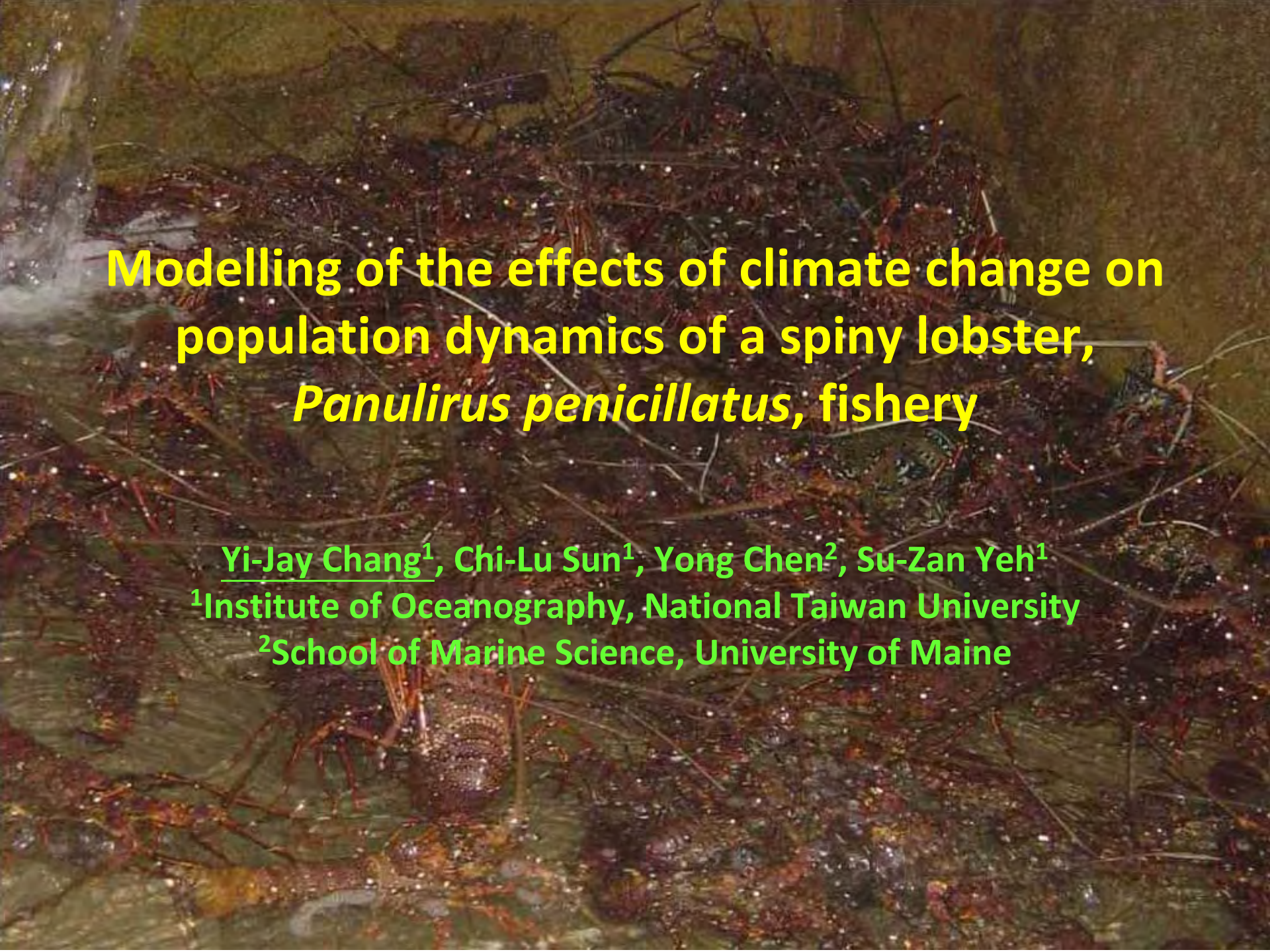

Modelling of the effects of climate change on population dynamics of a spiny lobster, *Panulirus penicillatus*, fishery

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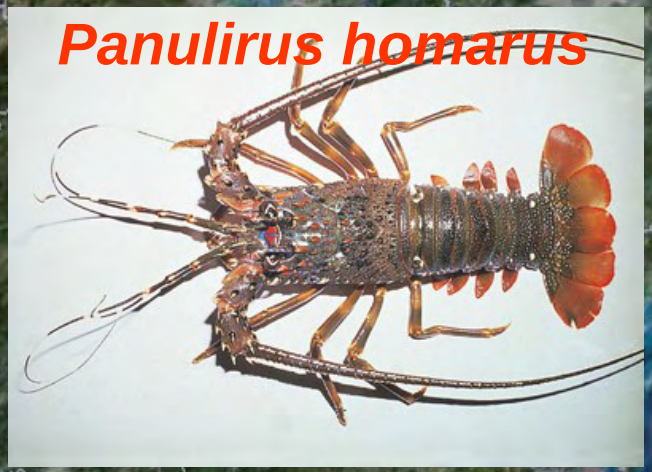
Introduction

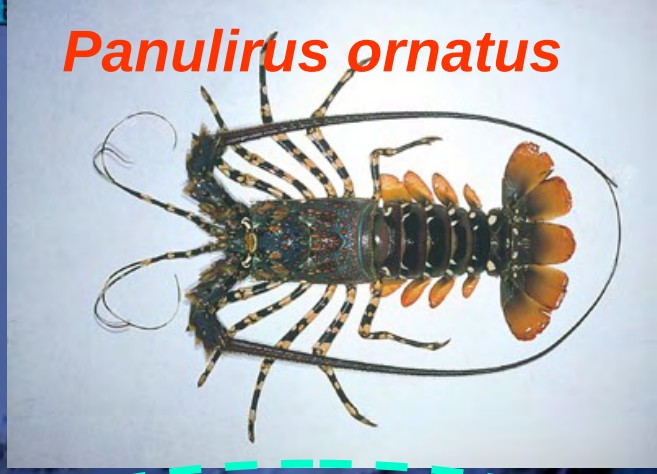
- Lobsters support some of the largest commercial fisheries in the world and artisanal fisheries. (e.g., *Homarus americanus* ; Australia rock lobsters)

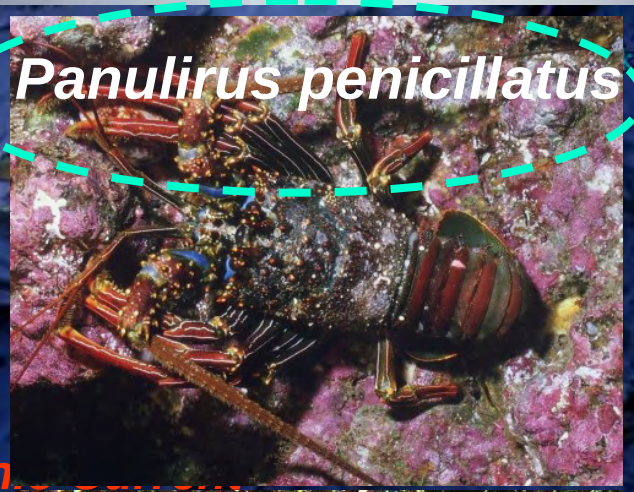
- There are important small-scale lobster fisheries in the coastal waters off Taiwan.
  - Highly prized (US$ 70/1kg; high demand in China)
  - Traditional culture (e.g., wedding banquet)

http://www.climateprep.org/wp-content/uploads/2011/05/Fishing-Boats.png

Common Lobsters in Taiwan







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The spiny fisheries in Taiwan

- Small-scale lobster fisheries (especially in eastern coast of Taiwan)
- Fishing methods: trap, trammel-nets, diving
- Regulation (e.g., legal size 20 cm TL for all lobsters)

Life cycle of palinurid lobsters

planktonic larvae

> 6 months

Late stage larvae recruit

Pueruli settlement

Nomadic

Seasonal migration

Feeding movement

Gravid females

...ics and stock productivity

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Incorporating ecological process and environmental change into spiny lobster population models using a spatially-explicit, individual-based approach

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Abstract

Marine fisheries and the ecosystems that sustain them are increasingly beset by environmental deterioration, yet traditional fishery models used for stock prediction typically handle these dynamics poorly if at all. To do so requires the integration of spatio-temporal change in environmental quality and its subsequent effects on habitat suitability and life history dynamics. Spatially-explicit, individual-based simulation models are particularly well suited to this task and, although they are seeing increased use in fisheries ecology and management, this approach has seen limited application in crustacean fisheries. In 1993, we began development of a spatially-explicit individual-based model (IBM) describing the recruitment of Caribbean spiny lobster (*Panulirus argus*) in the Florida Keys, Florida (USA) to investigate the impact of regional changes in environmental quality, habitat structure and postlarval supply on lobster recruitment. The shallow coastal waters of the Florida Keys ecosystem have experienced an unprecedented series of environmental perturbations over the past decade. Seagrass die-offs, cyanobacteria blooms, sponge die-offs and dramatic changes in salinity have occurred and these potentially impact the recruitment of spiny lobsters in the region via both direct and indirect means. Here I provide an overview of the unique approach that we have used to examine these dynamics, an approach that links environmental events that occur on large scales (e.g. changes in habitat structure and salinity) with their population-level consequences for lobsters via impacts that operate on the individual-level. Although not applicable in all situations, spatially-explicit IBMs should see wider use in crustacean fishery applications because of both the ecological insight they yield and their ability to integrate data across hierarchical scales of organization.

Keywords: Spiny lobster; Spatial modelling; Individual-based modelling; Recruitment

...cruitment
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Stock productivity

Can. J. Fish. Aquat. Sci. 67: 85–96 (2010)

The effect of climate change on the western rock lobster (*Panulirus cygnus*) fishery of Western Australia

Nick Caputi, Roy Melville-Smith, Simon de Lestang, Alan Pearce, and Ming Feng

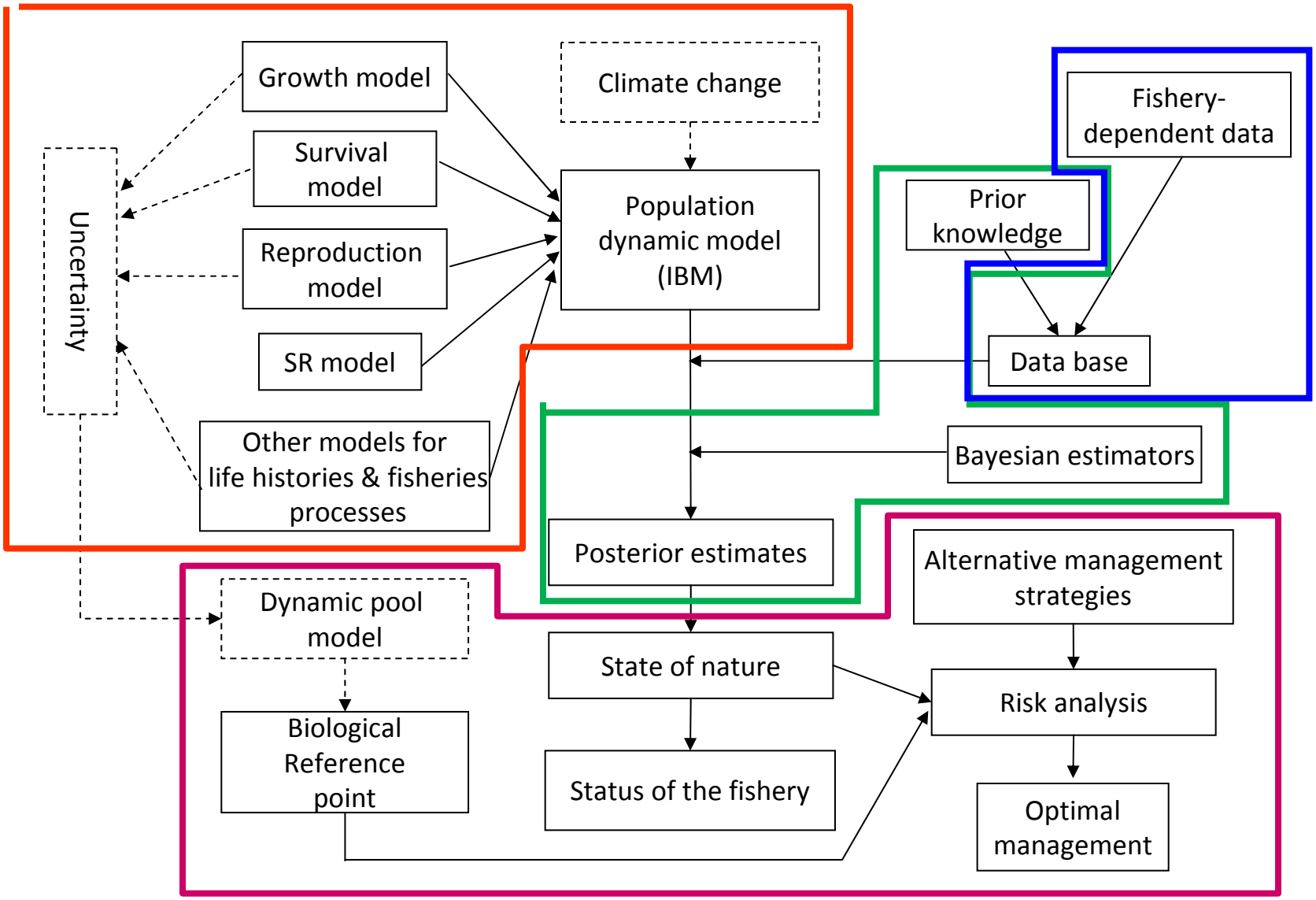
Abstract: Environmental factors such as the Leeuwin Current (influenced by the El Niño – Southern Oscillation cycle) and westerly winds in late winter – spring significantly affect puerulus settlement of the western rock lobster (*Panulirus cygnus*) fishery. Climate change is causing an increase in water temperature that is seasonally variable, a weakening of westerly winds in winter, and an increase in the frequency of El Niño events. Rising water temperatures over 35 years may have resulted in a decrease in size at maturity and size of migrating lobsters from shallow to deep water, increases in abundance of undersized and legal-sized lobsters in deep water relative to shallow water, and shifts in catch to deep water. The size of migrating lobsters is related to the water temperature about the time of puerulus settlement (four years previously). Climate change effects on puerulus settlement, catchability, females moulting from setose to non-setose, timing of moults, and peak catch rates are assessed. As climate change models project that the warming trend will continue, these biological trends are likely to continue. The changes may have negative (increasing frequency of El Niño events) or positive (increasing water temperature) implications for the fishery, which need to be taken into account in stock assessments and management.

Résumé : Les facteurs du milieu, tels que le courant de Leeuwin (influencé par le cycle austral d'oscillation d'El Niño) et

Objectives in this study

- To develop an **individual-based model (IBM)** which can incorporate the individual variability and the environmental effect into the model.
- To use the developed IBM for the stock assessment of the Taitung spiny lobster (*P. penicillatus*) fisheries
- To explore the possibility of using the developed model to evaluate the impacts of climate change on the estimation of biological reference points and the risk of overexploitation

A flowchart of stock assessment framework



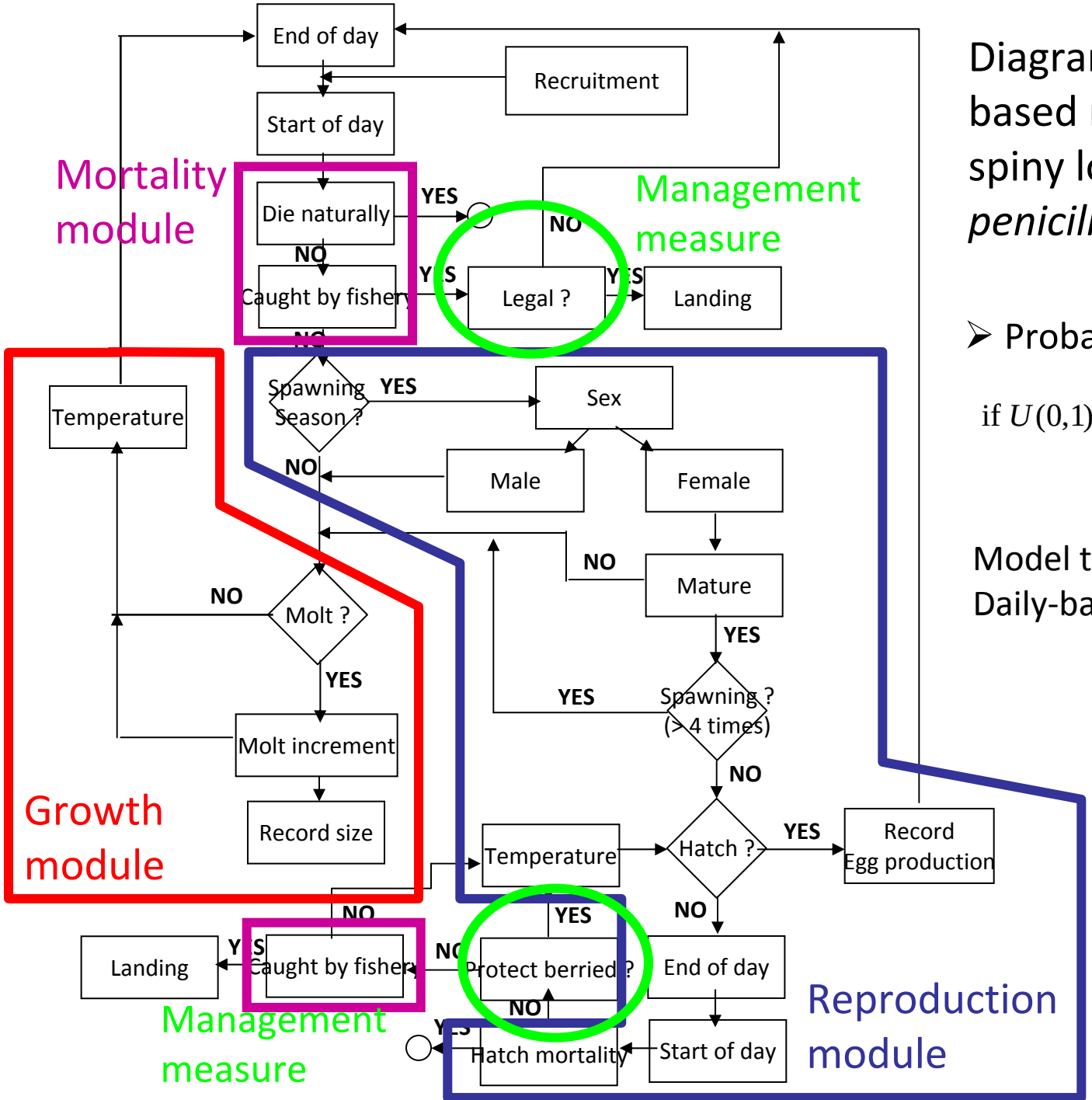
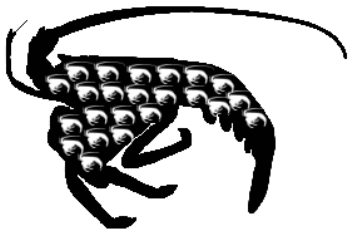


Diagram of individual-based model (IBM) for spiny lobster (*P. penicillatus*)

- Probabilistic approach

$$\text{if } U(0,1) \le 1 - e^{-M} \text{ then } N_{t+1} = N_t - 1$$

Model time
Daily-based

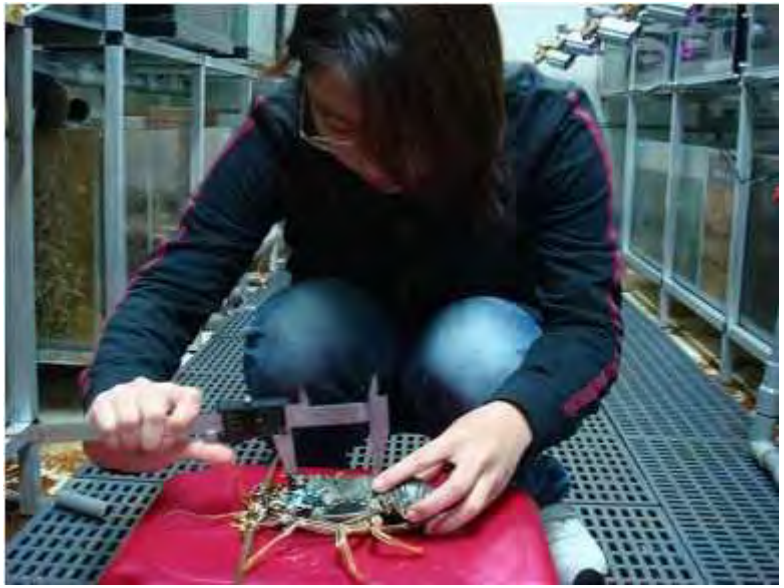


Super-individual
Scheffer *et al.*, 1995

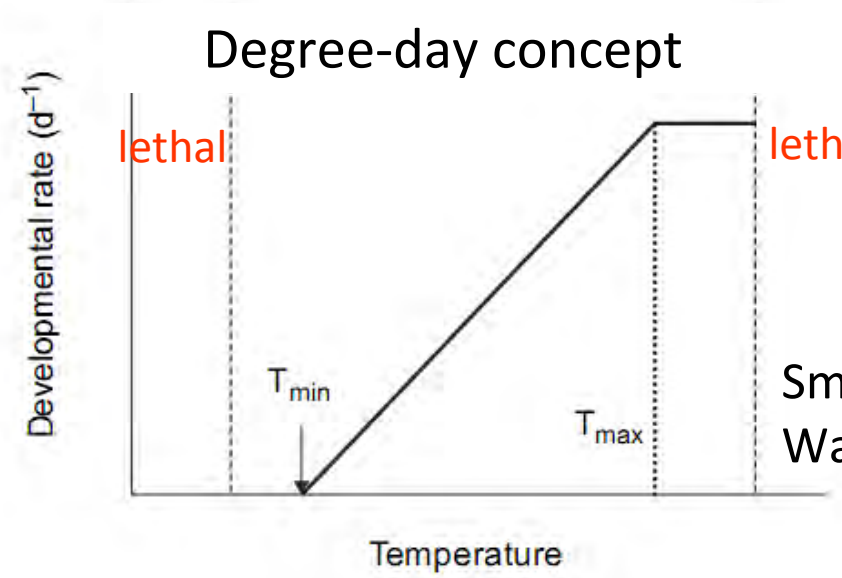
IBM's parameterization:

Our field and laboratory data (Chang et al. (2007), (2009); Huang (2009))

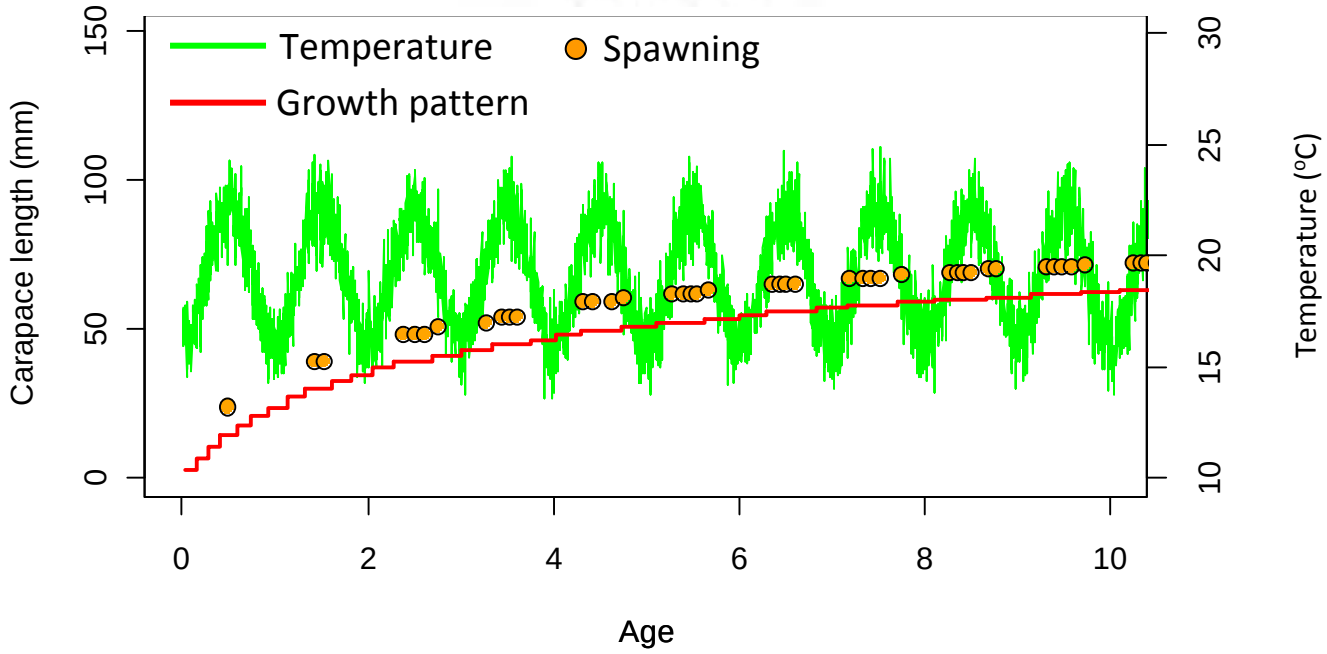
Lobster literatures



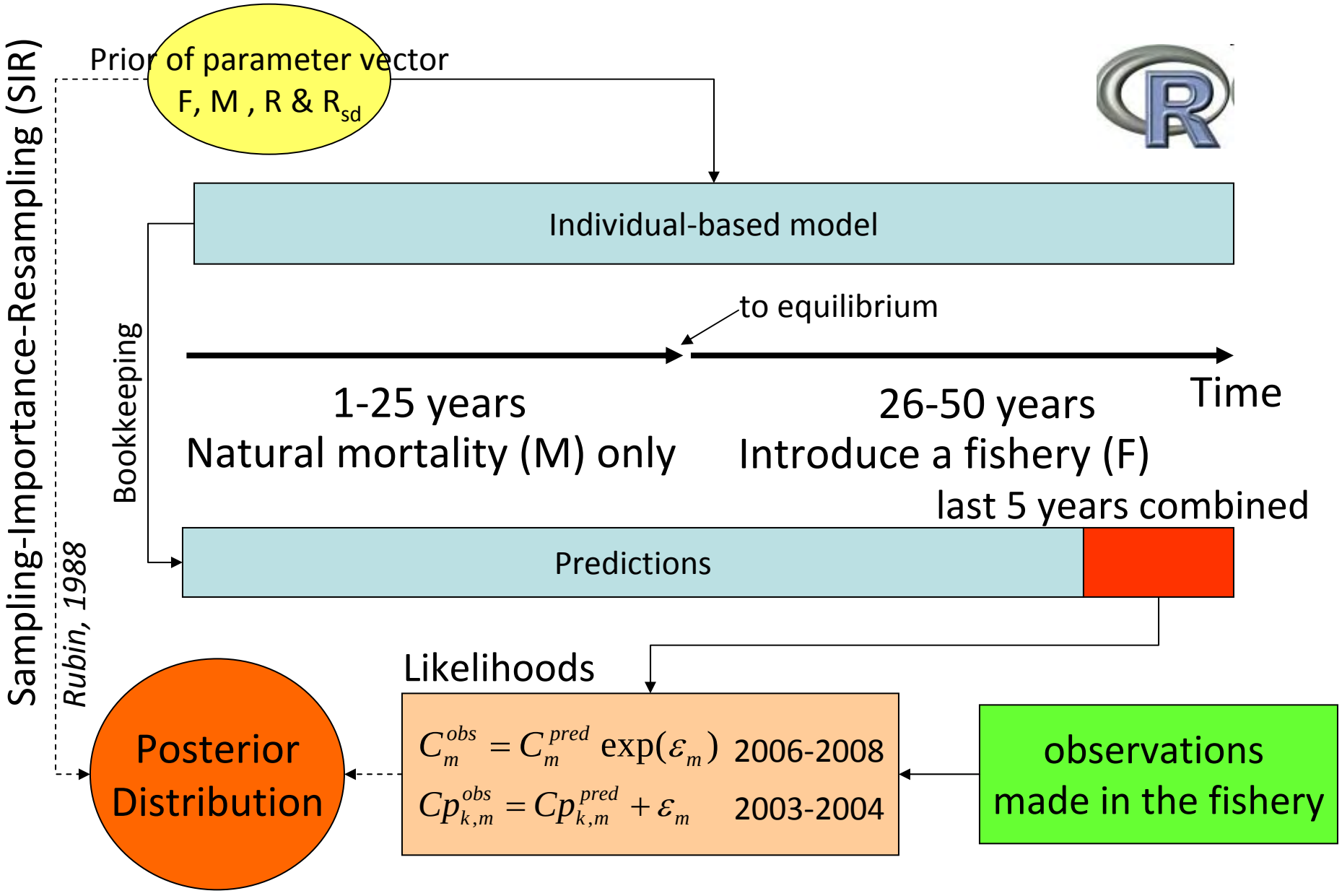
To Incorporate temperature into IBM



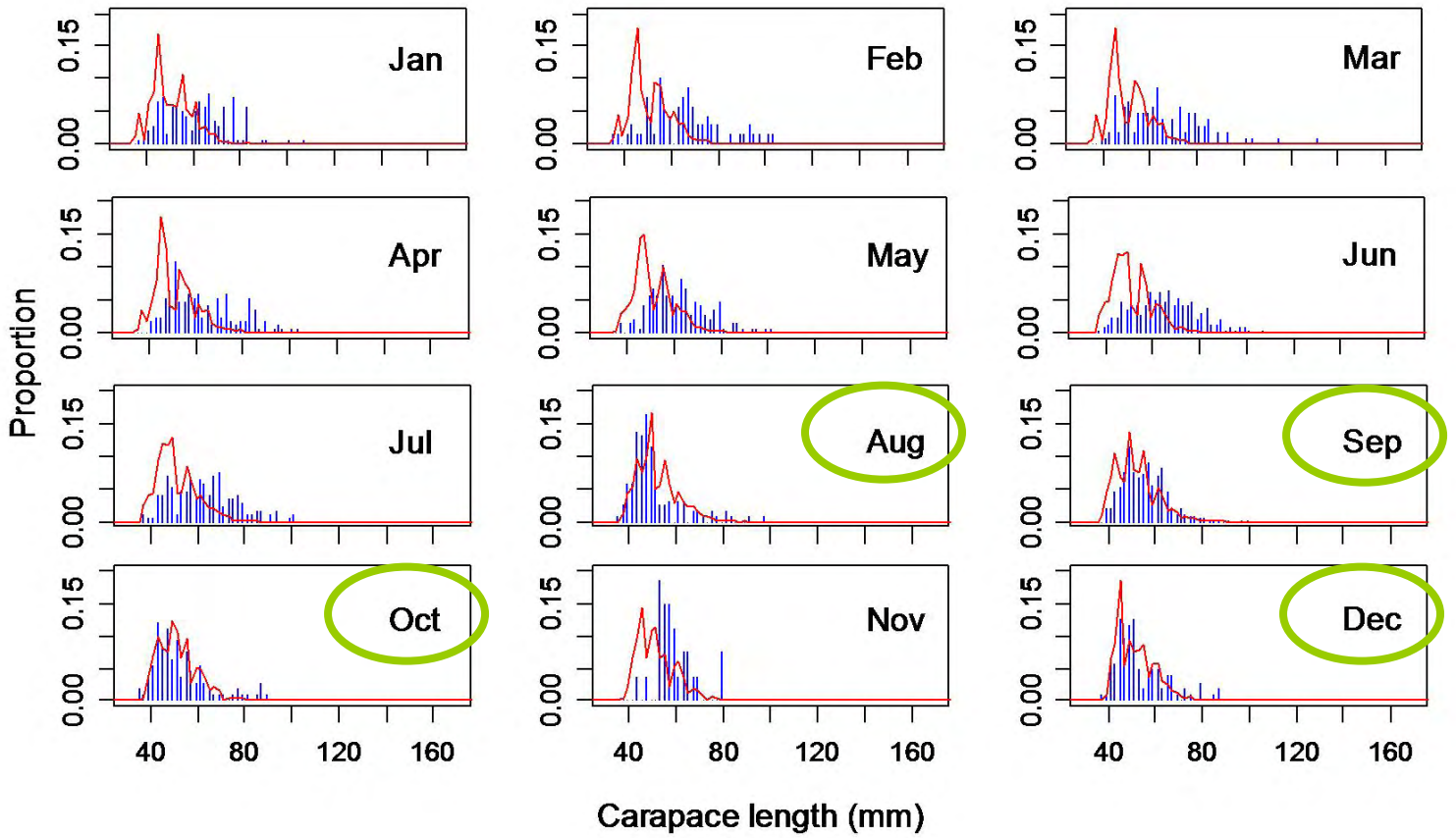
Smith (1997)
Wahle & Fogarty (2006)



Population dynamics & fishery simulation



MLE fit of catch-composition from the IBM

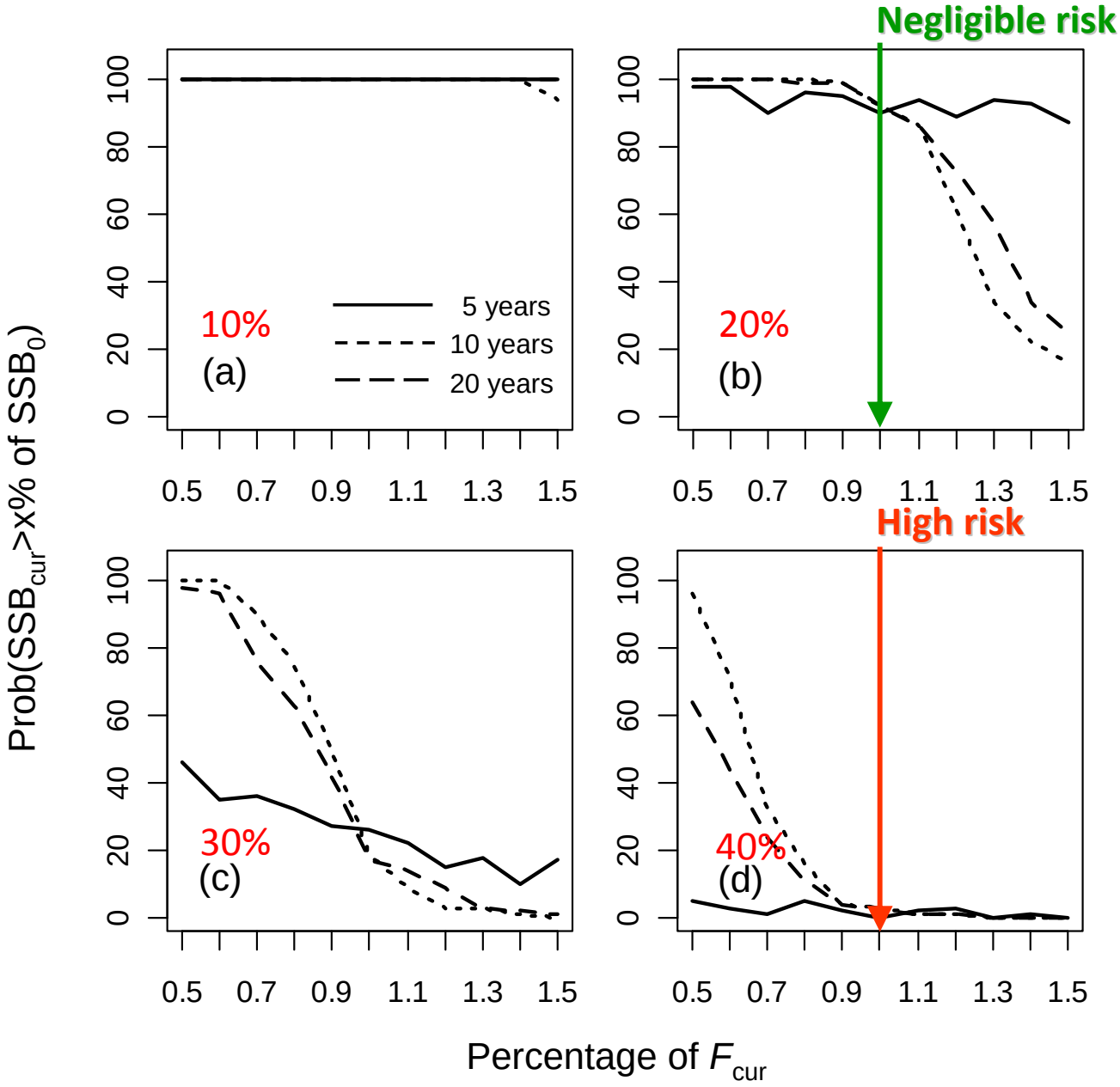


Model

Observation

(Year 2003-2004 combined)

Projected probabilities of SSB_{cur} larger than x% of SSB_0



Climate Change

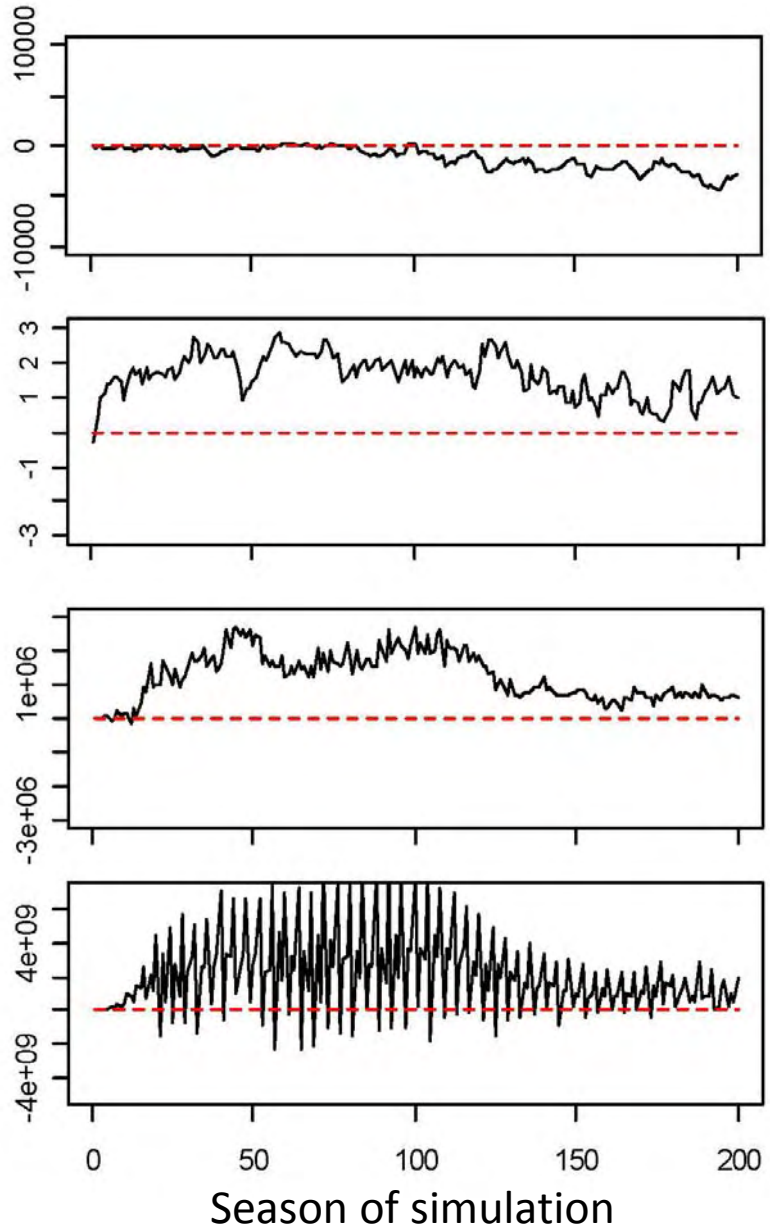
Difference of population dynamics between the base model and the temperature change scenario (+3 °C)

Abundance

Average size

SSB

Egg production



High molt mortality

Condensed intermoult period and incubation duration

Reach sexual maturity earlier

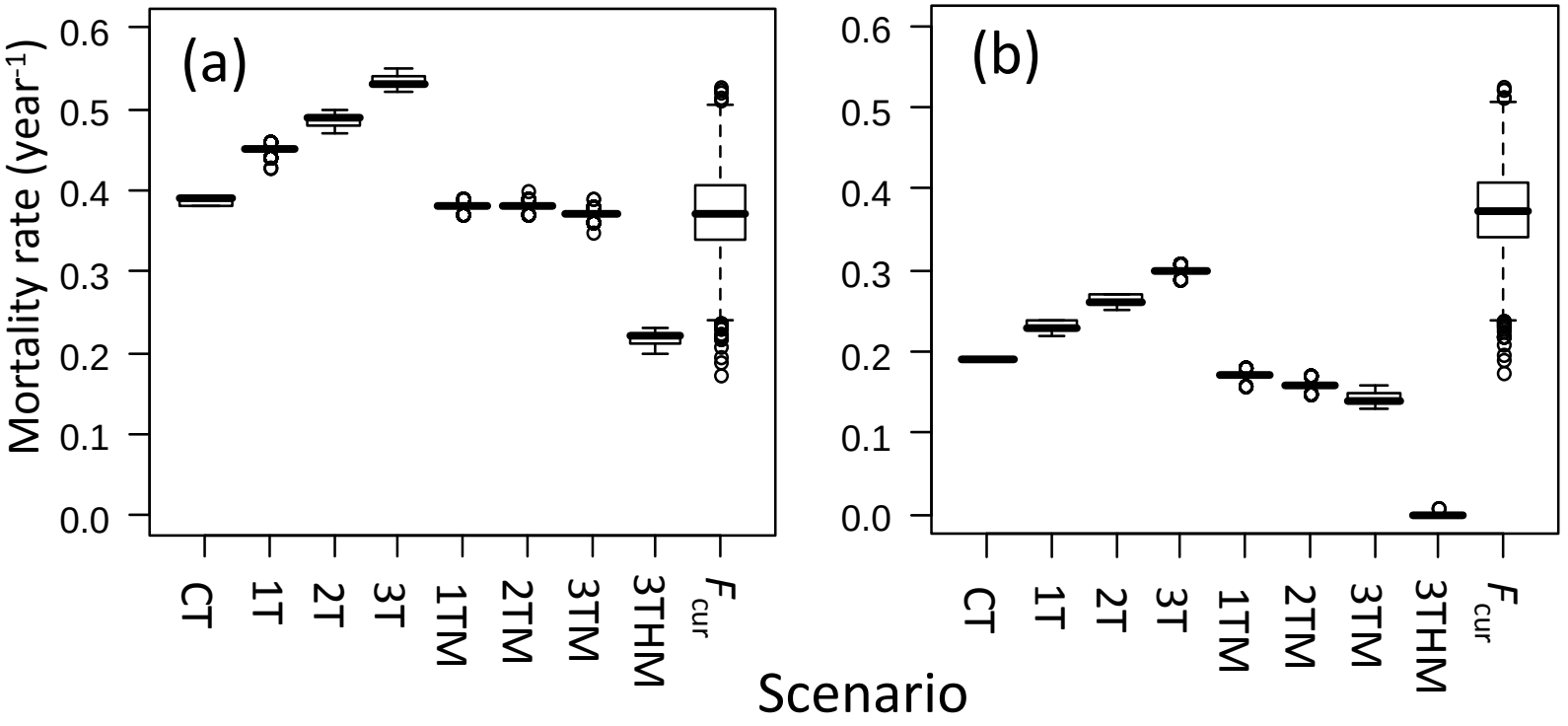
Increased spawning frequency
Extend spawning season

Define the simulation scenarios

Scenario	Model description	Average annual SST (°C)	Natural mortality ($year^{-1}$)
CT	Current temperature regime (years 2003-2004)	26.4	0.46
1T	Increased temperature would effect growth and reproduction only	27.4	0.46
2T		28.4	0.46
3T		29.4	0.46
1TM	Increased temperature would effect growth, reproduction, and mortality	27.4	0.49
2TM		28.4	0.52
3TM		29.4	0.55
3THM	Increased temperature would effect growth, reproduction, and introduce extra mortality	29.4	0.69

based on IPCC (2007)

Boxplots of the estimated BRPs $F_{20\%}$ (a) and $F_{40\%}$ (b) under eight different climate change scenarios



Summary

- The developed IBM can be used for the stock assessment for this small scale and data-limited fishery.

- Decision analysis based on samples from a Bayesian posterior distribution indicated that there is a negligible risk of the stock dropping below 20% of SSB_0.

- This study demonstrated warming temperature (climate change) can affect the estimation of BRPs.

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REVIEWS

Modelling the growth of crustacean species

Yi-Jay Chang · Chi-Lu Sun · Yong Chen · Su-Zan Yeh

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122 Can. J. Fish. Aquat. Sci. 68: 122–136 (2011)

Incorporating climate changes into population dynamic modelling: an individual-based modelling approach for lobster

Yi-Jay Chang, Chi-Lu Sun, Yong Chen, Yuying Zhang, and Su-Zan Yeh

Abstract: One of the most challenging issues in fisheries management is the evaluation of the effects of fishing in the context of a changing environment. Using the pronghorn spiny lobster (*Panulirus penicillatus*) fishery off the eastern coast of Taiwan as an example, we developed an individual-based model (IBM) that is capable of describing the temperature-dependent life history processes and fishery practices for the spiny lobster. We then used the model to evaluate potential impacts of increased ocean temperature on the estimation of mortality-based biological reference points for fisheries management. We demonstrate that a warming temperature would increase the yield-per-recruit and eggs-per-recruit values and consequently reduce the risk of overexploitation under the current exploitation level. However, there is likely a high risk of overexploitation in the long term if higher temperatures induce extra-high natural mortality. The evaluation of effectiveness of size regulations suggests that increasing minimum legal size is proposed as a good candidate measure to reduce the risk of overexploitation for pessimistically unfavorable environmental conditions. This study suggests that an explicit incorporation of the relationships between environmental variables and biological processes can greatly improve fisheries assessment and management.

Résumé : Un des plus importants défis dans la gestion des pêches est l'évaluation des effets de la pêche dans le contexte d'un environnement en changement. Prenant comme exemple la pêche de la langouste fourchette (*Panulirus penicillatus*) au large de la côte ouest de Taiwan, nous mettons au point un modèle basé sur l'individu (IBM) capable de décrire les processus du cycle biologique reliés à la température et les pratiques de pêche pour la langouste fourchette. Le modèle nous sert ensuite à évaluer les impacts potentiels de la température croissante de l'océan sur l'estimation des points de référence biologiques basés sur la mortalité pour la gestion de la pêche. Nous démontrons qu'une température croissante ferait augmenter les valeurs du rendement par recrue et des œufs par recrue et réduirait ainsi le risque de surexploitation au niveau actuel d'exploitation. Cependant, il y a vraisemblablement un risque élevé de surexploitation à long terme si la


Thank your for your attention