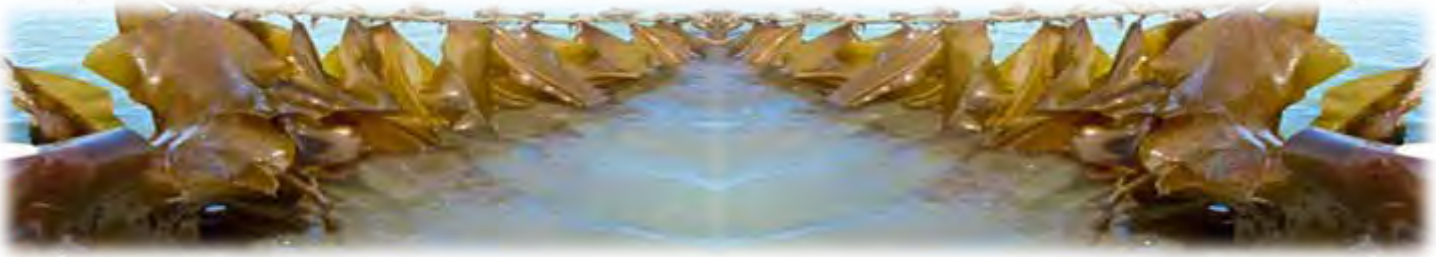
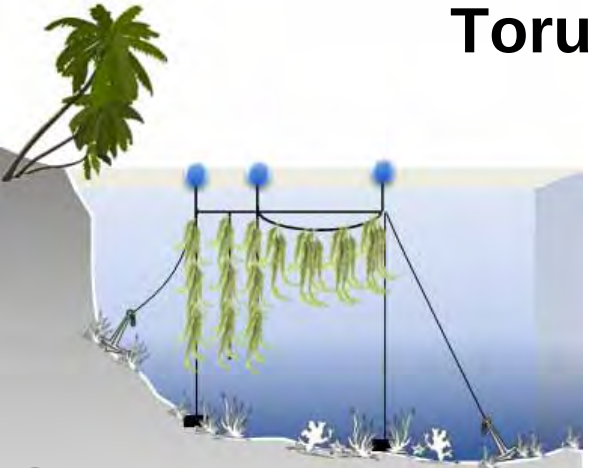


# GIS-Based Spatial Models for Japanese Kelp (*Laminaria japonica*) Aquaculture Site Selection in the Southwestern Hokkaido, Japan

**I Nyoman Radiarta[1,2] , Sei-Ichi Saitoh[1], Toru Hirawake[1] and Hajime Yasui[1]**

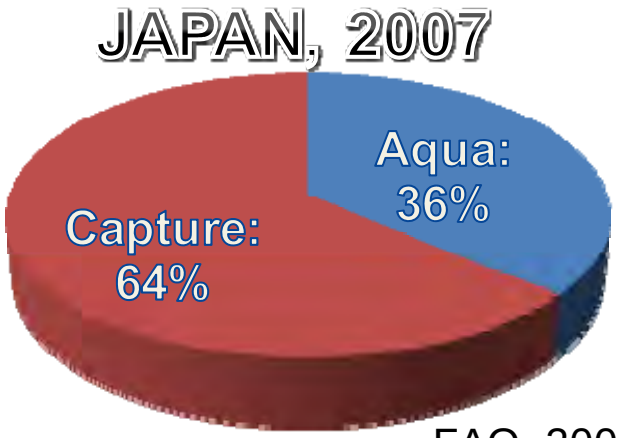




[1]Faculty of Fisheries Sciences, Hokkaido University
[2]Center for Aquaculture Research and Development, Indonesia
*Email: ssaitoh@salmon.fish.hokudai.ac.jp*

# Introduction

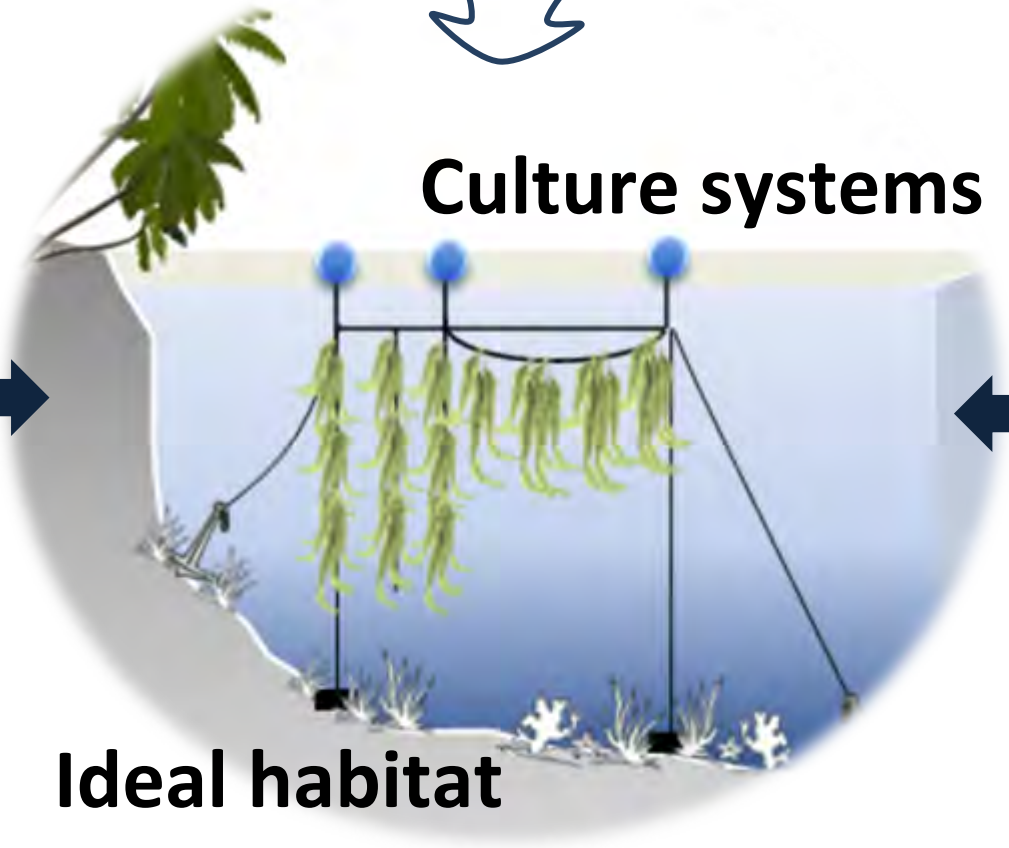
- >50 species reported, only about 20 kelp species present in Asia-Pacific regions (Scoggan *et al.*, 1989).
- Japanese kelp important species cultured and harvested in the world.
- In Japan, mainly found along the Pacific coast of southern Hokkaido and northern part of Honsu.
- Japan production from capture and aquaculture.
- In 2007, aquaculture contribute 36%.


FAO, 2009

# Introduction

## Sustainable kelp production



Culture systems

Government support

Existence of FCA

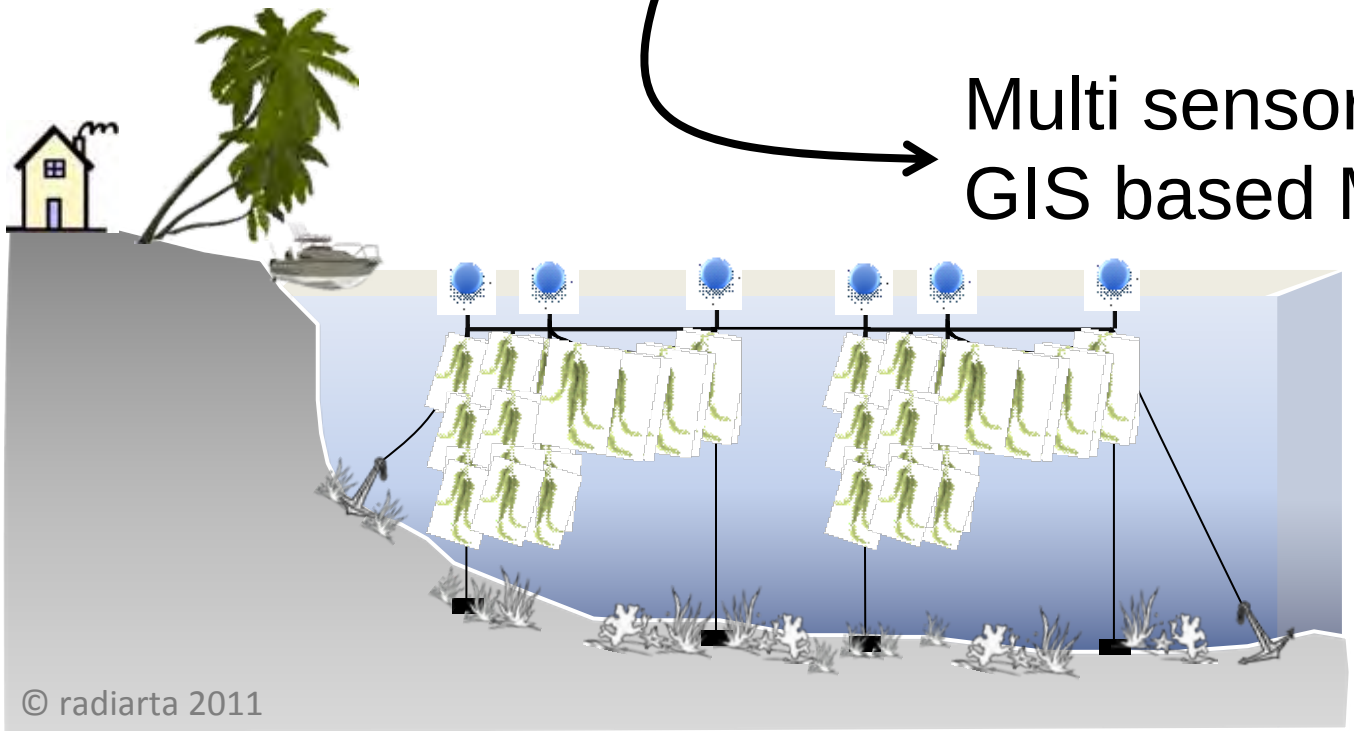
Ideal habitat

**Site selection is preliminary step for any aquaculture operations**

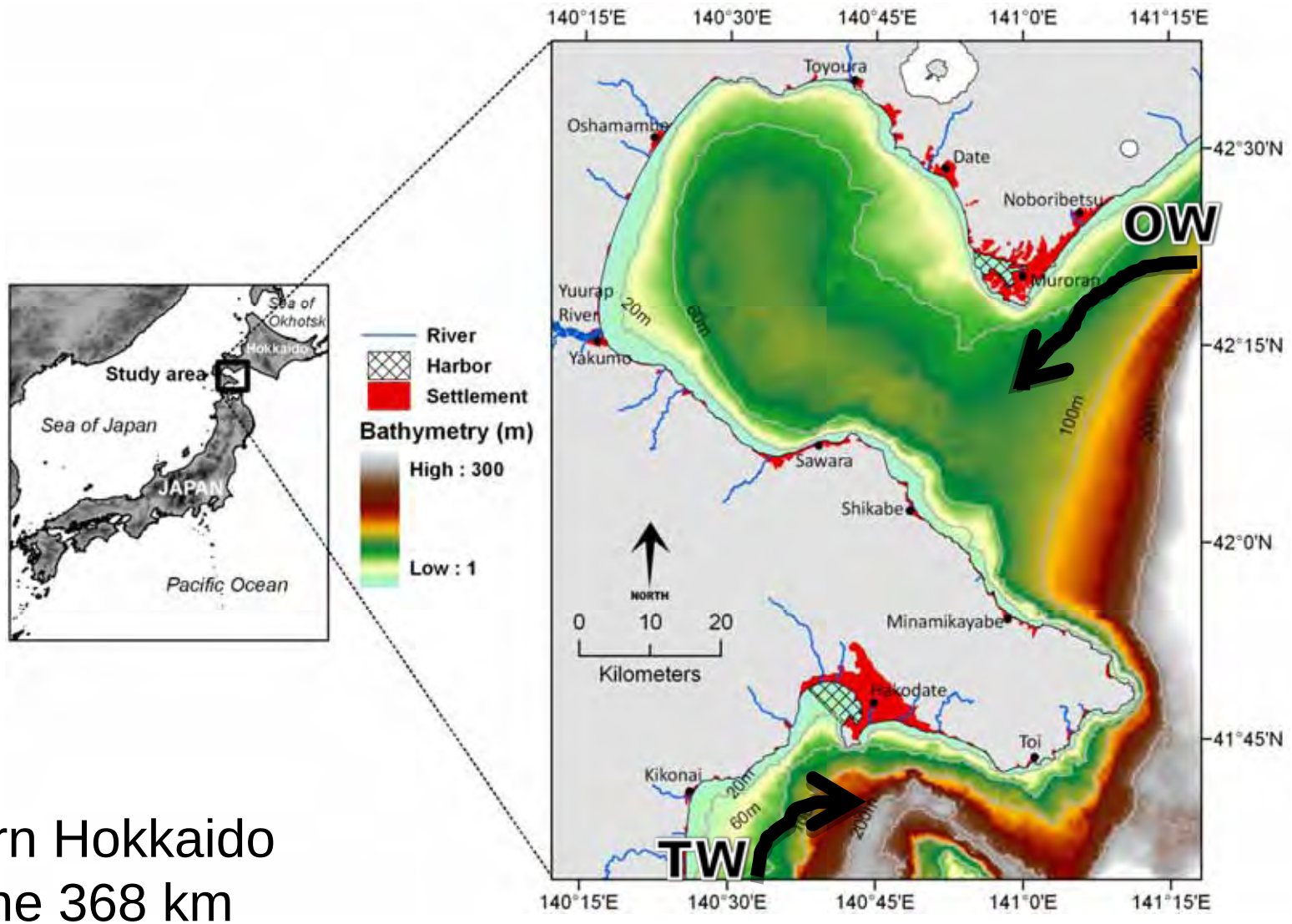
# Objective

To identify the most suitable sites for hanging culture of Japanese kelp, *Laminaria japonica*, aquaculture development in southern Hokkaido, Japan

Multi sensors of RS data
GIS based MCE model

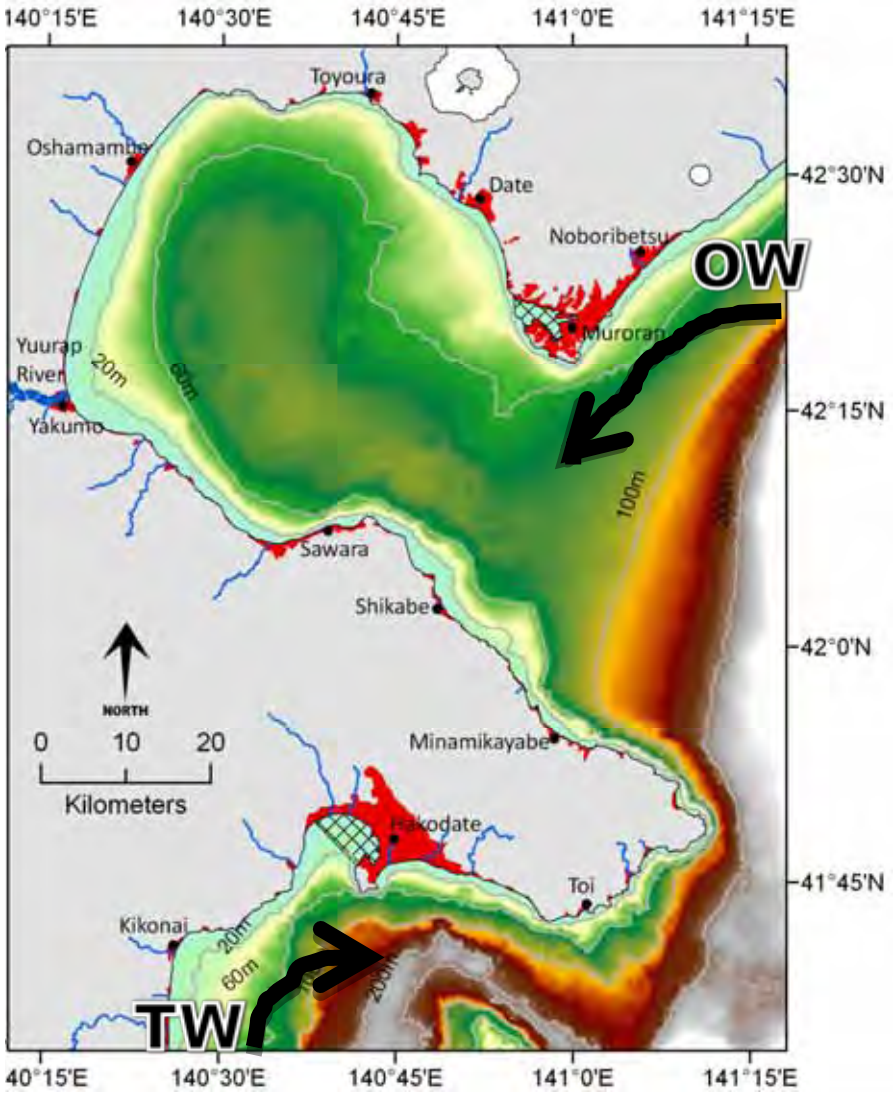


# Study area



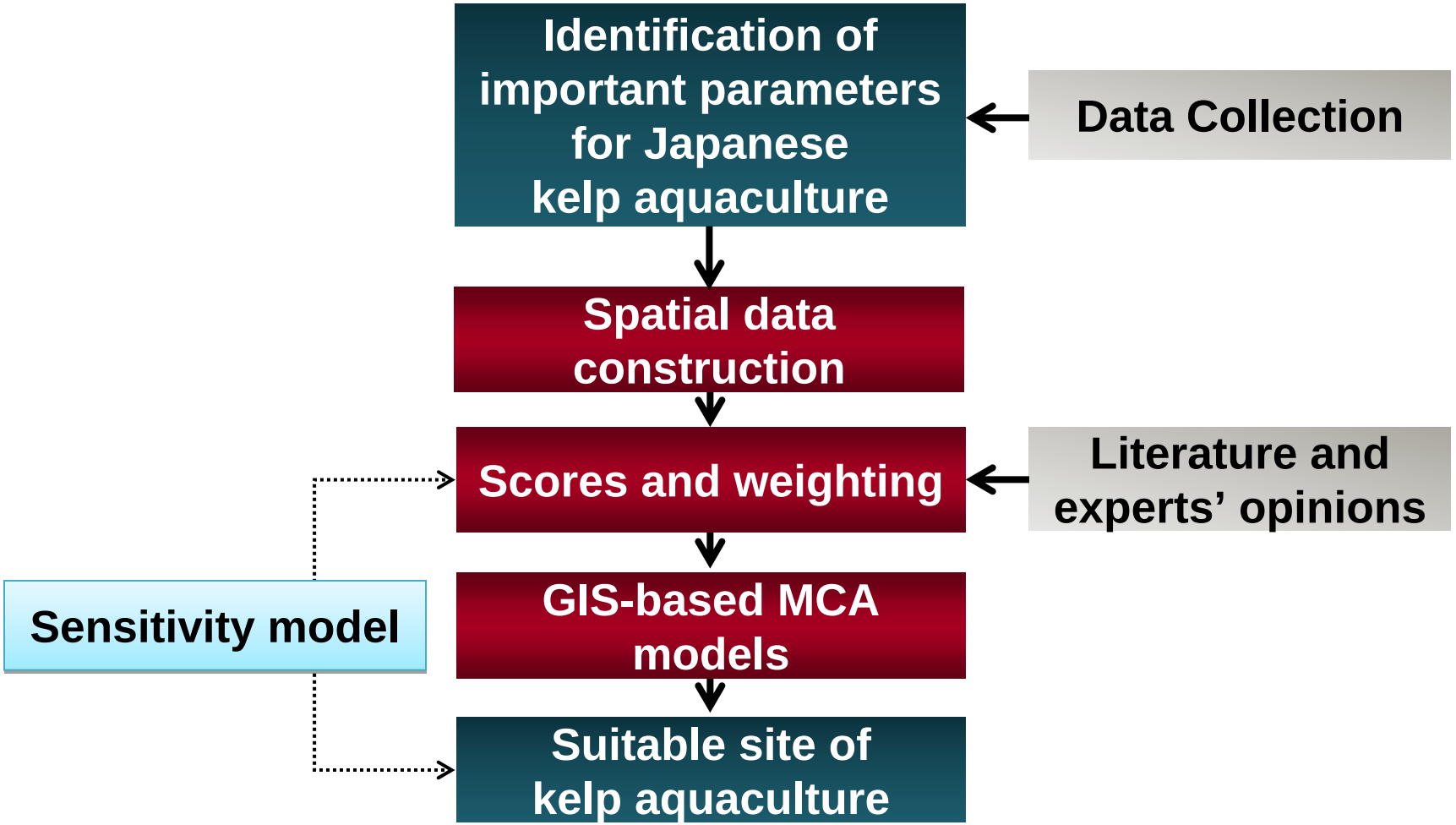

- Southern Hokkaido
- Coastline 368 km
- Influence by OW (cold water) and TW (warm water)

# Study area

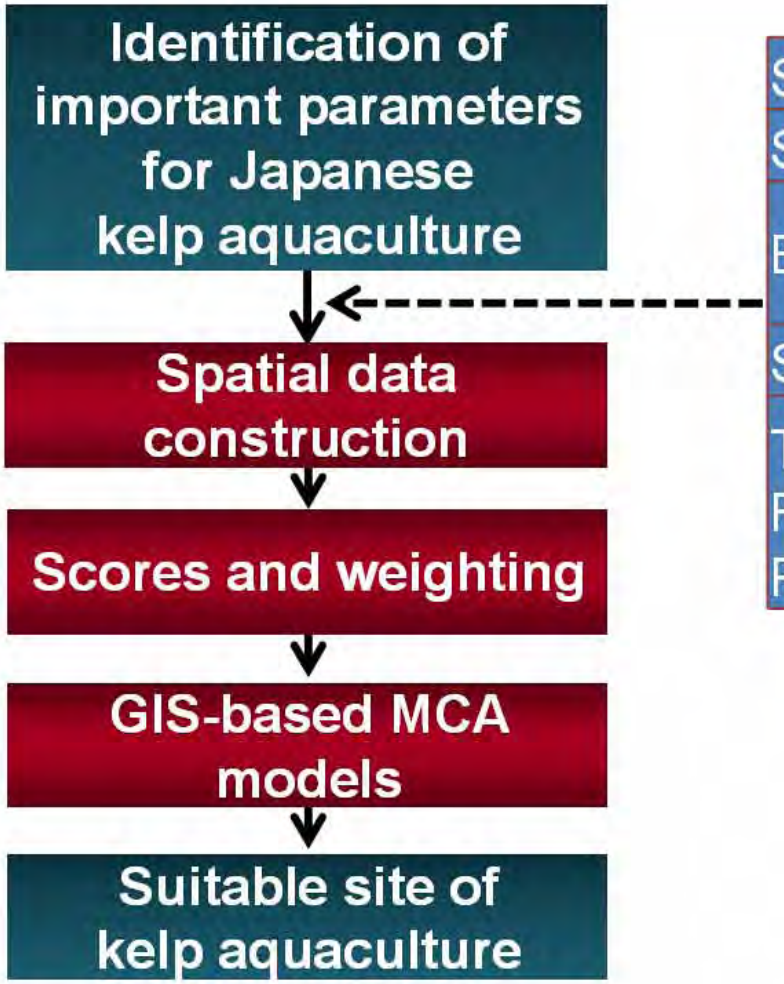




- Southern Hokkaido
- Coastline 368 km
- Influence by OW (cold water) and TW (warm water)

# General approach



# General approach




| | | |
|---|---|---|
| SST | MODIS | 2004-2010 |
| SDD* | $K_d$ 490-MODIS | 2004-2010 |
| Bathymetry | Hardcopy and digital | |
| Slope | Bathymetry | |
| Town; Pier; Facility; River; Harbor | ALOS AVNIR-2 | Nov., 5, 2009; Oct., 5, 2010 Dec., 7, 2010 |

* $SDD = 1.04 \times K_d(490)^{-0.82}$

[Chen et al., 2007. Remote Sensing of Environment 109, 249-259]

# Model construction

- Built on hierarchical structure
  - Factors: 7 parameters
  - Constraints: 2 parameters
- Scoring: 1 (least suitable) - 8 (most suitable) (Radiarta et al., 2008)

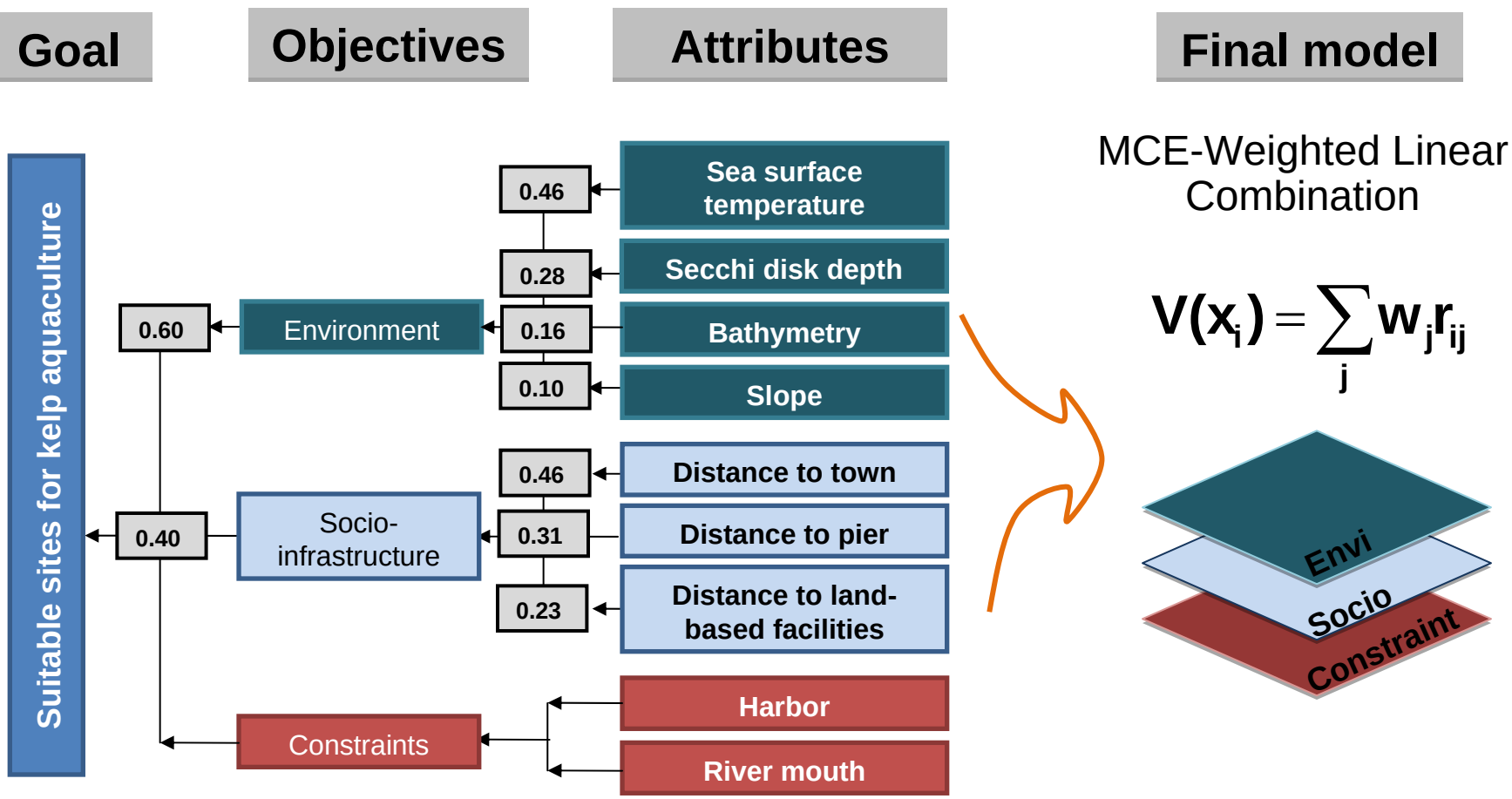
| Parameters | Suitability rating and score | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| Batymetry (m) | 10-25 | 9-10 or 25-30 | 8-9 or 30-35 | 7-8 or 35-40 | 6-7 or 40-45 | 5-6 or 45-50 | 4-5 or 50-60 | >60 or < 4 |
| Secchi Disk Depth (m) | 7 | 6-7 | 5-6 | 4-5 | 3-4 | 2-3 | 1-2 | <1 |
| Distance to town (km) | <3 | 3-4 | 4-5 | 5-6 | 6-7 | 7-8 | 8-9 | >9 |

- Weighting: MCE method known AHP (Saaty, 1977)

| Parameters | SST | Secchi disk depth | Bathymetry | Slope | Weight |
|---|---|---|---|---|---|
| SST | 1 | 2 | 3 | 4 | 0.46 |
| Secchi disk depth | 1/2 | 1 | 2 | 3 | 0.28 |
| Bathymetry | 1/3 | 1/2 | 1 | 2 | 0.16 |
| Slope | 1/4 | 1/3 | 1/2 | 1 | 0.10 |

Consistency Ratio: 0.015 (< 0.1 accepted)

# Model construction



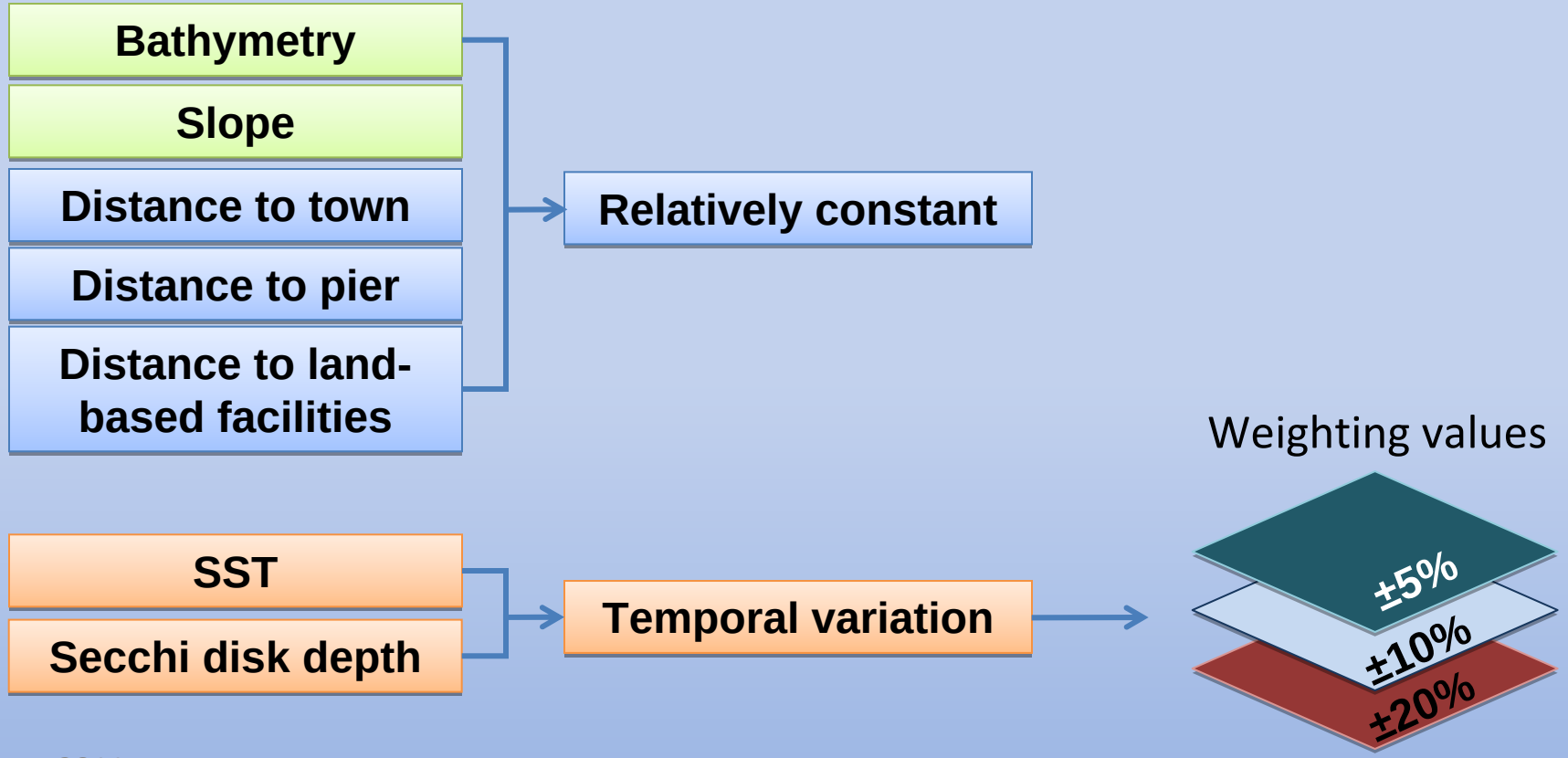

$w_j$ = weight, $\Sigma w_j = 1$,

$r_{ij}$ = the attribute transformed into score (1-8)

The most preferred alternative is the maximum $V(xi)$ value

# Sensitivity analysis

- This analysis connected to the parameters that had temporal variability
- Local sensitivity analysis  using interval values of ±5%, ± 10%, and ± 20% of the reference values

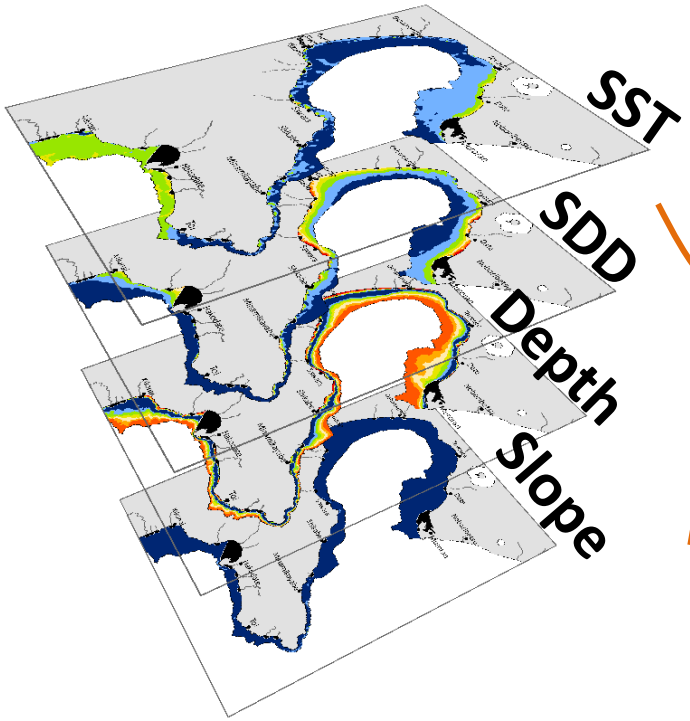


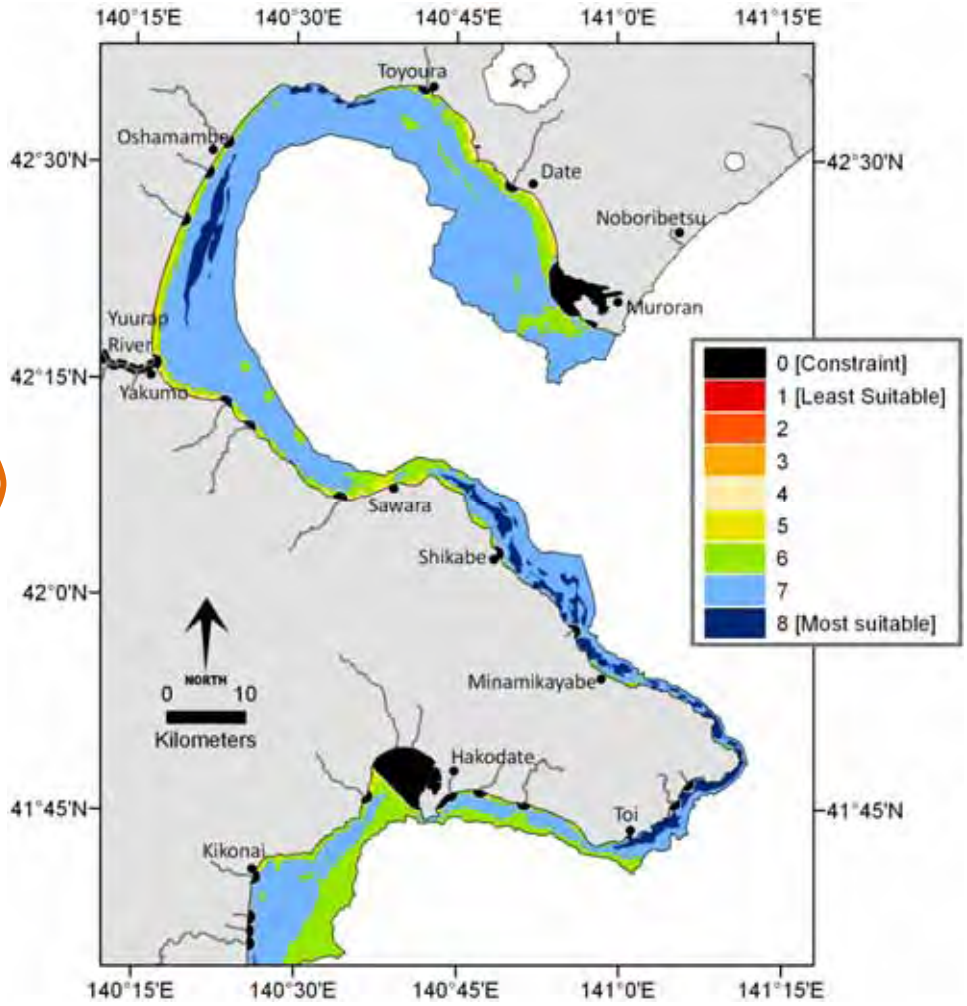
# Result: potential area



- **Suitable area based on 60m depth: to minimize operation costs and difficulty in mooring systems**
- **Potential area about 1541 km$^2$ [constraint = 104 km$^2$]**

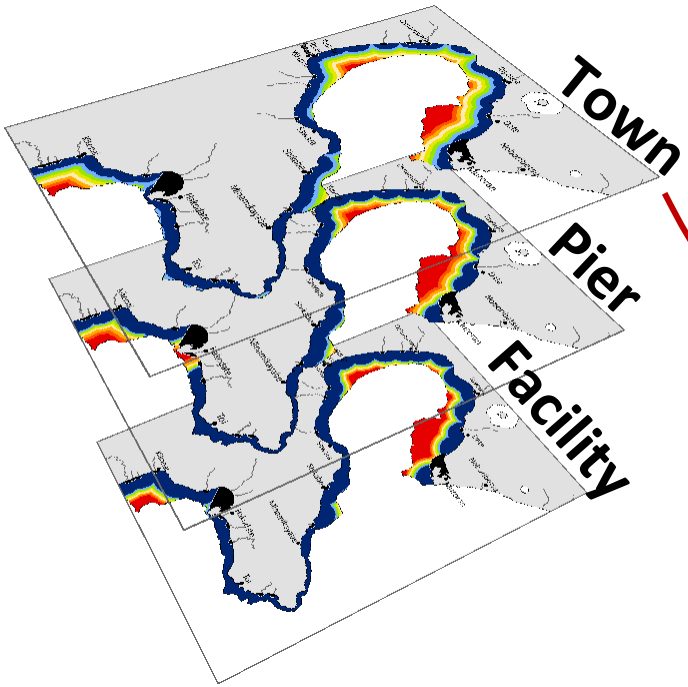
# Results: environmental submodel

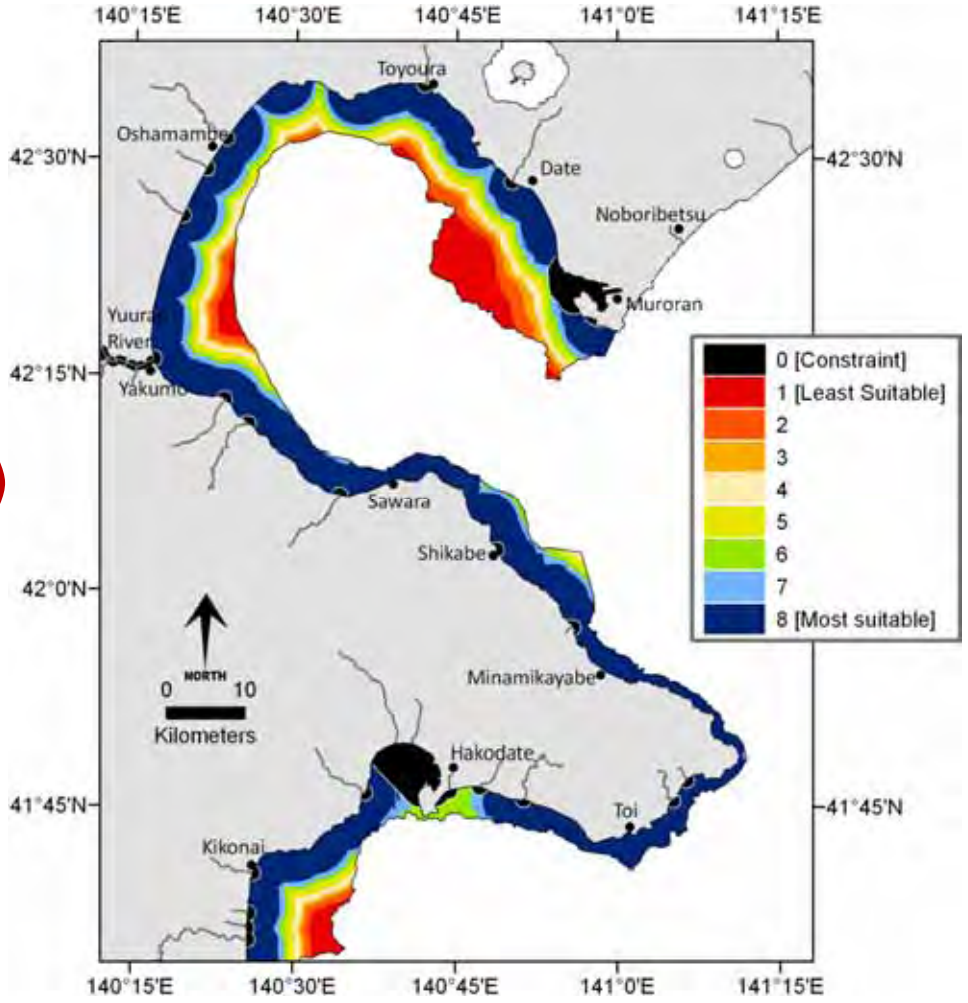



| Suitability levels (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 7.0 | 0.0 | 0.0 | 0.2 | 1.0 | 2.8 | 17.0 | 66.0 | 6.0 |

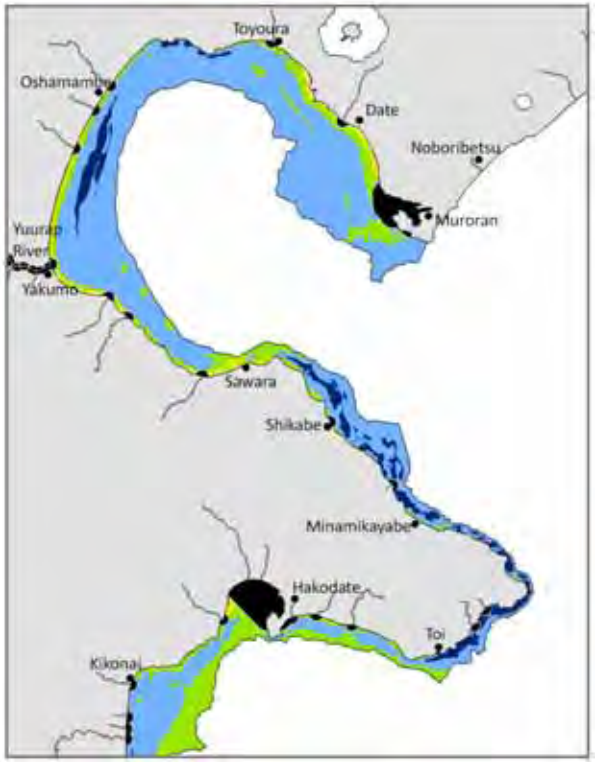
# Results: socio-infrastructural submodel



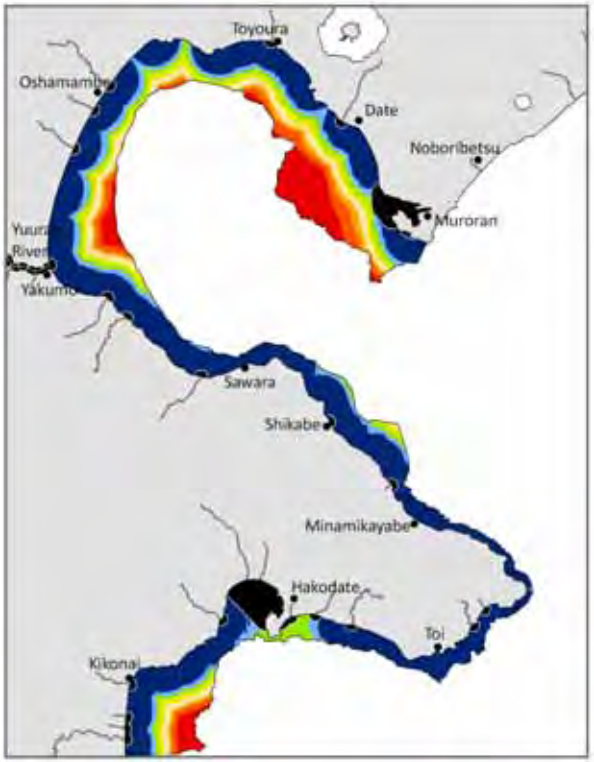




| Suitability levels (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 7.0 | 8.0 | 5.0 | 3.0 | 5.0 | 6.0 | 6.0 | 8.0 | 52.0 |

# Results: overall suitable model

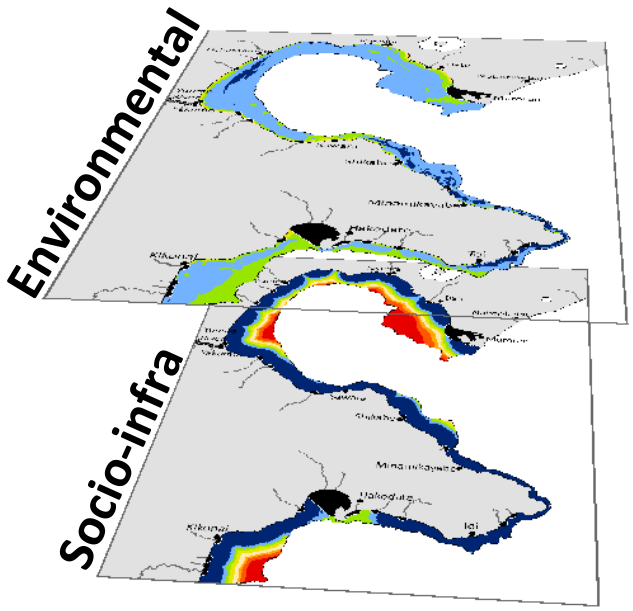


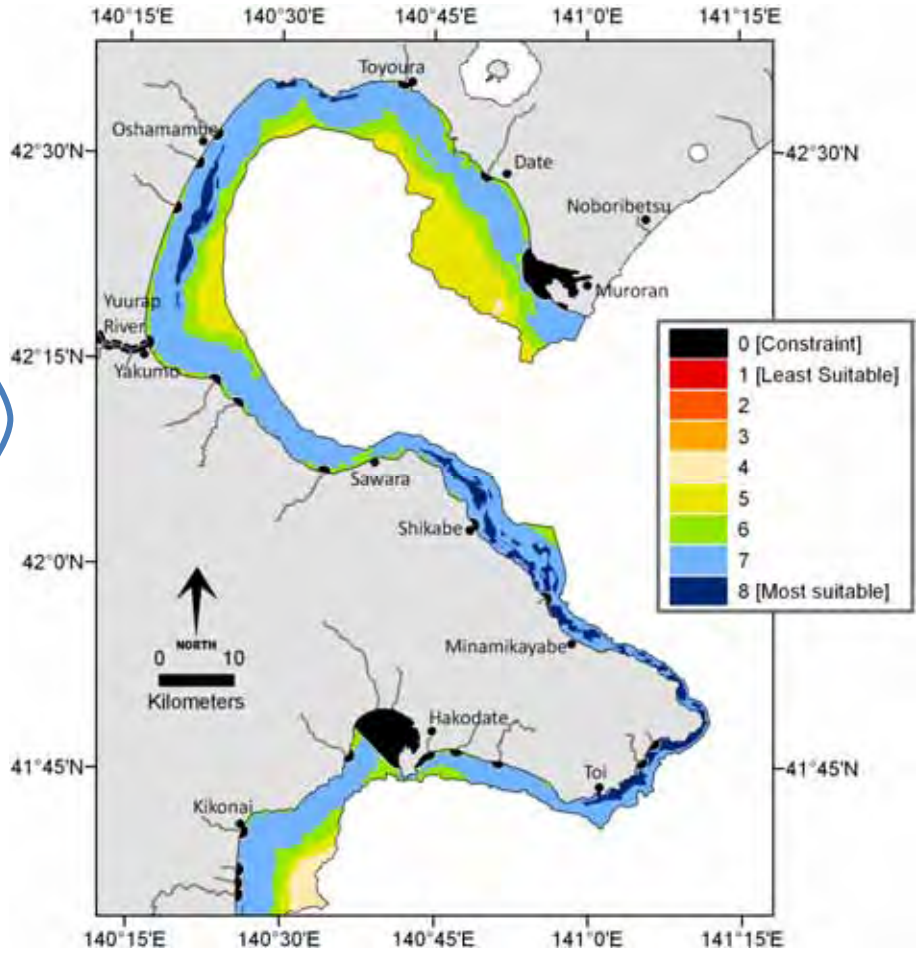

**Environment submodel**




**Socio-infra submodel**

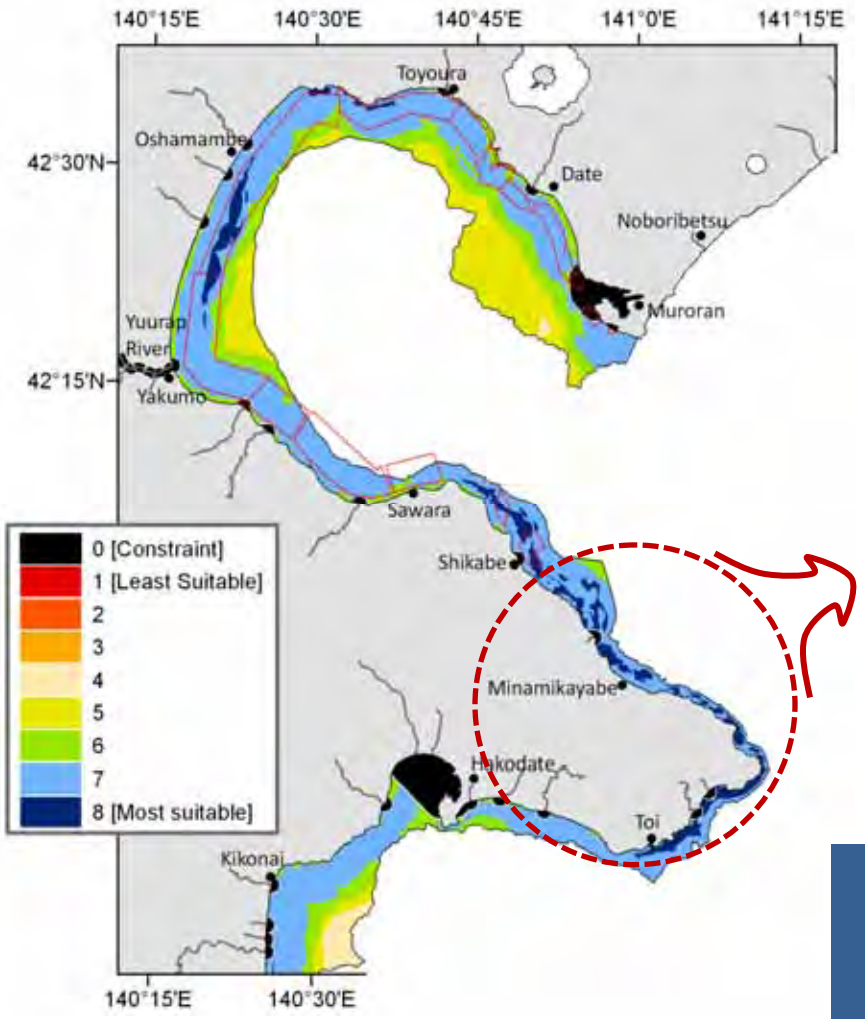
# Results: overall suitable model

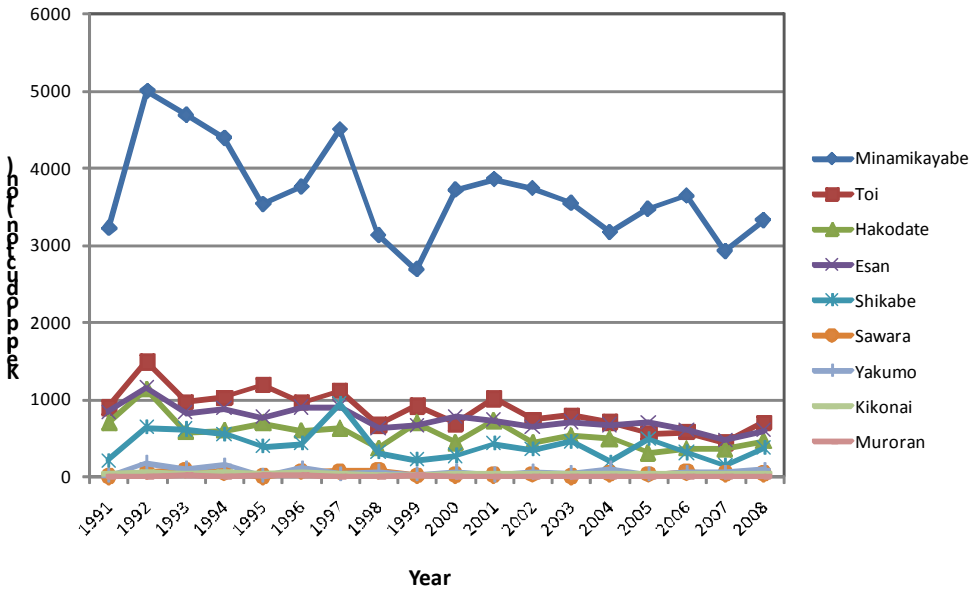



| Suitability levels (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 7.0 | 0.0 | 0.0 | 0.0 | 2.0 | 14.0 | 17.0 | 54.0 | 6.0 |

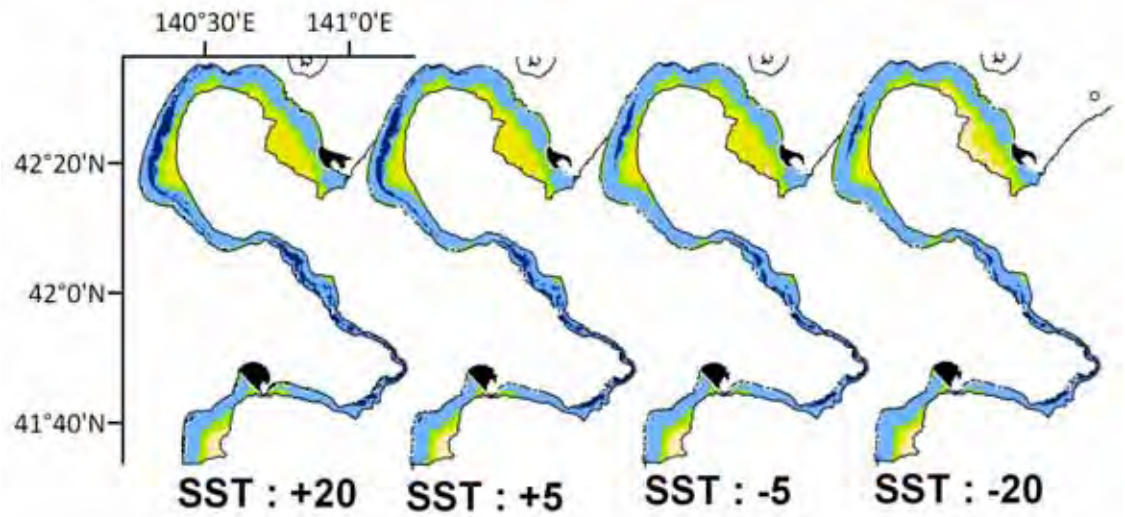
# Results: model validation



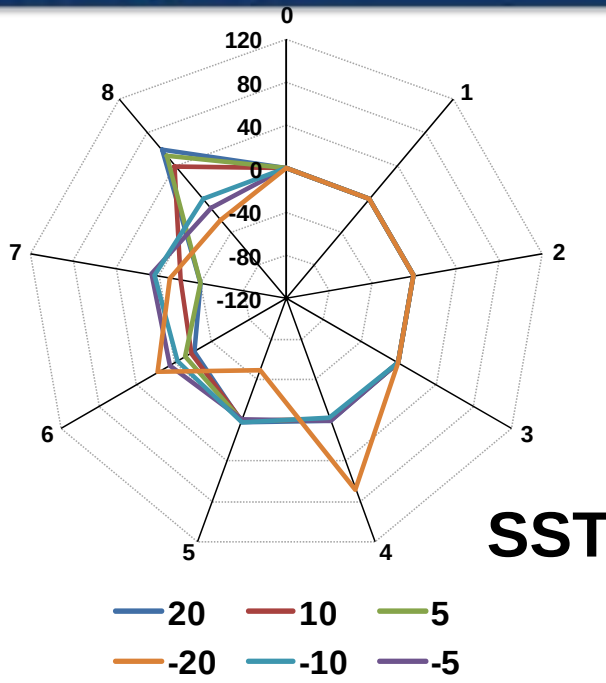



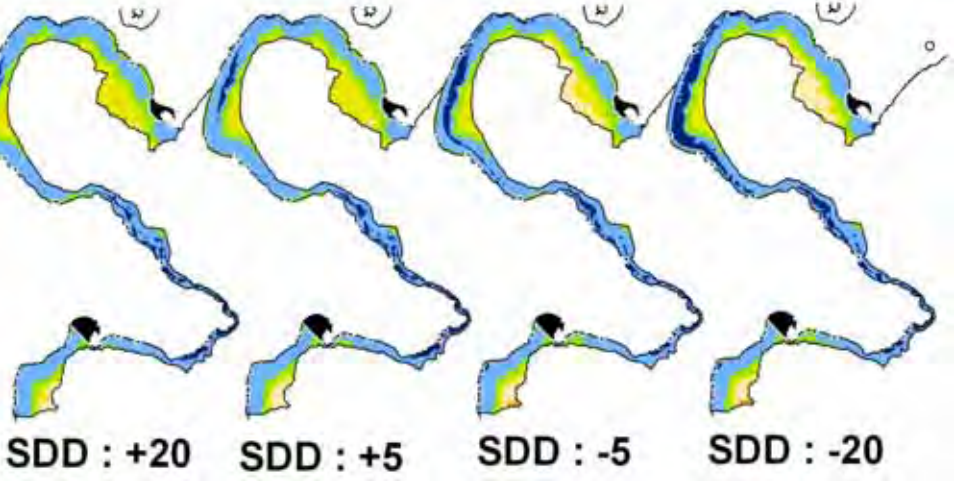

Minamikayabe; Shikabe; Esan, and Toi: High potential area for kelp cultivation [production]

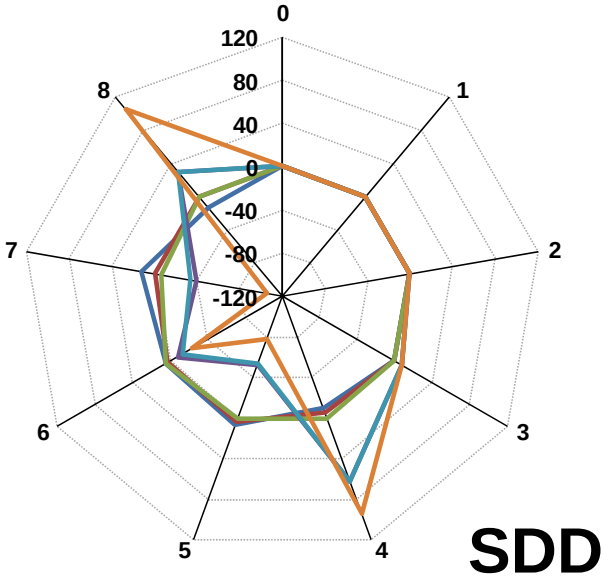
# Results: sensitivity analysis





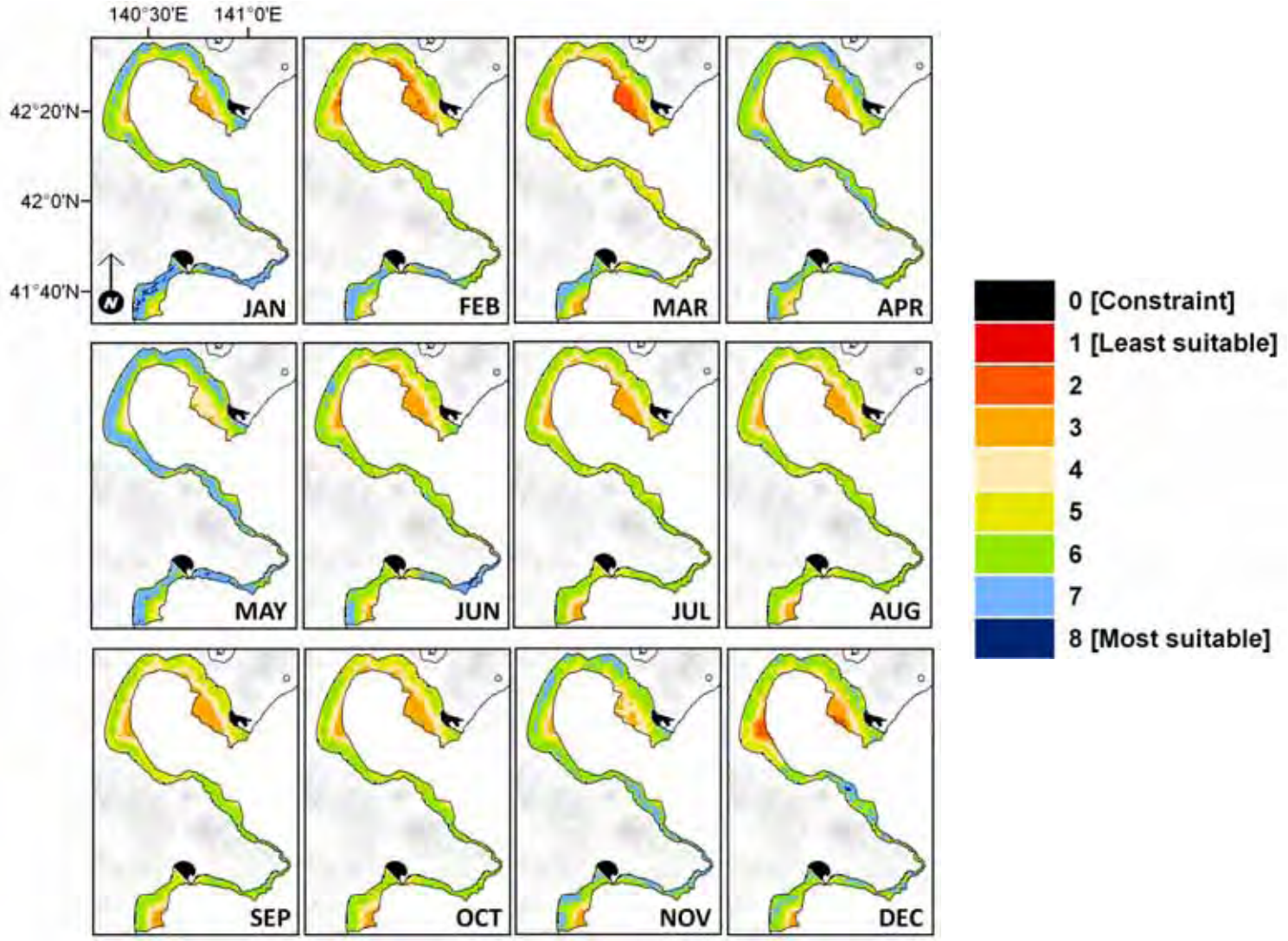


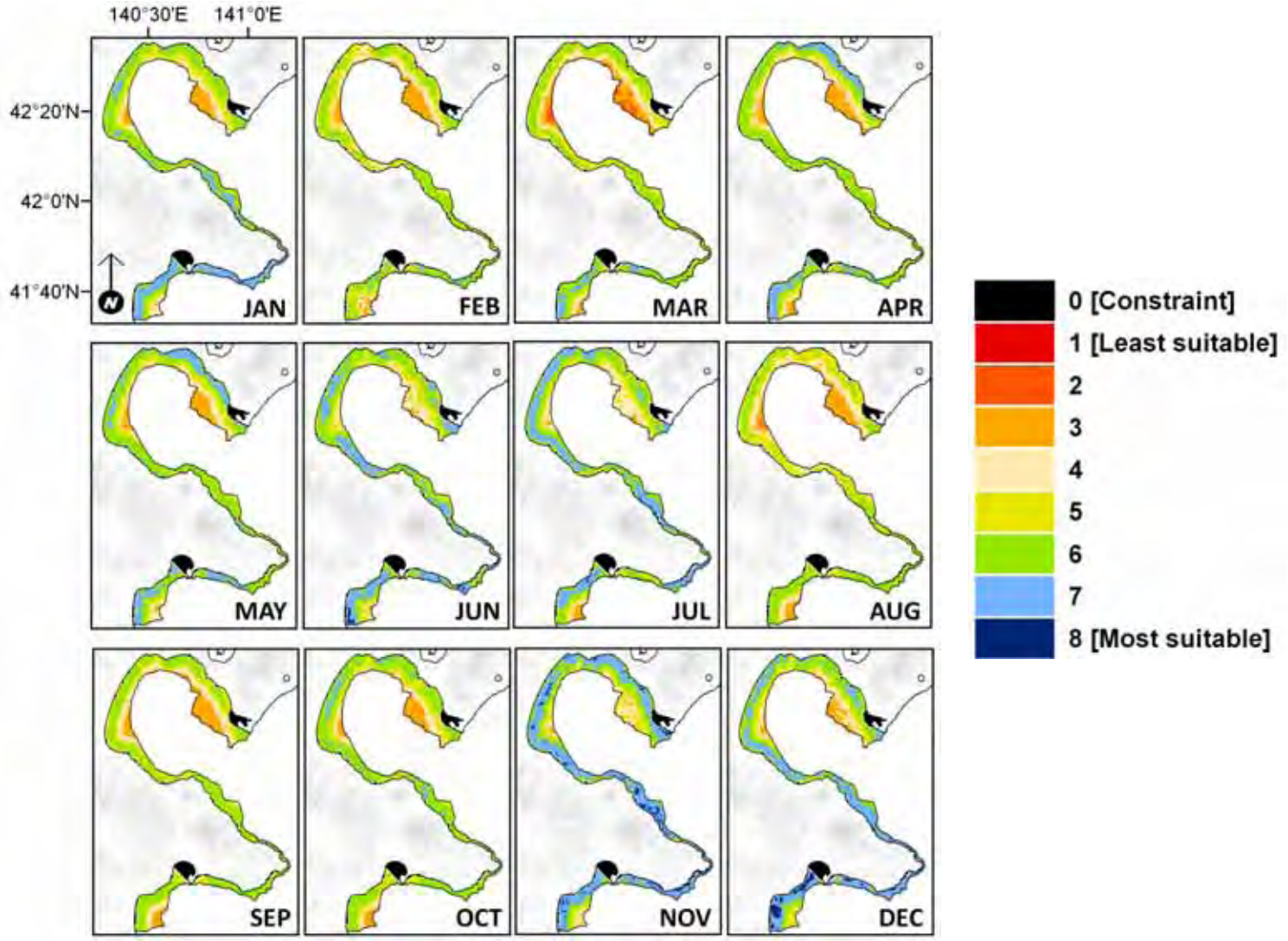
# Results: spatio-temporal model

## Monthly model in 2004



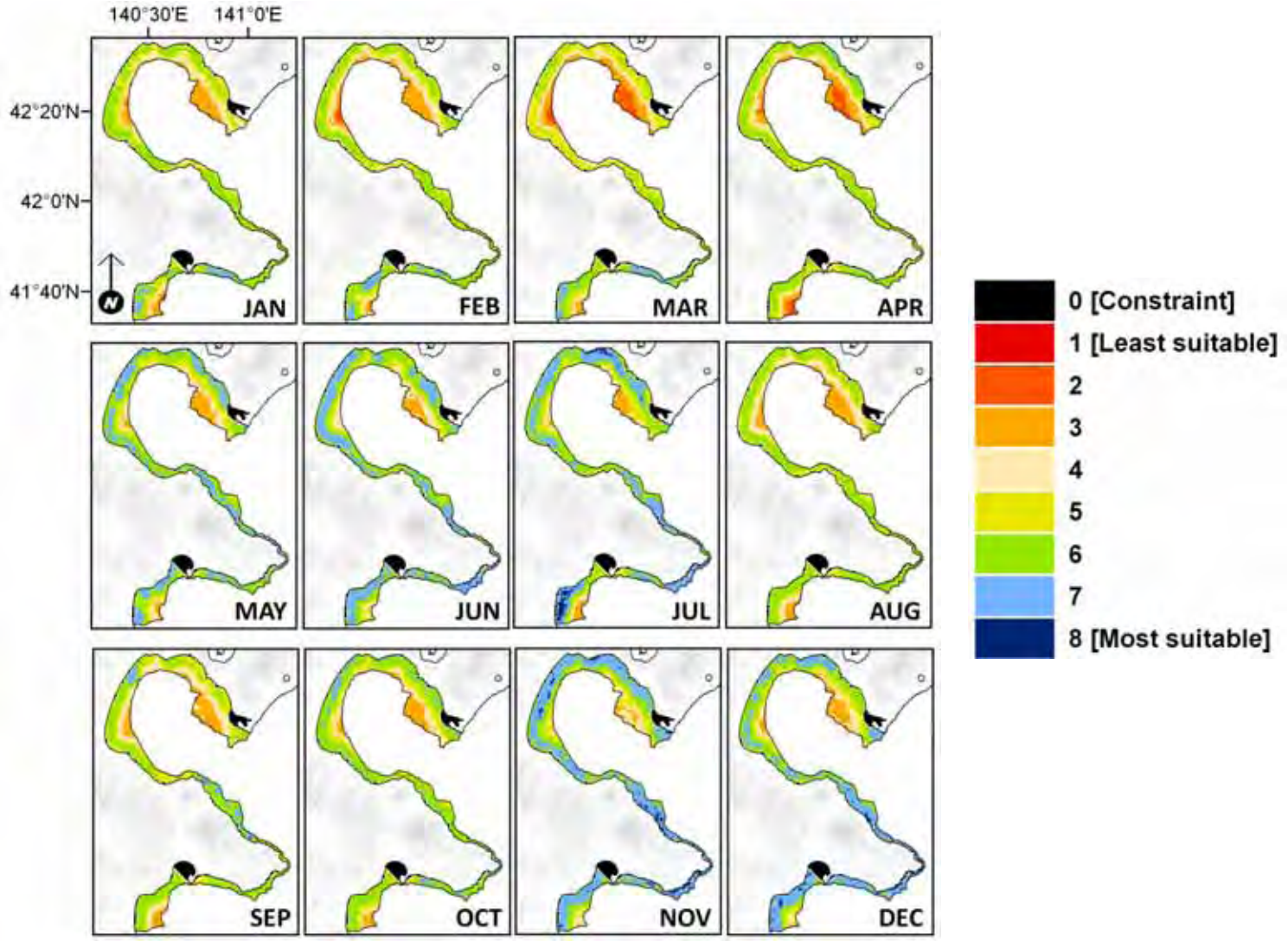
# Results: spatio-temporal model

## Monthly model in 2005



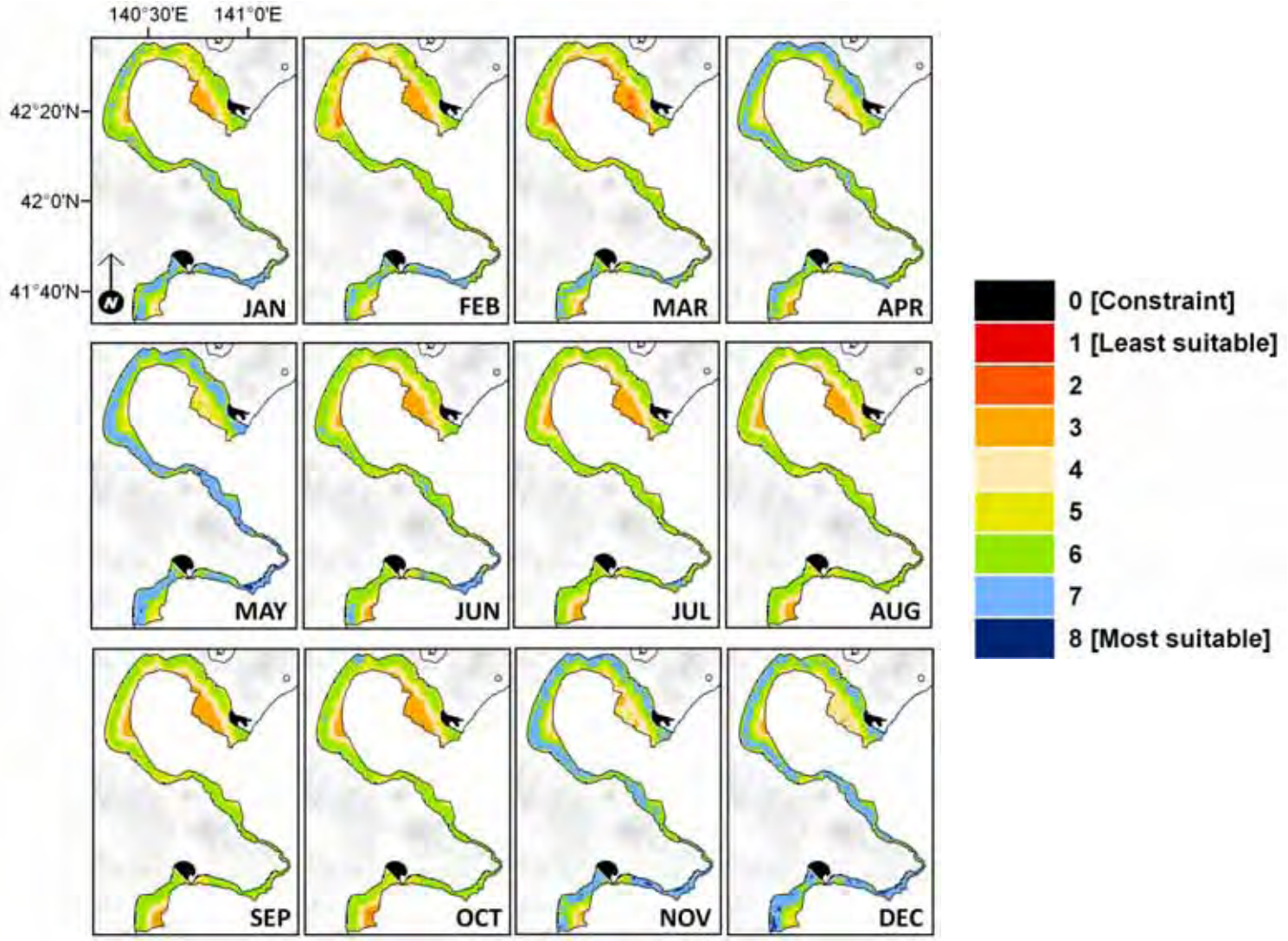
# Results: spatio-temporal model

## Monthly model in 2006



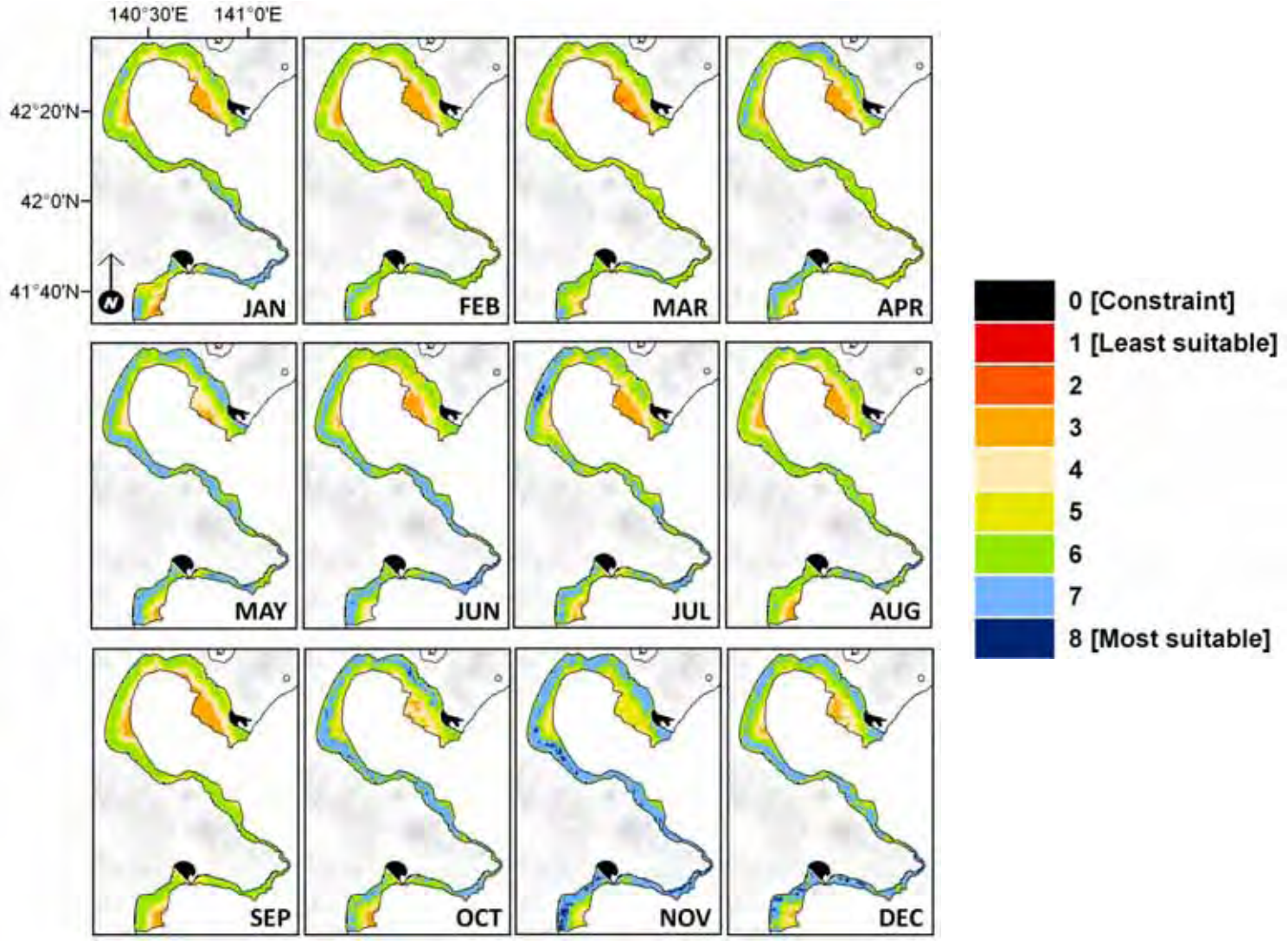
# Results: spatio-temporal model

## Monthly model in 2007



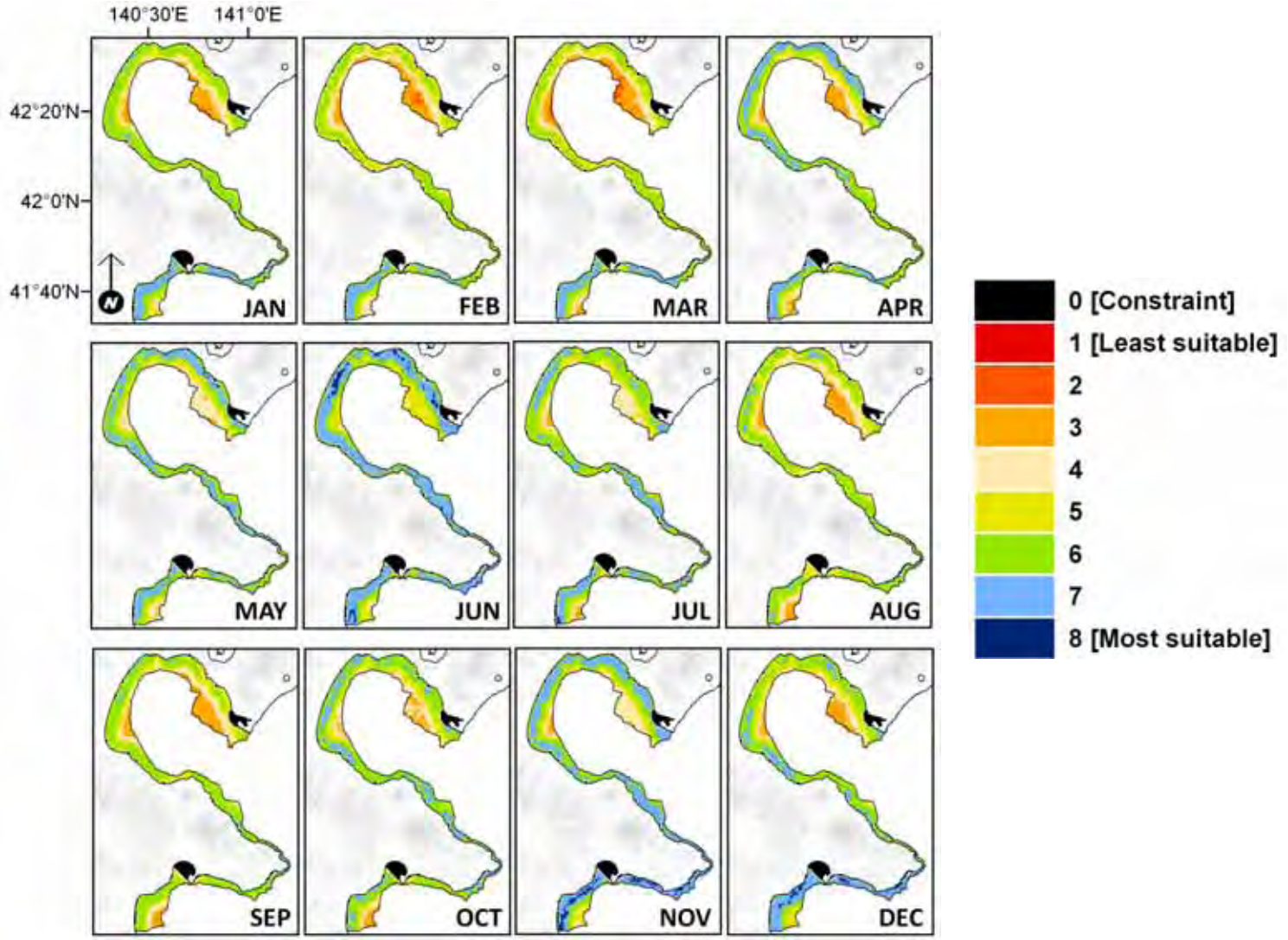
# Results: spatio-temporal model

## Monthly model in 2008



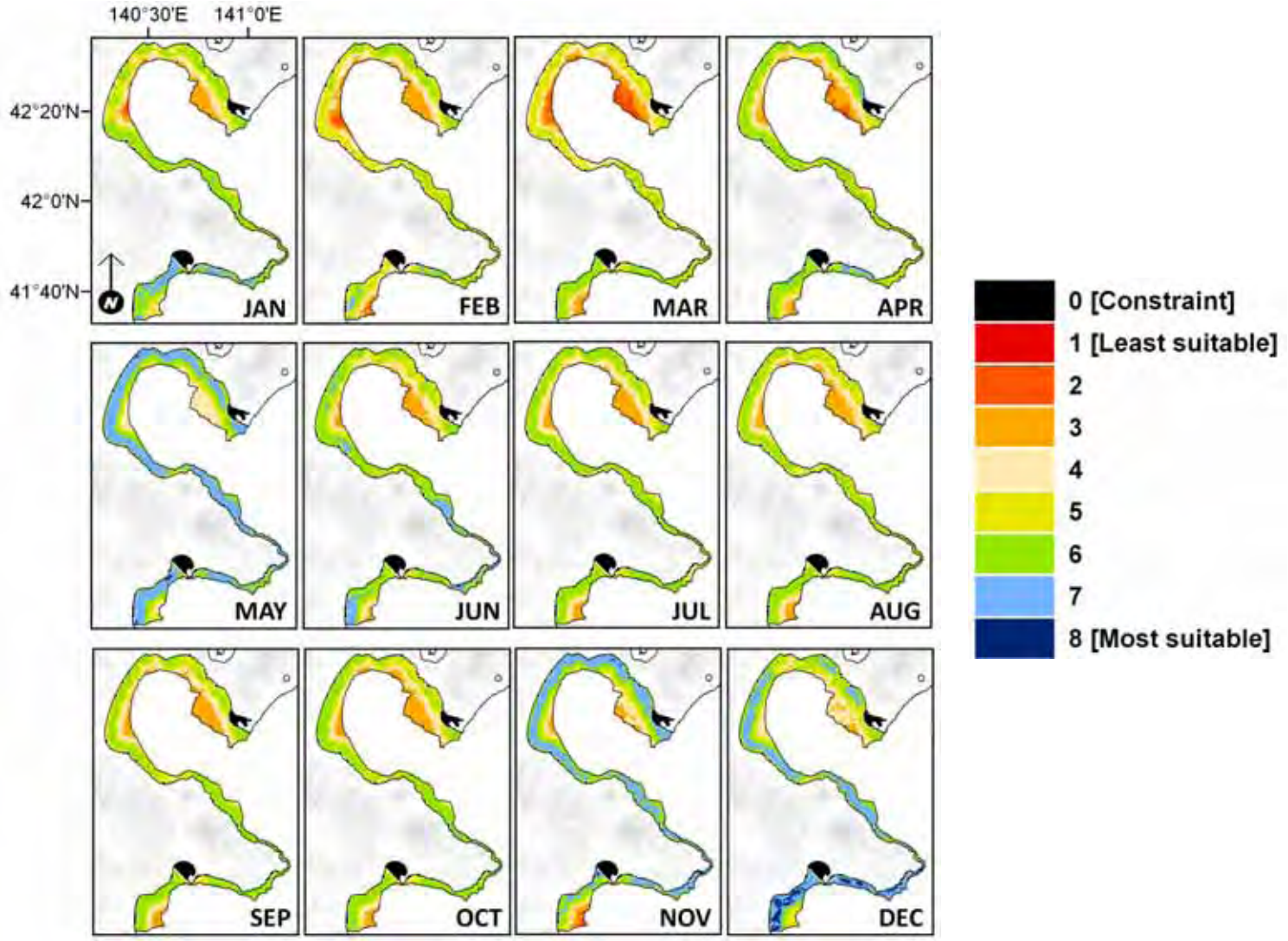
# Results: spatio-temporal model

## Monthly model in 2009



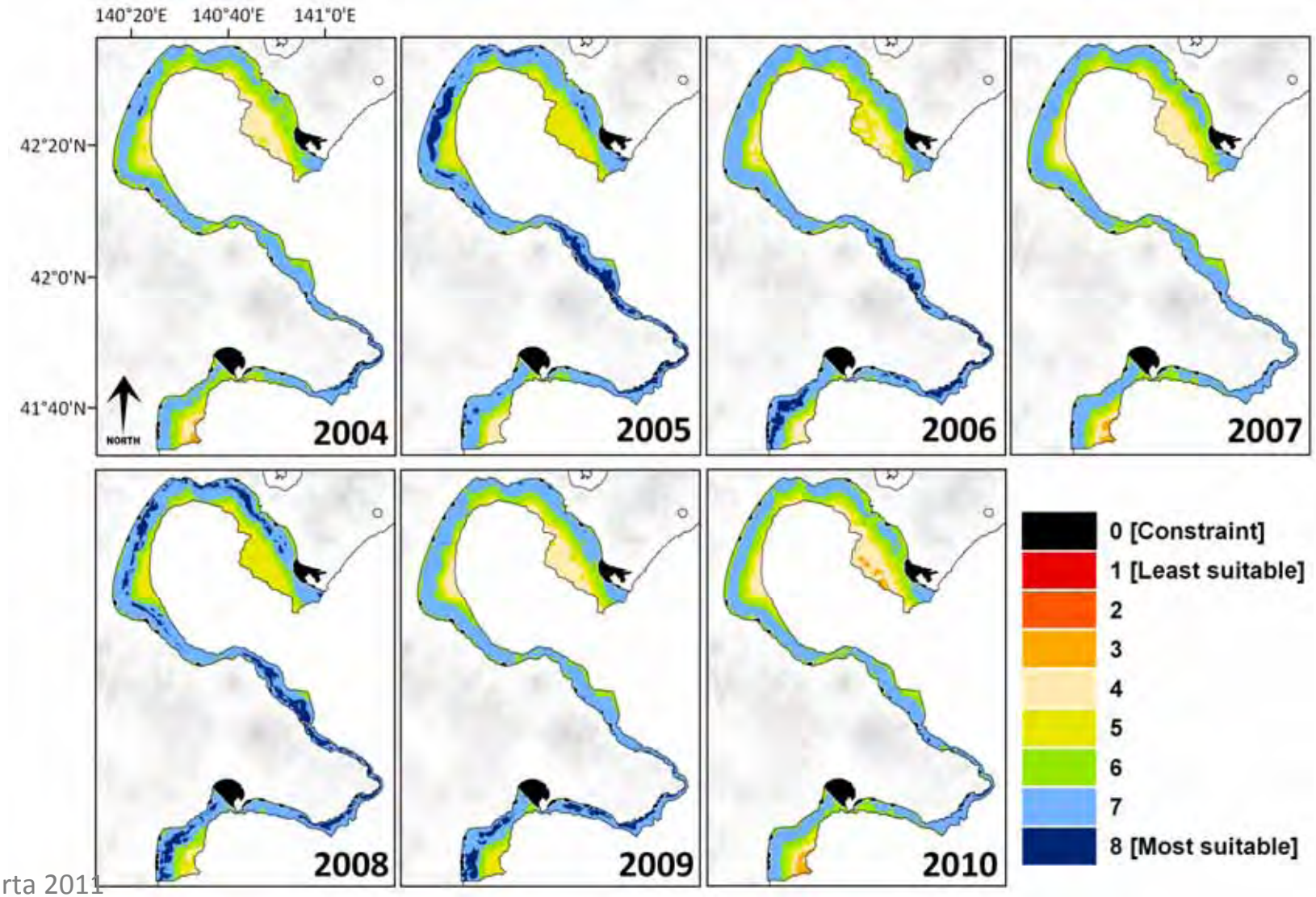
# Results: spatio-temporal model

## Monthly model in 2010

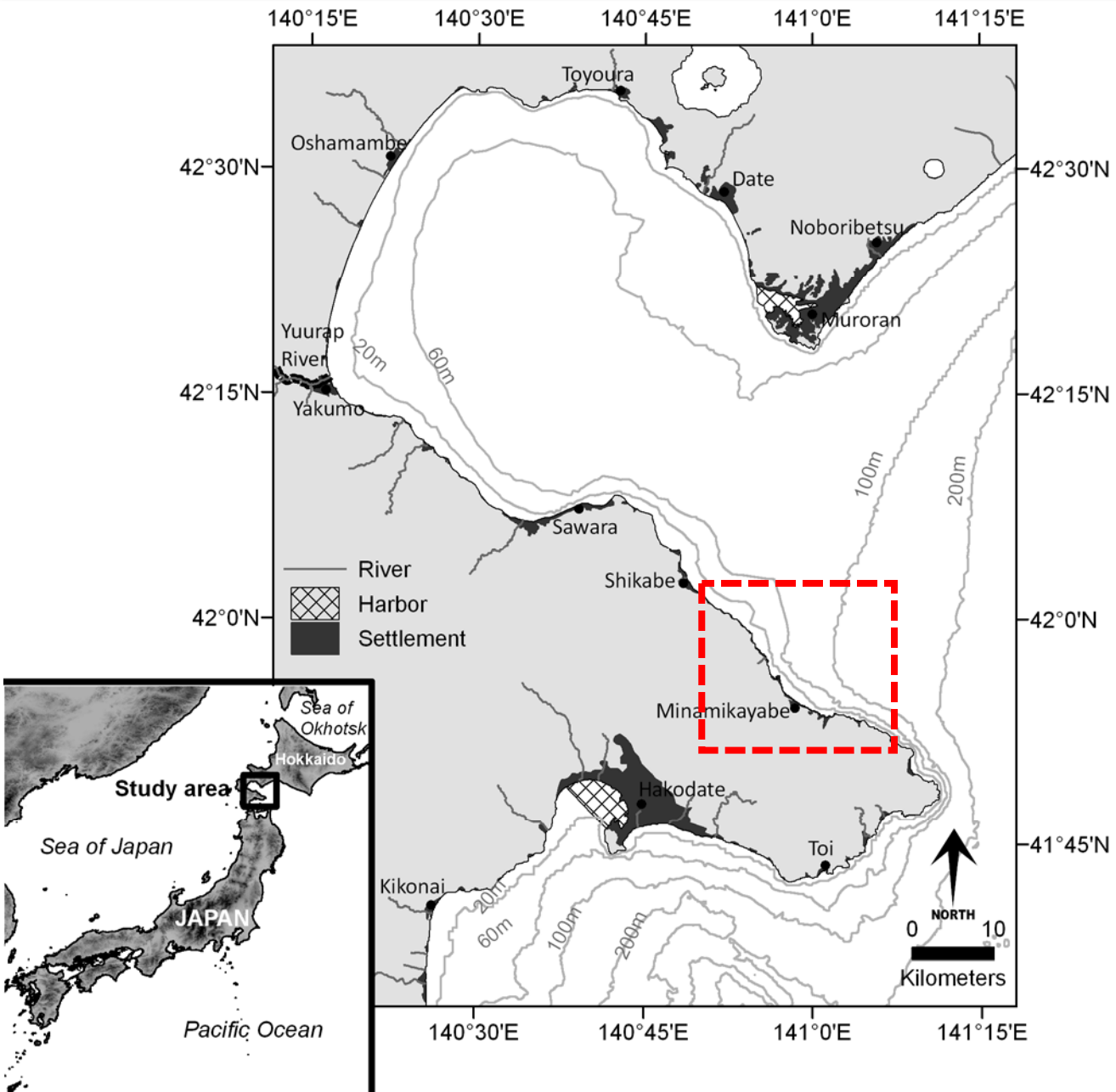


# Results: spatio-temporal model

## Yearly model from 2004-2010



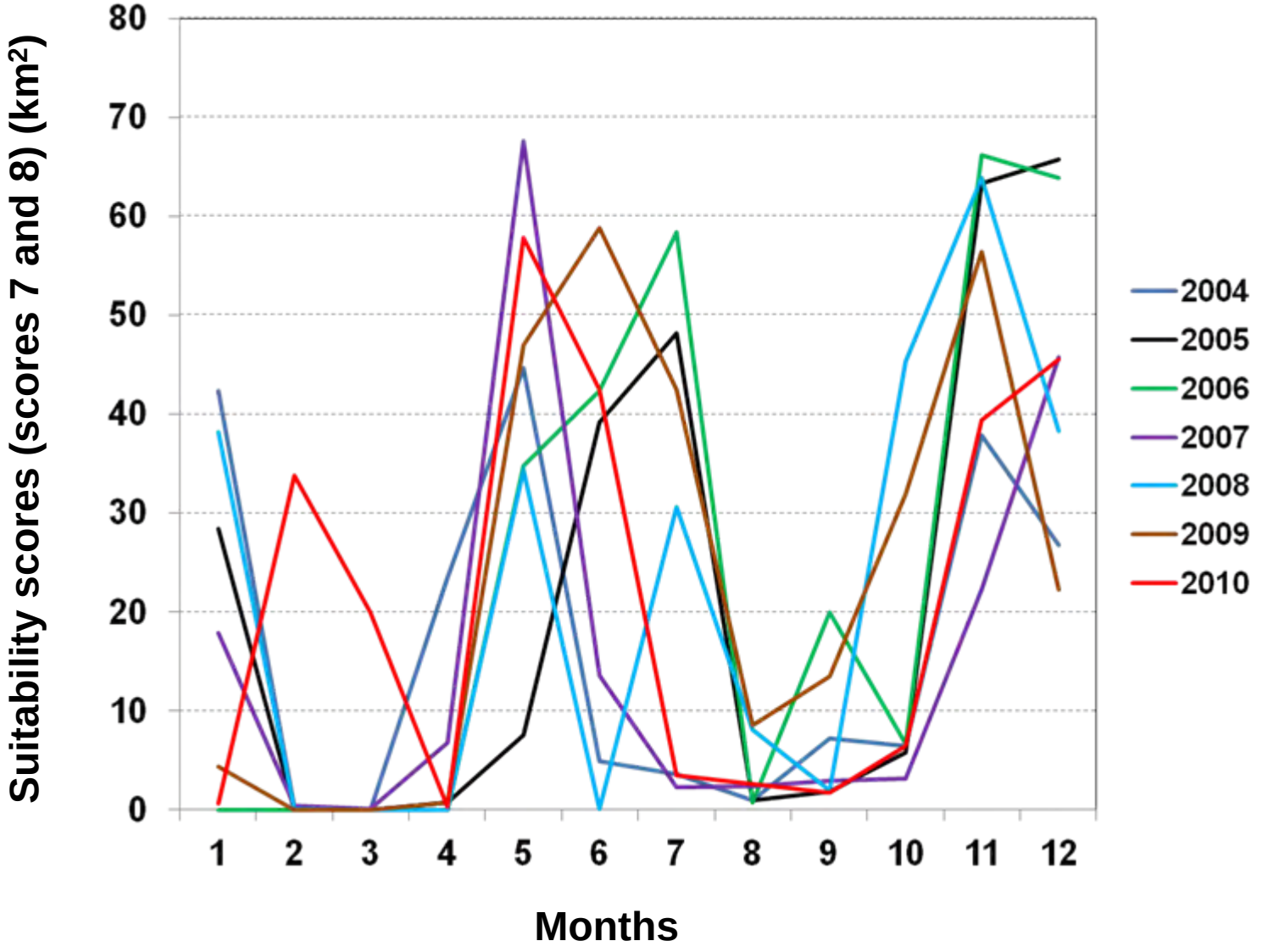
# Results: spatio-temporal model




Area calculation

# Results: spatio-temporal model

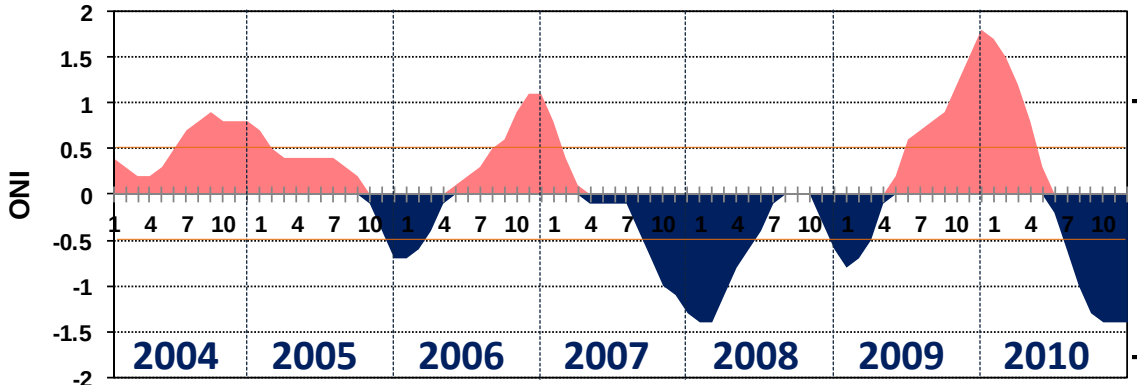
## 2004-2010



# Discussion

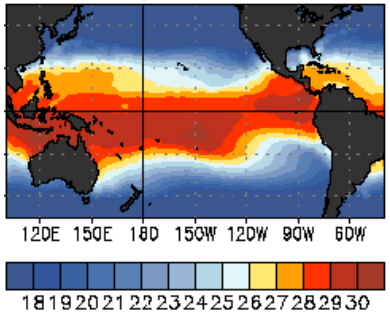
## The Oceanic Niño Index (ONI)

[3 month running mean of ERSST.v3b SST anomalies in the Niño 3.4 region]

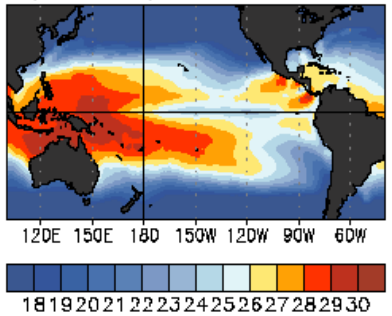



*http://www.cpc.ncep.noaa.gov*

El Niño




La Niña




- **The changes in sea surface temperature might impacts on the productivity across the coastal and marine systems**
- **El Niño- low spat density of scallop; La Niña- low growth of scallop (Baba et al., 2009)**
- **Normal or week El Niño years- increasing high score regions (2005, 2006 and 2008: warmer SST)**

# Conclusions

- Southern Hokkaido has a potential area for kelp aquaculture development.
- High suitable area dominantly located between **Shikabe to Toi coastal areas**.
- Interannual variability was observed: Good years – 2005, 2006 and 2008 (**Normal** or **week El Niño years)**
- This study has illustrated how GIS database of different formats and sources could be used to **establish spatial models** in the coastal area for kelp aquaculture development.