The Status of Chilipepper (*Sebastes goodei*) in U.S. Waters off California, Oregon and Washington in 2025

E.J. Dick*, John C. Field, Nicholas Grunloh and Tanya Rogers

* corresponding author; edward.dick@noaa.gov

Biology, Fisheries, and Data



U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

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Outline

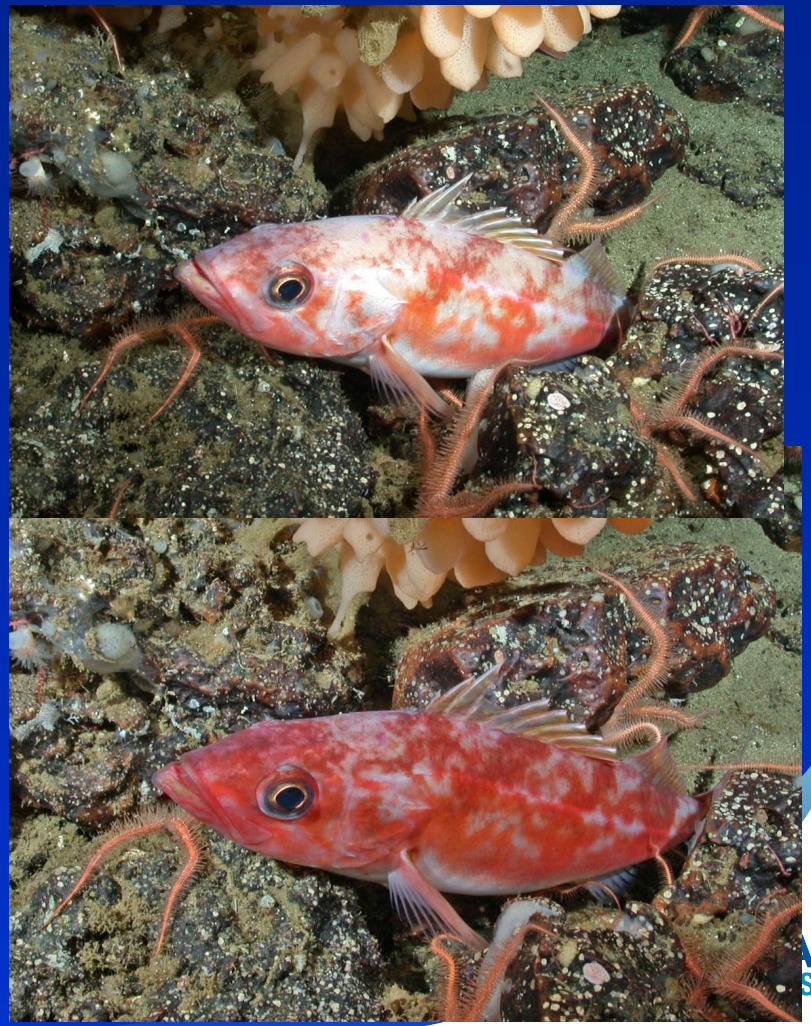
1. Biology
    a. Stock structure
    b. Growth
    c. Reproduction
    d. Natural mortality
    e. Ecosystem
2. Fisheries
    a. Commercial
        i. Fleets
        ii. Landings
        iii. Discards and regulations
    b. Recreational
        i. Landings and discard
        ii. Regulations
3. Data
    a. Fishery-dependent
    b. Fishery-independent
    c. Sources considered but not used

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Chilipepper (*Sebastes goodei*) are a mid-size, elongate (“streamline”) semipelagic rockfish with reduced head spines, similar in appearance to both shortbelly and bocaccio

Latin name honors the 19th century ichthyologist George Brown Goode, the common name was derived from the observation that long strings of these bright red fish resemble a string of drying chilis

Have ability to rapidly change color and pattern (often in just a few seconds), with drab colors in the water column, heavy mottling or blotching on substrate.



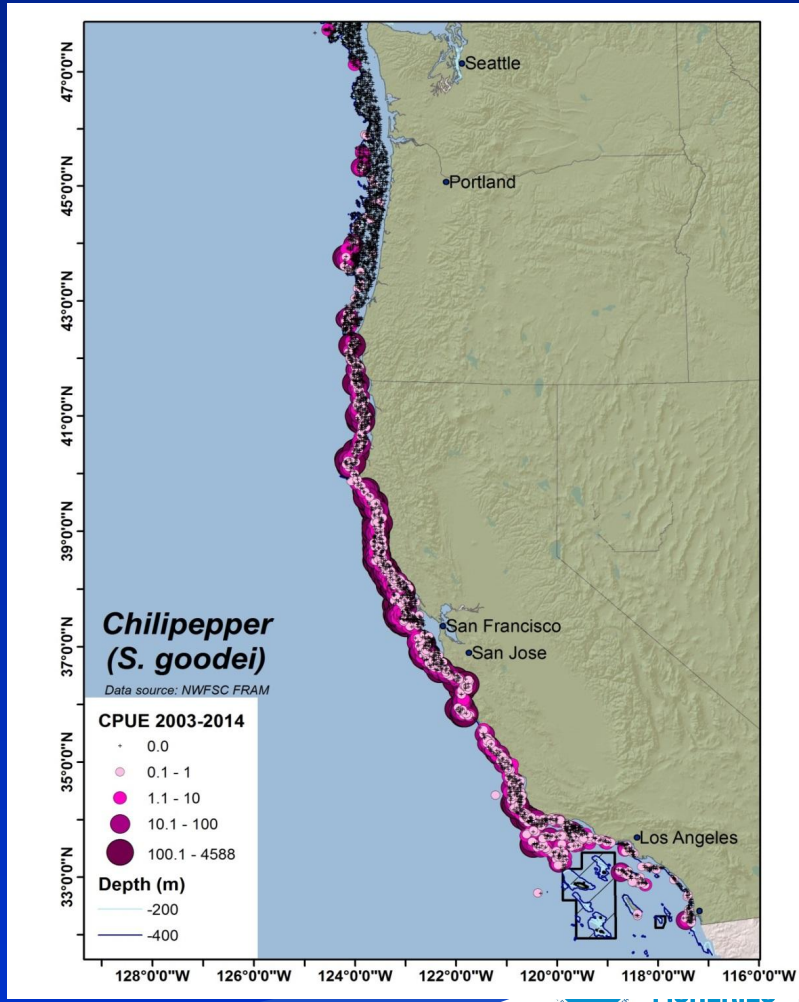
Stock Structure

Range extends from Baja California to British Columbia, but greatest abundance is central and southern California, survey data suggest a continuous distribution.

Wishard et al. (1980) conducted only known genetic study of stock structure, between 34° and 40° N. Concluded that chilipepper was unusual in its very low levels of allozyme variability, no suggestion of population structure.

Field and Ralston (2005; updated by Solinger 2019) evaluated spatial patterns in recruitment based on regional catch at age models. Results indicated that recruitment is largely synchronous throughout the range, suggesting strong demographic connectivity.

Minor differences in life history parameters (such as maturity and fecundity) by region, no significant evidence of regional differences in growth.



Reproductive ecology: Chilipepper are a great model species!

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Modeling growth and reproduction of chilipepper rockfish under var environmental conditions

Chris J. Harvey[a,*], John C. Field[b], Sabrina G. Beyer[b], Susan M. Sogard[b]

[a] NOAA Fisheries, Northwest Fisheries Science Center, 2725 Montlake Blvd. E, Seattle, WA 98112, United States
[b] NOAA Fisheries, Southwest Fisheries Science Center, 110 Shaffer Rd., Santa Cruz, CA 95060, United States

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ABSTRACT

Chilipepper rockfish (*Sebastes goodei*), a long-lived, highly fecund commercial
Current ecosystem, contend with a variable environment on several time scal
ics model, we simulated alternate strategies of energy allocation by female chil
conditions, and examined resulting patterns in age-dependent size and fecund
consisted of single climate events (one anomalous year, one 4-year regime shift
shift) that occurred at different points over the lifespan of the fish and were eith
to baseline conditions. Poor years or regimes reduced growth and fecundity, y

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Maternal influence on timing of parturition, fecundity, and larval quality in three shelf rockfishes (*Sebastes* spp.)

David M. Stafford[1,2,*], Susan M. Sogard[2], Steven A. Berkeley[3]

[1]Moss Landing Marine Laboratories, Moss Landing, California 95039, USA
[2]Fisheries Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, Santa Cruz, California 95060, USA
[3]University of California Santa Cruz, Santa Cruz, California 95060, USA

ABSTRACT: Differences in maternal investment and reproductive timing can have important consequences for offspring survival. Prior studies on nearshore rockfishes have shown significant effects of maternal age and size on the timing of parturition, fecundity, and larval quality, offering advantages to population persistence by maintaining age diversity in rockfish populations. In this study, reproduction in chilipepper *Sebastes goodei*, widow rockfish *S. entomelas*, and yellowtail rockfish *S. flavidus* was examined to determine whether age- and size-related effects on maternal investment and reproductive timing are exhibited in deeper-dwelling species of this genus. Parturition dates were derived from fine-scale staging of pre-parturition embryos from gravid females. Measurements of embryonic energy reserves (oil globule and yolk), indicators of condition, were used to estimate depletion rates and to test for maternal age and size effects on larval quality. For widow and yellowtail rockfish, larger or older rockfish gave birth earlier in the parturition season than younger, smaller fishes. Maternal factors of weight, length, or age were positively correlated to absolute and relative (weight-specific) fecundity in all species. A trade-off was observed between egg size and fecundity among species, with chilipepper displaying larger egg size and lower fecundity relative to widow and yellowtail rockfish. Embryonic reserves were weakly but significantly related to age only in chilipepper, with embryos from larger, older mothers having larger oil globules. Since the strength of maternal effects varies among *Sebastes*

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Variability in rockfish (*Sebastes* spp.) fecundity: species contrasts, maternal size effects, and spatial differences

Sabrina G. Beyer · Susan M. Sogard · Chris J. Harvey · John C. Field

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Abstract Over 60 species of rockfish (*Sebastes* spp.) reside off the coast of California, many of which are economically important to both recreational and commercial fisheries. Rockfish are live-bearers with a diverse array of reproductive strategies. Understanding the reproductive potential of an exploited stock is critical

rockfish produced a relatively highly fecund, single brood of smaller-sized larvae annually, in contrast to Chilipepper and Speckled rockfish, which produced larger-sized larvae with lower fecundity. In some regions multiple broods were common, complicating estimates of annual fecundity for these two species. There

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Effects of size-dependent relative fecundity specifications in fishery stock assessments

Xi He[a,*], John C. Field[a], Sabrina G. Beyer[a,b], Susan M. Sogard[a]

[a] Fishery Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service, 110 Shaffer Road, Santa Cruz, CA 95060, USA
[b] Institute for Marine Sciences, University of California Santa Cruz, Santa Cruz, CA, 95060, USA

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ABSTRACT

A comprehensive understanding of reproductive biology is fundamental to the accurate assessment of a given stock's spawning potential relative to the unfished level. Such an understanding is particularly important given the growing recognition of size, age or weight dependent relative fecundity (Φ_{rel}, eggs per kg of female weight), or other maternal effects that may demonstrate a relatively greater contribution of specific demographic components of a population toward reproduction. However, size-specific data on Φ_{rel}, or other data on maternal effects on reproductive output, are not always available for many stock assessments because intensive efforts are required to collect such data. In the absence of data, the assumption of no size-specific Φ_{rel} relationship is typically made, which can lead to bias in estimating stock status and related management parameters. We examined effects of misspecifications of size-specific Φ_{rel} functions on estimated stock assessment parameters and related management quantities using two stocks as case studies and three sets of simulation models, chosen to represent wide ranges of life and fishing histories. The results showed that misspecification effects were relatively small when stocks were less depleted (e.g. 75% of virgin spawning output), but could lead to more substantive misspecifications in more depleted stocks with slower growth and lower mortality rates. For example, we found that stock was estimated to be as much as 20% less depleted if a strong size-specific Φ_{rel} exists in a population, but no size-specific Φ_{rel} is used in the model. This represents a non-trivial shift in the perception of status for most stocks. The results also showed that overestimating the strength of the size-specific Φ_{rel} function in stock assessment models led to smaller estimation errors in assessment outputs compared to underestimating the size-specific Φ_{rel}. The results are insightful with respect to the

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Double or nothing: Plasticity in reproductive output in the chilipepper rockfish (*Sebastes goodei*)

Lyndsey S. Lefebvre[a,b,*], Sabrina G. Beyer[a,b], David M. Stafford[a,b], Neosha S. Kashef[a,b], Edward J. Dick[b], Susan M. Sogard[b], John C. Field[b]

[a] Cooperative Institute for Marine Ecosystems and Climate, Institute of Marine Sciences, University of California Santa Cruz, United States
[b] Fisheries Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service, National Oceanographic and Atmospheric Administration, 110 McAllister Way, Santa Cruz, CA 95060, United States

ARTI

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Shifting ocean conditions influence temporal variation in the fecundity of California Current rockfishes (*Sebastes* spp.)

Sabrina G. Beyer[a,b], Susan M. Sogard[b], David M. Stafford[b,c], Neosha S Kashef[b,c], Abel Rodriguez[d], Suzanne H. Alonzo[a], and John C. Field[b]

[a]Department of Ecology and Evolutionary Biology, University of California Santa Cruz, Santa Cruz, CA, USA; [b]Fisheries Ecology Division, Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA Fisheries, Santa Cruz, CA, USA; [c]Fisheries Collaborative Program, University of California Santa Cruz, Santa Cruz, CA, USA; [d]Department of Statistics, University of Washington, Seattle, WA, USA

Corresponding author: **Sabrina G. Beyer** (email: sabrina.beyer@noaa.gov)

Abstract

Successful reproduction is critical to the growth and persistence of marine fish populations, yet how changes in the environment influence reproduction remains largely unknown. We explored how shifting ocean conditions influenced larval production in four species of long-lived, live-bearing rockfish (*Sebastes* spp.) in the California Current. Brood fecundity, body size, and environmental information were analyzed from the mid-1980s through 2020. Interannual variation in brood fecundity was greater than 50% in the single-brooding yellowtail rockfish (*S. flavidus*) and widow rockfish (*S. entomelas*). Brood fecundity varied less in chilipepper (*S. goodei*) and bocaccio (*S. paucispinis*), two species capable of multiple broods per year. In these two species, interannual fecundity variability is more likely to depend on the number of broods produced than on brood size alone. In all four species, brood fecundity was positively correlated with maternal length and body condition. Variable ocean conditions influenced the strength of maternal size effects by year. These results provide evidence for reproductive plasticity and environmental effects on fecundity, with implications for changes in population reproductive potential with climate change.

Key words: reproductive plasticity, life history, environmental variability, *Sebastes*, California Current Ecosystem

1. Introduction

Successful reproduction is essential for the growth, persistence, and resilience of marine fish populations (Lowerre-

show that fecundity and spawning frequency respond to differences in water temperature and food availability under controlled conditions (Lambert and Dutil 2000; Yoneda et al.,

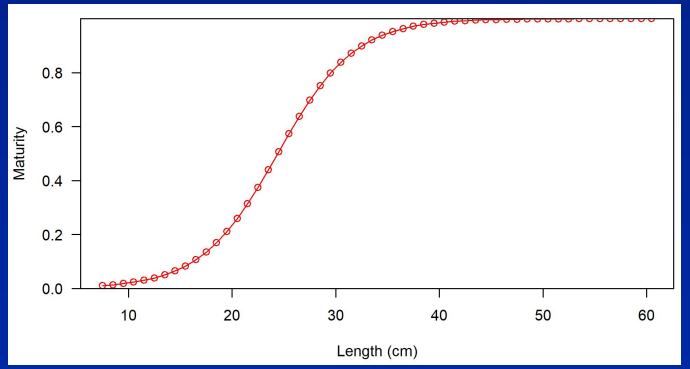
Maturity

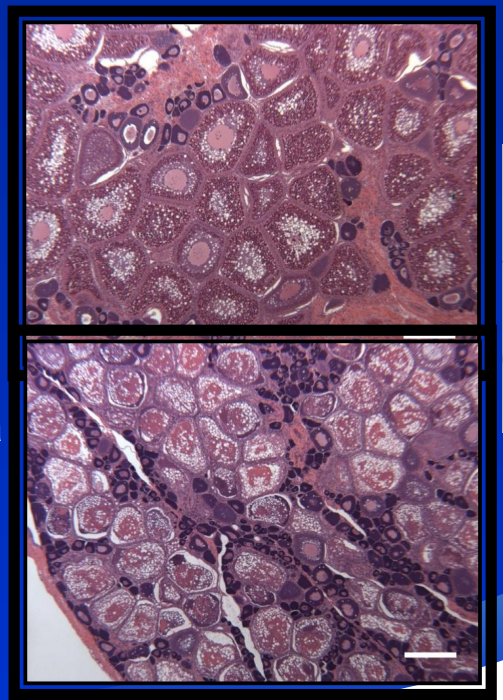
Most fish mature between ages 2 and 4. For the 2015 update, we evaluated new data from focused reproductive ecology sampling, leading to a slightly smaller size at maturity relative to 2007.

A subset of ovarian tissue samples was processed histologically (n=565) to inform macroscopic assignments of maturity, detect abortive maturation and atresia (mass resorption of developing oocytes), and document multiple brooding. Results are reported in the 2015 update as well as Lefebvre et al. (2018).

Atresia was observed frequently in smaller/younger females, however generally reflected low (5% or less oocytes) or moderate (5–25% of oocytes) downregulation. There were indications that some fish with stage 2 eggs were not functionally mature, however data were considered to be too sparse to rely on exclusively. The 2015 assessment pooled historic and recent data to update physiological maturity estimates.

The L_{50} and L_{95} were 24.4 and 35.2 cm for females. We continue to use these parameters for the current benchmark. Future work should be done to develop a functional maturity curve.





Normal Development



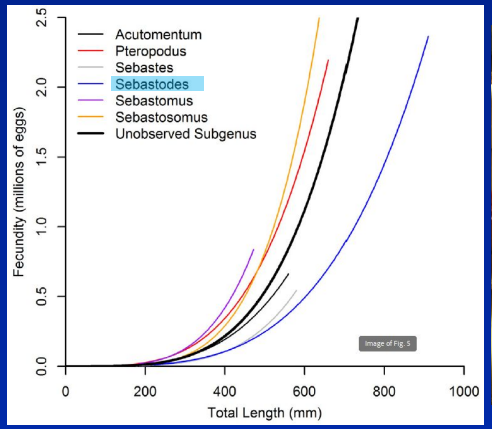
Mass Atresia

Fecundity, part 1

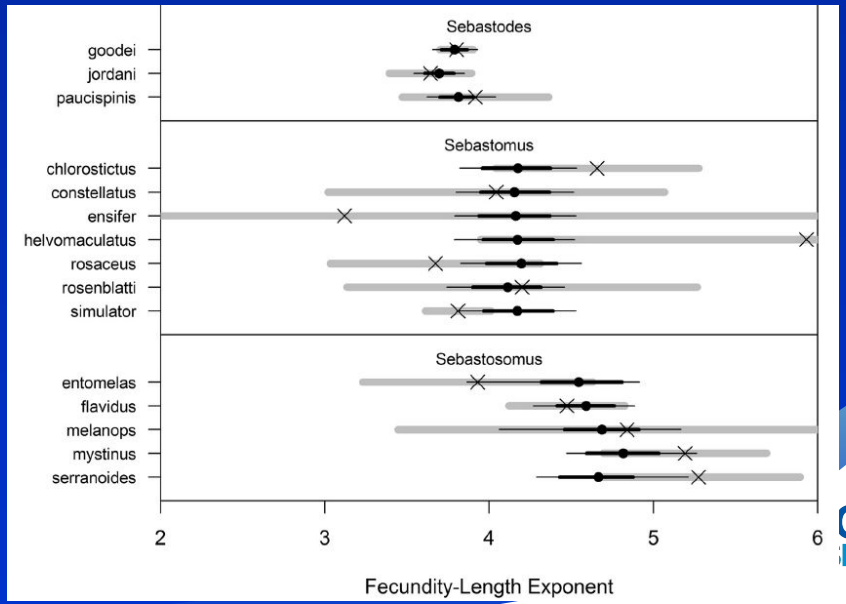
Rockfish have long been recognized to have strong size-dependent fecundity, such that fecundity is a power function of female body length and weight-specific fecundity increases with size.

Like most West Coast rockfish assessments, we initially used the results of the Dick et al. (2017) meta-analysis of fecundity. Chilipepper were well represented in the data (n= 853; most samples in the study).

From that work, the size dependent fecundity relationship is not terribly strong, however it does not account for production of multiple broods, which many southern species of *Sebastes,* including chilipepper, produce.





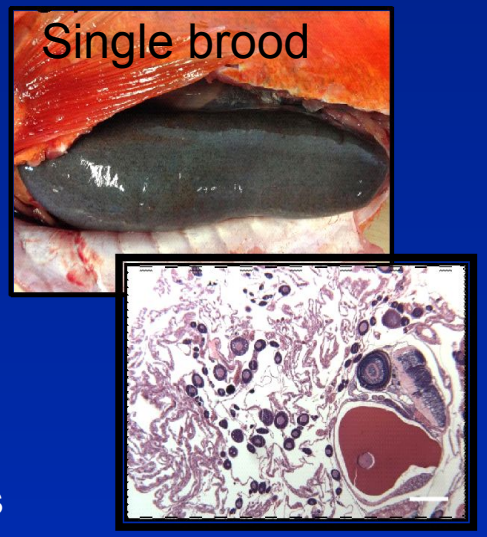


Fecundity, part 2

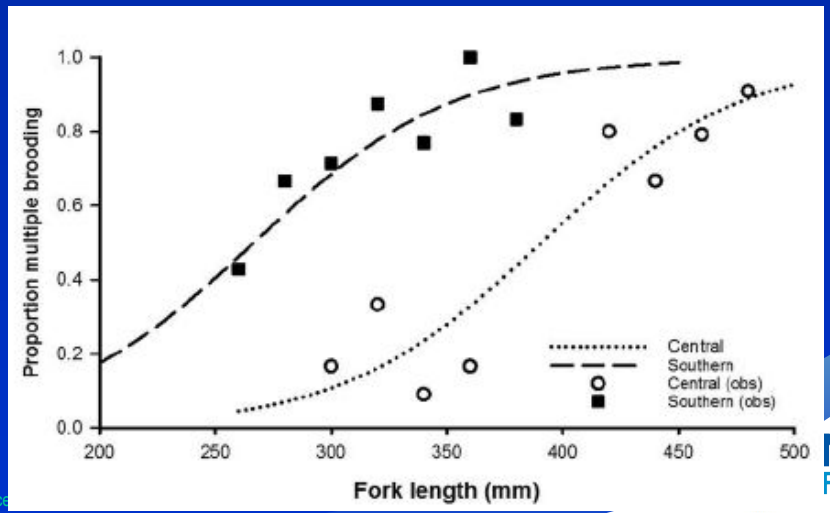
Multiple brooding in chilipepper and other Sebastes first described 58 years ago (Moser 1967). Documented in ~15 species of *Sebastes*, most frequently seen in the SCB, but seen with apparent increasing frequency in Central CA.

Macroscopic and histological evidence confirms the phenomena, and finds that more frequently seen in larger, older females. As such, accounting for MB substantially strengthens the magnitude of the size-dependent fecundity relationship (Lefebvre et al. 2018). It may also be that in some years more than two broods are produced (Rosy rockfish can produce up to 5!).

Despite extensive research, has not yet been accounted for in a WC stock assessment







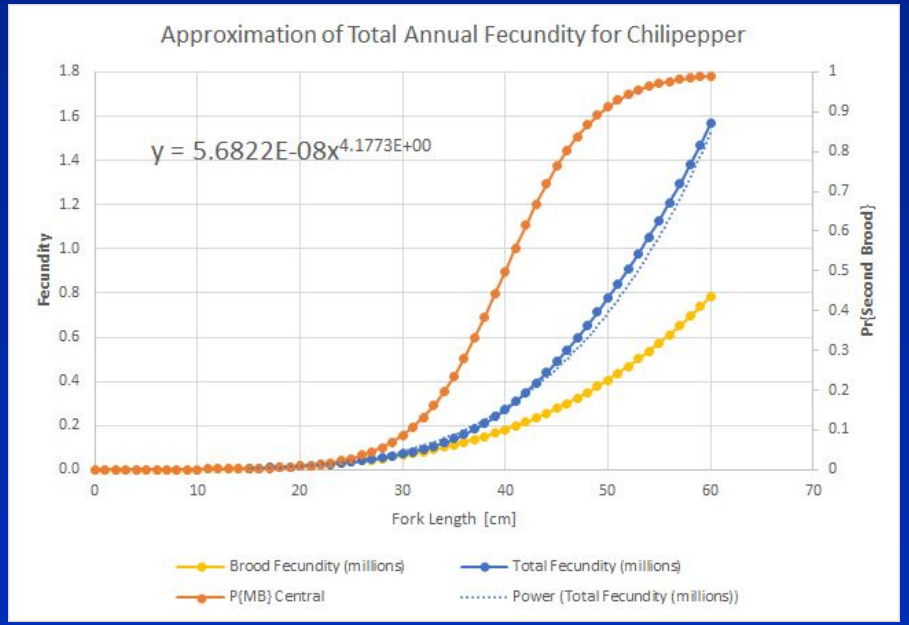
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Fecundity, part 3

To account for multiple brooding, we multiply the “brood” fecundity-length relationship from Dick et al. (2017) by a factor of 1 + Pr{multiple brooding | length} to approximate total annual fecundity (assuming max of 2 broods/year) using a fitted power function.

Data to inform the probability of multiple brooding from both Lefebvre et al. (2018) for 2013-2015 and S. Beyer (NWFSC, unpublished) for 2016-2019. We use data from central California only, as this represents the core area of the stock, and MB takes place at smaller sizes in southern California.

This increases the exponent of the fecundity-length relationship from ~ 3.8 to 4.2, accelerating the increase in weight-specific fecundity with increasing length. Still lower than many single brooding species.

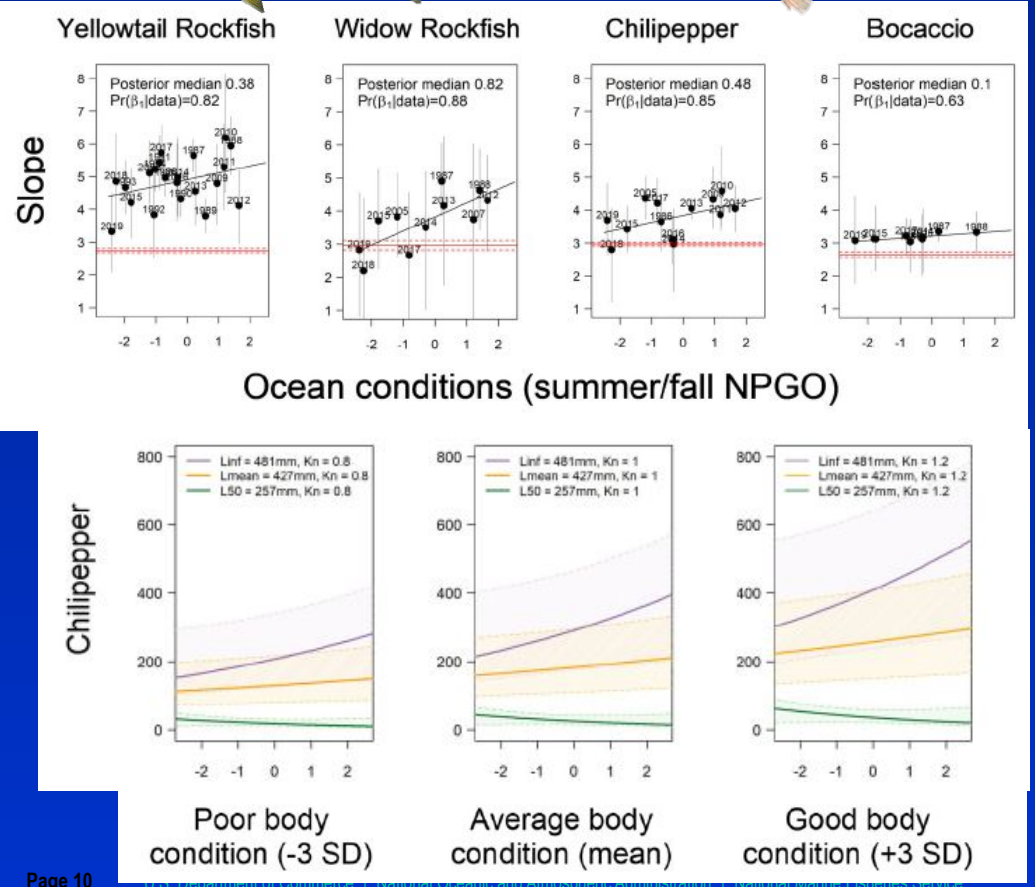








Fecundity, part 4



A culmination of this research focused on interannual variability in fecundity of multiple species as related to both oceanographic conditions (summer/fall NPGO) and female condition (lower panel, conditional plots, with NPGO on x axis; from Beyer et al. 2024).

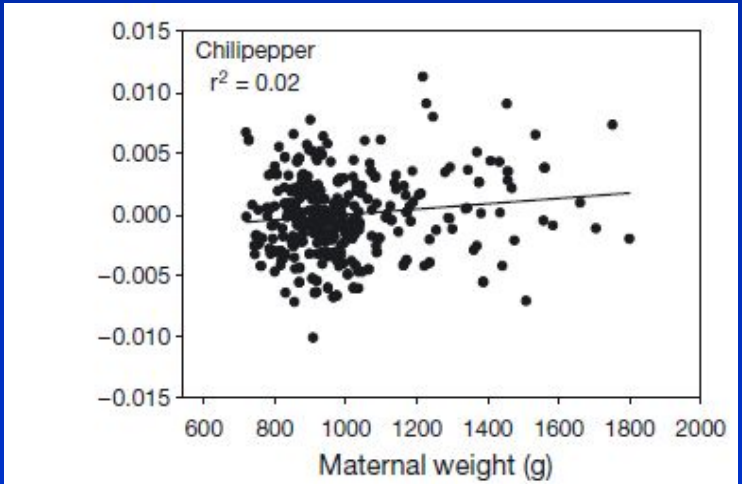
Both of these factors influenced the year-specific estimate of the slope parameter for the length-fecundity relationship. Larger fish had disproportionately greater larval production when their energetic reserves were greater and ocean conditions cooler/more productive

Effect was stronger in single brooding species but variability may be underestimated for multiple brooders as the mechanis[m] greater output is multiple broodin[g]

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Other maternal effects, part 1

Past studies evaluated other mechanisms of maternal influences on larval production, survival. In the Stafford et al. (2014) study of size-dependent relative fecundity, a maternal influence on oil globule volume (associated with condition) was noted, although it was fairly weak.



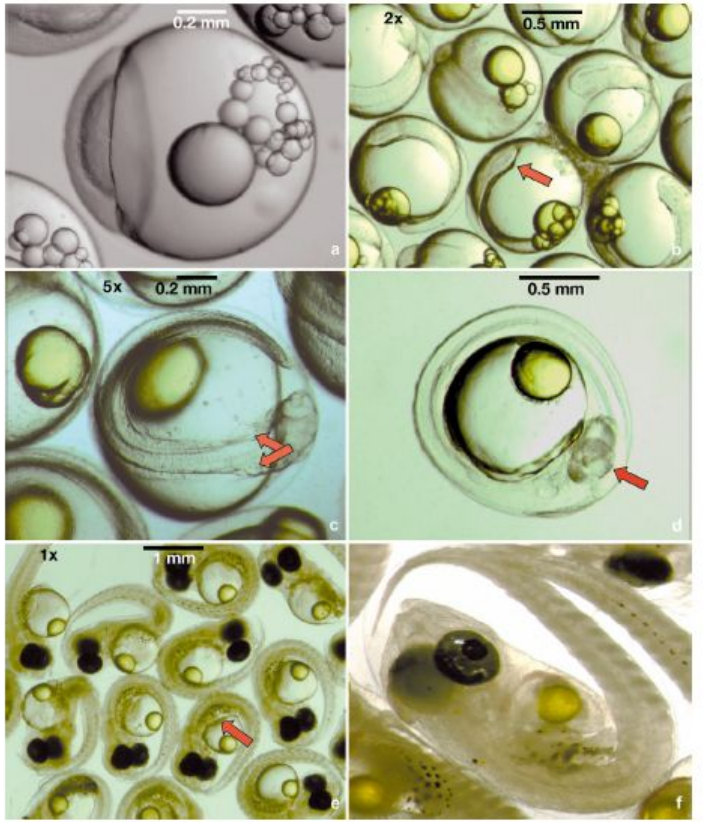
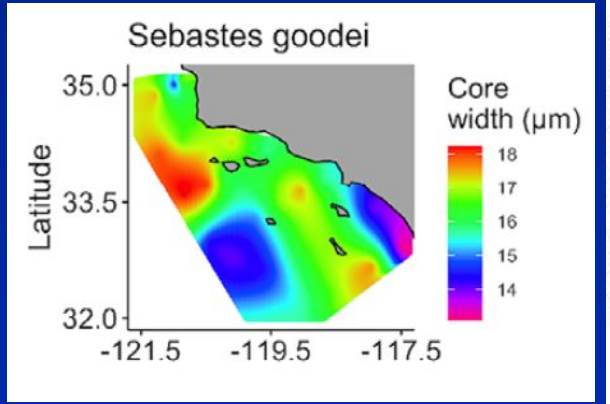


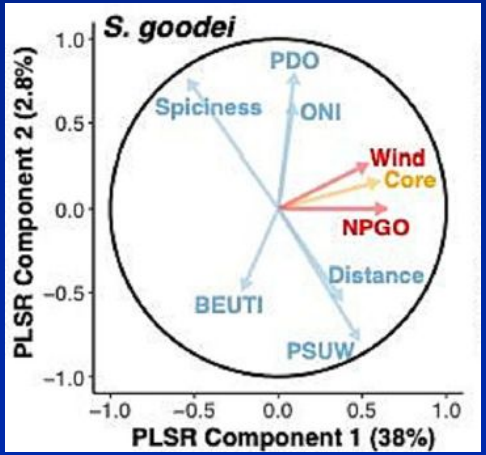
Fig. 1. Examples of embryonic features (highlighted by arrows) used in fine-scale staging of developing chilipepper embryos: (a) late blastula (stage 11), (b) head fold (stage 16), (c) appearance of otoliths (stage 23), (d) pigmentation of retina (stage 25), (e) pigmentation of peritoneal wall (stage 29), and (f) pre-hatching (stage 31). Note the oil globule surrounded by clear yolk in (d)

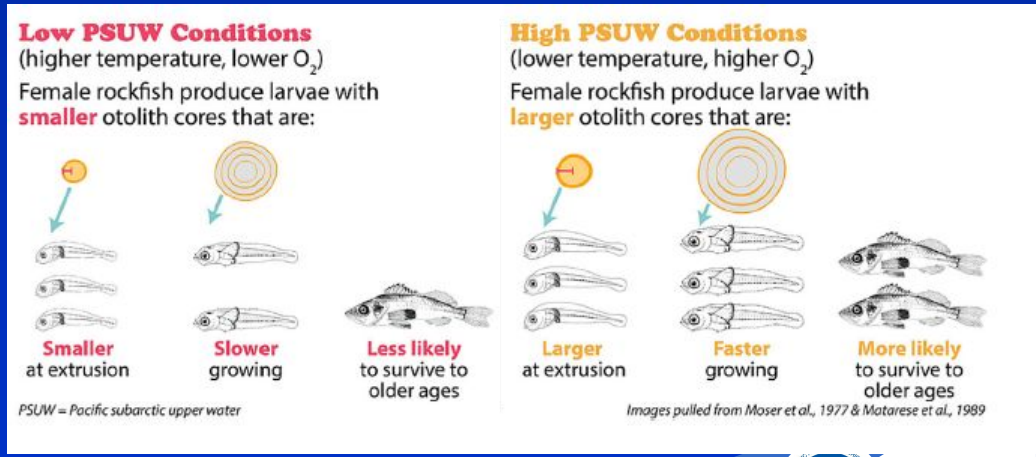
Other maternal effects, part 2

Fennie et al. (2023) used CalCOFI larval (from SCB) to evaluate spatial and temporal variability in otolith core width at extrusion and subsequent larval growth rates for eight species of rockfish, including chilipepper.

Their results suggested that otolith core width at extrusion is a function of both maternal and environmental conditions, and significantly related to larval rockfish growth rate and survival. You'll see a bit more in the risk table discussion later





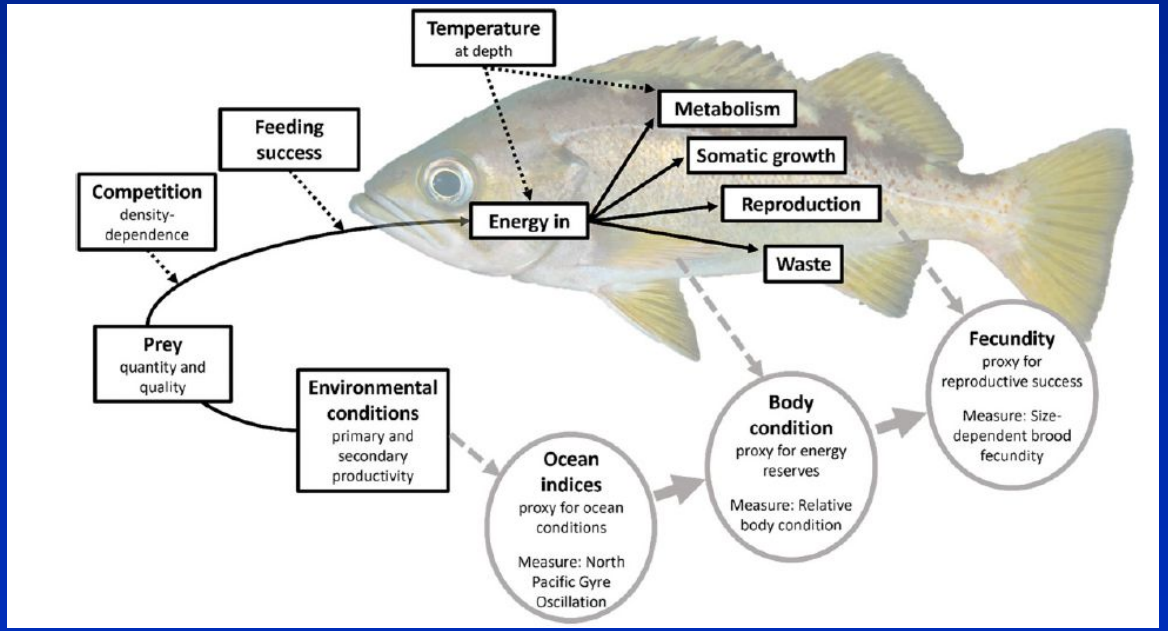


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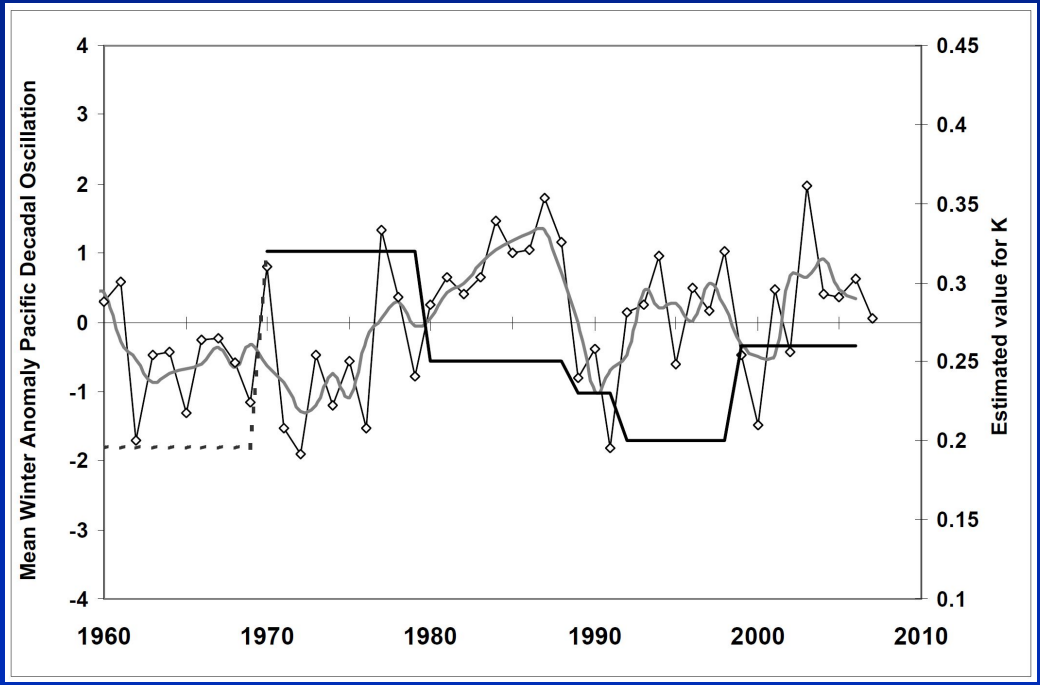
Growth

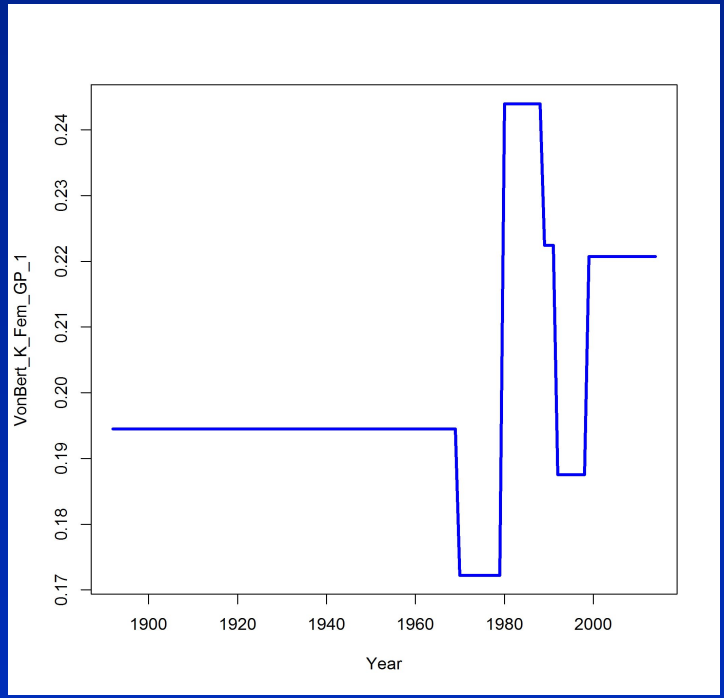
The bioenergetic trade-offs between growth and reproductive output underlie much of the reproductive ecology research, which was initiated following the 2007 assessment and recommendations to explore time varying growth and reproductive ecology.

Chilipepper are a good model organism for such studies; a fast growing species with strong sexual dimorphism in growth rates, variability in size at age and abundant age data from which to estimate growth and variability in growth.



(Figure from Beyer et al. 2024).





The 2007 model ultimately used offset parameters for the von-Bertalanffy growth parameter (K), in which the time blocks were based on major shifts in the Pacific Decadal Oscillation (PDO). During the 2015 assessment update, what ought to have been a couple of time blocks were merged into one continuous 2000-2015 time block.

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Growth

We took a deeper dive in this assessment (pivot to Grunloh growth variability analysis)

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Time-Varying Growth

ℓ: Length vs. a: Age

Year	Survey		Commercial	
	Combo	HKL	Calcom	PacFIN
1978	-	-	559	-
1979	-	-	330	-
1980	-	-	1094	-
1981	-	-	701	-
1982	-	-	1217	-
1983	-	-	2308	-
1984	-	-	3576	-
1985	-	-	3273	-
1986	-	-	2011	-
1987	-	-	2493	-
1988	-	-	2428	-
1989	-	-	2581	-
1990	-	-	1694	-
1991	-	-	1600	-
1992	-	-	2081	-
1993	-	-	2028	-
1994	-	-	742	-
1995	-	-	1403	-
1996	-	-	803	-
1997	-	-	1718	-
1998	-	-	2135	-
1999	-	-	2091	-
2000	-	-	998	-

Year	Survey		Commercial	
	Combo	HKL	Calcom	PacFIN
2001	-	-	768	-
2002	-	-	1029	-
2003	663	-	309	-
2004	743	-	949	-
2005	833	-	349	-
2006	596	-	-	-
2007	590	-	459	-
2008	698	-	437	-
2009	616	-	787	-
2010	806	-	305	-
2011	647	-	9	-
2012	833	-	348	-
2013	683	-	408	-
2014	873	-	301	-
2015	608	-	-	-
2016	720	-	-	-
2017	540	-	-	-
2018	500	-	-	-
2019	349	40	76	40
2020	-	-	103	40
2021	500	40	60	40
2022	506	40	59	40
2023	506	40	55	40
2024	507	40	47	40

Temporal Model

$$\ell_{sti} = VB(a_{sti};\ \kappa_{st}, L_0, L20_{st}) + \epsilon_{sti}$$

$$\epsilon_{sti} \sim N(0, \sigma_s) \qquad \sigma_s \sim \text{Student}_3(0, 10)\ 1_{\sigma>0}.$$

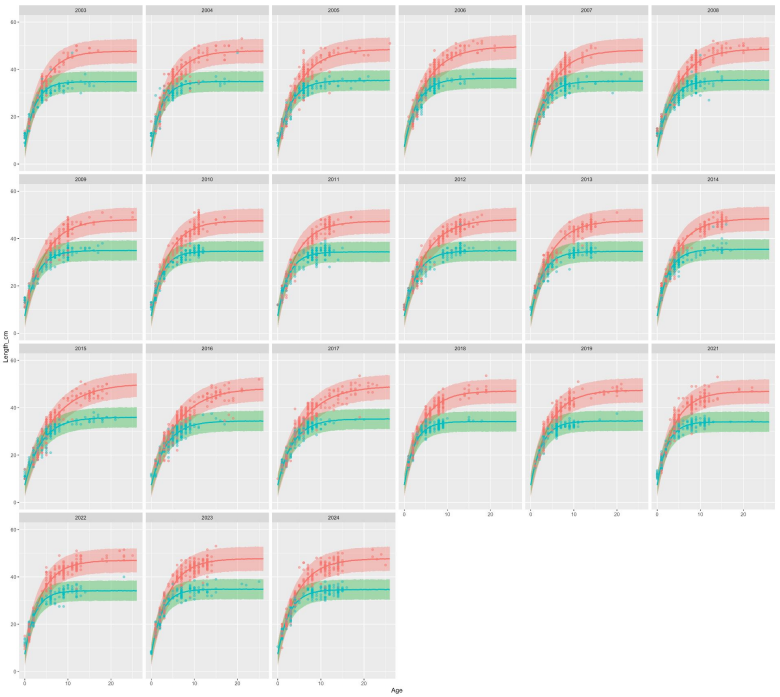
s: Sex
t: Year

$L_0 = 7.3$

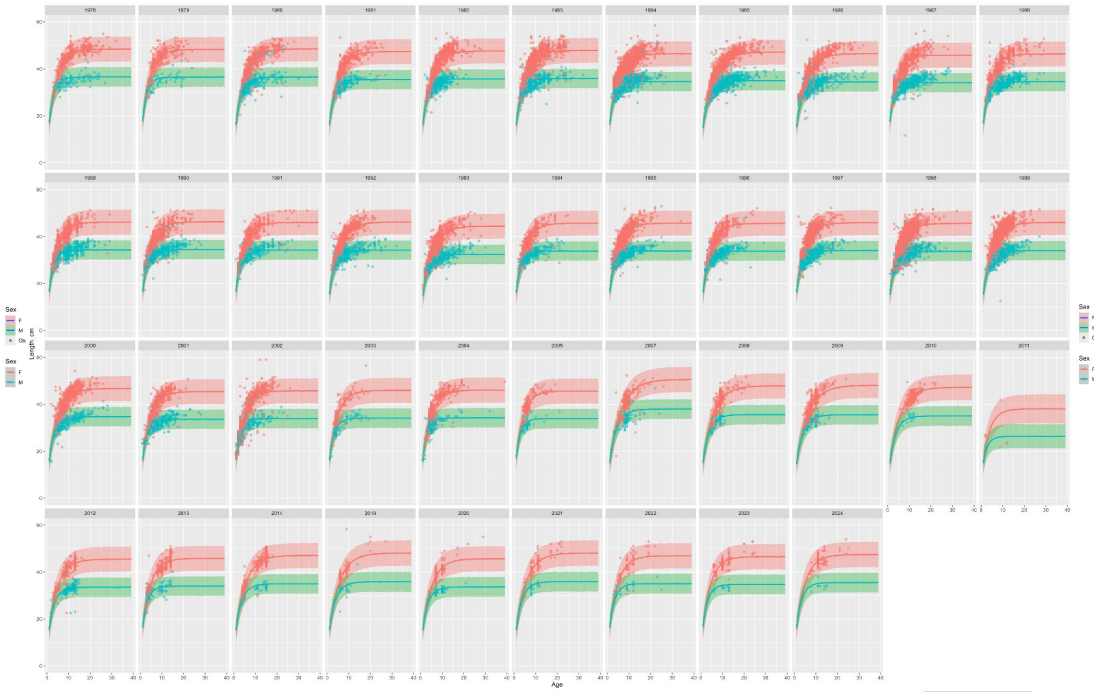
$$\log(\kappa_{st}) = \mathbb{1}_{0.05<\kappa<0.5}({}_{\kappa}\alpha_s + {}_{\kappa}\beta_t) \qquad {}_{\kappa}\beta_t \sim N(0, {}_{\kappa}\phi) \qquad {}_{\kappa}\phi \sim N(0,1)\ 1_{{}_{\kappa}\phi>0}$$

$$L20_{st} = {}_{L20}\alpha_s + {}_{L20}\beta_t \qquad {}_{L20}\beta_t \sim N(0, {}_{L20}\phi) \qquad {}_{L20}\phi \sim N(0,1)\ 1_{{}_{L20}\phi>0}.$$

Survey



Commercial



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Temporal Model

$$\ell_{sti} = VB(a_{sti};\ \kappa_{st}, L_0, L_{20_{st}}) + \epsilon_{sti}$$

$$\epsilon_{sti} \sim N(0, \sigma_s) \qquad \sigma_s \sim \text{Student}_3(0, 10)\ 1_{\sigma>0}$$

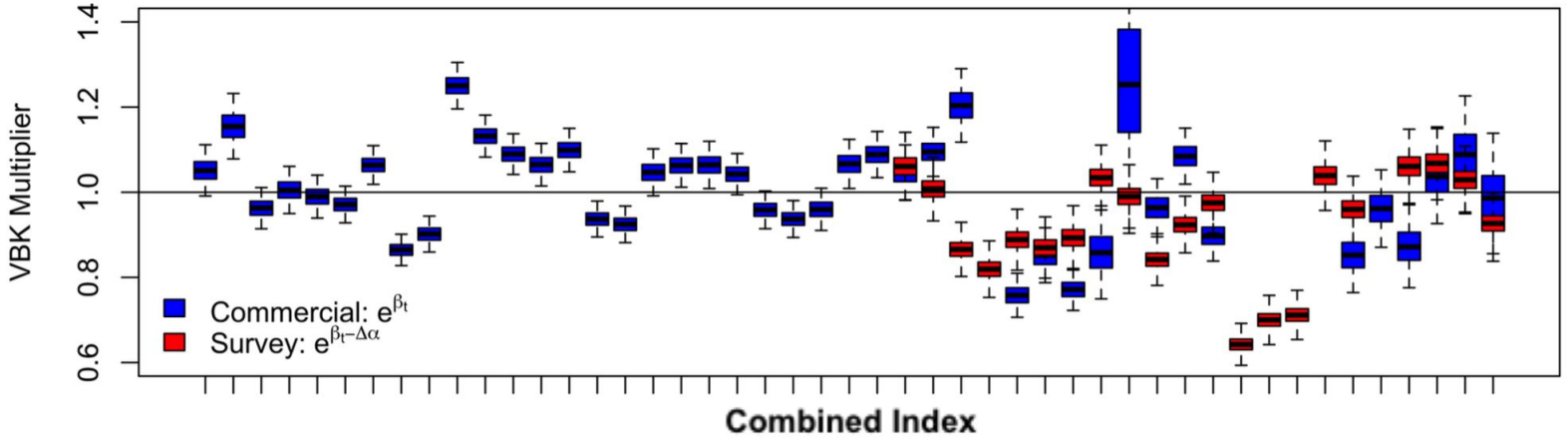
s: Sex
t: Year

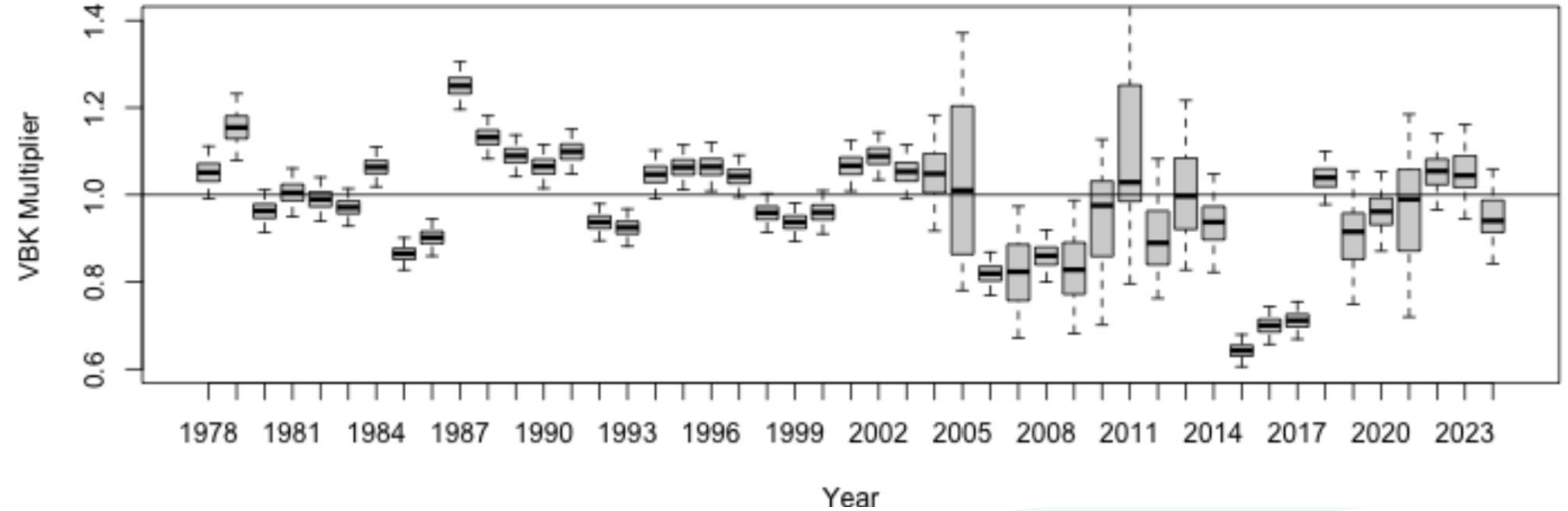
$L_0 = 7.3$

$$\log(\kappa_{st}) = \mathbb{1}_{0.05<\kappa<0.5}({}_{\kappa}\alpha_s + {}_{\kappa}\beta_t) \qquad {}_{\kappa}\beta_t \sim N(0, {}_{\kappa}\phi) \qquad {}_{\kappa}\phi \sim N(0,1)\ 1_{{}_{\kappa}\phi>0}$$

$$L_{20_{st}} = {}_{L_{20}}\alpha_s + {}_{L_{20}}\beta_t \qquad {}_{L_{20}}\beta_t \sim N(0, {}_{L_{20}}\phi) \qquad {}_{L_{20}}\phi \sim N(0,1)\ 1_{{}_{L_{20}}\phi>0}$$

κ Time-Varying Index





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Autocorrelation

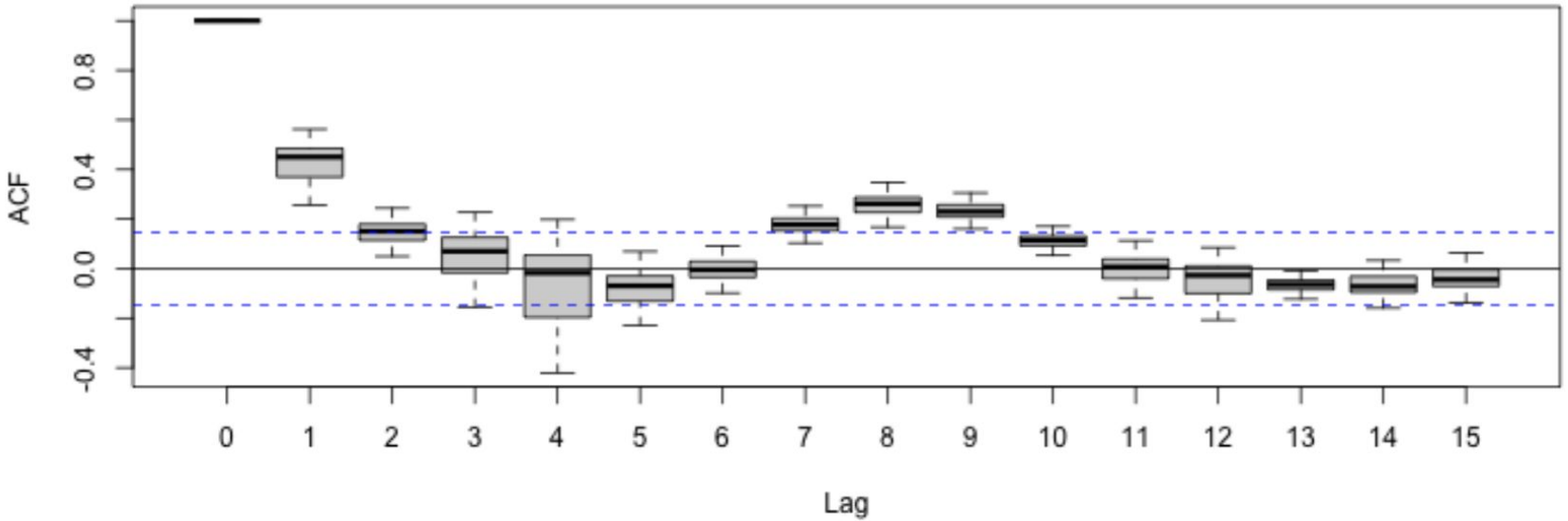


Figure 5: The grey boxplots represent the autocorrelation function as applied to the posterior draws of the combined index (whiskers represent an approximate 2σ interval). The blue dashed lines represent the asymptotic 2σ interval around the classical null hypothesis of 0 autocorrelation.

Regional Spatio-Temporal Model

$r \in \{N, C, S\}, \quad S \in [MX, 34^{\circ}27'), \quad C \in [34^{\circ}27', 40^{\circ}10'), \quad N \in [40^{\circ}10', CA)$

$$\ell_{rsti} = VB(a_{rsti};\ \kappa_{rst}, L_0, L_{20_{rst}}) + \epsilon_{rsti}$$

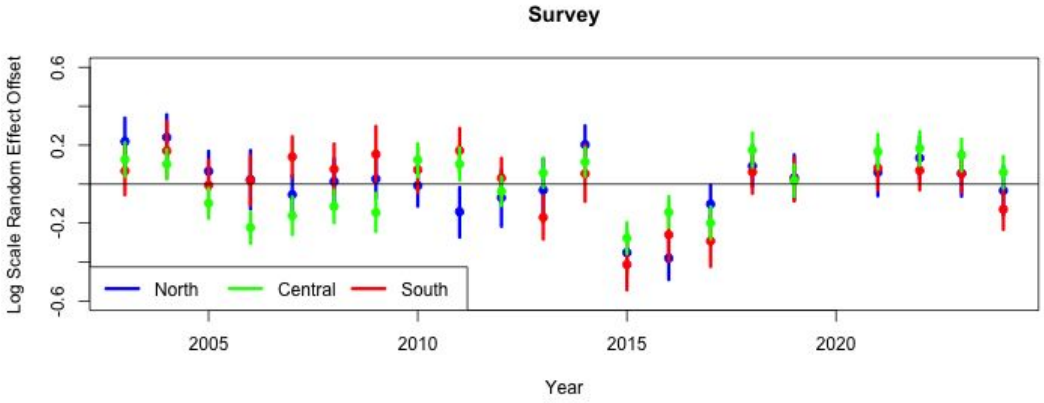
$$\epsilon_{rsti} \sim N(0, \sigma_s) \qquad \sigma_s \sim \text{Student}_3(0, 10)\ 1_{\sigma>0}$$

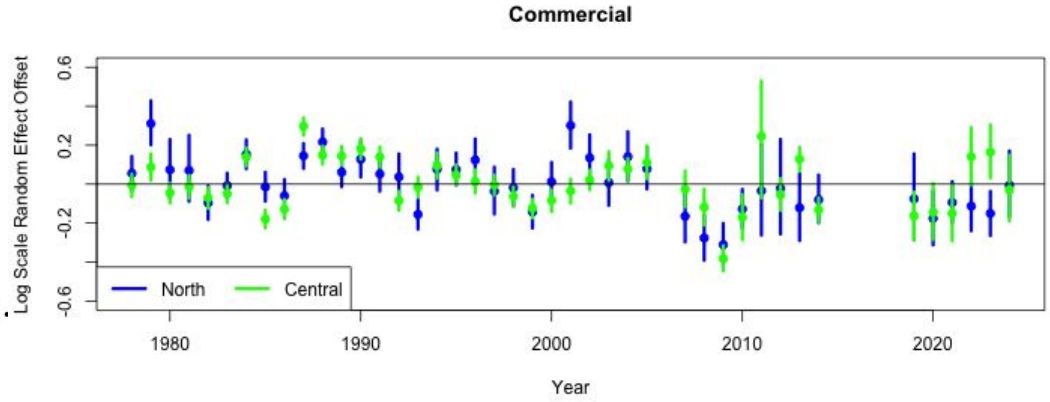
$$\log(\kappa_{rst}) = \mathbb{1}_{0.05<\kappa<0.5}({}_{\kappa}\alpha_{rs} + {}_{\kappa}\beta_{rst})$$

$$L_0 = 7.3 \qquad L_{20_{rst}} = {}_{L_{20}}\alpha_{rs} + {}_{L_{20}}\beta_{rst}$$

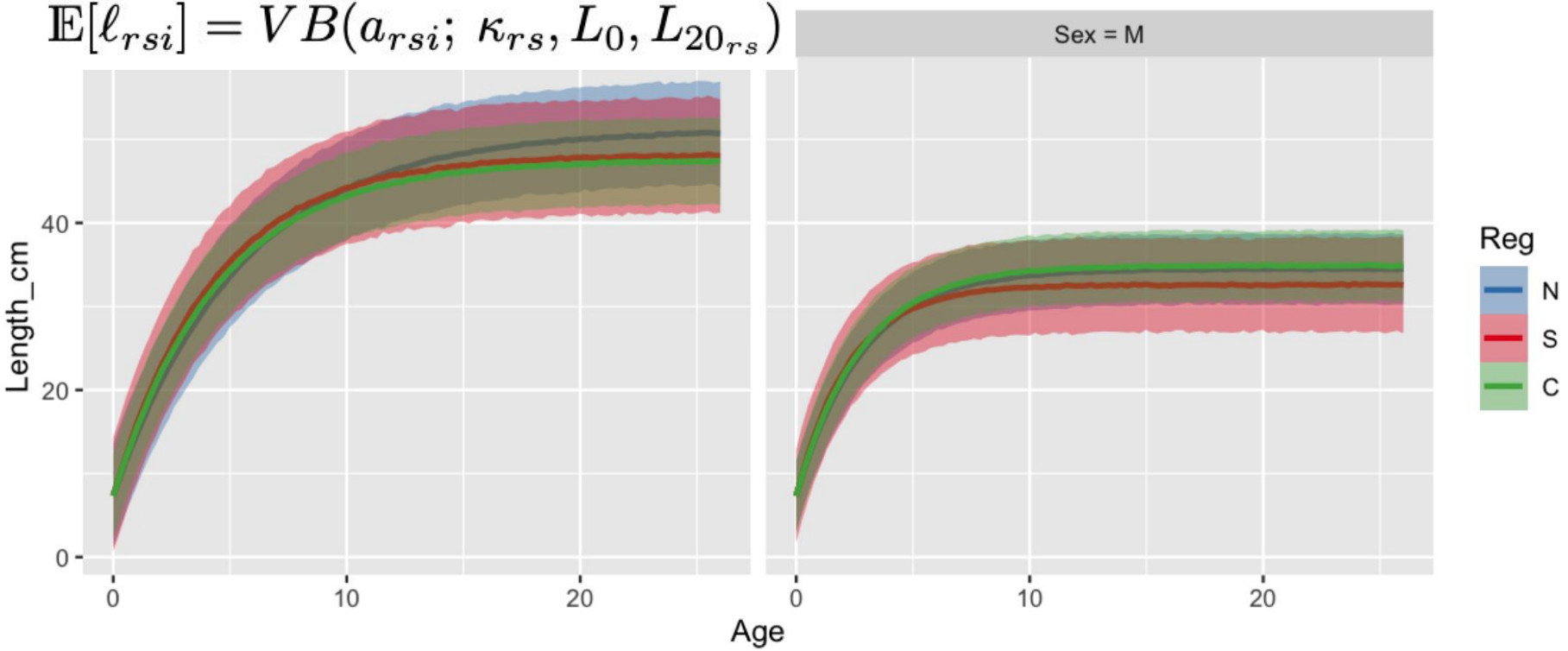
$${}_{\kappa}\beta_{rst} \sim N(0, {}_{\kappa}\phi) \qquad {}_{\kappa}\phi \sim N(0,1)\ 1_{{}_{\kappa}\phi>0}$$

$${}_{L_{20}}\beta_{rst} \sim N(0, {}_{L_{20}}\phi) \qquad {}_{L_{20}}\phi \sim N(0,1)\ 1_{{}_{L_{20}}\phi>0}$$





$$\mathbb{E}[\ell_{rsi}] = VB(a_{rsi};\ \kappa_{rs}, L_0, L_{20_{rs}})$$

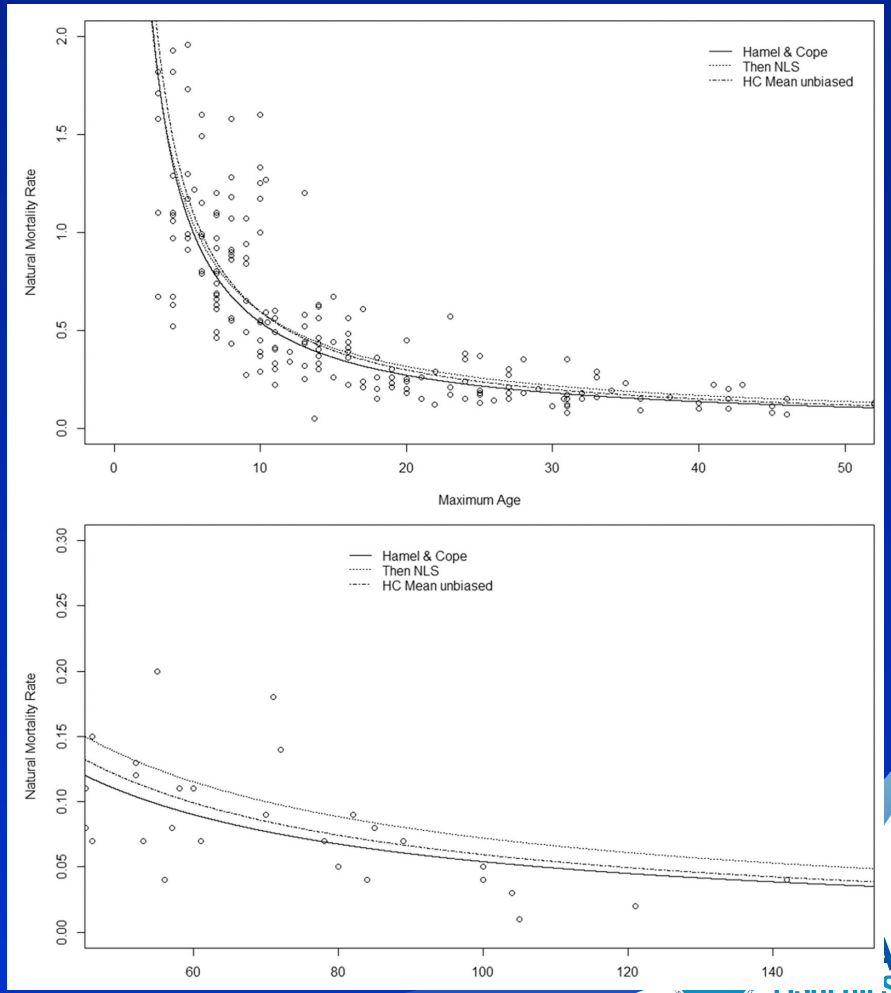


Natural Mortality

The 2007 model estimated natural mortality rates conducted prior to and during the stock assessment review, then fixed the values in the final base model, at 0.16 for females, and 0.202 for males. These values were unchanged in the stock assessment update.

We used the Hamel (2015) prior probability distribution for natural mortality (M) based on maximum ages (Hamel, 2015). The prior is defined as a lognormal distribution with median value = 5.40 / maximum age. We assumed 35 as the maximum age (second oldest fish in dataset, oldest was 39, several 34 year old females were observed). This represents 99.99th percentile (n=53,847).

The median of the prior was 0.154, natural mortality was estimated with that prior and the log-scale sigma of 0.31, consistent with the PFMC Groundfish accepted practices guidance. Natural mortality for males was modeled as an exponential offset with no explicit prior.



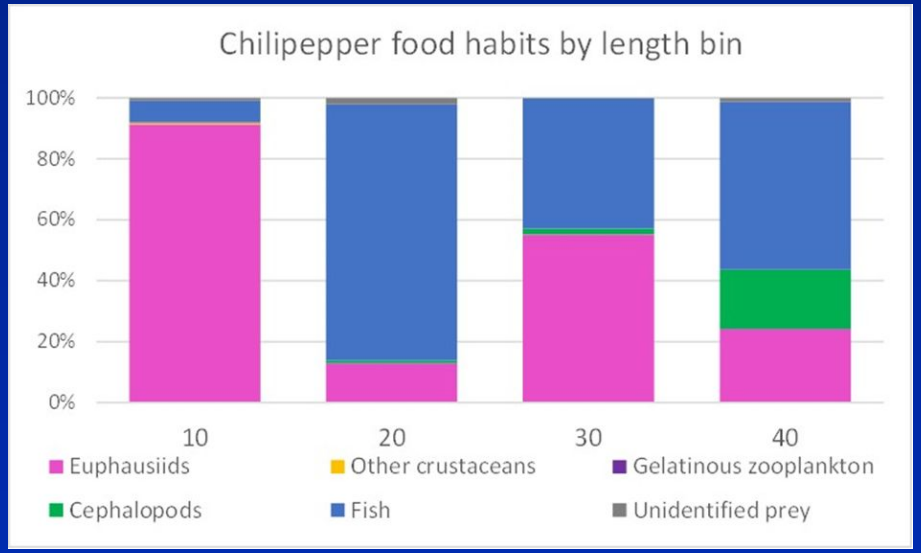
U.S. Department of Commerce | National Oceanic and Atmospheric Administration | National Marine Fisheries Service

Trophic Interactions: Prey

No published quantitative food habits studies, described by Love et al. (2002) as midwater foragers, with euphausiids, small fishes, squids and other crustaceans among key prey items.

Unpublished WCGBTS data collected between 2005-2008 were made available from 123 fish caught between 33 to 43 N, from wide depth range. Krill and small fish most abundant prey; fish that could be identified include myctophids (16%), Pacific hake (12%, size 11-12 cm), and other rockfishes (8%). Cephalopod prey included unidentified squid, octopus and gonatid squids; crustaceans included sergestid shrimp and unidentified crabs.

Our “food habits notes” from reproductive studies consistent with this, we have also observed southern chilipepper eating pelagic red crabs and pyrosomes.





Trophic interactions: Predators

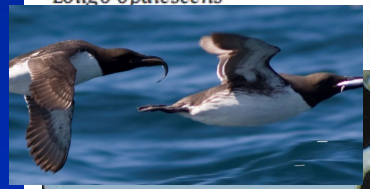
Chilipepper are prey for a broad mix of species. Pelagic juvenile rockfish are a key forage for a wide range of seabirds, marine mammals and piscivorous fishes.

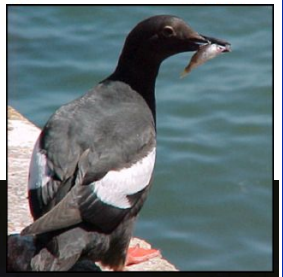
Settled juveniles and adults are similarly preyed upon by larger piscivorous fishes (particularly bocaccio and lingcod, but halibut, swordfish, others as well) and many marine mammals. Most food habits studies face challenges in discerning rockfishes to the species level, particularly for marine mammal food habits studies where taxonomic resolution is most frequently just “rockfish” (based on otoliths, vertebrae, etc).

Predation by Humboldt squid (*Dosidicus gigas*) was documented during a period of range expansion between the early 2000s and approximately 2010. Adult rockfish were a relatively minor component of the diet, although depredation during fishing operations was fairly common.

Table 2
Forage categories and summaries of their occurrence in the database, arranged by percentage for number of predators eating different prey taxa (highest (51–61 pre

Prey Category Scientific Name	Prey Common Name	Number of Predators	Number of Samples[d]
Sebastes spp.	rockfishes	61	-
Engraulis mordax[a]	northern anchovy		
Euphausiacea	krill		
Clupea pallasii[a]	Pacific herring		
Loligo opalescens	market squid		
	righteye flounders		
	lanternfishes		











Outline

1. Biology
   a. Stock structure
   b. Growth
   c. Reproduction
   d. Natural mortality
   e. Ecosystem
2. Fisheries
   a. Commercial
      i. Fleets
      ii. Landings
      iii. Discards and regulations
   b. Recreational
      i. Landings and discard
      ii. Regulations
3. Data
   a. Fishery-dependent
   b. Fishery-independent

NOAA FISHERIES

Commercial Fleets

California, north of Point Conception

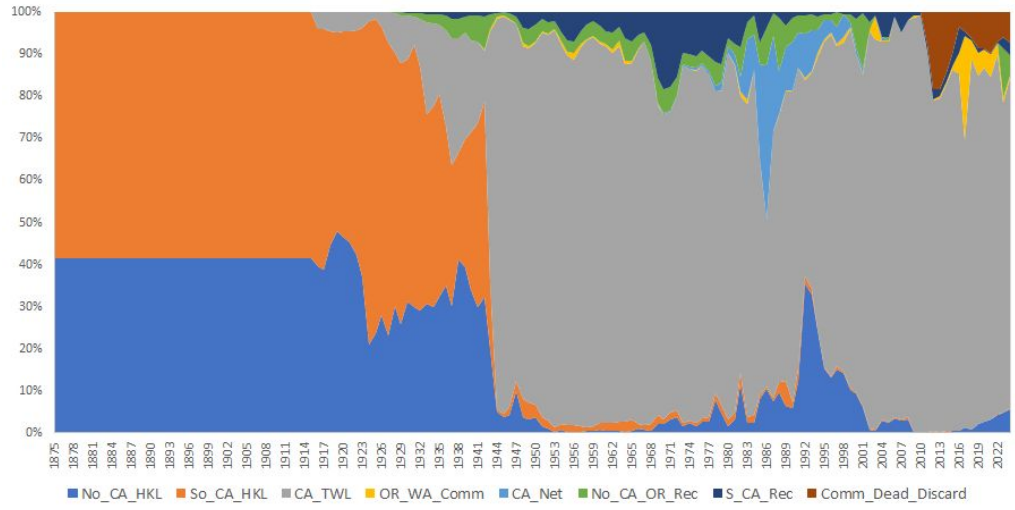
- Trawl (dominant gear post-WWII)
- Hook-and-line (pre-WWII and 1980s - 2000)
- Net (1980s and 1990s)

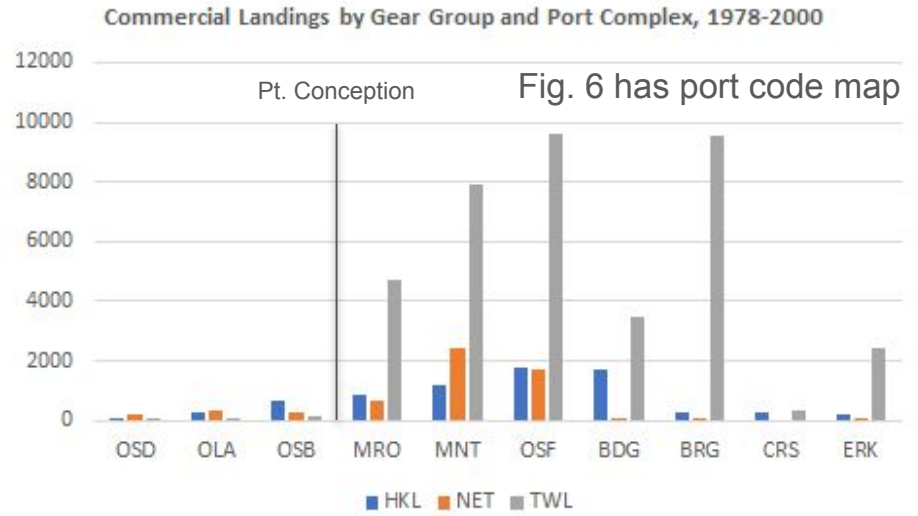
California, south of Point Conception

- >50% of landings pre-WWII (HKL)
- Net landings started here, but most net landi

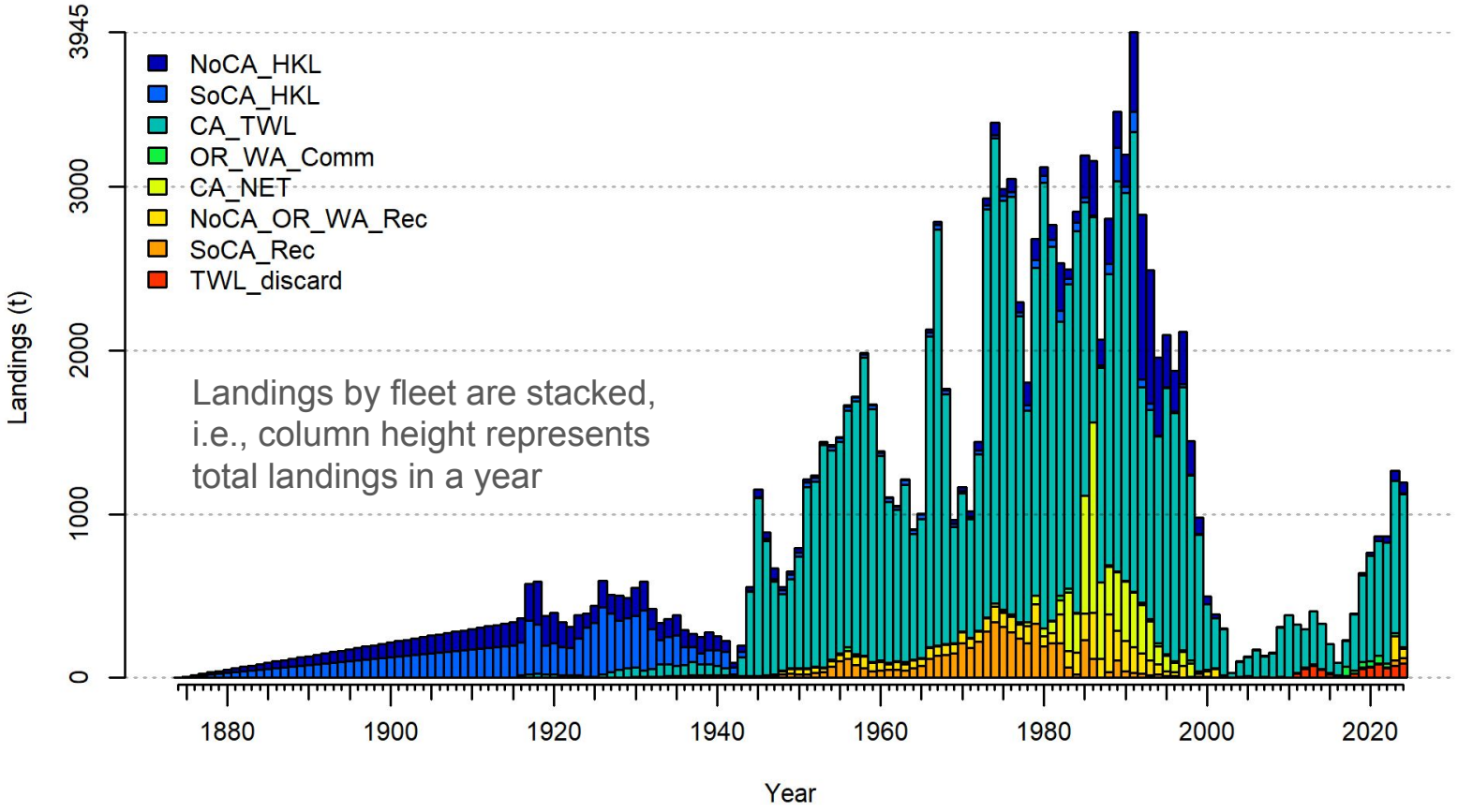
Oregon & Washington

- Generally minor, with recent increase
- Mainly Oregon (gears combined)



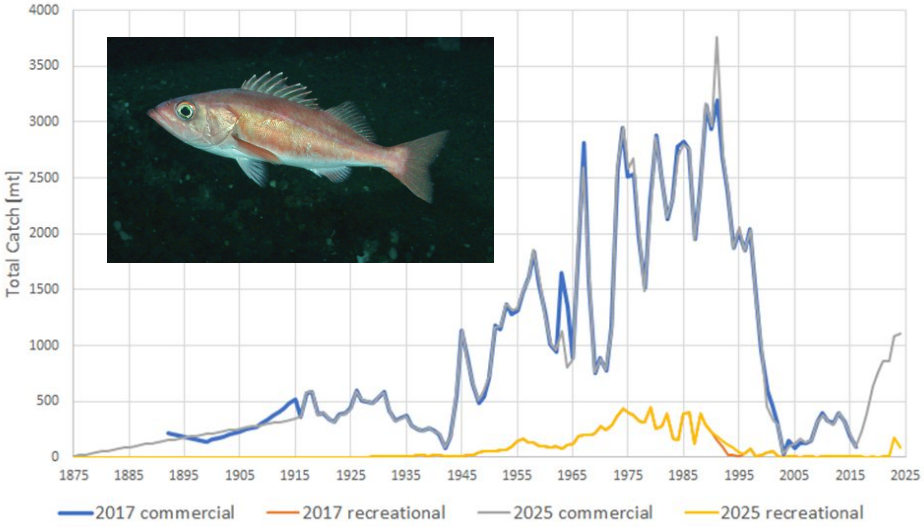


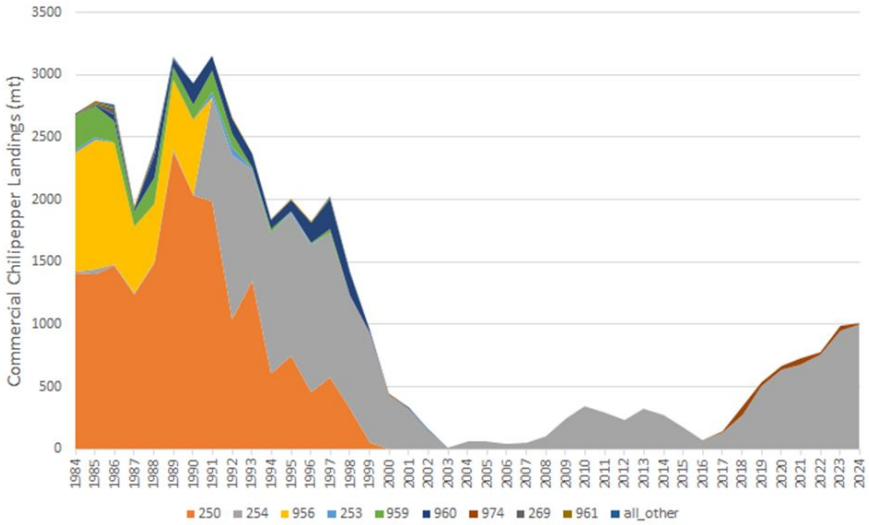
Commercial Landings

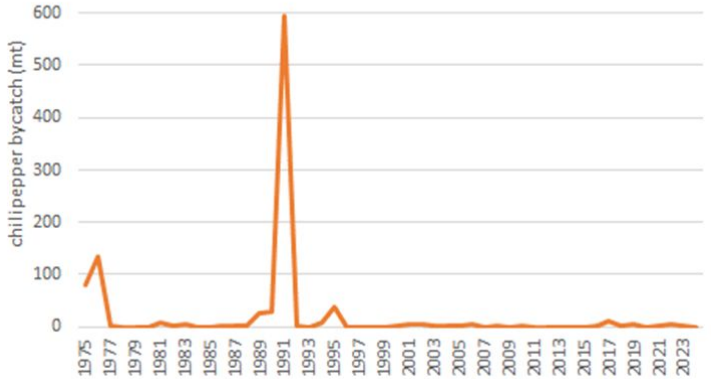


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Commercial Landings



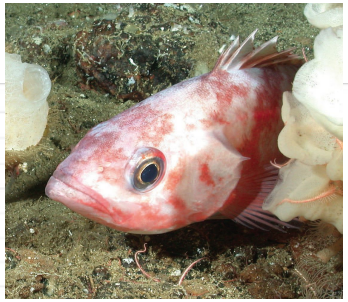


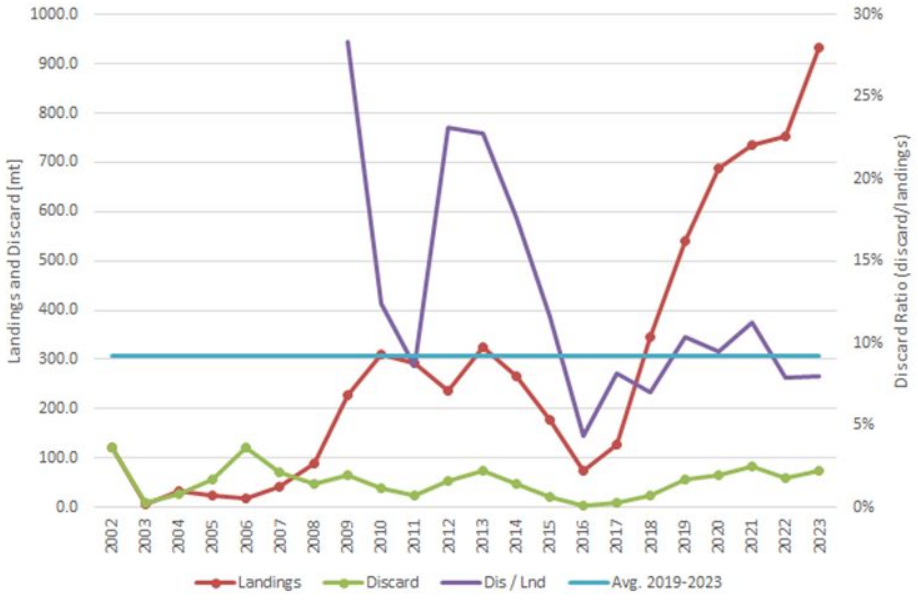


- Commercial landings >> Recreational
- Very little change since 2017 assessment
- Linear ramp approximates early years
- New data source: at-sea hake bycatch
- Landings since 2000 primarily in the ‘chilipepper’ market category (254)
- Mexican catches unknown

Recent commercial discards (Sources: WCGOP, GEMM)

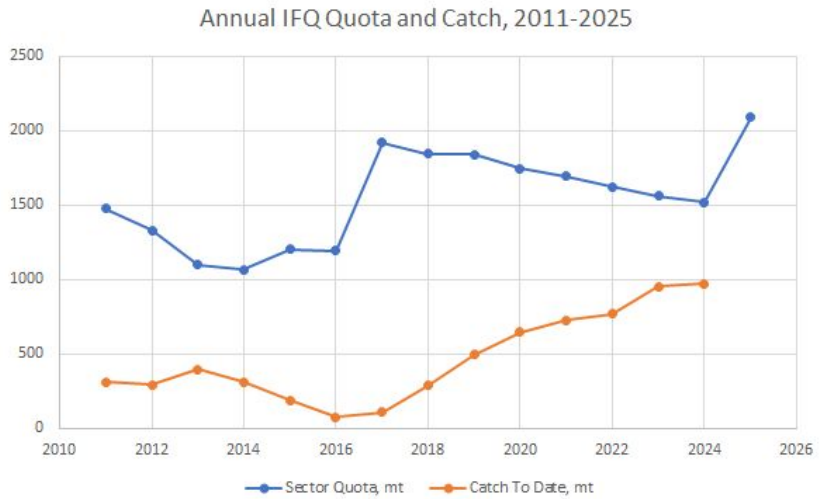
- Ratio of trawl discard:landings has been ~9%
- Used same discard rate for projections
- Change in discard length comps around 2011 (IFQ implementation; increased use of T90 cod end)





Overview of Commercial Regulations Affecting Chilipepper

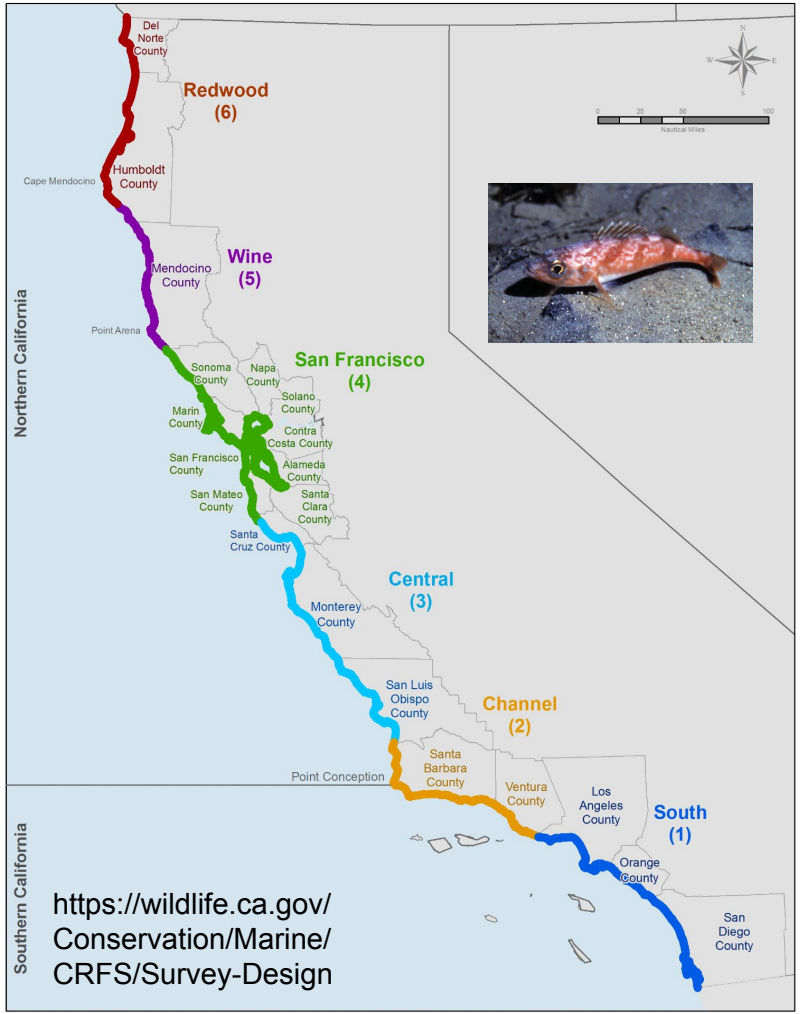
- Before 1999
  - Landed frequently in “Rockfish, unspecified” (250), “Rockfish, group bocaccio/chili” (956), and “Rockfish, Group Red” (959) market categories
  - 1991 requirement to sort bocaccio shifts chilipepper landings to the “chilipepper” market category (254)
  - ABCs from 1992-1997 ranged from 3400-4000 mt/year; landings over same period averaged 2000 mt/year.
- 1999 chilipepper removed from southern “Sebastes complex”; managed as part of nearshore rockfish complex; bocaccio declared overfished
- 2000-2010
  - Increasingly restrictive catch limits; response to other overfished spp.
  - Large-scale spatial closures, e.g., RCAs, CCAs
- 2011-present Chilipepper managed in part by Individual Fishing Quota (IFQ) program
- 2024 CCAs open to non-trawl gear, establishment of GEAs in So. CA



Recreational Removals

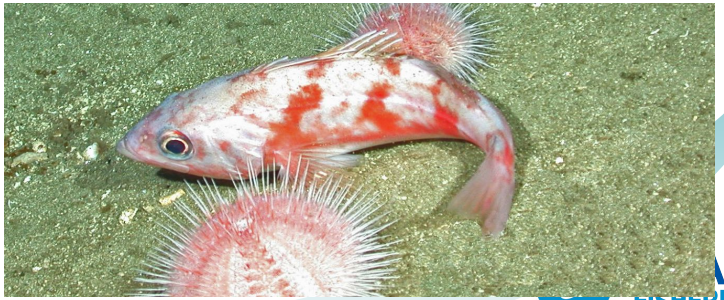
- Boat modes (mainly PC, some PR)
- Catch [mt] = CPUE * Total Effort * Mean Weight
- California Recreational Fisheries Survey (CRFS; CDFW survey)
  - 2004-present, 6 “districts”
- Marine Recreational Fisheries Statistics Survey (MRFSS; federal survey)
  - 1980-1989, 1992-2003 (sampling ‘hiatus’ 1990-1992, all modes)
- California Catch Reconstruction (Ralston et al. 2010; NMFS SWFSC)
  - Applied estimated species compositions to catch of total rockfish, 1928-1980
  - Stratified N/S of Pt. Conception
- Oregon + Washington combined << 0.5 mt/yr
- Discard added to retained catch
- Mexican catches unknown

California Recreational Fisheries Survey (CRFS) Districts



Historical ranking among recreational rockfish

- Roedel (1953): “With bocaccio, the most important Central California rockfish. Minor in Northern California, one of the three leading Southern California species.”
- Miller and Hardwick (1973): not listed as top species in 1960, between Crescent City and Avila
- Collins and Crooke (CDFG; unpublished Admin. Report): ranked 3rd among rockfishes caught 1975-1978 during onboard CPFV observer study
- Ally et al. (1991): noted substantial decreases in chilipepper catch, relative to Collins and Crooke; Chilipepper ranked ~5th in “importance” to So. CA anglers.
- Historically, rockfishes are targeted more when other primary targets are less available, e.g., salmon in northern CA, large pelagics in Southern CA



Recreational Regulations

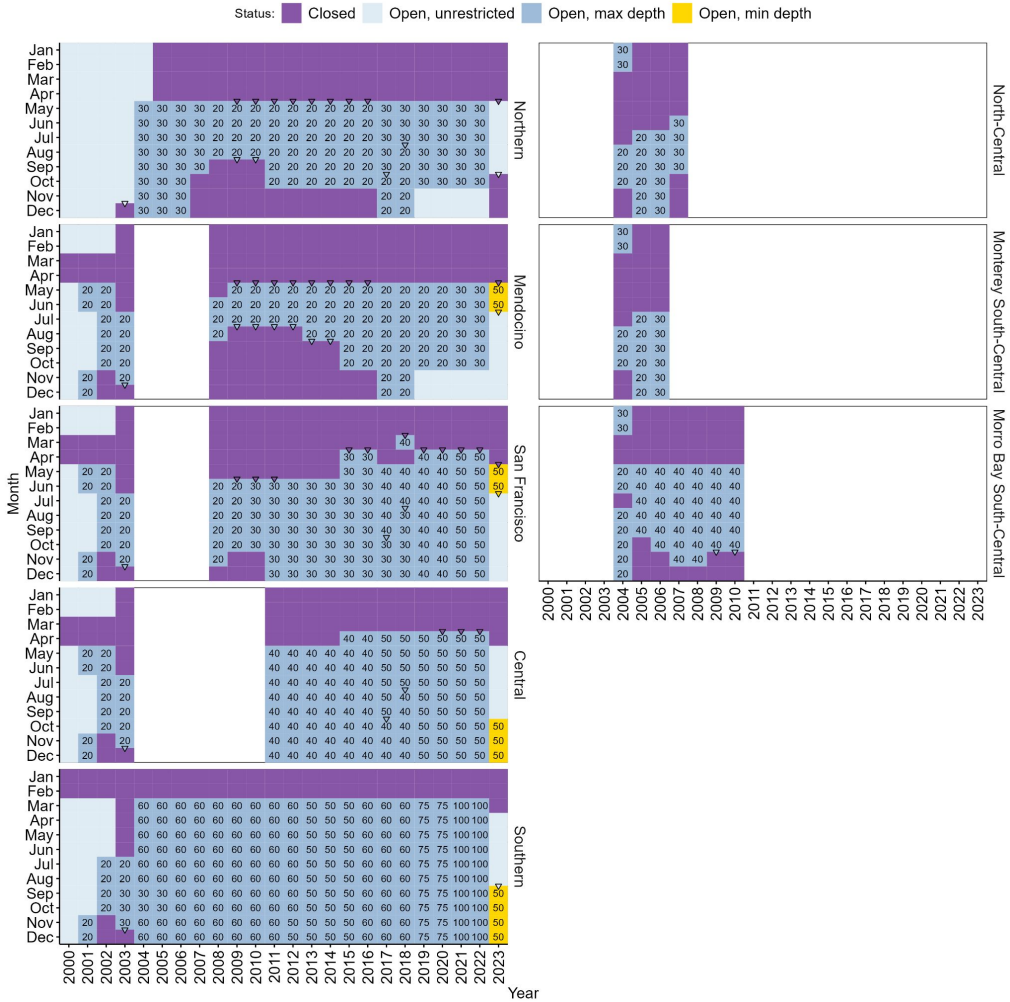
- Gear
  - Through 1999: Unlimited number of hooks and lines
  - 2000: Not more than three hooks and one line
  - 2001-present: Not more than two hooks and one line.
- No size limits
- Prior to 1971: 20 rockfish/day limit
- 1971-1999: 15 rockfish/day
- 2000-present:
  10-fish limit for all species in the Rockfishes, Cabezon and Greenlings Complex (includes chilipepper)
- Recreational Rockfish Conservation Areas (RCA) established 2004



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Recreational Depth Restrictions

- Statewide depth restrictions enacted in 2004
- Management area definitions changed over time
- Central and northern California rec. fleets restricted to <20 fm 2008-2016, <30 fm 2004-2022
- Restrictions relaxed in 2023, local targeting, increased catches



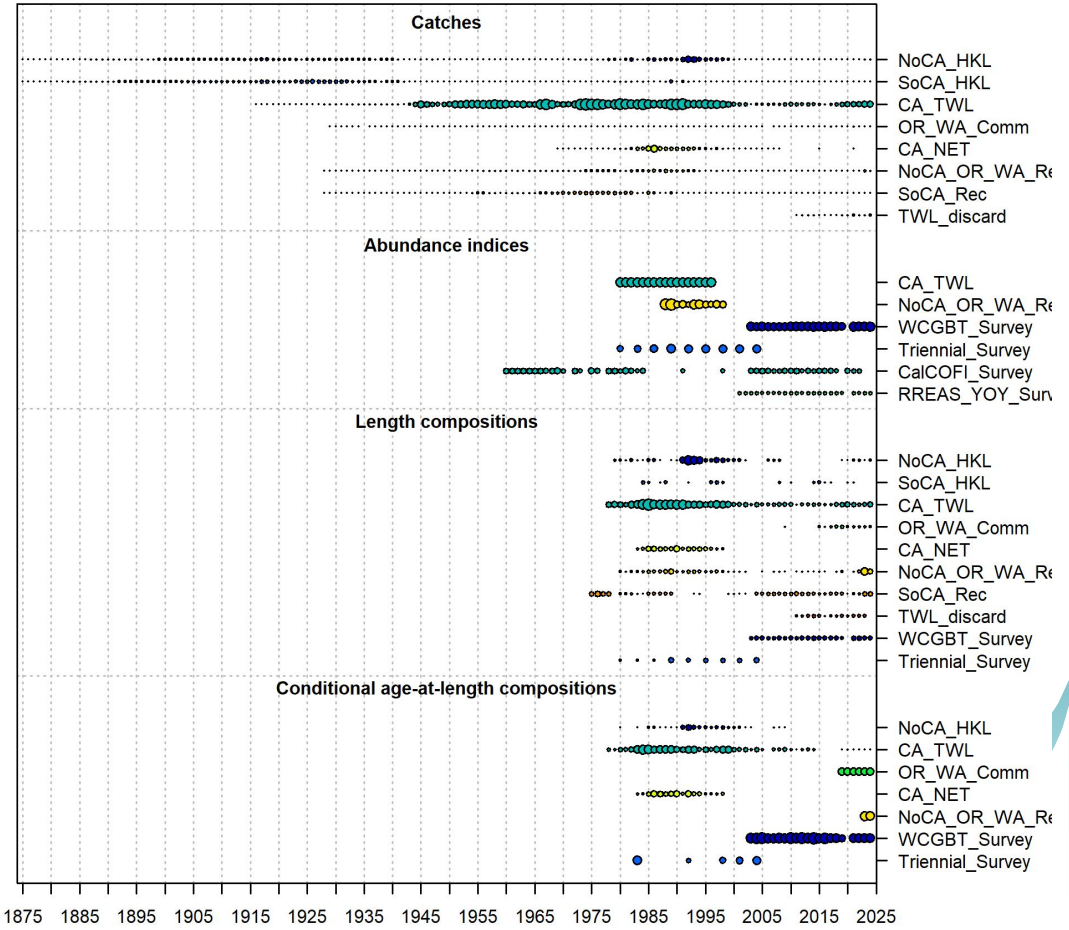
Outline

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    a. Fishery-dependent
    b. Fishery-independent
    c. Sources considered but not used

NOAA FISHERIES

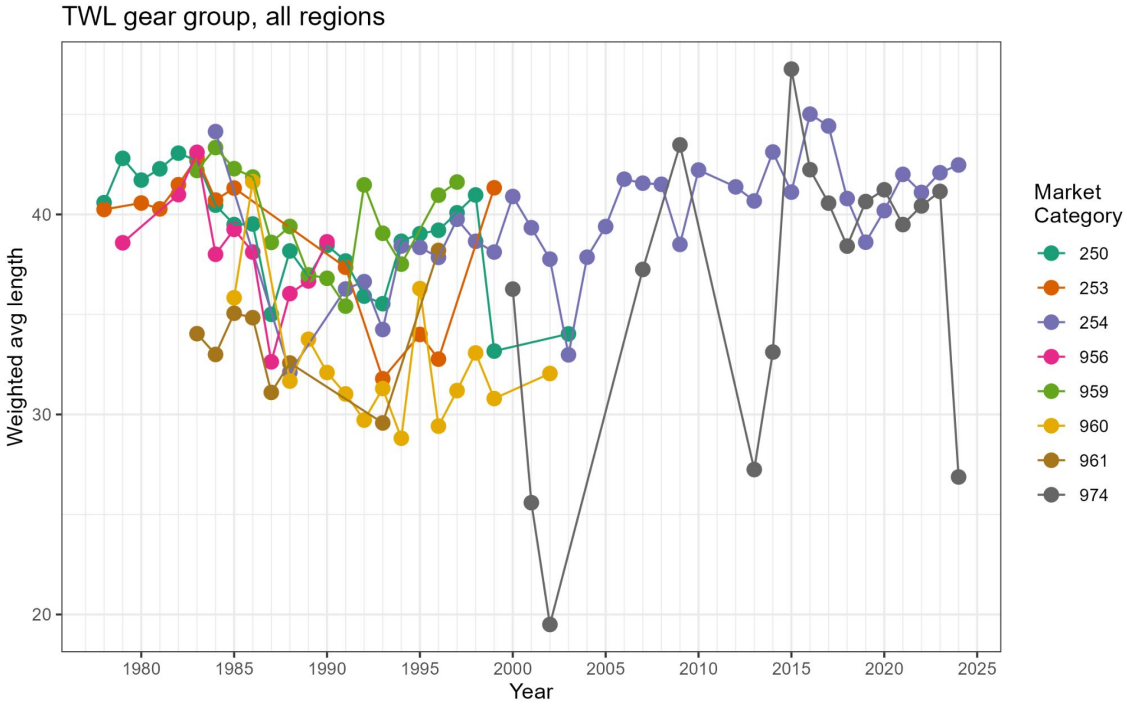
Overview of All Data Sources

- Commercial fleets defined by gear, area, retained/discarded
- Recreational fleets defined by area
  (all rec. 'modes' combined)
- 4 fishery-independent surveys; (with implied fits to trawl logbook & CPFV indices from last update)
- Marginal length compositions
- Conditional age-at-length compositions



Fishery-dependent data: commercial length compositions

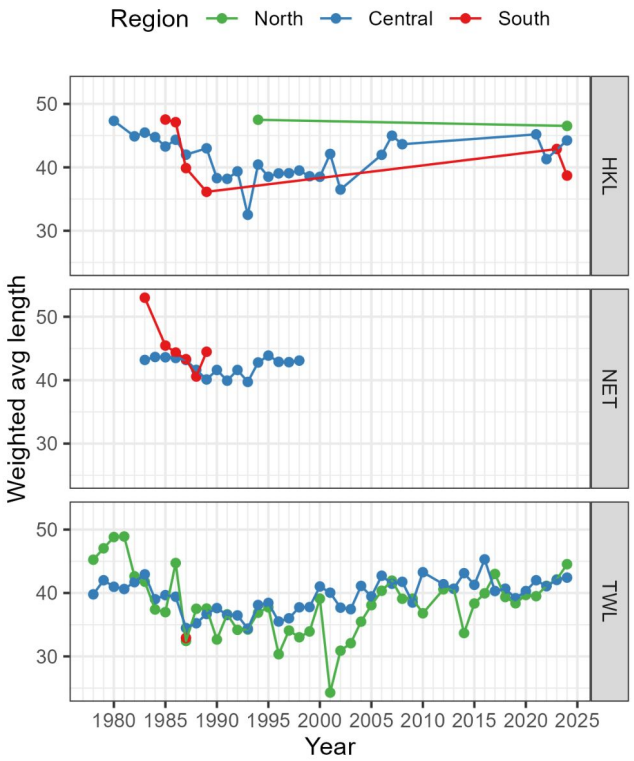
- Catch-weighted (“expanded”) length compositions estimated by gear, area, and year; using 2-cm “data” bins from 8-60cm
- Mean length varied by market category and port complex (region) in CA
- CALCOM length expansions stratify by year, market category, port complex, gear group, disposition (i.e., landed live or dead)

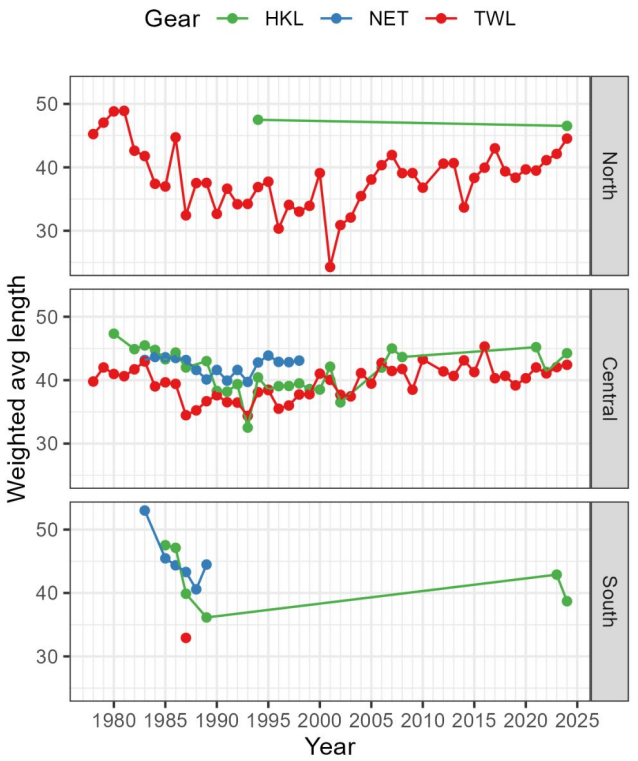


250 = “Rockfish, unspecified”; 253 = “bocaccio”; 254 = “chilipepper”; 956 = “Rockfish, group bocaccio/chili”; 959 = “Rockfish, group red”; 960 = “Rockfish, group small”; 961 = “Rockfish, group rosefish”; 974 = “Rockfish, shelf”

Fishery-dependent data: commercial length compositions

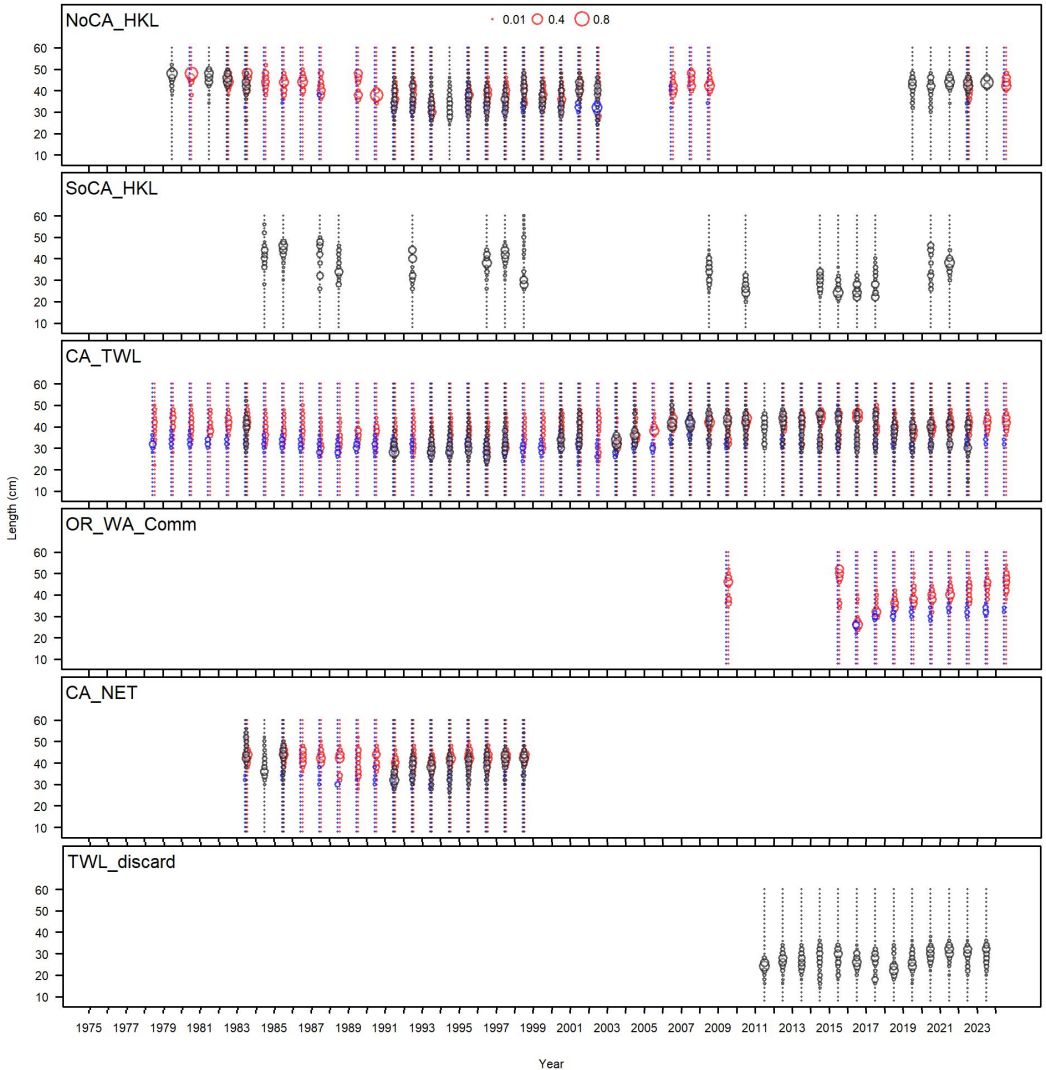
- Mean length varies by port complex (region); see Figure 6
- Mean lengths shown here aggregated into regions
  - **North**: Eureka, Crescent City
  - **Central**: Fort Bragg, Bodega Bay, San Francisco, Monterey, Morro Bay
  - **South**: Santa Barbara, Los Angeles, San Diego





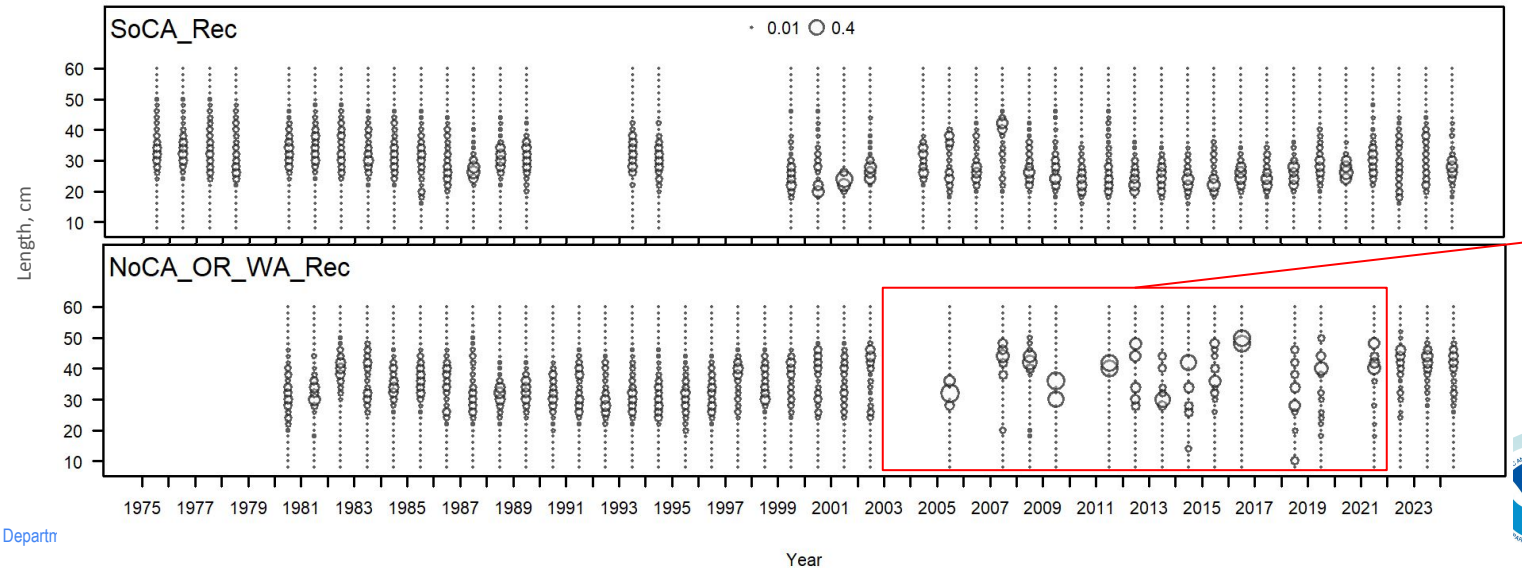
Fishery-dependent data: commercial length compositions

- Continuous time series for trawl fleet, 1978-2024
- Visual evidence of cohort progression
- Small sample sizes for sexed fish in So. CA hook-and-line
- Size distribution of discarded fish (unsexed) from IFQ trawl fleet included since 2011 to model selectivity for discard projections (~9% of landings)



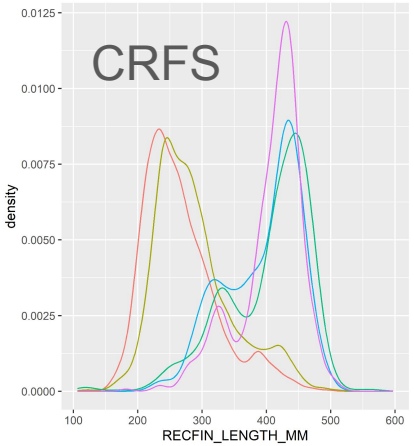
Fishery-dependent data: recreational length compositions

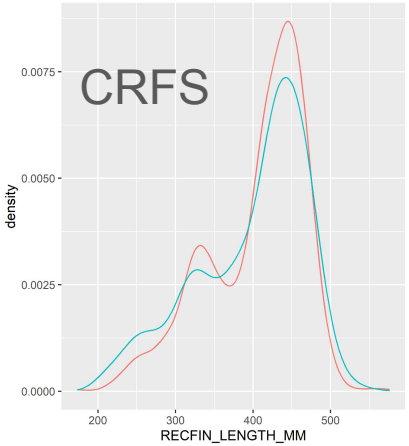
- Rec. length data is unsexed
  - Collins & Crooke onboard observer study, 1975-1978; So. CA only
  - Ally et al. 1985-1987; So. CA only
  - MRFSS, 1980-1989, 1993-2003 (see note, below)
  - CRFS, 2004-2024; almost all CRFS lengths N. of Point Conception from 2023-2024 (Table 3)
- Replaced some MRFSS data
  (Ally et al., So. CA 1985-1989; CDFG onboard, No. CA, 1988-1998)

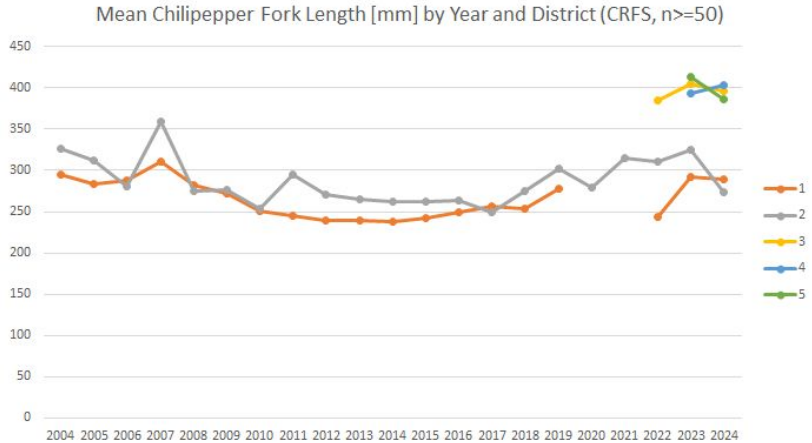


Fishery-dependent data: recreational length compositions

- Lengths not “expanded”, but sampling is roughly proportional to recent catch by stratum (CRFS), or effort by stratum (MRFSS)
- Work in progress with RecFIN to create catch-weighted comps
- No rec. compositions used from OR or WA
- Mean length varied by region (N/S of Pt. Conception), but not by boat mode





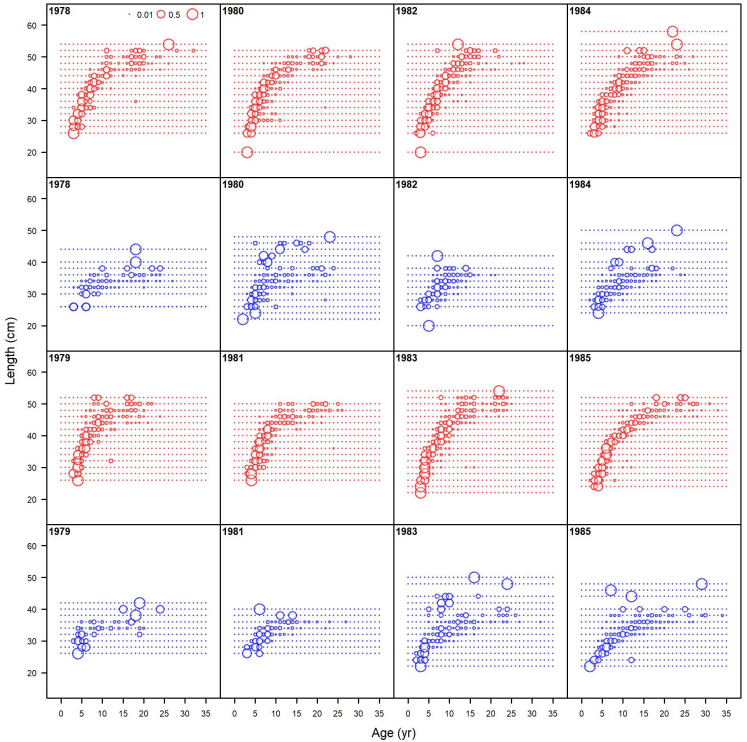


See Fig. 11 for CRFS district map

Commercial age data

Sample sizes by Fleet / Year / Sex: Table 4

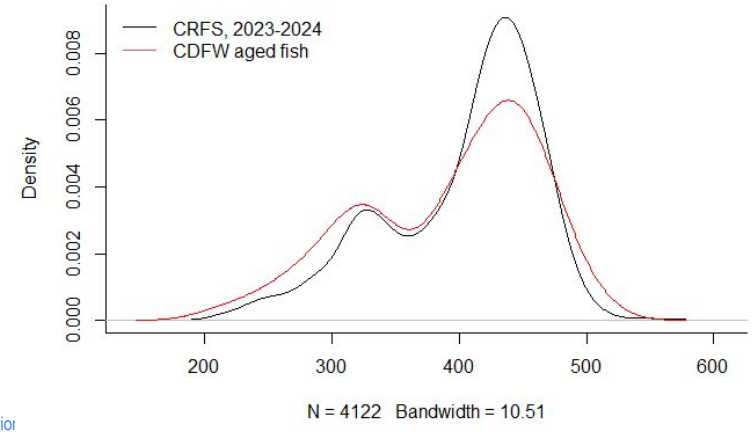
- First chilipepper assessment to use conditional age-at-length data
- **> 53,000 commercial ages**
- 1978 - 2024
- Excluded ~30 apparent errors from data file
  e.g., 10-cm 8-year-old female,
  48-cm 2-year-old female
- Unclear if occasional large males (~48+ cm) are ‘real’ or errors
- “Bubble” plots for all years available in model output files distributed to the panel

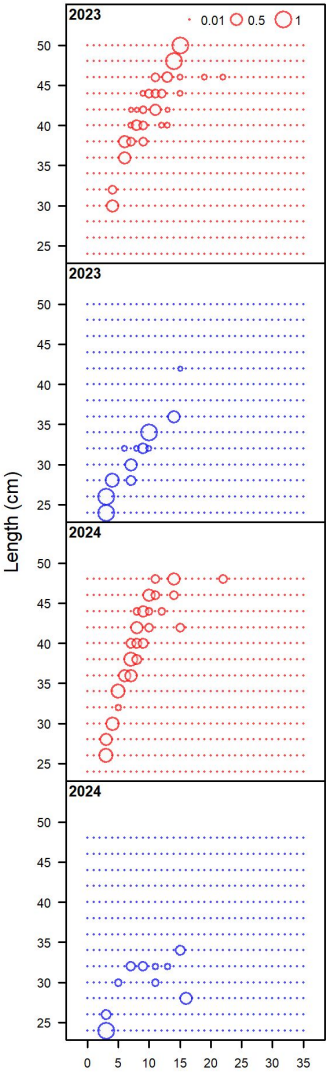


Recreational age data

- Opportunistic sampling, but lengths of aged fish align well with CRFS length comps
- 109 fish scanned; 81 fish not scanned (poor otolith condition)
  2 unsexed fish excluded from scanned subset; N = 107
- Ages predicted from FT-NIRS scans
- Sample sizes incorrect in Table 4 (correction below)
- Pre-STAR base model allowed rec. CAAL data to inform sex ratio (sex code=3); change to sex codes 1 & 2 had no effect on NLL

Year	Female	Male
2023	43	16
2024	36	12





Outline

1. Biology
   a. Stock structure
   b. Growth (length-at-age by sex, area, time; weight-length)
   c. Reproduction
   d. Natural mortality

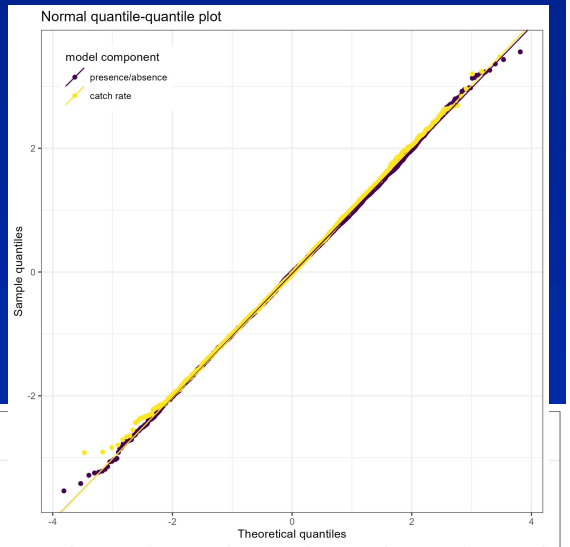
2. Fisheries
   a. Commercial
      i. Recent (1981-present)
      ii. Historical
   b. Recreational
      i. Recent (1980-present)
      ii. Historical

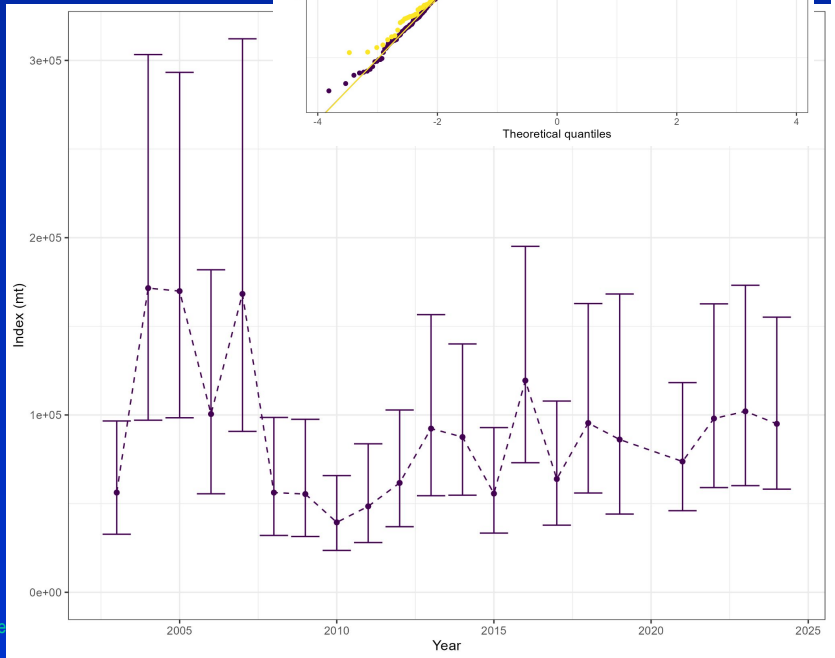
3. Data
   a. Fishery-dependent
   b. Fishery-independent
   c. Sources considered but not used

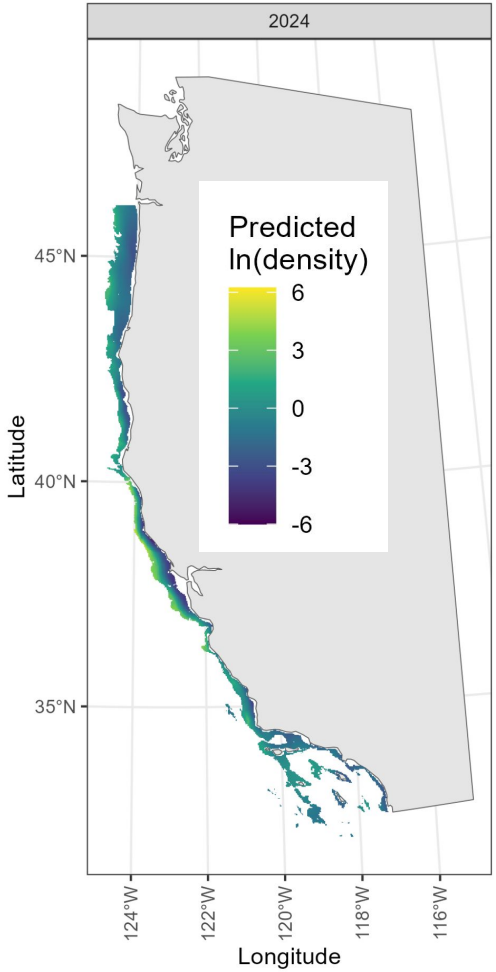
NOAA FISHERIES

Fishery-Independent Indices: WCGBTS (aka “combo”)

- Largest bottom trawl survey off the U.S. West Coast
- 2003-2024; ~7800 hauls
- Standardized index provided by NWFSC
- Explicitly spatial model estimated using sdmTMB
- ~7% of chilipepper est. abundance is north of Cape Mendocino, stable over time (5-8%)
- WA < 0.1% of abund.

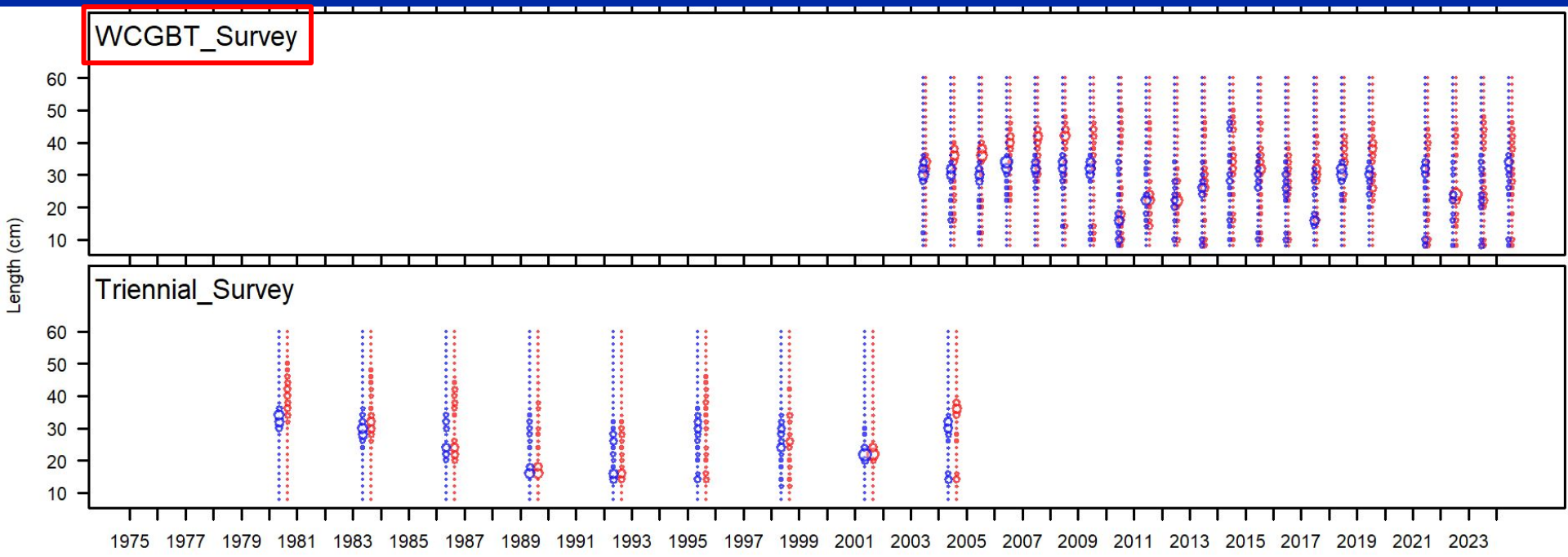






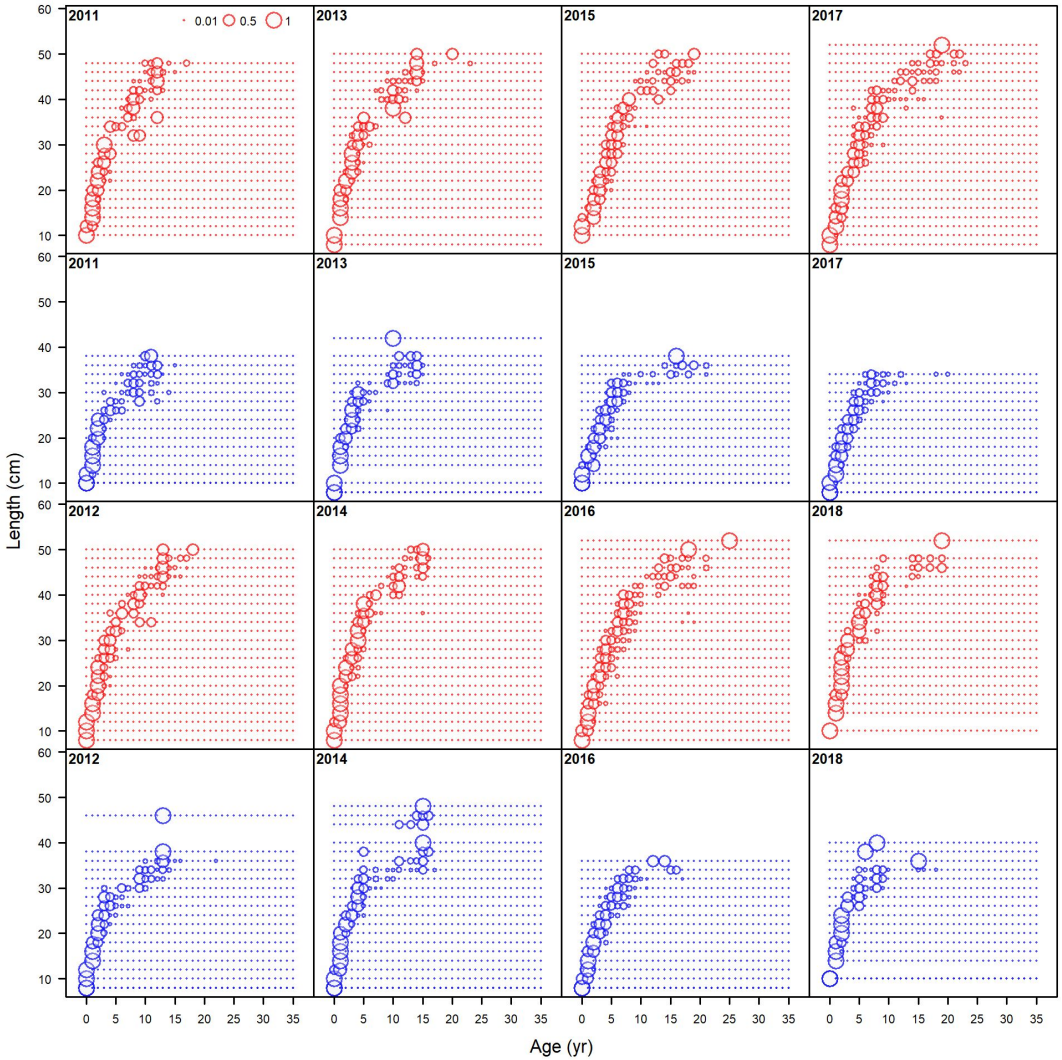
Fishery-Independent Indices: WCGBTS

- "Combo" survey captures a wide range of lengths, including some age-0 fish
- Sample sizes by year & sex in Table 7
- Unsexed fish were small (mean=11 cm, s.d.=2.3 cm); assigned 1:1 sex ratio



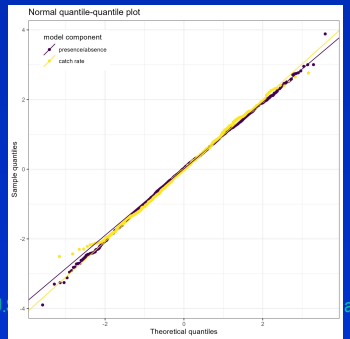
Fishery-Independent Indices: WCGBTS

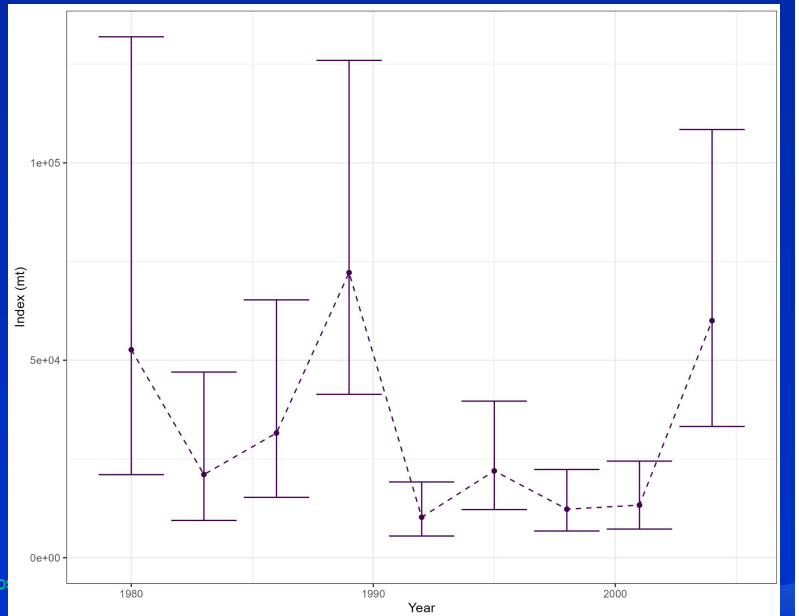
- Over 13300 ages from “combo” survey in base model, over 2800 new this year
- Unsexed fish were small (mean=11 cm, s.d.=2.3 cm); assigned 1:1 sex ratio
- Sample sizes by year & sex in Table 8 (after allocation of unsexed fish)

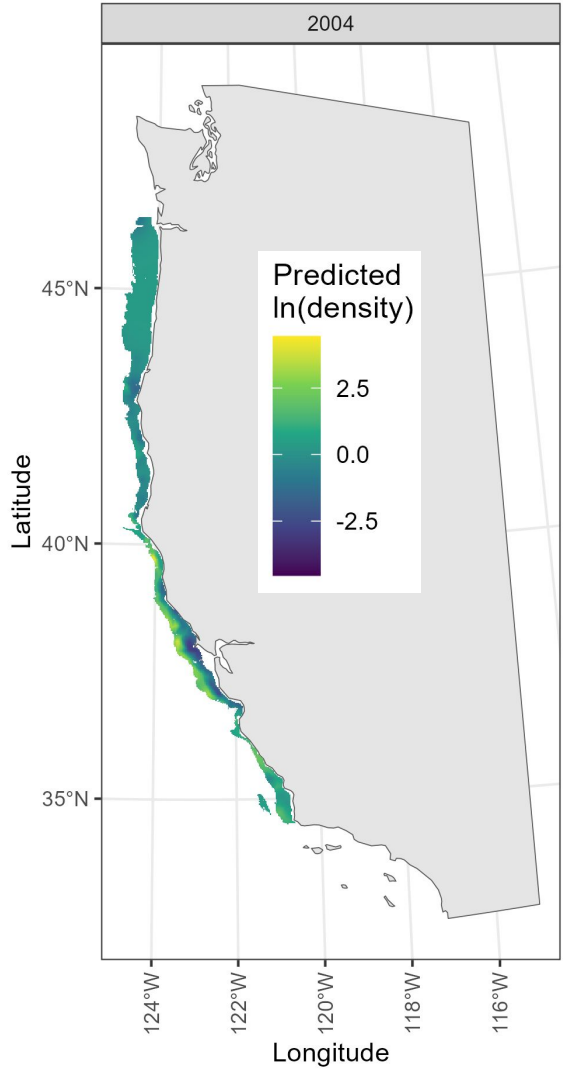


Fishery-Independent Indices: "Triennial" Trawl Survey (AFSC & NWFSC)

- Preceded WCGBTS; 1980 - 2004; dropped 1977
- Standardized index provided by NWFSC
- Explicitly spatial model estimated using sdmTMB
- Index treated as continuous time series as in previous assessments, i.e., not treated as two time series
- No sampling south of Point Conception; no sampling south of 36°48' N. lat. prior to 1989



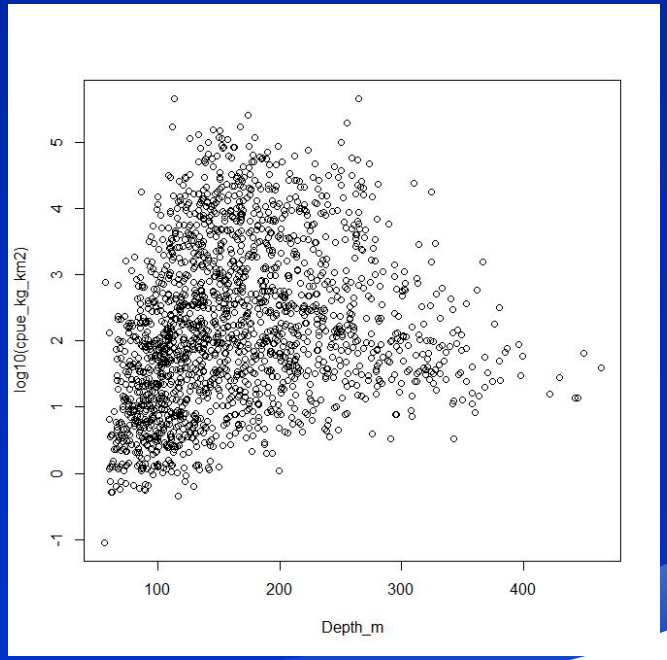




Fishery-Independent Indices: "Triennial" Trawl Survey (AFSC & NWFSC)

- "The depth range expanded from 55–366 m in 1992 to 55–500 m in 1995. For species that reside in the 366–500 m depth range in any substantial numbers, including this information is another reason to consider this a separate survey."
  – Keller, A. A., J. R. Wallace, and R. D. Methot. 2017. DOI: 10.7289/V5/TM-NWFSC-136

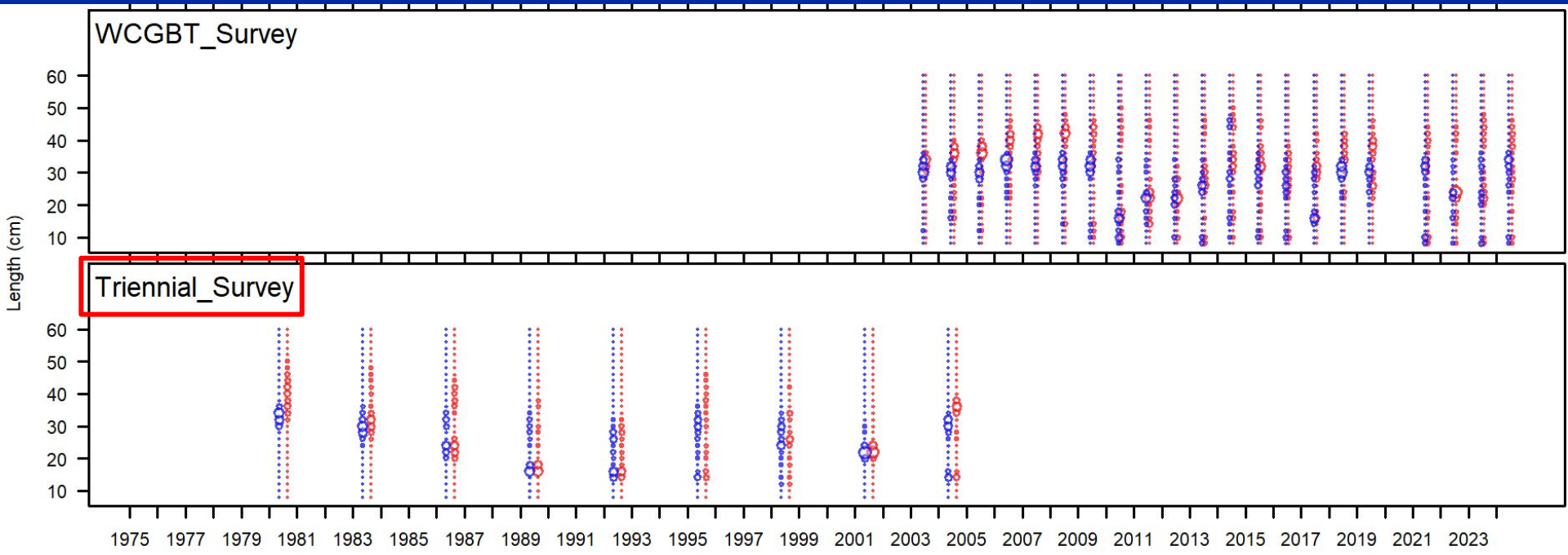
- Positive observations of chilipepper are rare deeper than 350 m, based on data from WCGBTS (right: $\log_{10}$(CPUE) by depth for positive hauls)



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Fishery-Independent Indices:
"Triennial" Trawl Survey (AFSC & NWFSC) Lengths

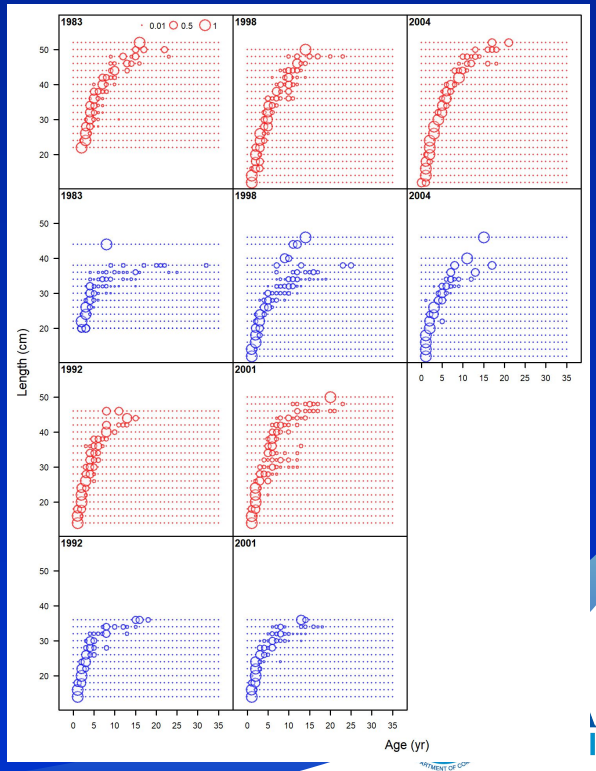
- "Triennial" survey captures a wide range of lengths, including some age-0 fish
- Sample sizes by year & sex in Table 6
- Unsexed fish were small, similar to WCGBTS; excluded due to small N



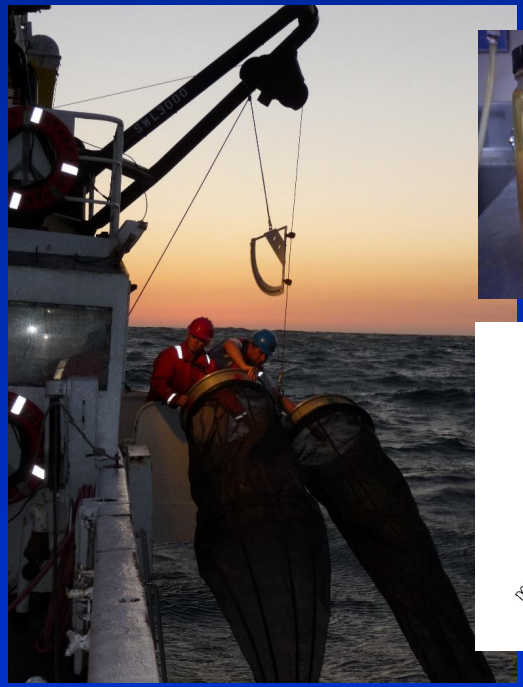
Fishery-Independent Indices: “Triennial” Trawl Survey Ages (AFSC & NWFSC)

Survey	Year	Female	Male	Unsexed	N
Triennial_Survey	1983	340	394	0	734
Triennial_Survey	1992	135	111	0	246
Triennial_Survey	1998	197	240	0	437
Triennial_Survey	2001	252	233	0	485
Triennial_Survey	2004	340	291	0	631

- 4 years of age data (1983-2001) were inadvertently left out of the base model in the pre-STAR draft (see table, top right)
- Unsexed fish were excluded due to small N
- Spoiler alert: addition of ages had almost no effect

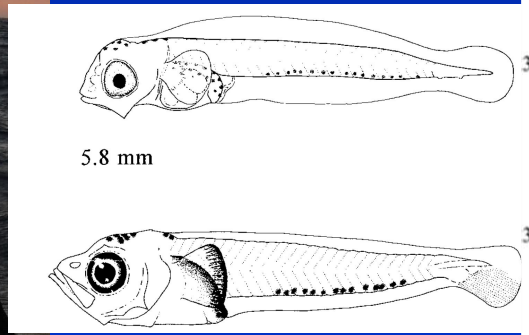


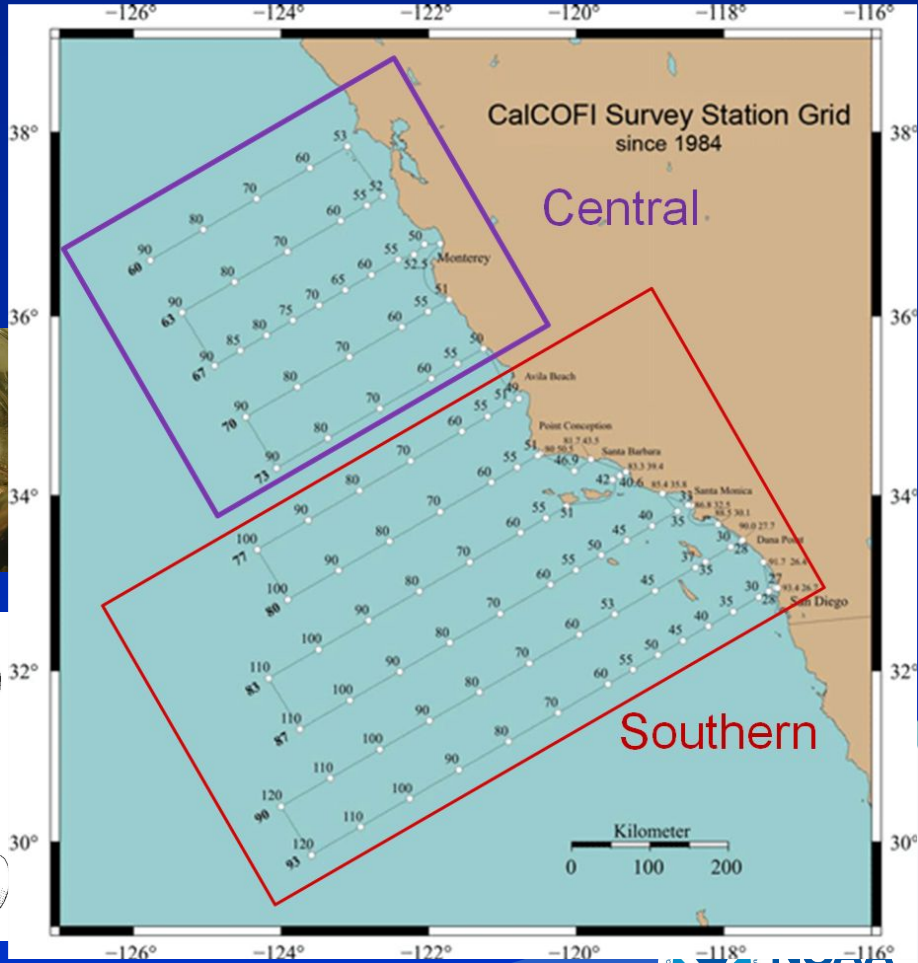
Fishery Independent Indices: Index of spawning output based on CalCOFI larval abundance



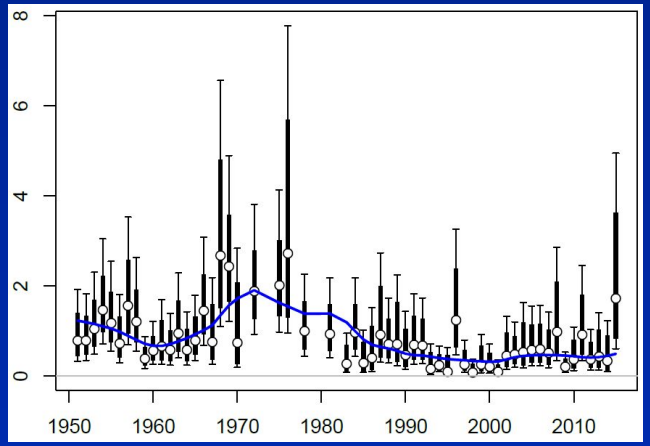






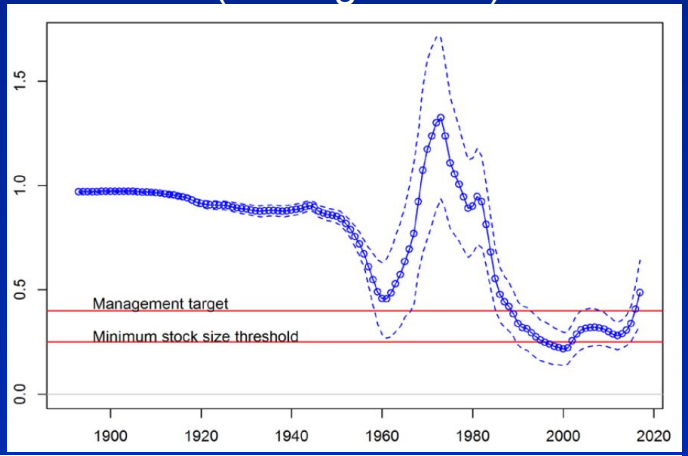


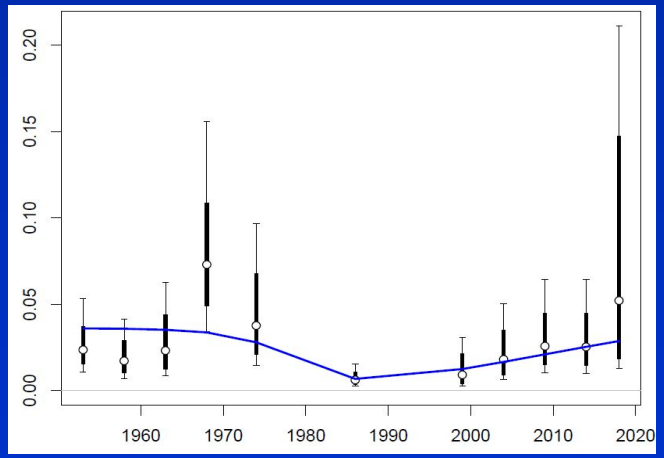
CalCOFI data used in bocaccio and cowcod assessment models (among others)





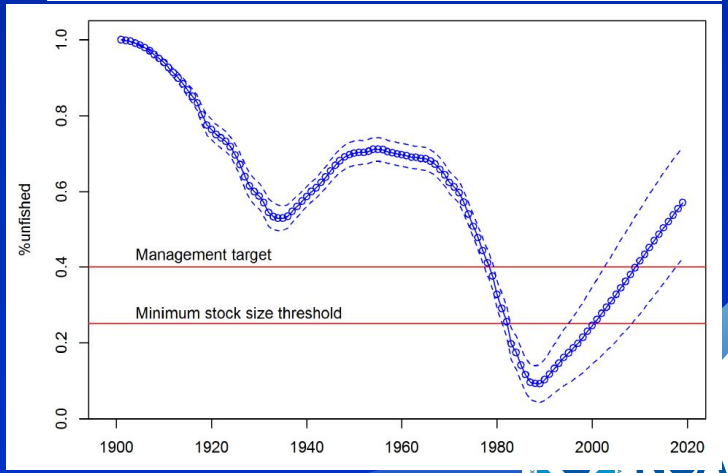
Bocaccio
(1996-2017)

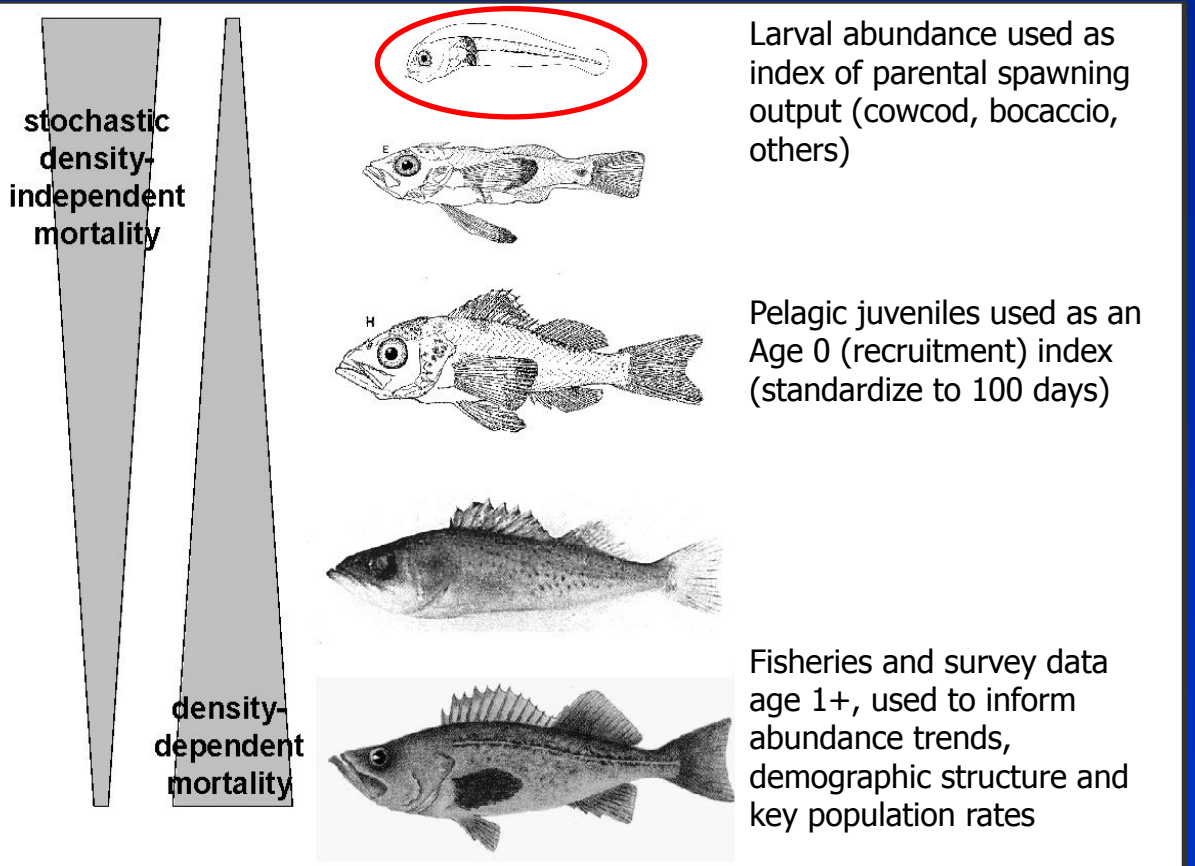






Cowcod
(1999-2019)





Assumption since earliest applications has been that larval abundance is directly related to parental spawning output: Larval index is mapped to larval production (total fecundity) by mature females, accounting for size- or age-dependent fecundity

Figure from Field et al. 2010

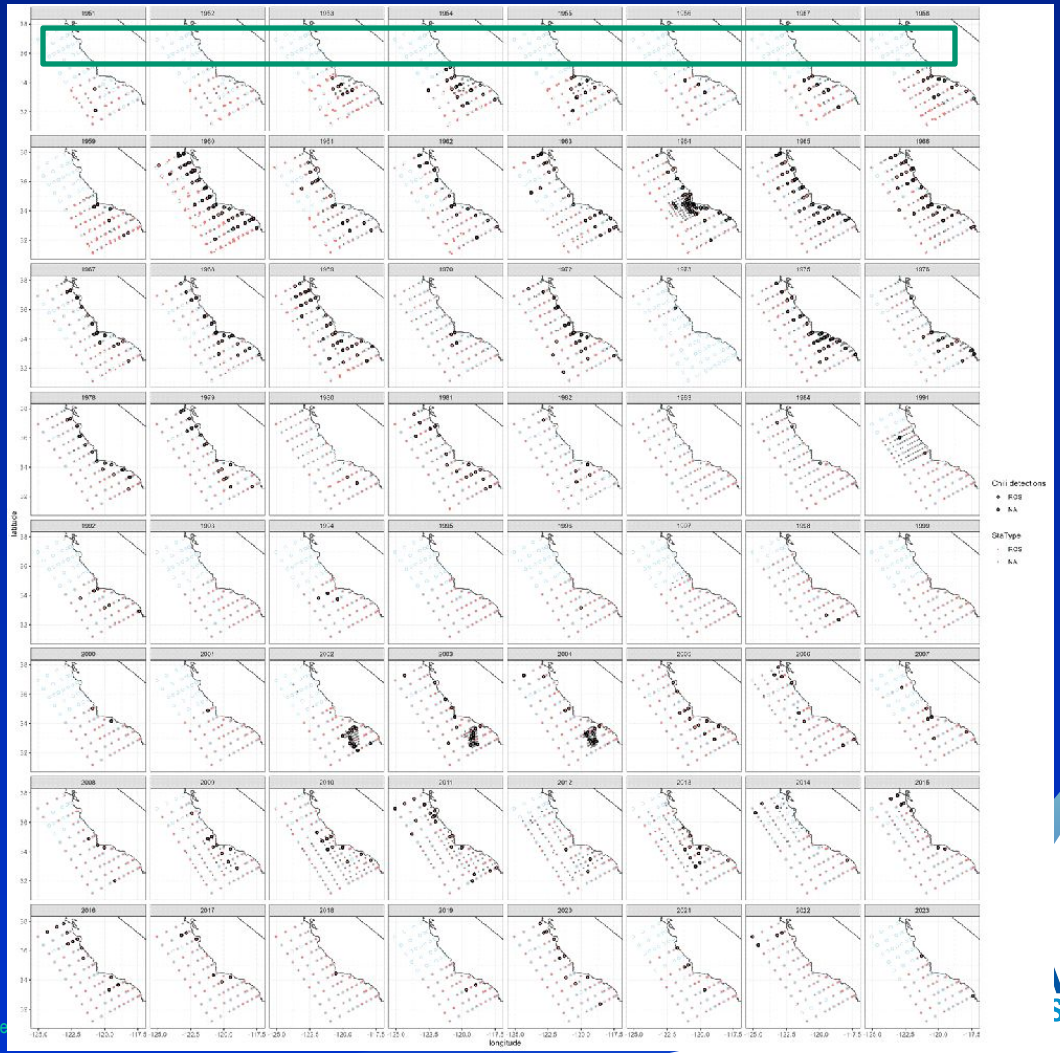
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CalCOFI Data: Summary

One of few *Sebastes* that can be identified morphologically, although not reliably until certain features develop (~ 1 week of age). Data available 1951- 2023, but historical central data (north 73.3) for 1950s and 1960 is still being sorted (green box). Late 80s unreliable (as per W. Watson pers com).

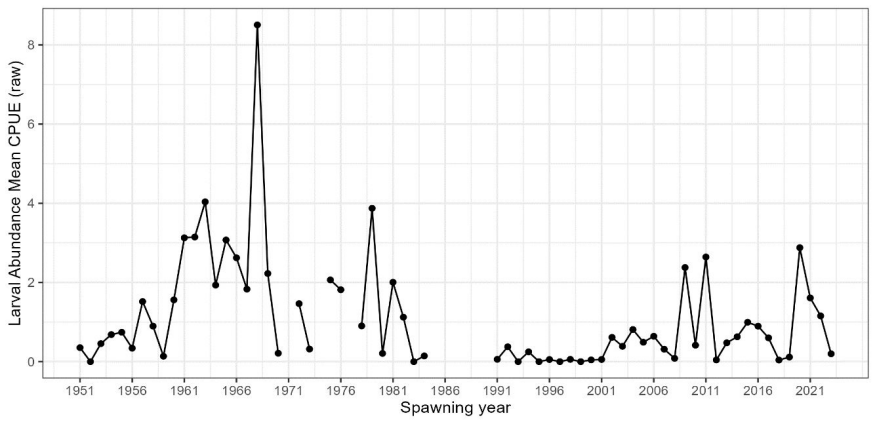
Excluded data north of line 60, south of line 93 and stations offshore of station 80 (very few positives), as well as (newer) SCCOOS inshore stations. Only included November to April, with Nov. and Dec. applied to the following calendar year (spawning year).

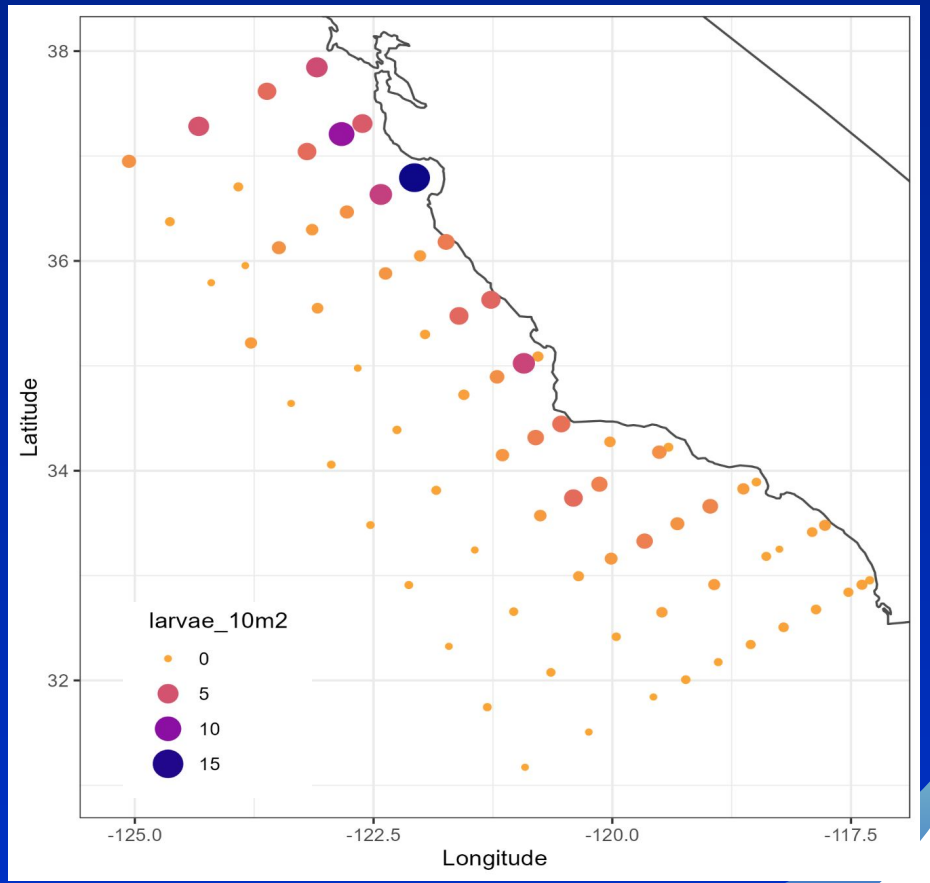
Light blue circles are standard station locations, filled have data, color indicates standard/otherwise, black are positives.



Raw average density of larval chilipepper (spatial average over all years to right, temporal average over all years below), using only the stations, months and years used in the index model

Description	Number of Tows	Number of chilipepper
All tows C1 and CB tows, excluding P net sides prior to 1997	46,496	3,251
Exclude SCOOS stations	45,969	3,251
Include only line>=60 & line<=93.3 & station<=80	20,390	3,148
Exclude years 1985-1990	19,052	3,147
Excluded lines <= 73.3 for years 1959 and earlier	18,145	3,146
Include only months 11, 12, 1, 2, 3, 4	10,846	3,023
Average S and P net sides for same tow	10,234	2,917.5





Modeled using sdmTMB with Tweedie error distribution (found to be suitable from diagnostic plots). There are 8 years (1952, 1983, 1993, 1994, 1995, 1996, 1997, 1999) with sampling but no positives.

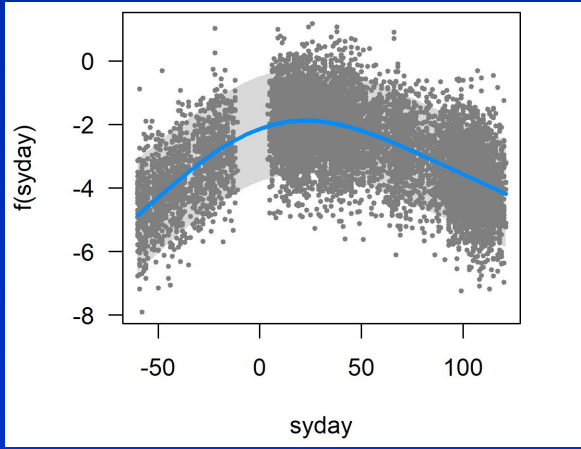
Consequently, we modeled year effects using time-varying (random walk) intercepts rather than fixed effects. Testing indicates that for years with positive catches, there is little difference between the two model structures, and that for years without positive catches, the time-varying intercept model produces low index values of reasonable magnitude.

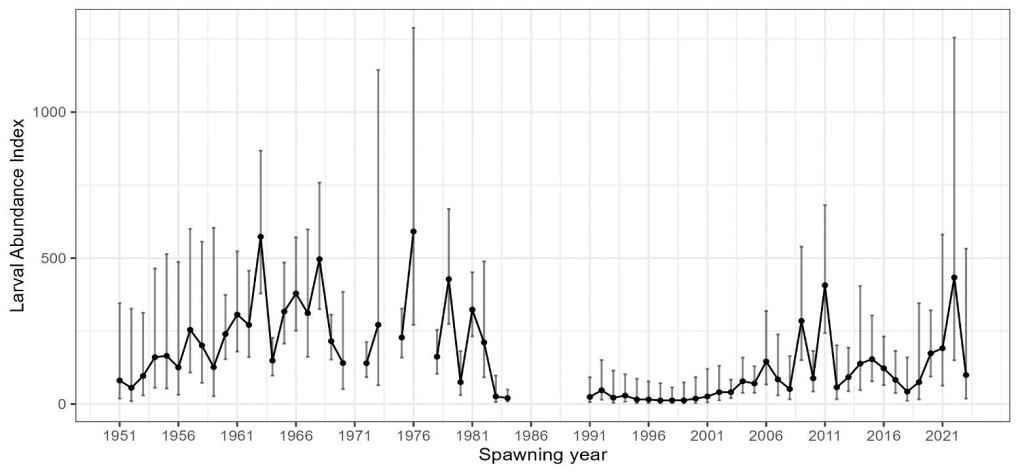
Model included Julian date (GAM smoother with k=4) to account for seasonality in spawning, a spatial random field, and IID spatiotemporal random fields. Figure is prediction grid summed to generate index.

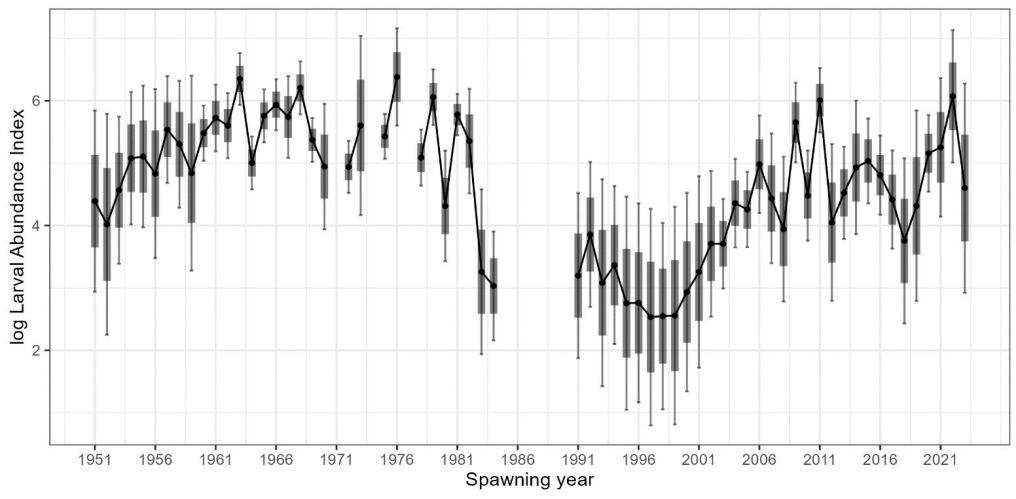


Right: Abundance index for larval chilipepper rockfish from the CalCOFI survey; Arithmetic (top) with 95% CI, and log scale (bottom) with +/- 1 SE (thick bars) and 95% CI (thin bars).

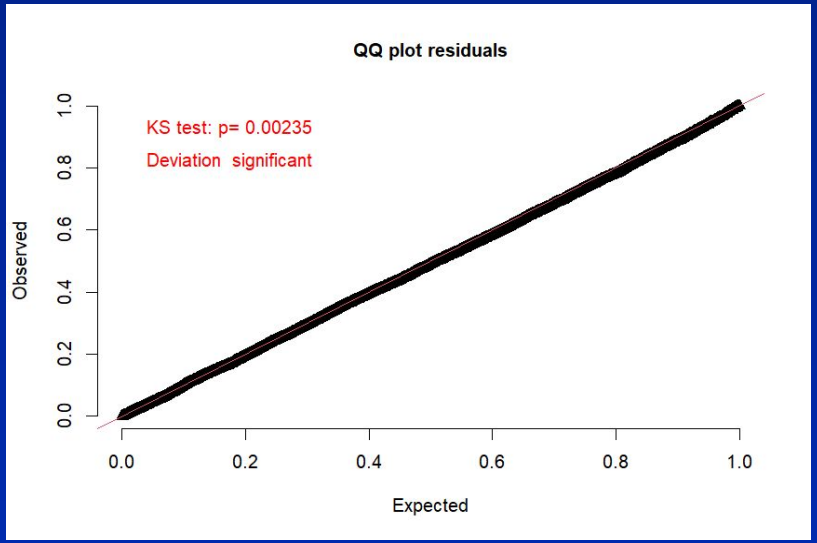
Bottom: Conditional effect of Julian date on larval chilipepper rockfish density from the CalCOFI survey. Points are partial randomized quantile residuals.

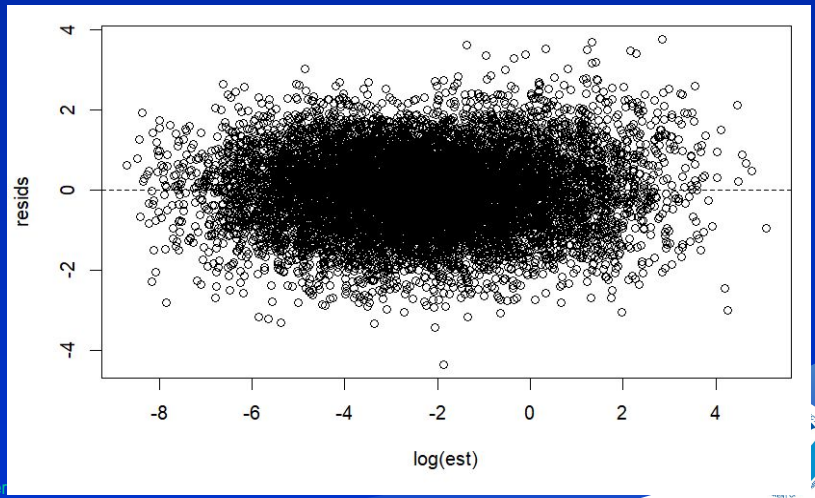




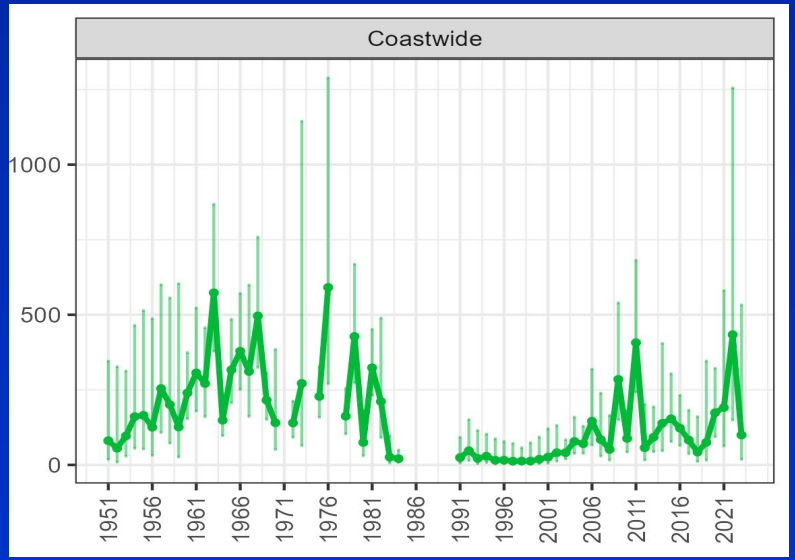


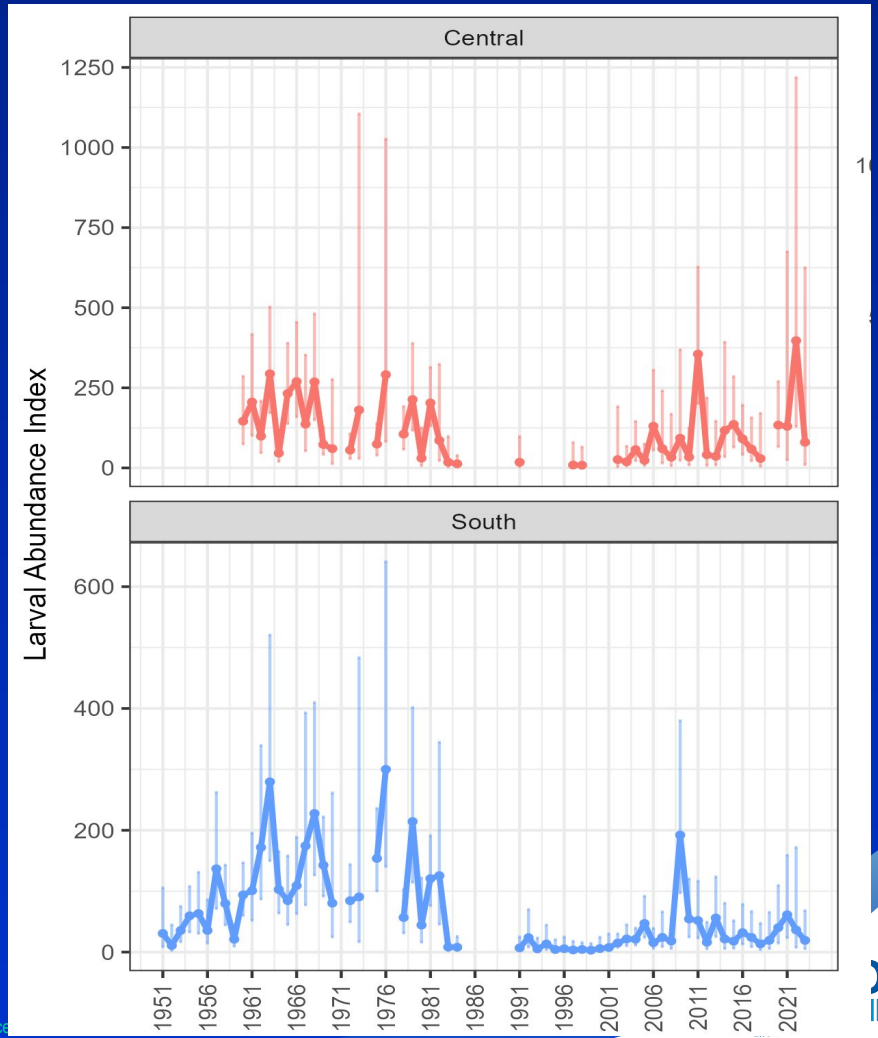
Diagnostic plots for the model of larval chilipepper rockfish from the CalCOFI survey. Q-Q plot for Dharma residuals based on 500 simulations (top), and plot of predicted values vs. residual (bottom). The KS normality test is often statistically significant when sample sizes are large, but there is not strong visual evidence of a meaningful deviation.





Regional models suggest that larval output may have been lower in southern area in the 1950s relative to the 1960s, and that southern area may also be relatively more depleted currently. For the base model, we used only years in which both southern and central data were available.





Rockfish Recruitment and Ecosystem Assessment Survey: 43 years



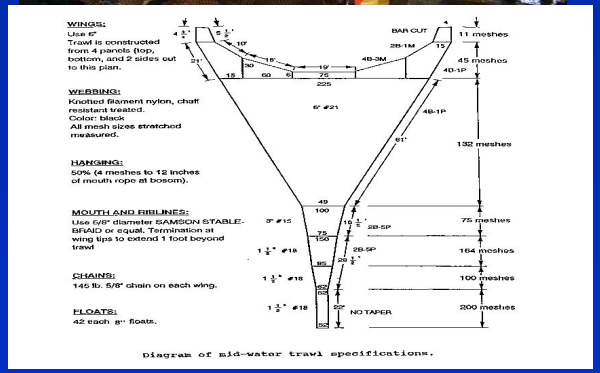
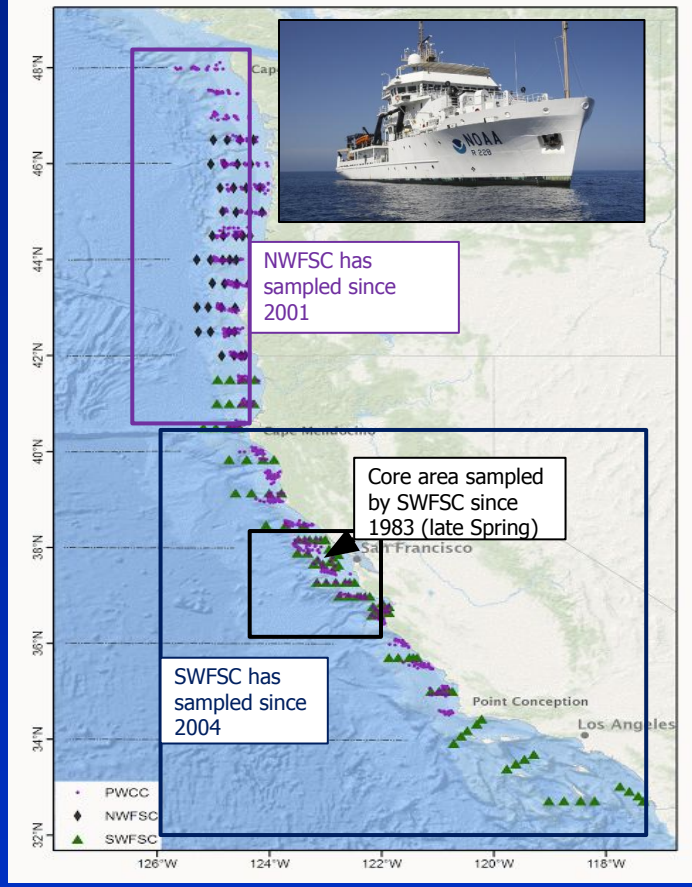
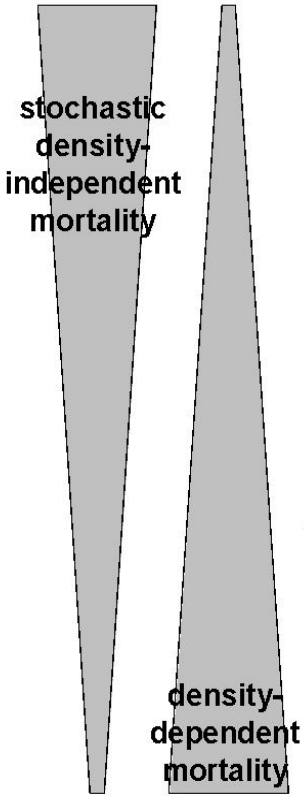


Diagram of mid-water trawl specifications.



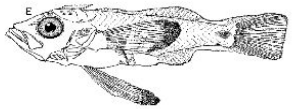


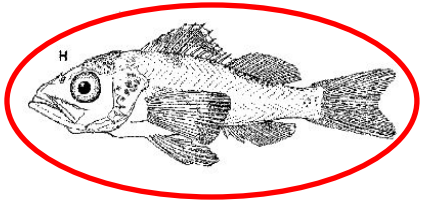
Survey began in 1983, coastwide data available most years from 2001 to present (several projects). Midwater trawling conducted at night using a modified Cobb midwater trawl. Catches sorted, measured at sea. Ralston et al. 2013, Field et al. 2021, Santora et al. 2021 for more background, methods.



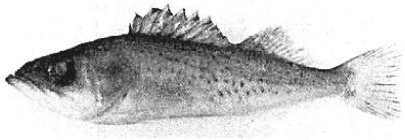


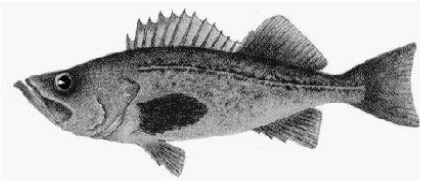
Larval abundance used as index of parental spawning output (cowcod, bocaccio, others)





Pelagic juveniles used as an Age 0 (recruitment) index (standardize to 100 days)



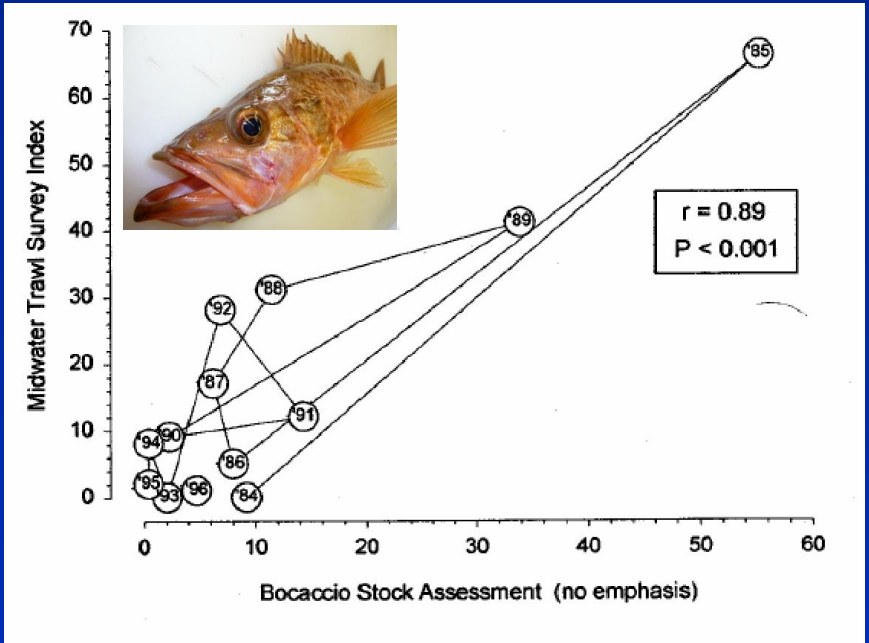


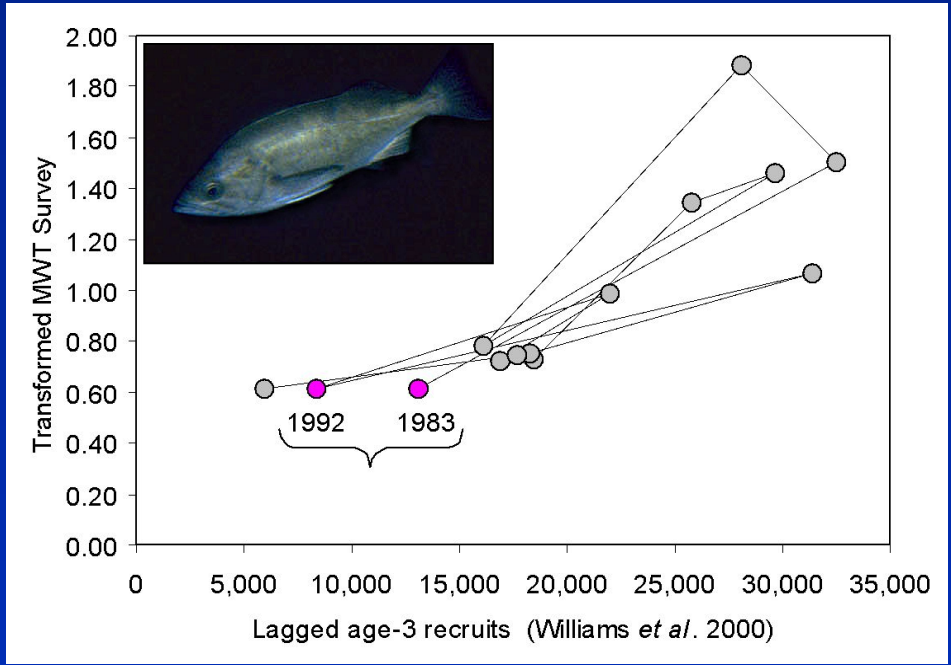
Fisheries and survey data age 1+, used to inform abundance trends, demographic structure and key population rates

In order to predict the presence or absence of strong year classes in rockfish stock assessments, our survey has provided pre-recruit (age 0) abundance indices for stock assessments of seven species (bocaccio, widow, canary, chilipepper, black, blue, shortbelly).

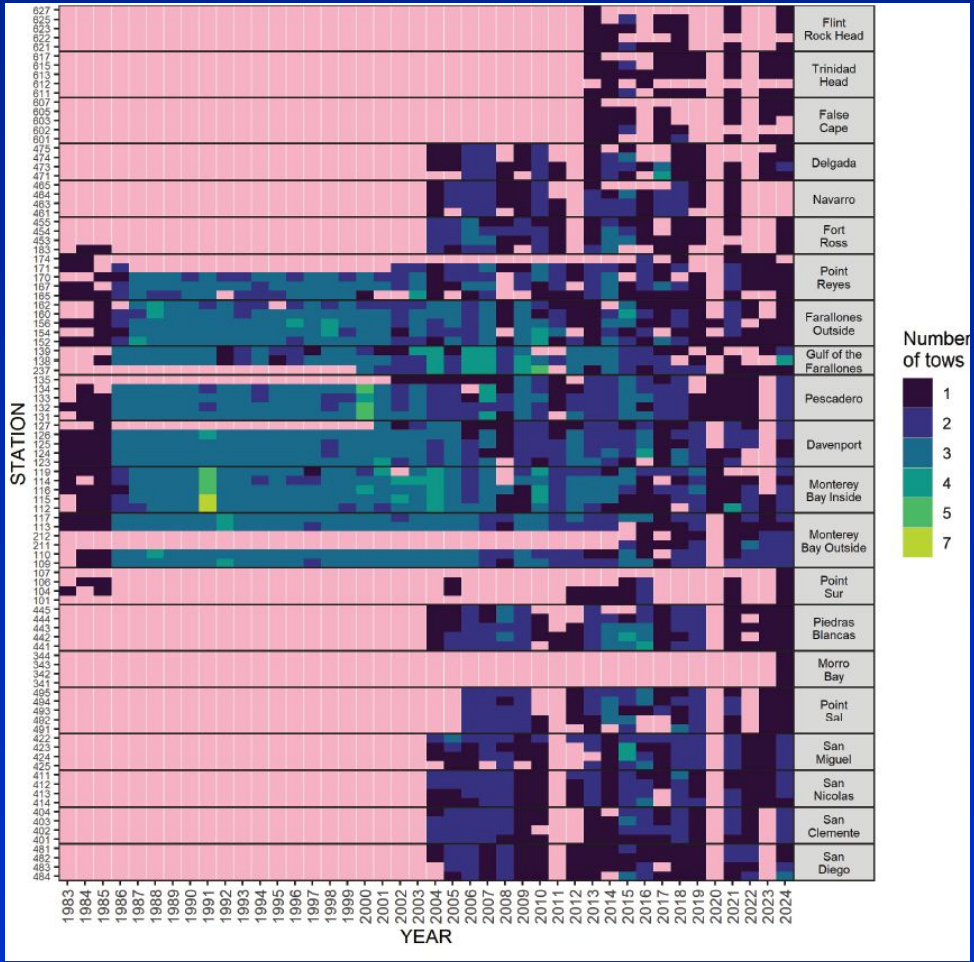
Figure from Field et al. 2010

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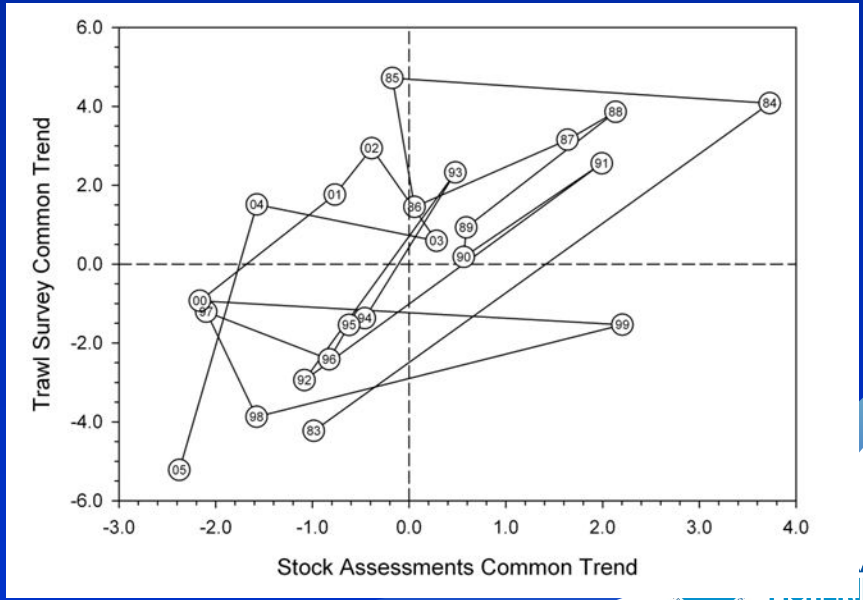




Used in a number of stock assessments from the 1990s to present. Prior to 1999, most of the fits between index and assessment recruitment estimates looked pretty good…



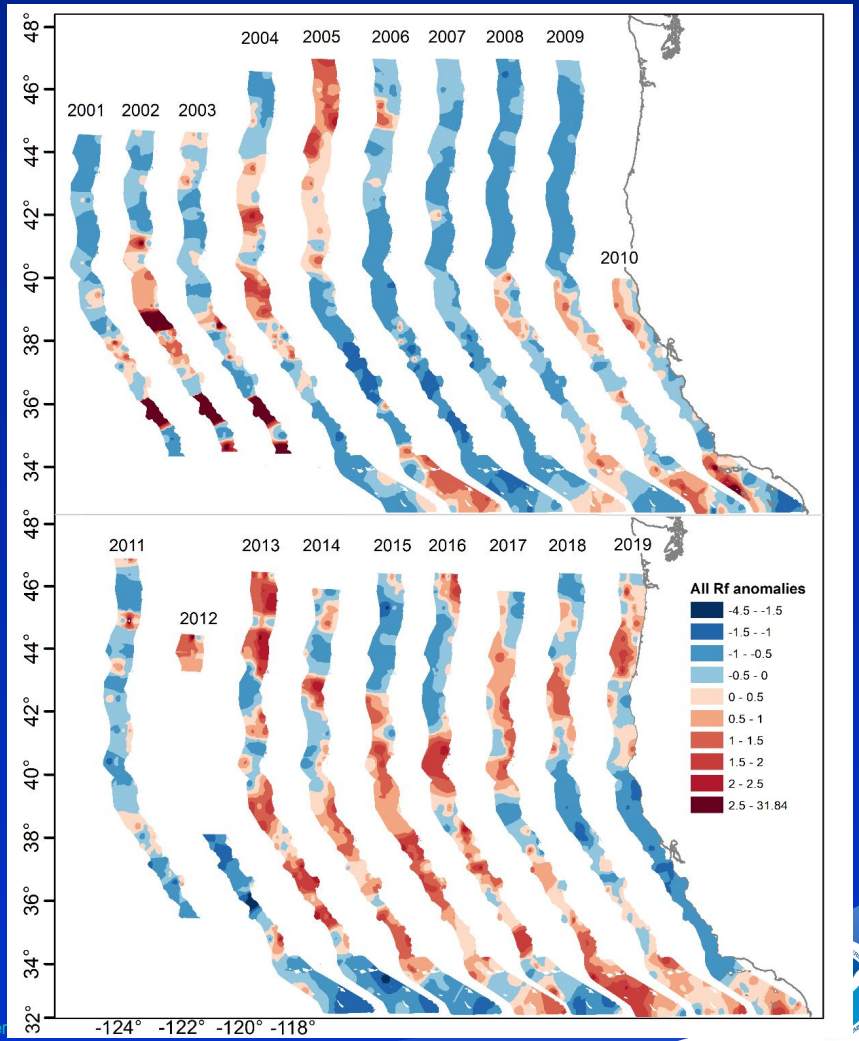
The failure to “see” the 1999 year class weakened the relationship between indices and assessment estimates of recruitment. This led to a decision to expand spatial scope of survey coastwide, and to use coastwide data in assessments until we knew a bit more about spatial variability (Ralston and Stewart 2012; Ralston et al. 2013).



- With coastwide data we have documented regional variability in pelagic YOY abundance.
- Signal robust over broad spatial scales, but can vary north and south of Cape Mendocino and Point Conception and (Field et al. 2021).
- Indices developed for assessments generally limited to coastwide period; from 2001 or 2004 period onward.
- We “standardize” the abundance to a common ontogenetic stage (100 days), based on the equation

$$N^*_{h,t} = N_{h,t} \exp[-\mathrm{M} \cdot (100 - \hat{t})]$$

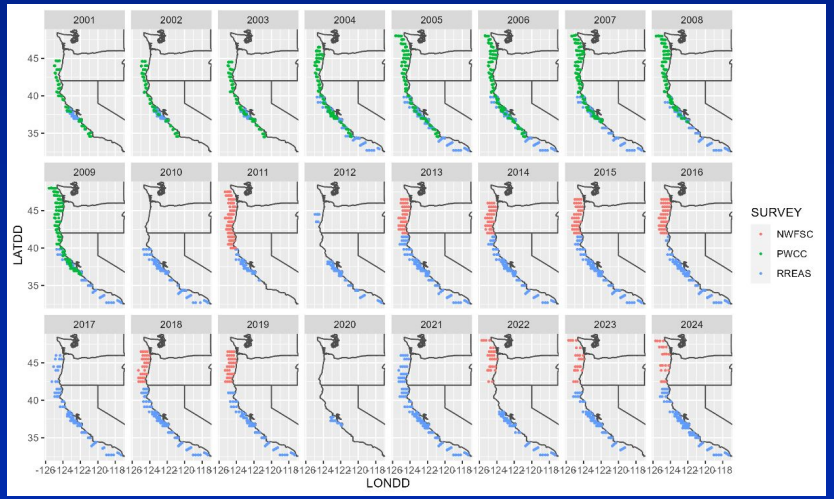
- Where h is haul, t is # days old, M is daily mortality rate (need daily age estimates, growth rate estimates). Within assessment, index relates to age 0



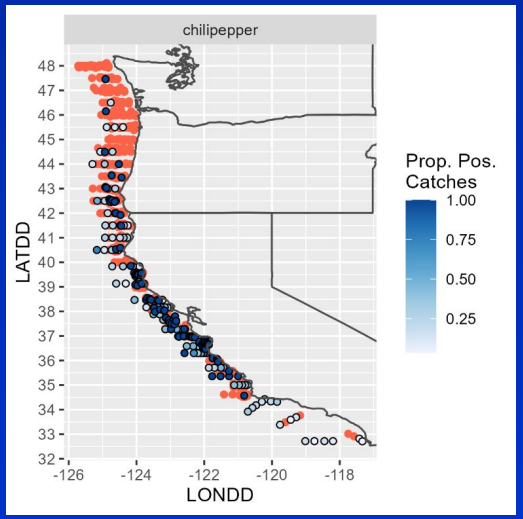
Similar to other indices, we modeled catch using a spatial GLM with sdmTMB (Anderson et al. 2022).

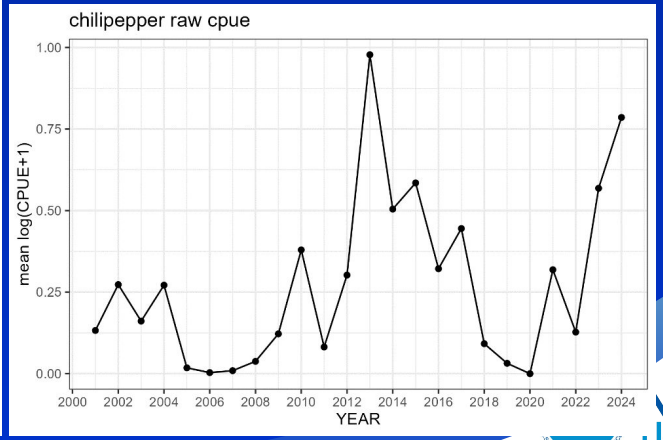
Standardized catch per tow was modeled as a function of fixed year effects along with Julian date (GAM smoother with k=4) to account for seasonality, a spatial random field, and IID spatiotemporal random fields.

2020 was excluded (covid 19, only 15 hauls). Catches generally greatest in central CA region.



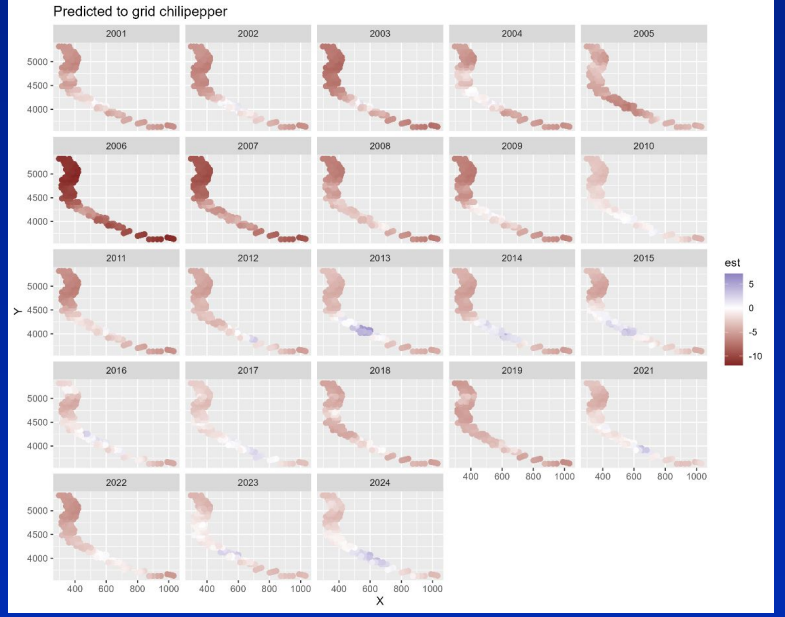


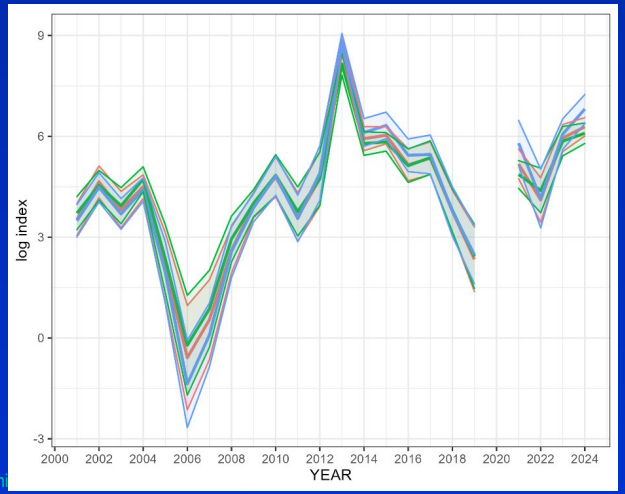




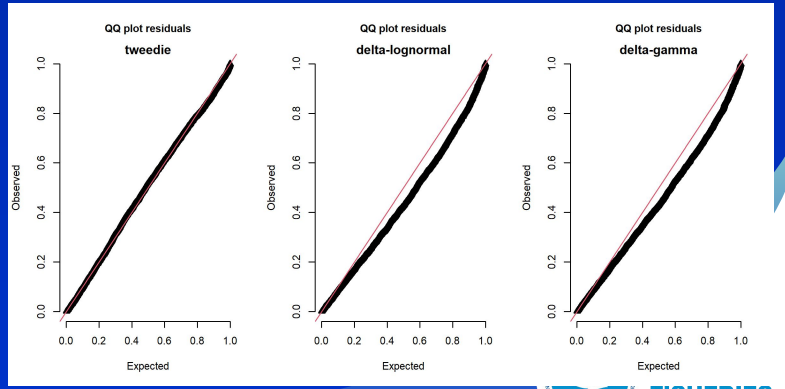
Explored 3 different error structures: tweedie, delta-lognormal, and delta-gamma. In all rockfish examined so far, dharma quantile residuals suggest that tweedie is the best, and best reproduced the observed proportion of zeros.

For the index, predictions from the model were made for all active stations within the geographic domain, for the mean Julian date, for each year, and summed to produce the index. Previous work has found that interpolating to a finer spatial grid has little impact on the resulting index.





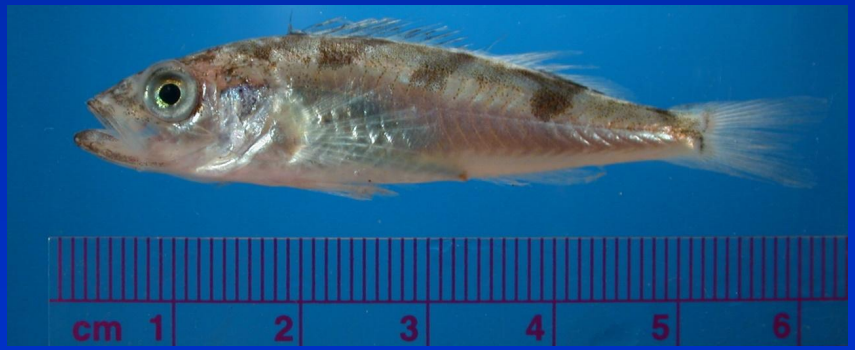
model
delta-gamma spatial-temporal chilipepper
delta-logn spatial-temporal chilipepper
tweedie spatial-temporal chilipepper

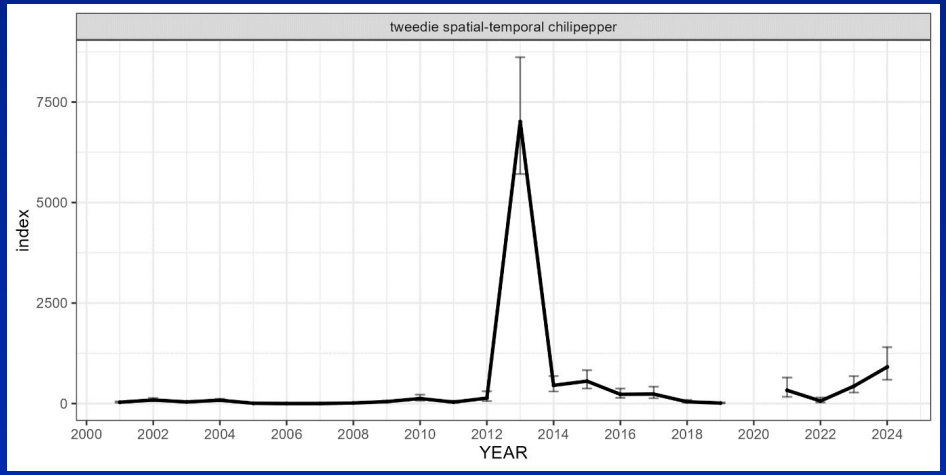


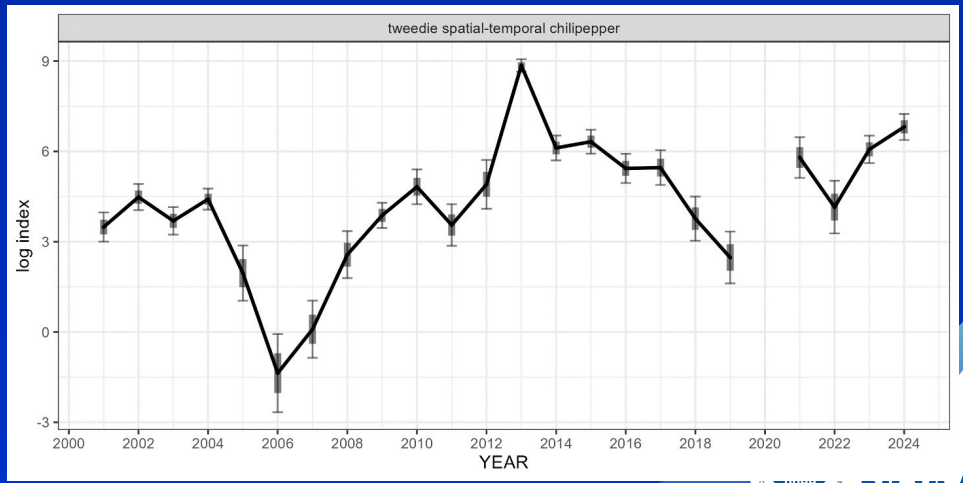
Resulting indices included in the model as an index of age 0 abundance (age 0 fish fully selected).

Index generally only informs most recent few years of recruitment, as age and length data provide more robust signal throughout most model years.

Results suggest strong 2010, 2013, 2015 year class, generally stronger recent year classes (2023, 2024)







Outline

1. Biology
   a. Stock structure
   b. Growth (length-at-age by sex, area, time; weight-length)
   c. Reproduction
   d. Natural mortality

2. Fisheries
   a. Commercial
      i. Recent (1981-present)
      ii. Historical
   b. Recreational
      i. Recent (1980-present)
      ii. Historical

3. **Data**
   a. Fishery-dependent
   b. Fishery-independent
   c. **Sources considered but not used**

NOAA FISHERIES

Data considered but not used in pre-STAR base models

- CDFG Onboard CPFV Observer index
  - Used in previous assessments; implied fits shown in output
  - >90% of chilipepper caught in <1% of drifts
  - Suggests that targeting was inconsistent for this species
- Commercial Trawl Logbook
  - Strong assumptions about species composition of “rockfish” catch and effective effort for chilipepper
  - Best available data at the time, but fishery-independent surveys provide higher-quality data
- NWFSC hook-and-line survey index; limited to So. CA Bight
  - Some age structures (~40/year) were aged to assist with analysis of spatial variation in growth
- Other sources may become useful with increasing catch

NOAA FISHERIES

Data considered but not used in pre-STAR base models

- SWFSC Rockfish Recruitment and Ecosystem Assessment Survey (RREAS)
- SWFSC SCUBA survey
- Partnership for Interdisciplinary Studies of Coastal Oceans (PISCO)
  - SCUBA survey
  - Recruitment Survey (SMURFs)
- MRFSS Dockside CPFV Index, 1980-1999
- NMFS Trawl Surveys (WCGBTS, Triennial)
- NWFSC Hook and Line Survey
- CDFW/MARE Remotely Operated Vehicle (ROV) survey