Understanding barrier effects of ocean fronts to implement actionable conservation

HABITABLE JAPAN
HOTSPOT III

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1. hotspot effects & barrier effects
2. example of SPF in NW Pacific
3. global analysis



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Underestimated barrier effects of ocean fronts shape global fishery distribution

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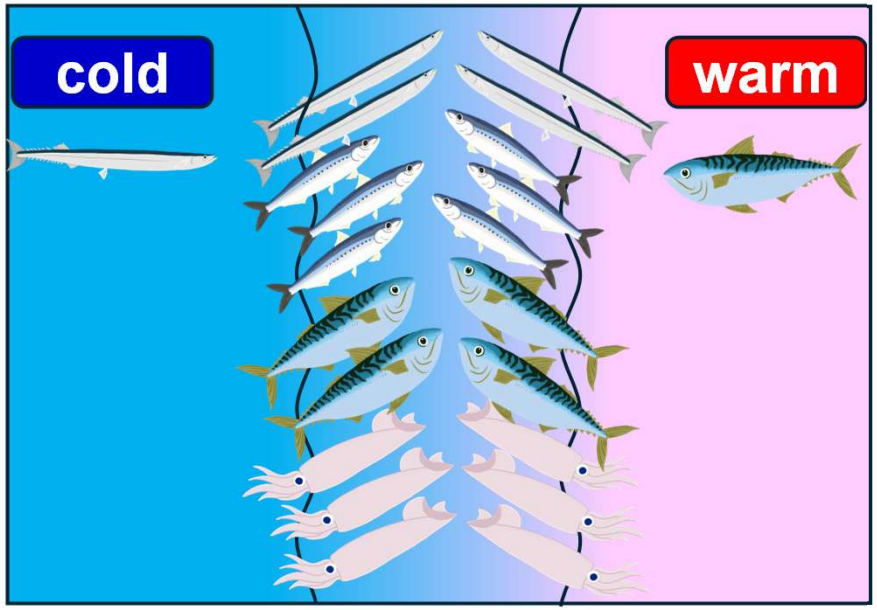
Effects of fronts on fish distribution

Classical idea:
hotspot effect

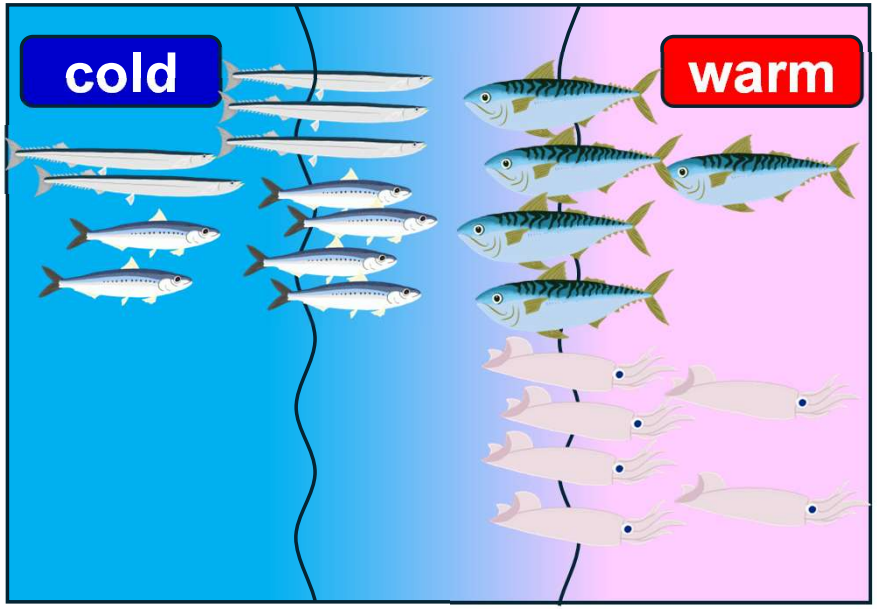
front



Woodson et al. (2015, PNAS), etc.

Another idea:
barrier effect

front

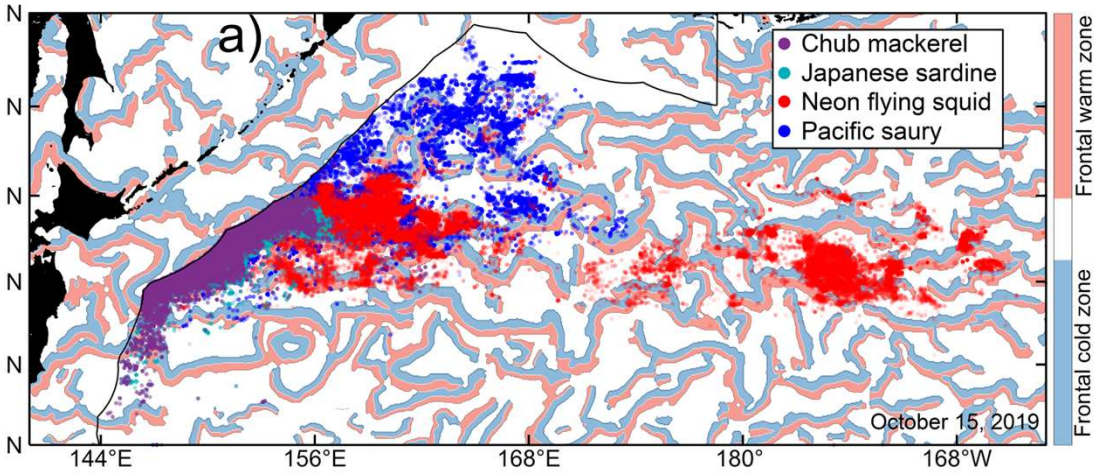


Kitagawa et al. (2004, FOG), etc.

Hotspot effect or barrier effect, which is important?

Methods

Xing et al. (2026, Nature Comm.)



Warm-side

Cold-side

Front detection (Xing et al., 2023)

- **SST (ESA SST) CCAIM: Cayula and Cornillon Algorithm coupled with IDW and Mathematical morphology operators**
- **Front, front-cold/warm side detection**

Chinese fishery boats logbook: 2017-2021

mackerel **sardine**

neon flying squid **saury**

Compare relative catch

in vs out: hotspot effect

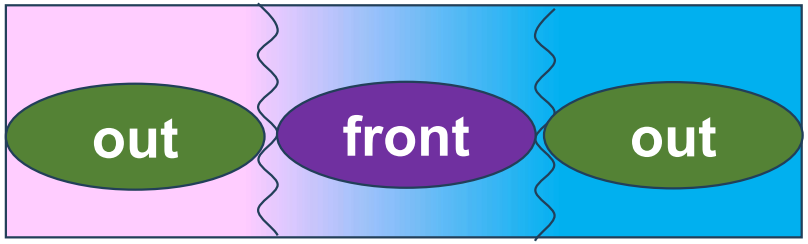
cold vs warm: barrier effect

Methods

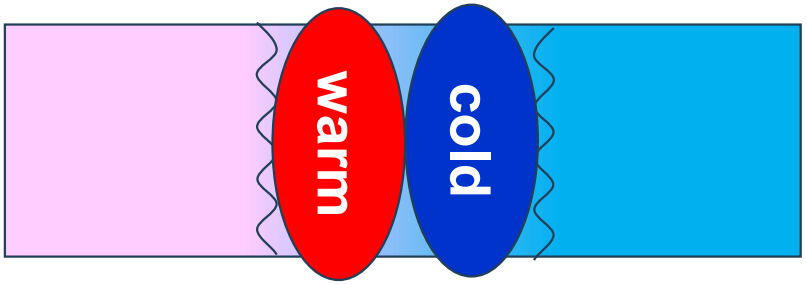
relative difference in fishing catch (or effort) per unit area

Hereafter "catch difference"

$$RD_{FPA}(hotspot) = \frac{\frac{Catch(\boldsymbol{front})}{Area(\boldsymbol{front})} - \frac{Catch(\boldsymbol{out})}{Area(\boldsymbol{out})}}{\frac{Catch(all)}{Area(all)}}$$

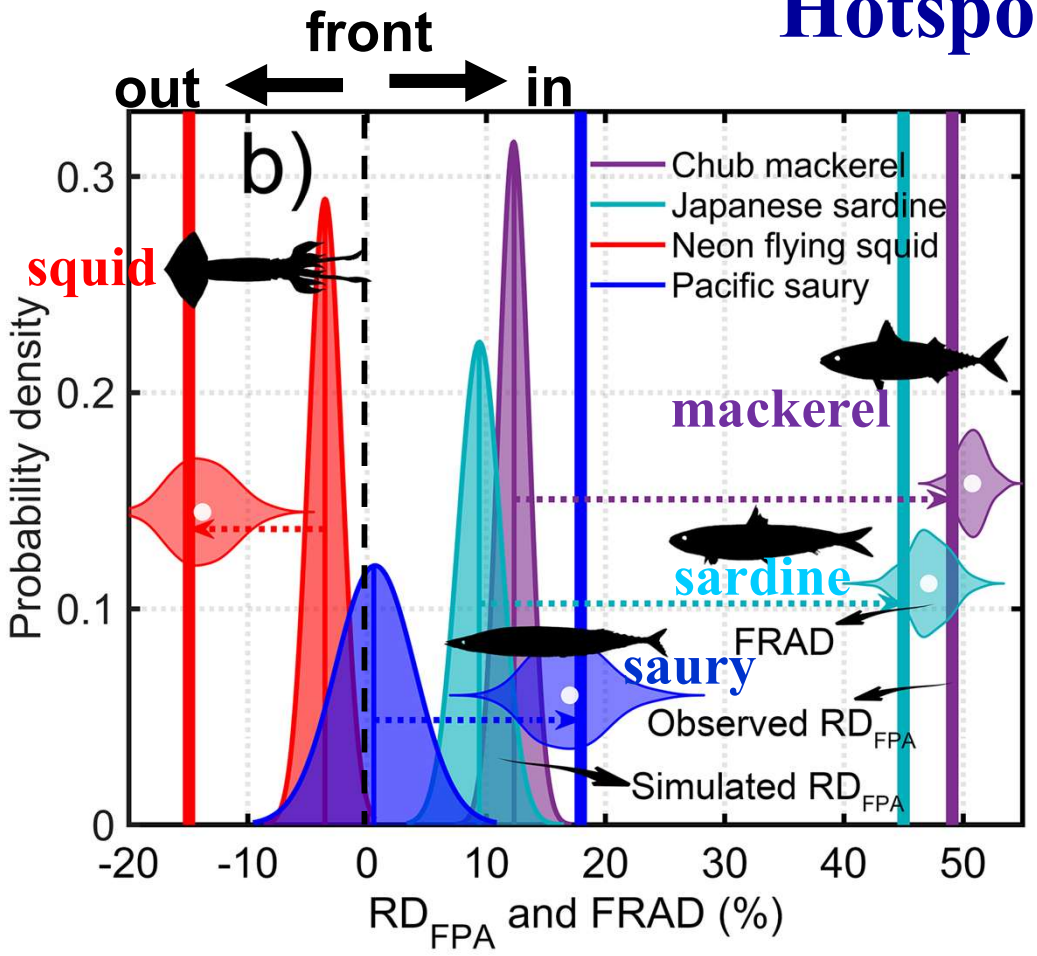


$$RD_{FPA}(barrier) = \frac{\frac{Catch(\boldsymbol{warm})}{Area(\boldsymbol{warm})} - \frac{Catch(\boldsymbol{cold})}{Area(\boldsymbol{cold})}}{\frac{Catch(all)}{Area(all)}}$$



Since fishery data may be biased, randomly distributed simulation was applied. If the value is larger than that from random simulation, it can be recognized as significant

Hotspot Effect



Xing et al. (2026, Nature Comm.)

Bar: catch difference

Bell: catch difference by random simulation

Violine: fishing catch relative anomaly difference (FRAD)

Positive: in > out

Bar > Bell : significant hotspot effects

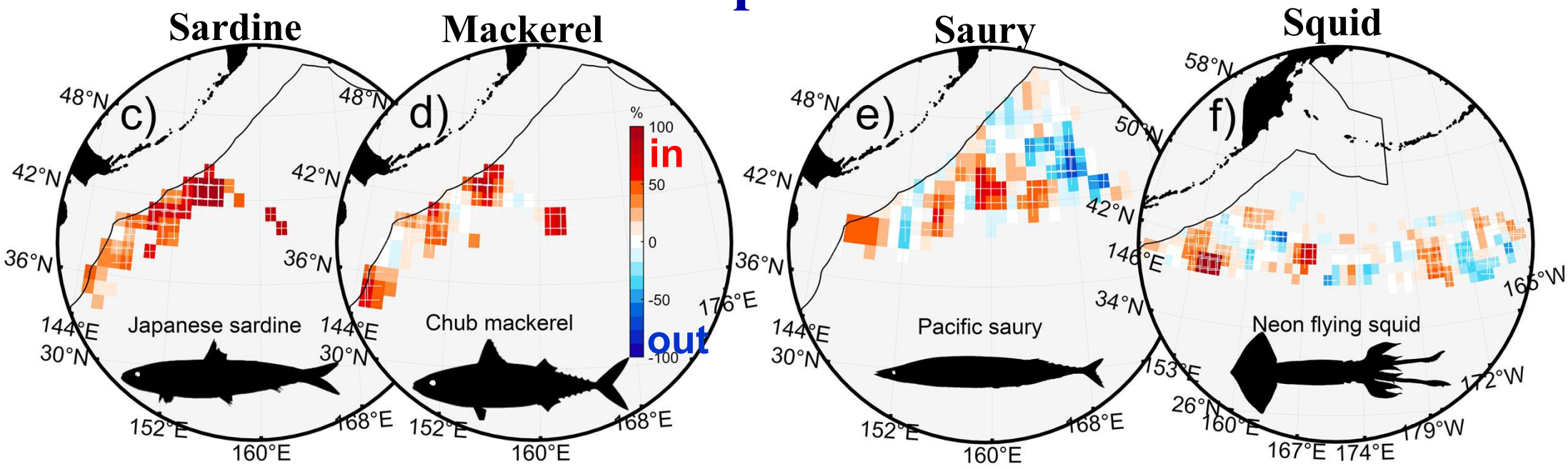
Mackerel: hotspot

Sardine: hotspot

Squid: no effect

Saury: weak hotspot

Hotspot Effect

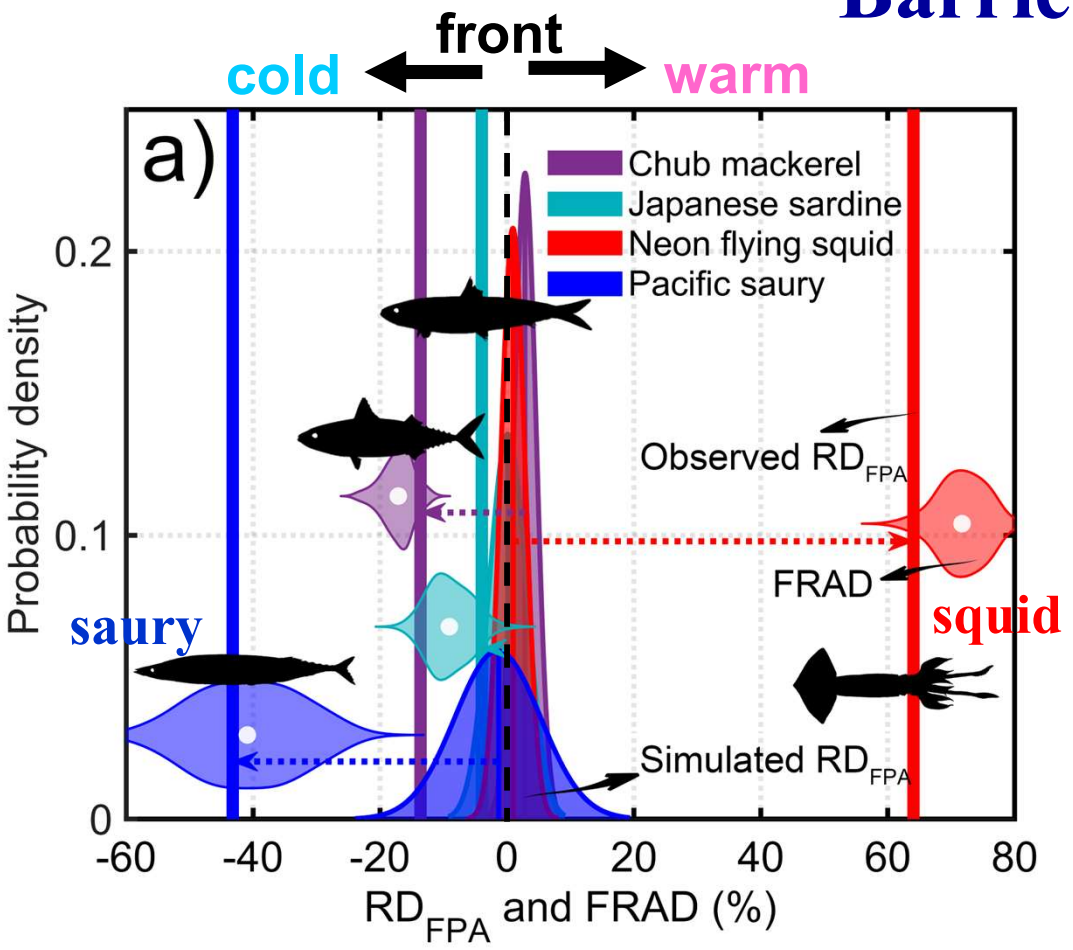


Xing et al. (2026, Nature Comm.)

Catch diff.
Positive: in > out
white +: significant

Sardine & mackerel: strong hotspot effects
Saury & squid: geographical dependent

Barrier Effect



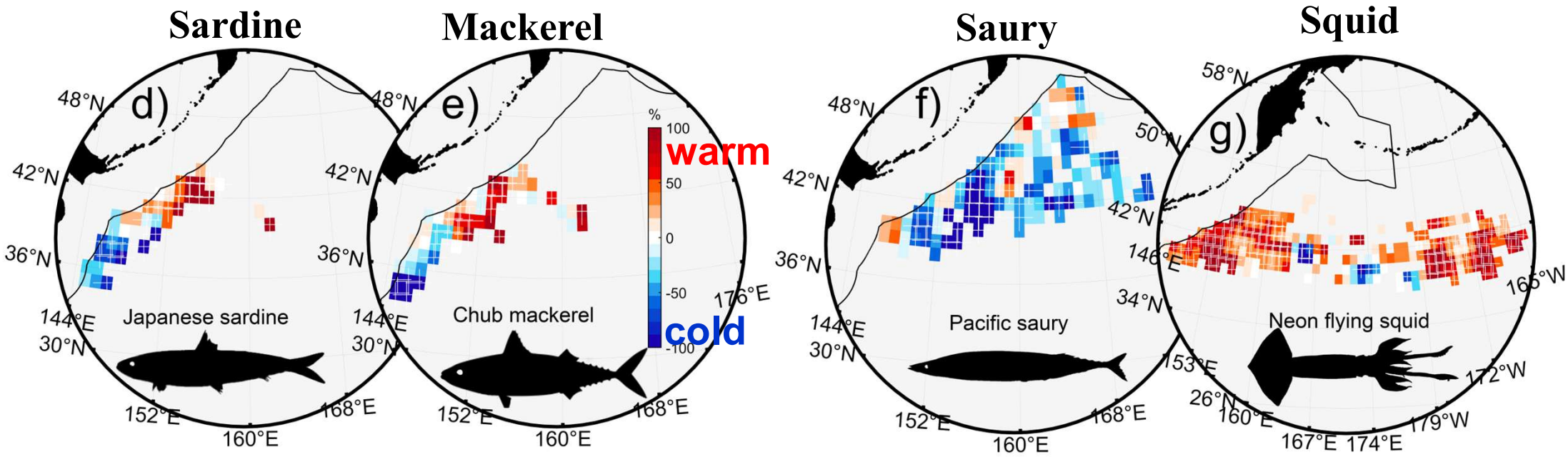
Xing et al. (2026, Nature Comm.)

Bar: catch difference
Bell: catch difference by random simulation
Violine: fishing catch relative anomaly difference (FRAD)

Positive: warm > cold
Bar > Bell: significant barrier effects

mackerel: weak barrier
sardine: weak barrier
squid: strong barrier (warm)
saury: strong barrier (cold)

Barrier Effect



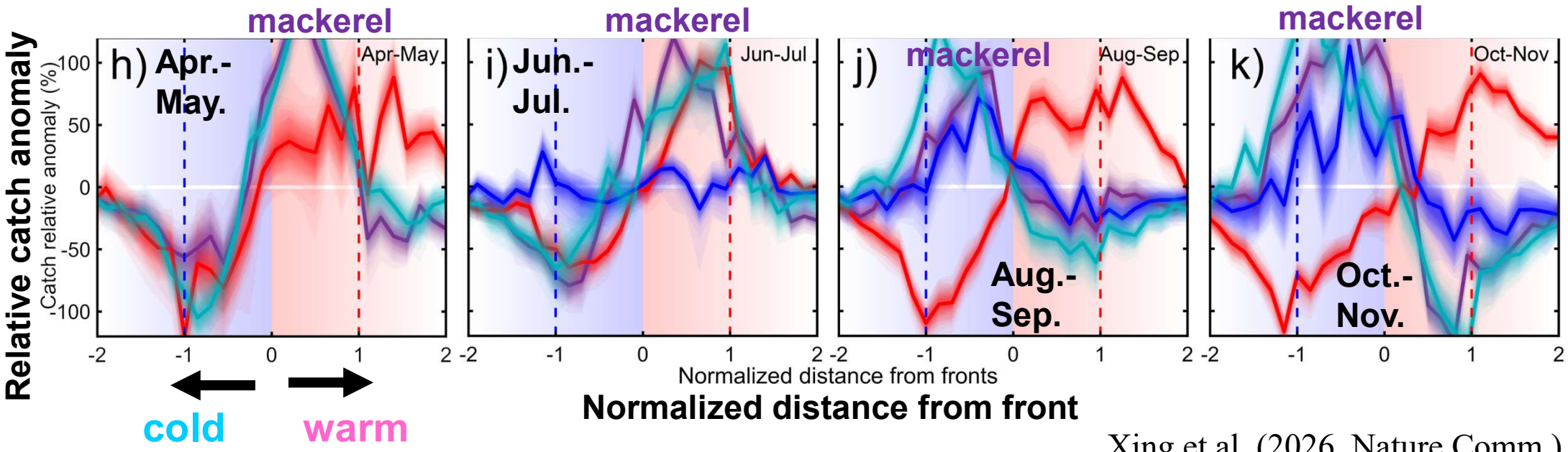
Catch diff.
Positive: warm > cold
white +: significant

Xing et al. (2026, Nature Comm.)

Sardine & mackerel: geographical dependent
Saury & squid: strong barrier effect

Small pelagic make seasonal migration.
Seasonality should be checked.

Barrier Effect



Xing et al. (2026, Nature Comm.)

Mackerel: warm in Apr-Jul., cold in Aug.-Nov.

Sardine: warm in Apr-Jul., cold in Aug.-Nov.

Squid: always warm

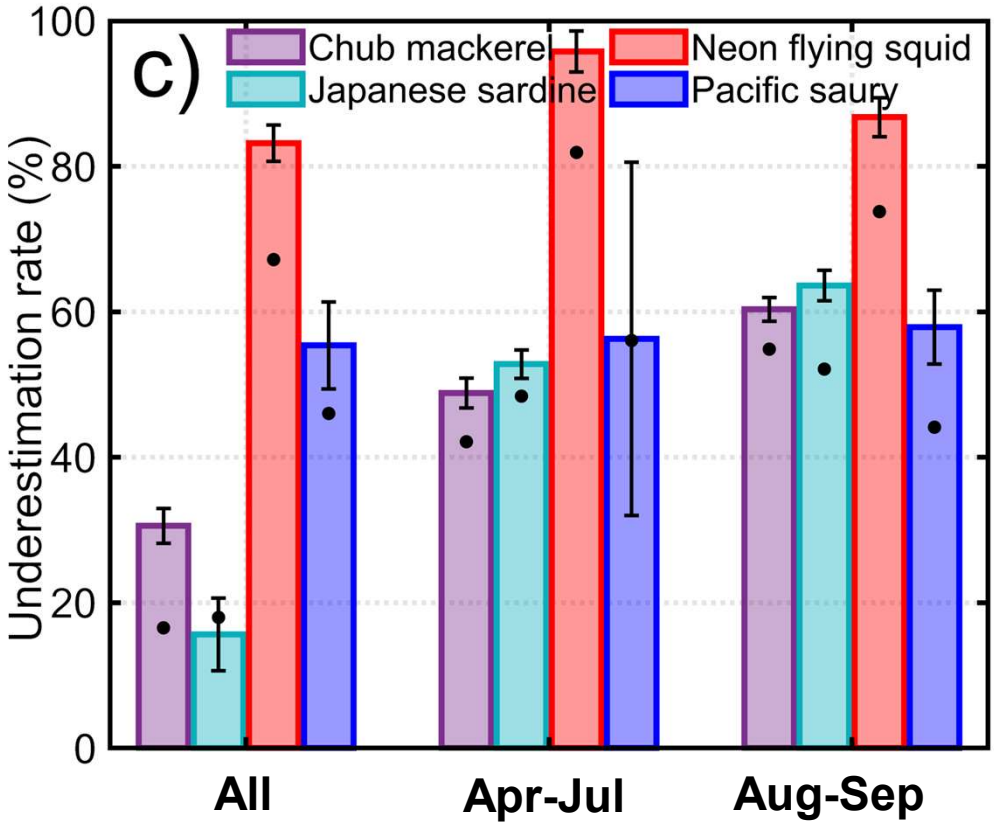
Saury: always cold

Relative diff. between barrier & hotspot effects

$$\frac{barrier\ effect - hotspot\ effect}{max(barrier\ or\ hotspot\ effect)}$$

For all year,
Mackerel: weak barrier
Sardine: weak barrier
Squid: strong barrier (warm)
Saury: strong barrier (cold)

Considering seasonal variation
- **Sarine & mackerel also have strong barrier effect**



Xing et al. (2026, Nature Comm.)

Barrier Effect

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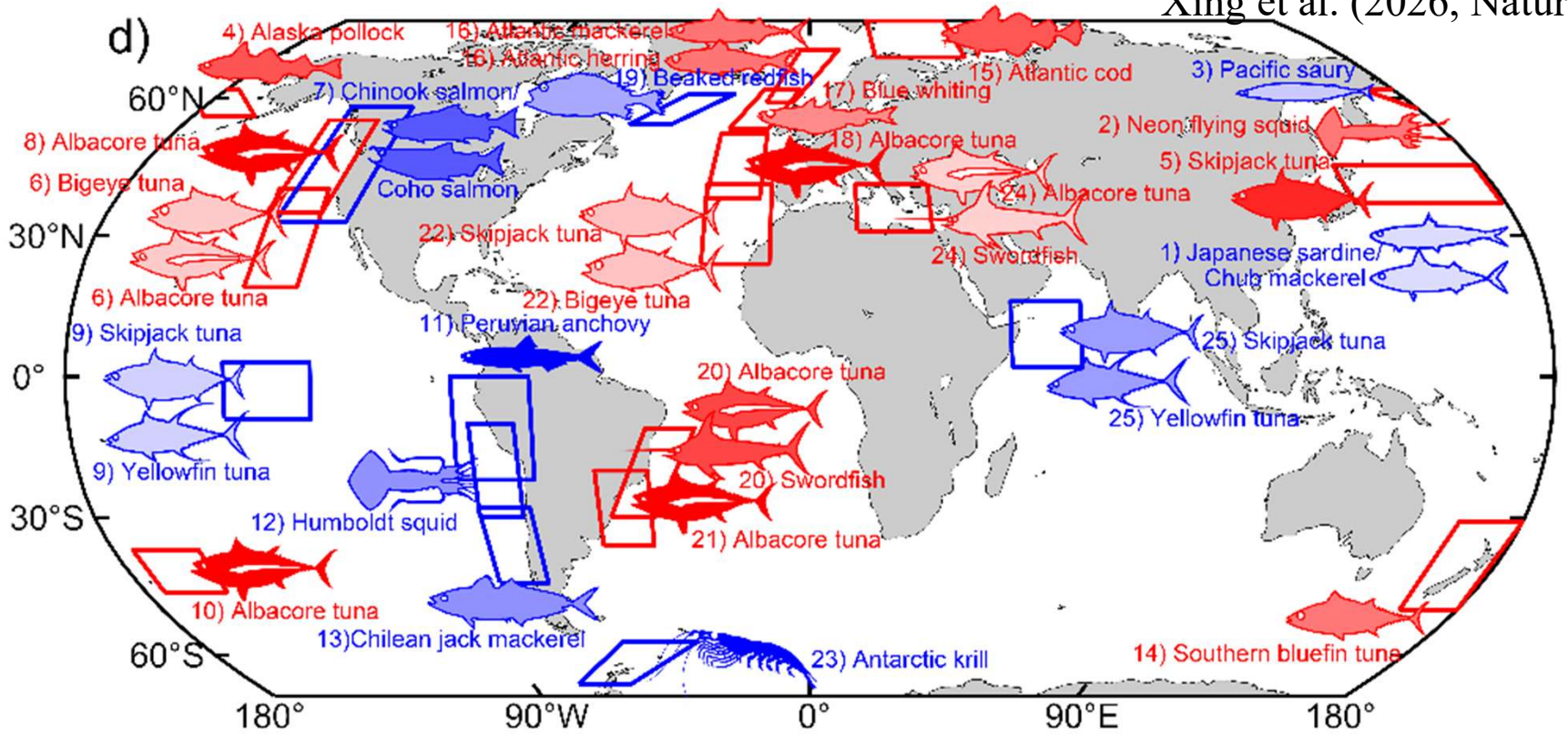
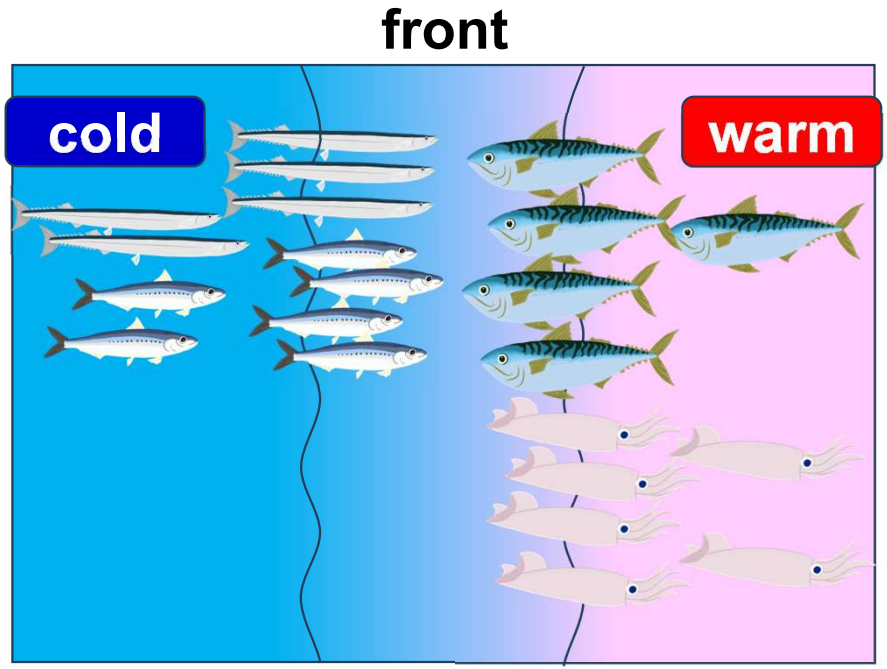


Color intensity: effect amplitude
Red: warmer side aggregation
Blue: colder side aggregation

Barrier effects are working in the world ocean.

Understanding barrier effects of ocean fronts to implement actionable conservation

- **Barrier effect (15-70%) often surpass hotspot effect (5-20%)**
- **Barrier effect possibly has seasonality**



The correct understanding of frontal effects on fish distribution enables actionable science (e.g. mitigating bycatch of endangered species) with dynamically fluctuating fronts in the ocean.

Xing Q., Z. Gao, S. Ito, H. Yu, B. Liu, H. Zhang, X. Chen, W. Yu, 2026, Underestimated barrier effects of ocean fronts shape global fishery distribution. Nature Communications, 17, 4545. https://doi.org/10.1038/s41467-026-71250-0

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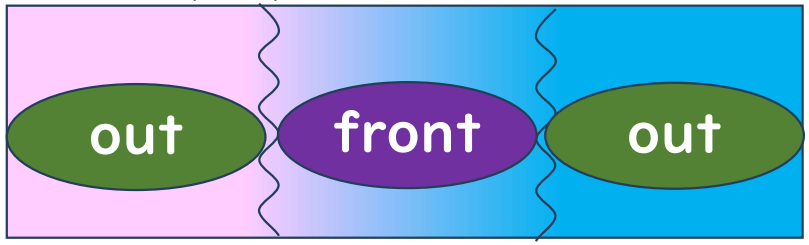
For questions

Method

fishing catch relative anomaly difference (FRAD)
Difference between relative anomaly from random simulation

$$FRAD(hotspot) = \frac{Catch(\boldsymbol{front}) - Catch(sim)}{Catch(sim)} - \frac{Catch(\boldsymbol{out}) - Catch(sim)}{Catch(sim)}$$



$$FRAD(barrier) = \frac{Catch(\boldsymbol{warm}) - Catch(sim)}{Catch(sim)} - \frac{Catch(\boldsymbol{cold}) - Catch(sim)}{Catch(sim)}$$

