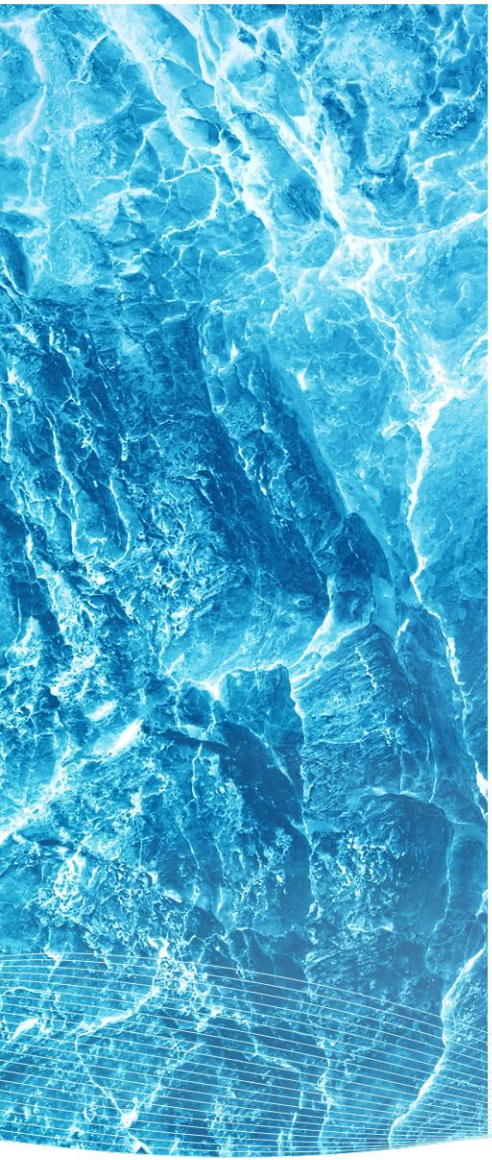

A Study on the Response to the Spread of Subtropical Species on the Korean Peninsula due to Climate Change

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KOREA MARITIME INSTITUTE

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CHAPTER

I

Introduction

01 Climate crisis and oceans

02 Subtropicalization and invasive species

03 Necessity and purpose of research

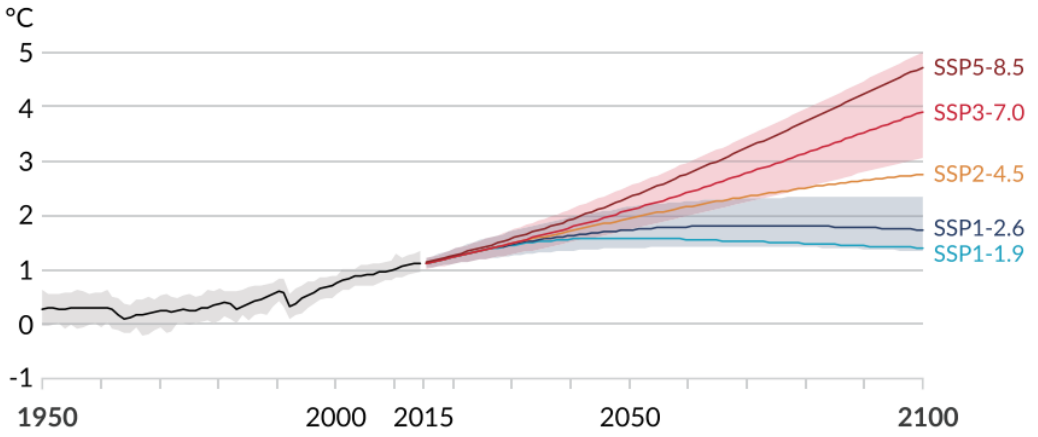
Climate crisis and oceans

In just three years, the 'irreversible temperature rise of 1.5 degrees(tipping point)' has been brought forward by 10 years

- The 'Special Report on Global Warming 1.5℃', published by the IPCC (Intergovernmental Panel on Climate Change) in 2018, **predicted the time to reach 1.5℃ between 2030 and 2052**, while the IPCC's '6th Climate Change Evaluation Report' published three years later **predicts between 2021 and 2040**

- We have entered the stage of global boiling, not global warming.

〈Changes in Earth's surface temperature between 1850 and 1900〉



Source: IPCC(2021)

Sea temperature is a key environmental variable that affects the marine ecosystem

- Seawater temperature has the greatest impact on the habitat environment of marine life and is a key environmental variable that changes ecosystems
- Species that are sensitive to environmental changes adapt to changes, or those that do not adapt cannot survive
- Sea temperature changes, which absorb more than 90% of energy generated from human activities, are expected to increase

Subtropicalization and invasive species

The rate of increase in sea temperature in the waters around the Korean Peninsula is about three times higher than the rate of increase in global sea temperature

- Over the past 55 years from 1968 to 2022, the average annual surface water temperature increase rate in Korean waters was 0.025℃/yr, **an increase of about 1.36℃**. During the same period, the average global surface water temperature increase rate was 0.0094℃/yr, **an increase of 0.52℃**(NIFS, 2023)
- The rate of increase in sea temperature in the waters around the Korean Peninsula is about **three times higher** than the rate of increase in global sea temperature
- In general, the average annual water temperature in subtropical waters is known to be 18-20℃, and the average annual water temperature in the South Sea has **already reached 19.0℃ in 2000**

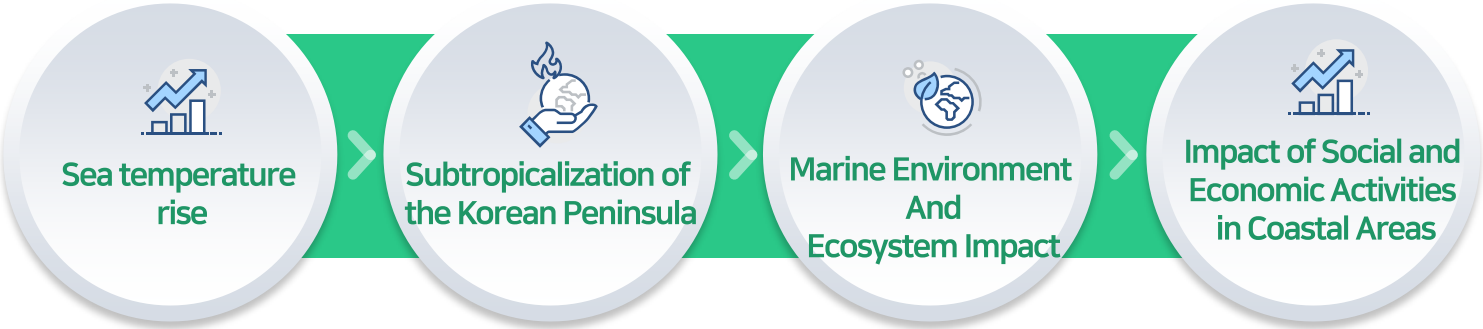
〈Long-term trends in climate change in the waters around Korea〉

Source: NIFS (2023)

Marine species move more than four times faster than terrestrial species

- The speed of movement (72km/10 years) of marine species is more than **four times faster** than that of terrestrial organisms (17km/10 years) (Pecklet al., 2017)
- Coral reefs are the most sensitive marine ecosystems affected by climate change, and seaweed, rock habitats, salt wetlands, and tidal flat ecosystems will also have a high risk of damage and impact (IPCC, 2022)
- Climate change can weaken or collapse ecosystem functions by changing the chemical properties of living environments (Harris and Tyrrell, 2001)

Necessity and purpose of research



The purpose of this study is
to predict the future habitat distribution of major subtropical species using detailed model prediction results of the waters around the Korean Peninsula, and
to respond to the influx of marine invasive life on the Korean Peninsula from the perspective of adaptation to marine climate change.

CHAPTER

II

Domestic trends

01 Research trends

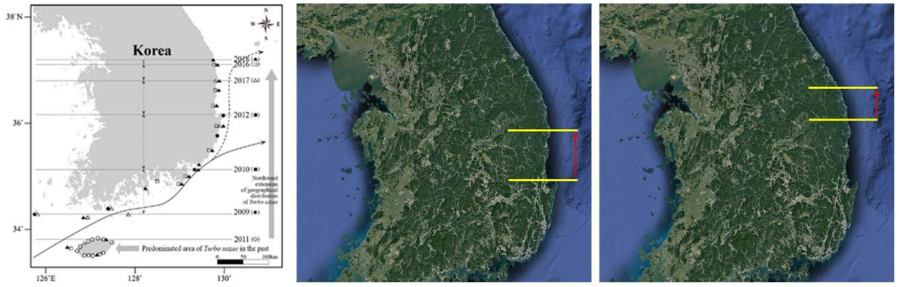
02 Policy trends

Research trends

The number of warm-water fish species increased by approximately 18% over 6 years.

- Tropical and temperate mixed seaweeds (red algae), which live in relatively warm seas compared to temperate seaweeds (algae), appear in all waters of Korea except the western part of the South Sea(National Oceanic Ecosystem Comprehensive Survey (2015-2020))
- The number of **warm current fish species** appearing in waters directly affected by Tsushima Current **has increased by about 18% in the past six years** (52% in 15 years → 70% in 20 years)
- As sea temperatures rise due to climate change, the limit for marine life to survive moves northward

〈 Northward of the Northern Limit Line for Marine Life〉



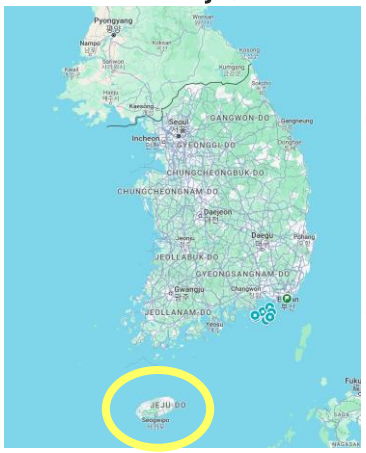
소라 서식지 북방 한계 변화 | 달랑게 서식 지역 변화 | 기수갈고둥 서식 지역 변화

Source: National Oceanic Ecosystem Comprehensive Survey (2015-2020)

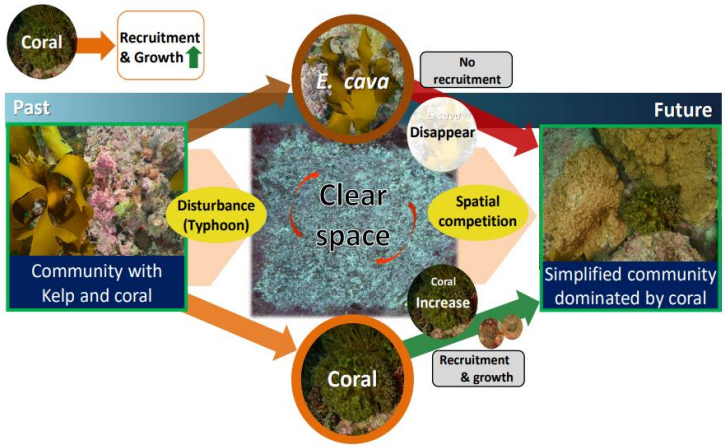
Large brown algae-centered seaweed-based ecosystem → Subtropical coral-centered coral-based ecosystem

- The miniaturization and simplification of seaweed communities in eastern and western Jeju are evident (Long Term Change of Structure and Function in Marine Systems of Korea, 2023)
- Observe that the Jeju coastal ecosystem, which formed **a seaweed-based ecosystem centered on large brown algae** such as *Ecklonia cava*, is changing into **a coral-based ecosystem centered on subtropical coral**

〈Location of Jeju , Korea〉



〈A schematic diagram for identifying the transition patterns of seaweed-based communities along the coast of Jeju〉



Source: Climate Change and Changes in the Marine Ecosystem on the Korean Peninsula (2021), p.287.

Policy trends

Korea's Alien Species Management

- The Korean Alien Species Management Act includes a **quarantine law** that blocks the influx of alien species, and **environmental laws** that prevent introduced alien species from being released into the domestic wild ecosystem or regulate alien species that have already established themselves and cause damage.

- The Ministry of Oceans and Fisheries' management of alien marine organisms is governed by 1) **border quarantine** based on the「Aquatic Products Disease Control Act」and the「Act on Transnational Movement of Genetically Modified Organisms」and 2) **the management of "marine ecosystem disturbance organisms" and "harmful marine organisms"** based on the「Act on the Conservation and Management of Marine Ecosystems」is representative

〈Policy of alien life management〉

Raw	Plan
Framework Act on Environmental Policy	• 5th National Comprehensive Plan for Environment
Marine Ecosystem Act	• 2nd Basic Plan for Conservation and Management of Marine Ecosystems
Basic Act on Carbon Neutrality	• Third National Climate Change Adaptation Measures
Biodiversity Act	• Fourth National Biodiversity Strategy • 5th National Biodiversity Strategy (under development) • Second Exotic Biological Management Plan
The Wildlife Act	• Fourth Basic Plan for the Protection of Wildlife • The Second Basic Plan for the Management of Wild Animal Diseases

Source: Hyonjeong Hong et al. (2022), A study on the improvement of the alien life management system for biodiversity conservation, and the author's summary with reference to p.29

CHAPTER

III

Prediction and impact

01 Trends of changes in seawater temperature in the surrounding seas of Korea

02 Forecast of change in sea temperature in Korea

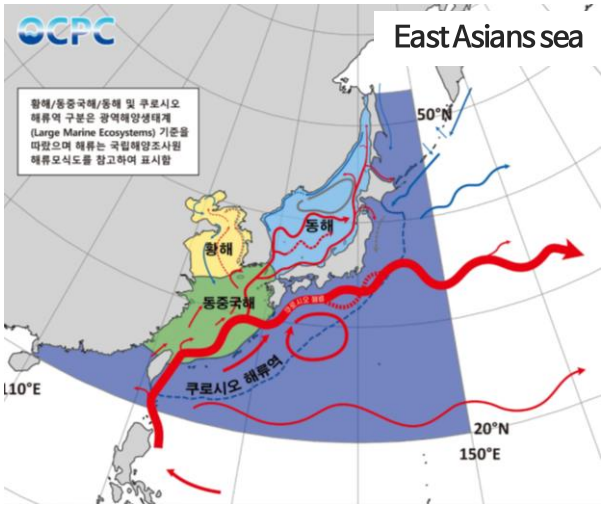
03 Prediction of spread range of subtropical species

Trends of changes in seawater temperature in the surrounding seas of Korea

East Asian waters

- The East Asian sea area is a sea area that includes the Yellow Sea, East China Sea, East Sea, Kuroshio Current area, and part of the Northwestern Pacific Ocean, and is a marine geographical area that affects climate change in Korea.

- The Kuroshio Current transports tropical materials and energy to the north, and some of them flow into the East Sea through the Jeju Strait and the Korea Strait, so it is very important in understanding and predicting Korea's marine climate.



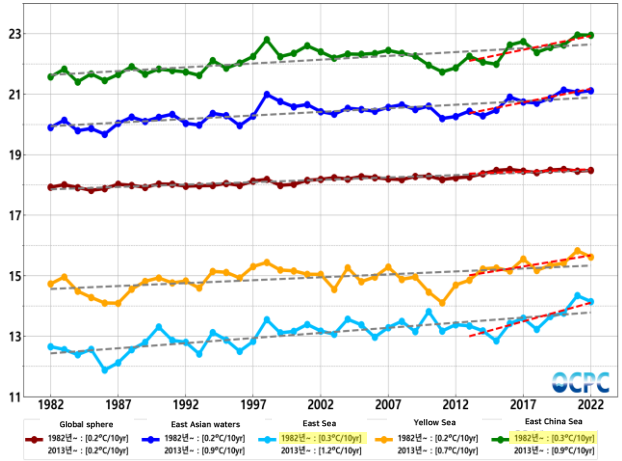
Source: KIOST Marine Climate Prediction Center website

Changes in sea surface temperature in waters around Korea (1982~2023)

- Over the past 40 years from the past to present, **Korea's average sea surface water temperature has risen by about 0.2°C every 10 years**, the same as the global water temperature increase rate.

- **The East Sea and East China Sea** were found to have risen by about 0.3°C every 10 years, showing **a rate of increase higher** than the average rise in **the global region and the waters around the Korean Peninsula**.

〈Sea surface temperature changes by sea area〉

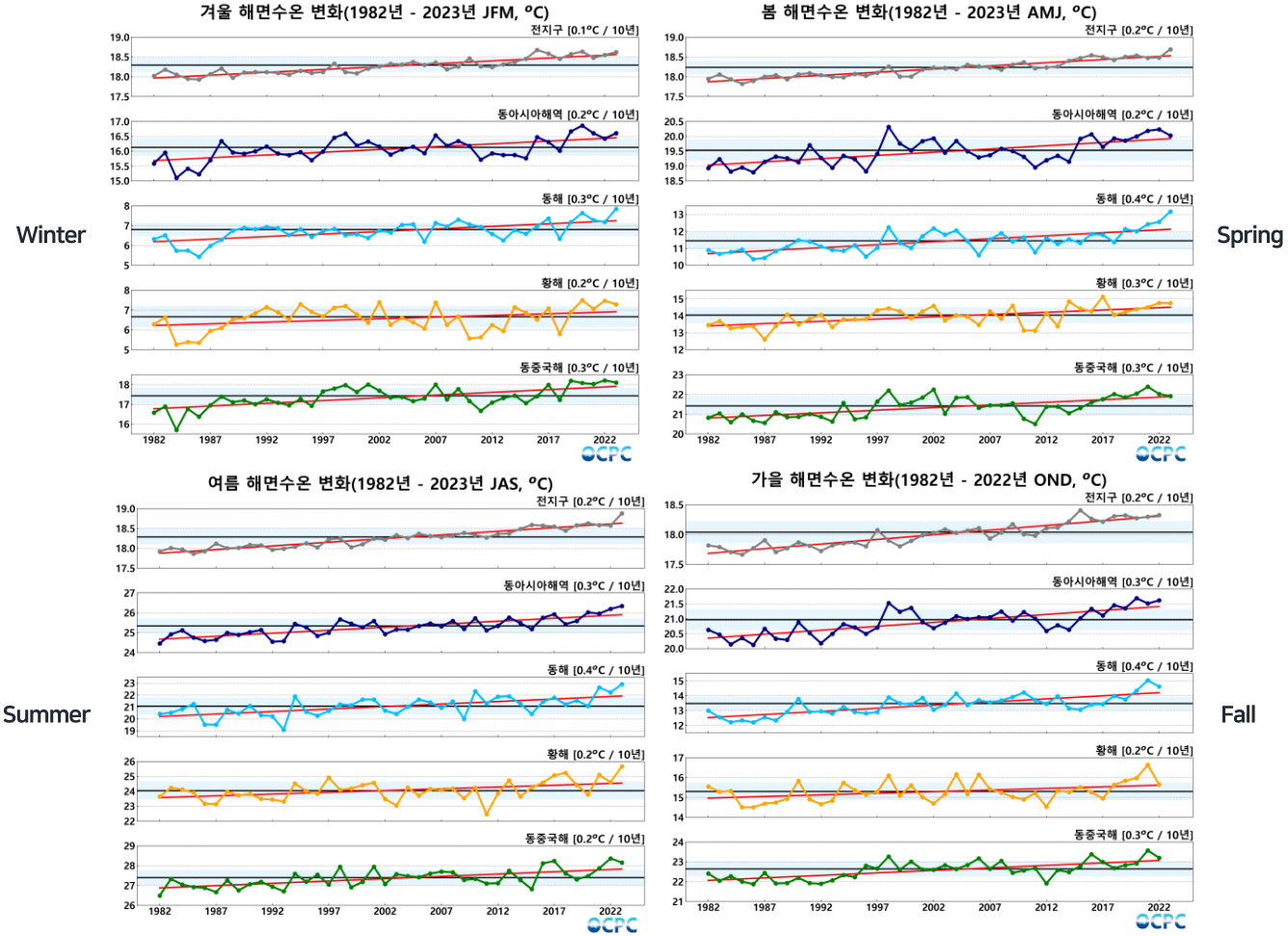


Source: KIOST Marine Climate Prediction Center website

Trends of changes in seawater temperature in the surrounding seas of Korea

Changes in sea surface temperature in waters around Korea (1982~2023)

- Since the sea surface water temperature varies greatly from season to season, it is important to look at seasonal changes in addition to the annual average increase rate
- The water temperature at sea level is rising in all four seasons, and **the rate of increase is high, especially in summer**



Source: KIOST Marine Climate Prediction Center website

Forecast of change in sea temperature in Korea

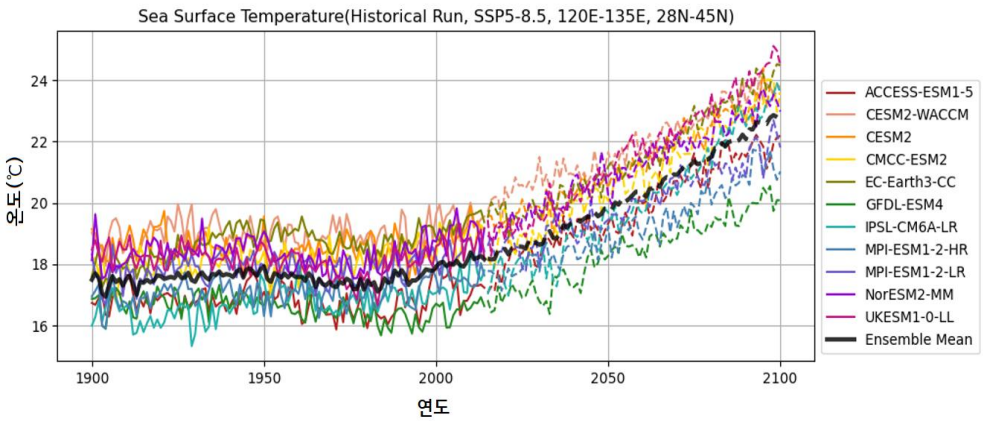
Korea's Sea Temperature Forecast for 2050 and 2100

- Kim Young-ho *et al.*(Pukyong National University) analyzed **the future trend of seawater temperature** using **SSP5-8.5 scenario based on CMIP6**

- Through the average value (ensemble) of predicted values produced by 11 models, it was confirmed that the **sea temperature in the surrounding seas of Korea is steadily rising.**

- In Korea, the temperature is expected to reach **approximately 20℃ in 2050 and approximately 24℃ in 2100.**

〈Korea's Sea Surface Temperature Forecast〉



Sourse: Pukyong National University Marine Dynamics Prediction Laboratory (2023)

〈11 models used for prediction〉

Model	Modeling center & Reference
ACCESS-ESM1-5	Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia (Ziehn et al., 2020)
CESM2	National Center for Atmospheric Research (NCAR), USA (Danabasoglu et al., 2020)
CESM2-WACCM	National Center for Atmospheric Research (NCAR), USA (Danabasoglu et al., 2020)
CMCC-ESM2	Euro-Mediterranean Centre on Climate Change (CMCC) (Lobato et al., 2022)
EC-Earth3-CC	European consortium of national meteorological services and research institutes (Döscher et al., 2022)
GFDL-ESM4	NOAA Geophysical Fluid Dynamics Laboratory (GFDL), USA (Dunne et al.m 2020)
IPSL-CM6A-LR	Institut Pierre-Simon Laplace (IPSL), France (Boucher et al., 2020)
MPI-ESM1-2-HR	Max-Planck-Institute fur Meteorologie (MPI), Germany (Mauritsen et al., 2019)
MPI-ESM1-2-LR	Max-Planck-Institute fur Meteorologie (MPI), Germany (Mauritsen et al., 2019)
NorESM2-MM	Norwegian Climate Center (NCC) (Seland et al., 2020)
UKESM1-0-LL	Met Office and National Environment Research Council (NERC), UK (sellar et al., 2019)

Sourse: Pukyong National University Marine Dynamics Prediction Laboratory (2023)

Prediction of spread range of subtropical species

Halophila nipponica

Characteristics

- The habitat temperature is **15℃ to 25℃**, and growth is stopped at 10℃ or less
- It is a seaweed that grows with roots in the coastal sedimentary layer and has **excellent water purification power** and has **potential as a blue carbon species** with perennial grasses

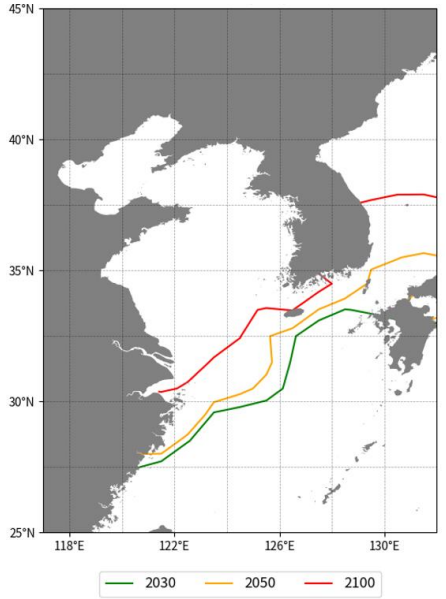
〈Distribution (left) and Appearance (right)〉

Source: Marine Life Resources Integrated Information System (left), Hankyoreh press release (right)

Predict the spread range

- The lower limit of habitat is expected **to move north to Gangneung coast in the East Sea by 2100**

〈Lower limit of habitat〉



Sourse: Pukyong National University Marine Dynamics Prediction Laboratory (2023)

Utilization plan

- There are no reports of damage caused by the inflow of the *Halophila nipponica*
- It is expected that the need for management will increase as blue carbon seaweed replaces '*Zostera marina*'
- For habitat conservation, it is important to control pollutants generated on land and to improve seawater flow that is disrupted by coastal artificial structures
- Although *Zostera marina* is mainly transplanted in the seaweed restoration project to expand blue carbon in Korea, **It is expected that *Halophila nipponica* will be able to play a role in absorbing marine carbon in the future** by securing *Halophila nipponica* seeds and developing transplantation technology.

Prediction of spread range of subtropical species

Mangrove

Characteristics

- Among East Asian mangroves, *kandelia obovata*, a highly cold resistant mangrove, lives in Vietnam, Indonesia, southern China, and Japan
- *Kandelia obovata* is cold-resistant and lives up to **an average winter temperature of about 10℃**, with a minimum **habitat lower temperature of -5℃** (Lu *et al.*, 2022).

Predict the spread range

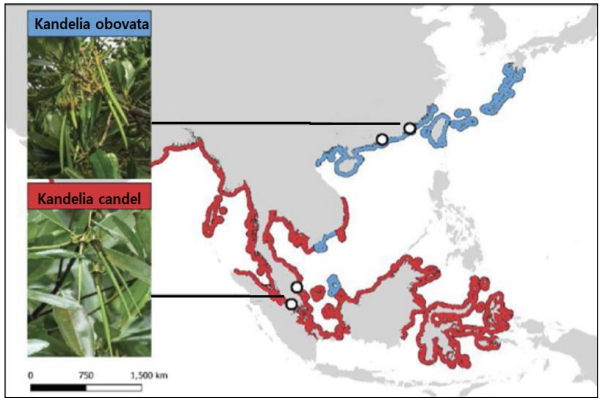
- Mangroves have not yet been found on the coast of Korea, but they are expected to live on the coast of Korea in 2040 due to climate change (Nam *et al.*, in press)
- Mangrove distribution area is expected **to expand to the South Sea coast in 2030 and Sokcho coast in Gangwon Province in 2050**

Utilization plan

- Southeast Asian mangroves were heavily destroyed by creating shrimp farms, but recently restored their habitat to prevent coastal erosion and reduce flood damage
- No damage has been reported from overseas mangrove inflows, and is classified as a restoration target due to its high carbon absorption and excellent coastal disaster reduction capabilities
- Mangroves have **a carbon absorption capacity of 30 to 40 times greater than that of rainforests** (Mcleod *et al.*, 2011)
- Mangroves are recognized as coastal green infrastructure as a natural buffer zone that reduces ocean waves and prevents coastal erosion and flooding.

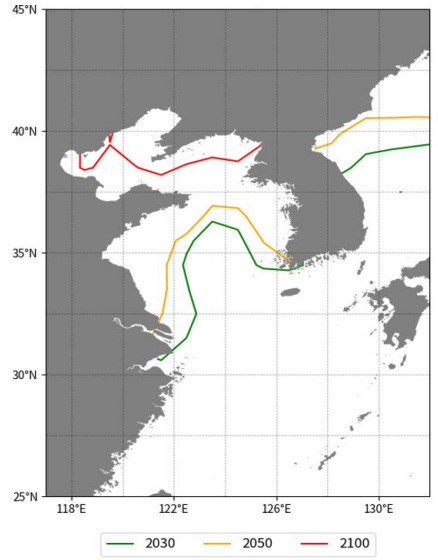
*According to Zhou et al., a mangrove habitat width of 275 meters or more reduces the wave impact by about 58%

〈Appearance (left) and Distribution (right)〉



자료: Short *et al.* (2021)

〈Lower limit of habitat〉



Sourse: Pukyong National University Marine Dynamics Prediction Laboratory (2023)

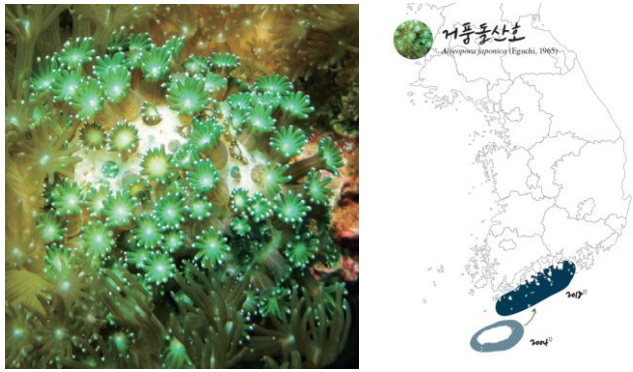
Prediction of spread range of subtropical species

Alveopora japonica Eguchi

Characteristics

- Habitat temperature is **10℃~32℃**, water depth is 5~20m
- Distributed domestically in Jeju and the coast of the South Sea, and overseas in Japan and Taiwan.
- The population size has expanded in Jeju waters due to the increase in average sea surface temperature over the past 10 to 20 years.
- The diversity of large or very large benthic organisms decreases as **they show absolute superiority in competition with other attached organisms** for attachment substrates.

〈Appearance (left) and Distribution (right)〉

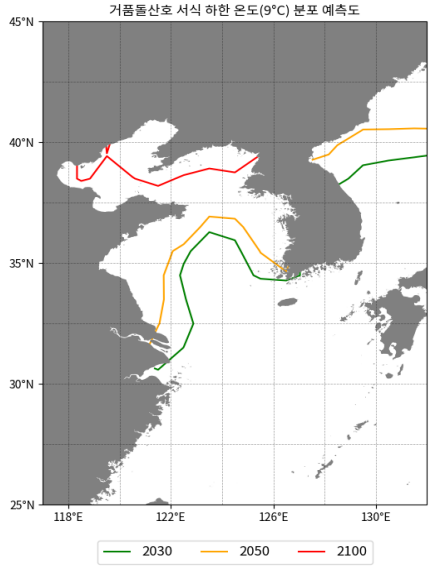


Source: Ministry of Oceans and Fisheries (2023), Guide to Marine Climate Change Indicator Species, pp. 30–31.

Predict the spread range

- The habitat range is expected to expand to **the entire East Sea by 2050 and all waters of Korea by 2100.**

〈Lower limit of habitat〉



Sourse: Pukyong National University Marine Dynamics Prediction Laboratory (2023)

Utilization plan

- Jeju's coastal ecosystem has changed from a seaweed-based ecosystem centered on large brown algae such as *Ecklonia cava* to a coral-based ecosystem centered on subtropical corals.
- There are impacts such as reduced species diversity and decreased productivity, but **there are also positive effects in terms of ecosystem services** due to the increase in coral reef colonies.
- The value of coral is utilized as a marine life resource, such as in the extraction of new pharmaceutical materials or new substances, and can contribute to eco-tourism using tropical fish and crustaceans that make up the coral ecosystem.

CHAPTER

IV

Countermeasures

Measures to respond to the influx of alien marine life

Adaptation conditions

Because the sea is physically difficult to access, adaptation measures are limited.

Investment priority is low due to lower policy interest compared to land.

Lack of research on marine climate prediction, marine species, and habitat environment

Countermeasures

1. Establishment of integrated adaptive governance
2. Linking expert science and citizen science
3. Designation and management of ‘climate change impact sentinel species’
4. Production of profit-damage distribution maps based on the inflow of exotic species
5. Cooperation with relevant countries and international organizations

Measures to respond to the influx of alien marine life

1 Establishment of integrated adaptive governance

- The Ministry of Oceans and Fisheries is responsible for managing artificial inflows from ships and surveying alien marine life, and the Ministry of Environment is responsible for investigating alien species in waters surrounding national parks and specific islands.
- There are limits to forming integrated adaptation governance and implementing measures for all species, but it is possible to establish collaborative governance focusing on species that pose a threat to socioeconomics and health.
- It is necessary **to establish a tentatively named 'Marine Climate Change Harmful Alien Species Management Governance'** in which the two ministries and local governments participate.

2 Linking expert science and citizen science

- There are limitations in the ability of government or public agency experts to investigate all marine invasive species, so citizen science can fill the gap in public research.
- Additionally, it is possible to discover alien species and determine their habitat range through citizen science.
- There is a need **to establish a 'marine climate change citizen science platform'** that links expert science and citizen science, and implement policies to develop and support citizen science projects.

Measures to respond to the influx of alien marine life

3 Designation and management of 'climate change impact sentinel species'

- There are limitations in designating and managing all subtropical species as introduced species, so designate and manage species with a high probability of influx that inhabit subtropical waters connected to Korea's surrounding waters.
- Species designated and managed by the Ministry of Oceans and Fisheries and the Ministry of Environment do not include species that may be potentially influxed.
- **Species that are likely to be influxed into Korea due to climate change** or **species that are likely to cause damage** should be separately designated as **'marine climate change indicator species' or 'marine climate change watch species'** for preventive management.

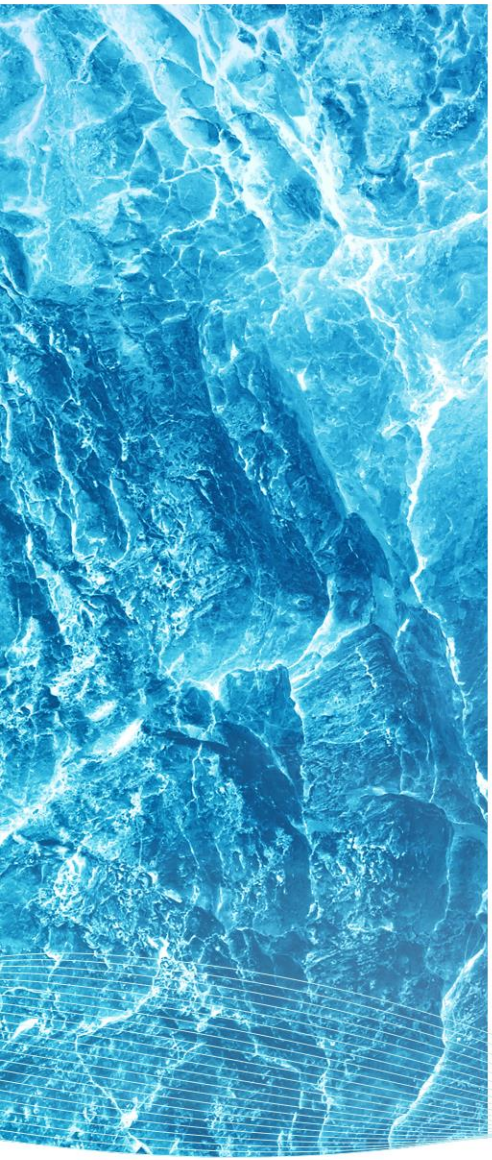
4 Production of profit-damage distribution maps based on the inflow of exotic species

- IPBES shows that 16% of alien species have a negative impact on ecosystem benefits, and as of 2019, the social cost borne by humanity due to the introduction of alien species exceeded $423 billion.
  * Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES): Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
- Globally, the introduction of alien species increases social costs, but in some cases regionally it increases economic benefits.
- Management resources can be utilized efficiently **by creating a spatial benefit-damage distribution map** according to the SSP scenario.
- Benefit-damage distribution maps can help local stakeholders proactively coordinate economic activities (e.g. aquaculture, tourism) to avoid or reduce damage.

Measures to respond to the influx of alien marine life

5 Cooperation with relevant countries and international organizations

- In order to properly understand climate change, changes in habitat environment, the possibility of establishment and spread of species, and the degree of damage and benefit, **research on the physiological and ecological characteristics of undetected or potentially introduced species is necessary.**
- In particular, potential introduced species have not entered the Korean Peninsula, so it is impossible to systematically study their physiological and ecological characteristics.
- **Only by conducting long-term international collaborative research with countries** where potential introduced species inhabit can **the physiological and ecological characteristics of the species be fully understood.**



THANK YOU

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