Use of ecosystem models for study and management of coastal estuarine ecosystems in Korea

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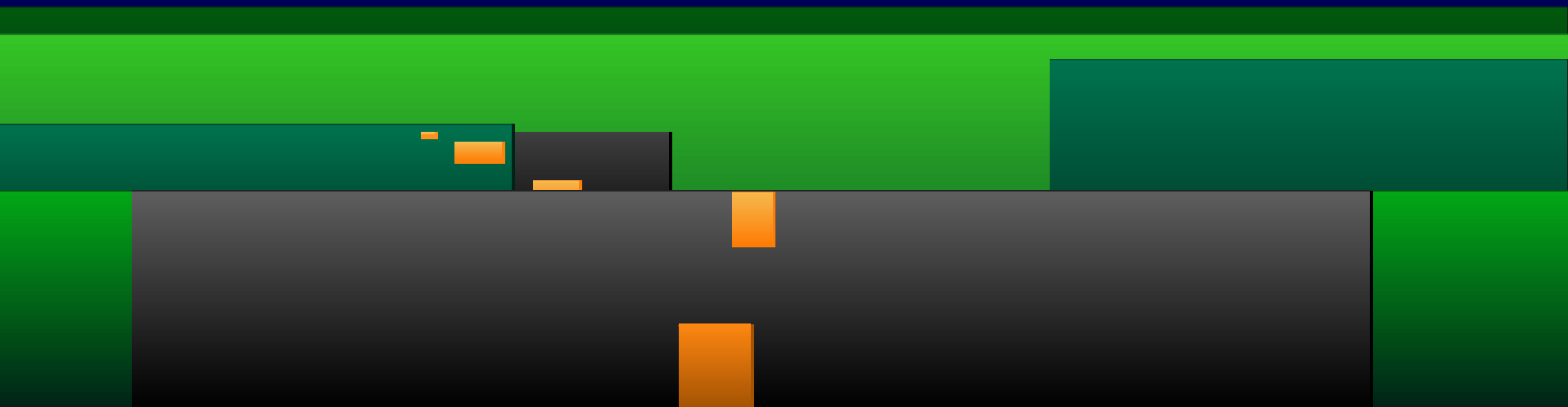

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- Steps of ecosystem model development
- Examples of ecosystem models
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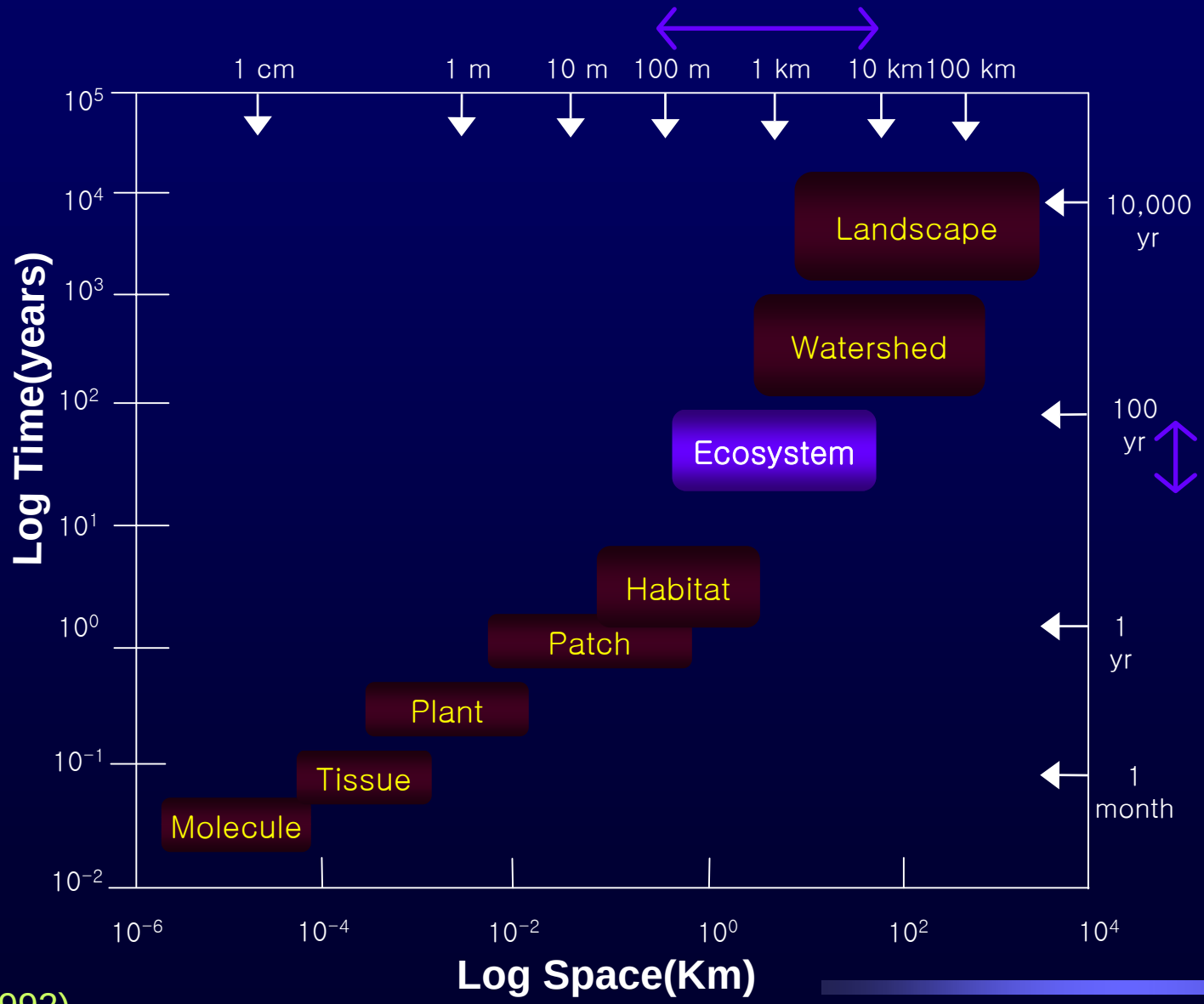
BACKGROUND

- Coastal estuarine dynamics
  - Complex mainly due to freshwater from adjacent land & tidal energy inputs from coastal ocean
  - Internally steep physical, chemical and biological gradients and high spatial and temporal heterogeneity

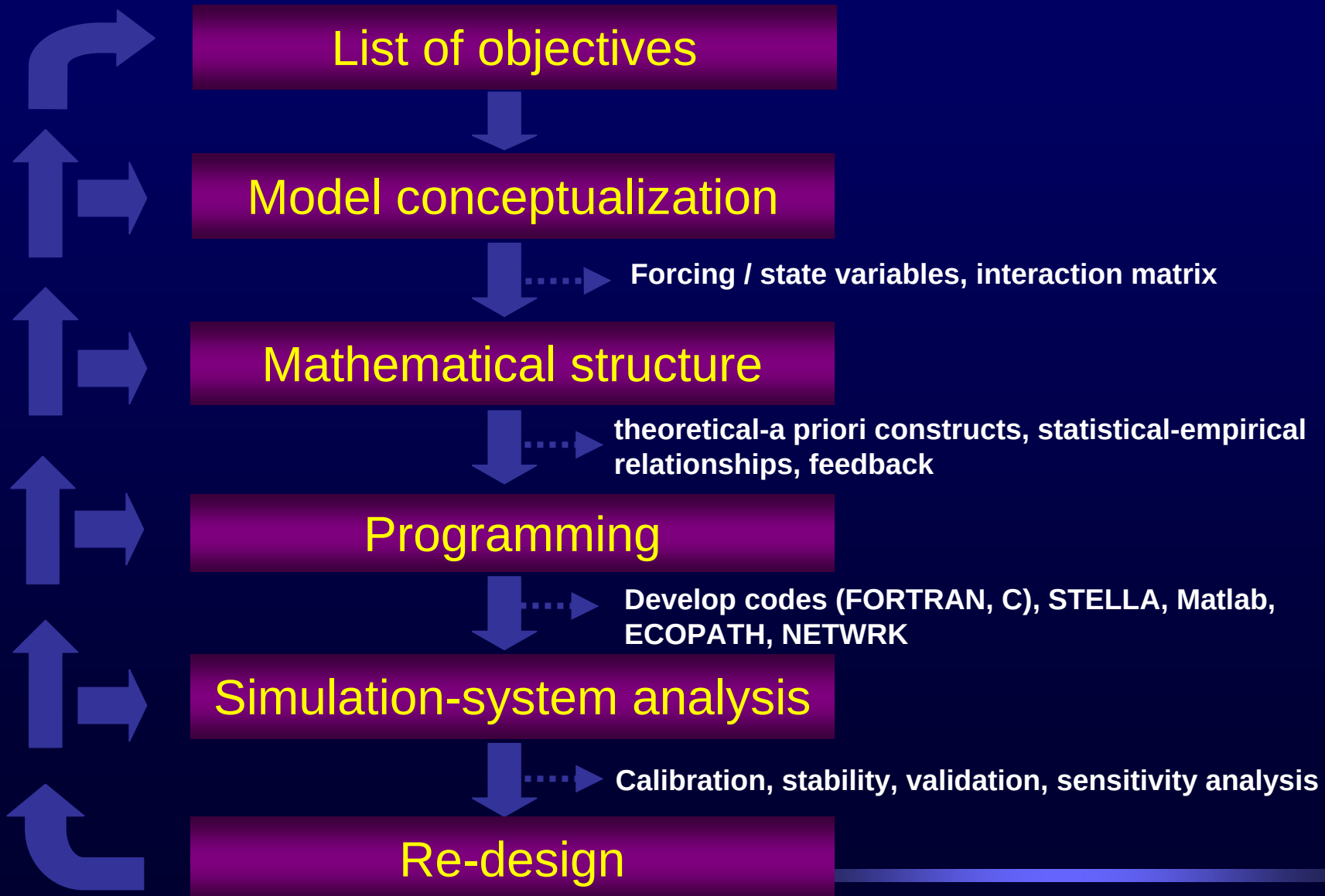
- Simulation models (simplification of systems)
  - Ability to integrate a vast array of information from multidisciplinary research and describe interactions between living resources and environments
  - Useful tools:
    ① to plan and guide research programs
    ② to identify data weaknesses and gaps
    ③ to formulate testable hypotheses about system's structure and function
    ④ to evaluate management-oriented alternatives

SPACE-TIME SCALES OF SYSTEMS ANALYSES

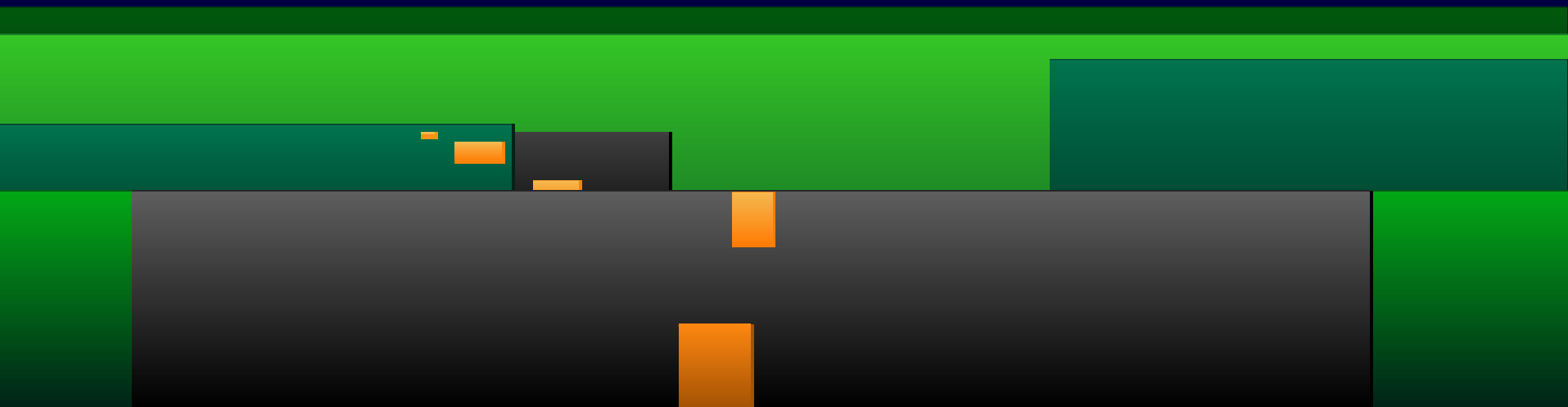


Holling (1992)

DEVELOPMENT OF ECOSYSTEM MODEL



I. Saemangeum plankton ecosystem model



Satellite Images

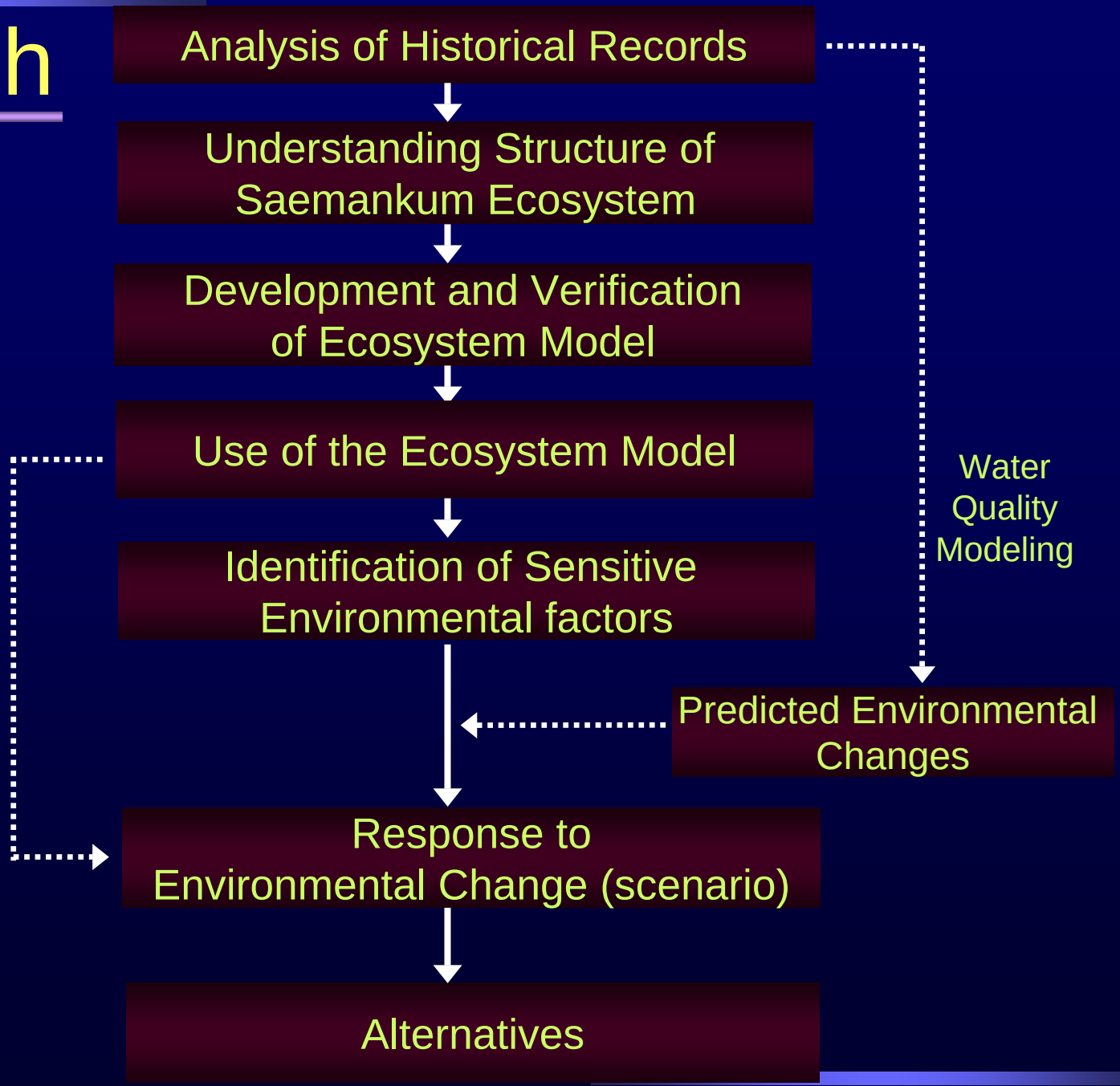
Background

- Construction of a dike and land reclamation in Saemangeum
  - Period: 1991 – 2011 (34km dike)
  - 2004: 32.3 km constructed (95 %)
  - Cost: 3.26 trillion won ($3.11 billion USD)

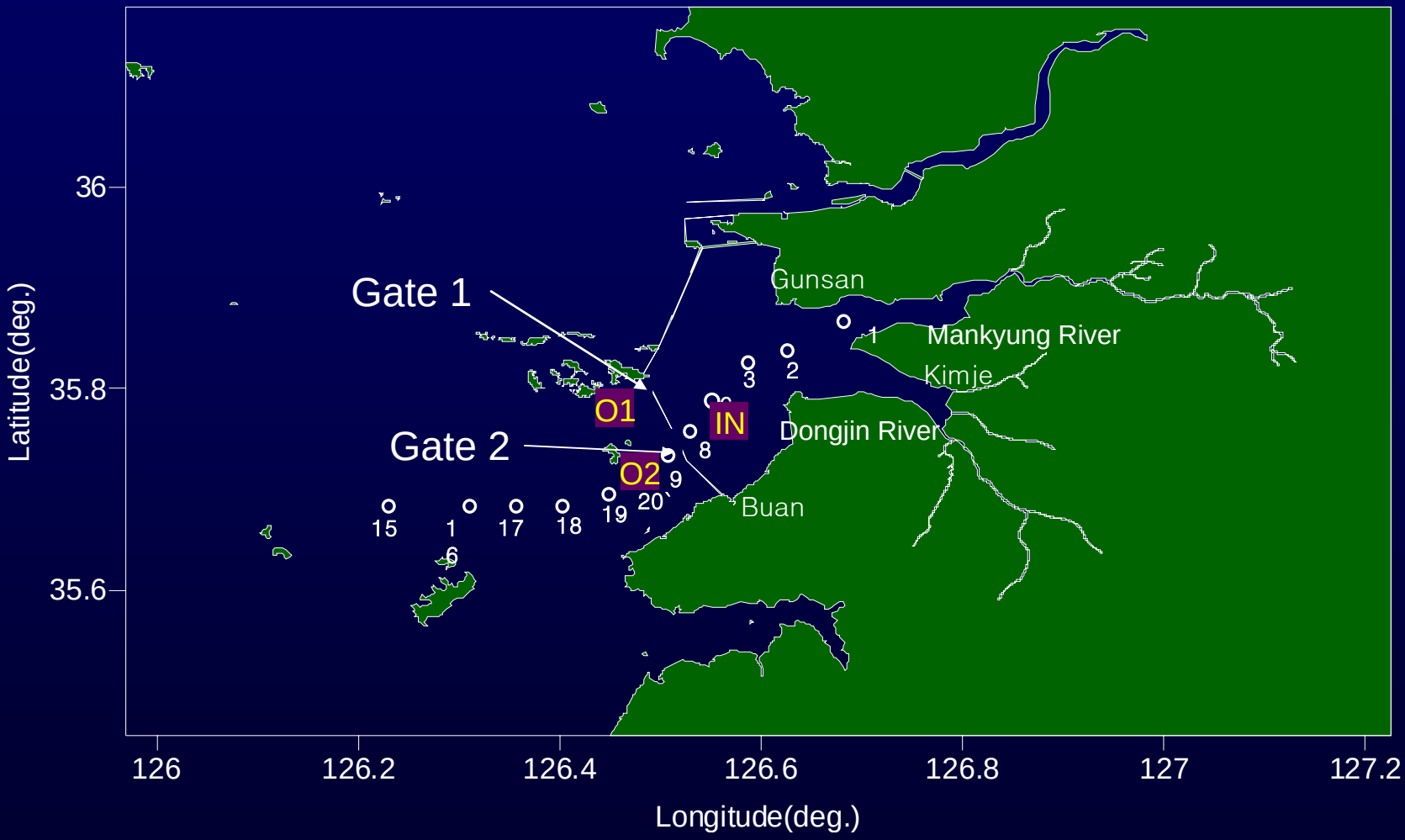
- Monitoring and modeling studies (2002 – current)
  - Multisciplinary (physio-, geo-, chem- and biology) survey supported by Korean Ministry of Maritime Affairs and Fisheries

- Objective of ecosystem modeling analysis (2004 –)
  - to identify sensitive environmental factors
  - to predict response of Saemangeum ecosystem to the environmental disturbance resulting from construction of the dike and land reclamation

Approach

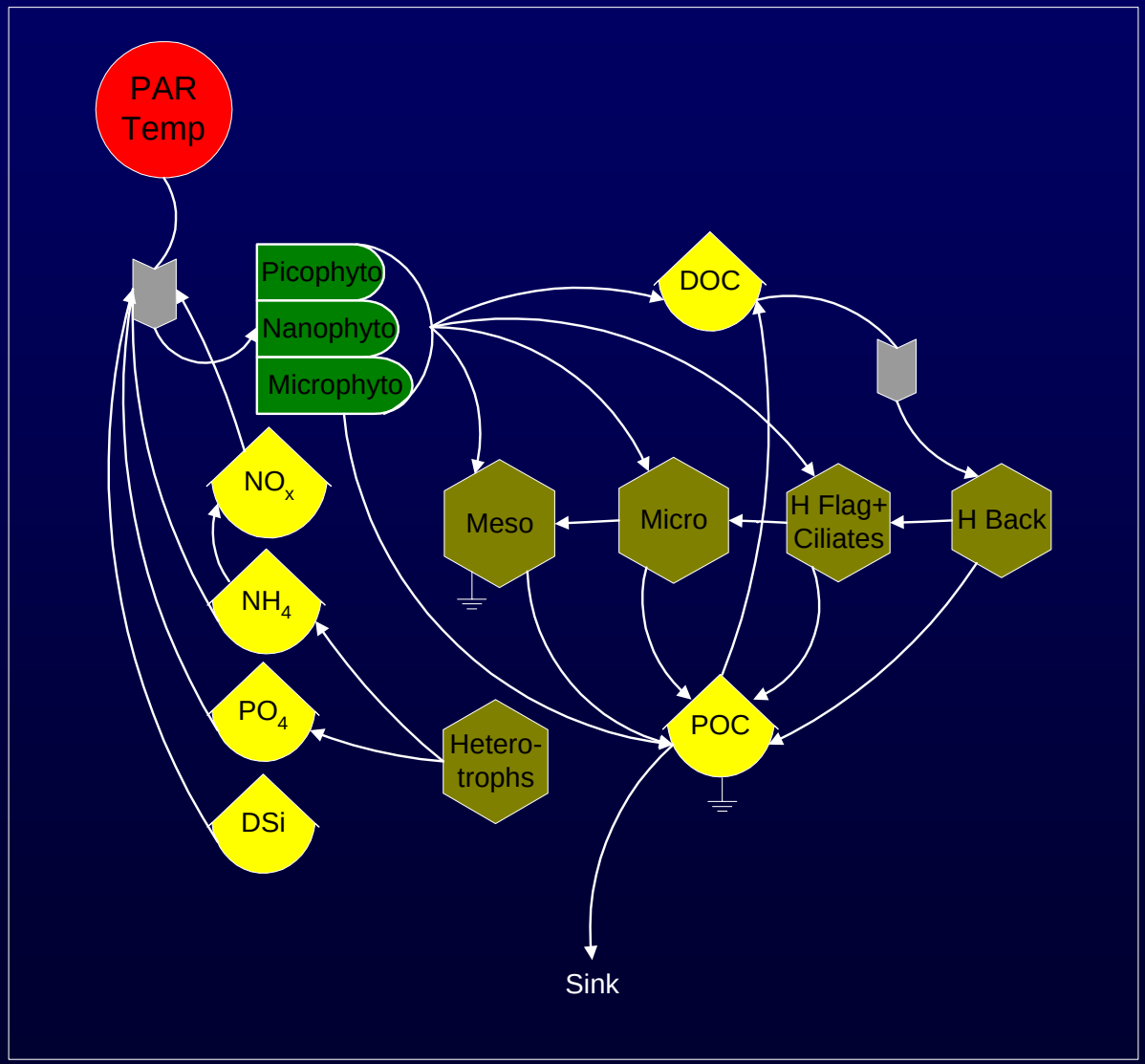

Analysis of Historical Records
Understanding Structure of Saemankum Ecosystem
Development and Verification of Ecosystem Model
Use of the Ecosystem Model
Identification of Sensitive Environmental factors
Water Quality Modeling
Predicted Environmental Changes
Response to Environmental Change (scenario)
Alternatives

Sampling and modeling stations



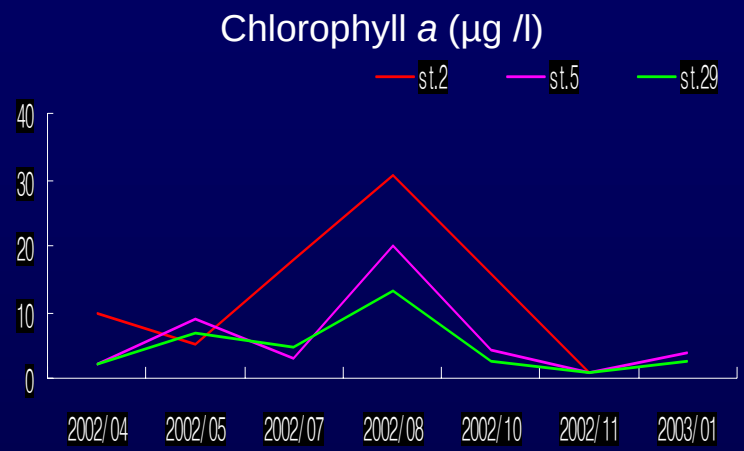
: Modeling Stations

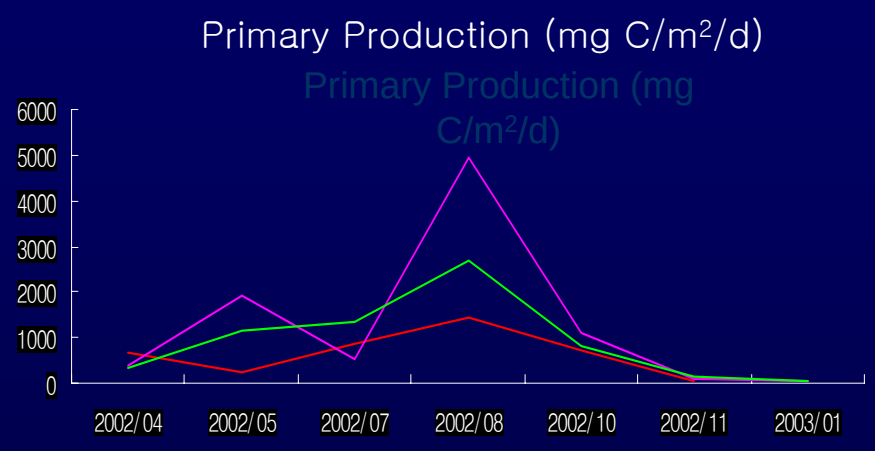
Conceptual Structure

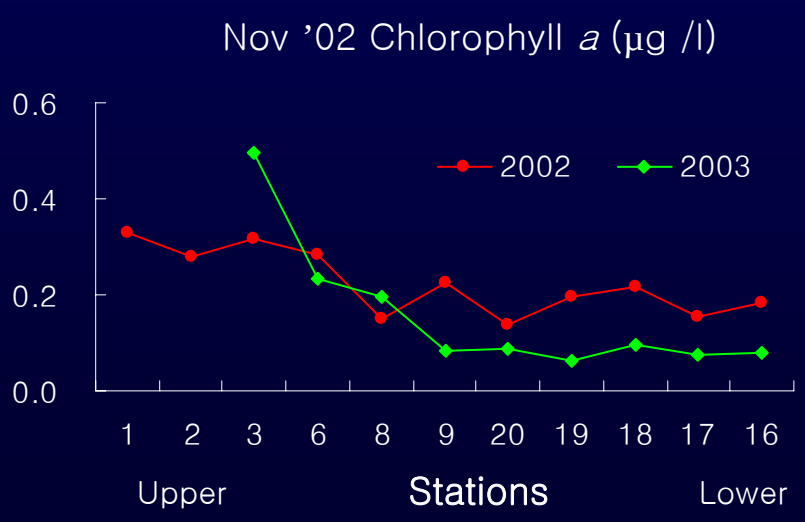


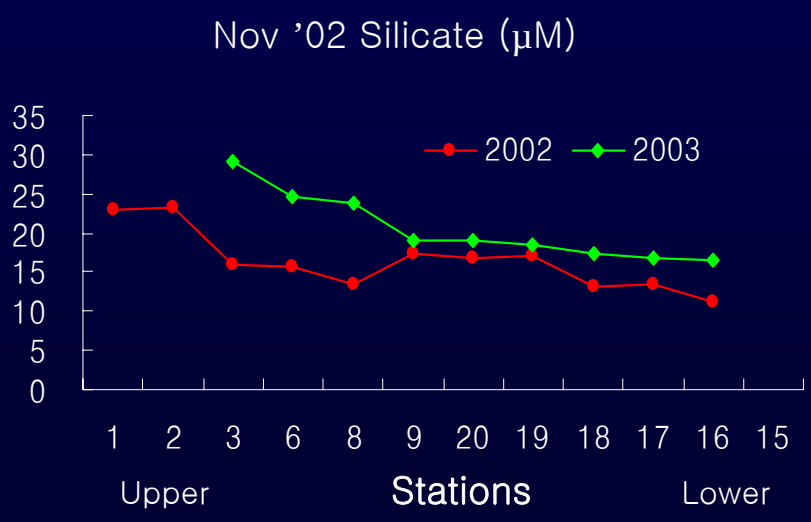
- Conceptualization based on historical data analysis
  - 12 state variables + forcing variables such as light and temperature
  - Mixotrophes not considered

Saemankum Pelagic Ecosystem

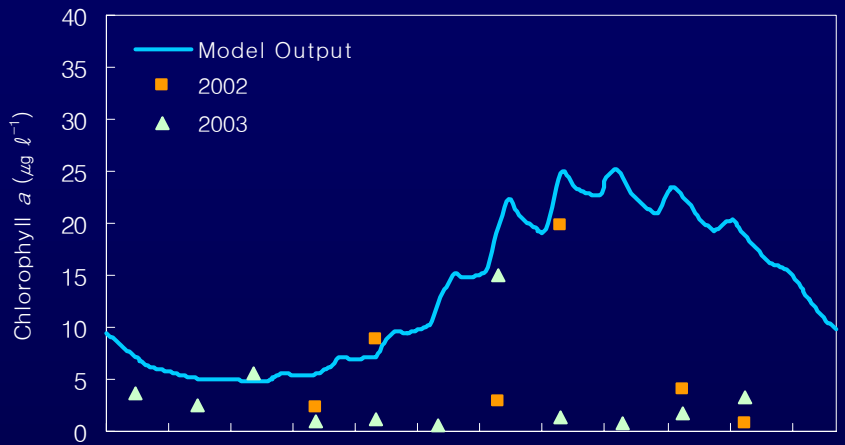


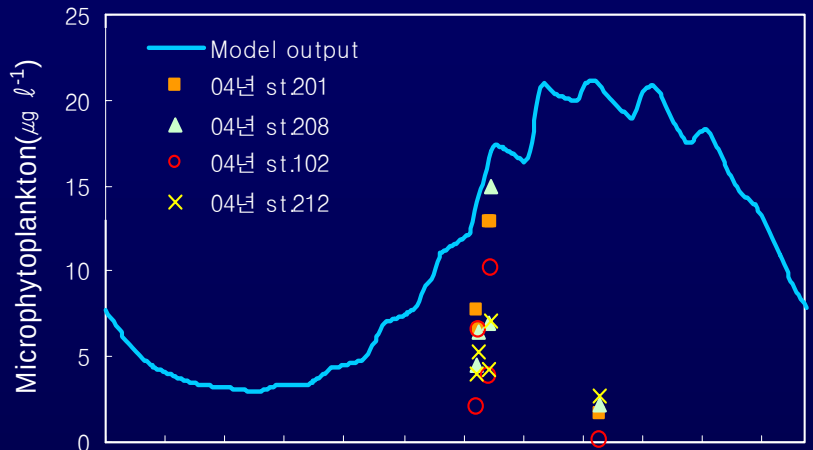


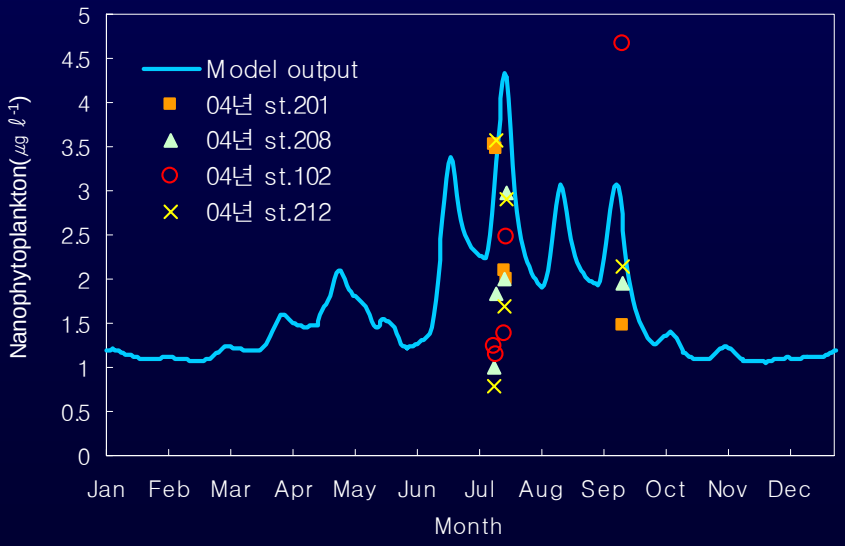


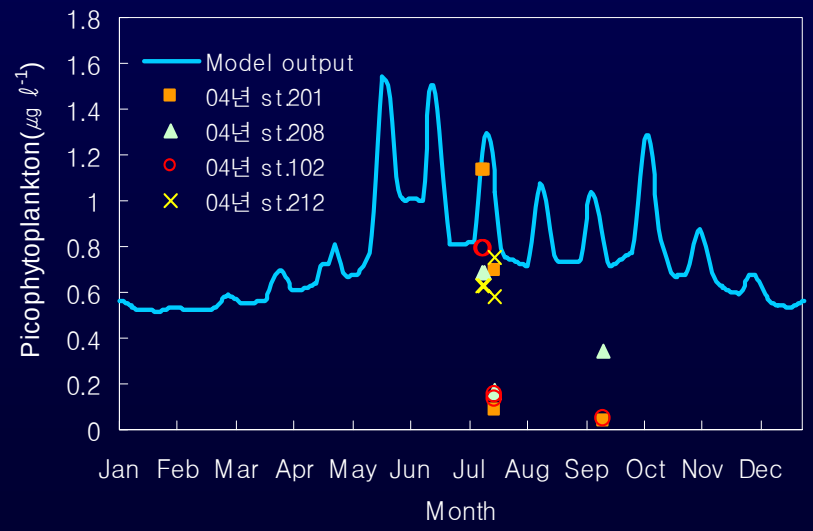


Model Validation (IN)







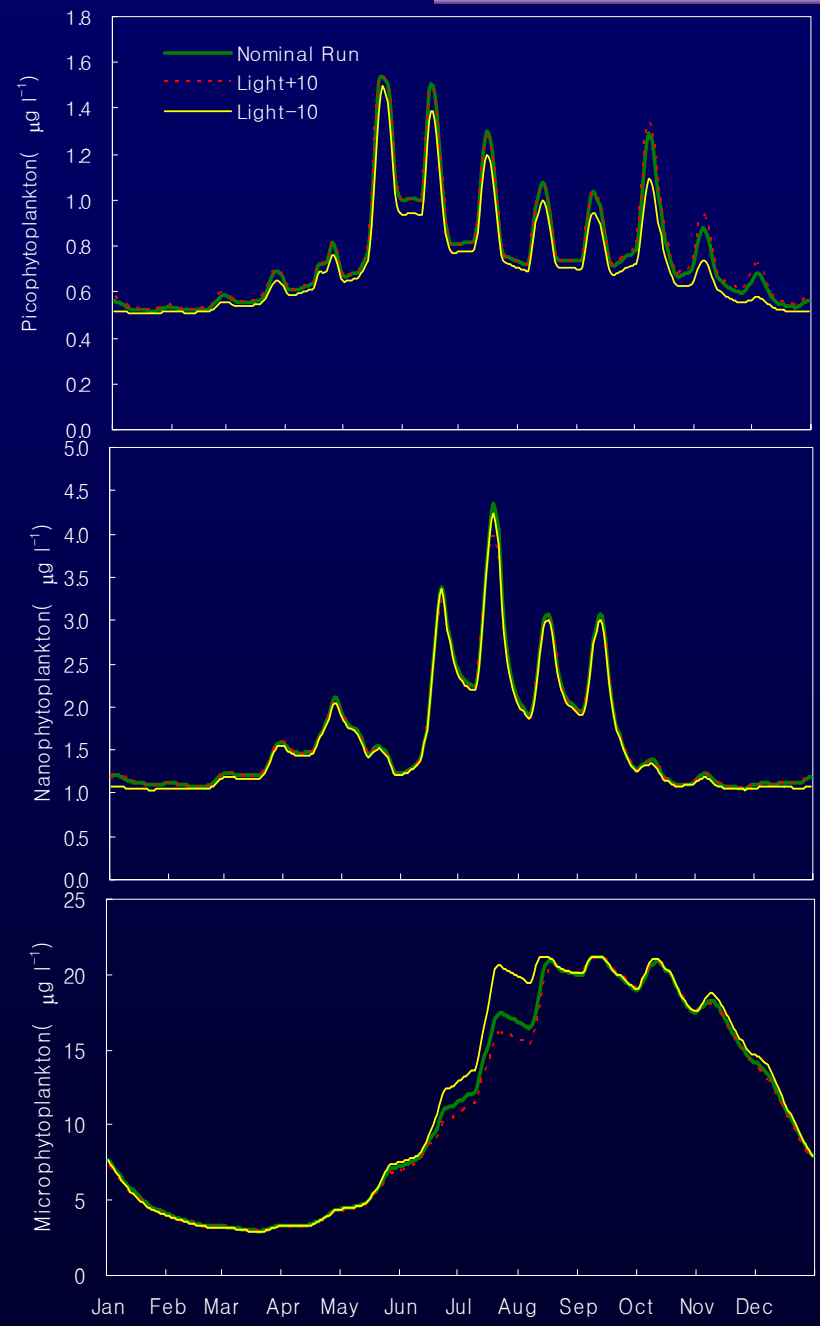


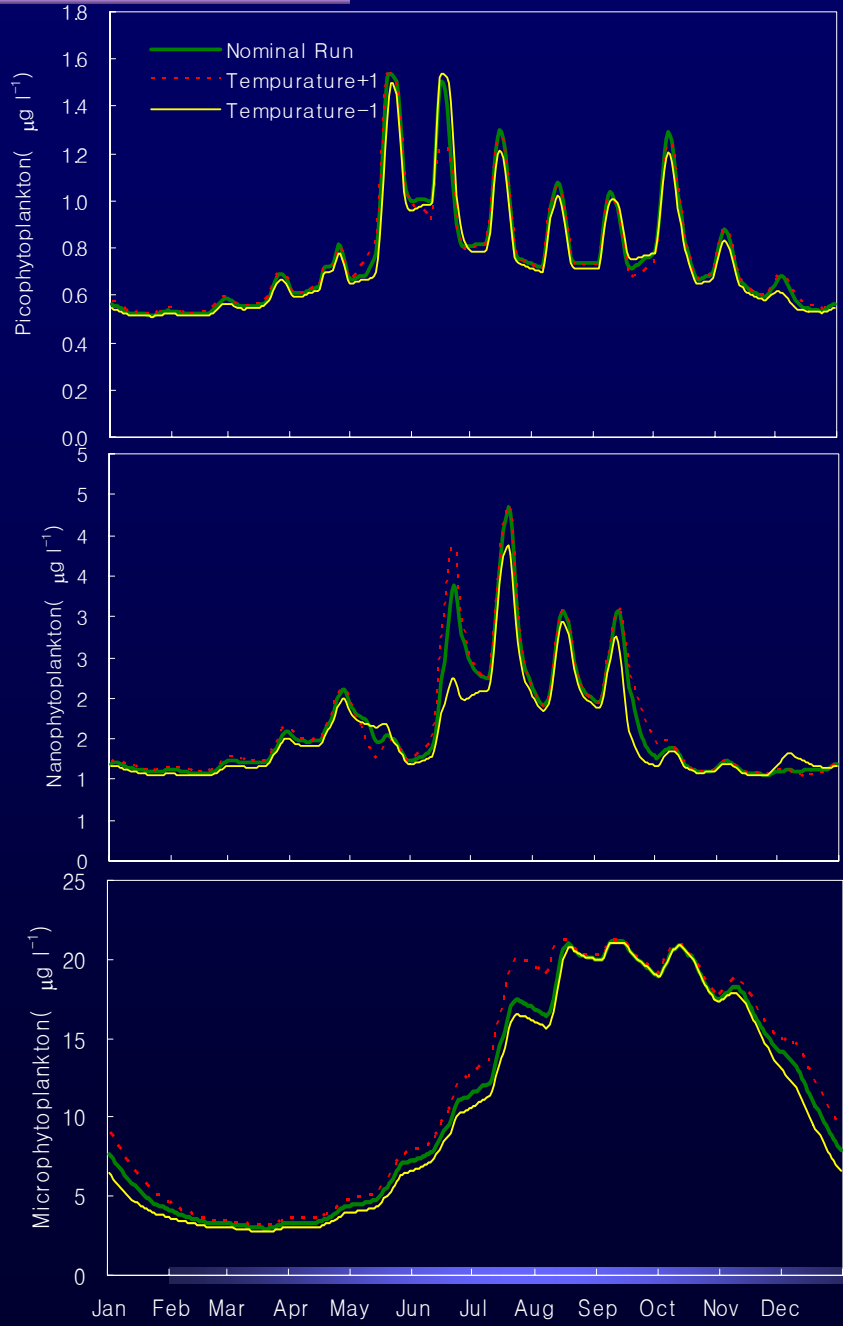
Model Stability (IN)

Parameters	State Variable											
	PP	NP	MP	HB	HP	Z1	Z2	POC	DOC	NH_4	NO_x	PO_4
Optimum light												
Exudation rate												
Grazer Preference												
Cell mass												
Mortality rate						0.0025/**11**	0.001/**18**					
Fraction of sloppy feeding						0.0032/**13**	0.0011/**18**					
Fraction of egestion						0.0032/**14**	0.0011/**18**					
Grazing by fishes							0.0007/**12**					
Grazing loss rate												
Leaching rate												
C:N ratio												
Denitrification												
C:P ratio												
N:P ratio												
C:Chl ratio												

RMS / % change to 10% changes of parameters (PP picophyto, NP nano-, MP micro-, HB heterotrophic bacteria, HP protozoa, Z1 microzooplankton, Z2 meso-)

Model Sensitivity (IN)





Design of Scenarios

Scenarios	Development stage	Water quality criteria
B	Dongjin region land-filled and gate 1 open all the time	
C	All regions land-filled and gate 2 open at flooding alone	C1: 3rd criteria of the freshwater discharged C2: 4th criteria C3: 5th criteria

Scenario Prediction
(% biomass change)

	Variables / Scenario	picophyto	nanophyto	microphyto	bact	protozoa	microzoo	mesozoo
Outside 1 (O1)	**B**	-0.84	-1.50	-1.31	-0.26	-5.04	-0.42	1.21
	C1	-0.93	-1.89	-9.21	-0.25	-4.84	-0.39	-0.42
	C2	-0.63	-1.10	-1.97	-0.17	-3.35	-0.30	0.80
	C3	-0.72	-1.22	-1.60	-0.20	-3.89	-0.37	1.11
Outside 2 (O2)	**B**	-0.90	-3.03	-0.90	-0.27	-2.89	-1.09	1.43
	C1	0.22	0.86	0.37	0.08	0.92	0.32	-0.82
	C2	0.14	0.58	0.87	0.04	0.48	0.19	-0.19
	C3	0.28	1.16	1.55	0.09	0.96	0.37	-0.53

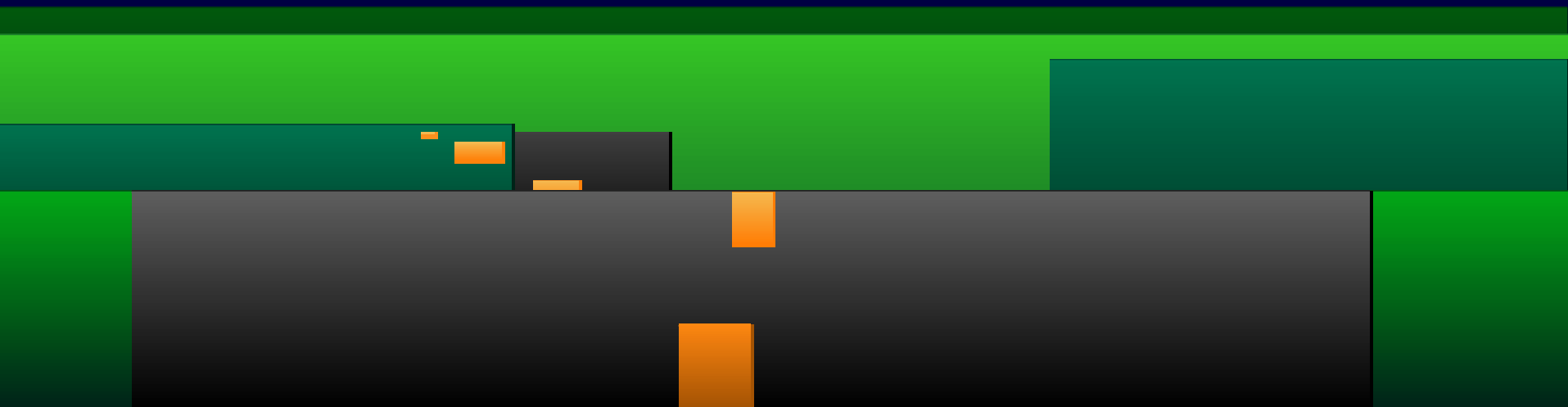
Pico(nano, micro)phyto=pico(nano, micro)phytoplankton; bact=heterotrophic bacteria; micro, mesozoo=micro, mesozooplankton

Summary

- Response of phytoplankton to changes of environmental variables is size-dependent in the modeling analyses for the Saemankum
- Water temperature may be more important factor than light intensity to control phytoplankton biomass in the Saemankum
- Response of plankton ecosystem in the outside region 1 near gate 1 is more likely sensitive to expected change of environmental disturbance than outside region 2 near gate 2.

II. Seagrass Ecosystem Model in the Kwangyang Bay

Yongsik Sin, Richard Wetzel



Kwangyang Bay

1994.7

2002.3

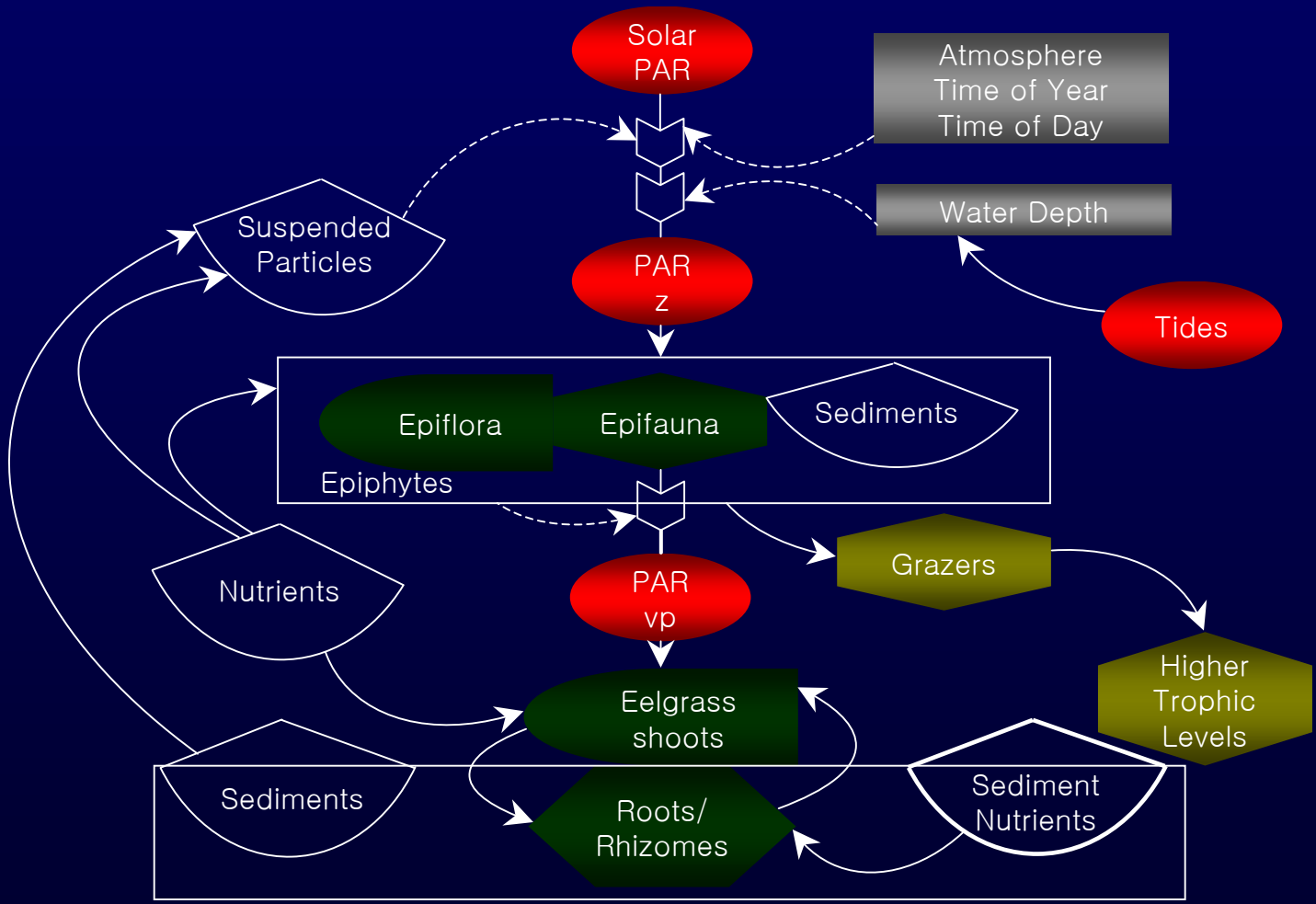
Aquaculture and fisheries active
(productive)

Land reclamation and industry activity ↑
Aquaculture and fisheries declined
Water quality declined

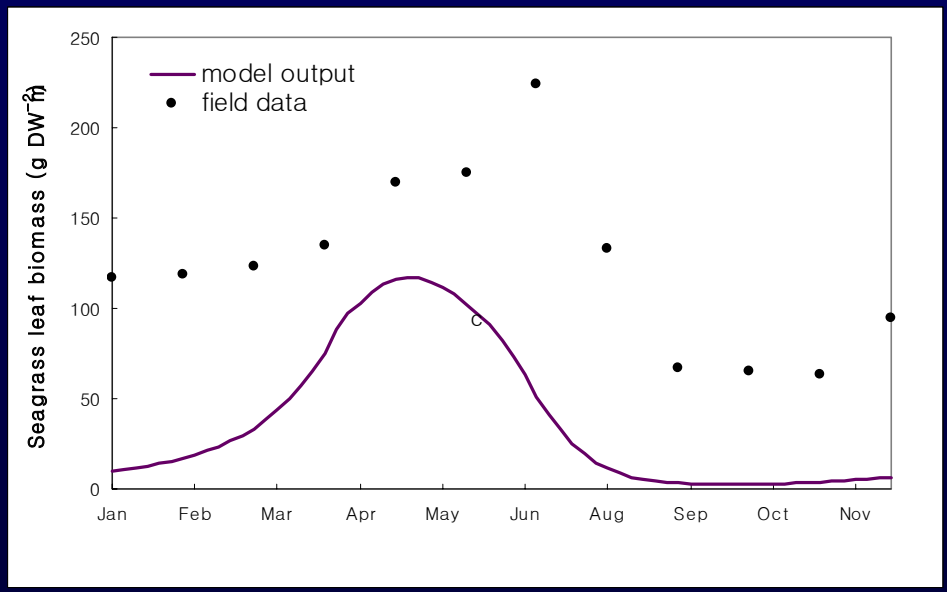
Background

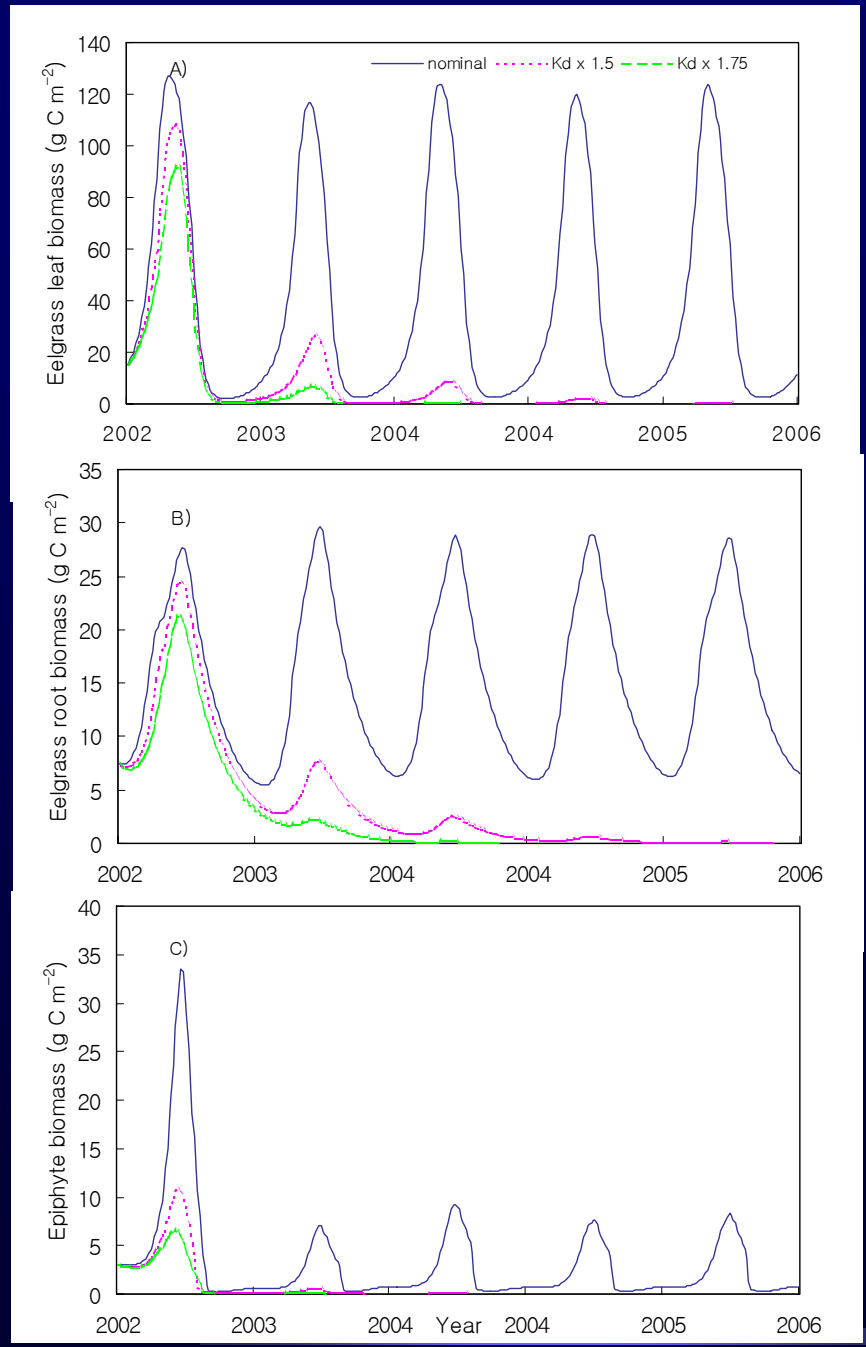
- Seagrass (SAV; Submerged Aquatic Vegetation) ecology
  - Benthic primary producer; sediment stabilization
  - Substrate for epiphytic algae, sessile invertebrates
  - Habitats for various lives (fish, shellfish, benthos etc.)
  - Indicator of water quality (especially water turbidity)
- Seagrass in the Kwangyang Bay
  - Dominant species in the Kwangyang Bay; *Zostera marina* (eelgrass)
  - Eco-physiological model for *Zostera marina (Wetzel & Neckles 1986)*
- Objective:
  - to identify major factor controlling the seagrass biomass using a seagrass ecosystem model
  - to suggest the water quality criteria to sustain seagrass habitats in the Kwangyang Bay

Conceptual Structure



Model validation and analysis





Summary

- The principal controlling factor for the dominant species *Zostera marina*: water clarity
- A reliable prediction of SAV survival and depth distribution (submarine light)
- A tool to test specific water quality habitat criteria in relation to achievement of ecosystem restoration goals (water quality management)

Conclusion

- Response of phytoplankton to changes of environmental variables is size-dependent and water temperature may be more important factor than light intensity to control phytoplankton biomass in the Saemangeum
- Response of plankton ecosystem in the outer region 1 is more likely sensitive to change of environmental disturbance than outer region 2.
- Water clarity may be an important factor to control the seagrass biomass in the Kwangyang Bay
- Ecosystem models are a useful tool for understanding phytoplankton and seagrass dynamics and better management of the ecosystem and water quality in the coastal estuarine systems

Future Research

- Carrying capacity in aquaculture
- Optimum condition for aquaculturing frawns (shrimps)
- Neural network technique in dynamic modeling analysis
- Network analysis