Summary of an FAO workshop regarding the effects of climate variability and change on short-lived species and their forecasting **with a focus on squid stocks and Western Boundary Currents**

by co-chairs
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4th ECCWO Symposium - Washington D. C. June 4-8, 2018

FAO-sponsored workshop

Held Nov. 21-23, 2017 in Rome, Italy

Invited squid and oceanography experts from 10 countries (eight squid species)

Five sessions in plenary (brief present./discussion)

Today’s summary limited to an example of one of the five squid species associated with a WBC

Thanks to the experts from:

- Scotland
- Italy
- USA
- Australia
- South Africa
- Falkland Islands
- England
- Mexico
- Russia
- Japan

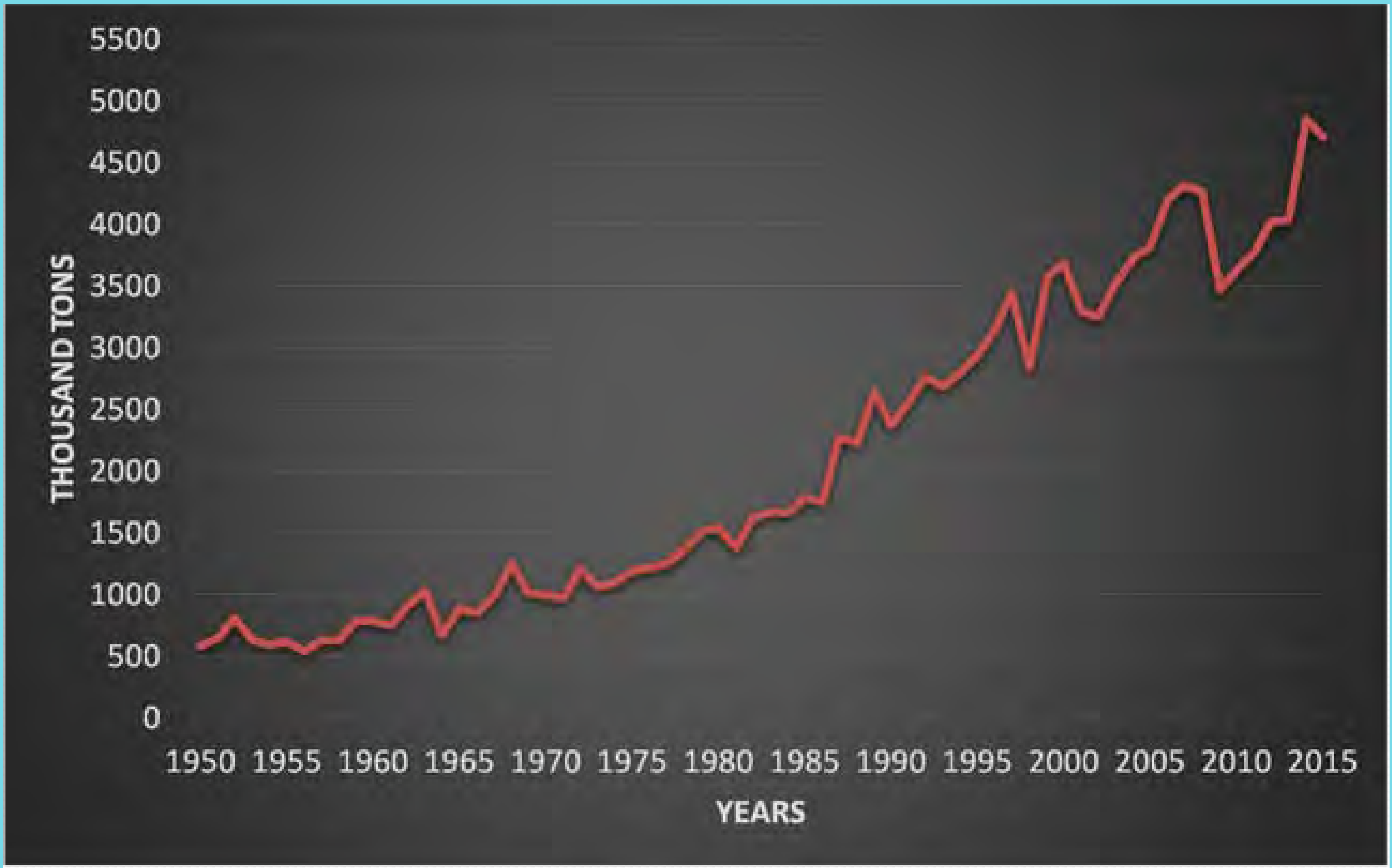
Session 8

Understanding the impact of abrupt ocean warming and continental scale connections on SQUID ~~marine~~ productivity and food security via Western Boundary Currents

So Why Squid?

1950-2017 global squid landings

Source: FAO



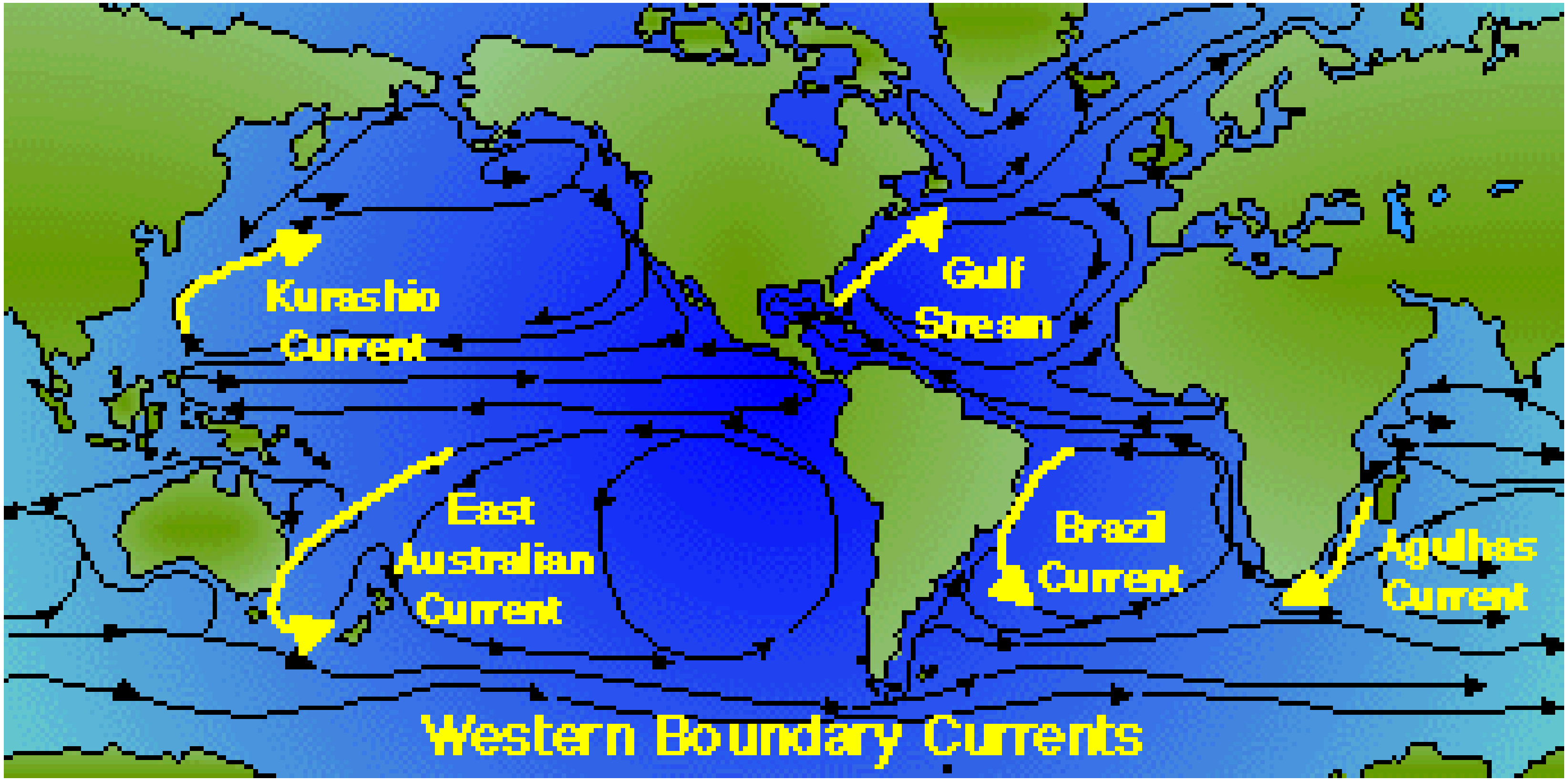
Why squid?

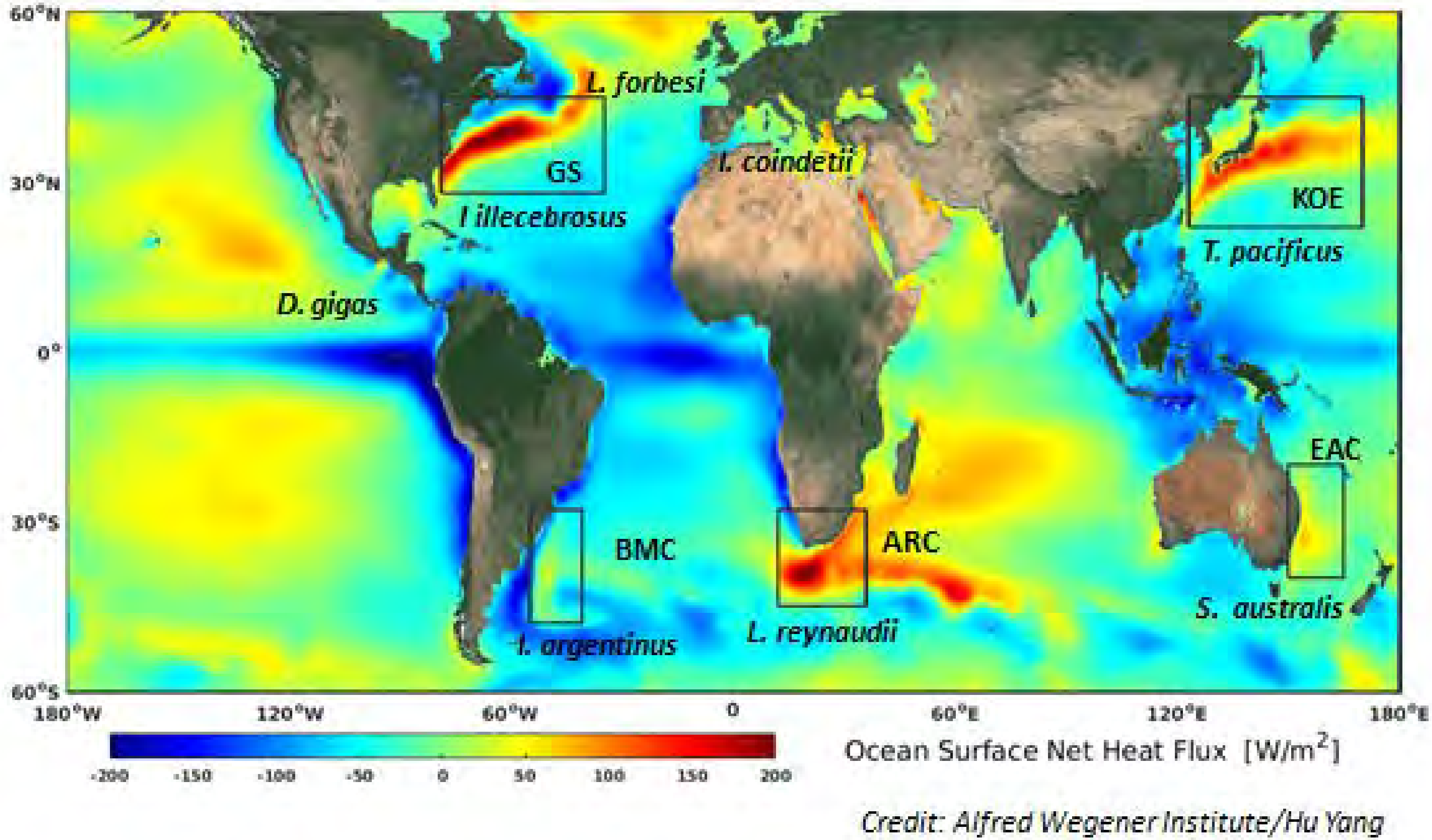
- Short-lived (annual or sub-annual), so respond quickly to environmental changes
- Early life history of some species is associated with WBCs
- Such species have wide lat. ranges and in both hemispheres
- Support large, valuable fisheries
- Population dynamics linked to environmental variability, so highly variable abundance requires forecasts for adaptive management
- Key ecosystem component

WBCs are associated with five of the workshop squid species:

Illex illecebrosus	Gulf Stream	NWA
Illex argentinus	Brazil-Malvinas	SWA
Loligo reynaudii	Agulhas	S. Atlantic
Sepioteuthis australis	E. Australian	Tasman Sea
Todarodes pacificus	Kuroshio	NW Pacific

Western Boundary Currents





Five squid species (boxes) and WBCs

Average ocean surface net heat flux

Challenges of forecasting squid abundance

- Very short lifespan (annual or sub-annual)
- Semelparous (one spawning period during lifetime)
- “Boom-bust” abundance patterns due to close linkage with environmental variability
- Highly migratory; not closed populations
- Most stocks are data-poor
- Transboundary shared resource, separately managed
- Rapid growth rates that differ for each seasonal cohort and cohorts may spawn in different areas

Workshop Objectives

1. Identify commonalities and differences in population dynamics, fisheries, stock assessment and management of each squid stock to understand forecasting needs

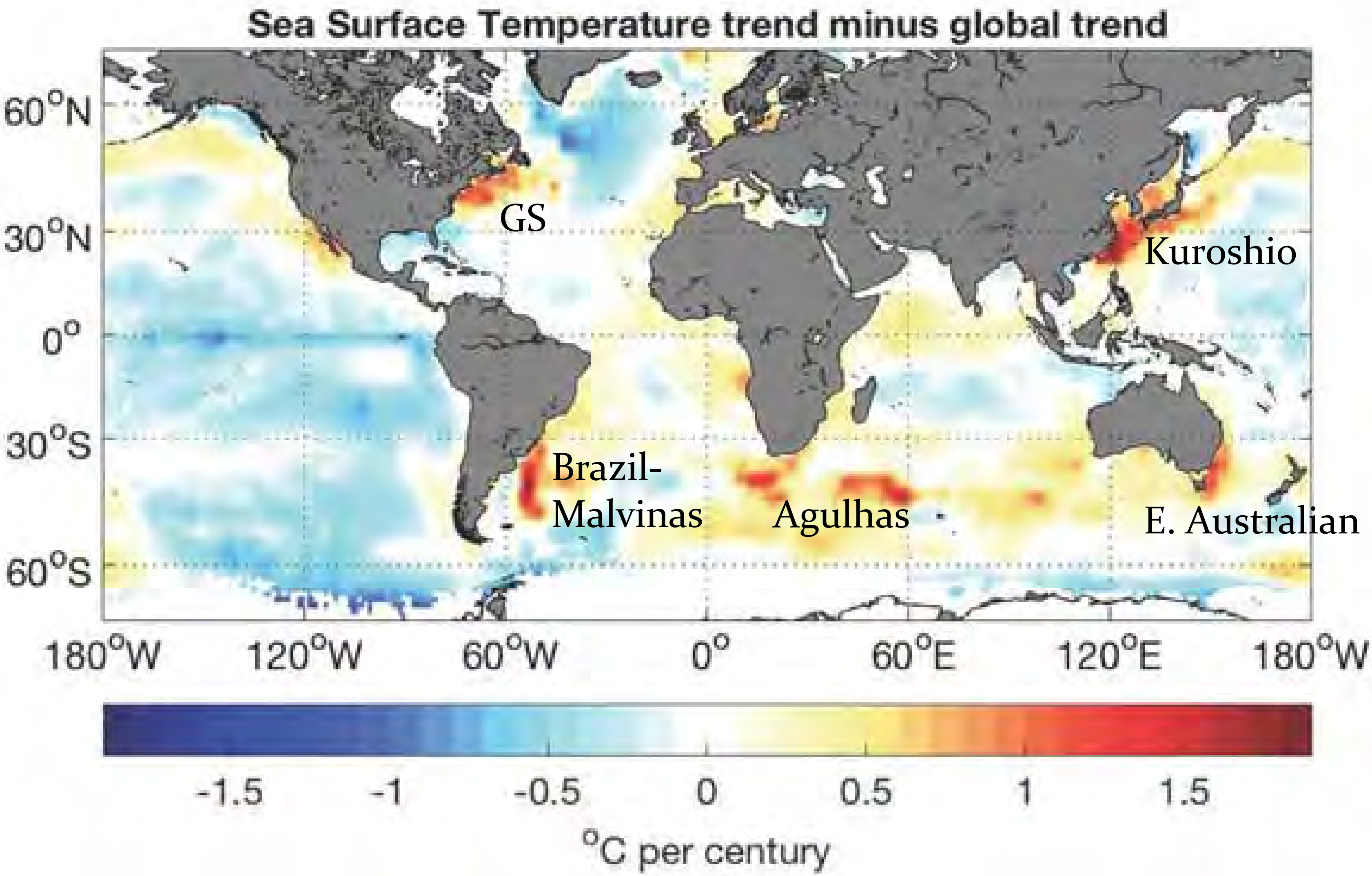
2. Review squid forecasting accomplishments (e.g., predictor variables, forecast methods, fisher/ manager buy-in, identify difficulties)

3. Identify next steps to improve development and implementation of squid forecast models

Workshop Sessions

1. Review population dynamics, fisheries, stock assessment and management for each stock
2. Review relationships between abundance/ recruitment and environmental variability
3. Identify best environmental predictors
4. Discuss squid forecast models and identify issues
5. Review/develop forecast models to support squid resource management

Is Warming of Global WBCs Impacting Squid Stocks?



Linear SST trend anomalies 1900-2016 (global trend of 0.56 ◦C per century removed)
Source: monthly HadISST2 reanalysis (Rayner et al., 2003).

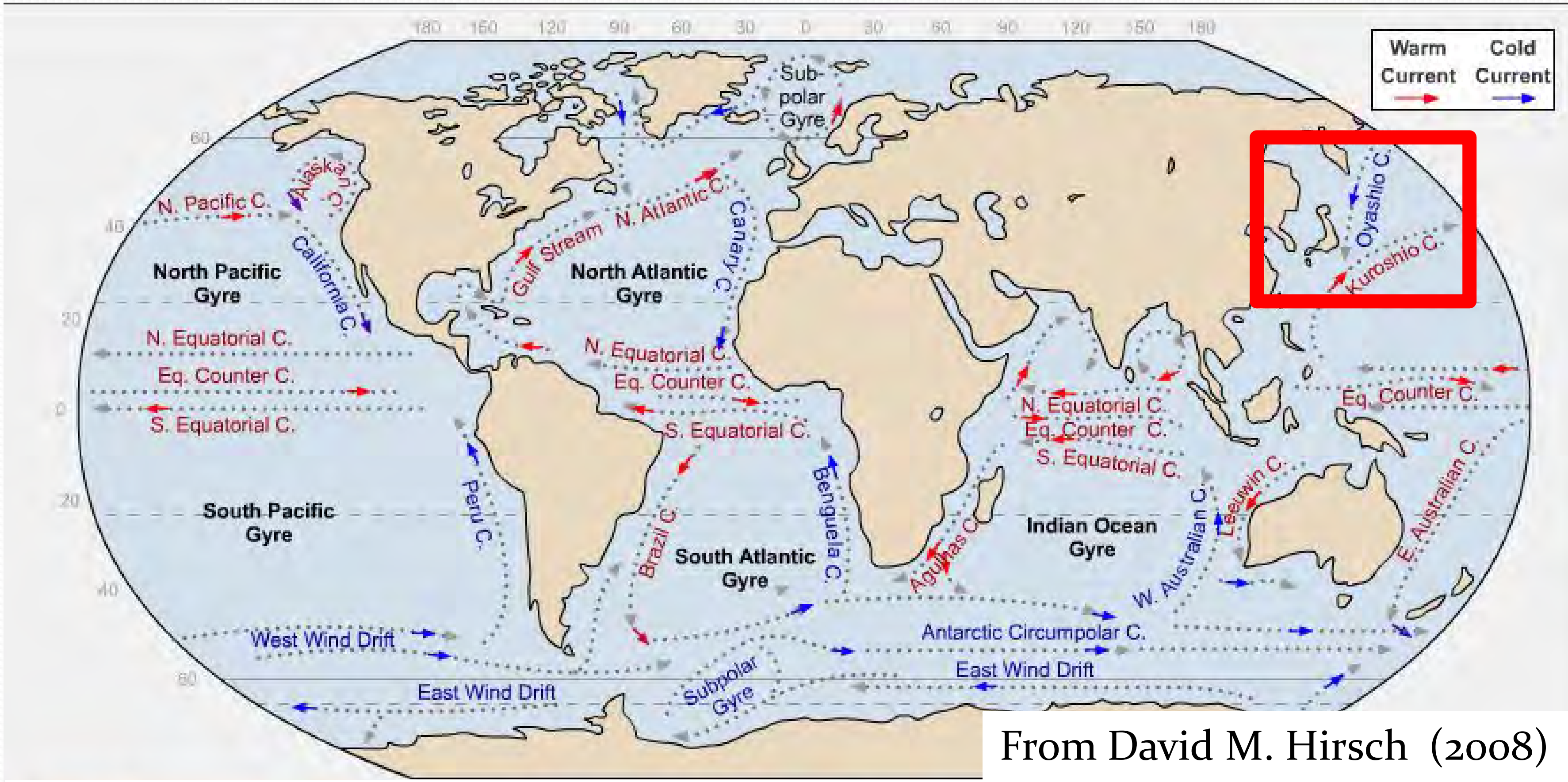
Potential effects of changing WBCs on associated squid species

1. Temperature – Egg/paralarvae growth rates
2. Velocity – Egg/paralarvae transport rates
3. Water density – Paralarvae metabolic rates and egg/paralarvae transport rates
4. Meandering – juvenile transport and distribution patterns
5. Latitudinal movement – favorable/unfavorable water mass properties, distance for juvenile travel

Squid Abundance and Environmental Variability Relationships

- Differ by life history stage
- Short time scales, but broad spatial scales with differing environmental conditions
- Environ. relationships have been identified, but may not be stable due to global impacts on WBCs from climate change

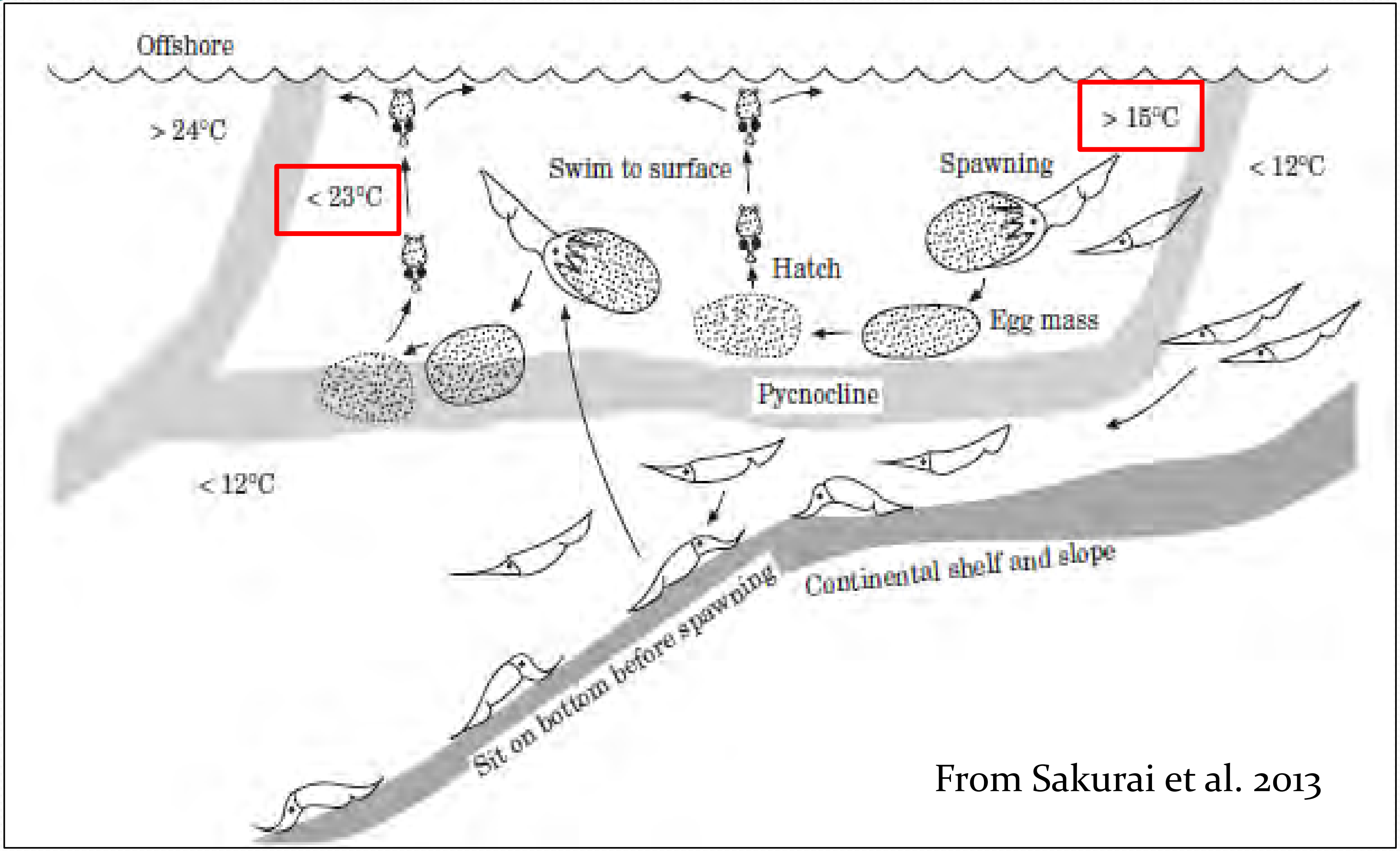
Example: Impacts of Kuroshio Current Changes on *Todarodes pacificus*



From David M. Hirsch (2008)

Todarodes pacificus is associated with Kuroshio Current in NW Pacific and Tsushima Current in Sea of Japan

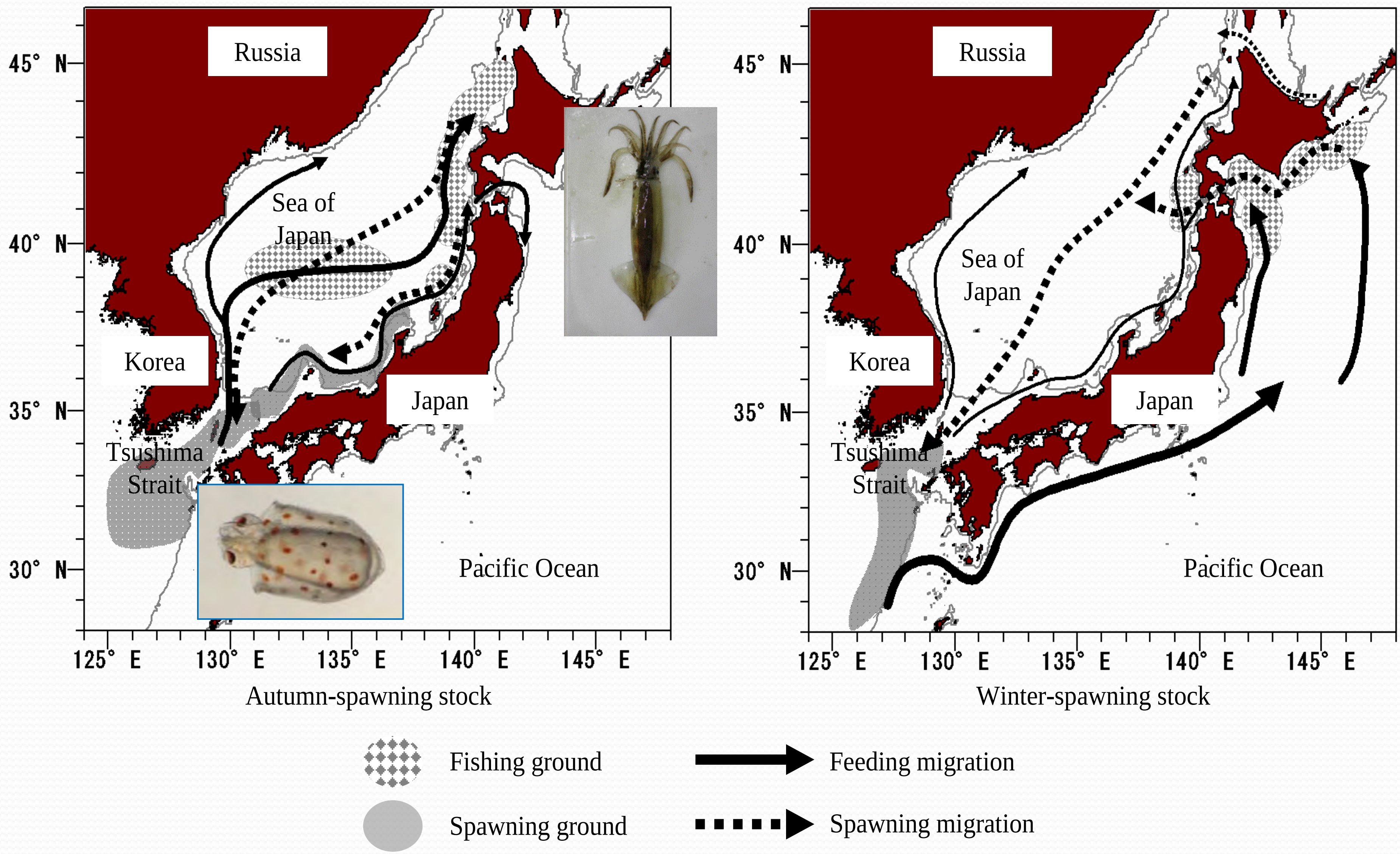
Life History of *Todarodes pacificus*



From Sakurai et al. 2013

Temperature preferences vary by life history stage

Migration routes throughout life cycle in relation to spawning, feeding and fishing grounds and important currents and water masses for two seasonal cohorts

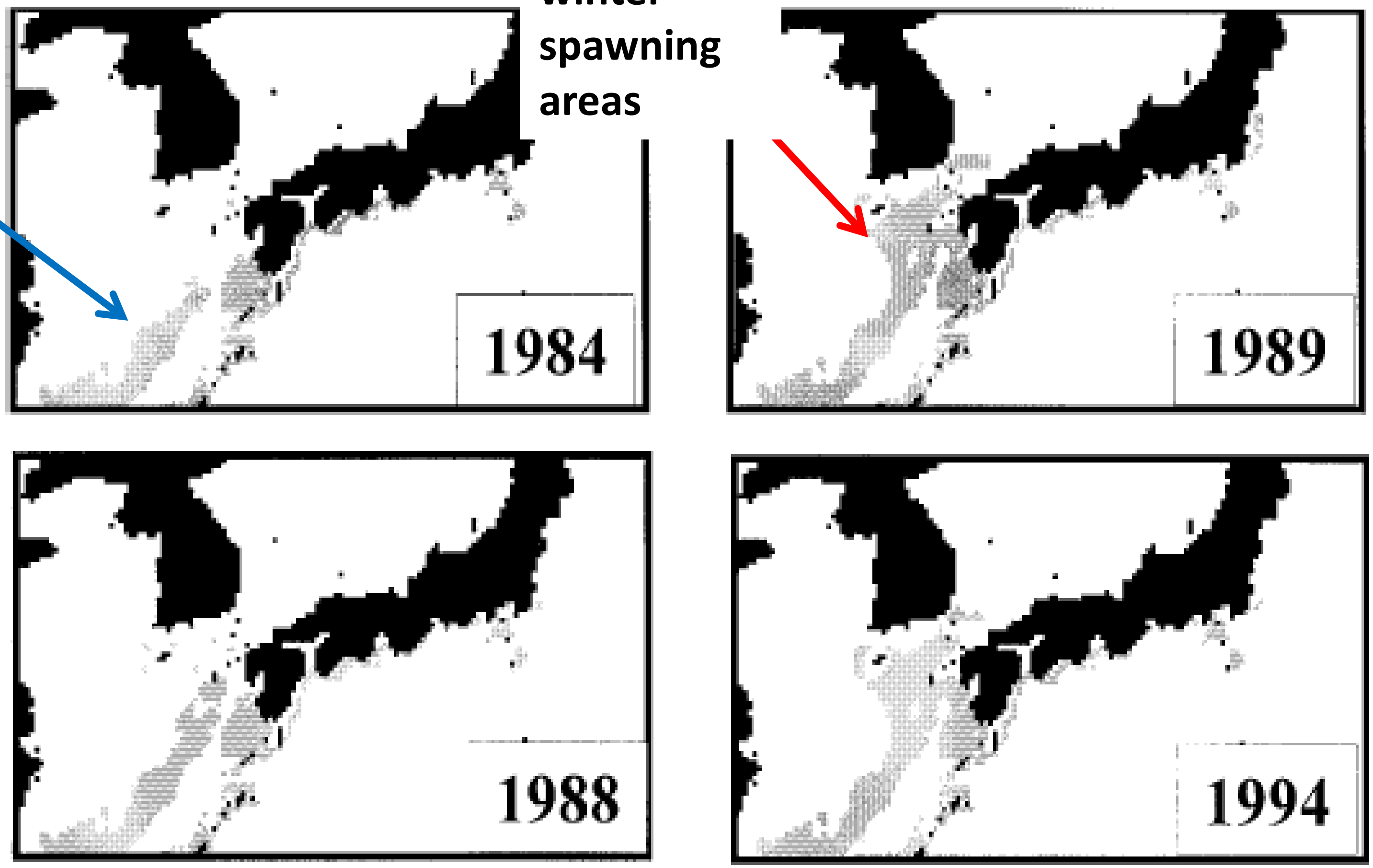


Environmental Predictors

- Population dynamics change due to temperature regime shifts
- Cool regime (1977-1988) - stock size decreases, small winter spawning area
- Warm regime (1989-current) - stock size increases, fall and winter spawning areas larger and overlap

Small spawning area

Overlap of fall and winter spawning areas



Cool regime

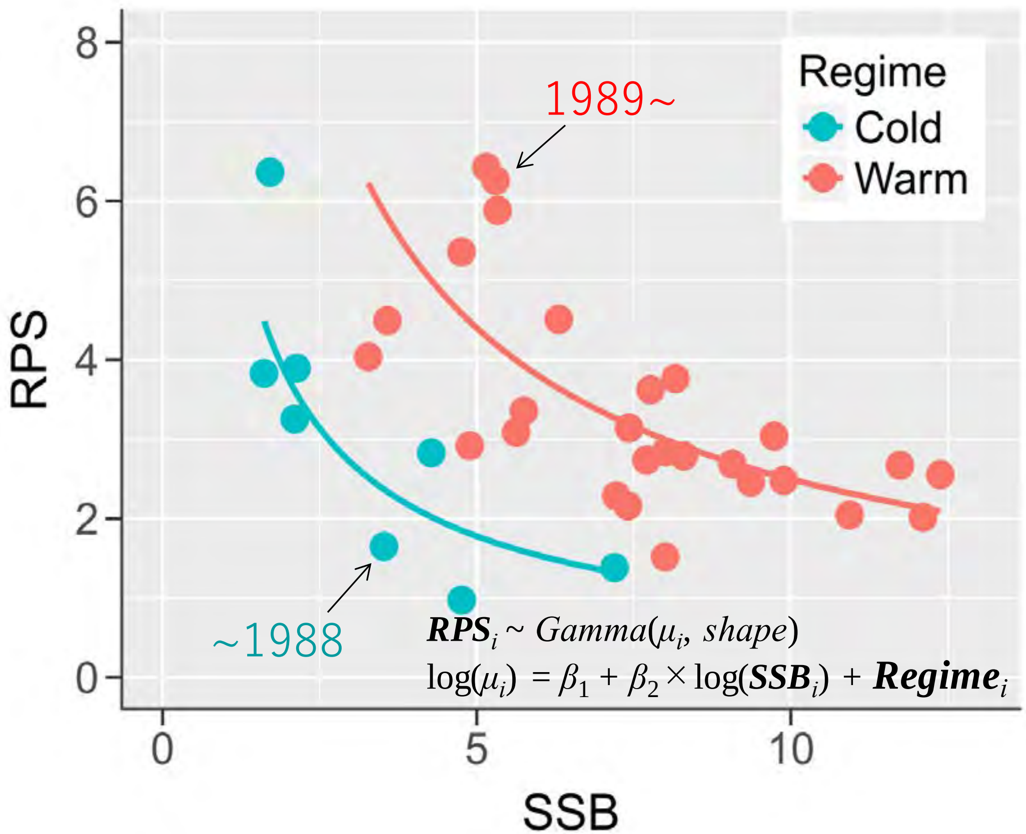
Warm regime

(From Sakurai et al. 2000)

Forecast modeling and issues

- In the developmental stages for most squid stocks, some data gaps
- Even short-term (1 yr) forecasts have very wide confidence limits
- May need two sets of harvest control rules: for low vs high productivity regimes
- Need buy-in of fishers/managers (e.g., quota reductions during low prod. years

T. pacificus BRPs



(Kidokoro et al., 2013; Yamashita and Kaga, 2013)

BRPs based on S/R relationship

Low/high stock size is dependent on cold/warm temperature regimes, so S/R BRPs are regime-specific

Workshop Outcomes

1. Developed squid forecasting framework

2. Workshop report (FAO publication)

3. Planned “Next Steps”

Next Steps

1. Present results at this symposium and Nov. CIAC meeting
2. Implement forecasting demonstration project
3. Peer-reviewed publication
4. Present forecast models to fishers/managers for feedback (assumptions, uncertainties and model skill)

“Squid aren’t fish”

Given their short lifespan and semelparous life history,

forecasting their abundance is much more challenging