Impact of climate change on the development of marine aquaculture: a case study on the Japanese scallop in Dalian, China, using satellite remote sensing and GIS-based models

Yang **Liu**[1], Sei-Ichi Saitoh[1], I. Nyoman Radiarta[2], and Toru Hirawake[1]

[1] Faculty of Fisheries Sciences, Hokkaido University, Japan.
[2] Ministry of Marine Affairs and Fisheries, Indonesia.

Introduction

Japanese scallop (*Mizuhopecten yessoensis*) in Dalian, China.

- An alternative species from Japan for aquaculture in **1982**.
- Accounts for about **90%** of the total national production
- Annual production was about **260,000** tons in 2009 (Dalian Bureau of Statistics, 2010).

Large–scale mortality from 2007 (Liu et al 2010.)

- Climate and environmental change
- Human activities

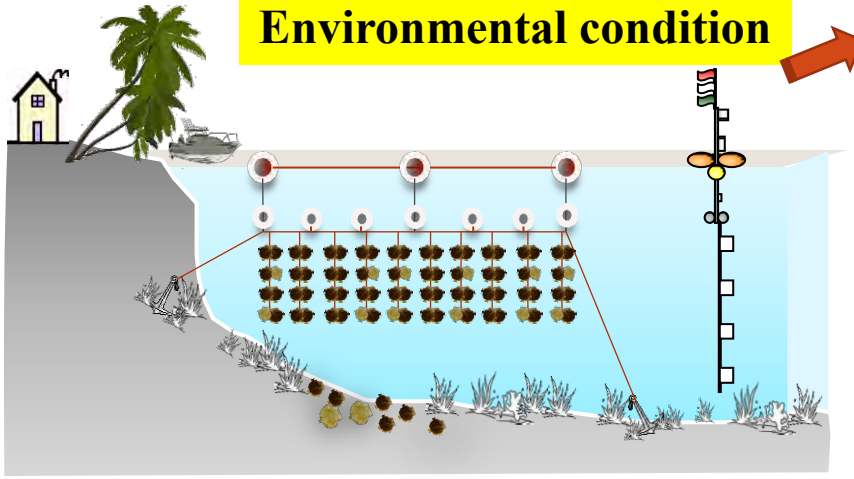
Introduction

Sustainable scallop culture

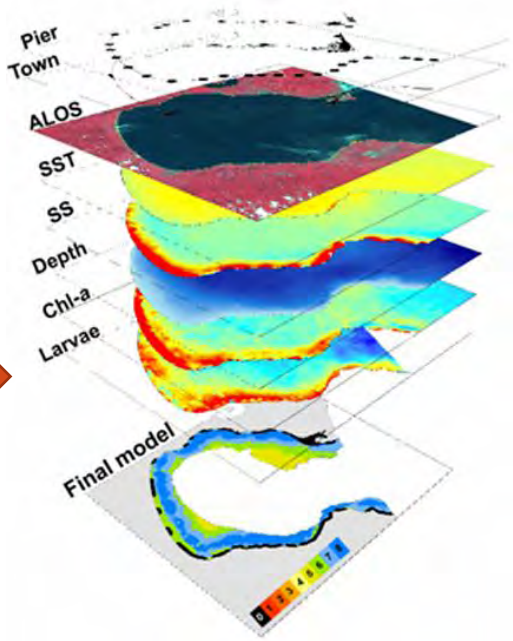
Satellite data

Climate condition

Environmental condition



GIS

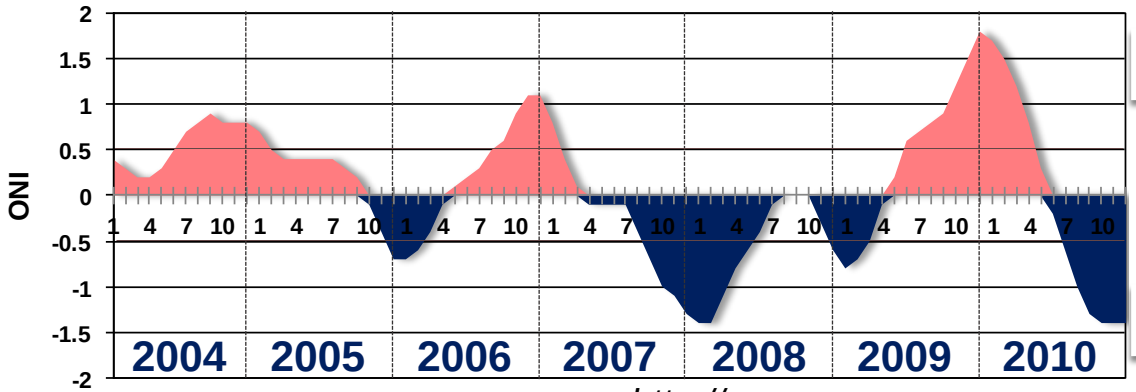


Suitable site map

Introduction

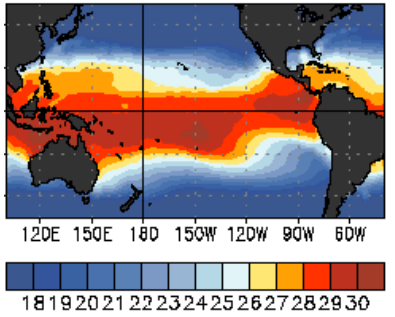
Climate variability

The Oceanic Niño Index (ONI)

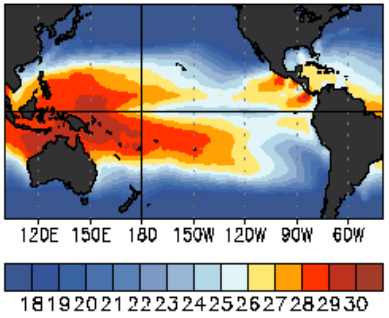


http://www.cpc.ncep.noaa.gov

El Niño



La Niña

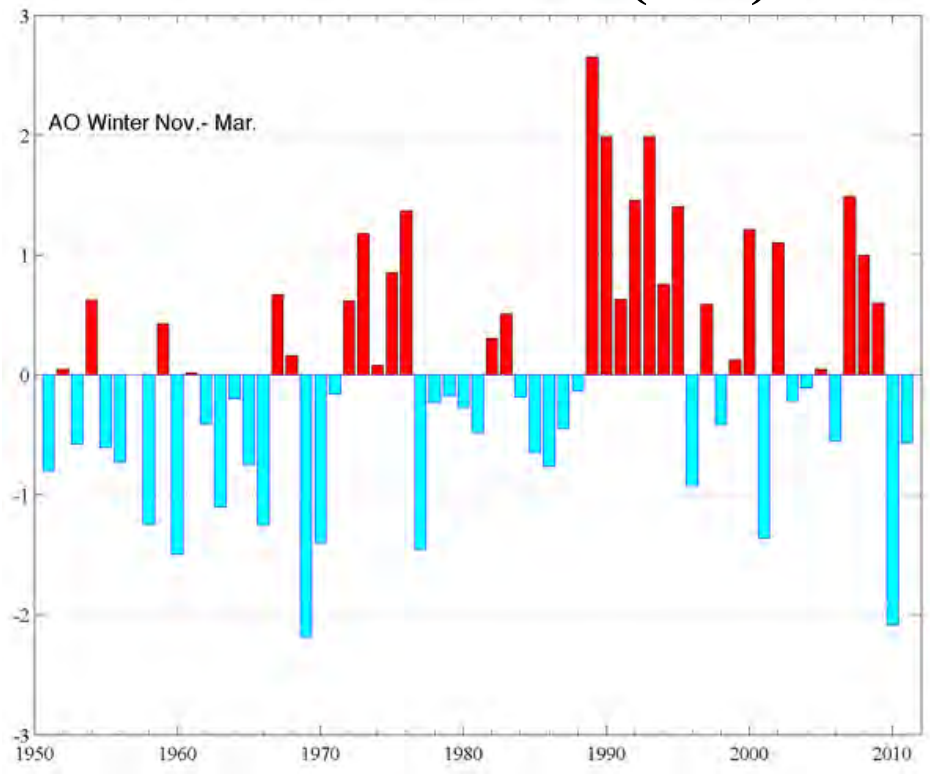


- **The changes in sea surface temperature might impacts on the productivity across the coastal and marine systems(Saitoh et al., 2011)**
- **El Niño- low spat density of scallop; La Niña- low growth of scallop (Baba et al., 2009)**

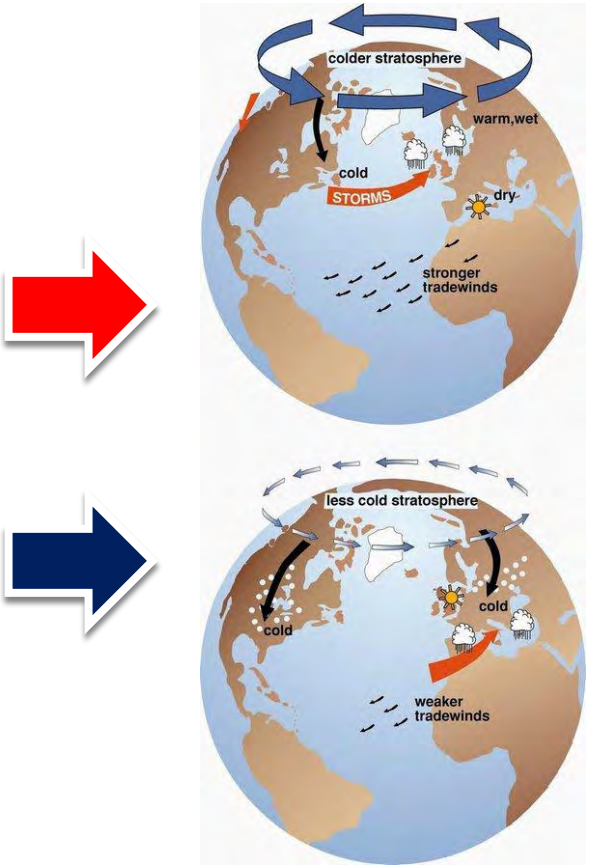
Introduction

Climate variability

Arctic Oscillation (AO)



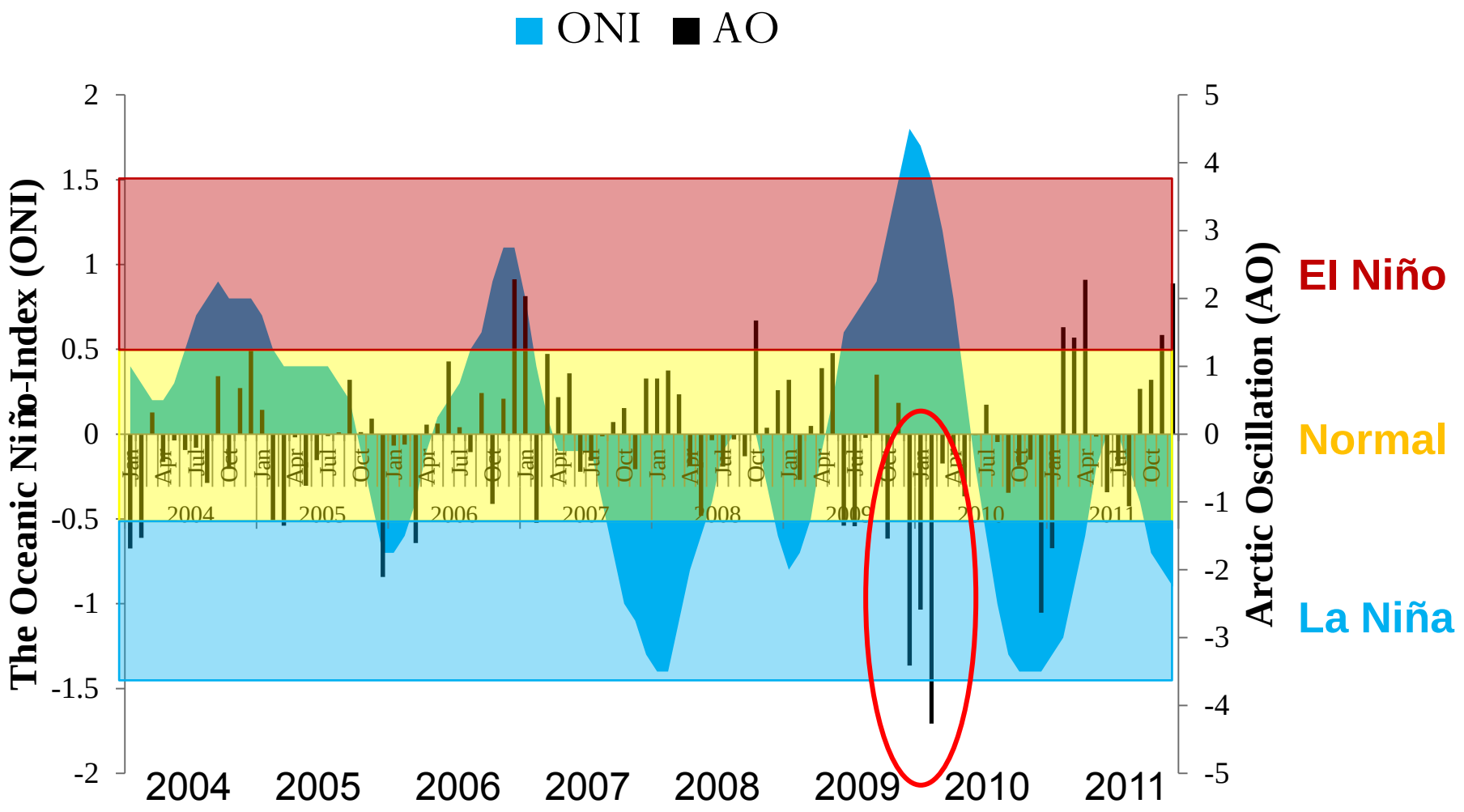
http://www.cpc.ncep.noaa.gov



- **The severe ice conditions over the Bo Sea, China in 2010 was mainly controlled by AO (Bai et al 2011)**

Introduction

Climate variability



Introduction

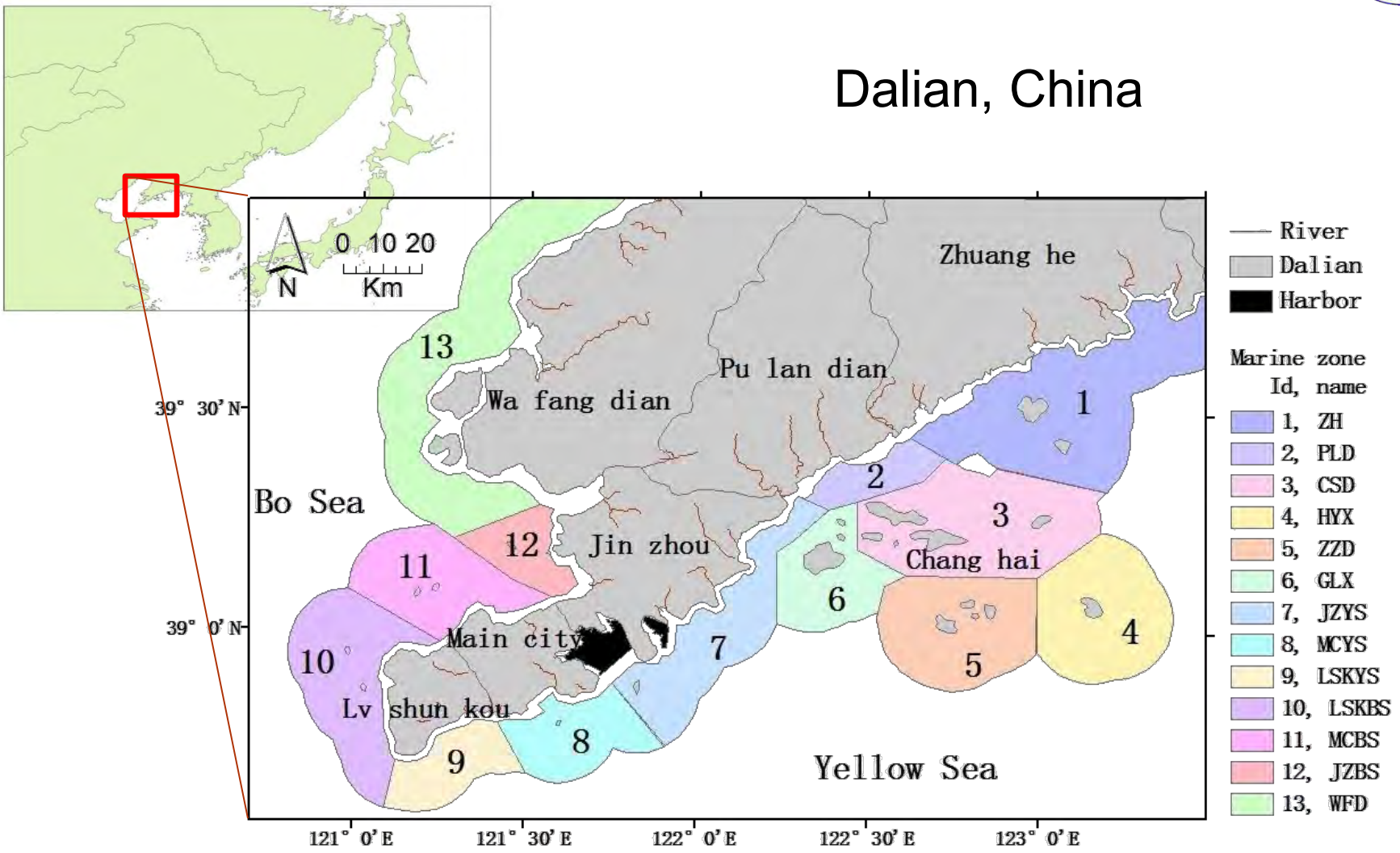
Objective

- To continue develop GIS–based models and use remote sensing data to identify the most suitable sites for hanging culture of Japanese scallop development in Dalian, China

- Compared with ENSO events and AO, in order to examine the impact of climate change variability on scallop aquaculture development.

Study area

Dalian, China



Data

Parameter	Data sources	Resolution	Time
Sea surface temperature	MODIS	1 km	2004 -2011 Daily
Chlorophyll-a	MODIS	1 km	2004 -2011 Daily
Secchi Disk Depth (SDD)*	$K_d(490)$ MODIS	1 km	2004 -2011 Daily
Bathymetry	E-TOPO 1	1 arc minute	
Harbor; Town; River; Pier; and Aquaculture pond	ALOS AVNIR-2	10 m	Nov., 5, 2009 Oct., 5, 2010 Dec., 7, 2010

* The SDD algorithm: **SDD =1.43 x $K_d(490)^{-0.89}$**
[Wang et al., 2005]

Method

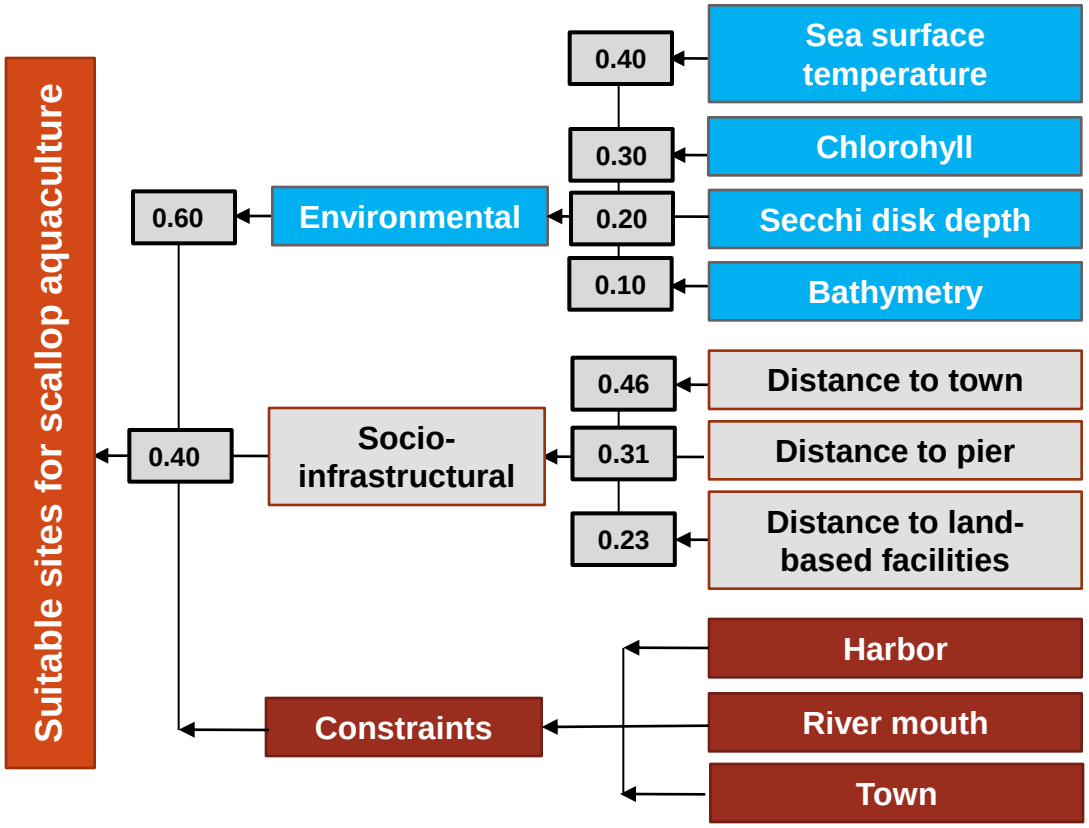
- Built on hierarchical structure
  - Factors: 7 parameters
  - Constraints: 3 parameters
- **Scoring: 1 (least suitable) - 8 (most suitable)** (Radiarta et al., 2008)

Parameters	Suitability rating and score							
	8	7	6	5	4	3	2	1
Chlorophyll-a (mg m^{-3})	1.4-2.0	1.2-1.4	1.0-1.2	0.8-1.0	0.6-0.8	0.4-0.6	0.2-0.4	< 0.2 or > 2.0
Bathymetry (m)	> 20.0	17.5-20.0	15.0-17.5	12.5-15.0	10.0-12.5	7.5-10.0	5.0-7.5	<5.0
Distance to pier (km)	< 4.0	4.0-4.5	4.5-5.0	5.0-5.5	5.5-6.0	6.0-7.0	7.0-8.0	>8
Distance to land facility (km)	< 5	5-5.5	5.5-6	6-6.5	6.5-7	7-7.5	7.5-8	> 8

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

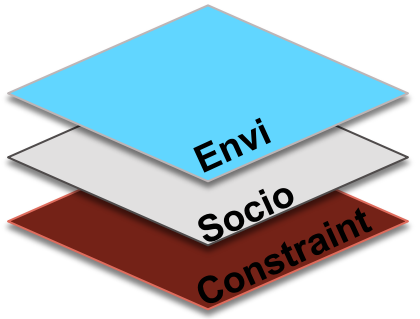
Method

Goal	Objectives	Attributes	Final model



MCE: Weighted Linear Combination

$$V(x_i) = \sum_j w_j r_{ij}$$

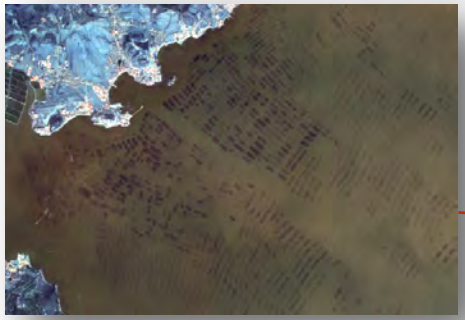


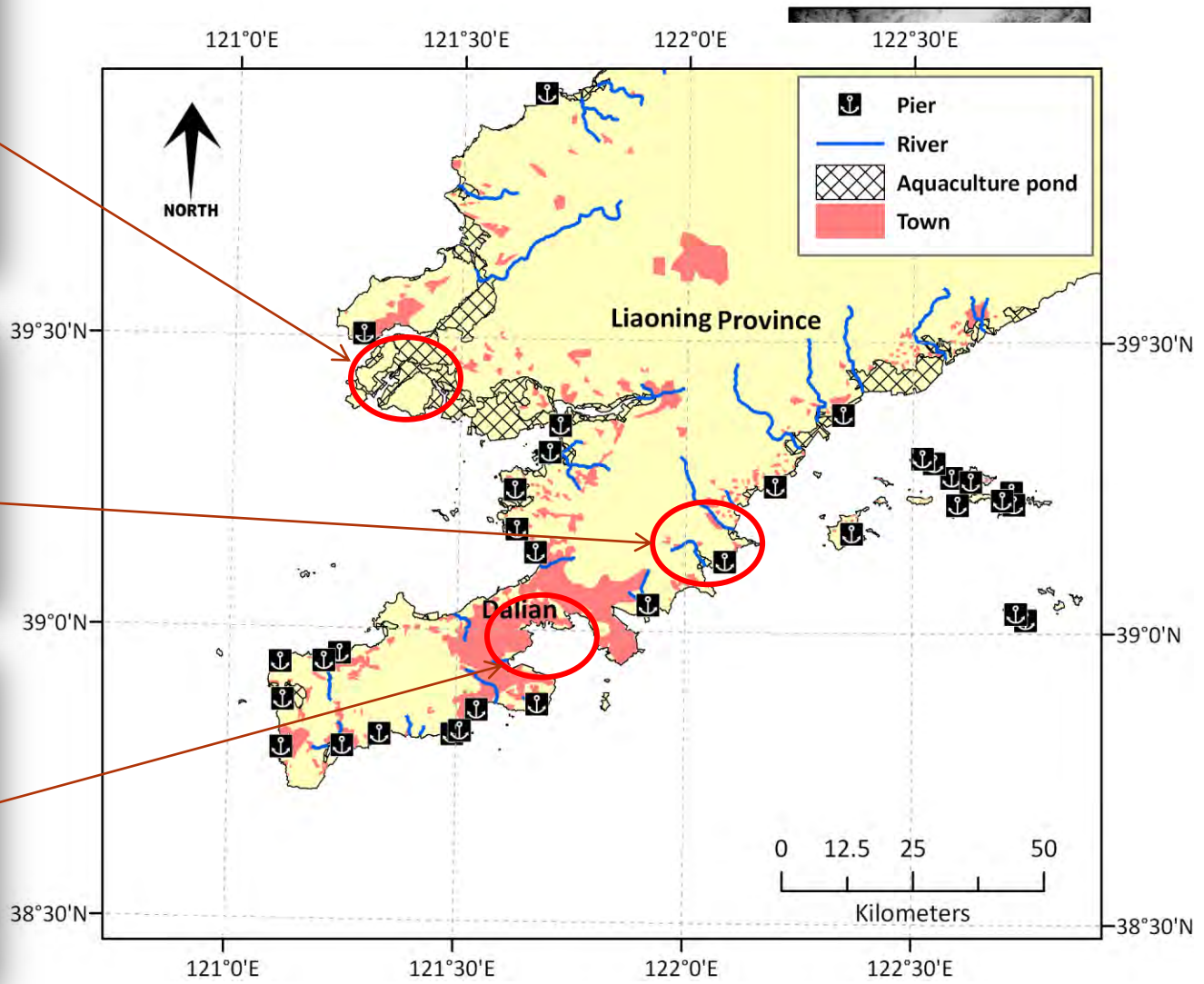
w_j = weight, $\Sigma w_j = 1$,

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

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

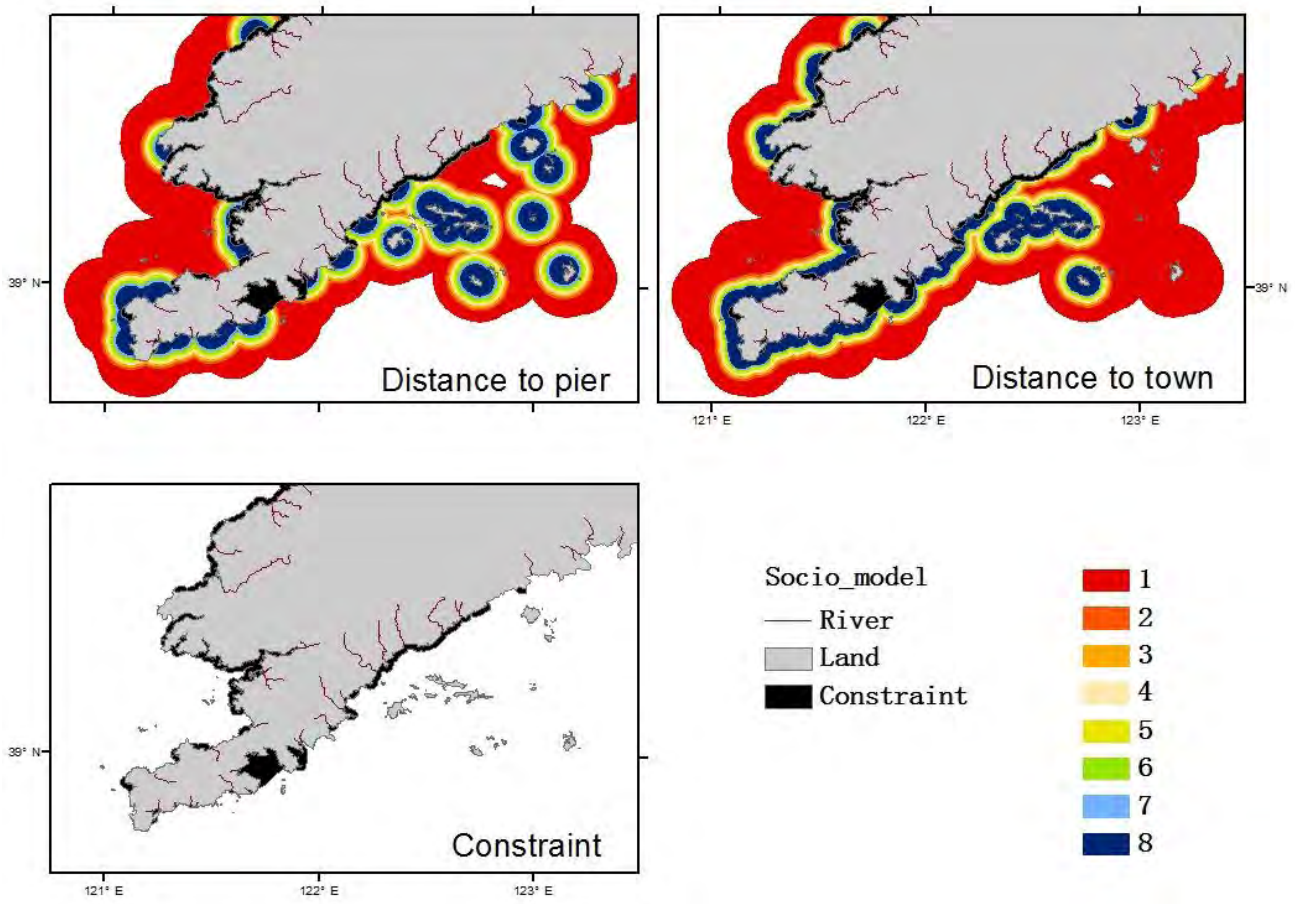
Results and Discussion





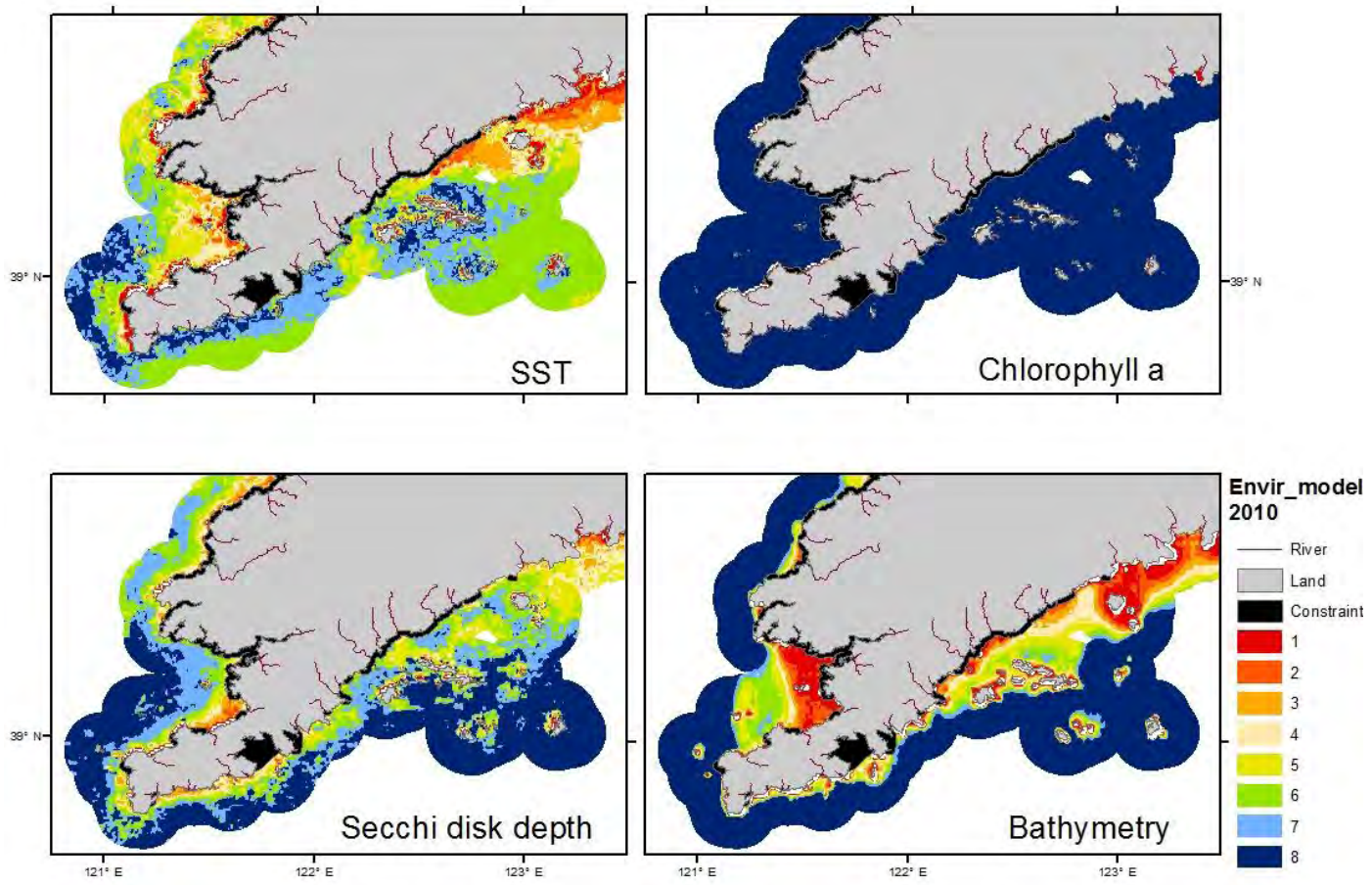
Results and Discussion

Socio-infrastructural and Constraint models



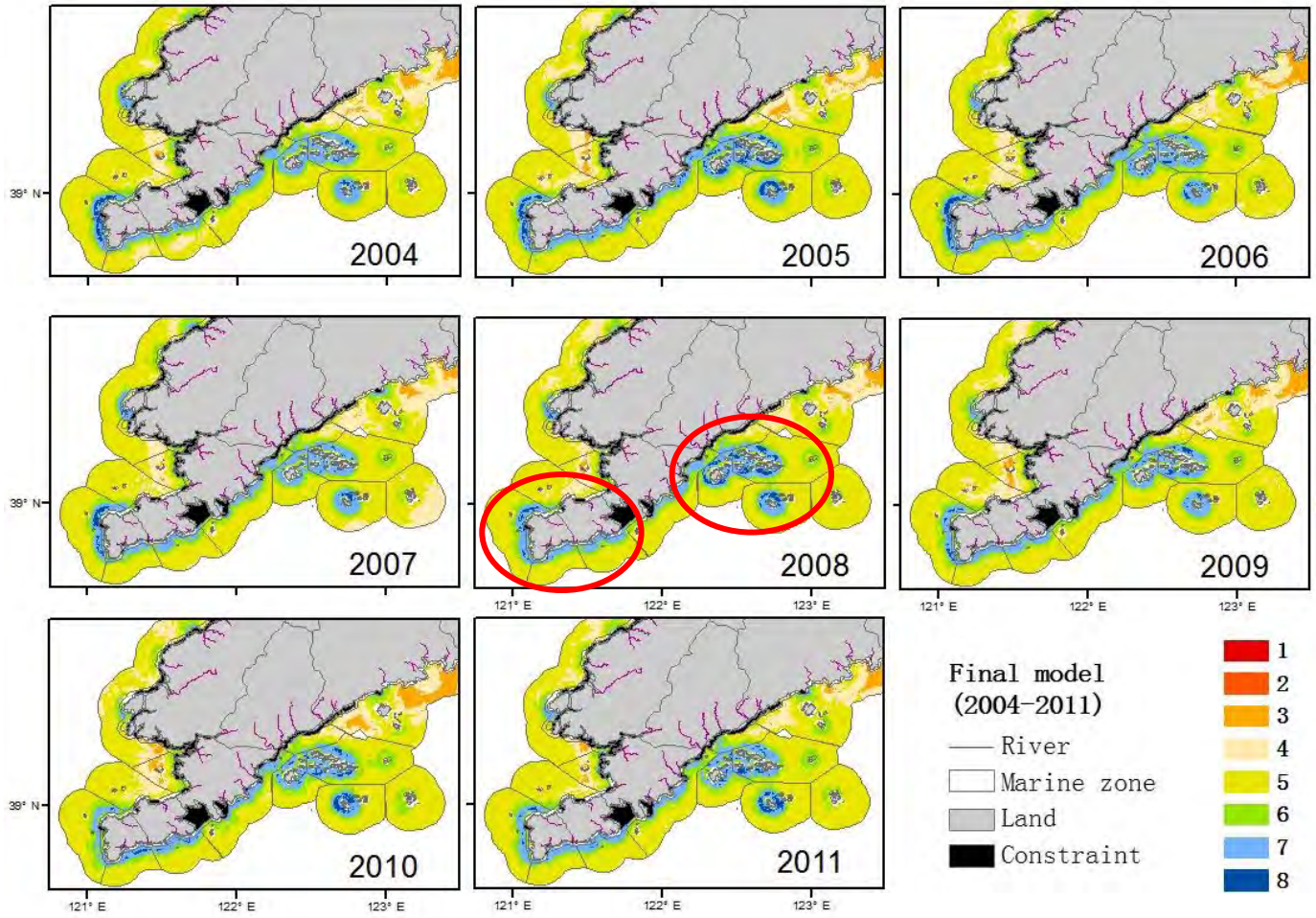
Results and Discussion

Environmental models

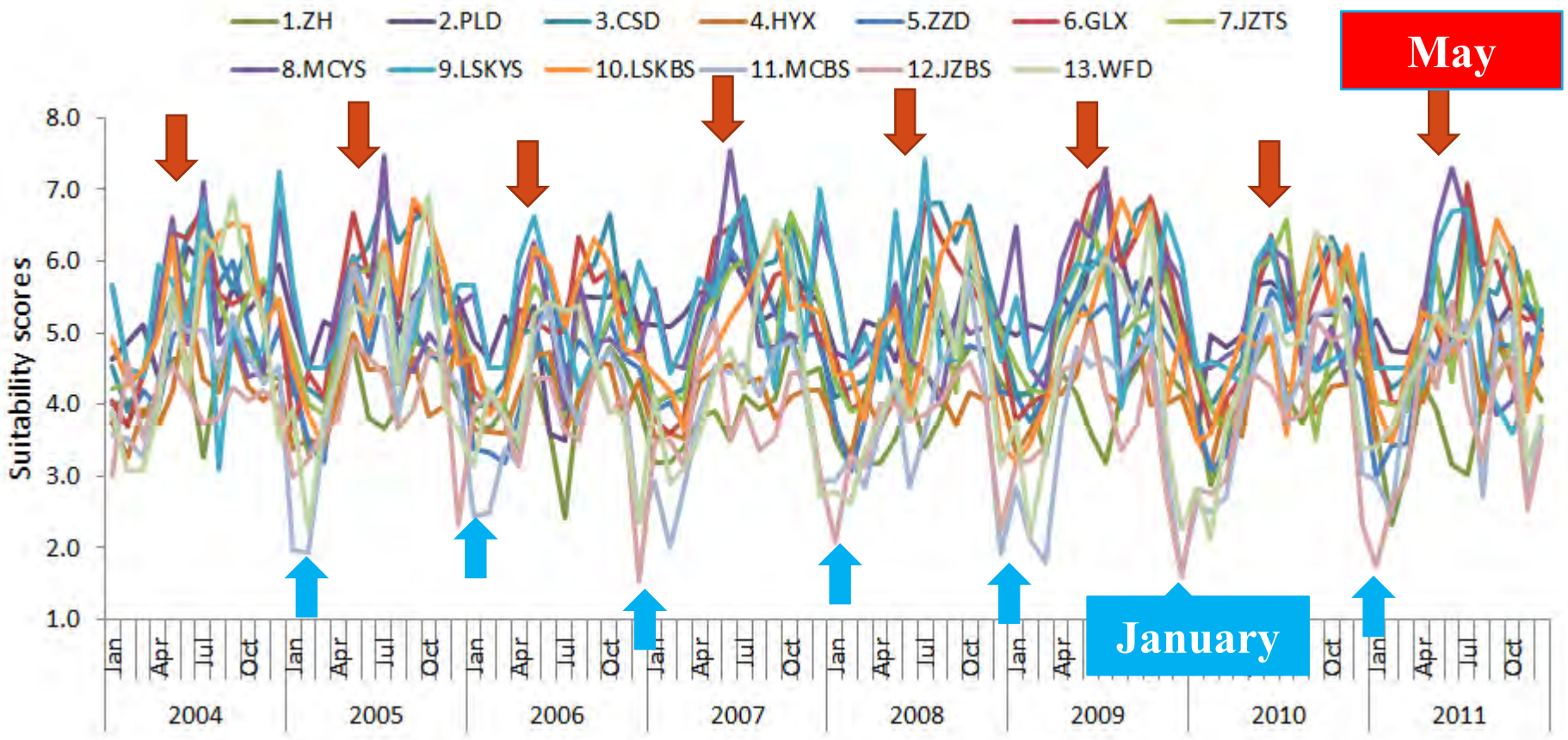


Results and Discussion

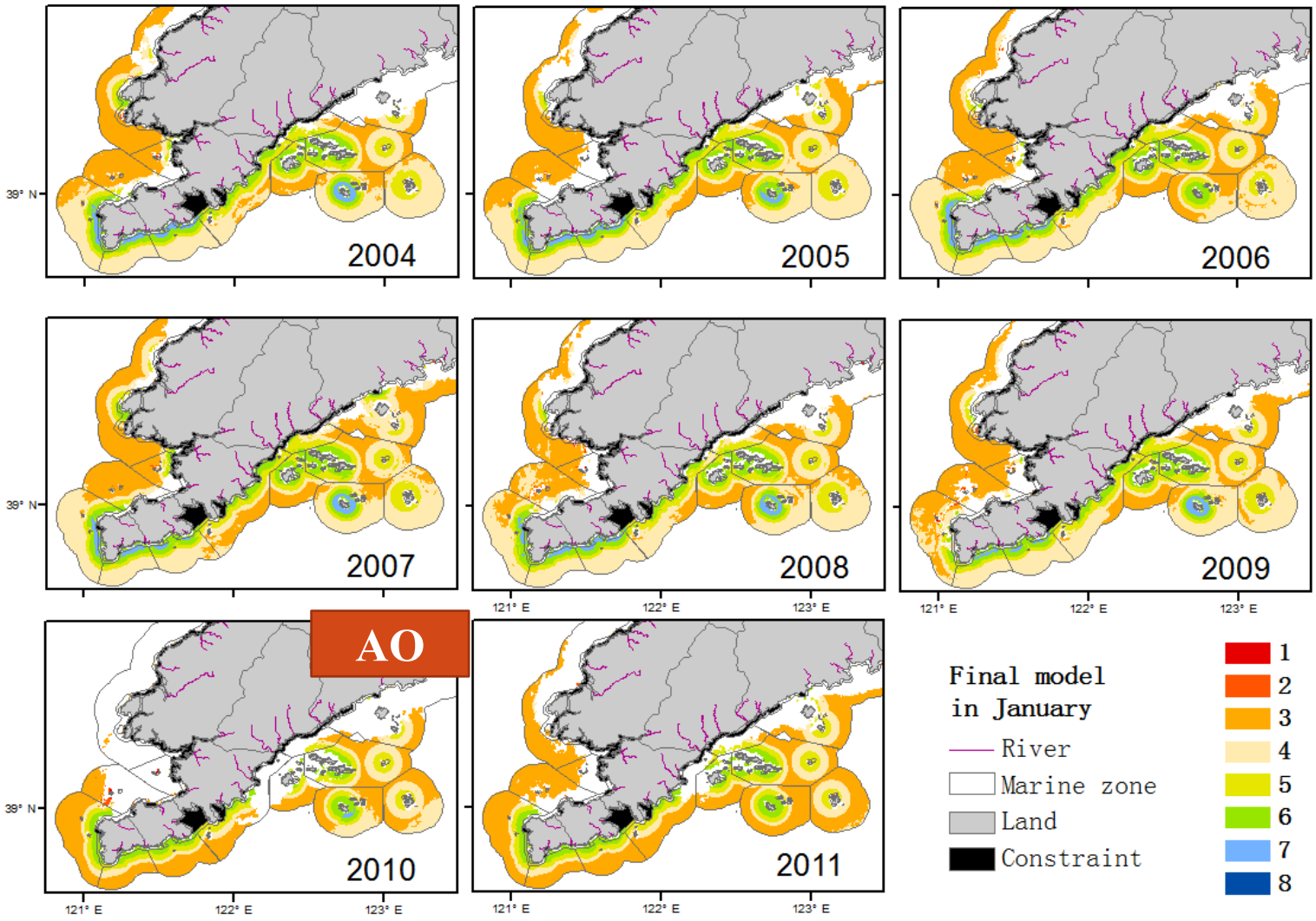
Final suitability maps（2004-2011）



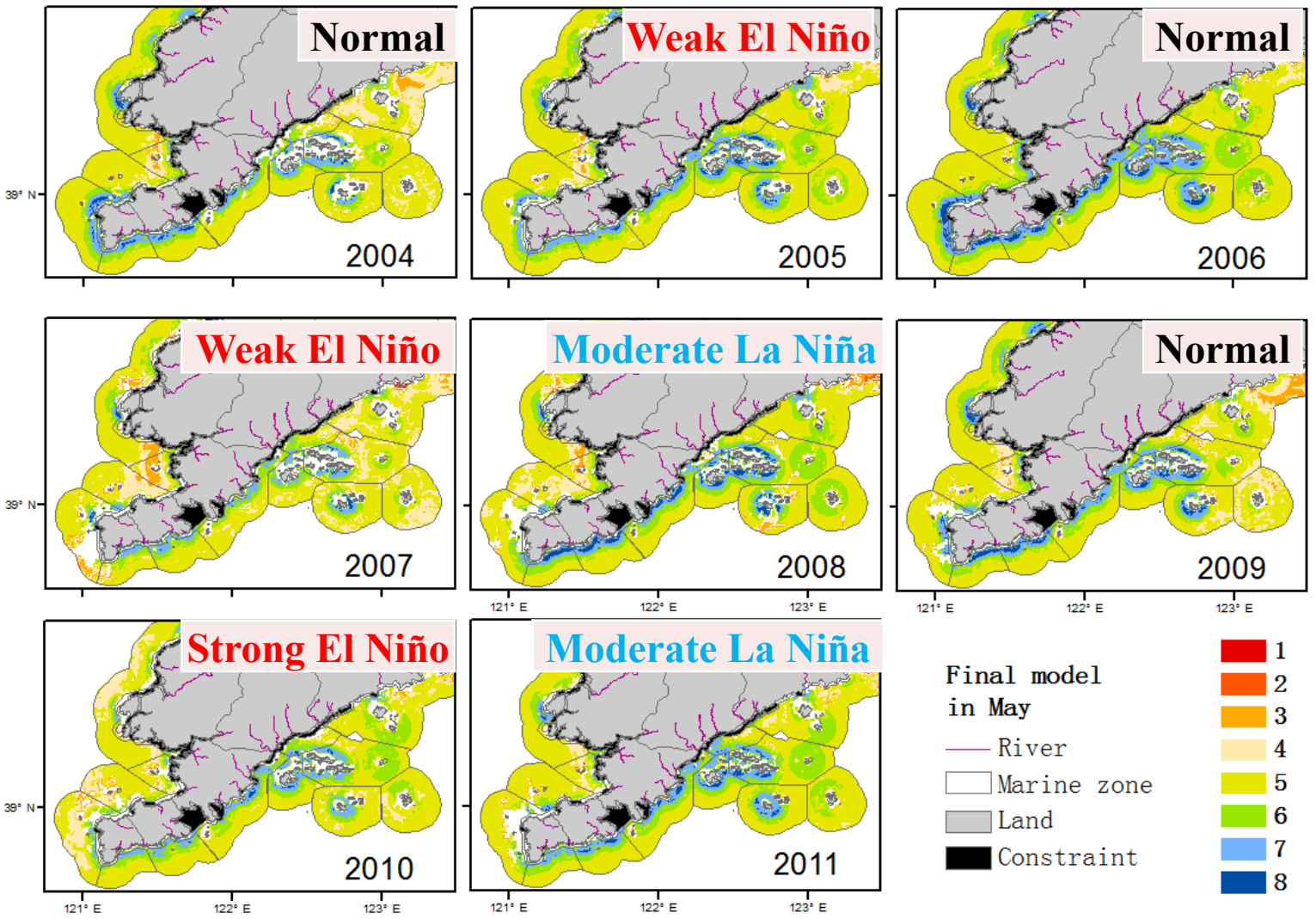
Results and Discussion



Results and Discussion



Results and Discussion



Results and Discussion

Different suitability levels (expressed as percentage of the total potential area) with ENSO events for Japanese scallop aquaculture site selection in Dalian, China

Year	Suitability scores (%)								ENSO events
	1	2	3	4	5	6	7	8	
Apr-May 2004	0.0%	0.9%	3.0%	26.2%	49.0%	13.6%	6.3%	0.9%	Normal
Apr-May 2005	0.0%	0.0%	7.6%	29.5%	41.4%	15.1%	5.7%	0.7%	Weak El Niño
Apr-May 2006	0.1%	0.6%	3.1%	32.6%	39.4%	15.9%	6.8%	1.4%	Normal
Apr-May 2007	0.1%	0.7%	4.1%	27.5%	49.2%	12.8%	5.3%	0.3%	Weak El Niño
Apr-May 2008	0.3%	5.6%	5.0%	26.8%	40.7%	15.3%	5.1%	1.2%	Moderate La Niña
Apr-May 2009	0.0%	0.1%	2.9%	35.1%	40.0%	14.5%	6.3%	1.1%	Normal
Apr-May 2010	0.0%	0.1%	18.0%	26.9%	37.6%	13.4%	3.9%	0.1%	Strong El Niño
Apr-May 2011	0.0%	0.0%	4.3%	33.8%	39.6%	16.1%	5.5%	0.6%	Moderate La Niña

Conclusions

- GIS–based model is an effectively tool to identify the most suitable areas for Japanese scallop development.
- Changhai County and Lushunkou areas have more potential area for scallop aquaculture development.
- Change of sea surface temperature significantly affected the suitable areas.
- Climate condition needs to be considered for future development of marine aquaculture.

Thank you very much

Laboratory of Marine Bioresource and Environment Sensing,
Faculty of Fisheries Sciences, Hokkaido University, Japan.

E–mail: yangliu315@salmon.fish.hokudai.ac.jp