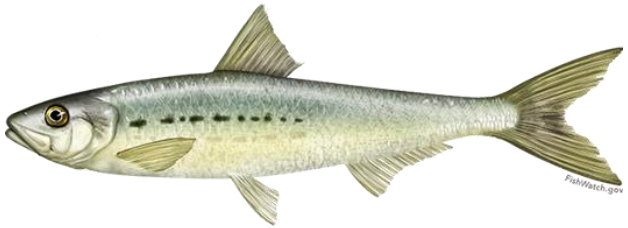
Incoherent Dimensionality Between the Population and Stock Structure of Pacific Sardine (*Sardinops sagax*)



THE SUBPOPULATION PROBLEM IN THE PACIFIC SARDINE
SARDINOPS CAERULEA

By

John C. Marr[1/]

Brad Erisman[1], Matthew Craig[1], Kelsey James[1], Emmanis Dorval[2]

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[2]Lynker Corporation under contract with SWFSC

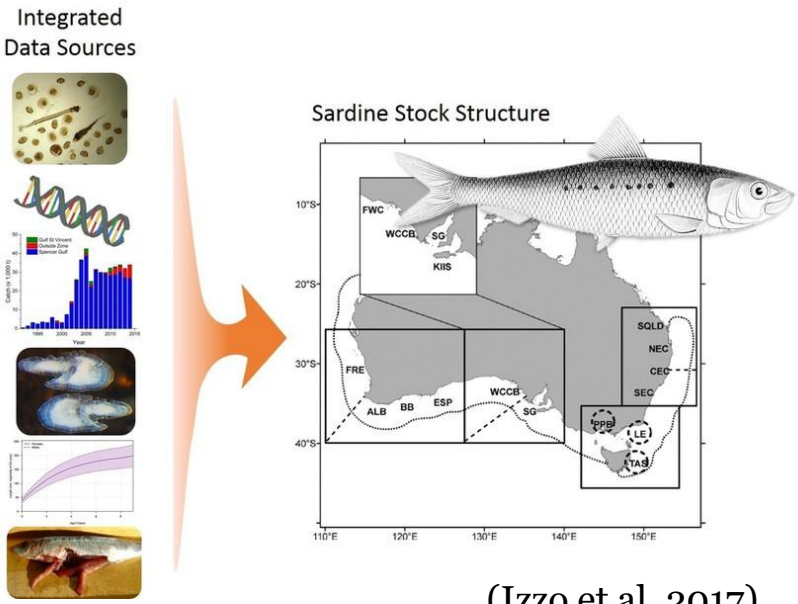
Best Practices for Defining Fishery Management Units

(Punt et al. 2015; Berger et al. 2021; Cadrin et al. 2023)

IDEAL SCENARIO: Stock boundaries represent a biological population and its spatiotemporal components at scales relevant to its life history.

PRACTICAL CONSIDERATIONS: Social, economic, and political factors (e.g., ***transboundary stocks***)

VALUE: Improves model performance; avoids biased reference points, corrupted stock assessments, misconceptions about stock status, and adverse management outcomes.



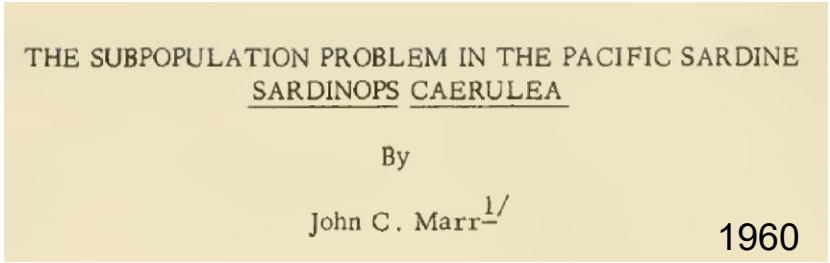
(Izzo et al. 2017)

U.S. Management of Sardine is Designed to Align Stock Structure with Population Structure

CPS Fishery Management Plan:

"It is ***generally accepted*** that sardine off the West Coast of North America form three **subpopulations or stocks….distinguished on the basis of serological techniques** (Vrooman 1964)"

EXPLANATORY HYPOTHESIS: "….Although the ranges of the northern and southern subpopulations overlap, the **stocks may move north and south at similar times and not overlap significantly**."


THE SUBPOPULATION PROBLEM IN THE PACIFIC SARDINE
SARDINOPS CAERULEA

By

John C. Marr[1/]

1960

Emphasis on biological populations (genetics)

MacCall (1984)

"a population of organisms (ideally sharing a **common gene pool**), that is sufficiently discrete (and nominally identifiable) to warrant consideration as a self-perpetuating system that can be managed."

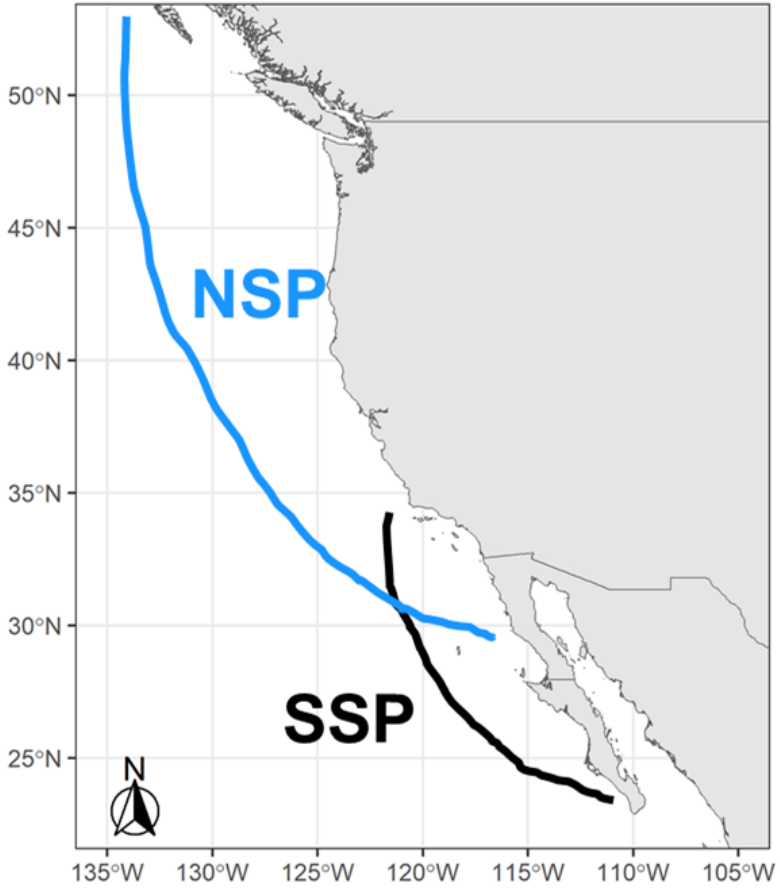
"We had reason to believe from blood **serological research** that there was a northern and southern stock of sardines".

Growing Uncertainty

- Blood groups (Sprague and Vrooman 1962; Vrooman 1964) unrelated to population genetics
- Allozymes (Hedgecock et al. 1989) Low variation; common gene pool
- mtDNA (Lecomte et al. 2004) No structure
- mtDNA and Microsatellites (Gutiérrez-Flores 2007) No structure

Smith (2005):

"Even when heterogeneity is in question, **precautionary management** principles, which reduce the risk of overfishing, should support management of stocks of fish in different areas as independent stocks"

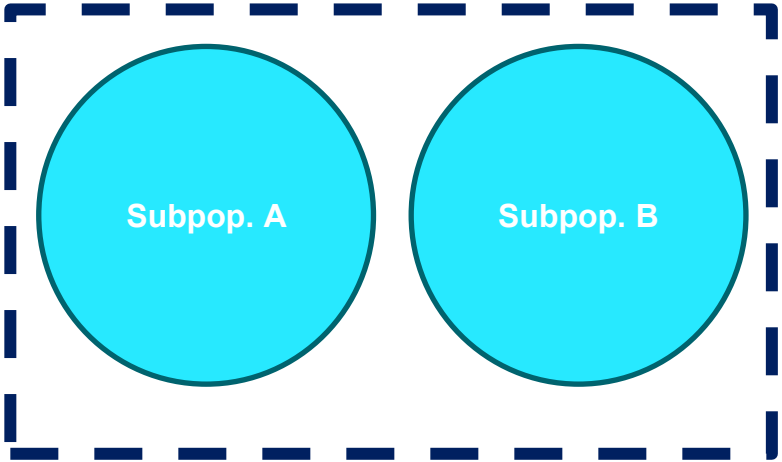


[Redrawn from Yau (ed.) 2023]

Incoherent Dimensionality in Fishery Management

Berger et al. (2021): Misalignment of management unit (stock) and biological unit (population)

Subpopulations managed as a single unit



Smith (2005):

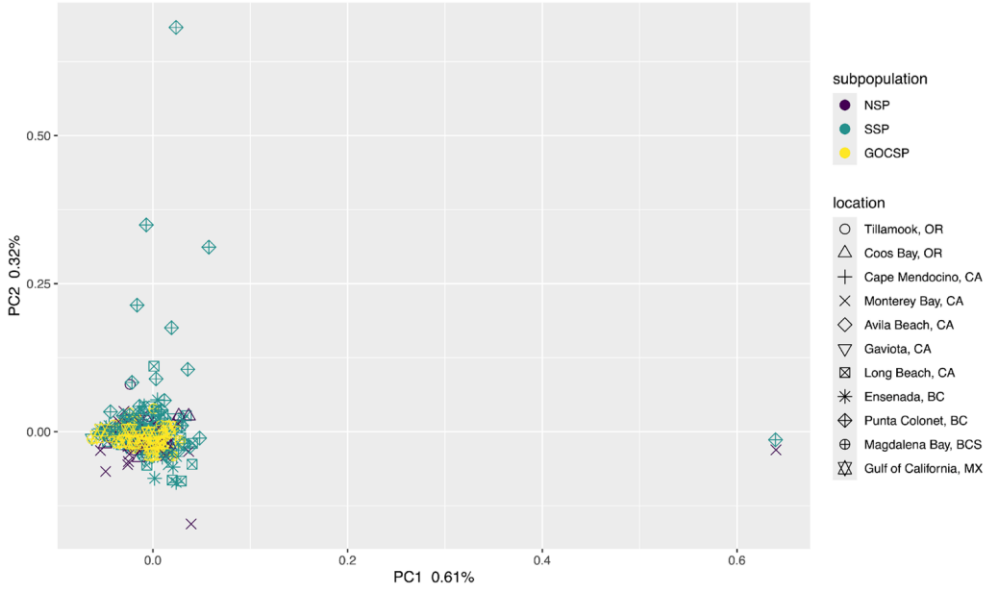
"The **stock with higher productivity could induce overharvest of the other stock** if a common quota is used."

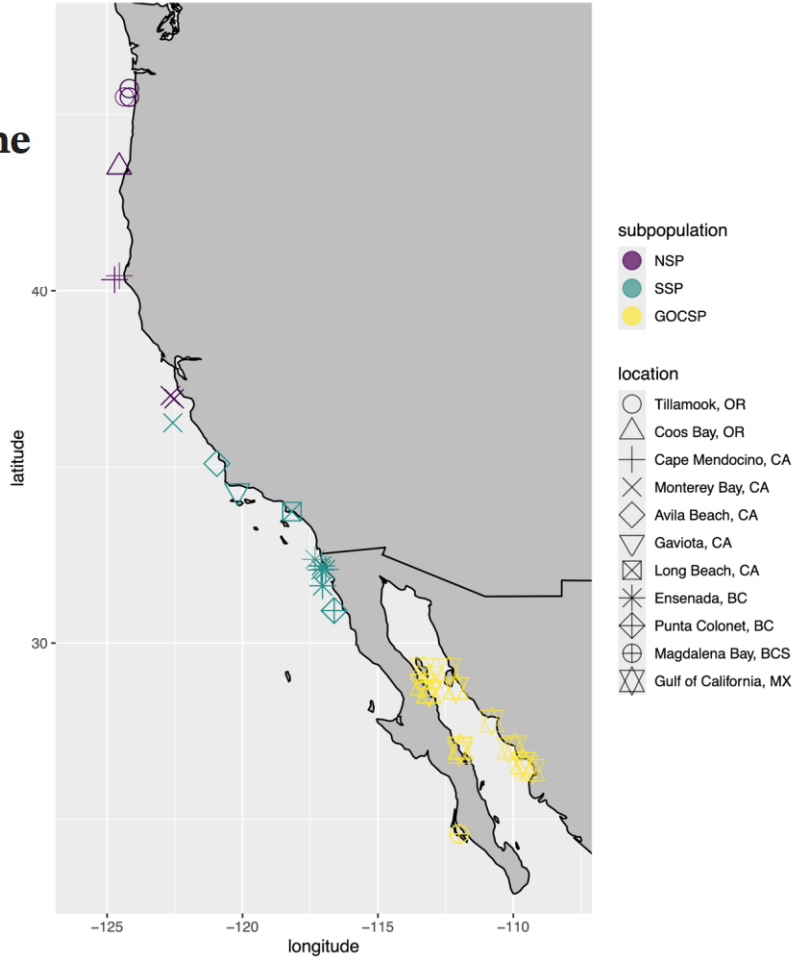
"**Asynchronous recruitment** could result in strong recruitment to one stock, leading to overfishing of the other stock."

Evolutionary Applications
Open Access

Population Genomics Reveals Panmixia in Pacific Sardine (*Sardinops sagax*) of the North Pacific

Gary C. Longo[1] | Katie D'Amelio[2] | Wes Larson[2] | Concepción Enciso Enciso[3] | Jorge Torre[4] | Jeremiah J. Minich[5] | Todd P. Michael[5] | Matthew T. Craig[6]

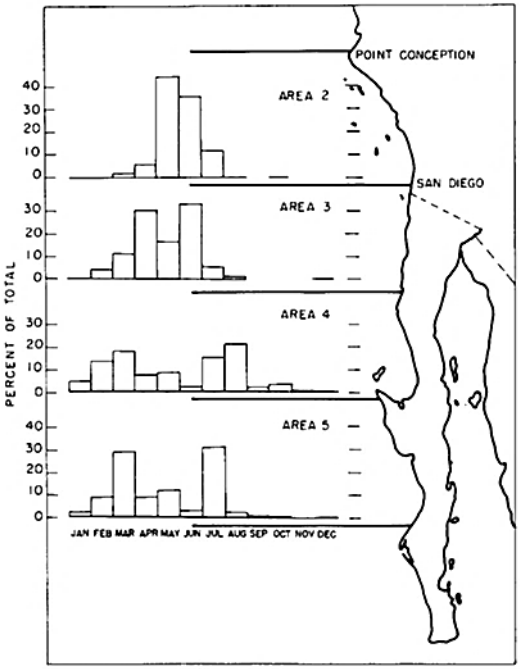




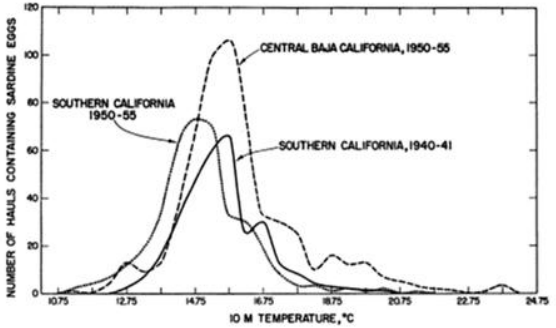
No Evidence of Reproductive Isolation in Pacific Sardine

(Tibby 1937; Ahlstrom 1954, 1959, 1967; Marr 1960; Kramer 1970; Hernandez-Vasquez 1994; Lluch-Belda et al. 1991, 2003)

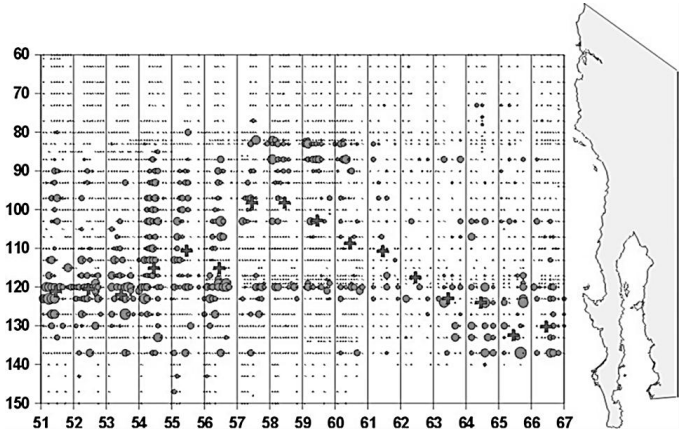
Protracted spawning seasons



Consistent, broad thermal range of spawning

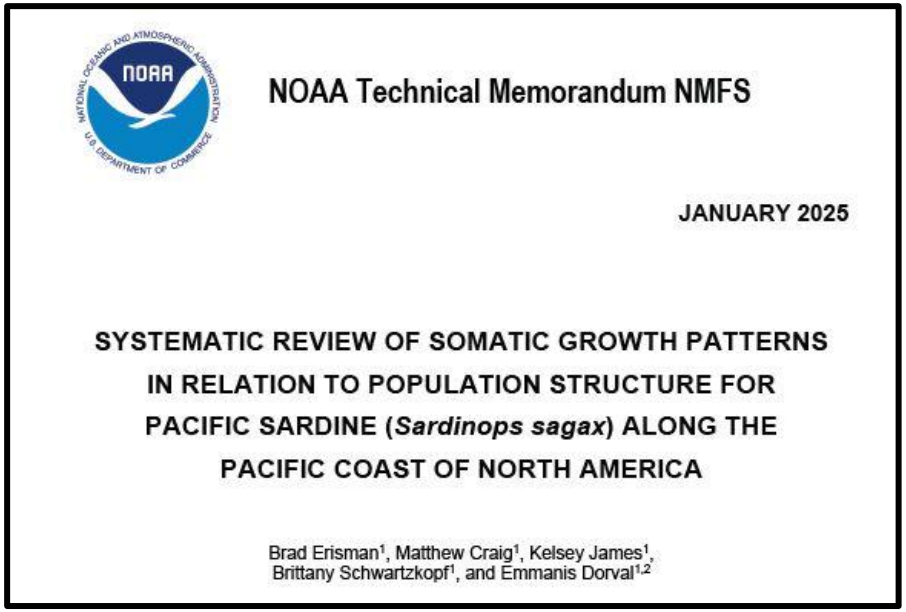


No distinct spawning areas or periods



Systematic Reviews Find No Evidence of Subpopulations

Empirical results from original studies consistent with genetics in support of a single biological population

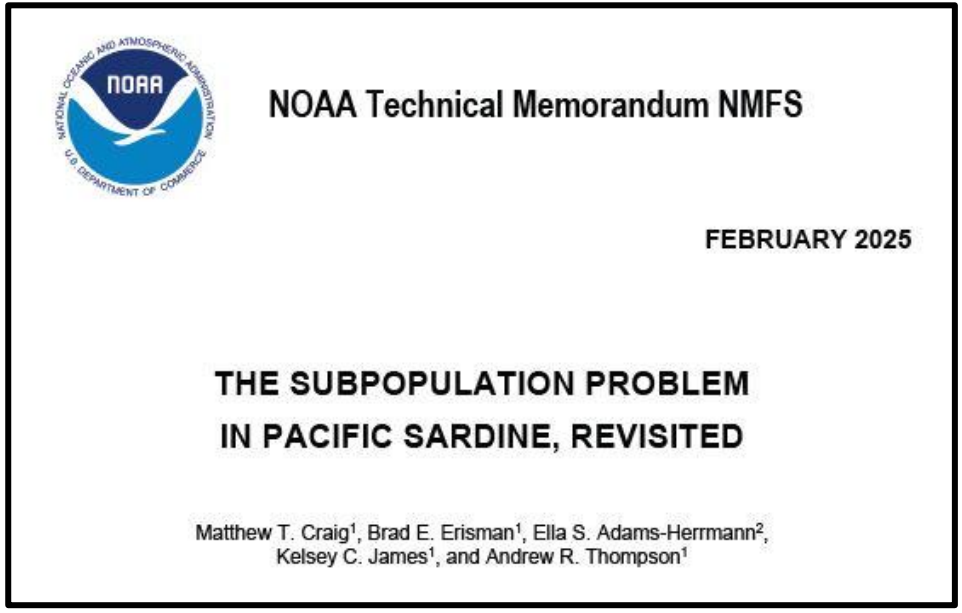


NOAA Technical Memorandum NMFS

JANUARY 2025

SYSTEMATIC REVIEW OF SOMATIC GROWTH PATTERNS IN RELATION TO POPULATION STRUCTURE FOR PACIFIC SARDINE (*Sardinops sagax*) ALONG THE PACIFIC COAST OF NORTH AMERICA

Brad Erisman[1], Matthew Craig[1], Kelsey James[1], Brittany Schwartzkopf[1], and Emmanis Dorval[1,2]



NOAA Technical Memorandum NMFS

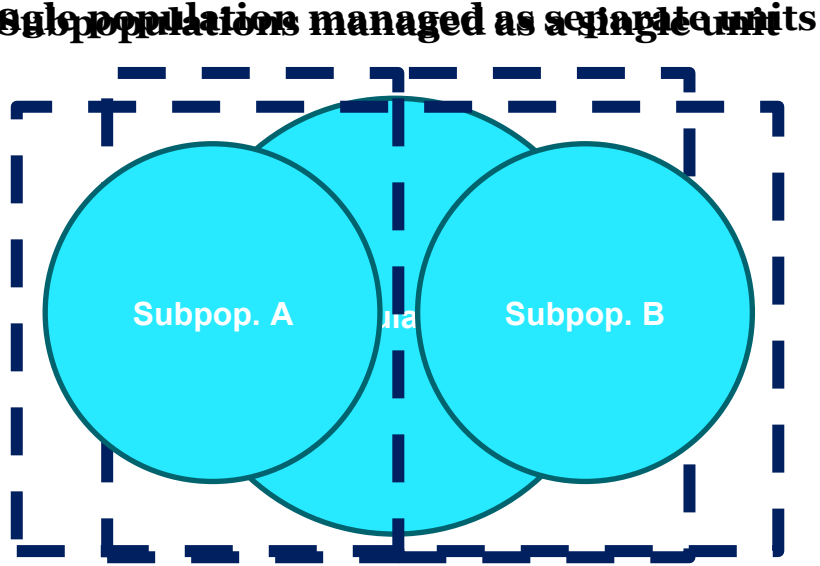
FEBRUARY 2025

THE SUBPOPULATION PROBLEM IN PACIFIC SARDINE, REVISITED

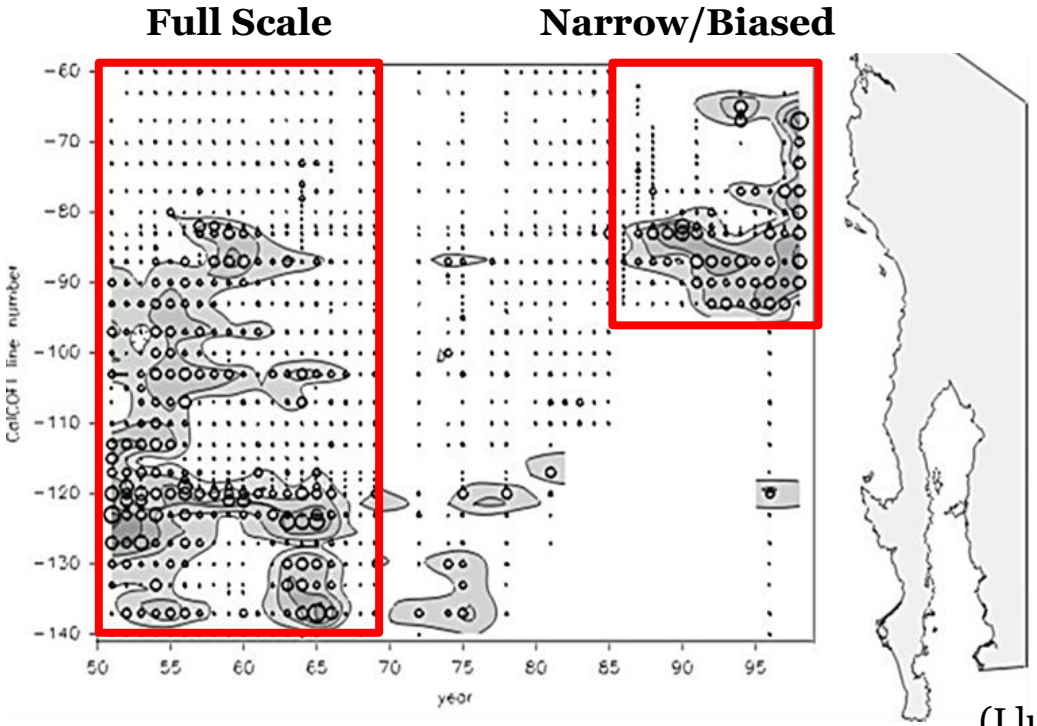
Matthew T. Craig[1], Brad E. Erisman[1], Ella S. Adams-Herrmann[2], Kelsey C. James[1], and Andrew R. Thompson[1]

Incoherent Dimensionality in Fishery Management

(Berger et al. 2021)

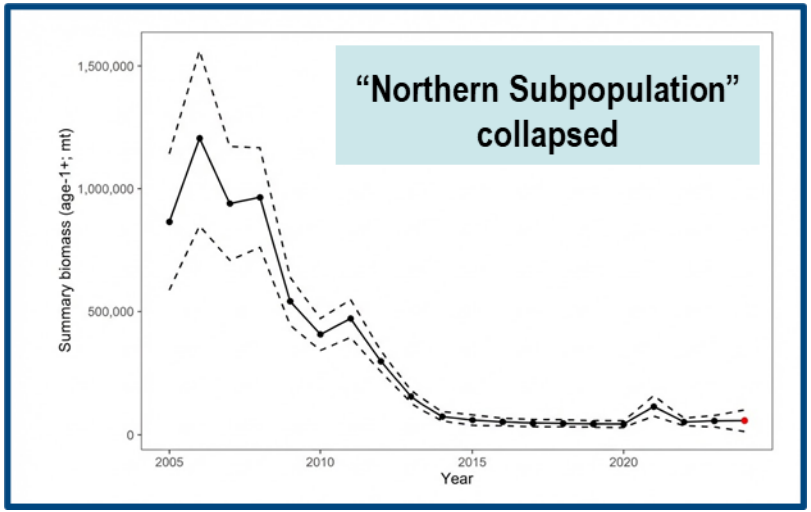


U.S. Sardine Perspectives: A shrinking universe based on consensus



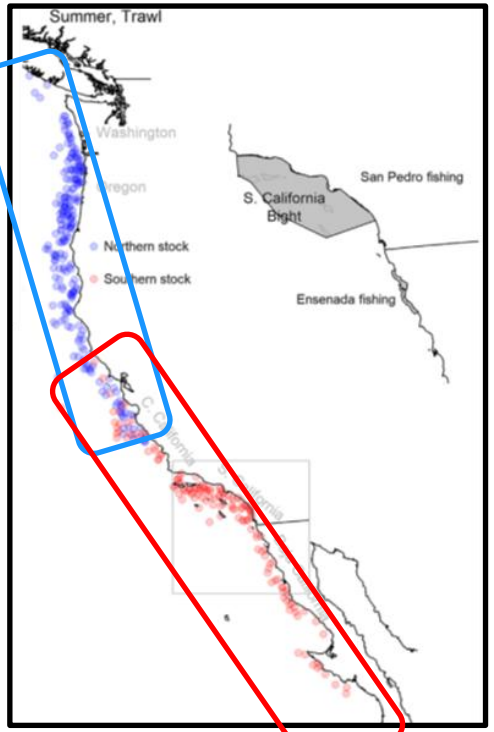
(Lluch-Belda et al. 2003)

Increased Focus on Subpopulations after Fishery Closure



(Kuriyama et al. 2024)

Habitat model that delineates Sardine subpopulations for biomass estimates and stock assessments



(Zwolinski and Demer 2024)

Habitat model to delineate the Northern Subpopulation

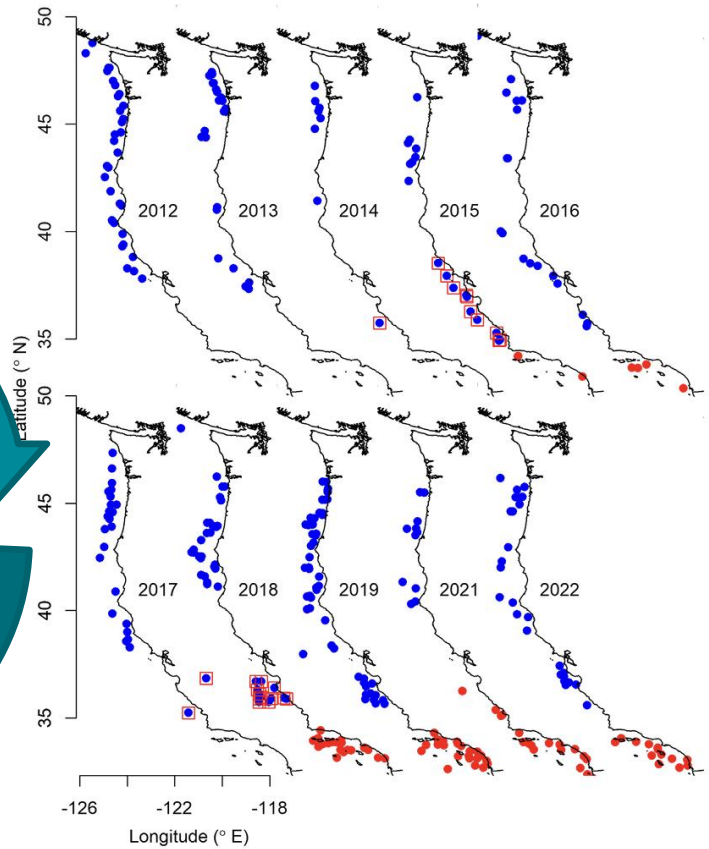
(Zwolinski & Demer 2024)

Specification: Northern subpopulation spawns offshore of California in the spring in colder waters (temperature threshold)

Inputs: Egg and larval data from Spring surveys offshore of California defined as spawning habitat (constrained)

Model outputs: Reflects the distribution during conditions off California during a summer survey

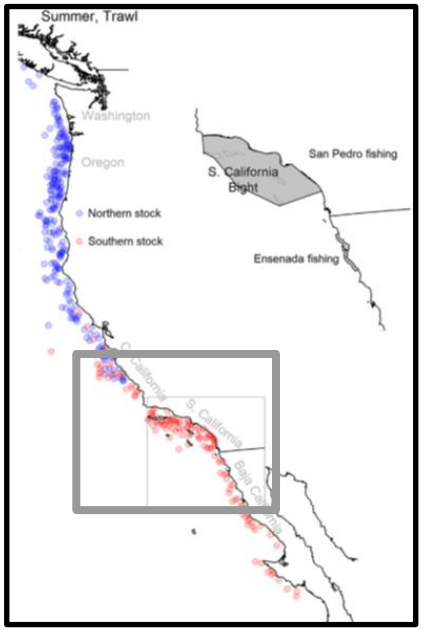
Conclusions: Northern subpopulation occurs in those conditions (built into model); Southern does not



Management Suffers from Incoherent Dimensionality

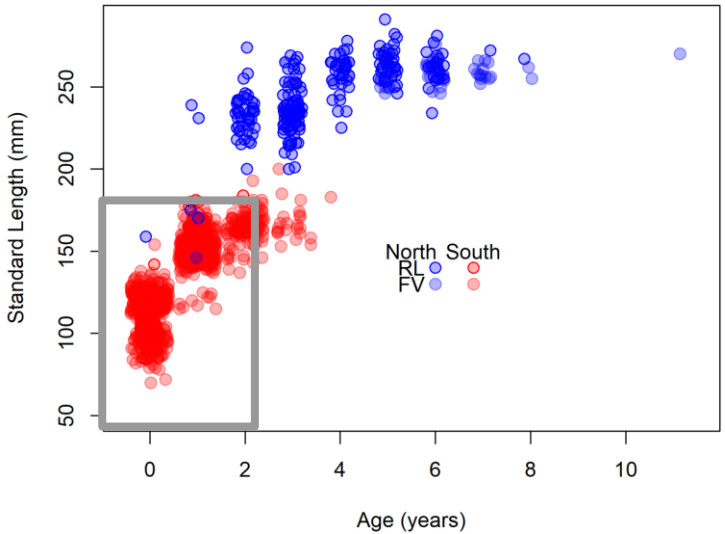
Management unit smaller than the biological unit —> biased management quantities

Biomass underestimated



(Zwolinski and Demer 2024)

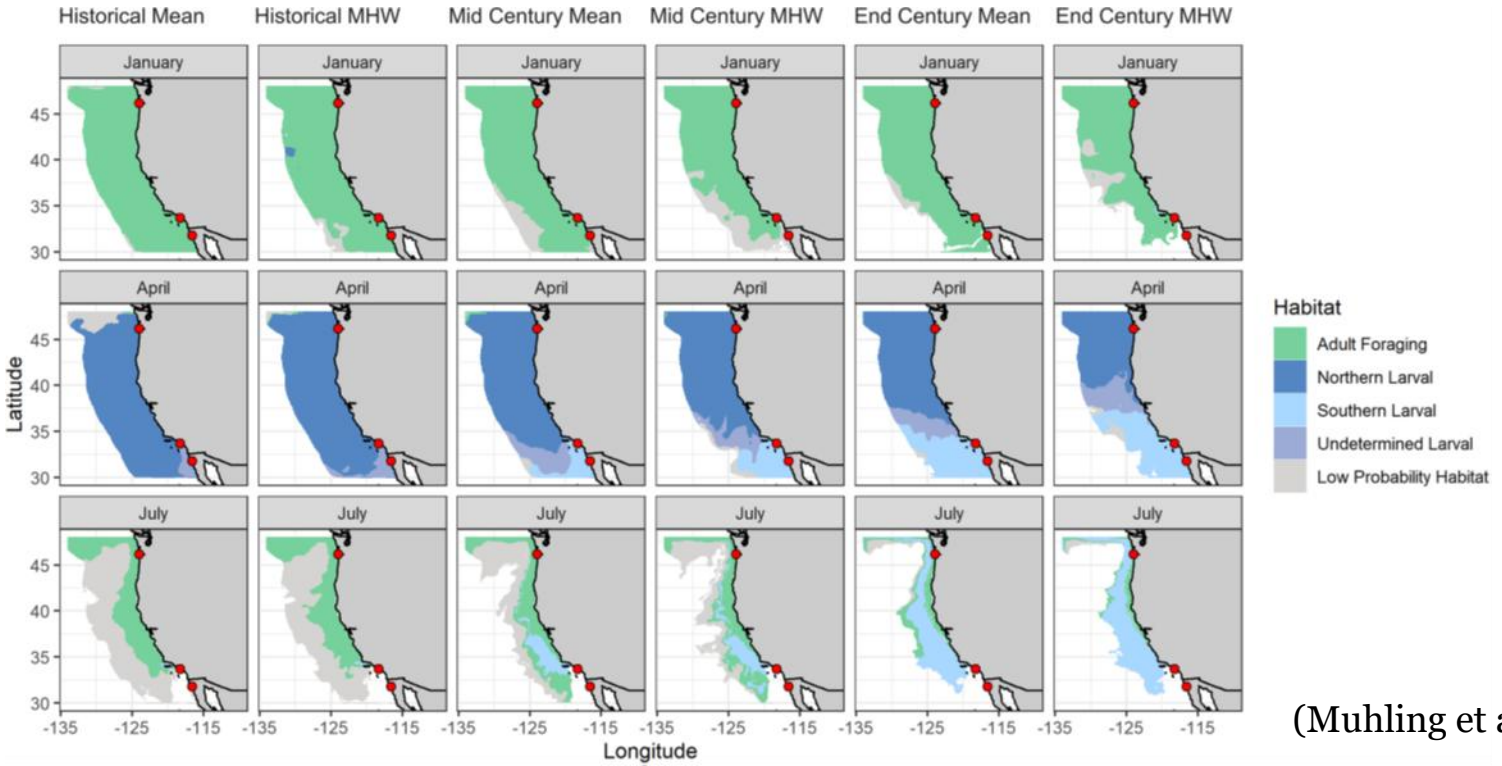
Unrepresentative data on length-age relationships



Most juveniles occupying nursery areas are excluded from assessment

Impacts on recruitment estimates?

Invalid reference points used to make predictions about future distributions and warming impacts

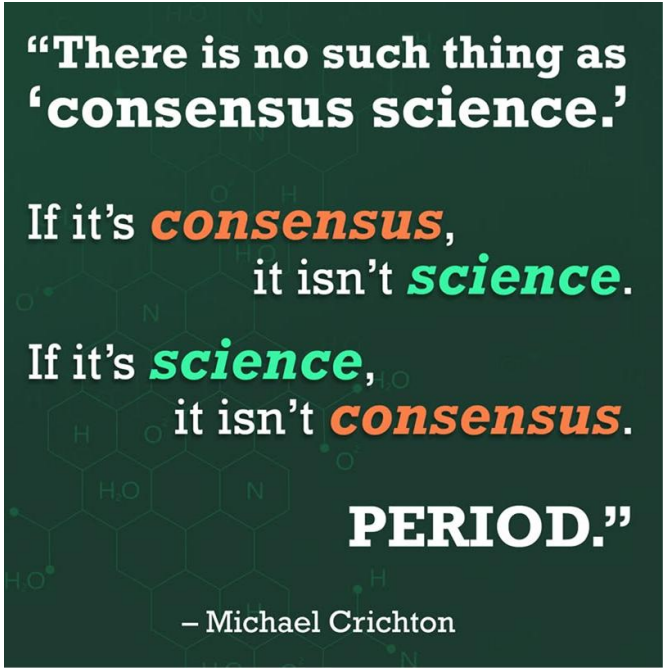


(Muhling et al. 2025)

Conclusions

Problem: One biological population is assessed as separate subpopulations based on invalid assumptions, consensus, and circular reasoning.

Solution: Recognize a single biological population (**transboundary**); include all survey data in assessments. **DISCLAIMER**



Recent Management Actions

May 2025: Pacific sardine off the west coast of the Baja California peninsula was assessed as a single management unit (DOF 3/2025; Enciso-Enciso et al. 2025)

April 2026: Pacific Fishery Management Council adopts plan to define Pacific Sardine in U.S. waters as a single management unit

Acknowledgments

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