및 사후관리

1. 바다숲 이관대상지 사업평가
2. 바다숲 사업 완료지 이관
3. 바다숲 이관지 사후관리

Chapter VII
Marine Forest Project Transfer and Follow-up Management

After the development of the marine forest (4 years), the project is evaluated based on the results of the efficacy survey. The project completion is then transferred to the relevant local government in order to stably maintain and spread the efficacy of the marine forest. The Local government will organise budgets and perform follow-up management.

<Table 7-1> Marine Forest Project transfer and follow-up management procedure

	Item	Details
Project transfer	① Project evaluation	■ FIRA: Report to MOF on the completion result of the project. * Results of the project evaluation committee for each transfer organisation, results of discussions on transfer of local governments ■ MOF: Judgment on the completion of the project * Project evaluation: Evaluation System of the Stock Enhancement Program * Evaluation: A-C grades are effective, D-E grades need to be improved, F grades to be re-examined.
	② Project completion transfer	■ MOF: Transfer the project completion to the local government ■ Local government, FIRA: The handover of the project transfer (result of project evaluation, history card, completion report), and the handover checklist; * Checklist: Guidelines for follow-up management of Stock Enhancement Program
Follow-up management	③ Follow-up management plan	■ Local government: The budget for follow-up management of the project transfer (directly or by a specialised agency), review of the designation of the fishery resource management area * Budgeting: Including local expenses, reef management or marine forest development projects ■ FIRA: cooperate with post management such as technical support and consignment
	④ Actual condition survey	■ Management period: 30 years after transfer, conducted every 3 to 5 years ■ Survey items: survey on the condition of facilities, seaweed growth, waste, herbivore density, etc. ■ Conduct an actual condition survey to determine whether waste collection, herbivore removal, seaweed transplantation, facility repair, etc., and is carried out if ne scessary * Criteria for herbivore removal: Maintain less than 5 extra-large n/m^2, and 10 medium-large-size n/m^2

※ Repeat ④⑤ during management period

	Item	Details
Follow-up management	⑤ Efficacy survey ▸	■ Management period: 5th, 10th, 20th, and 30th year after the transfer (total 4) ■ Efficacy evaluation: Surveying the biomass and species diversity of seaweed and invertebrates, and determining the efficacy through comparison before/after composition * Efficacy survey period: 4 times a year (by season) * No need to survey the efficacy in the future when determining effectiveness (Grades A to C) twice in a row
Report	⑥ Performance check ▸	■ Every year (local government reports to Ministry of Oceans and Fisheries) * Report of follow-up management results: Guidelines for follow-up management of Stock Enhancement Program

1. Evaluation of Marine Forest Project transfer

A. Project evaluation method

○ To ensure the objectivity of project evaluation, the project entity (FIRA) and the evaluation authority (evaluation committee) are operated separately.

○ The evaluation committee is run by the Ministry of Oceans and Fisheries.

○ Project evaluation: Before/after concept (before/after development) applied.

– Before the development: Survey result of the year of project start (1st year)

– After the development: Results of the efficacy survey at the end of the project

❊ 'End of the project' means the year of completion of the project before the transfer to the local government (including early completion and the year of additional management)

❊ Compare survey results for the same season when conducting an efficacy survey before and after the development

○ The project entity (FIRA) conducts an efficacy survey at the time of the annual efficacy survey of the project completion and submits the results of the survey to the evaluation committee when the project is completed. ❊ <Table 7-2>, <Table 7-3>

○ The evaluation is conducted by adding values for the main factors (goal-directed variables) for each project.

– Marine forest key factors: seaweed biomass and species diversity, invertebrates biomass and species diversity.

– Apply biomass and species diversity increase/decrease(%) comparison before and after

– Additional value: seaweed biomass (×2.0) and species diversity (×1.8), invertebrate biomass (×1.1) and species diversity (×1.5)

○ When evaluating marine forests for specific seaweeds (seagrasses) such as eelgrass forests and halophytes, the 'seaweed biomass' variable can be replaced with the 'target species biomass (or density)' variable, taking into account the habitat environment of the species. Seaweed species diversity variables are excluded from the evaluation.

○ When evaluating the efficacy of the project, variables that cannot be surveyed are excluded from the evaluation.

B. The composition and role of the evaluation authority

○ For project evaluation, an evaluation committee composed of 5-10 experts in the field of marine and fisheries is formed.

○ The qualifications of experts of the evaluation committee are as follows.

– Experts who belong to a fishery-related research institute established and operated by the national or local government

– Experts belonging to public institutions pursuant to the 'The Law on Management of Public Bodies'

– Professors of universities and industrial colleges under the 'Higher Education Act'

– Persons with more than 7 years of experience in the relevant field appointed by the MOF

○ The roles of the evaluation committee are as follows.

– Review of the scientific validity of survey plan and results

– Determination of efficacy and result notification

– Project improvement and performance enhancement through expert opinions

○ The Evaluation Committee determines the efficacy using Table 7-3 based on the baseline data of the survey results.

C. Efficacy survey method (seaweed & invertebrate)

○ Sampling tools and methods

– Use tools of the same type and size as those used in the efficacy survey on the year of project start (1st year)

– Use quadrats for collecting samples of a size suitable for the current status of the target site (facilities, development method, etc.)

(Standard: 50×50cm quadrat one per survey point, 0.25m^2)

– If the size of quadrats used by the survey period is different, repeat collection corresponding to the same collection area. (e.g. 50×50cm once → 25×25cm 4 times)

– Fixed quantity collection using the destructive method and underwater imaging (including underwater imaging for quantitative image analysis using quadrats (for seaweeds))

○ Survey point

– Set the location and number of points similar to the points used during the efficacy survey of the project start year (1st year)

– Setting random points for natural rocks and facilities in the target site (marine forest development area)

– Number of points: total 8

• Survey each natural rock and facility in the target site in the north, east, south, and west directions, respectively.

• Collect once per point

❊ For seasonal continuous surveys, set random point locations for each season

○ Number of surveys and frequency

– Same period (season) as the project start year (1st year) efficacy survey

– Survey once per season

– Use of the results: understanding the trend of changes in the number of resources through comparison with the survey findings

○ Seaweed analysis targets and items

– Analysis target: All seaweeds including coralline algae

– Analysis items: species identification, (relative) coverage, biomass(g/m^2, wet weight), species diversity index(H')

○ Invertebrates analysis targets and items

– Analysis target: Invertebrates (including small crustaceans such as amphipods) over 1mm in size (maximum length), including seaweed holdfast and epibenthos collected in quadrats

– Analysis items: species identification, (relative) coverage, biomass(g/m^2, wet weight), species diversity index(H')

❊ When collecting a large amount of the same species, 50 individuals are randomly selected by species and measured, after that the total amount is calculated arithmetically or the total amount by species

D. Efficacy survey method (condition of facilities such as artificial reefs)

○ Identifying inversion, damage, displacement, scouring, and burial of facilities such as artificial reefs

– Photograph still images of each facility condition

– Estimate the percentage (%) of the above-mentioned items to the total

○ Suggesting follow-up measures for cases other than inversion, damage, and displacement (site surveyor)

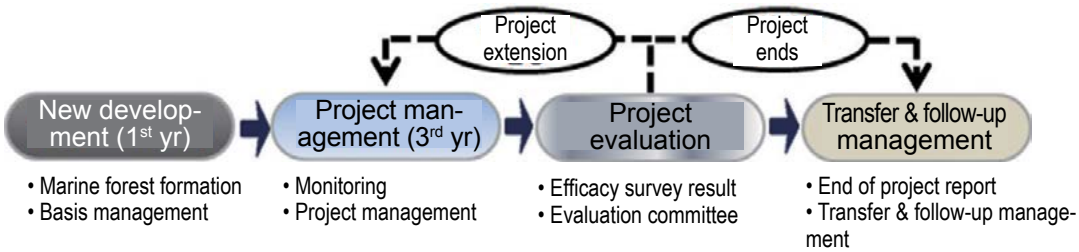
E. Report and determination on the end of the project

○ FIRA holds a transfer consultation with the relevant local government before the end of the project for the 4th year of the project sea area.

– Reporting results of consultation including the status and condition of marine forest development. This includes opinions of local governments regarding the project transfer, whether the transfer is carried out according to the management status, future plans, explanation of follow-up management guidelines and request for implementation (follow-up management budget, designation of the fishery resource management area) and attached photos of the consultation

○ FIRA reports the results of the project evaluation (maintained by MOF) and the results of the transfer agreement with local governments to the MOF.

○ MOF reviews the completion of the project reported by FIRA and makes the final decision on the completion of the Marine Forest Project.



<Image 7-1> Marine Forest Project transfer system

<Table 7-2> Field records for project evaluation field survey

Field records for project evaluation field survey

Area name											
Details	Target organism[1]				How to use[2]						
Work time	YYYY MM DD (00:00–00:00)										
Detailed location (center)							Barycentric coordinates		N E		
Survey point location	1	N E	2	N E	3	N E	4	N E			
	5	N E	6	N E	7	N E	8	N E			
Field survey participants	In charge				Person-in-charge contact						
	Joint[3]										
Surveyor organisation			Organisation contact details								
Sample transport and storage conditions											
Other special notes (sea conditions, before and after typhoons, large and small tidal periods, cold waters, red tide, damage to fishing gear, etc.)											

1) Record the main target organisms for the field survey, such as fish, invertebrates, seaweeds, plants, etc.
2) Record the results of catches using fishing gear (eg nets/traps, etc.) or diving observation using scuba diving equipment
3) Record all the surveyors who participated in the field survey

YYYY MM DD

I confirm and sign that the contents written on the field above are true.

Field survey person-in-charge: _____Agency_____ (signature)

To_____

<Table 7-3> Marine Forest Project field survey results evaluation table

[Marine Forest Project Field Survey Results Evaluation Table]

❊ This is for examples and variable descriptions.

Classification \ Variables		① Before	② After	③ Increase /decrease rate (%)	④ Weighted increase/decrease rate (%)	⑤ Average increase/decrease rate (%)
Sea-weeds	Biomass	30.0	40.0	133	200	203
	Species diversity	2.3	3.1	135	176	
Inverte-brates	Biomass	20.0	25.0	125	125	
	Species diversity	1.8	2.0	111	133	
⑥ Grade of increase/decrease rate						A
⑦ Efficacy determination						Effective
⑧ Management action						Transfer to local government

* Conduct economic evaluation if necessary at the end of the project

① Biomass ([average]/m^2) and species diversity (species diversity index [average H′]) at the time of project start year (1st year).
② After the project, biomass at the time of efficacy survey ([average]/m^2) and species diversity (species diversity index [average H′])
③ [②÷①×100]
④ [Increase/decrease rate × additional value by biological variable] (seaweed biomass ×2.0, seaweed diversity ×1.8, invertebrate biomass ×1.1, invertebrate diversity: ×1.5)
⑤ [Sum of weighted increase/decrease rate for each biological variable] ÷ 4
⑥ A: 181% or more, B: 161-180%, C: 141-160%, D: 121-140%, E: 101-120%, F: 100% or less
❊ Reasons for differentiating grade standards from coastal marine ranches: considering the global trend of calcification(whitening) due to the climate change, etc., it is difficult to expect ecosystem restoration effects within a short period of 1-3 years.
⑦ A-C: Effective, D-F: Not effective
⑧ [Based on the increase/decrease rate] A-C: transfer to local government, D-E: improvement measures (adaptation management, supplementary plantation, herbivore removals, etc.) required, F: re-survey (however, if the'F' grade is judged twice in a row, the origin is reviewed)

2. Transfer of Marine Forest Project completion

A. Transfer process

○ The Marine Forest Project ends after four years of development (December 31).

○ MOF reviews the completion of the project reported by FIRA and makes a final decision on the completion of the Marine Forest Project.

– Additional management is required for waters deemed insufficient (grade D to F) or not stabilised from the project evaluation.

○ MOF will transfer the completion of the project to the relevant local government for the stable maintenance and spread of the effect of marine forests (enforcement by an official letter).

○ After MOF notifying the transfer, FIRA submits the transfer data to the local government and prepares a handover checklist for the two agencies.

– Transfer data: project evaluation result, project report, project history card (included in the report)

– Handover checklist: <Table 7-4>

B. Project report

○ The project report must be prepared by collecting all data for four years from marine forest formation to management, and the history card must be attached.

– Topography and environment of the marine forest development area

– Marine forest development management status by year (facilities such as seaweed reefs, seaweed transplantation, herbivore removals, mid-water rope culturing system, spore bags, etc.)

– Results of efficacy survey

– Post-management guidelines

– Project history card: <Table 7-5>

<Table 7-4> Checklist for project transfer and handover

[Checklist for Project Transfer and Handover (Example)]

<table>
<tr><th colspan="3">Checklist</th><th>Relevant materials and documents</th><th>Result</th></tr>
<tr><td colspan="2" rowspan="2">Project evaluation results</td><td>Official document</td><td>Official document (copy) of evaluation result of the project evaluation committee for the project</td><td></td></tr>
<tr><td>Efficacy evaluation</td><td>Effect evaluation result, including analysis raw data</td><td></td></tr>
<tr><td rowspan="6">Project-related information</td><td colspan="2">Project methods</td><td>Installation of fish reefs or rock cleaning (for fish reefs, type and size of the fish reef)</td><td rowspan="6">• Project history card (FIRA)
• Project report</td></tr>
<tr><td colspan="2">Project location</td><td>Center and vertex coordinates</td></tr>
<tr><td colspan="2">Project scale</td><td>The number of installed reefs or the area of rock cleaning, etc.</td></tr>
<tr><td colspan="2">Management method</td><td>Herbivore removal, supplementary transplantation, etc.</td></tr>
<tr><td rowspan="2">Project and management period</td><td>Project period</td><td>From the start to the end (transfer)</td></tr>
<tr><td>Management period</td><td>From the start to the end (transfer)</td></tr>
<tr><td colspan="3">Special note</td><td>Write special matters specific to the project or the project sea area</td><td></td></tr>
</table>

* Confirmation and inspection results are recorded as ‘O’, ‘X’ or details.

Based on the confirmation and inspection results of the above matters,
I agree to the transfer of the ‘Marine Forest Project’.

YYYY MM DD

Undertaking agency: name and representative of the organisation (seal)

Handover agency: name and representative of the organisation (seal)

<Table 7-5> Project history card

(Area name) Marine Forest Project History Card (General)

Card No.	Year	Branch	Project	City	County	Area

Project name					
Project period					
Project area	(ha)				
Project cost (KRW million)	Total	Project management cost			
		1st year	2nd year	3rd year	4th year
Project location					

Sea area (zone) coordinates (WGS-84)

Classification	Latitude (N)	Longitudes (E)
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

Sea area map

Metropolitan City/Province

Detailed sea area

Classification	Sea area characteristics and fishing community status			
■ Calcification progress	Stage 1 (normal)	Stage 2 (progressed)	Stage 3 (intensified)	
■ Sea area characteristics	Water depth (m)	Gradient (°)	Transparency (m)	
	Rock (%)	Gravel (%)	Sand (%)	Mud (%)
■ Fishing community status	Village fishing ground (ha)	Number of fishermen	Self-managed community	
			Yes / No	

■ Village Fishery Production (kg)	Fish species	Before	Formation	1st year	2nd year	3rd year	Total

<Table 7-5> continued

(Area name) Marine Forest Project History Card (1st Year)

Card No.	Year	Branch	Project	City	County	Area

Classification	Project details	Attach-ment No.	Project briefing and council			Attach-ment No.
			Classification	Target	Content (number)	
■ Site selection	☐ City/province confirmation letter (consent and sign) ☐ Site survey report	1-1	Briefing	local fishing community	/	1-2
■ Formation type	☐ Ecological recovery type ☐ Resource conservation type ☐ Spawning induction type ☐ Underwater tourism type ☐ Experience learning type ☐ Other ( )					
■ Method	☐ Artificial reef ☐ Natural rocks ☐ Seedling panel ☐ Seaweed transplant ☐ Mid-water rope culture ☐ Spore bag ☐ Adhesion substrate ☐ Feeding ground ☐ Herbivore removal					

■ Production and installation of facilities (artificial reef, natural stone, seedling panel)	Classification	Zone 1			Zone 2			Zone 3			1-3
	Facility No.										
	Facility name										
	Standard (unit)										
	Quantity										
	Production/installation cost										
	Production/installation company										
	Production/installation period										
	Installation date										
	Material Inspector										
	Production Inspector										
	Facility Inspector										
	Completion Inspector										

■ Facility coordinates (WGS-84)	Classification		N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	
	Zone coordi-nates	1	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	
		2	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	
		3	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	
		4	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	N: E:	

<Table 7-5> continued

(Area name) Marine Forest Project History Card (Zone 1)

Card No.	Year	Branch	Project	City	County	Area

Classification	Survey and project details									Attach-ment No.
■ Natural stone facilities	Classification	Layout								1-3
	A	☐ Concentrated plane ☐ Dispersion ☐ Equal concentration ☐ Doksal ☐ Other ( )								
	B	☐ Concentrated plane ☐ Dispersion ☐ Equal concentration ☐ Doksal ☐ Other ( )								
■ Seedling attachment panels	Classification	Adhesive substrate				Attachment method				1-3
	A	☐ Natural stone ☐ Artificial reef ☐ Other ( )				☐ Anchor bolt ☐ Other ( )				
	B	☐ Natural stone ☐ Artificial reef ☐ Other ( )				☐ Anchor bolt ☐ Other ( )				
■ Seaweed (seagrass) transplant	Month	Seaweed type	Total amount (m)	Artificial reef (m/n)	Seedling panel (m/n)	Mid-water rope (m)	Cost (KRW)	Total length (cm)	Germling n/1m	1-4
■ Spore bag	Period (month)	Seaweed type	Amount (kg)	Number of bags	Spore bag material/mesh	Spore bag application				1-5
					/	☐ Natural stone ☐ Artificial reef ☐ Other ( )				
■ Rock cleaning	Supervisor	Agency	Project period	Area(ha) or quantity(unit)	Project cost (KRW million)	Adhesive substrate				1-6
						☐ Natural stone ☐ Artificial reef ☐ Other ( )				
■ Feeding ground	Period (month)	Seaweed type	Length (cm)	Facility volume (m)	Installation method/location					1-7
					/					
■ Herbivore removal	Number of times	Seaweed type	Length (cm)	Amount of removed herbivores (kg)						1-8
				Echinoidea	Sea hare	Turban shell	Other gastropods	Other		
■ Habitat	Classification	Seaweeds			Zoobenthos			Fish			1-9
		No. of species	Population	Biomass (g/m²)	No. of species	Population	Biomass (g/m²)	No. of species	Population	Biomass (g)	
	Before										
	After										
■ Special note	❊ If there are multiple development zones, please fill out each zone.										

<Table 7-5> continued

(Area name) Marine Forest Project History Card (Layout)

Card No.	Year	Branch	Project	City	County	Area

Layout of completed development		Sea area Sonar image	
Total sea area	Zone 1 layout	Total sea area	Zone 1 layout
Zone 2 layout	Zone 3 layout	Zone 2 layout	Zone 3 layout
Sea area multi-beam (single-beam) image		Representative picture data	
Total sea area	Zone 1 layout	Artificial reef condition	Seaweed bed
		Representative picture	Representative picture
Zone 2 layout	Zone 3 layout	Periphyton	
		Representative picture	Representative picture

<Table 7-5> continued

(Area name) Marine Forest Project History Card (2nd Year - Zone 1)

Card No.	Year	Branch	Project	City	County	Area

Classification	Project management details	Department in charge	General manager	Person in charge	Contact detail

■ Monitoring	Number	Condition of artificial reefs			Seaweed growth		Seaweed (per 1m²)		Periphyton (per 1m²)			Herbivore density (per 1m²)			Fishing test			Attachment No.
		Damaged (n)	Inverted (n)	Buried (n)	Frond length (cm)	Blade length (cm)	No. of species	Biomass (g)	No. of species	Population (n)	Biomass (g)	No. of species	Population (n)	Biomass (g)	No. of species	Population (n)	Biomass (g)	
	1st	/ Total	/ Total	/ Total	Average	Average		Average		Average	Average		Average	Average		Average	Average	2-1
	2nd	/ Total	/ Total	/ Total														
	.																	
	.																	

■ Herbivore removal	Period (month)	No. of work days	Amount of removal (kg)					Removal method			Related imagery data		Attachment No.
			Echinoidea	Sea hare	Turban shell	Other gastropoda	Other	Diving agency	Fishery boat	Other	Photo	Video	2-2

■ Seaweed (grass) supplementary transplnt	Period (month)	Type of seaweed (grass)	Target facility for re-plantation	Number of target facilities	Amount of re-plantation (m)	Length of seaweed (cm)	No. of germlings/1m	Related imagery data		Attachment No.
								Photo	Video	2-3

■ Waste collection	Type	Derelict fishing net	Derelict fish trap	Other	Related imagery data		Attachment No.
					Photo	Video	2-4
	Collected amount (kg)						

■ Project participation and consultation	Classification	Target (number of times)	Details (common to the sea area, fill in only Zone 1)	Related material	Attachment No.
	Project participation	Local government ( ) Fishing community ( )		Public notification & result report, etc	2-5
	Consultation	Local government ( ) Fishing community ( )		Public notification & result report, etc	

■ Special note	❊ If there are multiple development zones, please fill out each zone.

<Table 7-5> continued

(Area name) Marine Forest Project History Card (3rd Year - Zone 1)

Card No.	Year	Branch	Project	City	County	Area

Classification	Project management details	Department in charge	General manager	Person in charge	Contact detail

■ Monitoring

Number	Condition of artificial reefs			Seaweed growth		Seaweed (per 1m²)		Periphyton (per 1m²)			Herbivore density (per 1m²)			Fishing test			Attachment No.
	Damaged (n)	Inverted (n)	Buried (n)	Frond length (cm)	Blade length (cm)	No. of species	Biomass (g)	No. of species	Population (n)	Biomass (g)	No. of species	Population (n)	Biomass (g)	No. of species	Population (n)	Biomass (g)	
1st	/ Total	/ Total	/ Total	Average	Average		Average		Average	Average		Average	Average		Average	Average	3-1
2nd	/ Total	/ Total	/ Total														
.																	
.																	

■ Herbivore removal

Period (month)	No. of work days	Amount of removal (kg)					Removal method			Related imagery data		Attachment No.
		Echinoidea	Sea hare	Turban shell	Other gastropoda	Other	Diving agency	Fishery boat	Other	Photo	Video	3-2

■ Seaweed (grass) supplementary transplnt

Period (month)	Type of seaweed (grass)	Target facility for re-plantation	Number of target facilities	Amount of re-plantation (m)	Length of seaweed (cm)	No. of germlings/1m	Related imagery data		Attachment No.
							Photo	Video	3-3

■ Waste collection

Type	Derelict fishing net	Derelict fish trap	Other	Related imagery data		Attachment No.
				Photo	Video	3-4
Collected amount (kg)						

■ Project participation and consultation

Classification	Target (number of times)	Details (common to the sea area, fill in only Zone 1)	Related material	Attachment No.
Project participation	Local government ( ) Fishing community ( )		Public notification & result report, etc	3-5
Consultation	Local government ( ) Fishing community ( )		Public notification & result report, etc	

■ Special note

※ If there are multiple development zones, please fill out each zone.

<Table 7-5> continued

(Area name) Marine Forest Project History Card (4th Year - Zone 1)

Card No.	Year	Branch	Project	City	County	Area

Classification	Project management details	Department in charge	General manager	Person in charge	Contact detail

■ Monitoring	Number	Condition of artificial reefs			Seaweed growth		Seaweed (per 1m²)		Periphyton (per 1m²)			Herbivore density (per 1m²)			Fishing test			Attachment No.
		Damaged (n)	Inverted (n)	Buried (n)	Frond length (cm)	Blade length (cm)	No. of species	Biomass (g)	No. of species	Population (n)	Biomass (g)	No. of species	Population (n)	Biomass (g)	No. of species	Population (n)	Biomass (g)	
	1st	/Total	/Total	/Total	Average	Average		Average		Average	Average		Average	Average		Average	Average	4-1
	2nd	/Total	/Total	/Total														
	.																	
	.																	

■ Herbivore removal	Period (month)	No. of work days	Amount of removal (kg)					Removal method			Related imagery data		Attachment No.
			Echinoidea	Sea hare	Turban shell	Other gastropoda	Other	Diving agency	Fishery boat	Other	Photo	Video	4-2

■ Seaweed (grass) supplementary transplnt	Period (month)	Type of seaweed (grass)	Target facility for re-plantation	Number of target facilities	Amount of re-plantation (m)	Length of seaweed (cm)	No. of germlings/1m	Related imagery data		Attachment No.
								Photo	Video	4-3

■ Waste collection	Type	Derelict fishing net	Derelict fish trap	Other	Related imagery data		Attachment No.
					Photo	Video	4-4
	Collected amount (kg)						

■ Project participation and consultation	Classification	Target (number of times)	Details (common to the sea area, fill in only Zone 1)	Attachment No.	Final results	Attachment No.
	Project participation	Local government ( ) Fishing community ( )		4-5	☐ Completion report ☐ Marine forest plan ☐ Hydrographic notice result ☐ Management manual ☐ Visual data ☐ Comprehensive file (CD or USB)	4-6
	Consultation	Local government ( ) Fishing community ( )				

■ Special note	※ If there are multiple development zones, please fill out each zone.

3. Follow-up management of the Marine Forest Project

A. Follow-up management period and evaluation cycle

○ Marine Forest Project follow-up management period: 30 years

○ Follow-up management evaluation items

– Status survey: maintenance status and physical and biological status such as the amount of buried artificial reefs (including natural stones), the presence of derelict fishing gear, and the density of herbivores.

– Efficacy survey: separate field survey and evaluation on the level of satisfaction against the project purpose indicated in the handover document at the time of transfer of the project

○ Evaluation cycle by evaluation item

– Status survey: 3-5 year cycle

– Efficacy survey: 5, 10, 20, and 30 years after the transfer (4 times in total)

B. Follow-up management main items and methods

○ Designation and management of fishery resource management water area

– Area: determined by the City Mayor/County Governor according to the characteristics of the project area

– The direction of basic management in the fishery resource management area

• The Mayor/County Governor shall establish regulations for the management and use of the fishery resource management water area in accordance with Article 49 (1) of the Fishery Resources Management Act.

• In accordance with Article 49 (2) of the Fishery Resources Management Act, an ecology experience centre may be designated and operated to be used as a marine friendly space within the fishery resource management area.

• Under Article 40 of the Enforcement decree of the Fishery Resources Management Act, the Mayor/County Governor predetermines the types and numbers of fishing vessels and fishing gear. This also includes only allowing the fishermen specified in the Enforcement decree to fish and collect within the limits to not interfere with the breeding and protection of marine resources.

○ Status of waste (derelict fishing gears) collection and condition of artificial reefs

– Waste collection in and around the project site

– Review and collection of waste according to the actual condition of the project site and the results of the efficacy survey.
– Decision factors based on actual conditions of artificial reefs: refer to <Table 7-6> below

○ Herbivore removal
– Decide whether or not to proceed on removal based on the results of the 'status survey' above
– Conditions for determining whether to proceed with the removal work: refer to <Table 7-7> below

<Table 7-6> Decision factors based on actual conditions of artificial reefs

[Decision factors based on actual conditions of artificial reefs]

□ Independent of the above field survey evaluation grade
□ Follow-up measure unnecessary (can maintain its reef function)
– Simple inversion, less than 50% scouring and burial
□ Follow-up measure necessary (can maintain its reef function)
– Over 50% scouring and burial
– However, it is necessary to review the economic feasibility between the relocation of the facility and the cost of new installation.
– If the cost of relocation is relatively low, relocate to a suitable location to achieve the purpose.

<Table 7-7> Conditions for determining whether to proceed with removal work

[Conditions for determining whether to proceed with removal work]

□ When using seaweed reefs and reefs for shellfish
– [Condition 1] Extra large herbivores (shell size 2cm or more, randomly set size for convenience): 5(n)/m^2 or more (example: Lischke's top shell snail, sea urchin, etc.)
– [Condition 2] Medium/large herbivores (shell size 1cm or more, randomly set size for convenience): 10(n)/m^2 or more (example: limpet, Lischke's top shell snail, etc.)
❊ [Condition 1], [Condition 2] if any one of the two conditions is satisfied.
❊ In the case of marine forests, considering that seaweed growth is an essential condition for achieving the purpose of the project, the density of herbivores is set to 1/2 of that of coastal marine ranches in the decision condition for the removal project.
□ Provided, when creating a marine forest using eelgrasses (common eelgrass/surfgrass, etc.)
– No organisms to be removed

○ Comprehensive field survey (efficacy survey)
  – Survey method: The project entity (local government) conducts an efficacy survey either directly or through an agency, and submits the survey results to the evaluation committee.
  – Action required according to evaluation result grade: Refer to <Table 7-8> and <Table 7-9>
  – If the evaluation result is 'effective (grade A to C)' twice in a row, no future effect survey is required.

○ Annual report on follow-up management status and results
  – Reporting system: head of local government subject to follow-up management → Minister of Oceans and Fisheries
  – Reporting form: Refer to <Table 7-10>

<Table 7-8> Marine Forest Project field survey results evaluation table

[Marine Forest Project field survey results evaluation table (Example)]

❊ This is for examples and variable descriptions.

Classification \ Variables		① Before	② After	③ Increase /decrease rate (%)	④ Weighted increase/decrease rate (%)	⑤ Average increase/decrease rate (%)
Sea-weeds	Biomass	30.0	40.0	133	200	203
	Species diversity	2.3	3.1	135	176	
Inverte-brates	Biomass	20.0	25.0	125	125	
	Species diversity	1.8	2.0	111	133	
⑥ Grade of increase/decrease rate						A
⑦ Efficacy determination						Effective
⑧ Management action						Transfer to local government

* Conduct economic evaluation if necessary at the end of the project

① Biomass ([average]/m^2) and species diversity (species diversity index [average H′]) at the time of project start year (1st year).
② After the project, biomass at the time of efficacy survey ([average]/m^2) and species diversity (species diversity index [average H′])
③ [②÷①×100]
④ [Increase/decrease rate × additional value by biological variable] (seaweed biomass ×2.0, seaweed diversity ×1.8, invertebrate biomass ×1.1, invertebrate diversity: ×1.5)
⑤ [Sum of weighted increase/decrease rate for each biological variable] ÷ 4
⑥ A: 181% or more, B: 161-180%, C: 141-160%, D: 121-140%, E: 101-120%, F: 100% or less
❊ Reasons for differentiating grade standards from coastal marine ranches: considering the global trend of calcification (whitening) due to climate change, etc., it is difficult to expect the ecosystem to be effectively restored within a short period of 1-3 years.
⑦ A-C: Effective, D-F: Not effective
⑧ [Based on the increase/decrease rate] A-C: transfer to local government, D-E: improvement measures (adaptation management, supplementary plantation, herbivore removals, etc.) required, F: re-survey (however, if the 'F' grade is judged twice in a row, the origin is reviewed)

<Table 7-9> Follow-up measures based on project evaluation result

[Follow-up measures based on project evaluation result]

□ A-C: Effective
- – Maintaining the management system and method before the transfer
  - ❉ Management system and method before transfer: to maintain the frequency of removal work of herbivores and harmful organisms, and collection of sedimented waste, etc.
- – It is necessary to conduct status surveys according to the survey cycle (3 to 5 years).
- – Survey is required at the time of the next efficacy survey (project evaluation)
- – If the result is 'Effective (A-C grade)' twice in a row, no future efficacy survey is required

□ D-E: Improvement measures needed
- – Increase the intensity and frequency of removal of herbivores (more than twice a year.
- – Review the necessity of seaweed supplementary plantation and carry out.
- – Strengthen management activities in the fishery resource management area.
- – Request for consultation with external experts when determining the need for other separate improvement measures.

□ F: Improvement measures needed
- – Re-survey → If the result is 'Grade F' twice in a row, re-examine the origin → Need to consult with the project entity and experts

❉ The above evaluation criteria (A~F, 6 grades) are derived by the evaluation committee based on the results of the efficacy survey, and the final grade is notified from the subject in charge of evaluation to the local government.

❉ If improvement measures are required, the detailed improvement measures are decided based on the confirmation, inspection items submitted at the time of transfer of the project, and the project purpose, facility management and special matters presented in the final field survey and evaluation report.

❉ Therefore, the local government will carry out follow-up management measures based on the final grade sent from the evaluation committee.

<Table 7-10> Result report of follow-up management of Stock Enhancement Program

[Result report of follow-up management of Stock Enhancement Program]

Classification		Details				Note
Target project	Detailed project[1]					
	Purpose of project					
	Project type[2]					
	Area of project site					
Follow-up management[3]		Details[4]	Quantitative result[5]	Budget		
				Item[6]	Amount (KRW)[7]	
		Status and efficacy survey				
		Sedimented waste collection				
		Removal of herbivore and harmful organism				
		Seedling release				
		Education and promotion				
		Field survey (project evaluation)				
		Related to management water[8]				
		Related to game fihsing activity[9]				
		Other[10]				
Special note and suggestion[11]						

1) Select from the coastal marine ranch or marine forest development project or artificial reef installation project (must be entered in the relevant year)
2) Selection of artificial reef installation, natural stone drop, and rock cleaning
3) Write only the relevant part of the details
4) Multiple selections from detailed contents available
5) Enter quantifiable values such as weight, quantity, and number of cases (must indicate units)
6) Select a relevant item among items such as national expenses, local expenses, and special support expenses, etc.
7) Write the total budget for the year
8) List of the new designation, extension, and cancellation, etc. of management water
9) Restrictions on leisure fishing such as the number of fishermen, species of game fish, fishing ban period, and restricted fish size, etc. as a part of follow-up management.
10) Write other details of follow-up management not listed.
11) Write down the special notes on the follow-up management process for the year and recommendations to the Ministry of Oceans and Fisheries.
❊ Attach evidence

The results of the follow-up management of the YYYY 000 sea area
Stock Enhancement Program are reported as above.

YYYY MM DD

Mayor(Governer) _____

To Minister of Oceans and Fisheries

부 록

1. 바다숲 국내외 사례
2. 바다숲 조성용 해조류 생태 및 종자 생산
3. 조식동물
4. 해중림초 현황
5. 용역 과업지시서(일반사항)
6. 공사 시방서(인공어초_일반사항)

Appendix-1. Domestic and International cases of marine forests

A. USA

In the United States, marine forest restoration projects have been promoted for a long time. Marine forest projects in the US are focused on seagrasses rather than seaweeds.

※ The awareness and importance of seaweeds are lower than in Korea, where seaweed is used for food. As a spawning ground for marine life and ease of restoration, marine forests in the US are being developed mainly with seagrass.

<Seagrass distribution in the early 1980s>

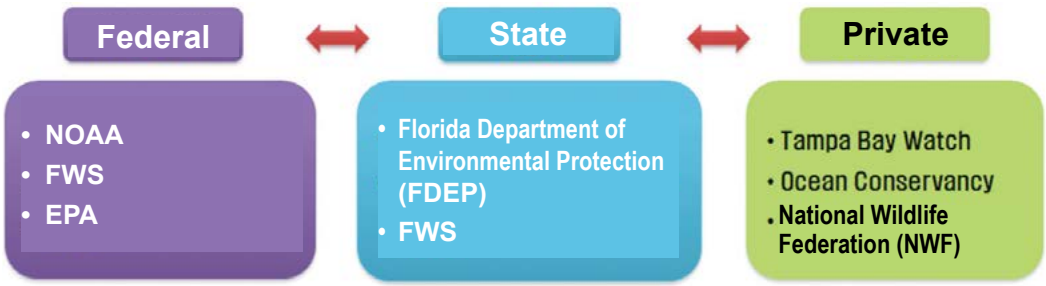
<Marine forest development areas>

<Apendix Image 1-1> Seagrass distribution in the past and marine forest development status in the US

The US marine forest project is focused on restoring the state of destroyed seagrass. Florida is trying various methods to restore severely damaged marine forests.

<Apendix Image 1-2> Damaged marine forest and restoration

The US federal and state governments have tried various approaches to assessing the value of marine forests. It is evaluated based on the value that spreads across the industry concerned. Florida's marine forest management bodies are largely divided into federal, state, and private organisations. The main federal agencies involved in the development and management of Florida's marine forests are the National Oceanic and Atmospheric Administration (NOAA), the Fish and Wildlife Service (FWS), and the Environmental Protection Agency (EPA).

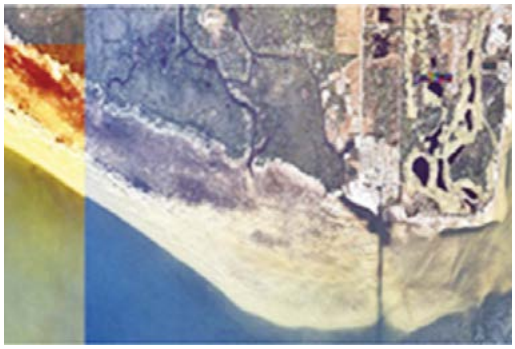


<Apendix Image 1-3> Florida's marine forest management bodies

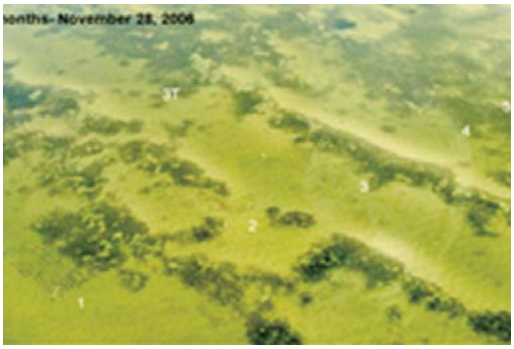
State agencies linked to Florida's marine forests include the Florida Department of Environmental Protection (FDEP) and the Florida Fish and Wildlife Service (FWS). Private organisations mainly lead restoration-related volunteer activities and educational activities. In the process of implementing the development project, the public's support and participation are drawn through various programs. In Florida, the Seagrass Outreach Partnership Program is in operation to conserve marine forests.

<Apendix Image 1-4> Education and restoration activities of the Marine Forest Restoration Private Organisation (TBW)

<View of Tampa Bay in 1938>



<View of Tampa Bay in 2002>



<2006 project sea area>

<2007 (1 year since the project)>

<Apendix Image 1-5> Aerial images before and after marine forest development

There are about 12 species of eelgrass inhabiting the United States coast. Common eelgrass (eelgrass: Z. marina) is distributed in temperate regions along with the ditch grass (Ruppia maritima). On the West coast, Phyllospadix spp. (surf grass) and Z. japonica, an exotic species, are appearing on the intertidal reef coast. Turtlegrass (Thalassia testudinum) is intensively distributed in the southeast coast and the Gulf of Mexico, and also the genera Syringodium filiforme, Halodule wrightii, and Halophila are appearing in the region.

It is said that the Native American Indians utilised eelgrasses, and Europeans used eelgrasses as insulators in the early 20th century. More recently, it has been valued for its role in supporting water birds as well as scallops (Argopecten irradians), which are a major fishery resource.

In the early 1920s, it was first recognised the functional role of seaweeds in the coastal ecosystem of the East Coast of the States. However, quantitative research was carried out in the 1970s, and since then, research on seaweed has increased rapidly.

Although the main causes of damage to the eelgrass fields are previously known to be dredging and deterioration of water quality, it has been found that the majority of habitat damage is not by direct dredging and reclamation activities. Direct impacts from mooring ropes, propellers, jet skis, boat tracks, etc. are found to be the main cause of the habitat damage. Improving sewage treatment and surface run-off, restrictions on scraping fishing gear and methods, and restrictions on boat traffic are the key factors identified to protect eelgrass beds in the Chesapeake Bay Program (1995).

The damage to eelgrass beds caused problems in the Chesapeake Bay, the Gulf of Mexico, Tampa Bay, Sarasota Bay, Charlotte Harbor in Florida, Mississippi Sound, Galveston Bay in Texas, Puget Sound in Washington, and San Francisco and San Diego Bays in California by destroying the major fisheries resources habitat such as scallops, clams and crabs. The loss of these habitats has emerged as a result of the development of the coastal areas. These disturbances cause rapid damage to the habitat and slow recovery.

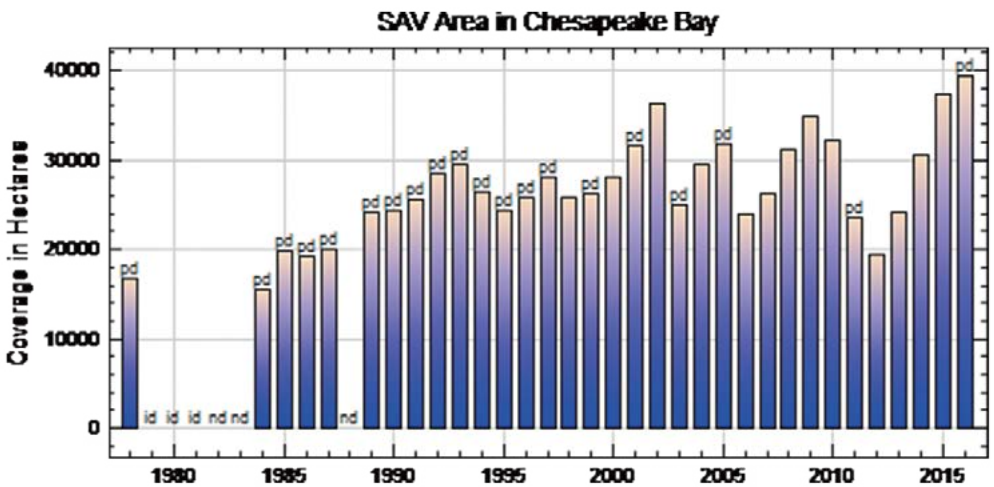
Recognising the ecological function and role of the eelgrass habitat, the eelgrass ecosystem is now being protected under the "no-net-loss policy" of the US federal government.

NOAA's National Marine Fisheries Services recognised eelgrasses play an important role in managed fish species under the Magnuson-Stevens Fishery Conservation and Management Act. Due to its biological, physical, and economical value, they developed the California Eelgrass Mitigation Policy in September 2014 to recommend a no-net-loss policy of eelgrass habitat functions based on section 404 (b)(1) of the Clean Water Act.

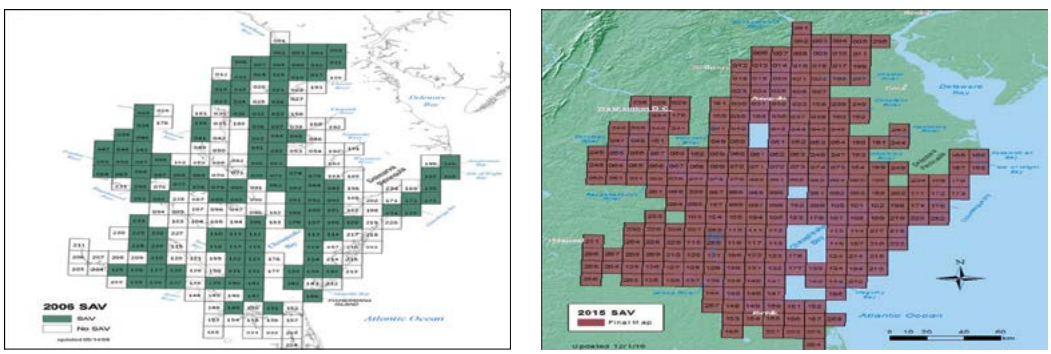
The no-net-loss policy is a strategy to minimise habitat damage and create alternative habitats (considering area and function) as much as the damaged habitats when the development project is inevitably carried out as a basic premise of the total eelgrass habitat area management system. It goes along with the "compensatory mitigation" option. For compensatory mitigation, the preservation of habitats in the development project areas is prioritised. Where damage to habitat is inevitable from a development project, the damage shall be minimised. If it is difficult to minimise the damage, the management system can be applied which includes a comprehensive management plan, creation or restoration of the same species habitat, the purchase or use of mitigation bank credits, an in-lieu fee program, and the creation or restoration of other species.

In accordance with the Chesapeake Bay Program, submerged aquatic vegetation (SAV) has been restored in the Chesapeake Bay since 1978. As you can see in the results monitored by the Virginia Institute of Marine Science (VIMS), the submerged aquatic vegetation was 15,400 ha in 1984, 23,942 ha in 2006, 30,528 ha in 2014, and 37,358 ha in 2015.

When looking at the geographical distribution comparison results of Chesapeake Bay submerged aquatic vegetation in 2006 and 2015 in the figure below, it is proven that the marine aquatic vegetation is being restored.



<Apendix Image 1-6> SAV area in Chesapeake Bay



<Apendix Image 1-7> Comparison of Geographical Distribution of SAV in Chesapeake Bay in 2006 and 2015

The Tampa Bay Estuary Program in Florida is a good example of the restoration effort of eelgrass forests in Florida. The Tampa Bay Estuary Program was operated with a long-term goal of restoring the eelgrass forest, which reached 15,380 hectares in the 1950s. Since 1980, nitrogen inflow has been suppressed through sewage treatment facilities, resulting in a 60% reduction in nitrogen load compared to the mid-1970s. In 2008, eelgrass forest distribution was lower than 15,380 hectares in 1950, but reached 11,990 hectares (Greening et al. 2011).

Along with the large-scale marine forest development with a long-term goal, there is another example in the US. Under the no-net-loss policy for habitat function based on the federal Clean Water Act, Section 404(b)(1), the damaged 96.87m^2 eelgrass forest in the Florida Keys from the 2001 N-Control ship grounding accident, was restored for 3 years and monitored for 5.5 years [ONMS (2010)].

In Korea, based on the Fishery Resources Management Act, the national or local governments are responsible for developing marine forests with national and local funds. In the US, on the other hand, the no-net-loss policy of section 404 (b)(1) of the Clean Water Act requires developers to minimise habitat damage and create alternative habitats (region and functional considerations) as much as the damaged habitat. Compensatory mitigation options such as comprehensive management plans, creation or restoration of habitats of the same species, purchase or use of mitigation bank credits, in-lieu fee programs, and creation or restoration of habitats for other species, are made available.

If the developer is not known, it is assumed that the restoration project is being carried out through donations and taxes.

B. Japan

In the history of calcification research in Japan, Shinnosuke Matsubara (1892) introduced the phenomenon of whitening (Isoyake) to academia for the first time in Japan. Matsubara was the third-ranked engineer in the Agricultural Affairs Bureau of the Ministry of Agriculture and Trade of Japan during the Meiji period. He mentioned the phenomenon of the decline of agar colonies in various places, and called it 'Isokare', in a report on a fisheries survey. Later, Kamikichi Ishinoue became the first scholar to use the term used the term 'calcification (Isoyake)', which was a dialect of the eastern coastal region of the Izu Peninsula. Afterwards, Endo Kichisaburou (1911) wrote the first textbook in Japan, Marine Botany, discussing the theory of seaweed reduction and placing Isoyake(calcification) as part of it. It

was Endo who introduced the concept of calcification to other countries, and his interpretation of calcification has been used in Japanese dictionaries such as Kōjien published by Iwanami Shoten in Japan to this day.

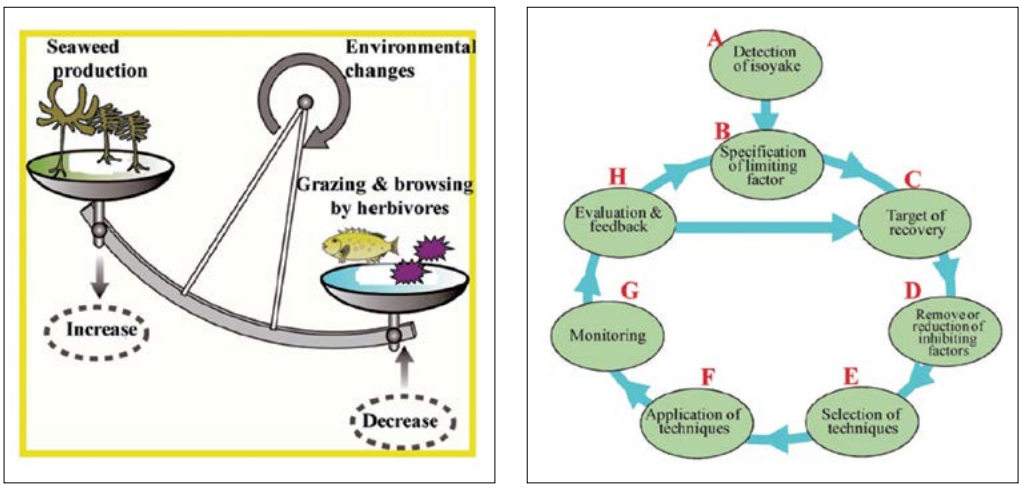
In addition, Fujita (2001) found that the seasonal change of seaweeds (seaweed colonies) in the natural coral reefs and boulder areas greatly deviated from the range of annual fluctuations and significantly declined, disappeared and resulting in poor seaweed vegetation. He defined this phenomenon as calcification. According to Fujita (2001), calcified areas can take a long time to recover, and poor seaweed vegetation appears in various ways, including cases in which non-articulated coralline algae dominate, become close to bare, or only a small number of upright seaweeds grow.

He also said that causes of calcification are diverse, which are depending on the topography, oceanographic characteristics, species composition of organisms, and the history of coastal use of each region. As calcification causation factors, examples of direct weather and sea conditions change include physical factors such as record high temperatures due to the occurrence of the El Niño or approaching of the Kuroshio current. Poor nutrition, strong waves caused by typhoons, increased grazing pressure of sea urchins and fish are also factors. There are man-made causal factors, such as pollution and eutrophication caused by the inflow of domestic sewage or industrial wastewater, stagnation of seawater due to river repair or shore maintenance, increase in suspended matter and sedimentation, overfishing of mammals, fish and invertebrates which are predators for herbivores. In addition, the deposition of volcanic ash can be an example of other factors.

In Japan, along with the long history of the occurrence of calcification, the research on restoration of the calcified sea area has been conducted in various ways over a long time. Initially, only ornithologists focused on trying to determine the cause and restore it. However, in recent years, various seaweed bed restoration techniques have been researched and developed in cooperation with the Fisheries Agency and research institutes representing the Japanese government, local governments centred on prefectures, fishery engineers, non-profit private organisations and private businesses, etc. In particular, joint research for marine forest restoration in the form of a consortium of seaweed ecologists, fish and shellfish ecologists, and fishery engineers has resulted in qualitative progress in marine forest development techniques.

In general, calcification is caused by the decline of seaweed beds due to changes in the marine environment and increased grazing pressure. When the grazing pressure decreases, the seaweed productivity increases, and the seaweed bed is naturally restored. By adding various artificial efforts and technical restoration techniques, the seaweed can be restored and managed.

The current status of calcifications in Japan is shown in Appendix Image 1-9,

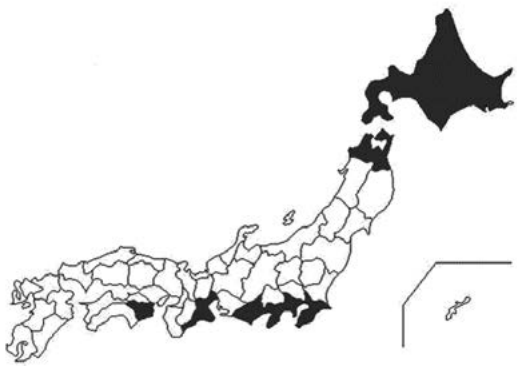
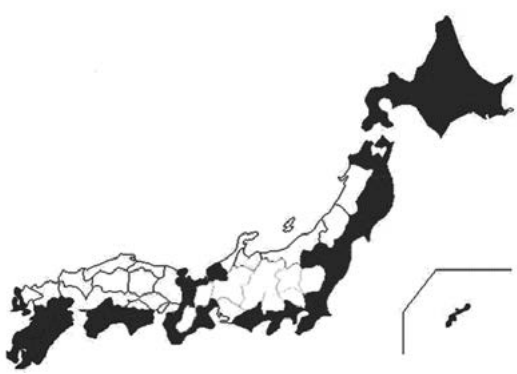


<Apendix Image 1-8> Mechanism for calcification(left) and management techniques to restore the calcifying sea area

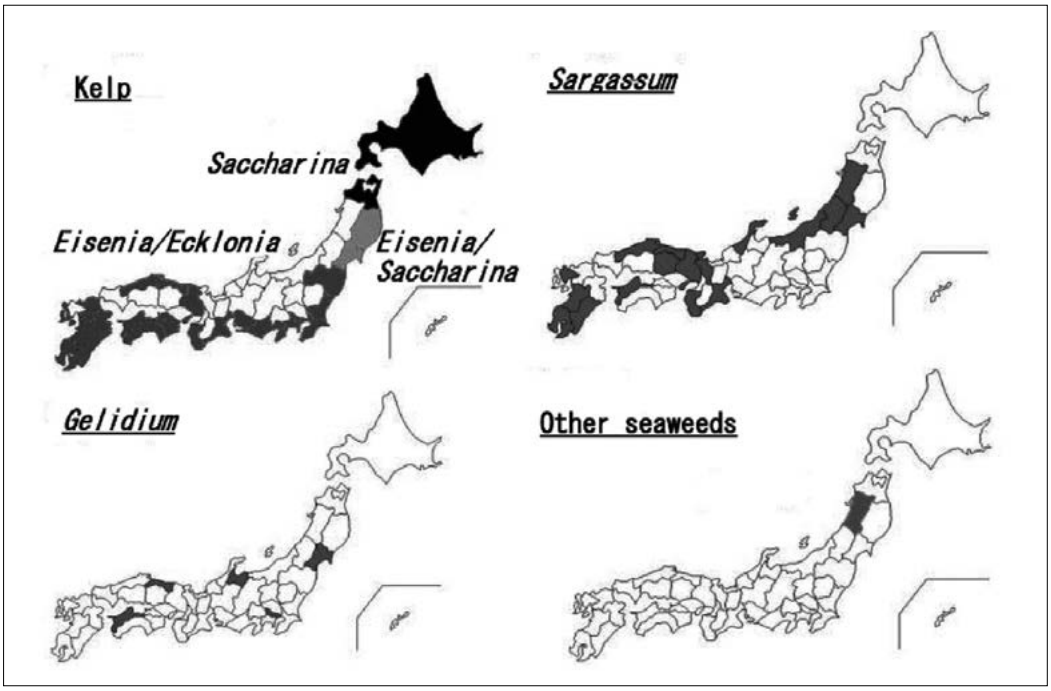
and the current status of calcifications by species is shown in Appendix Image 1-10 for major species that are declining and decreasing. In Japan, 37 out of a total of 46 metropolitan and regional governments are near the sea. As shown in the image below, calcification was reported in 7 cities and provinces around 1990, 23 cities and provinces in 1980, and 34 cities and provinces in 2015. It is clear that seaweed beds have declined sharply due to pollution and landfills, and almost the entire coast is suffering from calcification.

In Japan, a separate calcification distribution map is prepared according to affected major industrial seaweed species, such as large brown algae such as sargassum, sea oak, Ecklonia cava, and kelp, as well as agar and other seaweeds with high economic value.

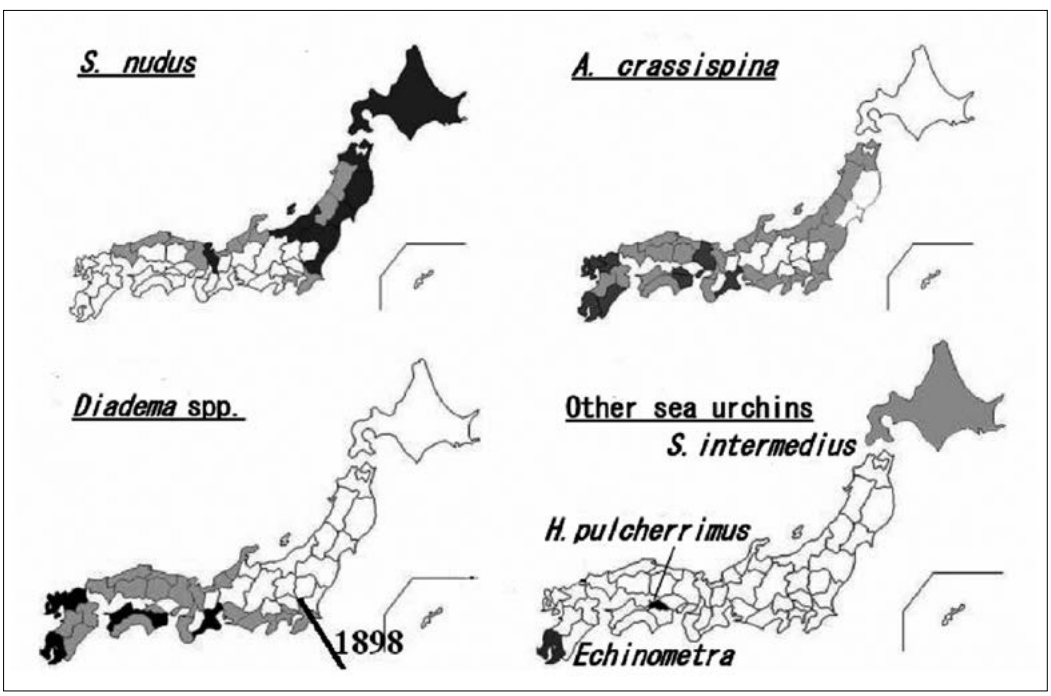
In addition, in the case of calcification due to biological causes, a different calcification distribution map is prepared according to the type of sea urchin with high grazing pressure or the type of herbivorous fish causing the calcification.

Early 20th century	7 cities and provinces	
Late 20th century	23 cities and provinces	
Early 21st century	34 cities and provinces	

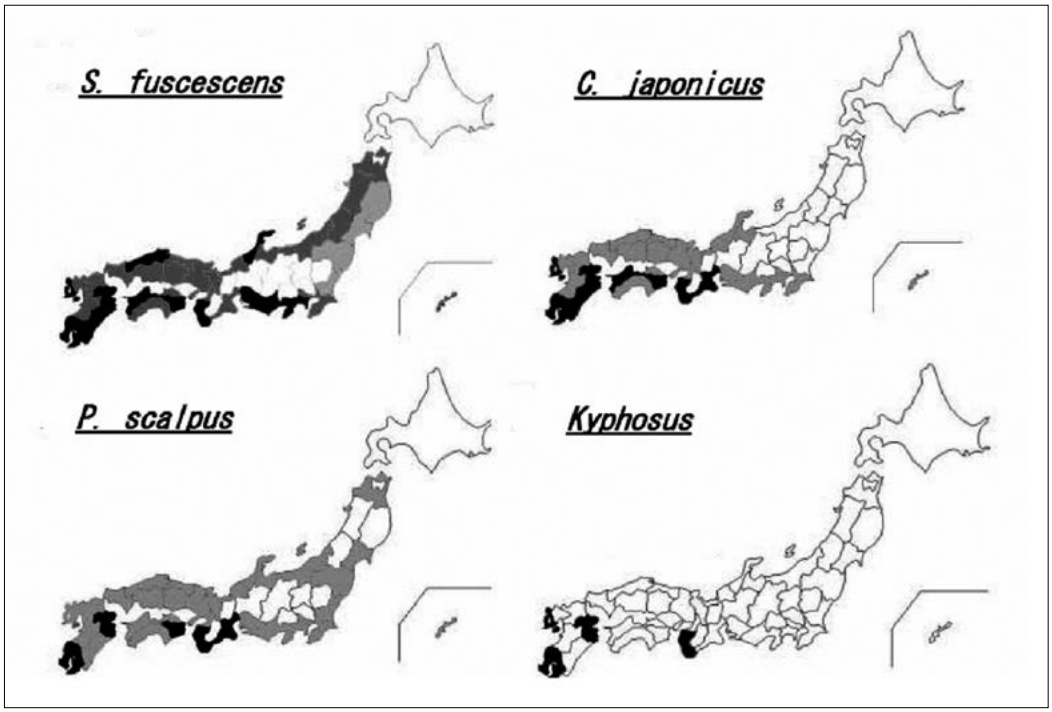
<Apendix Image 1-9> Trends of local governments in which the calcification of the sea has appeared



<Apendix Image 1-10> Distribution map of major types of seaweeds in decline in Japan



<Apendix Image 1-11> Distribution map of calcification by major species of sea urchin in Japan, the cause for calcification



<Apendix Image 1-12> Distribution map of calcification by major species of fish in Japan, the cause for calcification

Japan's marine forest development technologies include; 1) a method of adjusting the height of algae reefs (a method of increasing the height of marine forest reefs), which is used to largely secure the amount of light or reduce the influence of sand, 2) a method of using the substrate material for seaweed, such as making it easier to attach seaweed seedlings and making uneven surfaces so that they do not fall off even in strong waves, 3) installation of anti-grazing nets and sea urchin fences to reduce grazing pressure or damage by herbivores, 4) fertilization method using special equipment that continuously releases inorganic fertilizers, organic fertilizers and nutrients, 5) removing sapropel deposited on the substrate, 6) a rarely used technology, a sand and gravel removal project that is carried out when the sea forest is buried due to flooding, etc. (implemented in Kochi Prefecture, Japan) and 7) miscellaneous seaweed removal projects, such as the removal of Iwate surfgrass and sargassum, which are mainly conducted in kelp fishing grounds, are being implemented (Fisheries Agency, 2009).

There are other examples of using seeds obtained through seed production of eelgrass.

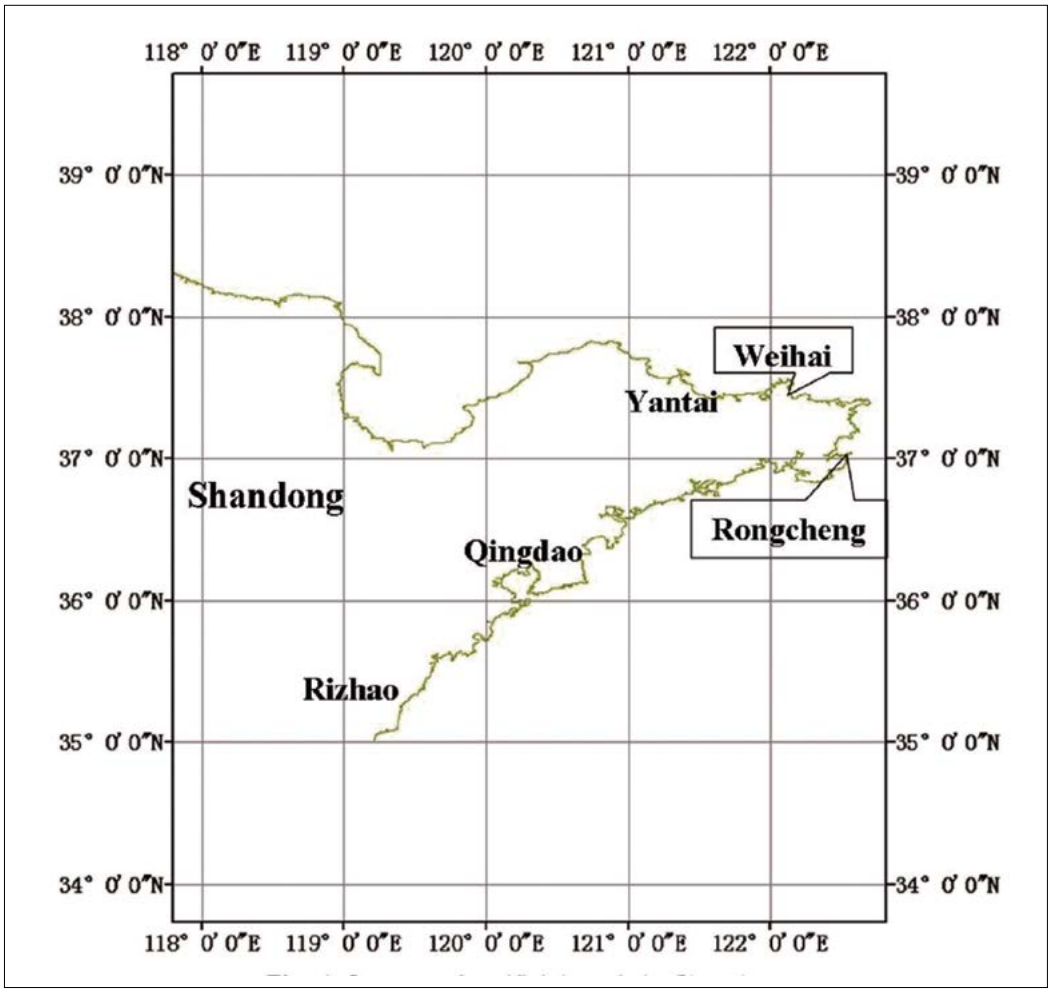
<Apendix Image 1-13> Example of using seeds obtained through seed production of eelgrass

C. China

Yao et al. (2010) describe marine forests as playing an important role in coastal biological production, marine ecological environment improvement, and the accession of fishery resources. In China, it has been reported that marine forest resources on the northern coast of China are seriously decreasing due to the influence of factors such as excessive development and global climate change. Since 2006, the local government of China has invested about 1.6 million RMB to start artificial reef facilities in the coastal areas of the Shandong Peninsula (Weihai, Yantai, Longcheng, Qingdao, etc.) to relieve calcification and enhance natural marine resources. Through this project, the goal of creating a 3,000ha marine forest, 10 locations along the coast of China are selected and the marine forest development project is being implemented. Since the artificial reef facility project, the economic and ecological effects are considered to be invaluable.

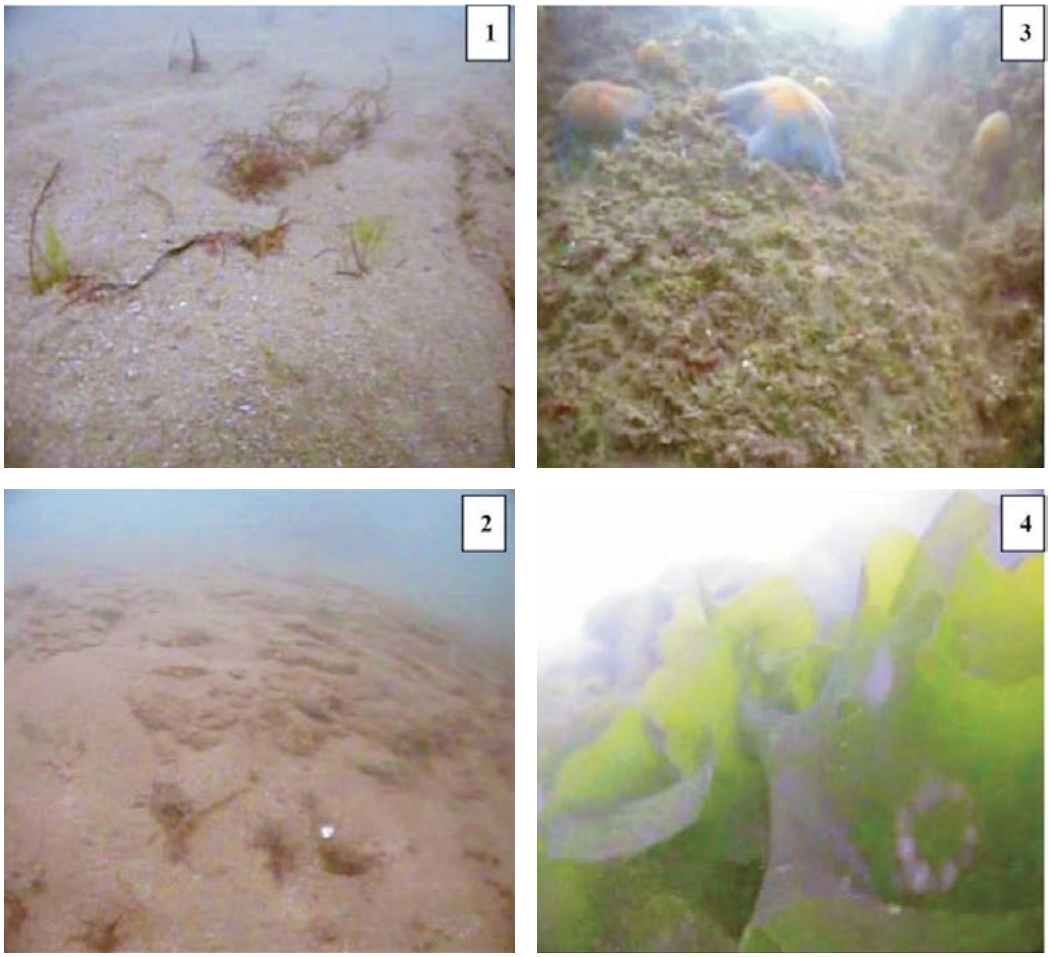
Judging from the history of China's marine forest project and the photos of artificial reefs and facility sites, Korea's marine forest project and artificial reef facility project are much more successful than China in terms of ecological technology and artificial reef production technology.

This suggests that Korea's experience and technology in marine forest development projects, could be an intellectual property that can be exported to China.



<Apendix Image 1-14> Artificial reef facility sites on the coast of Shandong Peninsula

<Apendix Image 1-15> Various types of artificial reefs installed on the northern coast of China



<Apendix Image 1-16> Changes in benthic seaweed ecosystem before (1, 2) and after (3, 4) artificial reef facilities for marine forest development

Appendix-2. Seaweed ecology and seed production for Marine Forest Project

A. Saccharina sculpera

○ Ecological characteristics

There are three types of kelp in Korea: Saccharina japonica, S. religiosa, and S. sculpera.

The origin of kelp was imported from Hokkaido, Japan in 1969, and started culturing in the sea off Bangeojin through seed production in Korea. On the other hand, in the Gangneung region, S. sculpera is called native kelp, and as it is known that it has higher functionality than S. japonica, it is over-collected and overfished, leading to the risk of extinction. Since then, restoration efforts have been made, but it is not easy to find large natural colonies in the northern seas of the east coast, where they are native.

S. sculpera is a perennial seaweed that inhabits at a depth of 20-30m in the northern part of the east coast, and is a native species endemic to the east coast. Until the 1990s, about 1,000 had been naturally produced per year in the Gangwon area, but it is now in danger of disappearing due to excessive harvesting and the failure of resource management.

S. sculpera has more than double the hypertrophy compared to other kelps and contains a lot of fucoidan, glutamic acid, aspartic acid and minerals. As the utilisation of S. sculpera resources increases, they are being developed into medicines, new substances, and health foods.

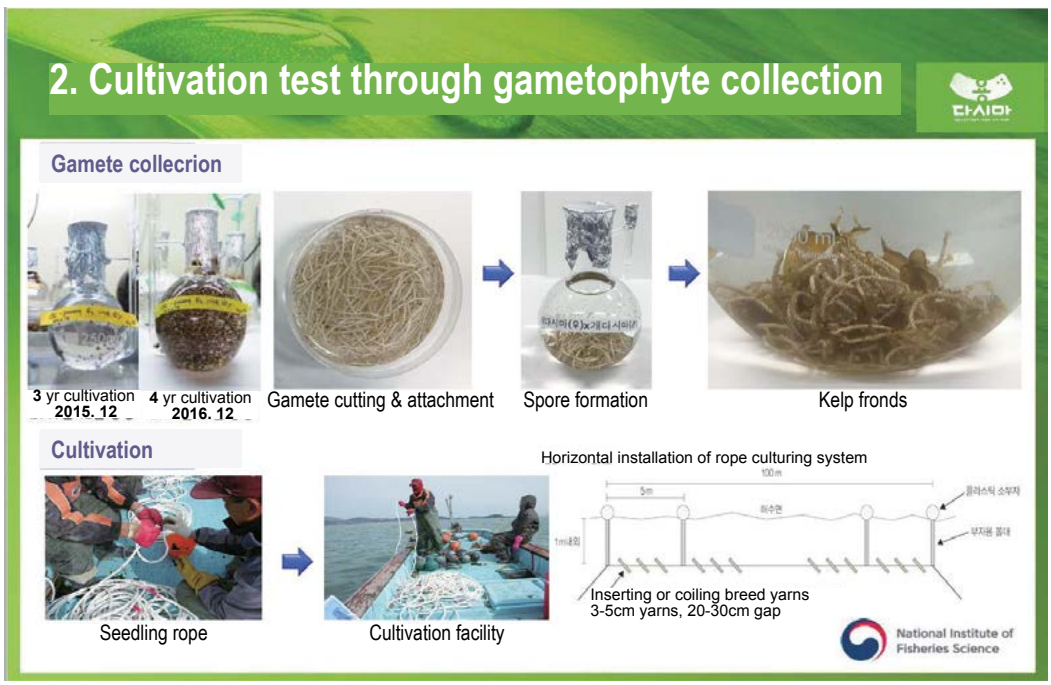
S. sculpera has dendritic adhesive material, which is typically found in Saccarina algae. On the front of its blade, uneven dragon patterns are formed, and the patterns do not disappear the entire life cycle. The frond grows up to 3m, and the width is about 20-50cm. The frond is rather tough and has a lot of mucilage. It is 2–3 mm thick, the middle part is about 1/3~1/4 of the blade width, and the lower part of the stipe is the columnar shape and the upper part is rather flat. The juvenile form appears after December and grows until the fall of the following year.

○ Seedling production

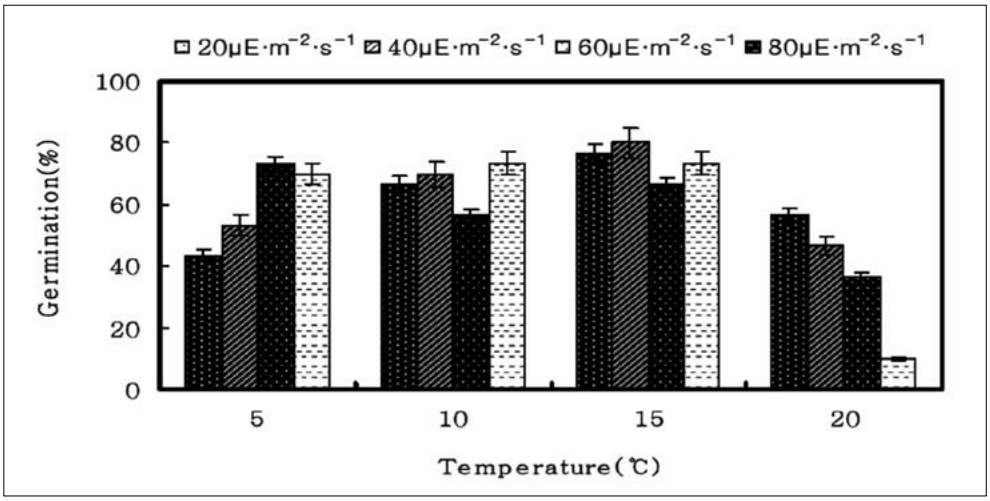
In 2007, the National Institute of Fisheries Science succeeded in producing and growing kelp seedlings through research on the restoration and aquacultural industrialisation of S. sculpera. The Seaweed Research Center has succeeded in producing and growing endangered S. sculpera seedlings.

Seedling production of S. sculpera is performed by cutting out the sorus formation part from the collected S. sculpera parent algae, and drying it in the shade for 12 hours in cold storage. After that, by inducing the release of zoospores, the movement and density of zoospores are studied under a microscope. If about 30 or more specimens are visible at 100 times field of view of the microscope and they are active, they are judged to be healthy and appropriate zoospores to be collected and produced. This leads to successful seed production.

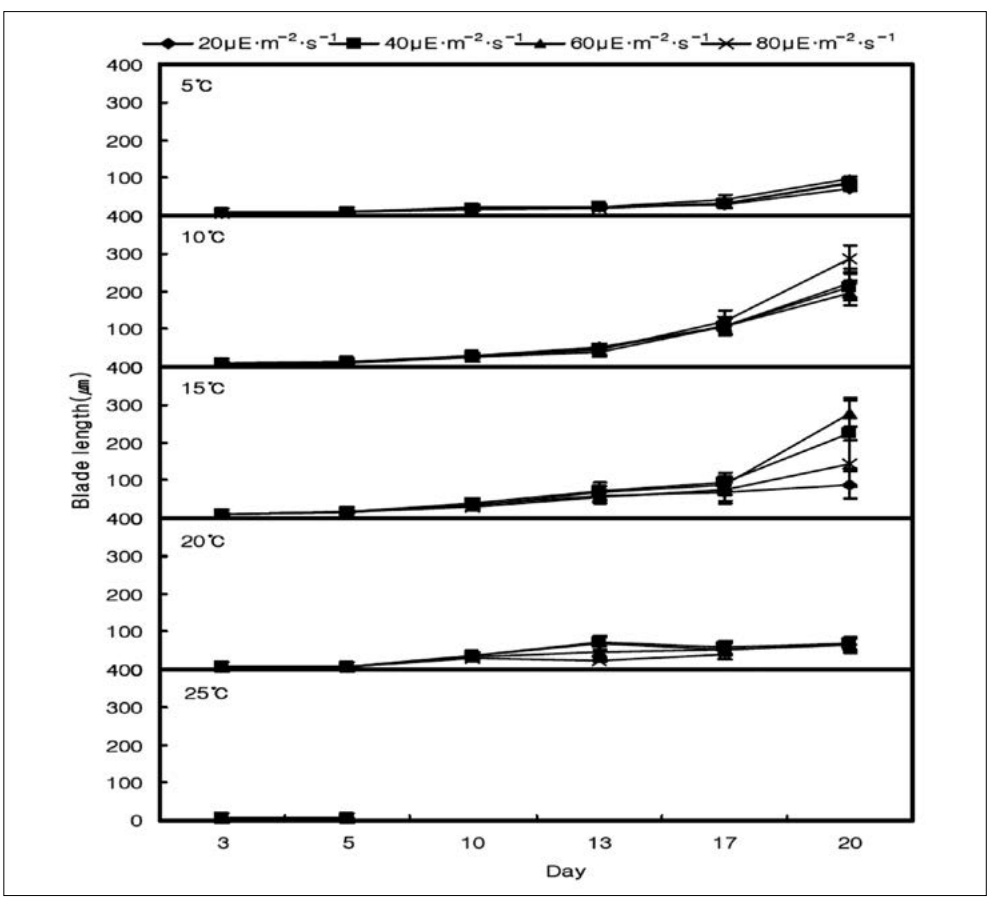
The best environmental condition for the germination of zoospores is found to be 15°C water temperature and 40μmol·m^{-2}·s^{-1} amount of light recording germination rate of 80.0%, and the worst at 20°C and 80μmol·m^{-2}·s^{-1} with 10.0% germination rate. At 5°C and 10°C, where the water temperature is relatively low, the germination rate was high at high light amount level. At 15°C and 20°C, where the water temperature was relatively high, the germination rate was high at a low light level, and it did not germinate at 25°C. The growth rate of gametophytes by environmental conditions was 95.6 ± 8.04μm at 60μmol·m^{-2}·s^{-1} at 5°C until the 20th day of culture, and the growth was good. At 10°C, it showed the best growth among all the test groups at 80μmol·m^{-2}·s^{-1}, 286.0 ± 35.20μm. At 15°C, it grew from 60μmol·m^{-2}·s^{-1} to 277.0 ± 113.60μm, and at 20°C, growth was good at 40μmol·m^{-2}·s^{-1} with 68.8 ± 36.64μm. At 25°C, all of them were found to die without germination until 5 days of incubation.



<Apendix Image 2-1> S. sculpera seed production and cultivation process



<Apendix Image 2-2> Germination rate of S. sculpera according to temperature and amount of light



<Apendix Image 2-3> Growth rate of S. sculpera gametophyte according to temperature and amount of light

B. Ecklonia stolonifera

○ Ecological characteristics

Ecklonia stolonifera is a perennial seaweed that belongs to the Lessoniaceae family under Laminariales, and is the only temperate seaweed in the kelp family. E. stolonifera is known as a species endemic to the southern part of the east coast but recently, colonies have been identified in Tongyeong and Yeosu. In particular, large colonies are found commonly in areas with rocks scattered on the hard sediments such as muddy bottom and in rocky beds at a depth of 4 to 10 m off the coast of Tongyeong. In addition, in Yeosu, Jeollanam-do, it is known that they formed colonies with no other species in the bedrock at a depth of 4-5 m and in the lower layers of the muddy bottom.

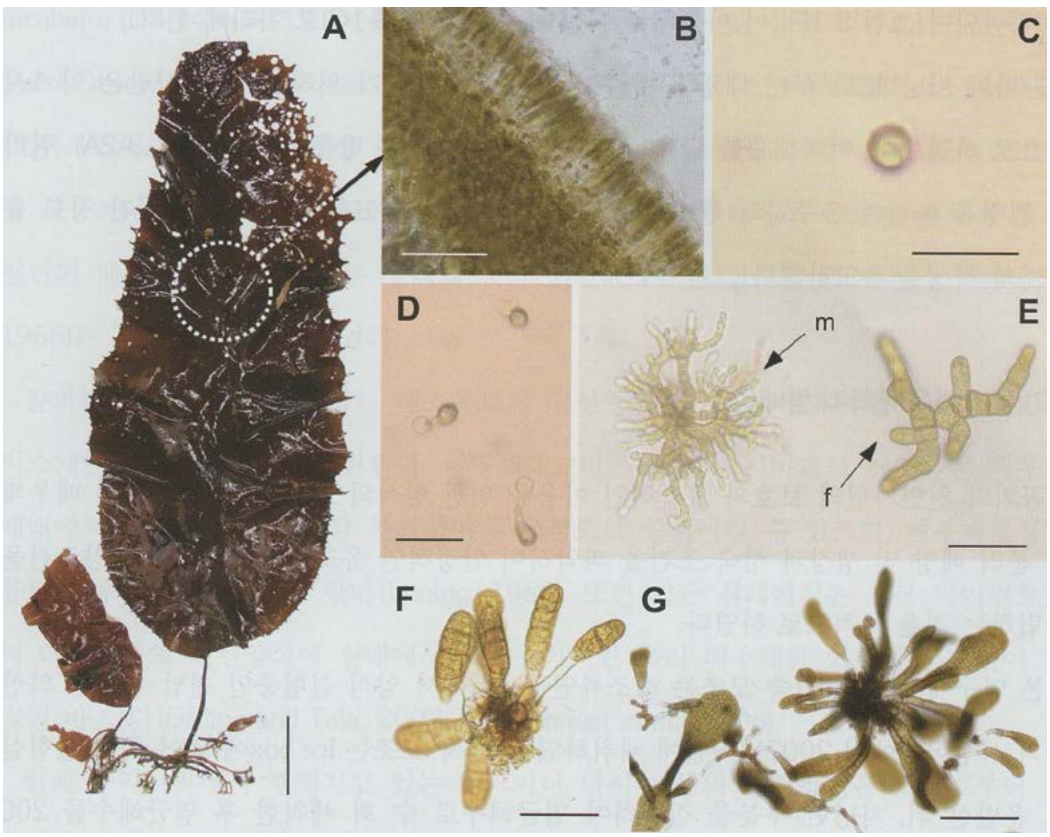
The maturation period of E. stolonifera is known to be from October to November (Kim et al., 2003), but in recent surveys, it is also observed that the period is gradually delayed depending on the sea area. The stipe is columnar and the thickness is about 3-5mm. The base is mostly wedge-shaped, but sometimes U-shaped, with serrated edges. The roots stretch out in all directions, forming new fronds at the end. Sori are formed in the lower part in the second year, but in the third year, it is formed at the newly formed growth point, so that a new body can be generated by stolon propagation. Due to its foliation, it is used as an alternative food source when abalone food is insufficient in summer.

○ Seedling production

The life cycle observed through the cultivation process of E. stolonifera is shown in the figure below. If you cut the sori region that appears on an E. stolonifera mature fronds, you can see spores filled inside the zoosporangium. The zoospores released from the zoosporangium attaching to an object immediately upon release, form a germ tube and grow into gametes. After 10 days of culture, it is possible to distinguish the sexes of each gamete, and sexual maturity occurs after 15 days of culture. Young sporophytes are formed through fertilisation between sperm and oocyte cells, which grow into sporophytes.

About 1-hour drying in the shade is suitable for inducing the release of a large number of spores from the zoosporangium of E. stolonifera. Then, put them in a tank containing filtered seawater to release the spores. After checking the active movement of the zoospores through a microscopic examination, seedling frames are put in for about 3 hours to induce the attaching of the zoospores. The zoospores attach to the cover glass within 30 minutes in the water and become immobile spores, and then, within 1 day of culture, germ tubes begin to form through

cytoplasmic migration. The fastest germination of spores is that more than 95% of germ tubes are formed in 3 days of culture at 25°C, and the slowest germination at 5°C, however, spores germinate in all conditions after 9 days of culture. The first gametophyte formation begins to appear from the third to fourth days of culture, and cell division begins at the same time.

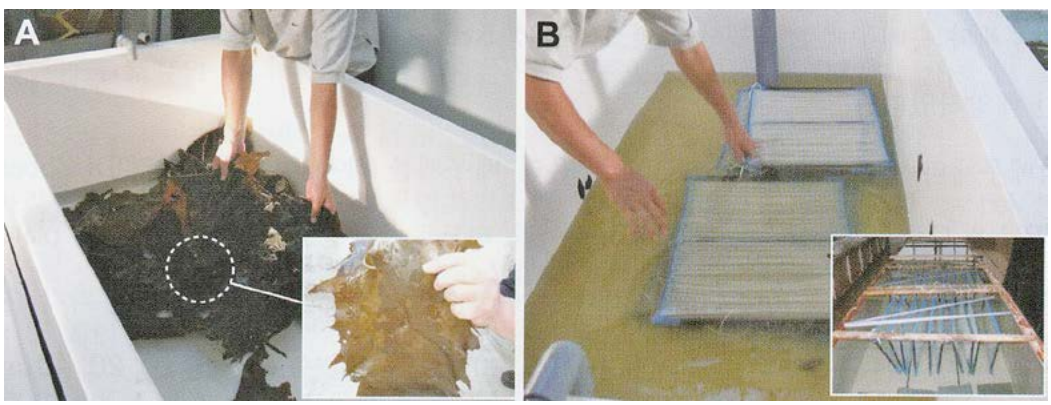


<Apendix Image 2-4> The process of releasing and generating zoospores of E. stolonifera

❊ A: mature parent algae with sorus. B: zoosporangium. C: zoospore immediately after release. D: germling 1 day after culture in which the germ tube was formed. E: female gametes(f) and male gametes(m) after 15 days of culture. F: young sporophyte after 18 days of culture. G: sporophyte after 33 days of culture. Scale bars 10cm(A), 50μm(B), 10μm(C), 20μm(D, E), 50μm(F) and 500μm(G). Culture conditions were 15°C, 30 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 10:14 (L:D)

The time when male and female gametes were differentiated is the 7th-10th days of culture, and the ratio of male to female is 6:4, indicating the higher ratio of female gametes. In the case of stationary culture, it appears the highest germination at 20°C. In the case of indoor culture, initial growth is more active under low illuminance conditions rather

than high illuminance (light intensity) overall, and various temperature conditions are required depending on the growth stage. For the growth and maturation of female and male gametes, they mature the earliest at 25°C, which is a high-temperature condition, and become sporophytes. In high-temperature conditions, growth and maturation take place earlier in low-light conditions rather than high illuminance conditions. Even at 10°C, gametes mature and progress to the sporophyte stage, but at 5°C, the male and female gametes do not mature or progress to the sporophyte stage. In the case of stationary culture of sporophytes, growth was highest at 20°C, and by illuminance, a high growth rate was observed at 1,000 lux, which is a low illuminance. The limit of stationary culture is that growth begins to slow down at 900-1,000μm. In indoor culture, initial growth is more active in low-light conditions than in high illuminance conditions, and various temperature conditions are required depending on the stage of growth. When it reaches a certain size, it is recommended to transfer them to an indoor water tank and culture them in flowing water.



<Apendix Image 2-5> Seedling collection by hand and water tank culture process of E. stolonifera

※ A: E. stolonifera blades with sori and mature parent algae into a water tank. B: Put the seedling frame in the tank from which zoospores were released

C. Ecklonia cava

○ Ecological characteristics

Ecklonia cava is also a perennial seaweed that belongs to the Lessoniaceae family under Laminariales same as E. stolonifera and Eisenia bicyclis, and is from warm temperate regions. In Korea, it has been known as a special species of Jeju, Ulleung, and Dokdo islands, but it was found that they inhabit the coastal waters of Busan and Ulsan waters in the southern part of the East Sea and Gampo to Yeongdeok-gun in the east coast of Gyeongbuk and Wangdolcho. Also, recently, it can be seen

in Tongyeong of the southern coast and Samcheok sea area of the east coast of Gangwon. On the coast of Jindo, Jeollanam-do, the distribution area is so wide that colonies can be observed even in the intertidal zone. This distribution is a good example of continuous marine forest development projects, by transplantation of E. cava seedlings and mass aquaculture production to obtain functional resources, they are spreading to areas where E. cava did not inhabit and distribute before, even spreading northward to the cool temperate zone. In particular, it has been shown that the E. cava grew in the sea area of Sageunjin, Gangneung and Mukho-dong, Donghae, as part of the Gangwon-do Marine Forest Project in 2006, are growing well. From this, it can be concluded that this is the result of the transplanted E. cava in the east coast getting adapted well to the range of year-round water temperature change in this sea area, and reproductions continue to occur.

Although the maturation period of E. cava is known to be from October to November or from autumn to winter, it is different depending on the sea areas such as Hongdo of Tongyeong, Jeju Island, and Ulleungdo. Especially, in recent years, the maturation period has been delayed, as it can be observed that mature sori are formed in early and mid-December. In general, the life cycle of seaweeds of the Laminariales order, which undergoes hetero generation alternation, generally matures through autumn and winter, except for sea mustard, which matures in spring. When diving in the waters of Wangdolcho or Dokdo, you can see young fronds growing all year round. Sometimes in the middle of the summer, in July, a population that formed the sori is found. In Udo Island, Jeju Island, mature fronds appear in January, September, and December, especially October is known to be the peak of the maturity of the species. Therefore, there is a possibility that E. cava mature year-round depending on the environment of the habitat, especially the water temperature. In order to determine the appropriate time for seedling production, it is necessary to investigate the maturation period according to habitat in more detail. A recent survey conducted to collect E. cava parent algae reveals that in Tongyeong Hongdo and Jeju Island, it was possible to collect fully mature E. cava parent algae in mid-December. The general habitat of E. cava is found from the lower intertidal zone (Jindo) to a depth of 25m in high-transparency waters such as Jeju Island, Ulleungdo and Dokdo. The main habitat water depth is 5-15m, and the largest colonies are developed at the depth of 10m.

○ Seedling production

If you cut the sori region that appears on an E. cava mature fronds, you can see spores filled inside the zoosporangium. Zoospores released from the zoosporangium attaching to an object immediately upon release, form a germ tube

and grow into gametes. After 10 days of culture, it is possible to distinguish the sexes of each gamete, and sexual maturity occurs after 15 days of culture.

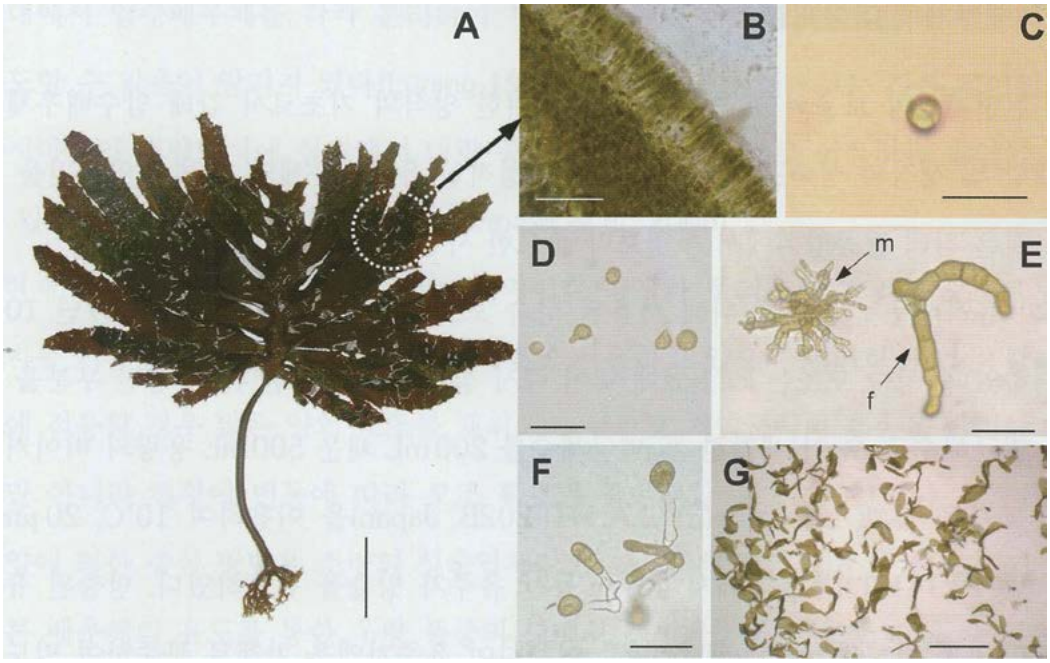
Through fertilisation between sperms released from the male gamete's antheridium and oocyte cells created during the female gamete's fertilisation stage, form young sporophytes. These young sporophytes grow into sporophytes and grow into parent algae of E. cava.

For the E. cava seedling production, to harvest mature fronds and only the blades with sori are cut and dried in the shade for about 1 hour. Afterwards, they are placed in a tank filled with filtered seawater to induce the release of zoospores. After examining the number of zoospores released under a microscope, the seedlings are collected by immersing seedling frames (45×55 cm) in the zoospore liquid for about 3 hours. After 3 hours of seeding collection, the seedling frames are transferred to another tank filled with filtered seawater and cultured in the tank. When culturing in a water tank, the surface illuminance is maintained at about 60 $\mu mol \cdot m^{-2} \cdot s^{-1}$, and the position of seedling frames is changed upside down on a weekly basis so that they receive light evenly.

The zoospores attach to the cover glass within 30 minutes in the water and become immobile spores, and then, within 1 day of culture, germ tubes begin to form through cytoplasmic migration. The fastest germination of spores is in 3 days of culture, more than 90% of germ tubes are formed at 20°C, and the slowest germination at 5°C, however, spores germinate in all conditions after 11days of culture.

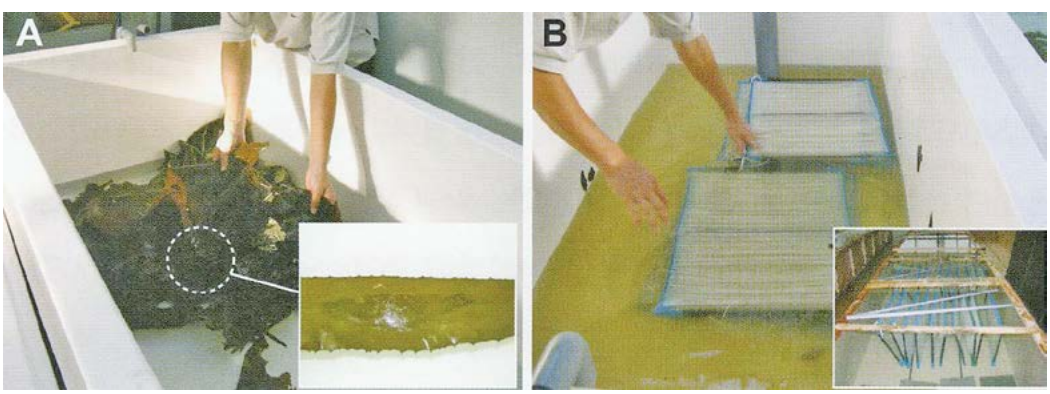
The first gametophyte formation begins to appear from the fifth days of culture, and cell division begins at the same time. The time when male and female gametes were differentiated is the 11th day of culture, and the ratio of male to female is 5.5:4.5, indicating the higher ratio of female gametes. In the case of the sporophyte, it appears that the 15°C condition is the most suitable. In the case of indoor culture, initial growth is more active under low illuminance conditions rather than high illuminance (light intensity) overall, and various temperature conditions are required depending on the growth stage.

For the growth and maturation of female and male gametes, they mature earliest at 20°C, which is a high-temperature condition, and become sporophytes. In high-temperature conditions, growth and maturation take place earlier in low-light conditions rather than high illuminance conditions. Even at 10°C, gametes mature and progress to the sporophyte stage, but at 5°C, the male and female gametes do not mature or progress to the sporophyte stage. Sporophytes appear highest at 20°C, and by illuminance, high growth is seen at 1,500 lux, which is a low illuminance. and by illuminance, a high growth rate was observed at 1,500 lux, which is a low illuminance. The limit of stationary culture is that growth begins to slow down at 1,200-1,500μm.



<Apendix Image 2-6> The process of releasing and generating zoospores of E. cava

❉ A: mature parent algae with sorus. B: zoosporangium. C: zoospore immediately after release. D: germling1 day after culture in which the germ tube was formed. E: female gametes(f) and male gametes(m) after 15 days of culture. F: young sporophyte after 18 days of culture. G: sporophyte after 30 days of culture. Scale bars 10cm(A), 50μm(B), 10μm(C), 20μm(D, E), 50μm(F) and 500μm(G). Culture conditions were 15°C, 30 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and 10:14 (L:D)



<Apendix Image 2-7> Seedling collection by hand and water tank culture process of E. cava

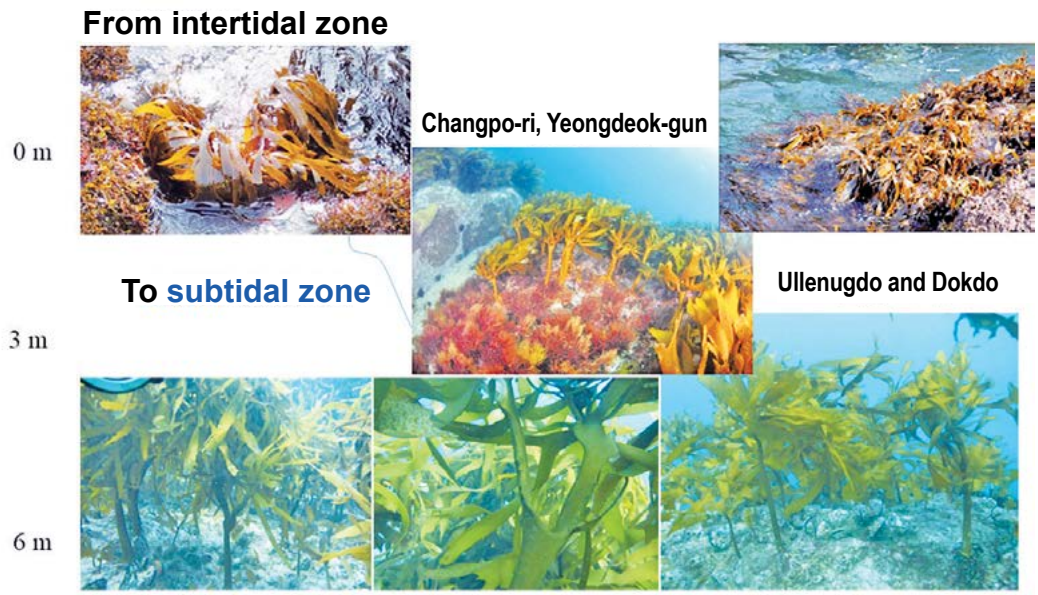
❉ A: E. cava blades with sori and mature parent algae into a water tank. B: Put the seedling frame in the tank from which zoospores were released

D. Eisenia bicyclis

○ Ecological characteristics

Eisenia bicyclis is also a perennial seaweed that belongs to the Lessoniaceae family under Laminariales same as E. stolonifera and E. cava, and is from warm temperate regions. It was known that its distributions are limited to the subtidal zone within 10m from the low-water line of Ulleungdo and Dokdo. However, in the coastal area of Changpo-ri, Yeongdeok-gun, Gyeongsangbuk-do, large colonies were found not only in the subtidal zone but also in the lower tidal pools.

In Japan, E. bicyclis is distributed in large colonies in the coastal waters of the Kii Peninsula and Ibaragi Prefecture, where the Tsushima warm current is strong from the south of central Japan. The roots of the E. bicyclis are dendritic, whorled and columnar or oblate. Its length varies depending on the depth of the habitat, but the average length is 1m and can reach up to 1.5m, with a stipe of 20–40cm and a diameter of 2–3cm. The initial frond is monotonous, large-leaved, and when it grows, it has pinnate lobes like the algae of the Ecklonia genus. The blade part of the early years decays and disappears down to the growing zone of the junction of the stipe. The growing zone grows side to side in a similar form, making the stipe look like a dichotomy, each will have lobes in the second year which bifurcated into pinnate. Eisenia bicyclis, whose stipe end is branched in a 'Y' shape, is morphologically easily distinguished from Ecklonia cava. From autumn (October to November) of the second

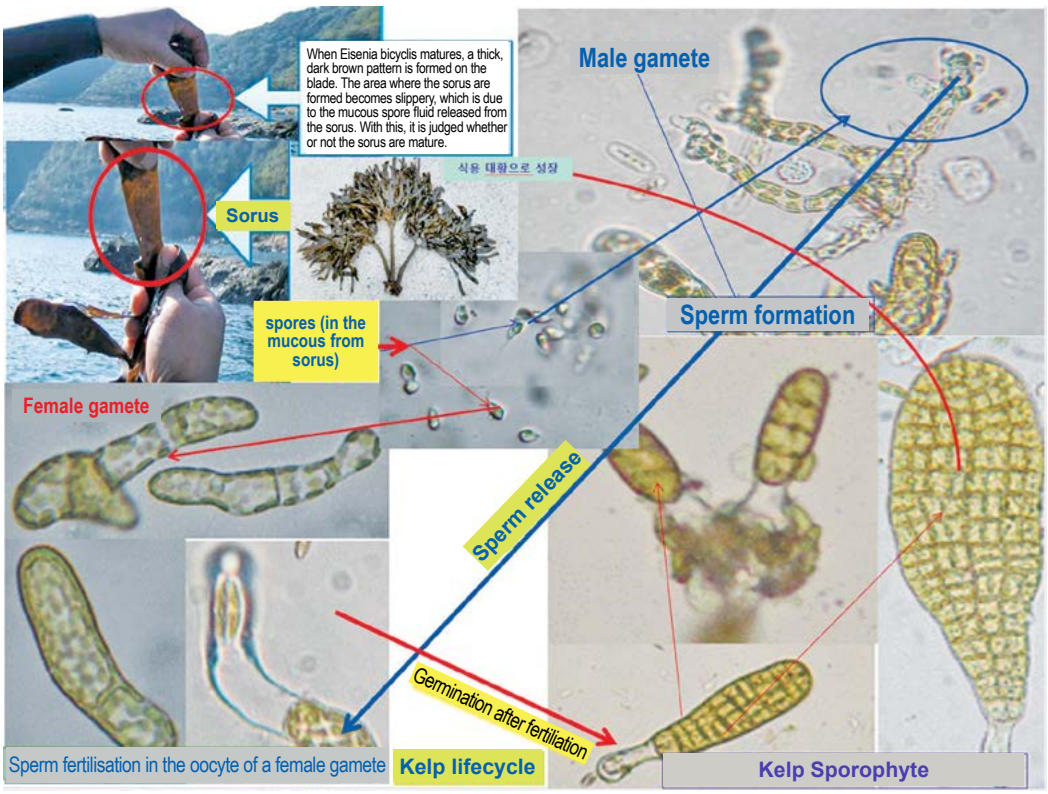


<Apendix Image 2-8> Habitat and distribution of Eisenia bicyclis

year to winter, sori form on both sides. After releasing zoospores, the blades are lost, and new blades are formed again, and juvenile fronds appear in the spring.

○ Seedling production

At the end of November, mature Eisenia bicyclis fronds are collected and the blade part with sori is cut off, and dried in the shade for about 1 hour and 30 minutes. Then, place them in a tank filled with filtered seawater about 3/4 of the way. After microscopic examination of the release of zoospores, seedling frames are immersed in the zoospore fluid for about 4 hours and seedling collection is carried out. After that, the seedlings of E. bicyclis are produced through the cultivation process in the same way as E. cava. Thereafter, seedlings are secured for transplantation or supplementary plantation, by carrying out the main cultivation through the preliminary transplantation process.



<Apendix Image 2-9> Life cycle of Eisenia bicyclis

Drying parent algae indoor in shades

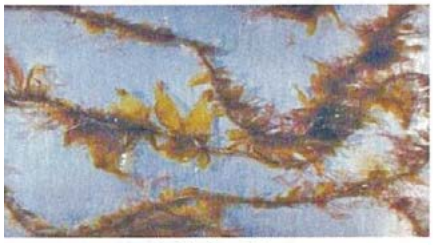
Zoospore release

Examine density and activity of zoospores

Zoospore transplant

Indoor mass cultivation

Preparing seedling frame



Produced seedlings

Mid-water cultivation

<Apendix Image 2-10> Seedling production and cultivation process of algae of Lessoniaceae family

E. Sargassum horneri

○ Ecological characteristics

Sargassum horneri is an annual seaweed species that is widely distributed on the east and south coasts of Korea and all coasts of Japan.

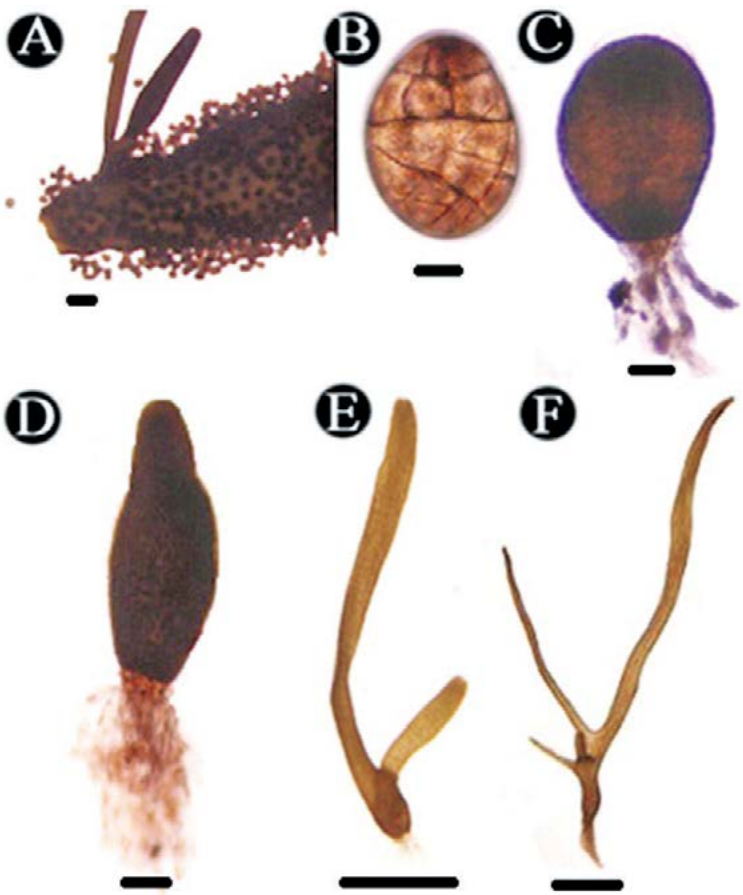
Uchida (1993) has revealed the life cycle of this species through indoor culture, and also, Honda and Okuda (1989) revealed its oocyte release and embryogenesis of fronds which mature in autumn and seasonal changes of photosynthetic rate. As for researches on Korean S. horneri, starting with the taxonomic study of Ryu (1975), and there are studies on the growth and maturation of sargassums (Ahn, 1991). Kim (2015) has revealed the effect of light intensity and photoperiod on the growth of the embryo of S. horneri. S. horneri is a seaweed with a very high reproductive ability with very large biomass due to its fast growth rate and good fertility.

Recently, a large quantity of farmed S. horneri from China flooded the beaches of Jeju Island and the west and south coasts of Korea, damaging the aesthetics of the area in the form of marine debris, raising the eyebrows of local residents. On the other hand, it also has a value of resources that should not be overlooked, such as function as a useful seaweed and as an excellent food source.

According to a report from the Kyoto newspaper in Japan in 2019, the Kyoto Sealife Centre and local fishermen developed the full-scale aquaculture technology for “S. horneri (Japanese name: Akamoku)” for food resource. The report also said that fishermen are farming the seedlings which are cultured in the centre to stabilise the production amount that fluctuates every year. The paper goes on to say that S. horneri of the Sargassaceae family, inhabits all over the country except for parts of Hokkaido. More and more areas use S. horneri for food, due to its unique texture and toughness, and it contains a lot of calcium, magnesium, and dietary fibre compared to other seaweeds. However, it was pointed out that the imbalance in the number of resources is a problem because a new habitat is required every year for S. horneri, of which, life cycle ends after a year. As such, it has as much importance as a resource seaweed as the ecological risk, so the resource management policy of S. horneri is important in terms of functional stabilisation when developing sargassum-based marine forests.

○ Seedling production

The released oocytes obtained from mature fronds of the collected S. horneri are washed in sterile seawater. After that, shake well in the seawater so that the concentration of embryos is the same. Then, apply it evenly on a seedling frame wrapped with Cremona synthetic fibres (attachment substrate for sargassum seedlings) using a wide brush. At this stage, the seawater is changed every week. If necessary, it can be added MGM medium, PES medium, or liquid medium for water culture at a concentration of 500cc per 1 Ton to promote growth.



<Apendix Image 2-11> Germination and growth process of S. horneri embryo

❊ A: female receptacle with embryos. B: embryo released from the receptacle. C: germling of the embryo which formed rhizome after 2 weeks of culture. D: frond after 4 days of culture. E: frond with main and branched branches after 14 days of culture. F: frond having a main branch and three small branches after 18 days of culture ($40\mu mol \cdot m^{-2} \cdot s^{-1}$, $20^{o}C$ and 14L:10D). Scale bars : 2mm(A, E, F), 0.1mm(B, C, D)

The initial growth of the embryos occurs rapidly at the temperature of 20°C or higher and the high light intensity of 40μmol·m^{-2}·s^{-1} or higher under a long-day cycle. Embryos in aeration culture are more active. In general, it has been confirmed that the germination and growth of the embryos of the S. horneri, which naturally mature in autumn and release oocytes until midwinter, progress rapidly under high temperature and high light under long/short-day conditions. Therefore, it should be applied for seedling production with reference to the fact that the embryos of S. horneri are affected more by temperature than by the photoperiod.

<Appendix Table 2-1> Physiological and ecological characteristics of seaweeds in major marine forests

Item	Family	Species	Growth env.			Distribution	Maturity	Life-span	Reproduction	Seedling spread
			Sea	Mid	Embayment					
Laminaria japonica	Laminariaceae	Laminaria japonica		—	—	Temperate/ polar zone	Late autumn	Perennial	Zoospore (5μm) ↓ Male and female gamete ↓ Sporophyte	Relatively wide range with zoospore activity
		Laminaria religiosa						Annual		
Eisenia bicyclis	Lessoniaceae	Eisenia bicyclis		—	—	Temperate zone		Perennial		
Ecklonia cava		Ecklonia kurome Okamura		—	—					
Ecklonia stolonifera		Ecklonia cava		—	—					
		Ecklonia stolonifera		—	—					
Sargassum fulvellum	Sargassaceae	Sargassum fulvellum			—	Warm temperate/ temperate zone	Winter-Spring	Perennial	Oocyte (embryo) (80~100μm)	Relatively small range as fertilised embryo have no movement
		Sargassum filicinum			—					
		Sargassum piluliferum		—	—					
		Sargassum macrocarpum		—	—		Spring-Summer			
		Sargassum coreanum		—	—		Autumn			
Zostera marina	Zosteraceae	Zostera marina			—	Warm temperate-polar zone	Spring	Perennial	Seedling, vegetative reproduction	Relatively small range

F. Sargassum fulvellum

○ Ecological characteristics

Sargassum fulvellum is a well-known edible seaweed in Korea along with S. fusiforme, a seaweed of the same Sargassum genus, and is an important industrial species that is cultivated in large quantities on the southern coast.

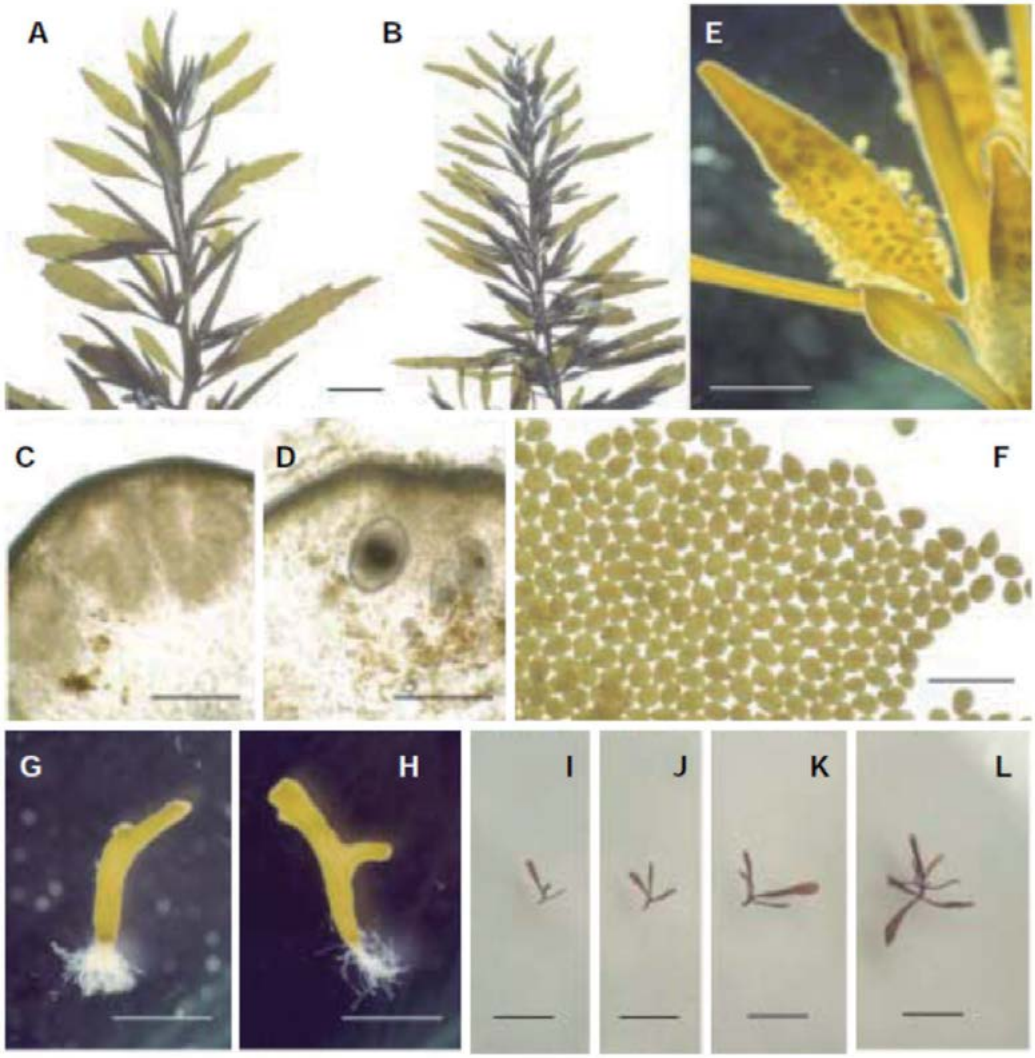
Although it is reported that various environmental factors have a complex impact on the growth and maturity of S. fulvellum, and among external factors, water temperature conditions are known to have the greatest influence. S. fulvellum starts to grow rapidly from February when the water temperature starts to rise, and the maximum growth occurs around the middle of March. Maturity is also known to reach its peak in March, when the water temperature starts to rise from February, and the formation of the receptacle begins in March when the water temperature is 10°C or higher.

○ Seedling production

In order to secure mature parent algae for artificial harvesting of S. fulvellum, mature wild parent algae are collected between February and March or those under culture management are collected. In the case of wild parent algae collection, it is impossible to check their receptacles frequently, so the collection is usually between the 3rd and 5th tide of February to March. In the case of collection from culture, the receptacle formation to be checked frequently from February. After the receptacle formation, it is best to collect them when sperms are released from the receptacle and attached to the female receptacle with mucilage.

S. fulvellum is dioecious, and sexual reproduction is achieved by fertilisation of oocytes and sperms. Zygotes are released from the female receptacle to the outside of the conceptacles and develop while attached to the surface of the receptacle with mucilage. The zygotes begin to develop and undergoes several cleavages. After that, at the stage where the rhizomes start to form, they are fell from the receptacles and attach to an object. Mass release and excretion of embryos from genital deposits occur within 4 to 5 days after fertilisation.

The formation of germling develops in a spatula shape after 14 days of culture, forming secondary lobes after 40 days. After 60 days, the main branch differentiates and tertiary lobes are formed, and after 90 days, quaternary lobes are formed. After 100 days, not only the elongation has progressed, also the formation of blades begins to speed up, while lower blades grow thick.



<Apendix Image 2-12> Early growth stage of S. fulvellum

※ A: male gametophyte plant. B: female gametophyte plant. C: cross section of male receptacle. D: cross section of female receptacle. E: fertilised embryo on the surface of female receptacle. F: embryo released and fell from receptacle. G: germling after 14 days of culture. H: secondary lobe formation after 40 days of culture. I-J: frond with main branch differentiation and tertiary lobe formation after 60 days of culture. K: frond after 90 days of culture. L: frond after 100 days of culture. Scale bars : 1cm(A, B, E, I, J, K, L), 1mm(F, G, H), 100㎛(C, D)

Cremona 42 braids or thicker threads are suitable for collecting S. fulvellum, and make sure to burn off the fine hairs of the threads. If there are fine hairs left on the thread, the embryos get attached to the fine hairs and are easily fall off. Newly purchased seedling frames are soaked in freshwater overnight to soak out the bleach substances, etc., and the process is repeated three times. Afterwards,

they are dried completely in the sun to remove the toxicity and ready to be used for the seedling collection. Threads being loosely wound rather than tightly wound to the frame prevents the tension-induced fallout and increases the surface of contact with the seawater. You can loosen the threads of the seedling frame by hitting the

<Apendix Image 2-13> Seedling collection process of S. fulvellum

❊ A: straining embryo fluid. B: collecting embryo fluid. C: immersion of seedling frames in the fluid (seeding). D: drying of seedling frames. E: threads of a seedling frame with the embryos attached. F: Aquatic culture of embryos.

frame hard after removing the middle strips of the frame leaving only two side edges. The embryos released from the receptacle of naturally matured parent algae are collected and filtered using Muller-gauze (Φ300~500μm) or mosquito nets. Then, they are washed several times with sterile seawater to prepare dense fluid. The seedling collection is done by immersing 45×55cm plastic seedling frames (42 Cremona threads, approximately 100m per frame) into the germling fluid (wet method). Or use a brush to apply it onto the threads of the seedling frames (dry method). The wet method is used for a large volume of germling fluid, and the dry method is used for a small volume. After collected embryos are dried in the shade for about 1 to 2 hours, they are placed in an indoor water tank for culture.

The growth rate of the S. fulvellum germlings was the highest at 3.9 ± 0.2 mm in the 15°C and 4,000 lux range after 35 days of culture and followed by in order of 3.7 ± 0.5 mm in 2,500 lux and 3.1 ± 0.3 mm in 5,000 lux. It also showed 1.8 to 2.6 mm of length growth in the 10°C temperature and 20 to 25°C range. In the temperature range of 5°C, it shows the lowest length growth of 0.3~0.33mm in all illuminance range.

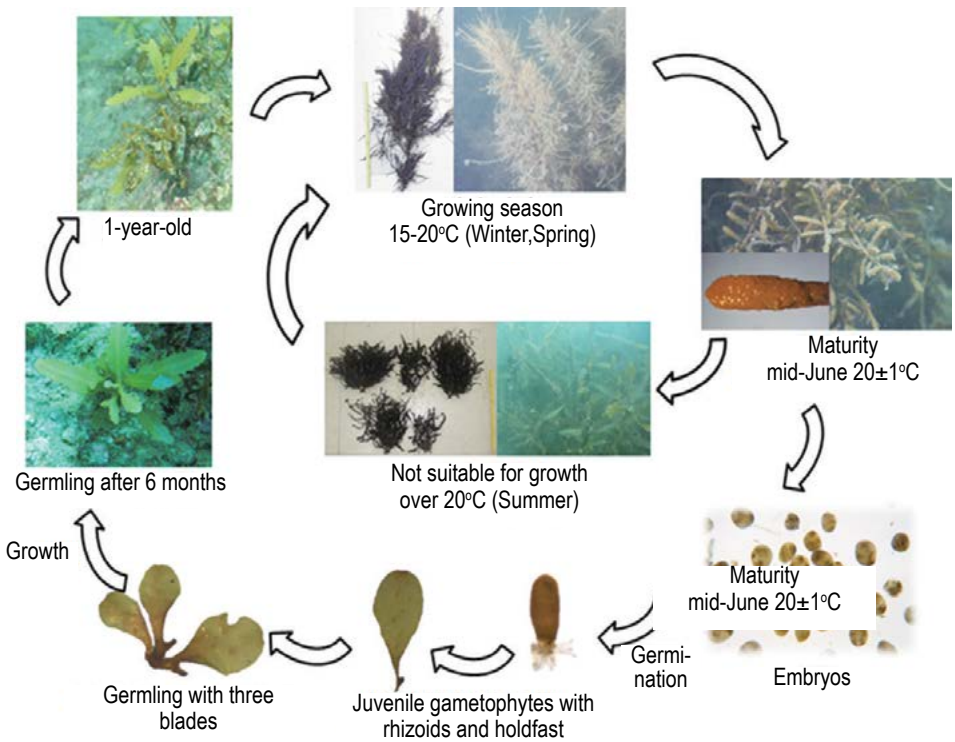
G. Sargassum macrocarpum

○ Ecological characteristics

S. macrocarpum is a large dioecious species whose frond grows up to several meters in height. The holdfast is conical, reaching a diameter of 5 cm. The main axis is columnar and stands upright independently from the holdfast, 4–5 mm in diameter, and it branches several times with 1 cm gaps to form multiple central branches. Central branches are unevenly compressed in shape, with serrate margins. The lower part of the main branch is a bigon and is 3-4 mm wide. Its lateral branch is unevenly compressed at the lower part, and forms a trigon shape at the upper part. The lower blades are lanceolate and linear, and the serrations may develop up to the shallow caudal margin or midrib, or sometimes form double serrations. The upper blades are linear and narrow. Vesicles are spindle-shaped and elliptical, with protuberance or leaf-shaped coronal foliar. The female receptacles are compressed spatula shape, and the male receptacles are compressed linear shape. The body is blackish-brown and turns black after drying.

This species has been identified as S. serratifolium by many scholars in Korea and Japan. The two species have similar characteristics in which the blades of the lower part of the frond form deep cavities and both grow in the subtidal zone. However, S. macrocarpum is distinguished by the fact that the blades of the species

are thicker, and form double serration. S. macrocarpum has spindle-shaped vesicles and there are few vesicles with leaf-shaped coronal foliar. Also, in the shape of the spines on the margins of the main axis, the species shows sharp spines, whereas S. serratifolium has blunt spines at the tip. These identifying traits are also consistent with the Japanese species found in Yoshida (1983), indicating that they are solid traits with no regional differences.

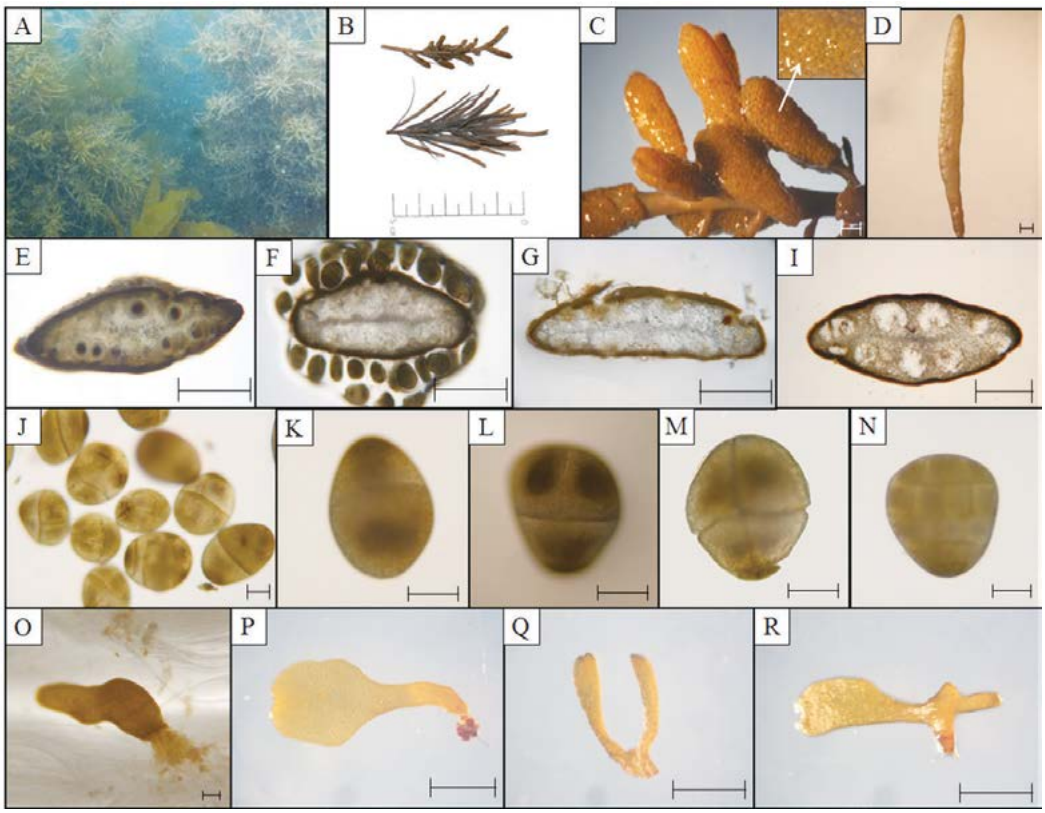


<Apendix Image 2-14> Lifecycle of S. macrocarpum

○ Seedling production

It is necessary to prepare and carry out the collection of mature parent algae of S. macrocarpum with attention to details like a serious operation. It is because the embryos of S. macrocarpum are released soon after maturation, which we 've learnt while surveying S. macrocarpum colony in Dumi-do, Tongyeong-si. From the end of May to the beginning of June, the entire area of Yeongun-ri (aka amphibious ground) in Tongyeong city was surveyed every three days, and fully mature parent algae were collected around June 10, making it possible to harvest artificial seedlings. The subsequent seeding process is the same as Myagropsis myagroides.

It is better to cultivate artificial seedlings under the same conditions as M. myagroides, the illuminance of 6,000 Lux, and the water temperature of 20°C. After that, the growth of the embryos is smooth, and they can be grown into germlings of about 5mm.



<Apendix Image 2-15> Germination and early growth process of embryos of S. macrocarpum

※ A: mature S. macrocarpum colony (left: female (♀), right: male (♂). B: female and male receptacles (top: female; bottom: male). C: female receptacles with formed embryo. D: male receptacle. E: cross section of female receptacle (early stage of maturation in which embryos are formed inside). F: The cross section of female receptacle where embryo is released out of the receptacle. G: cross section of female receptacle after all embryos released. I: cross section of male receptacle. J-N: the process of cleavage of S. macrocarpum. O: S. macrocarpum with rhizoids formed. P: elongation of S. macrocarpum. Q: S. macrocarpum with secondary lobe. R: S. macrocarpum forming tertiary lobe. Scale bars : 1mm(C-I). 100μm(J-O). 1mm(P-R)

For the germination and early growth process of S. macrocarpum embryo, after 7 days of culture, an average of 10 or more rhizoids are formed under all conditions. After 14 days of culture, the number of rhizoids was not significantly different from the initial number. However, since it appears that more rhizoids are formed in stationary culture than in aeration, so is recommended for initial seed culture

under short-day conditions at 20°C, 80μmol·m^{-2}·s^{-1}. The reason for the large number of rhizoids in stationary culture is that, due to the physiological characteristics of seaweeds living a sedentary life based on an adherent substrate, a survival strategy to maintain stability by firmly fixing the holdfast in at stationary culture environment rather than in an inorganic aeration culture environment.

Species		Annual work schedule (monthly)																							
	Seedling method	1			2			3			4			5			6			7			8			9			10			11			12		
		Early	Mid	End	Early	Mid	End	Early	Mid	End	Early	Mid	End	Early	Mid	End	Early	Mid	End	Early	Mid	End	Early	Mid	End	Early	Mid	End	Early	Mid	End	Early	Mid	End	Early	Mid	End
Sargassum macrocarpum	Artificial	Maximum growth period												Prepare for collection			Collection			Seedling culture		Nursery culture	Early stage of culture (water depth 2-3m)						Main culture (seedling transplant) (water depth 3-9m)					
	Natural	Maximum growth period												Maturity (natural collection facility)			Germination of embryo and growth						Parent algae withering (growth of germlings)						Growth of seedlings and new parent algae (seedling transplant is available)					

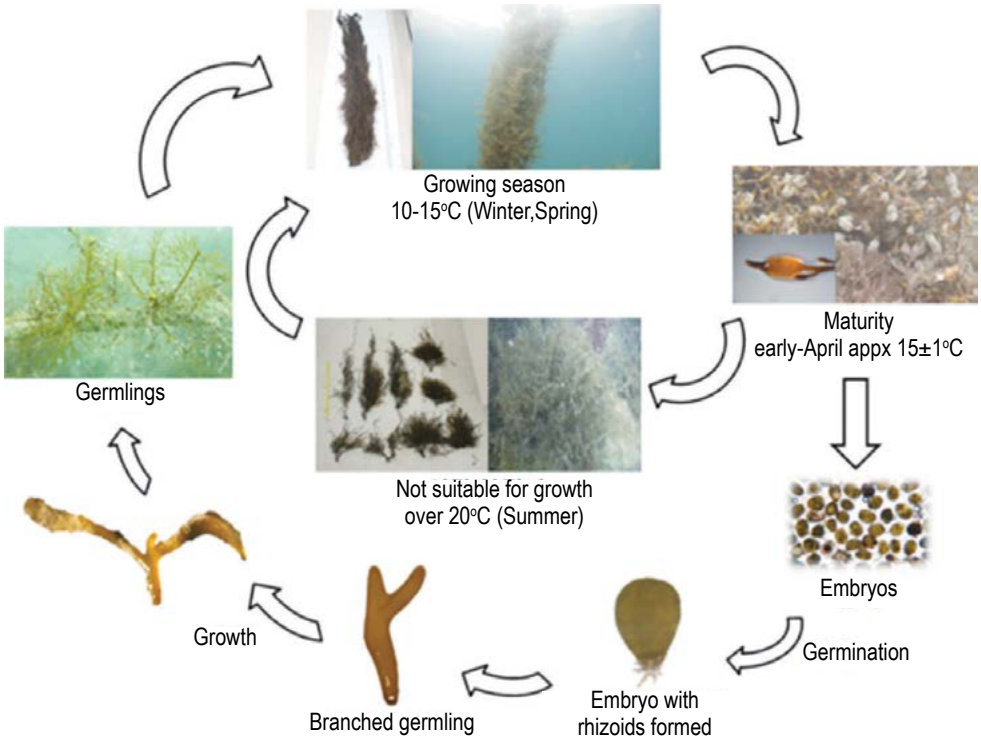
<Apendix Image 2-16> Seedling production and culture manual S. macrocarpum

H. Myagropsis myagroides

○ Ecological characteristics

According to a monthly survey of the biological seasons of M. myagroides, the average blade length and biomass were maximum in March, showing 220.2cm and 41,294.0 g/m^2, respectively. The minimum values were observed in July, 39.2 cm and 4,343.6 g/m^2, respectively.

On the coast of Tongyeong, the average blade length and biomass were found to increase as the age group of M. myagroides increases. However, there was no significant difference in blade length by age. This is the withering of blades that appears when the embryos are released after maturation, so the change in blade length by age is severe. On the other hand, in the older age group, the number of branching increases as the age increases, and as the annual growth ring increases, the stipe and branches become thicker, which affect the change in biomass. The life cycle of M. myagroides is shown in the figure below.

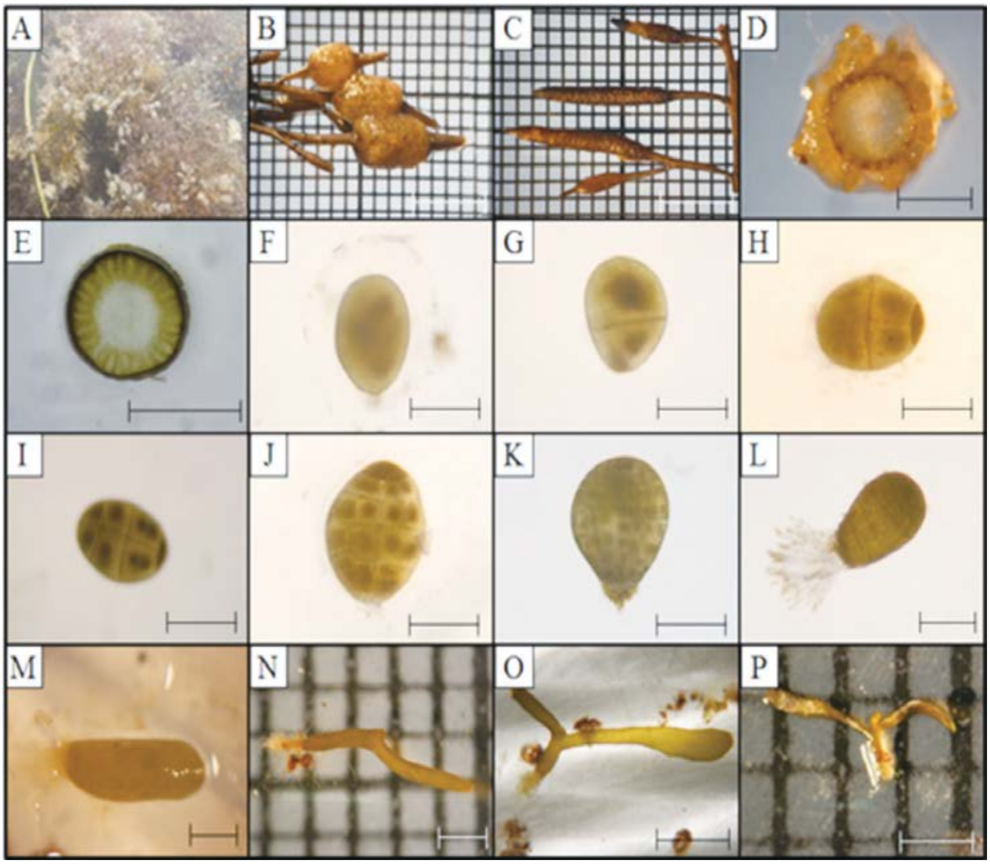


<Apendix Image 2-17> Lifecycle of M. myagroides

○ Seedling production

In the southern coast, M. myagroides matures in early April, so if parent algae are collected around early April, the basis of producing large amounts of seedlings would be ready. If you refer to the life cycle of M. myagroides above, it won't be difficult to secure parent algae.

After that, by referring to the seedling production manual of M. myagroides, the seedling production process, nursery and culture period can be adjusted through the cultivation process as shown in the figure below to secure seedlings for marine forest development.



<Apendix Image 2-18> Morphological characteristics of male and female recepstacle of mature M. myagroides and germination and early growth process of embryos

※ A: M. myagroides with formed embryos. B: female receptacles. C: male receptacles. D: cross section of female receptacle. E: cross section of male receptacle. F-J: cleavage process of M. myagroides. K-M: M. myagroides with rhizoids. N: elongation of M. myagroides. O: M. myagroides with secondary lobes formed. P: M. myagroides with tertiary lobe forming. Scale bars : 5mm(B,C). 1mm(D, E, N, O, P). 200μm(F-M).

<table>
<tr><th colspan="2">Species</th><th colspan="36">Annual work schedule (monthly)</th></tr>
<tr><td rowspan="4">Myagropsis myagroi-des</td><td rowspan="2">Seedling method</td><td colspan="3">1</td><td colspan="3">2</td><td colspan="3">3</td><td colspan="3">4</td><td colspan="3">5</td><td colspan="3">6</td><td colspan="3">7</td><td colspan="3">8</td><td colspan="3">9</td><td colspan="3">10</td><td colspan="3">11</td><td colspan="3">12</td></tr>
<tr><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td><td>Ear-ly</td><td>Mid</td><td>End</td></tr>
<tr><td>Artificial</td><td colspan="7">Maximum growth period</td><td colspan="2">Prepare for collection (part collec-tion)</td><td>Collection</td><td colspan="4">Seedling culture</td><td>Nursery culture</td><td colspan="9">Early stage of culture (water depth 2-3m)</td><td colspan="12">Main culture (seedling transplant) (water depth 3-6m)</td></tr>
<tr><td>Natural</td><td colspan="7">Maximum growth period</td><td colspan="3">Maturity (natural collection facility)</td><td colspan="5">Germination of embryo and growth</td><td colspan="9">Parent algae withering (growth of germlings)</td><td colspan="12">Growth of seedlings and new parent algae (seedling transplant is available)</td></tr>
</table>

<Apendix Image 2-19> Seedling production and culture manual S. macrocarpum

I. Sargassum thunbergii

○ Ecological characteristics

The root is conical, 5-7cm in diameter, and a little soft like rubber. The main branches are very close and come out pinnate on both sides of the stipe and broaden. The length is 1-3m, the central branch is oblate, branching pinnately several times, and small branches have fronds on both edges. Blades have midribs, linear, thin, and branch out pinnately. Vesicles are elliptical, both ends are thin, and the ones on the upper part is spindle shape. Some large vesicles are 5 to 10 mm long, 4 to 5 mm in diameter, and others are 4 mm in length and 2 mm in width.

Receptacles form a raceme on the upper part of a small branch, and the one at the top is the largest and longest in a conical or columnar shape. As it gets thinner upwards and the lower part suddenly becomes really thin, becoming a stalk shaped like a number 4. S. thunbergii inhibits near low tide line and matures in spring.

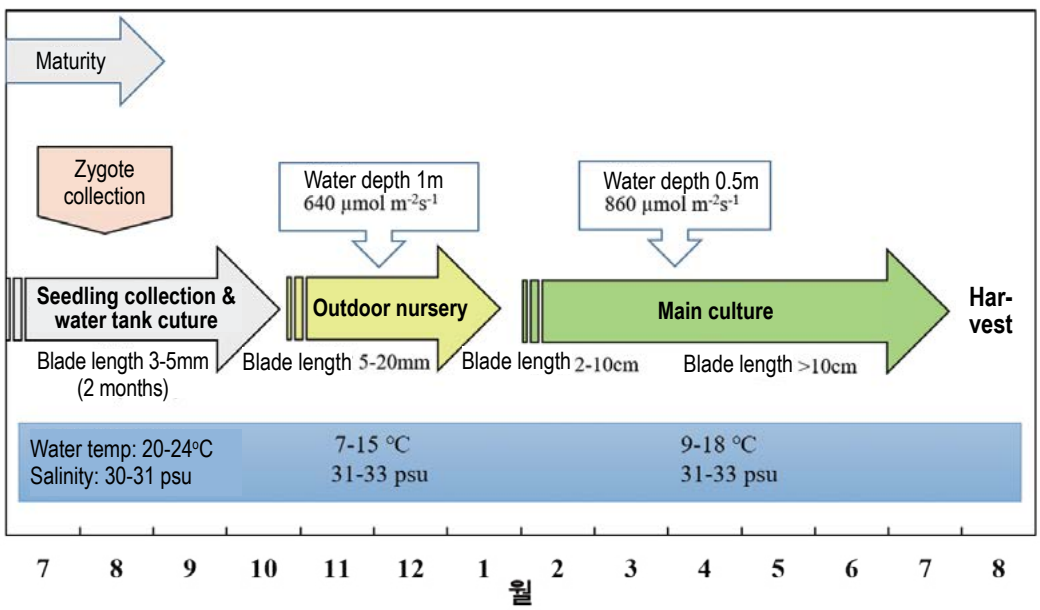
S. thunbergii in the intertidal zone can be observed throughout the year. The euryhaline eurythermal perennial seaweed inhabits bedrock, tidal pools, and upper subtidal zones. When summer passes, which is the peak period for the biomass and maturation, the whole frond dies except for the holdfast. Later, in late autumn and winter, the holdfast began to produce new frond. Oocytes and sperms released in the summer grow into embryos from the fertilised zygotes. The seasonal length growth of S. thunbergii ranges from 14.87 ± 1.08 cm to 27.93 ± 1.30 cm, with the maximum in summer and minimum in winter. The growing season of S. thunbergii in the summer when the water temperature rose. The maturation rate is 0~76% by season, and no matured ones are found in spring and winter, indicating the maximum maturity rate in the summer.

○ Seedling production

For S. thunbergii seedling collection, parent algae with mature oocytes and sperms are collected in summer, dried in the shade for 1 hour, and then submerged in seawater to secure a large number of zygotes (350(n)/ml). In indoor culture, S. thunbergii embryos grew at 10~30°C and 30~120μmol photons $m^{-2}·s^{-1}$. After 14 days of culture, the length of the embryos is 0.22 to 1.12 cm, and the maximum growth is shown at 90 μmol photons $m^{-2}·s^{-1}$ at 25°C. In various photoperiods, the embryos grew between 0.83cm to 1.17cm, and the maximum growth was achieved at 16 hours of photoperiod. In the growth experiment by salinity, the length was measured 0.63-0.88cm, the minimum at 45psu, and the maximum growth at 35psu, showing physiological and ecological characteristics of delayed growth in

low-salinity and high-salinity environments.

Therefore, according to the manual, as shown in the figure below, seedlings can be secured through seed collection, culture, nursery, and main cultivation process.



<Apendix Image 2-20> Seedling production and culture manual S. thunbergii

Appendix-3. Marine herbivores

A. Grazing of marine herbivores

○ Feeding ecology of sea urchin (Globular sea urchin) according to the type of seaweed

As for the overall feeding pattern of Globular sea urchins, the amount of seaweed consumption tends to increase somewhat as the weight increases. The correlation between food intake and the weight of sea urchins is appeared to be low value as E. stolonifera R_2= 0.268, L. japonica R_2= 0.353, Undaria pinnatifida R_2= 0.258, and Costaria costata R_2 = 0.014. This shows greater differences in food intake by individual than changes in body weight.

○ Effect of marine herbivores on the ecosystem

According to a study of sea urchins (5 to 7cm in diameter) as target herbivores and L. japonica (120±45cm in aquaculture) as target seaweeds, the seaweed forest was destroyed with less than 15% of coverage when the herbivores inhibit at high density. After herbivore removal, the coverage increased to 95%. When L. japonica was added, the density of sea urchins increased from 5 to 45, forming a high-density colony.

In the sea area with serious calcification, there was herbivore distribution of 20 to 30 per 1m^2, and the phenomenon of whitening continued. In the case of Daejin, Goseong-county, where natural seaweed forest is, there is about 0-2 per 1m^2 of herbivore density, which is one of the factors for the continuous maintenance of the natural seaweed forest.

○ Seaweed grazing pressure of herbivores

It is confirmed that sea urchins migrate following seaweed colonies. The test area surveyed is a calcified sea area with a density of about 20 to 25 sea urchins/1m^2 and seaweeds with 10 to 25% coverage of Dictyotaceae and Gelidiaceae families. After removing sea urchins within a radius of 20m in this test area, 10kg of kelp was tied to a sandbag in the centre. As a result, there were five herbivores appeared after one day, seven in two days, 12 in three days, and 15 in seven days, leaving only the stipe and roots of kelp in a week.

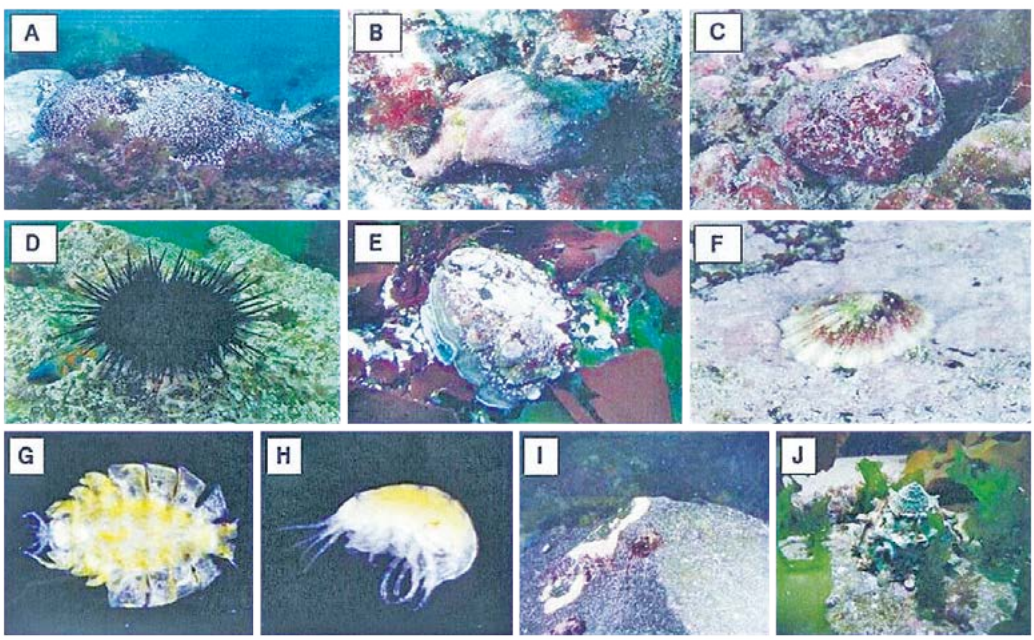
According to the results of a study in Japan, the northern Korean common sea urchins, which inhabited the dominant waters of non-articulated coralline algae, migrated to a sea oak forest and grew rapidly. Analysis of the stomach contents of sea urchins in the sea oak forest showed that more than 80% were seaweeds. Whereas, about half of the stomach contents of the sea urchins live in the non-articulated coralline algae were non-articulated coralline algae.

B. Types of herbivorous animals

○ Invertebrates

Sea urchins that inhabit the East Sea include Globular sea urchins, northern Korean common sea urchins, and Korean common sea urchins. Among them, Globular sea urchins are most common in calcified waters and have the most influence on the maintenance and destruction of marine forests. These sea urchins not only eat attached diatoms, but are also omnivorous, which is why they can live in high density even in calcified sea areas without seaweeds. In addition, there are other invertebrates such as sea hares, Lischke's top shell snails, abalone, turban shells, brown turban shells, and Gammarus.

Snails, Gammarus, and amphipods live near young algae, eating intensively, and cause damage such as making holes in the side of algae fronds. Sea hares are also animals with high grazing pressure, and in order to accumulate energy for spawning, they eat a large amount of seaweed until just before the spawning season.

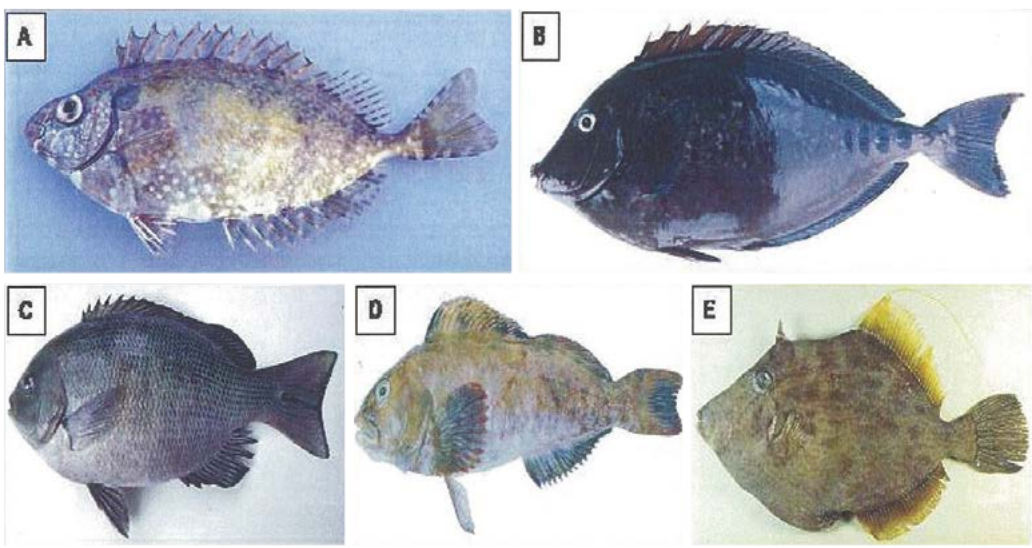


<Apendix Image 3-1> Herbivorous invertebrates that cause grazing of algae

❊ A: sea hare. B: ezoneptune shell. C: silver-mouthed monodont. D: Globular sea urchin. E: abalone. F: snowy limpet. G: Gammarus. H: Stenothoe valida. I: barnacle. J: murex

○ Fish

There is almost no destruction of marine forests or grazing of seaweeds by herbivorous fish on the east coast of Korea. However, in subtropical and temperate regions, the destruction of marine forests or the damaging of a large amount of seaweed by herbivorous fish occur often. Herbivorous fish species include black rabbitfish, Japanese parrotfish, Japanese sawtail, thread-sail filefish, greenling, and largescale blackfish. Black rabbitfish are warm-water fish that feed on sea mustard seedlings along the southern coast of Tongyeong, causing enormous damage that makes it impossible to cultivate sea mustards. They are heading north along the current to the east coast of Yangyang and Sokcho, so it is necessary to prepare for it.

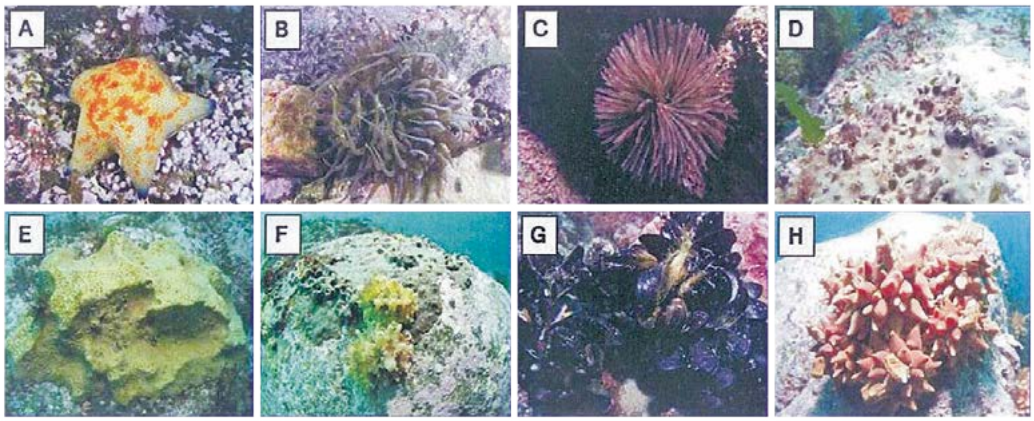


<Apendix Image 3-2> Major herbivorous fish species

❉ A: black rabbitfish. B: Japanese sawtail. C: largescale blackfish. D: greenling. E: thread-sail filefish.

○ Competitors

Competing animals that attach to the bedrock where seaweeds inhabit and hinder the reproduction of seaweeds include sea squirts, clam worms, barnacles, mussels, sponges and sea anemones. Competing seaweeds include non-articulated coralline algae and Dictyotaceae algae.



<Apendix Image 3-3> Periphyton that occupy bedrocks and inhibits the reproduction of seaweeds

❊ A: bat starfish. B: warty rock anemone. C: fanworms. D: purple sponge. E: sponge. F: blue-spot nudibranch G: blue mussel H: sea squirt

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