Potential impacts of climate change on the habitat of striped marlin (*Kajikia audax*) in the Pacific Ocean

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Outline

1. INTRODUCTION
   - *Background information*
   - *Objectives of this study*

2. MATERIALS AND METHODS
   - *Fishery data*
   - *Environmental data*
   - *Statistical modeling*
   - *Predict distribution*

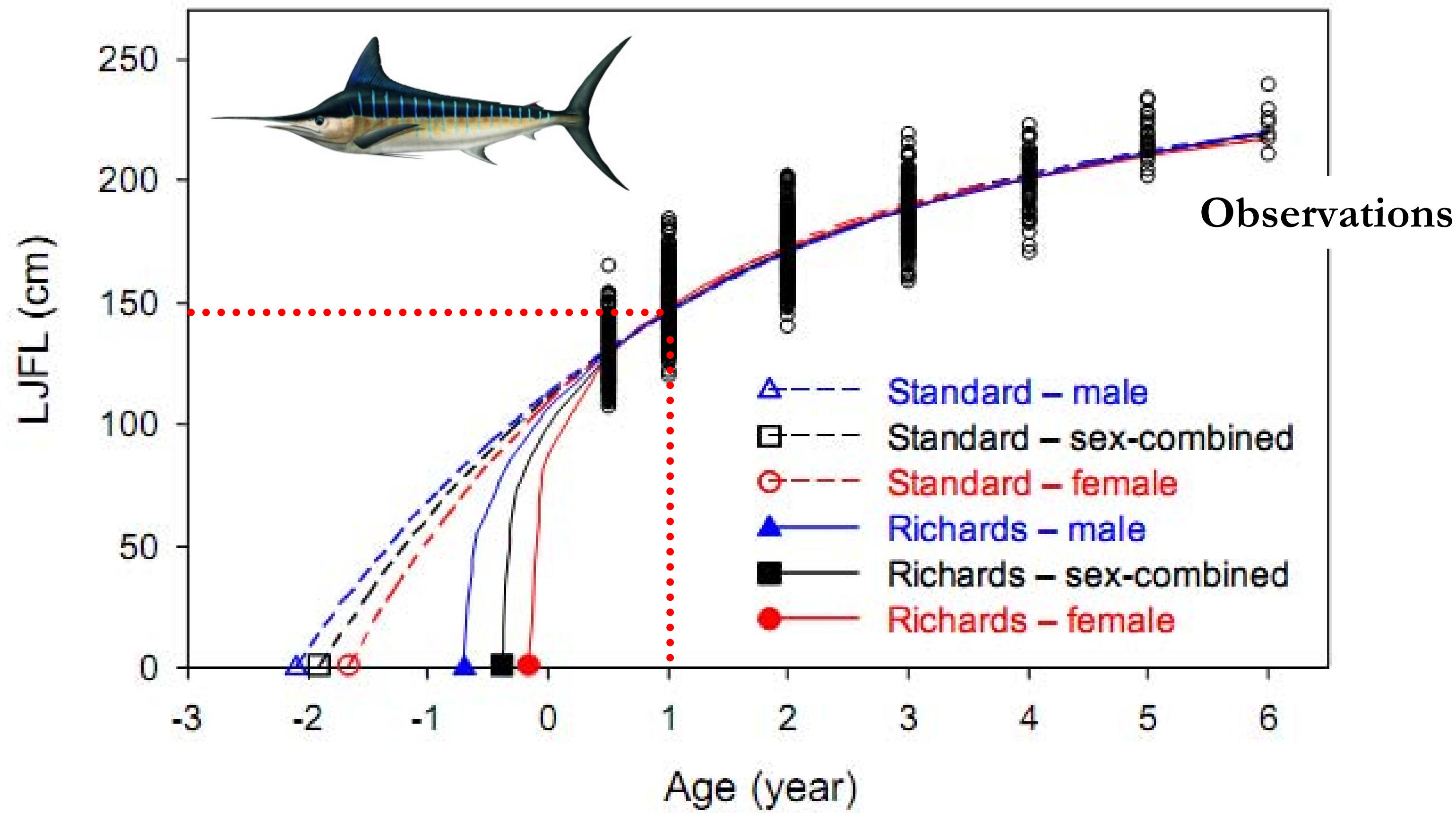
3. RESULTS AND DISCUSSION
   - *Model fitting*
   - *Spatial distribution*
   - *Habitat preference*
   - *Conclusions*

Taxonomy

- 鯖亞目 suborder Scombroidei 6科 30屬 53種
  - 金梭魚科 472 Family Sphyraenidae 1屬 8種
  - 帶鰆科 473 Family Gempylidae 8屬 8種
  - 帶魚科 474 Family Trichiuridae 5屬 9種
  - 鯖科 475 Family Scombridae 11屬 22種
  - 劍旗魚科 476 Family Xiphiidae 1屬 1種
    - 劍旗魚(劍魚) *Xiphias gladius* Linnaeus, 1758
  - 旗魚科 477 Family Istiophoridae 4屬 5種
    - 屬 Genus Istiompax 1種
      - 立翅旗魚(印度槍魚) *Istiompax indica* (Cuvier, 1832)
    - 旗魚屬 Genus Istiophorus 1種
      - 雨傘旗魚(平鰭旗魚) *Istiophorus platypterus* (Shaw & Nodder, 1792)
    - 槍魚屬 Genus Makaira 1種
      - 黑皮旗魚(藍槍魚) *Makaira nigricans* (Jordan & Snyder, 1901)
    - 四鰭旗魚屬 Genus Tetrapturus 2種
      - 小旗魚(小吻四鰭旗魚) *Tetrapturus angustirostris* Tanaka, 1915
      - 紅肉旗魚(尖吻四鰭旗魚) *Tetrapturus audax* (Philippi, 1887)

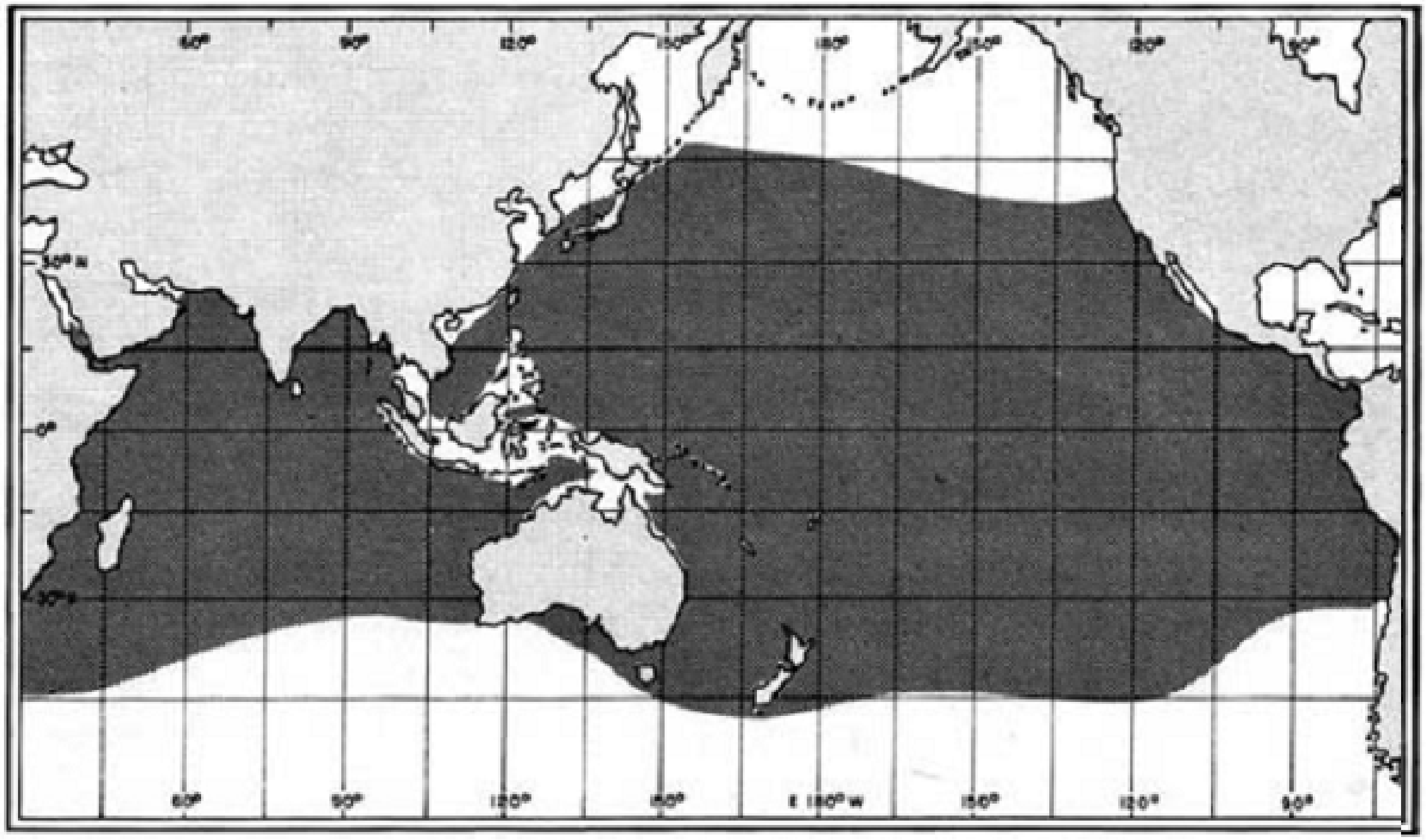
Source: Fish database of Taiwan

Age and growth



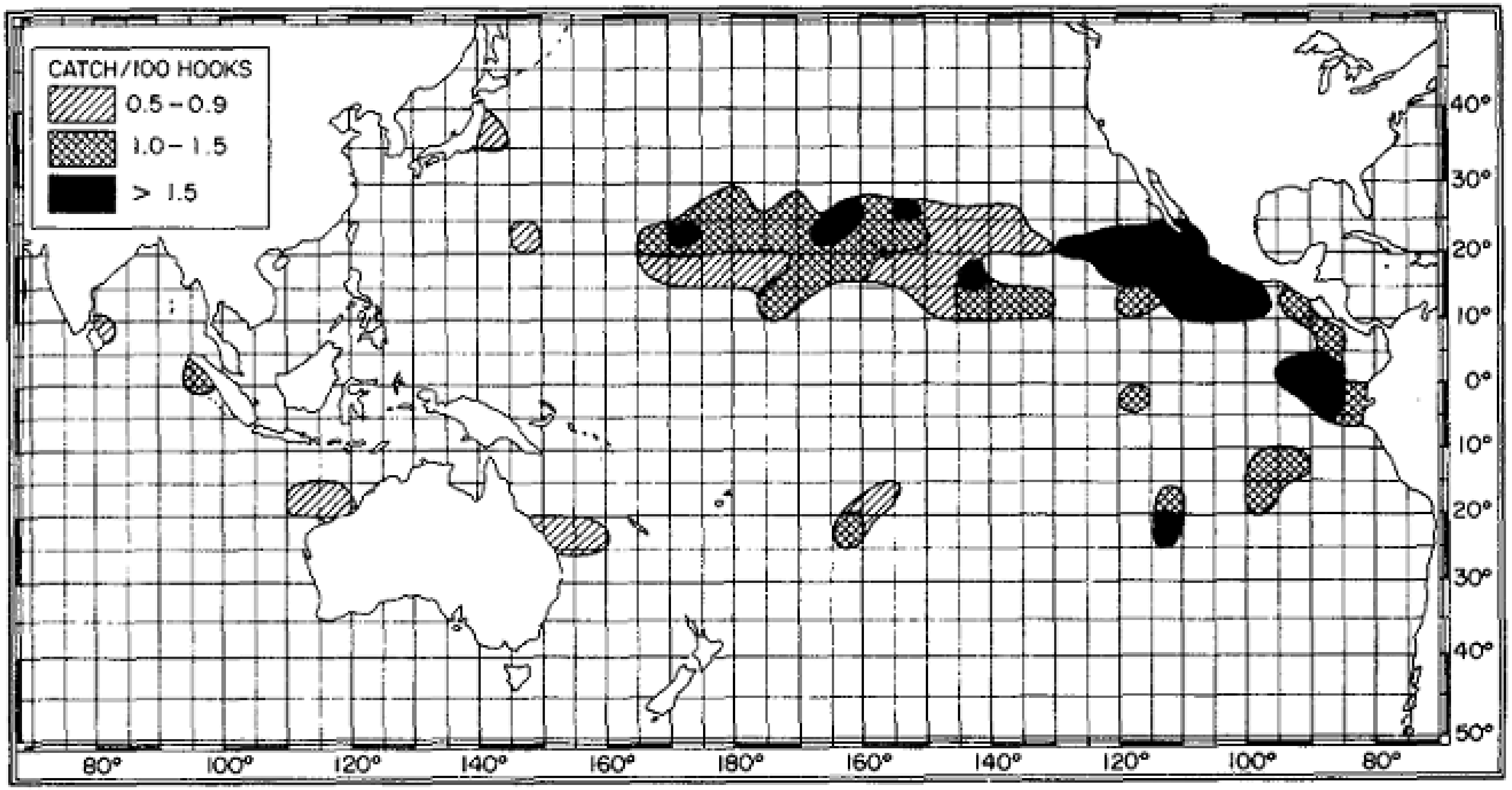
Source: Sun et al., 2011

Distribution



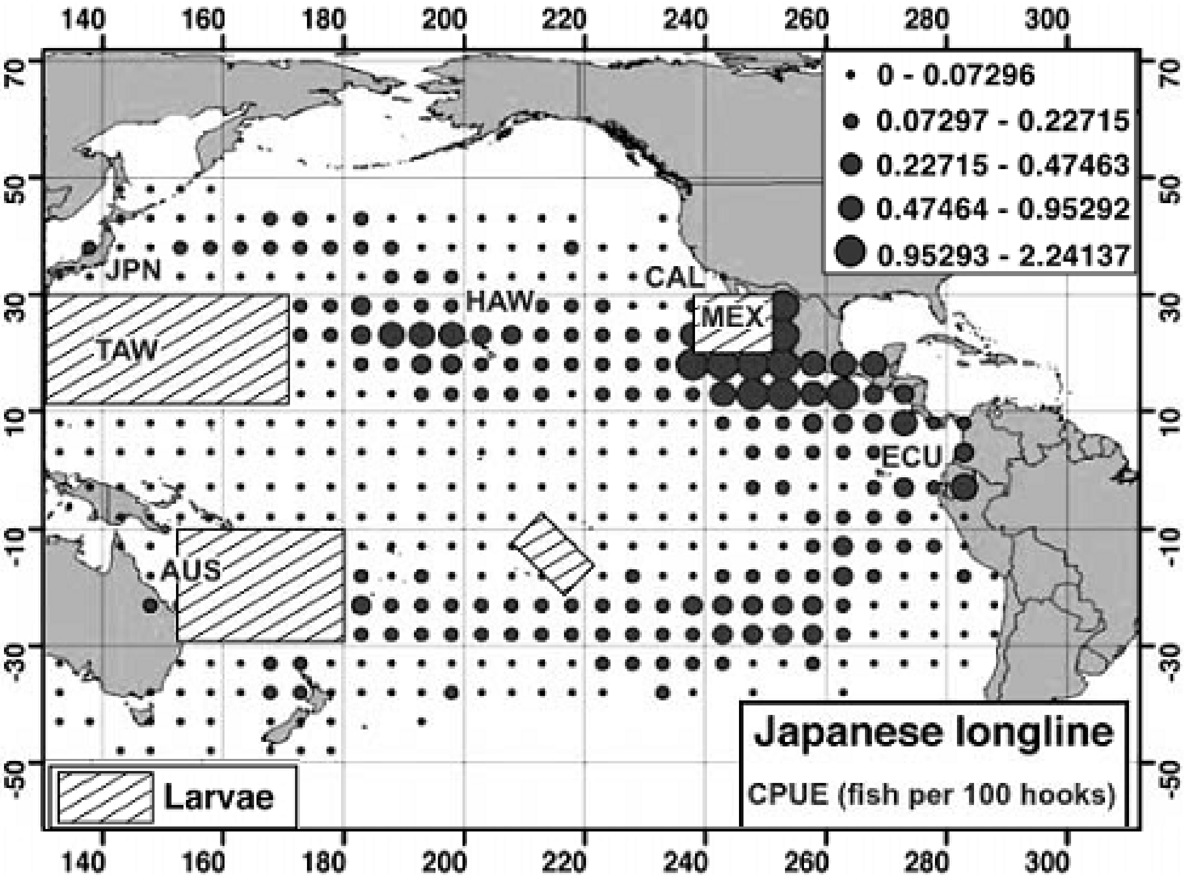
Source: Nakamura, 1985 (FAO)

Fishing ground



Source: Ueyanagi and Wares, 1972

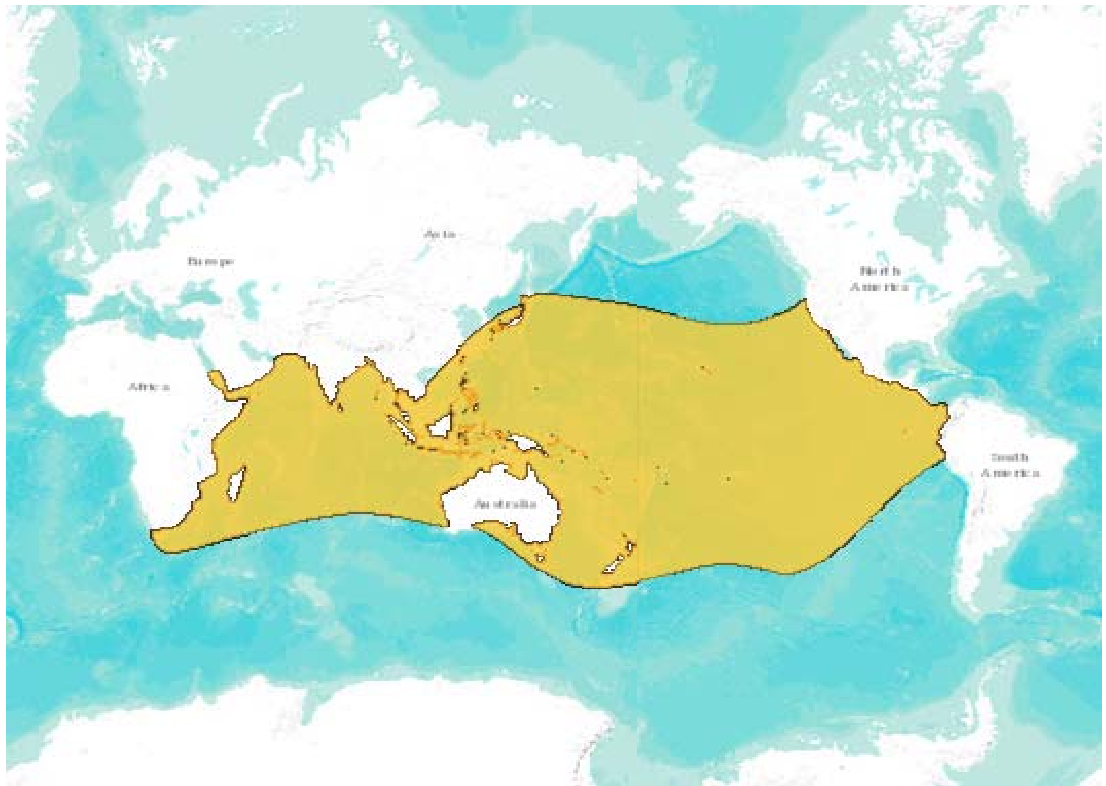
Spawning ground



Source: McDowell and Graves, 2008

Stock status

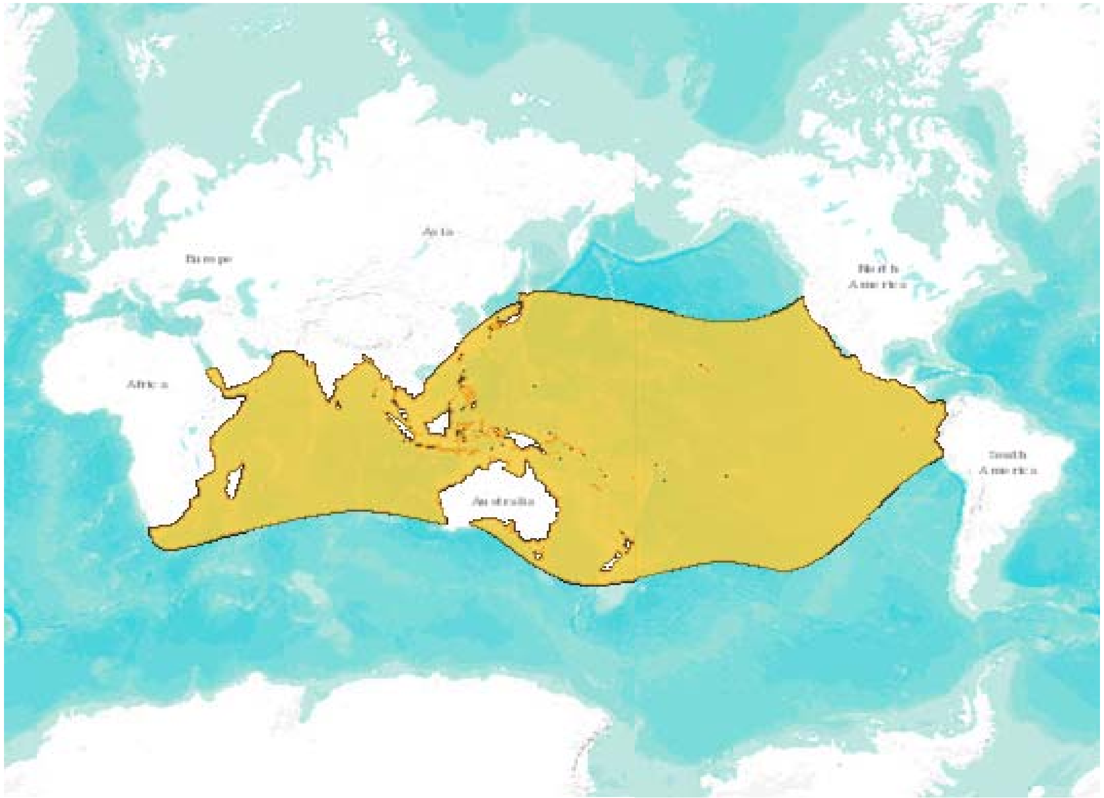
Kajikia audax



http://www.iucnredlist.org/

Stock status

Kajikia audax



http://www.iucnredlist.org/

Tagging study

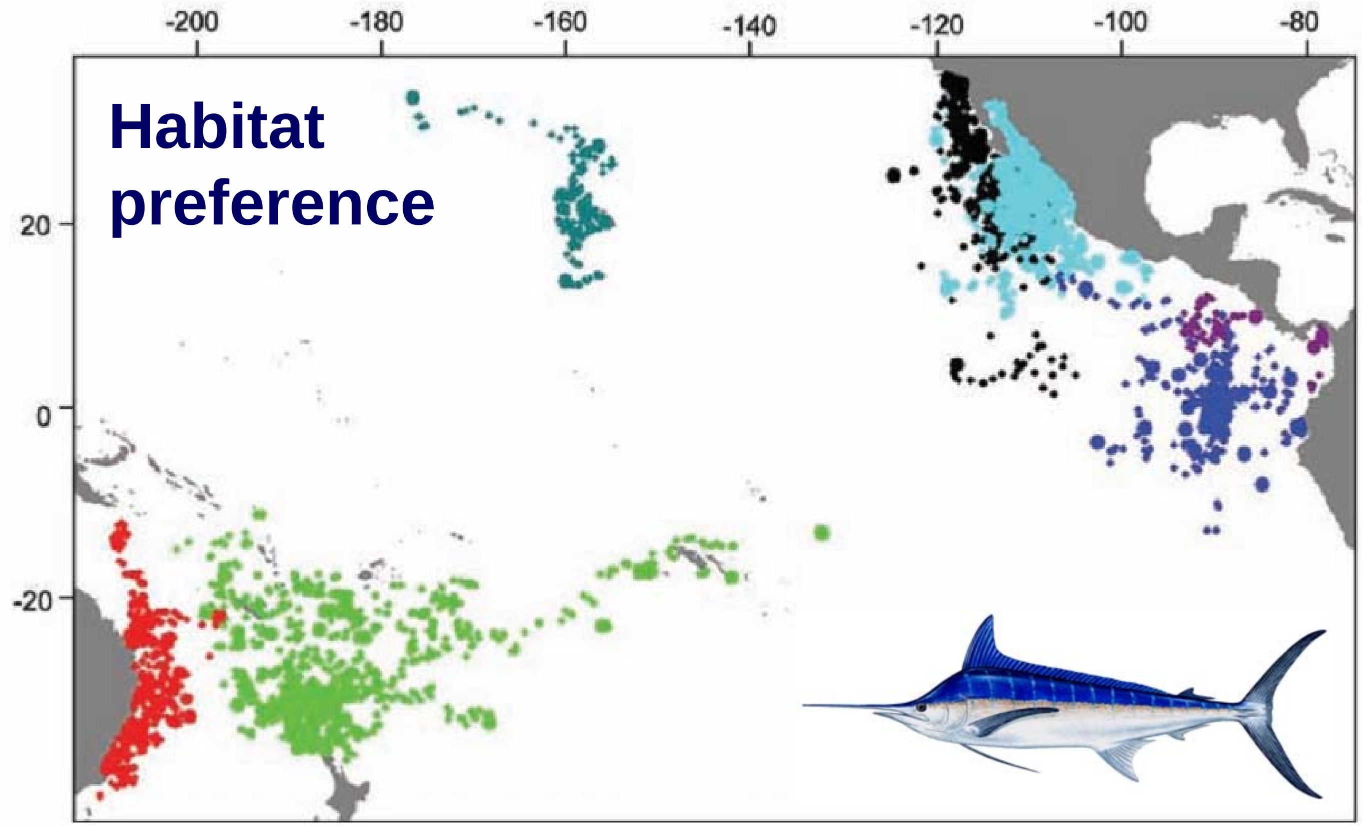
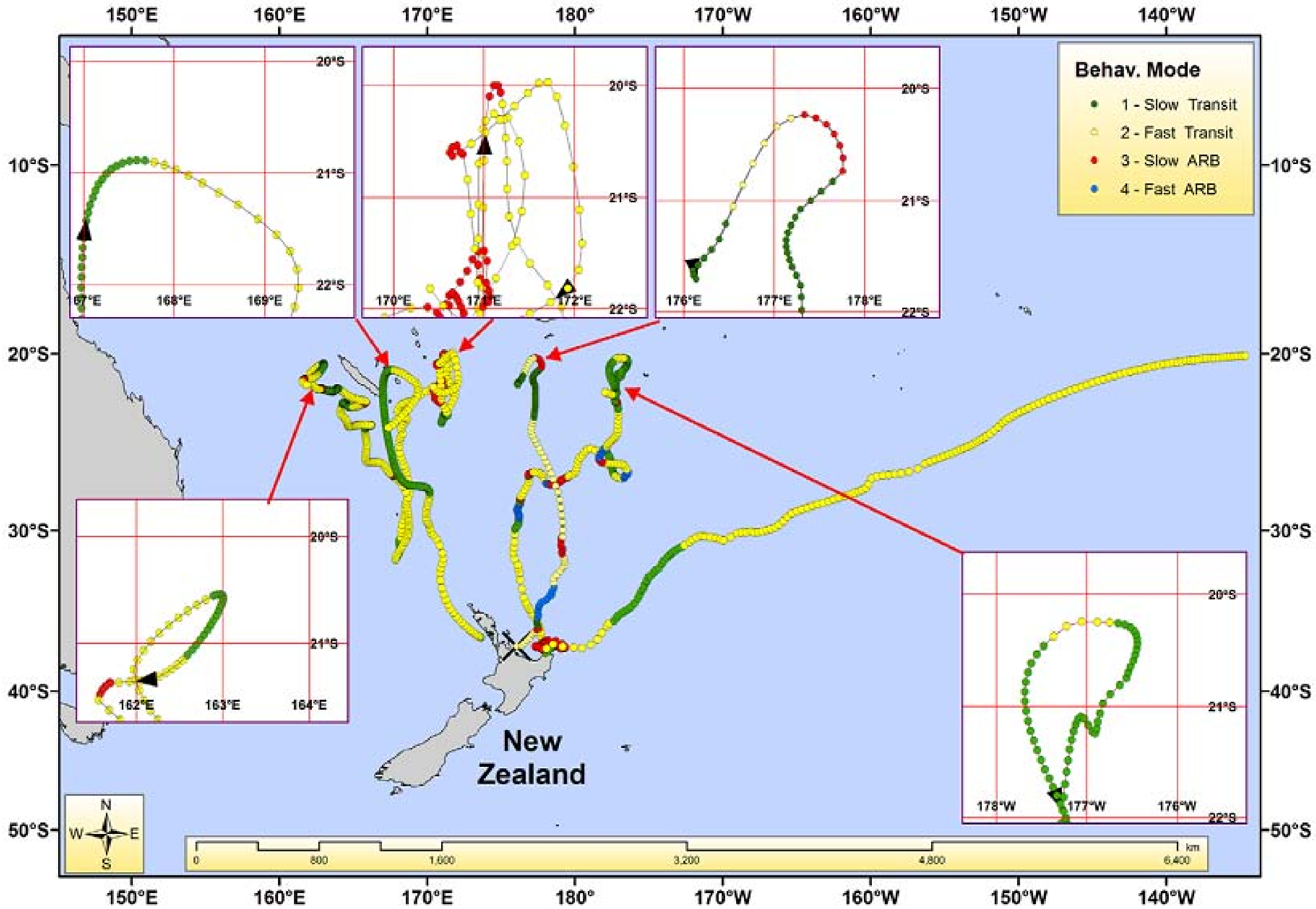


Figure 1. Position estimates for all tagged striped marlin. Different colors represent positions for fish tagged in a particular region (red = Australia; light green = New Zealand; teal = Hawaii; black = California; light blue = Mexico; dark blue = Ecuador; and purple = Costa Rica and Panama).

Source: Domeier, 2006

Tagging study



Source: Sippel et al., 2011

CPUE & SST

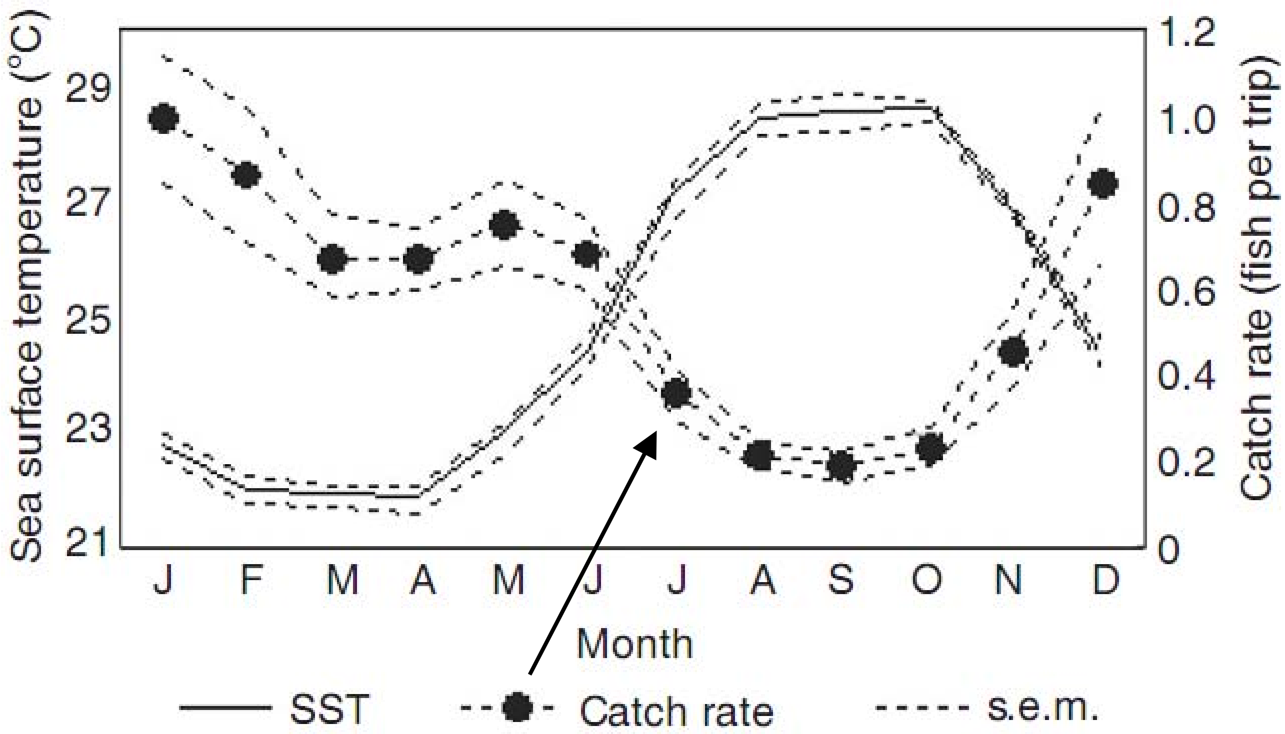


Fig. 5. Monthly average variation of striped marlin catch rates and sea surface temperature (SST) in Cabo San Lucas, B.C.S., 1990–1999.

Source: Ortega-Garcia et al., 2003

Objectives

Striped marlin inhabit certain *preferred habitats* in the open ocean. The preference of this species for particular habitats may impact its distribution and vulnerability to being caught.

The objectives were to:

1. Examine the relationships between spatial pattern of abundance and satellite-based oceanographic variables;
2. Predict the spatial distribution based on the relationships;
3. Identify the habitat preferences of striped marlin;
4. Evaluate potential impacts of climate change on habitats.

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Fishery data

Taiwanese longline fisheries from OFDC for 1998-2008

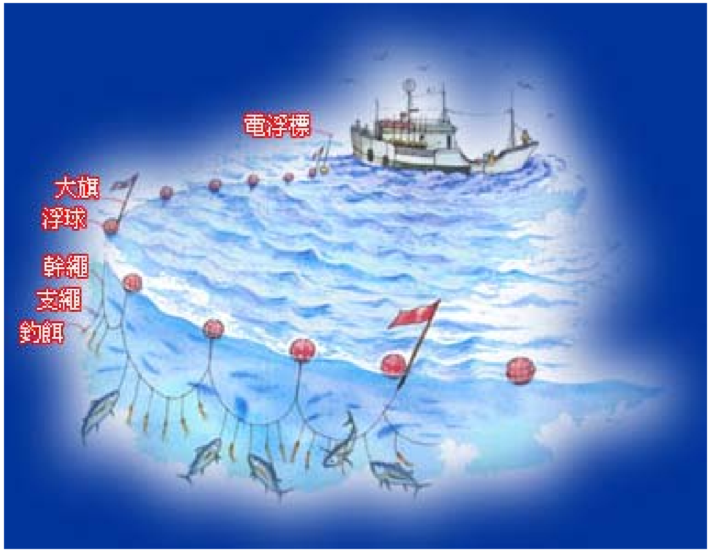
中華民國對外漁業合作發展協會
Overseas Fisheries Development Council of The Republic of China

Covariates: Year, Month, Latitude, Longitude, Fishing effort
and number of striped marlin caught

8597 observations (5x5):

> 500,000 operation sets

> 1,000,000,000 hooks



Oceanographic data

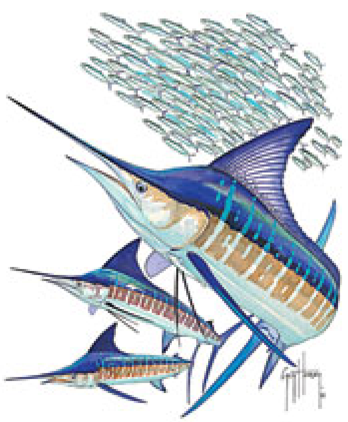
a) chlorophyll a concentration (CHL): SeaWiFS

b) mixed layer depth (MLD):

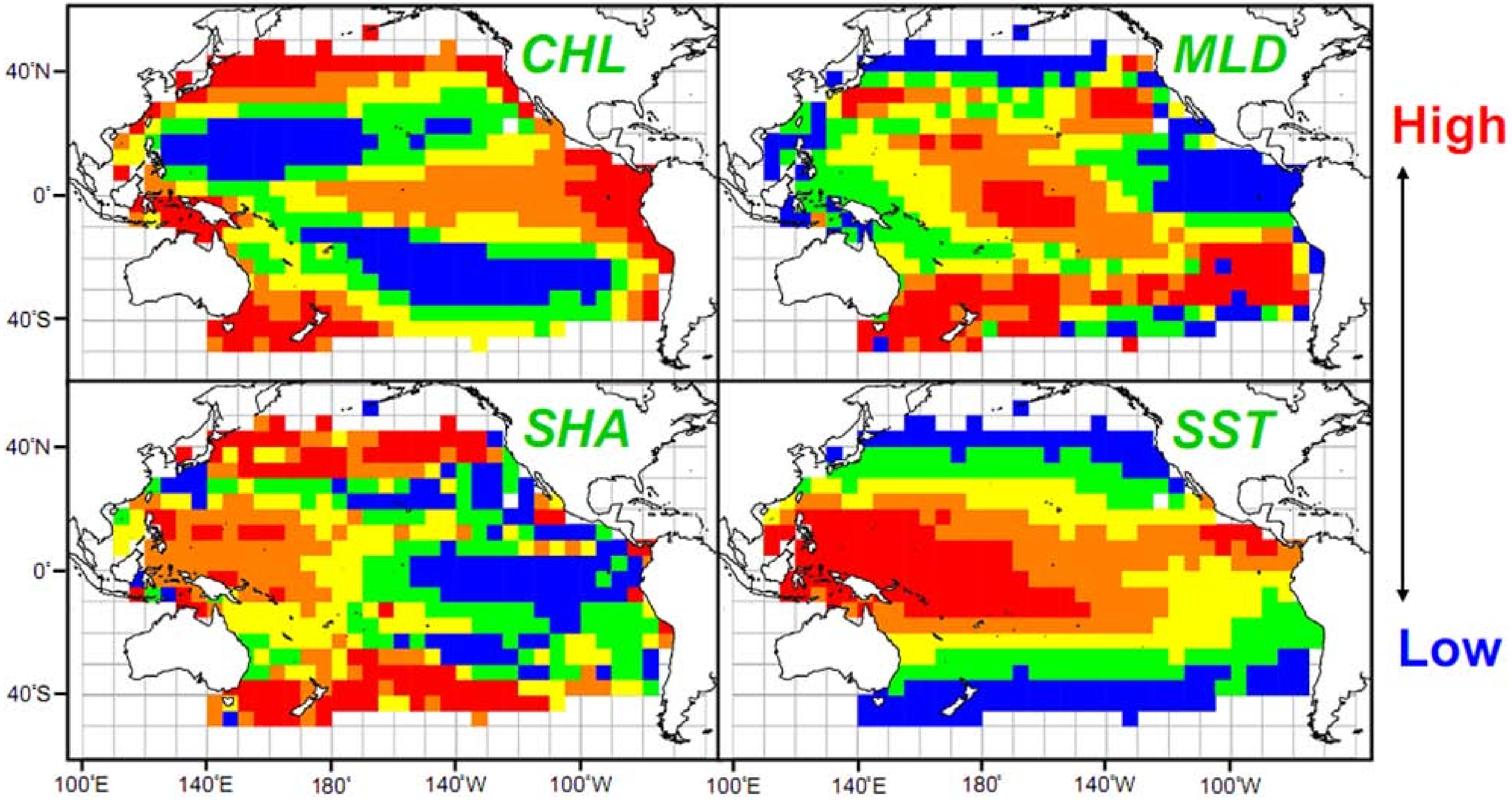
c) sea surface height anomaly (SSH): AVISO

d) sea surface temperature (SST): PODAAC

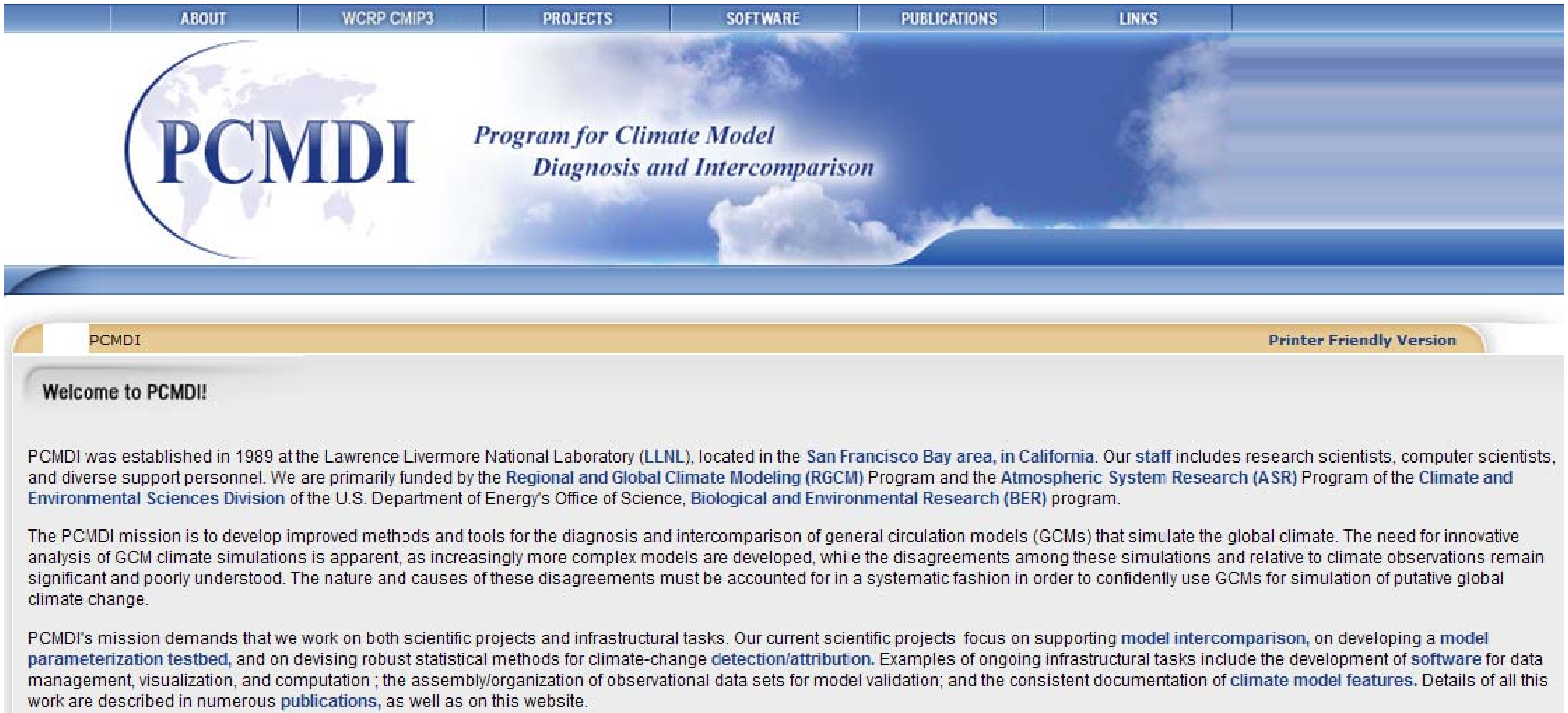
-- Average to 5x5 grids to match the fishery data



Oceanographic data



SST from climate models



ABOUT | WCRP CMIP3 | PROJECTS | SOFTWARE | PUBLICATIONS | LINKS

PCMDI

Program for Climate Model Diagnosis and Intercomparison

PCMDI — Printer Friendly Version

Welcome to PCMDI!

PCMDI was established in 1989 at the Lawrence Livermore National Laboratory (LLNL), located in the San Francisco Bay area, in California. Our staff includes research scientists, computer scientists, and diverse support personnel. We are primarily funded by the Regional and Global Climate Modeling (RGCM) Program and the Atmospheric System Research (ASR) Program of the Climate and Environmental Sciences Division of the U.S. Department of Energy's Office of Science, Biological and Environmental Research (BER) program.

The PCMDI mission is to develop improved methods and tools for the diagnosis and intercomparison of general circulation models (GCMs) that simulate the global climate. The need for innovative analysis of GCM climate simulations is apparent, as increasingly more complex models are developed, while the disagreements among these simulations and relative to climate observations remain significant and poorly understood. The nature and causes of these disagreements must be accounted for in a systematic fashion in order to confidently use GCMs for simulation of putative global climate change.

PCMDI's mission demands that we work on both scientific projects and infrastructural tasks. Our current scientific projects focus on supporting model intercomparison, on developing a model parameterization testbed, and on devising robust statistical methods for climate-change detection/attribution. Examples of ongoing infrastructural tasks include the development of software for data management, visualization, and computation ; the assembly/organization of observational data sets for model validation; and the consistent documentation of climate model features. Details of all this work are described in numerous publications, as well as on this website.

Spatial modelling

GAM (generalized additive models)

$$g(\mu_i) = \mu + \sum_{j=1}^{p} f_j(X_i)$$

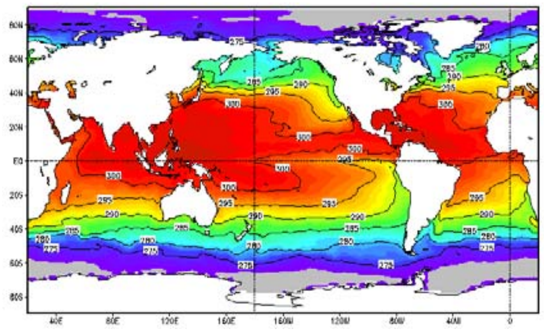
spline smoother function

CPUE: number caught / 1000 hooks

Catch-rates of striped marlin ~ s(CHL) + s(MLD) + s(SSH) + s(SST)

+ Year + Month + Latitude

+ Longitude + Latitude:Longitude



Predict the spatial distribution

Spatial modelling

GAM (generalized additive models)

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spline smoother function

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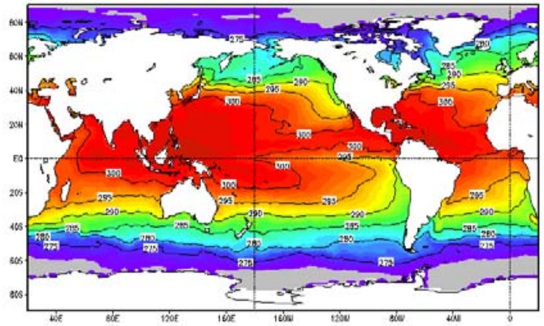

Predict the future distribution

SST from climate models

Model	Source	TCR (°C)*
BCCR-BCM2.0	University of Bergen, Norway	NA
CCSM3‡	University Corporation for Atmospheric Research, USA	1.5
CGCM (T47)	Centre for Climate Modelling and Analysis, Canada	1.9
CGCM (T63)‡	Centre for Climate Modelling and Analysis, Canada	NA
CNRM (CM3)	Centre National de Recherches Météorologiques, France	1.6
CSIRO (Mk3.5d)	Commonwealth Scientific and Industrial Research Organisation, Australia	1.4
ECHAM5	Max Planck Institute for Meteorology, Germany	2.2
ECHO-G	University of Bonn, Germany	1.7
FGOALS‡	Institute of Atmospheric Physics, China	1.2
GFDL-CM2.0	Geophysical Fluid Dynamics Laboratory, USA	1.6
GFDL-CM2.1	Geophysical Fluid Dynamics Laboratory, USA	1.5
GISS-AOM (c4×3)‡	Goddard Institute for Space Studies, USA	NA
GISS-ER	Goddard Institute for Space Studies, USA	1.5
HADCM3	Met Office, Exeter, UK	2.0
INMCM3.0	Institute for Numerical Mathematics, Russia	1.6
IPSL	Institut Pierre Simon Laplace, France	2.1
MIROC-medres	Center for Climate System Research – National Institute for Environmental Studies – Frontier Research Center for Global Change, Japan	2.1
PCM	National Center for Atmospheric Research (NCAR), USA	1.3

*Transient climate response (TCR) is a measure of modeled climate sensitivity. It is defined as the global mean temperature change doubling when CO_2 is increased at a rate of 1% per year in a simulation (Randall et al. 2007).

SST from climate models

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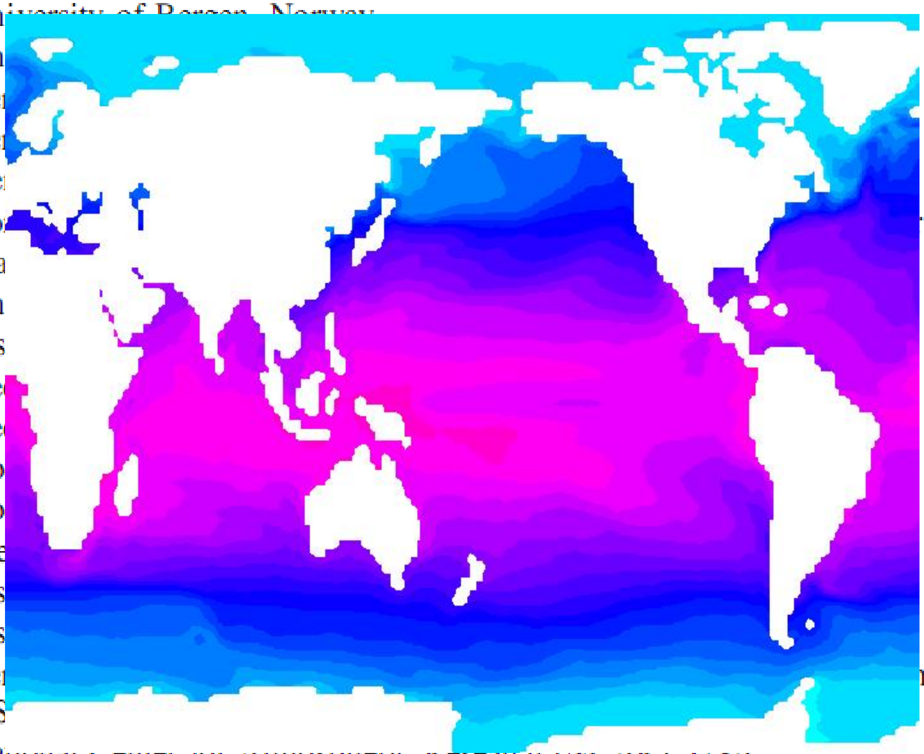
BCCR-BCM2.0	University of Bergen, Norway	NA
CCSM3‡	Un	1.5
CGCM (T47)	Ce	1.9
CGCM (T63)‡	Ce	NA
CNRM (CM3)	Ce	1.6
CSIRO (Mk3.5d)	Co … alia	1.4
ECHAM5	Ma	2.2
ECHO-G	Un	1.7
FGOALS‡	Ins	1.2
GFDL-CM2.0	Ge	1.6
GFDL-CM2.1	Ge	1.5
GISS-AOM (c4×3)‡	Go	NA
GISS-ER	Go	1.5
HADCM3	Me	2.0
INMCM3.0	Ins	1.6
IPSL	Ins	2.1
MIROC-medres	Ce … nental S	2.1
PCM	National Center for Atmospheric Research (NCAR), USA	1.3



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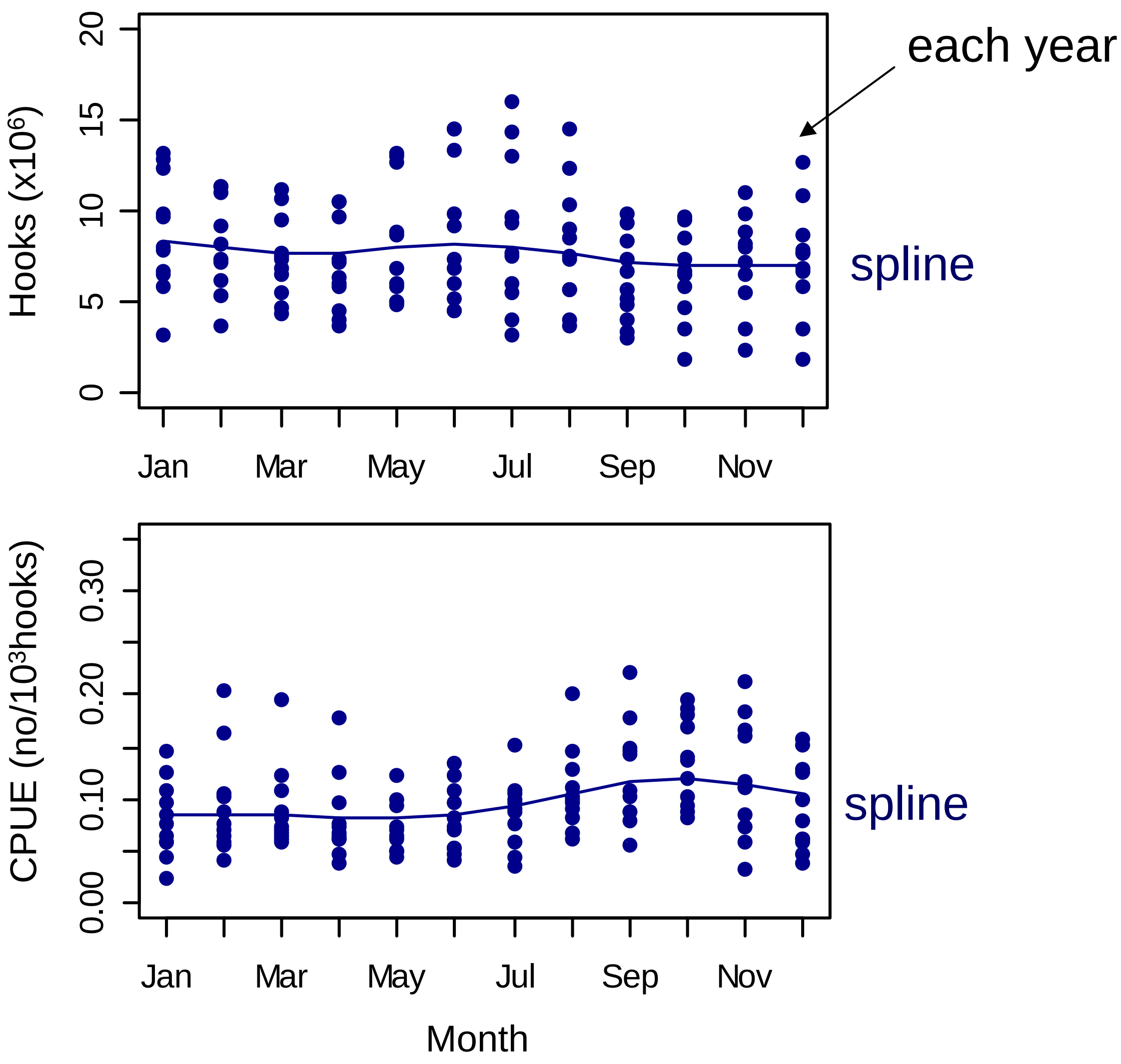
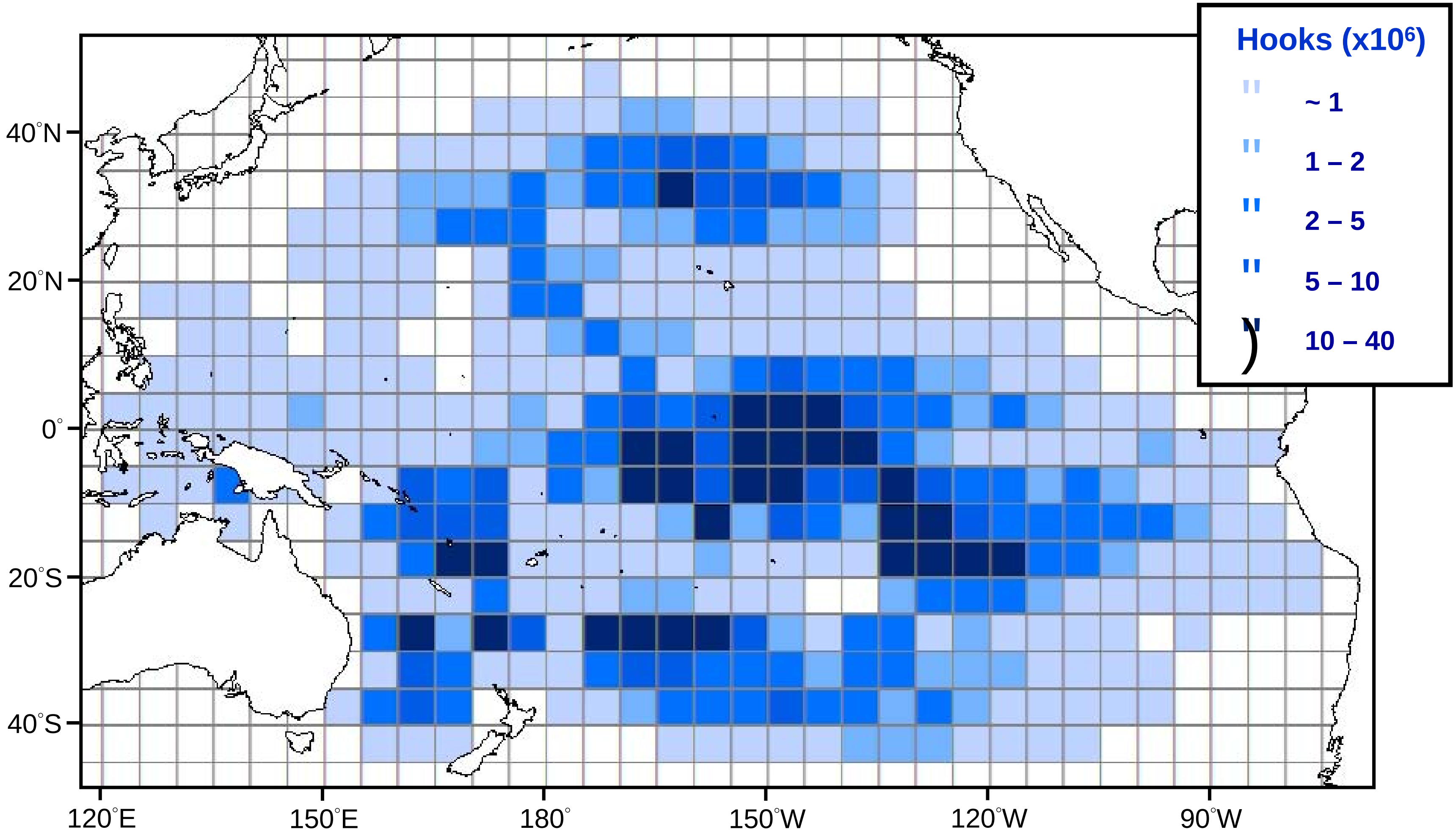
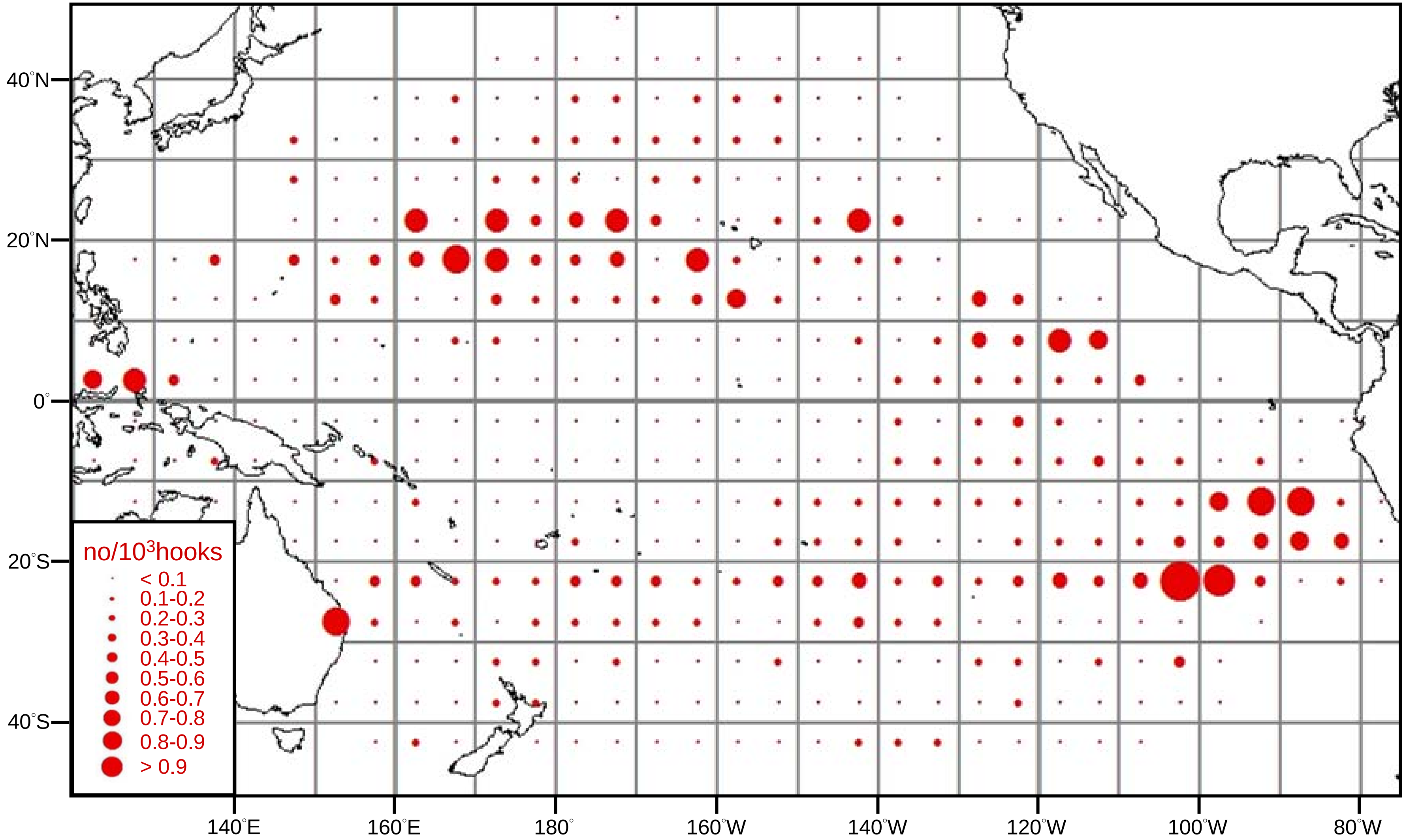
Fishery data used



Fishing effort of Taiwan LL for 1998~2009

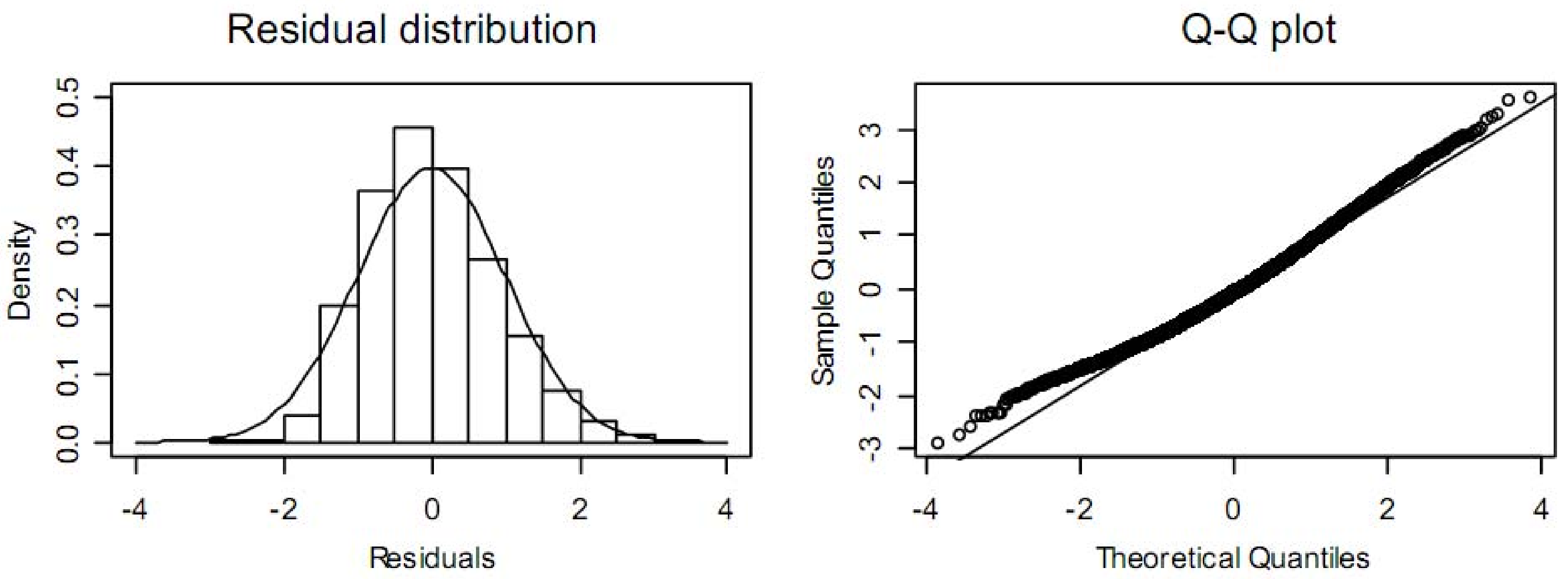


Nominal CPUE of Striped marlin



Model fitting - Diagnostic

Assume log-normal error distribution

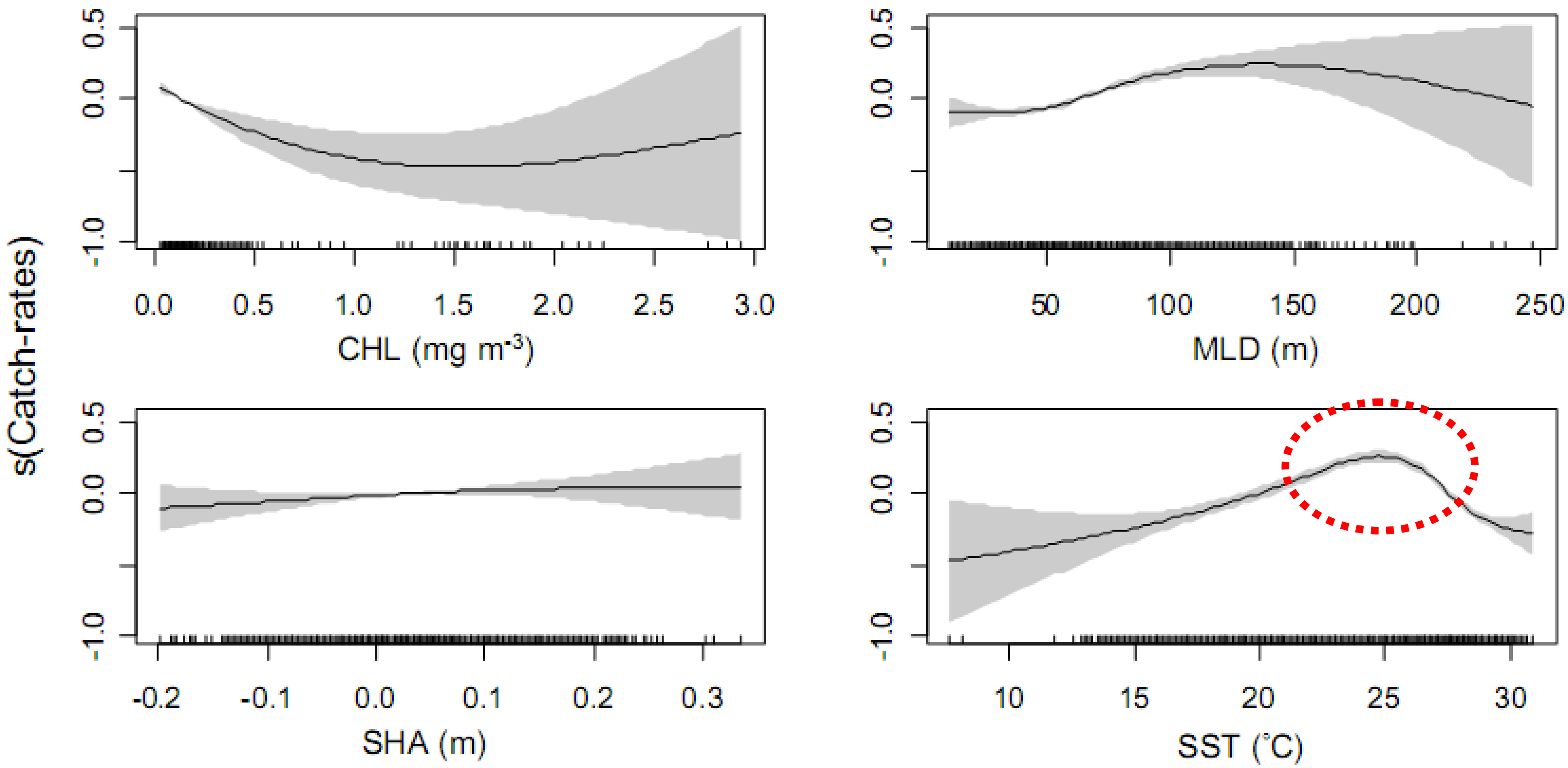


ANOVA Table

	Residual deviance	Deviance explained	Dev(%)	*p*-value
NULL	8343			
+ Year	8090	252	0.13	< 0.001
+ Month	7993	97	0.05	< 0.001
+ CHL	7930	64	0.03	< 0.001
+ MLD	7894	36	0.02	< 0.001
+ SSH	7810	84	0.04	< 0.001
+ SST	7440	**370**	0.19	< 0.001
+ Lat	7300	**141**	0.07	< 0.001
+ Lon	7110	**189**	0.10	< 0.001
+ Lat:Lon	6429	**681**	0.36	< 0.001

22.9%

Environmental effects on catch-rates



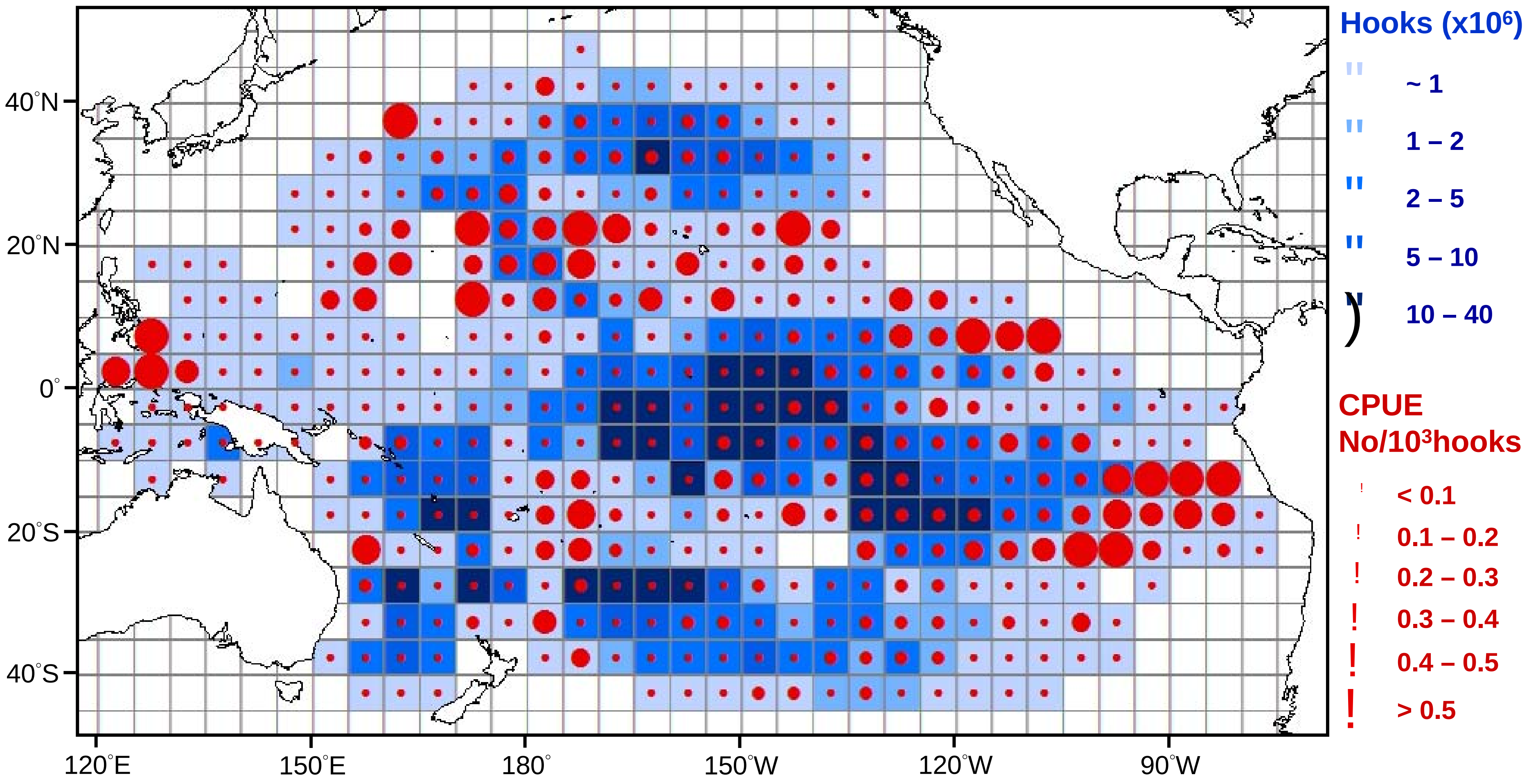
CHL: chlorophyll-a concentration

MLD: mixed layer depth

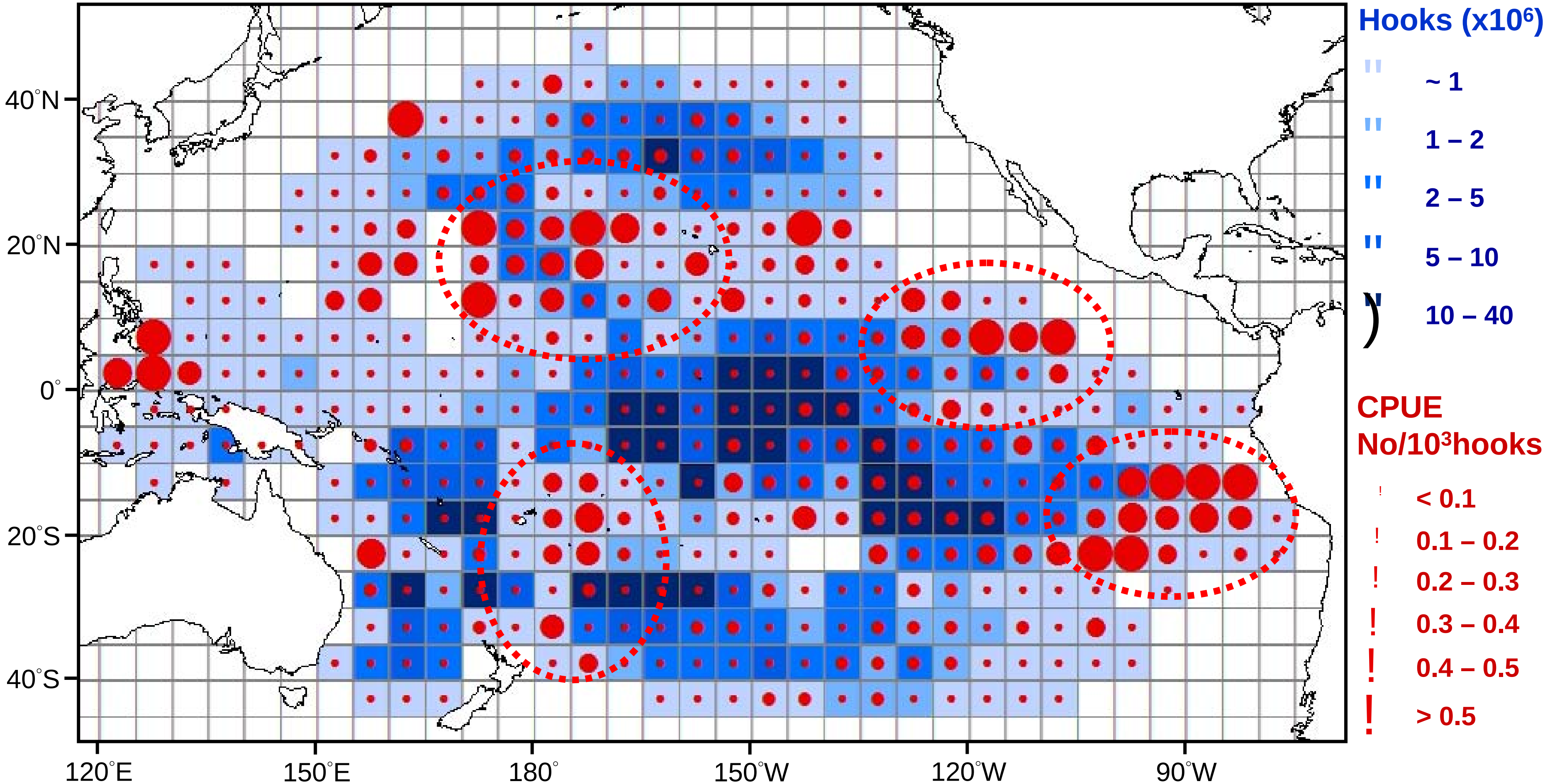
SHA: sea-surface height anomaly

SST: sea-surface temperature

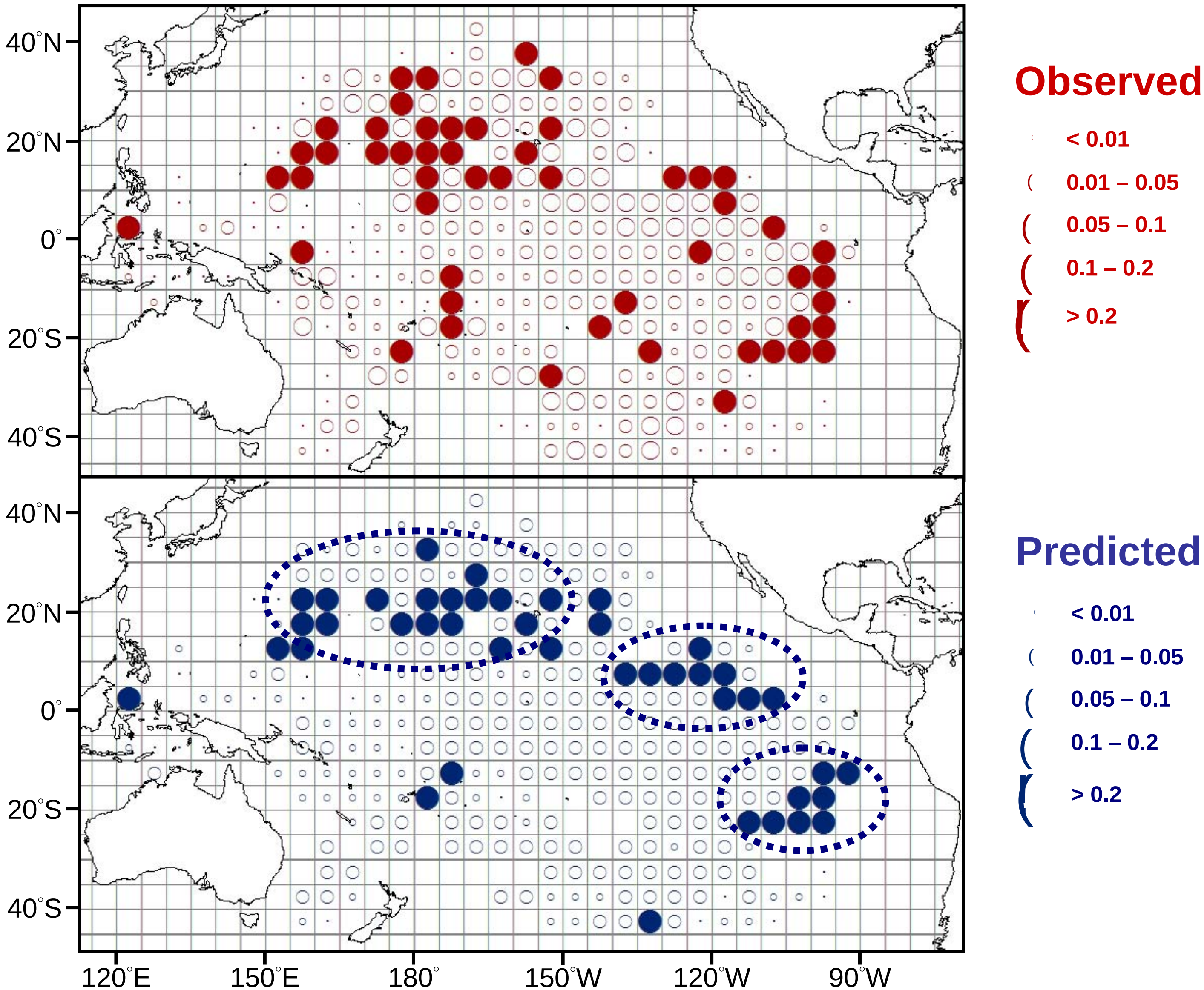
Model-predicted CPUE of striped marlin



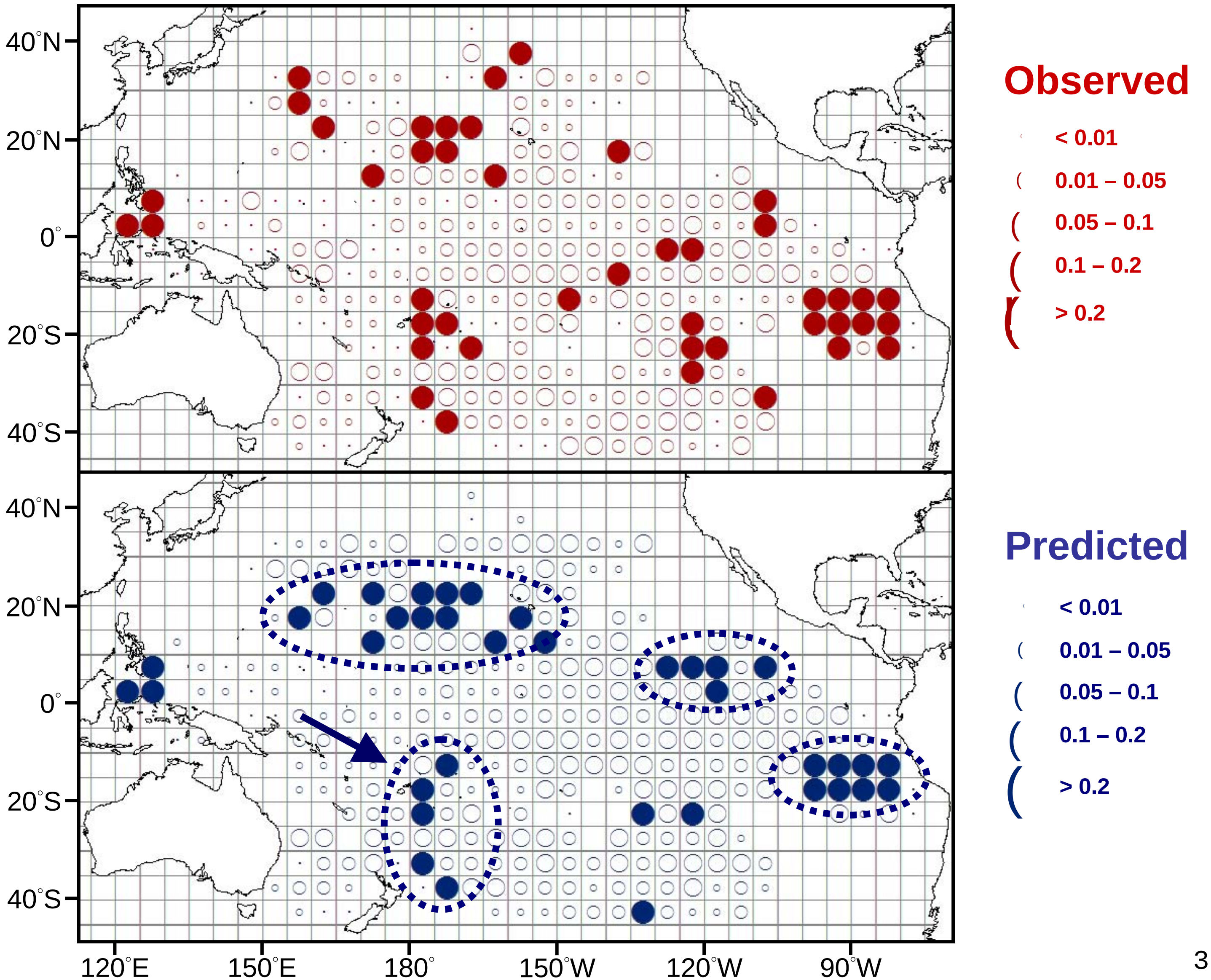
Model-predicted CPUE of striped marlin



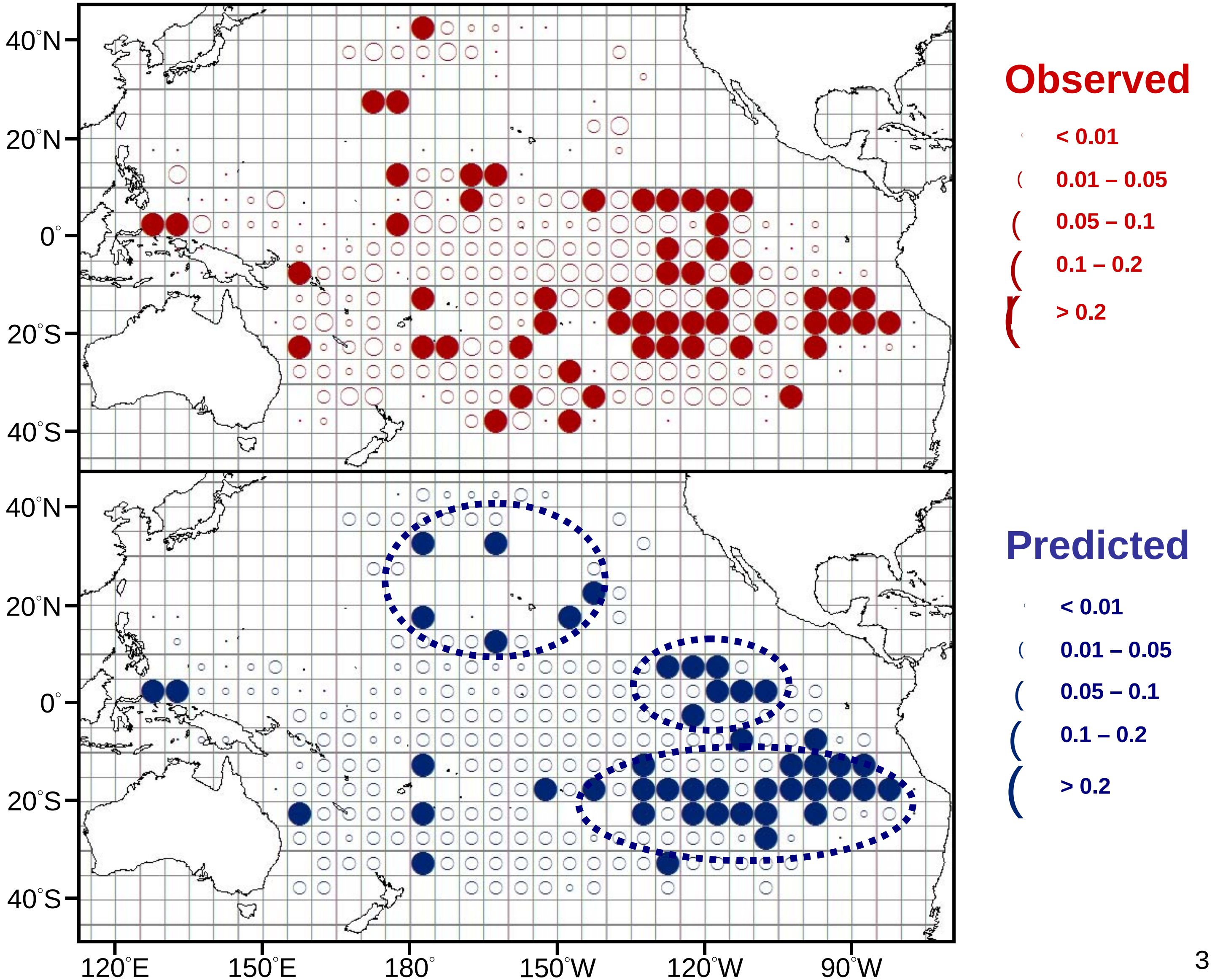
1st Quarter: January – March



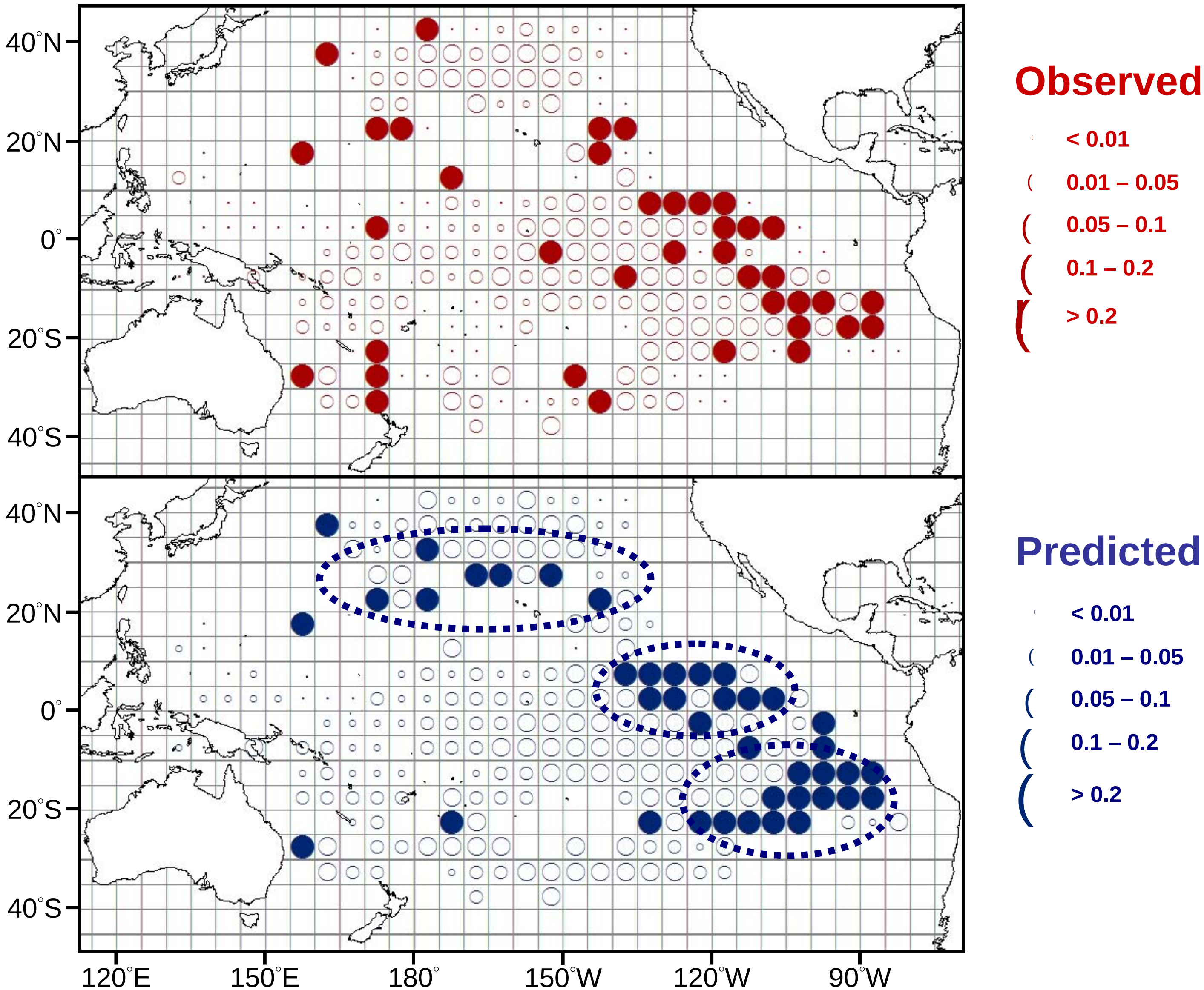
2^{nd} Quarter: April – June



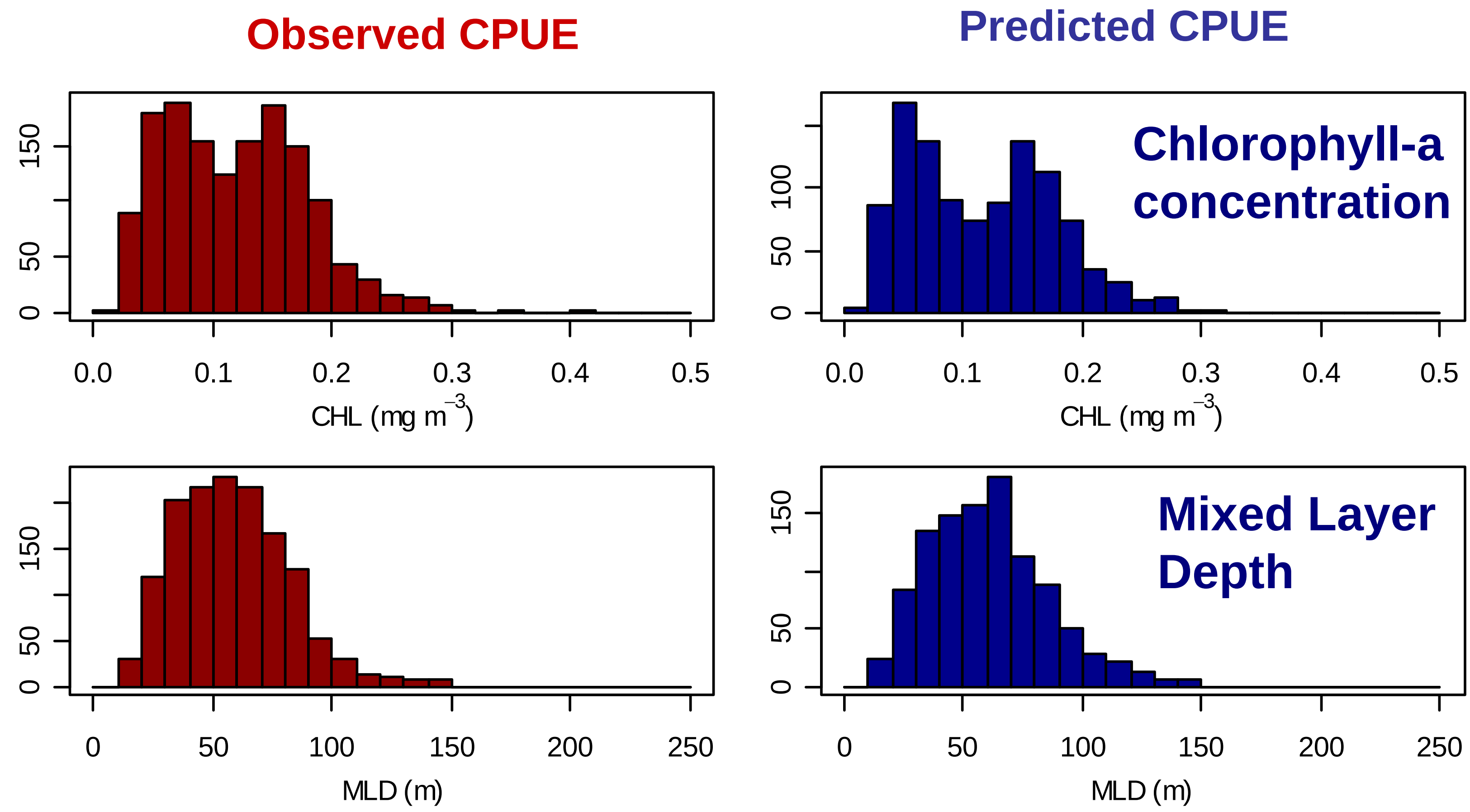
3rd Quarter: July – September



4th Quarter: October – December

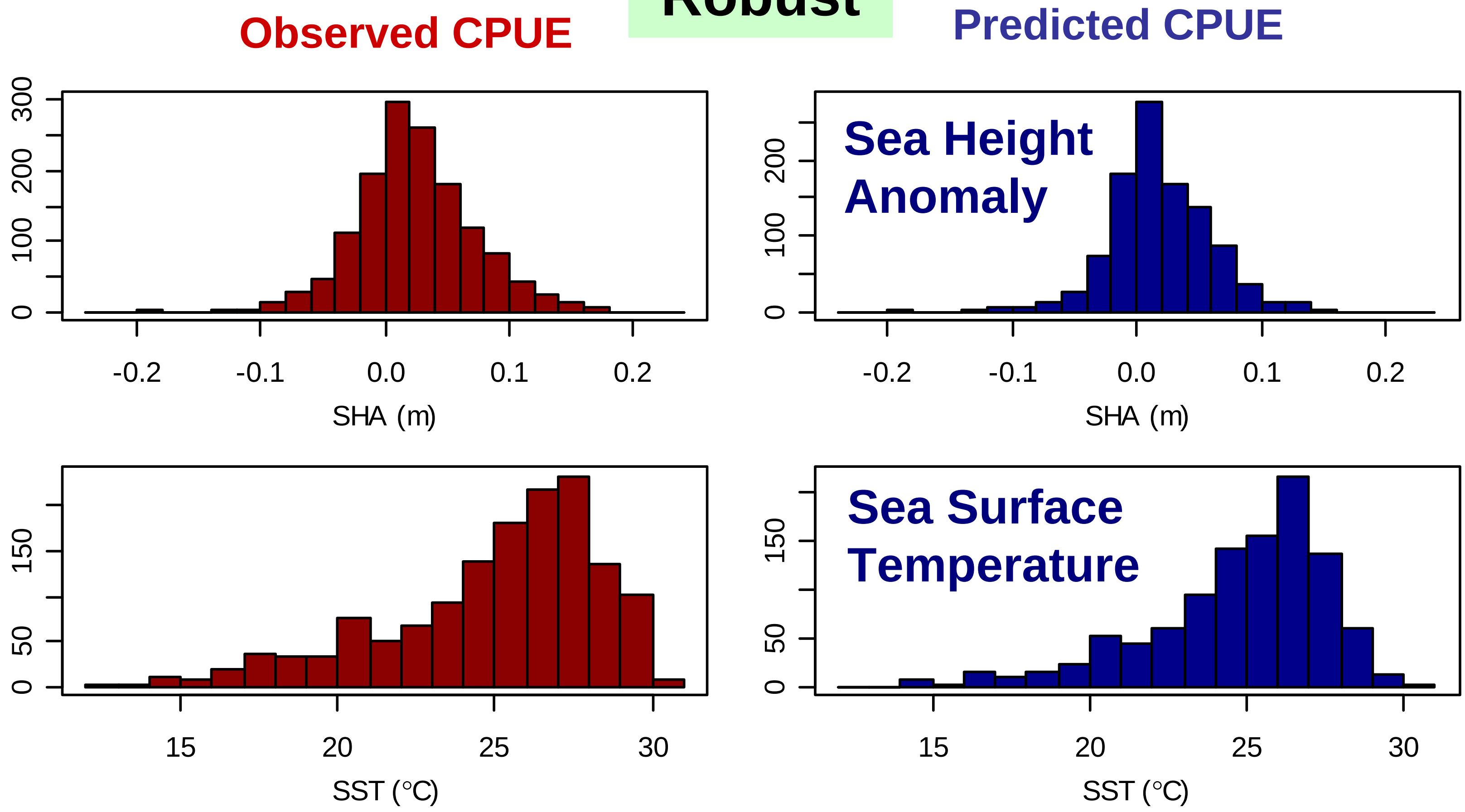


Habitat characteristics (CPUE > 0.2)

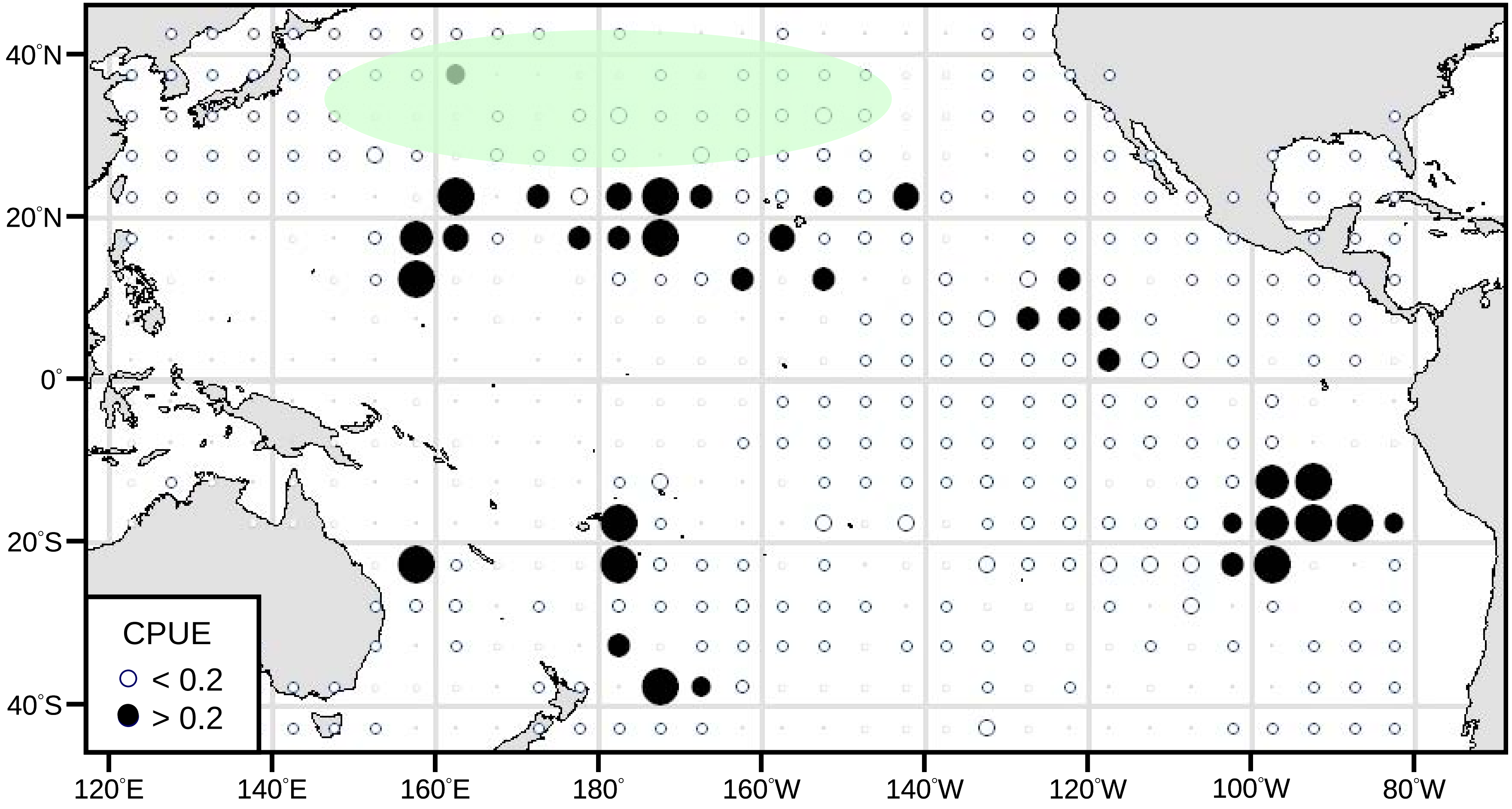


Habitat characteristics (CPUE > 0.2)

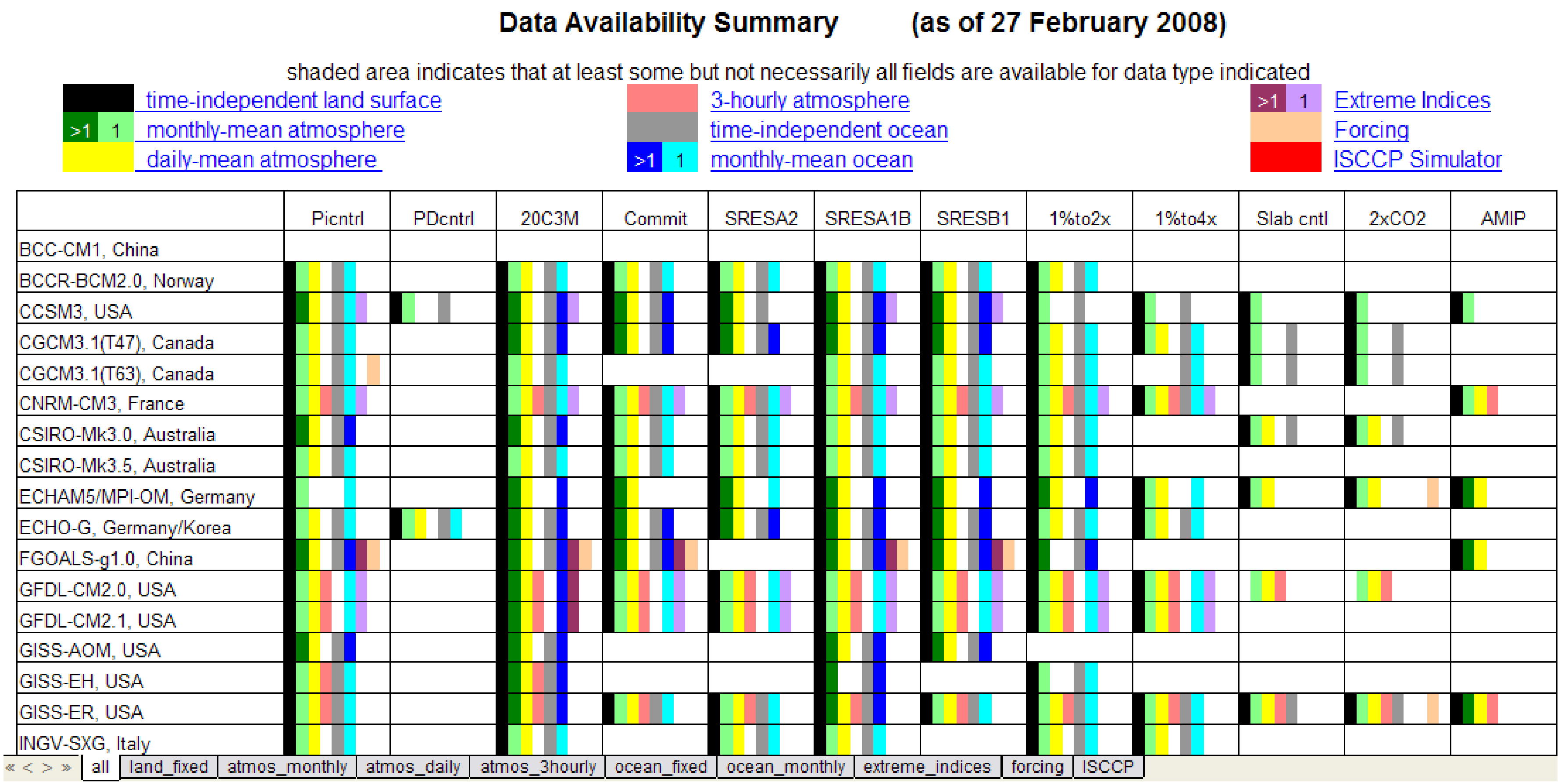
Robust



Distribution of striped marlin for 2020



SST from other climate models
to 2050~2100



Summary

1. Lat, Lon and SST explain the largest proportion of deviance in the distribution of striped marlin in the Pacific Ocean.

2. Habitat preferences of striped marlin:

   Chlorophyll-*a*: 0.02 ~ 0.2 mg m^{-3}
   Mixed layer depth: 50 ~ 80 m
   Sea height anomaly: -0.1 ~ 0.1 m
   Sea surface temperature: **24 ~ 26°C**

3. Management of Pacific striped marlin could be based on the spatial distribution predicted by the habitat models.


Thank you!!
Questions?
NATIONAL
GEOGRAPHIC