Agenda Item G.3
Attachment 1 (**Electronic Only**)
April 2025

https://doi.org/10.25923/z1xh-b932

NOAA Technical Memorandum NMFS

MARCH 2025

UPDATE ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2025 FOR U.S. MANAGEMENT IN 2025-2026

Caitlin Allen Akselrud[1], Alexander J. Jensen[1], Peter T. Kuriyama[1],
Kevin T. Hill[1], and Juan P. Zwolinski[2]

[1] NOAA Southwest Fisheries Science Center
Fisheries Resources Division
La Jolla, California

[2] University of California, Santa Cruz
Institute of Marine Sciences
affiliated with NOAA Southwest Fisheries Science Center

NOAA-TM-NMFS-SWFSC-719

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center

About the NOAA Technical Memorandum series

The National Oceanic and Atmospheric Administration (NOAA), organized in 1970, has evolved into an agency which establishes national policies and manages and conserves our oceanic, coastal, and atmospheric resources. An organizational element within NOAA, the Office of Fisheries is responsible for fisheries policy and the direction of the National Marine Fisheries Service (NMFS).

In addition to its formal publications, the NMFS uses the NOAA Technical Memorandum series to issue informal scientific and technical publications when complete formal review and editorial processing are not appropriate or feasible. Documents within this series, however, reflect sound professional work and may be referenced in the formal scientific and technical literature.

SWFSC Technical Memorandums are available online at the following websites:

SWFSC: https://swfsc-publications.fisheries.noaa.gov/

NOAA Repository: https://repository.library.noaa.gov/

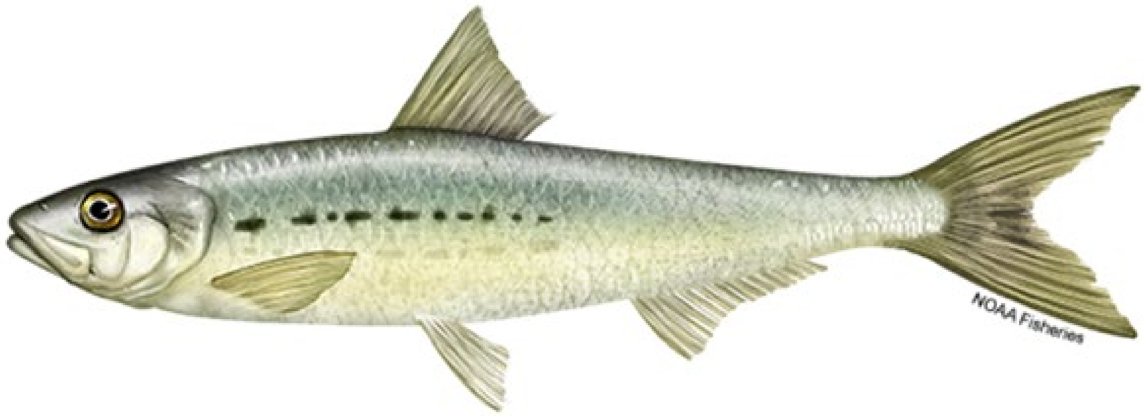
Accessibility information

NOAA Fisheries Southwest Fisheries Science Center (SWFSC) is committed to making our publications and supporting electronic documents accessible to individuals of all abilities. The complexity of some of SWFSC's publications, information, data, and products may make access difficult for some. If you encounter material in this document that you cannot access or use, please contact us so that we may assist you.
Phone: 858-546-7000

Recommended citation

Allen Akselrud, Caitlin, Alexander J. Jensen, Peter T. Kuriyama, Kevin T. Hill, and Juan P. Zwolinski. 2025. Update assessment of the Pacific sardine resource in 2025 for U.S. management in 2025-2026. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-719.
https://doi.org/10.25923/z1xh-b932

UPDATE ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2025 FOR U.S. MANAGEMENT IN 2025-2026



Caitlin Allen Akselrud[1], Alexander J. Jensen[1], Peter T. Kuriyama[1],
Kevin T. Hill[1], Juan P. Zwolinski[2]

[1] NOAA Southwest Fisheries Science Center
Fisheries Resources Division
La Jolla, California

[2] University of California, Santa Cruz
Institute of Marine Sciences
affiliated with NOAA Southwest Fisheries Science Center

Table of Contents

1. Executive Summary

This update assessment was conducted to inform U.S. fishery management for the cycle that begins July 1, 2025 and ends June 30, 2026, and updates the benchmark assessment conducted during 2024 (Kuriyama et al., 2024). It was produced per the Pacific Fishery Management Council's Coastal Pelagic Species Fishery Management Plan (PFMC CPS FMP; PFMC, 2024a), to provide scientific information as required by the Magnuson-Stevens Fishery Conservation and Management Act for federal fishery management (Public Law 94-265, and as amended in the Magnuson-Stevens Fishery Conservation and Management Reauthorization Act; Public Law 109-479).

1.1. Stock

This assessment focuses on the northern subpopulation of Pacific sardine (NSP) that ranges from northern Baja California, México to British Columbia, Canada and extends up to 300 nm offshore. The habitat model used to partition out northern subpopulation (NSP) sardine has been updated since the 2020 benchmark sardine assessment (Zwolinski and Demer 2023) and used in the 2024 benchmark assessment. Satellite oceanography data (Demer and Zwolinski 2014; Zwolinski and Demer 2019) were used in the updated habitat model to partition catch data from Ensenada (ENS) and southern California (SCA) ports to include landings and biological compositions attributed only to the northern subpopulation.

1.2. Catches

The assessment includes sardine landings (mt) from six major fishing regions: Ensenada, Mexico (ENS), southern California (SCA), central California (CCA), Oregon (OR), Washington (WA), and British Columbia, Canada (BC) (Figure ES.1). Landings for each port and for the NSP over the modeled years/seasons are given in Table ES.1. The updated habitat model has been applied to distinguish NSP in the catch data.

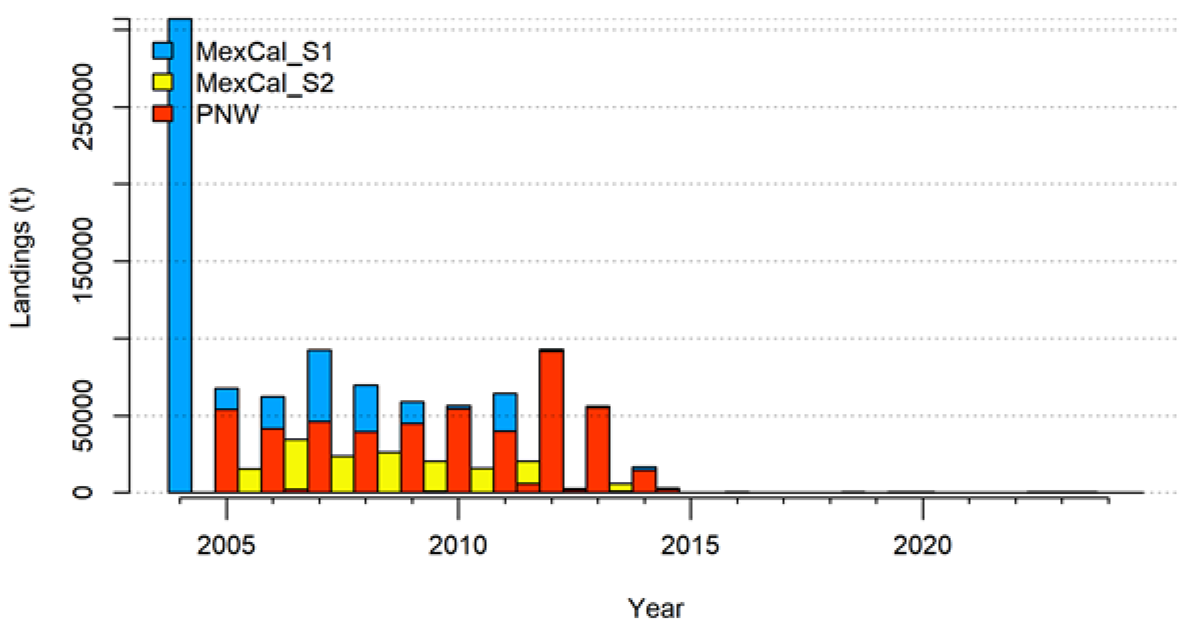


Figure ES.1. Catch by fleet and year.

Table ES.1. U.S. Pacific sardine harvest specifications and landings (mt) for the last ten year. U.S. harvest limits and closures are based on total catch, regardless of subpopulation source. *2024-25 management year landings are preliminary (through Dec. 31, 2024).

Mgmt. Year	OFL	ABC	HG or ACL	Tot. Landings	NSP Landings
2015-16	13,227	12,074	7,000	1,919	75
2016-17	23,085	19,236	8,000	1,885	602
2017-18	16,957	15,479	8,000	1,775	351
2018-19	11,324	9,436	7,000	2,278	525
2019-20	5,816	4,514	4,000	2,062	627
2020-21	5,525	4,288	4,000	2,276	657
2021-22	5,525	3,329	3,000	1,772	298
2022-23	5,506	4,274	3,800	1,620	565
2023-24	5,506	3,953	3,600	1,774	844
2024-25*	8,312	6,005	5,500	*772*	*267*

1.3. Data and Assessment

Commercial catch values were updated through Dec. 31, 2024, and biological sample data from California's Exempted Fishing Permit (EFP) fishery through June 30, 2024, were included. The EFP weights-at-age data were added to the state-space conditional weights-at-age model (Kuriyama et al., 2024). Survey biomass, age-composition, and weights-at-age were updated to include data from the 2024 core and nearshore surveys. The update assessment base model uses the same model parameterization as the 2024 benchmark assessment (described in Kuriyama et al., 2024; Stock Synthesis v.3.30.22). The stock-recruit bias-correction parameters were updated, recruitment deviations were updated to include 2024, and blocking for catchability and selectivity was extended. Catchability was 1 for 2024, and natural mortality was estimated at 0.53 yr^{-1}. The forecasted fishing mortality was also updated based on most recent catch and fishing mortality rates.

1.4. Stock Biomass and Recruitment

Estimated spawning stock biomass (ages 1+) for 2024 was 36,190 mt, which is less than the 45,376 mt projected in the 2024 benchmark (Kuriyama et al., 2024). Projected age 1+ biomass for 2025 is 30,158 mt (Table ES.2; Figure ES.2). Current recruitment continues to be low, as in recent years, although it is forecasted to increase in 2025 (Table ES.2; Figure ES.3)., though this is attributable to the parameterization of the stock-recruit curve, which is explored in Appendix A.

Table ES.2. Base model estimated age-1+ biomass (mt) and age-0 recruits (thousands).

Model year	Seas	1+ Biomass	Recruits	Model year	Seas	1+ Biomass	Recruits
2016	1	52,065	183,401	2021	1	145,641	610,498
2016	2	32,702	0	2021	2	54,255	0
2017	1	47,499	315,672	2022	1	64,580	389,308
2017	2	25,831	0	2022	2	53,826	0
2018	1	46,912	609,893	2023	1	62,214	209,191
2018	2	26,242	0	2023	2	57,007	0
2019	1	43,126	563,073	2024	1	36,190	289,283
2019	2	28,207	0	2024	2	50,418	0
2020	1	44,651	2,230,190	2025	1	30,158	1,391,300
2020	2	29,325	0	2025	2	42,224	0

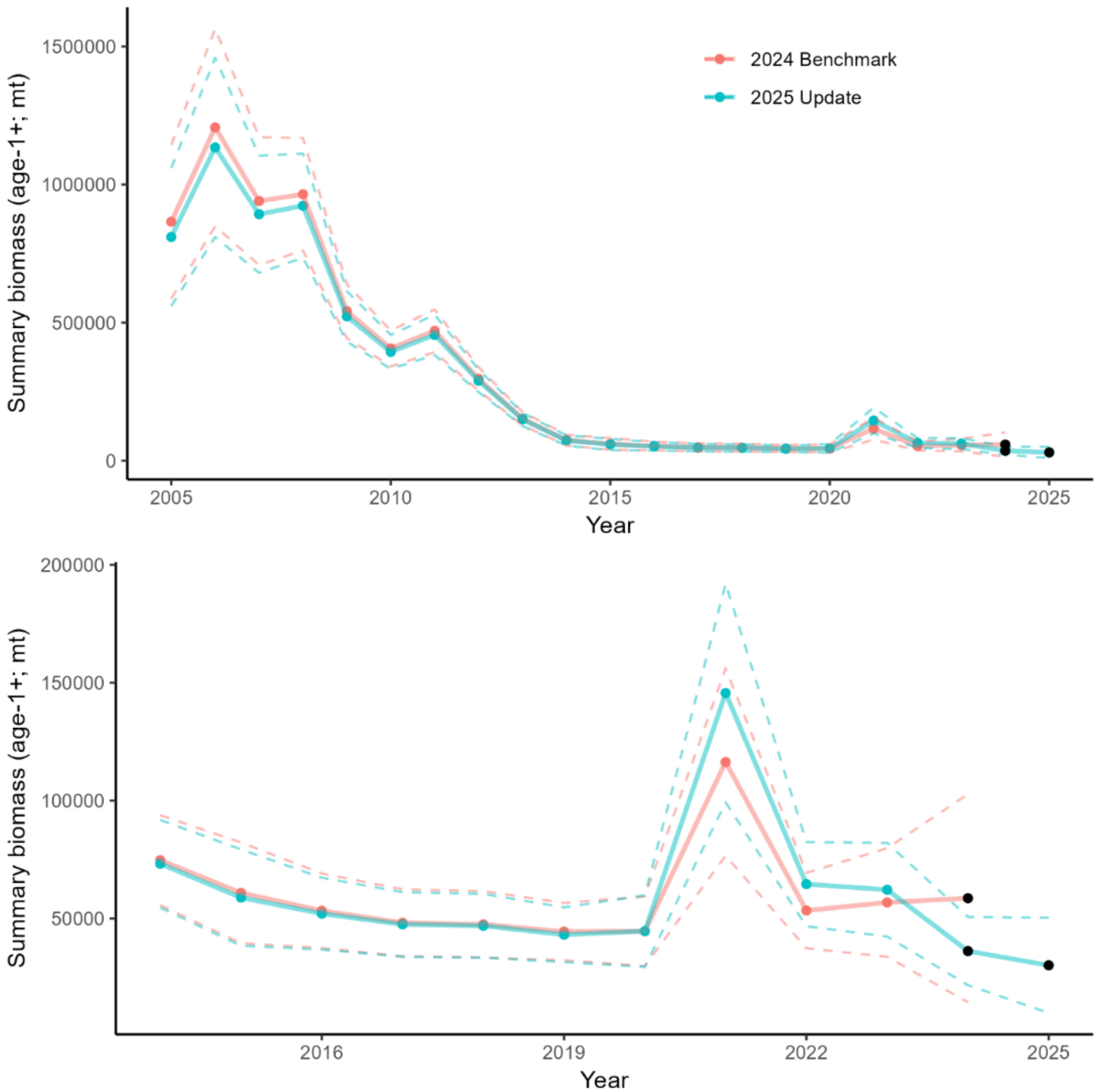


Figure ES.2. Time series of summary biomass (age-1+; mt) 2025 update assessment (blue). Dotted lines represent 95% confidence intervals. Black points indicate forecasted age-1+ biomass.

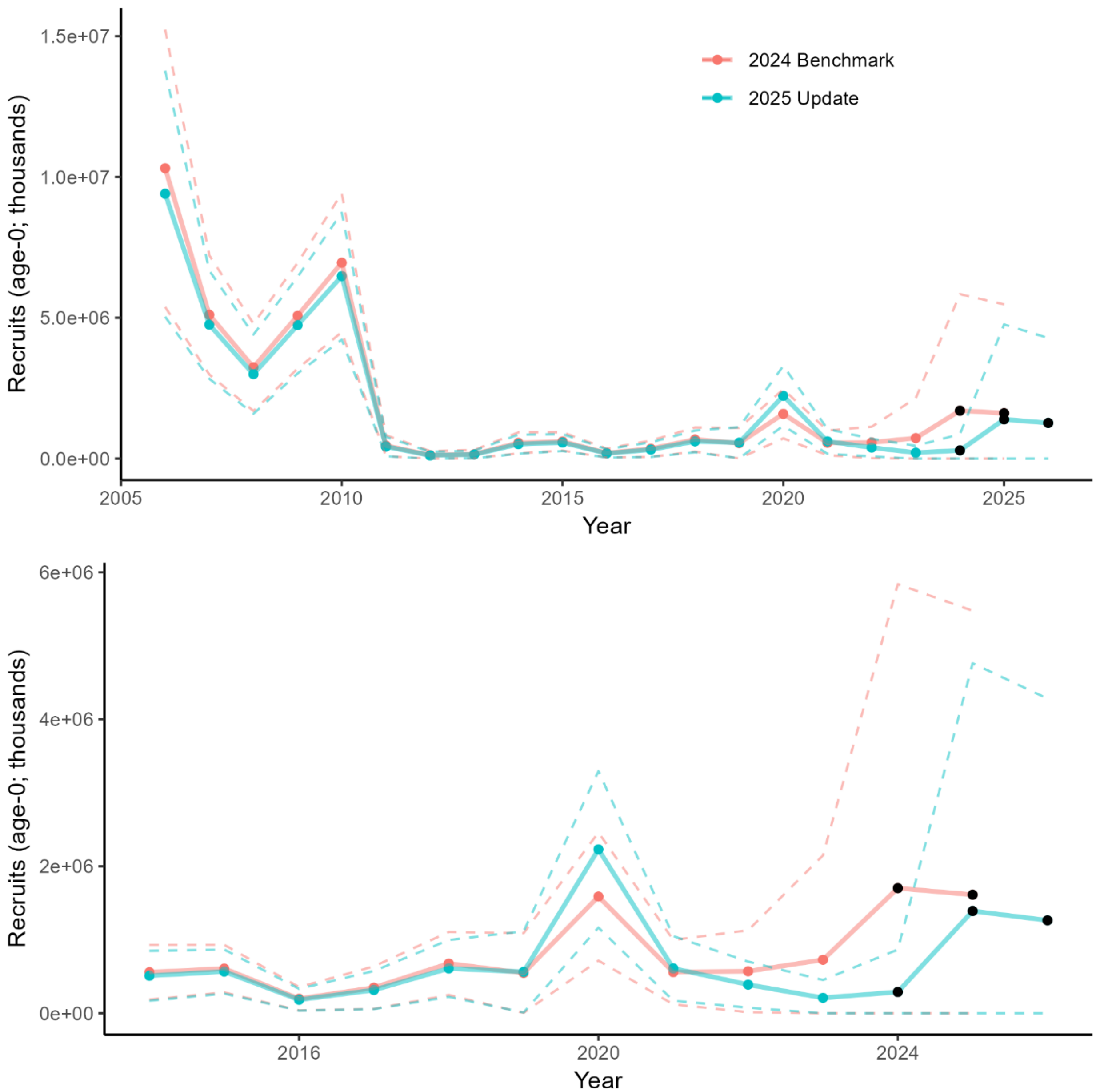


Figure ES.3. Time series of recruits entering the population (thousands of age-0 fish) for the 2025 update assessment (blue). Dotted lines represent 95% confidence intervals. Black points indicate values based on recruitment values from the stock-recruit relationship.

1.5. Exploitation Status

The U.S. and total exploitation rate was about 2% in 2024 (Table ES.3, Figure ES.4), and Mexico and Canada both had an annual exploitation rate of 0%.

Table ES.3. Annual exploitation rate (calendar year landings / July total biomass) of the NSP by country and calendar year.

Calendar Year	Mexico	USA	Canada	Total
2015	0	0.05	0	0.05
2016	0	0.01	0	0.01
2017	0	0.01	0	0.01
2018	0	0	0	0
2019	0	0.01	0	0.01
2020	0	0.01	0	0.01
2021	0	0	0	0
2022	0	0.01	0	0.01
2023	0	0.01	0	0.01
2024	0	0.02	0	0.02

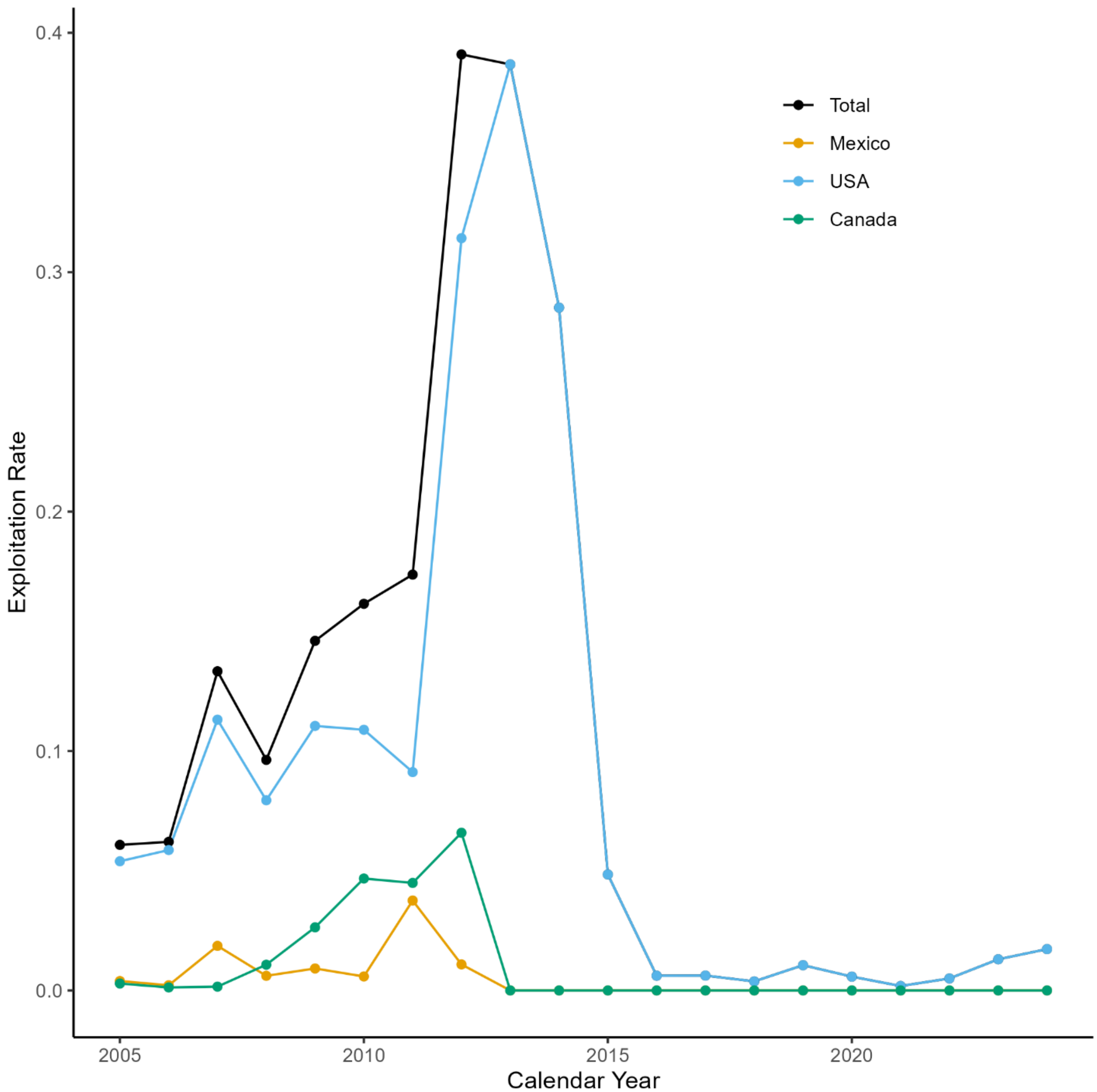


Figure ES.4. Annual exploitation rates (calendar year landings / July total biomass) for NSP in the base model. (Note that since Canada and Mexico exploitation rates are zero after 2013, the total exploitation rate is equal to the US exploitation rate.)

1.6. Ecosystem Considerations:

The CalCOFI sea surface temperature (SST) data were used to generate a mean SST of 15.69 °C for 2024, using methods consistent with the 2024 benchmark assessment (Kuriyama et al., 2024).

About 99% of the sardine biomass was observed in the nearshore component of the survey in Central California in 2024. This high biomass area overlapped with the highest observed proportions of Japanese sardine detected in the survey data. Both factors underscore the importance of continuing nearshore survey efforts and genetic sampling of sardine coastwide. While sardine genetics are not currently used in this assessment, the presence and distribution of Japanese sardine mixed with Pacific sardine is informational.

1.7. Reference Points

The harvest guidelines based on a CalCOFI sea-surface temperature (SST) of 15.69 (average for 2022-2024), resulting in an E_{MSY} of 0.1771, and 2025 forecast age 1+ biomass of 30,158 mt (Table ES.4). The stock is below the 150,000 mt management threshold. For the current base model, the OFL for the 2025-2026 fishing year is 4,645 mt, and the harvest guideline is 0 mt.

Table ES.4. Pacific sardine harvest control rules for fishing year 2025-2026.

Harvest Control Rule Formulas									
OFL = BIOMASS * E_{MSY} * DISTRIBUTION; where E_{MSY} is bounded 0.00 to 0.25									
$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION; where E_{MSY} is bounded 0.00 to 0.25									
HG = (BIOMASS – CUTOFF) * FRACTION * DISTRIBUTION; where FRACTION is E_{MSY} bounded 0.05 to 0.20									
Harvest Guideline Parameters									
BIOMASS (ages 1+, mt)	30,158								
P-star	0.45	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05
ABC $Buffer_{Tier\ 1}$	0.9230	0.8508	0.7822	0.7158	0.6505	0.5847	0.5164	0.4417	0.3504
ABC $Buffer_{Tier\ 2}$	0.8519	0.7239	0.6118	0.5124	0.4231	0.3419	0.2667	0.1951	0.1228
ABC $Buffer_{Tier\ 3}$	0.7778	0.6025	0.4627	0.3504	0.2595	0.1858	0.1258	0.0771	0.0373
CalCOFI SST (2022-2024)	15.69								
E_{MSY}	0.1771								
FRACTION	0.1771								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
Harvest Control Rule Values									
OFL =	**4,645**								
$ABC_{Tier\ 1}$ =	4,288	3,952	3,634	3,325	3,022	2,716	2,399	2,052	1,628
$ABC_{Tier\ 2}$ =	3,957	3,363	2,842	2,380	1,965	1,588	1,239	906	570
$ABC_{Tier\ 3}$ =	3,613	2,799	2,149	1,628	1,205	863	584	358	173
HG =	**0**								

1.8. Management Performance

US landings in recent years have remained below the annual catch limits (or annual catch targets, when applicable; Table ES.5). The 2024-2025 annual catch target for Pacific sardine was 5,500 mt for Pacific sardine (Table ES.5). Landings-to-date of the northern subpopulation in the U.S. were 267 mt for 2024-2025, less than 5% of the annual catch limit, with no NSP landings in Canada or Mexico.

Table ES.5. U.S. Pacific sardine harvest specifications and landings (mt) since the onset of federal management. U.S. harvest limits and closures are based on total catch, regardless of subpopulation source. *2024-25 management year landings are preliminary (through Dec. 31, 2024).

Mgmt. Year	**OFL**	**ABC**	**HG or ACL**	**Tot. Landings**	**NSP Landings**
2000	-	-	186,791	73,766	67,691
2001	-	-	134,737	79,746	57,019
2002	-	-	118,442	103,134	82,529
2003	-	-	110,908	77,728	65,692
2004	-	-	122,747	96,513	78,430
2005	-	-	136,179	95,786	73,104
2006	-	-	118,937	107,471	86,952
2007	-	-	152,564	125,145	104,716
2008	-	-	89,093	83,797	74,424
2009	-	-	66,932	72,847	61,220
2010	-	-	72,039	60,862	49,751
2011	92,767	84,681	50,526	55,017	43,725
2012	154,781	141,289	109,409	86,230	76,410
2013	103,284	94,281	66,495	69,833	63,832
2014 (1)	59,214	54,052	6,966	6,806	6,121
2014-15	39,210	35,792	23,293	23,113	19,969
2015-16	13,227	12,074	7,000	1,919	75
2016-17	23,085	19,236	8,000	1,885	602
2017-18	16,957	15,479	8,000	1,775	351
2018-19	11,324	9,436	7,000	2,278	525
2019-20	5,816	4,514	4,000	2,062	627
2020-21	5,525	4,288	4,000	2,276	657
2021-22	5,525	3,329	3,000	1,772	298
2022-23	5,506	4,274	3,800	1,620	565
2023-24	5,506	3,953	3,600	1,774	844
2024-25*	8,312	6,005	5,500	*772*	*267*

1.9. *Unresolved Problems and Major uncertainties*

The concentration of sardine biomass around a relatively small area in nearshore Central California and near absence in the core area shows a continued deviation from historical patterns of distribution, as noted in the 2024 benchmark assessment (Kuriyama et al., 2024), and warrants close monitoring over the next few years leading up to the 2027 benchmark. As a result of these two factors, ~99% of sardine biomass is represented by biological samples from two strata in nearshore California. These samples result in a lower weights-at-age than seen in previous years or in more northern samples this year, and the age classes from these samples are composed of individuals ranging from 2 to 5 years old with a mode at 4. The STAT's concerns about including these data in the update assessment are explored in Appendix A. In addition, the relatively high proportion of Japanese sardine overlapping with this singular high-biomass area should continue to be monitored.

1.9.1. *Scientific Uncertainty*

Scientific uncertainty in the base model is based on asymptotic standard errors associated with summary biomass (age-1+) estimates derived in the model relative to the default sigma when calculating ABCs from OFLs. The base model summary biomass was forecasted to be 30,158 mt, with a SD of 10,298 in July 2025. The CV is 0.34.

1.9.2. *Research and data needs*

The alternative models in Appendix A highlight a source of uncertainty around the stock-recruit relationship for Pacific sardine. The STAT recommends exploring the use of the stock-recruit regime parameter for Pacific sardine in the 2027 benchmark assessment, to better characterize high and low recruitment phases for Pacific sardine.

2. Introduction

The northern subpopulation of Pacific sardine (*Sardinops sagax*) (NSP) is assessed annually in support of the Pacific Fishery Management Council's process of specifying annual catch levels for the U.S. fishery (PFMC, 2024b). The following update assessment was conducted to provide a biomass estimate for setting harvest specifications for the 2025-2026 fishing year. This model contains updated fishery data through model year-semester 2024-1 (July-December of calendar year 2024) and the 2024 survey data. Observations from the acoustic-trawl survey indicated continued low biomass levels in the core survey area, and ~99% of the observed biomass occurred in the nearshore area. Based on the habitat model, no catch in Ensenada was apportioned to the NSP for any month of calendar year 2024. Any catch that occurred between San Pedro, California and the southern US border during January-April 2024 was attributed to the NSP, based on the habitat model results. Recent management performance is shown in Table 1.

Table 1. U.S. Pacific sardine harvest specifications and landings (mt) since the onset of federal management. U.S. harvest limits and closures are based on total catch, regardless of subpopulation source. *2024-25 management year landings are preliminary (through Dec. 31, 2024).

Mgmt. Year	OFL	ABC	HG or ACL	Tot. Landings	NSP Landings
2000	-	-	186,791	73,766	67,691
2001	-	-	134,737	79,746	57,019
2002	-	-	118,442	103,134	82,529
2003	-	-	110,908	77,728	65,692
2004	-	-	122,747	96,513	78,430
2005	-	-	136,179	95,786	73,104
2006	-	-	118,937	107,471	86,952
2007	-	-	152,564	125,145	104,716
2008	-	-	89,093	83,797	74,424
2009	-	-	66,932	72,847	61,220
2010	-	-	72,039	60,862	49,751
2011	92,767	84,681	50,526	55,017	43,725
2012	154,781	141,289	109,409	86,230	76,410
2013	103,284	94,281	66,495	69,833	63,832
2014 (1)	59,214	54,052	6,966	6,806	6,121
2014-15	39,210	35,792	23,293	23,113	19,969
2015-16	13,227	12,074	7,000	1,919	75
2016-17	23,085	19,236	8,000	1,885	602
2017-18	16,957	15,479	8,000	1,775	351
2018-19	11,324	9,436	7,000	2,278	525
2019-20	5,816	4,514	4,000	2,062	627
2020-21	5,525	4,288	4,000	2,276	657
2021-22	5,525	3,329	3,000	1,772	298
2022-23	5,506	4,274	3,800	1,620	565
2023-24	5,506	3,953	3,600	1,774	844
2024-25*	8,312	6,005	5,500	*772*	*267*

3. Data

3.1. Fishery-Dependent Data

Catch values were updated through model year-semester 2024-1 (i.e., through Dec. 31, 2024 from the PacFIN database) and historical catch values were reviewed and validated by State representatives from California, Oregon, and Washington (Tables 2-5; Figures 1-2). Age-composition and weights-at-age (WAA) data were updated from the California EFP fishery for model year 2023 for the MexCal S2 fishery and minor corrections to the MexCal S1 fishery. There were 4 independent sample from the EFP fishery that contributed to the 2023-1 MexCal S2 fishery. The fishery weights-at-age were estimated for this 2025 update assessment using conditional variance weights-at-age for the fishery data consistent with the methods applied in the 2024 benchmark assessment (Kuriyama et al. 2024) and described in Cheng et al. (2023). Results from all model years were updated for the assessment weights-at-age, though there were only new values added to the MexCal S2 fishery for model year-semester 2023-2 and minor corrections to the MexCal S1 fishery data (*see* Appendix B, Tables B.1-4). The methods by Cheng et al. (2023) allow for the simultaneous estimation of autocorrelation for time, age, and cohort. The STAT applied AIC model selection to choose a correlation structure for each fleet independently, as was done for the 2024 benchmark assessment, and the same model configurations were selected for each fleet (Tables B.1-3). Based on the AIC values:

- The MexCal S1 (Fleet 1) used year and age correlation parameters (Table B.1). The 2024 benchmark also used year and age correlation parameters, though this final configuration was mis-reported in the 2024 benchmark report.
- The MexCal S2 (Fleet 2) used year and cohort correlation parameters (Table B.2). This same model was selected in the benchmark.
- The PNW (Fleet 3) used year and age correlation parameters (Table B.3). This same model was selected in the benchmark.

The new weights-at-age matrices for each fleet were compared with the 2024 benchmark values (Appendix Table B.4), and the updated model output from all years and fleets was used.

Table 2. Pacific sardine landings (mt) for major fishing regions off northern Baja California (ENS – Ensenada, Mexico), the United States (SCA – Southern California, CCA – Central California, OR – Oregon, WA – Washington), and British Columbia (BC – Canada). ENS and SCA landings are presented as totals and northern subpopulation (NSP) portions. Y-S stands for year-semester for calendar and model time periods.

Calendar Y-S	Model Y-S	ENS Total	ENS NSP	SCA Total	SCA NSP	CCA	OR	WA	BC
2005-2	2005-1	38,000	4,397	16,615	1,581	7,825	44,418	6,395	3,231
2006-1	2005-2	17,601	2,710	18,290	10,643	2,033	102	0	0
2006-2	2006-1	39,636	0	18,556	5,016	15,710	35,565	4,364	1,575
2007-1	2006-2	13,981	5,800	27,546	20,567	6,013	2102	0	0
2007-2	2007-1	22,866	11,928	22,047	5,531	28,769	40,041	4,662	1,522
2008-1	2007-2	23,488	0	25,099	21,186	2,515	0	0	0
2008-2	2008-1	43,378	5,930	8,980	124	24,196	22,949	6,032	10,425

2009-1	2008-2	25,783	5,339	10,167	9,650	11,080	0	0	0
2009-2	2009-1	30,128	0	5,214	109	13,936	21,481	8,009	15,334
2010-1	2009-2	12,989	2,781	20,334	13,812	2,909	437	0	422
2010-2	2010-1	43,832	0	11,261	384	1,404	20,415	12,389	21,801
2011-1	2010-2	18,514	0	13,192	12,959	2,720	0	0	0
2011-2	2011-1	51,823	17,330	6,499	0	7,359	11,023	8,009	20,719
2012-1	2011-2	10,534	3,166	12,649	7,856	3,673	2,874	2,981	0
2012-2	2012-1	48,535	0	8,621	930	598	39,792	32,758	19,172
2013-1	2012-2	13,609	0	3,102	973	84	149	1,423	0
2013-2	2013-1	37,804	0	4,997	0	811	26,139	29,064	0
2014-1	2013-2	12,930	0	1,495	491	4,403	0	908	0
2014-2	2014-1	77,466	0	1,601	0	1,831	7,788	6,876	0
2015-1	2014-2	16,497	0	1,543	0	728	2,131	31	0
2015-2	2015-1	20,972	0	1,421	0	6	0	66	0
2016-1	2015-2	23,537	0	423	0	1	1	0	0
2016-2	2016-1	42,532	0	964	49	234	3	85	0
2017-1	2016-2	30,496	0	513	145	0	0	0	0
2017-2	2017-1	99,967	0	1,205	0	170	1	0	0
2018-1	2017-2	25,721	0	395	177	0	2	0	0
2018-2	2018-1	38,049	0	1,424	0	35	7	2	0
2019-1	2018-2	30,119	0	750	421	58	4	0	0
2019-2	2019-1	64,295	0	870	49	174	9	1	0
2020-1	2019-2	74,817	0	681	67	328	0	0	0
2020-2	2020-1	74,687	0	1,204	0	429	0	0	0
2021-1	2020-2	48,988	0	603	187	37	3	0	0
2021-2	2021-1	74,710	0	1,093	90	3	9	3	0
2022-1	2021-2	73,385	0	663	192	2	0	0	0
2022-2	2022-1	79,533	0	988	52	116	7	2	0
2023-1	2022-2	39,810	0	493	374	14	0	0	0
2023-2	2023-1	96,556	0	1,053	292	152	1	0	0
2024-1	2023-2	114,368	0	493	324	75	0	0	0
2024-2	2024-1	43,829	0	762	257	10	0	0	0

Table 3. Comparison of Pacific sardine landings (mt) for major fishing regions off northern Baja California (Ensenada, Mexico), the United States, and British Columbia (Canada) for calendar years 2023 and 2024 between this update assessment and the 2024 benchmark. ENS and SCA landings are presented as totals and northern subpopulation (NSP) portions. Y-S stands for year-semester for calendar and model values. Estimates in parentheses represent values reported in Kuriyama et al. (2024), if different than the values used for the update assessment.

Calendar Y-S	Model Y-S	ENS Total	ENS NSP	SCA Total	SCA NSP	CCA	OR	WA	BC
2023-1	2022-2	39,810	0	493	374	14	0	0	0
		(46,179)			(326)	(13)			
2023-2	2023-1	96,556	0	1,053	292	152	1	0	0
		(106,035)		(1,052)	(0)				
2024-1	2023-2	114,368	0	493	324	75	0	0	0
2024-2	2024-1	43,829	0	762	257	10	0	0	0

Table 4. Pacific sardine NSP landings (mt) by year-semester and fleet for the 2025 update base model.

Calendar Y-S	Model Y-S	MexCal S1	MexCal S2	PNW
2005-2	2005-1	13,803	0	54,044
2006-1	2005-2	0	15,386	102
2006-2	2006-1	20,726	0	41,504
2007-1	2006-2	0	32,381	2,102
2007-2	2007-1	46,228	0	46,225
2008-1	2007-2	0	23,701	0
2008-2	2008-1	30,249	0	39,406
2009-1	2008-2	0	26,069	0
2009-2	2009-1	14,045	0	44,824
2010-1	2009-2	0	19,502	859
2010-2	2010-1	1,787	0	54,605
2011-1	2010-2	0	15,679	0
2011-2	2011-1	24,689	0	39,751
2012-1	2011-2	0	14,694	5,855
2012-2	2012-1	1,528	0	91,722
2013-1	2012-2	0	1,057	1,572
2013-2	2013-1	811	0	55,203
2014-1	2013-2	0	4,894	908
2014-2	2014-1	1,831	0	14,664
2015-1	2014-2	0	728	2,162
2015-2	2015-1	6	0	66
2016-1	2015-2	0	1	1
2016-2	2016-1	284	0	88
2017-1	2016-2	0	145	0
2017-2	2017-1	170	0	1
2018-1	2017-2	0	177	2
2018-2	2018-1	35	0	9
2019-1	2018-2	0	479	4
2019-2	2019-1	224	0	10
2020-1	2019-2	0	395	0
2020-2	2020-1	429	0	0
2021-1	2020-2	0	224	3
2021-2	2021-1	93	0	12
2022-1	2021-2	0	193	0
2022-2	2022-1	168	0	9
2023-1	2022-2	0	387	0
2023-2	2023-1	445	0	1
2024-1	2023-2	0	399	0
2024-2	2024-1	267	0	0

Table 5. Comparison of Pacific sardine NSP landings (mt) by year-semester and fleet for calendar years 2023 and 2024 between this update assessment and the 2024 benchmark. Estimates in parentheses represent values reported in the previous benchmark, if different than the values used for the update assessment.

Calendar Y-S	Model Y-S	MexCal S1	MexCal S2	PNW
2023-1	2022-2	0	387 (340)	0
2023-2	2023-1	445 (152)	0	1
2024-1	2023-2	0	399 (0)	0
2024-2	2024-1	267	0	0

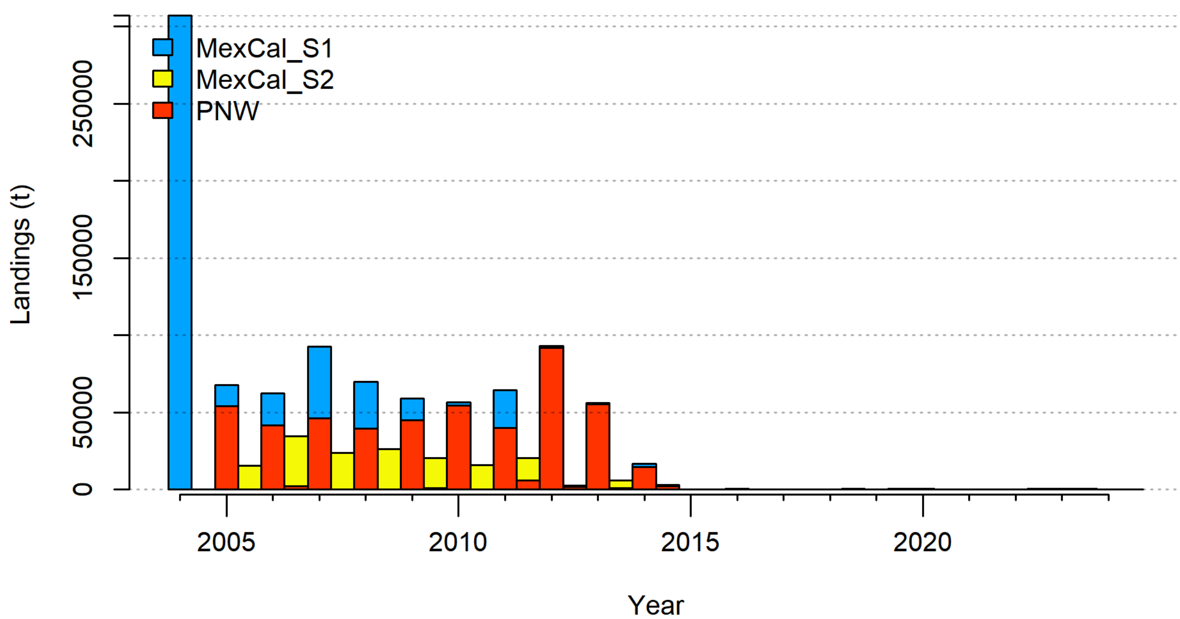


Figure 1. Catch by fleet and year.

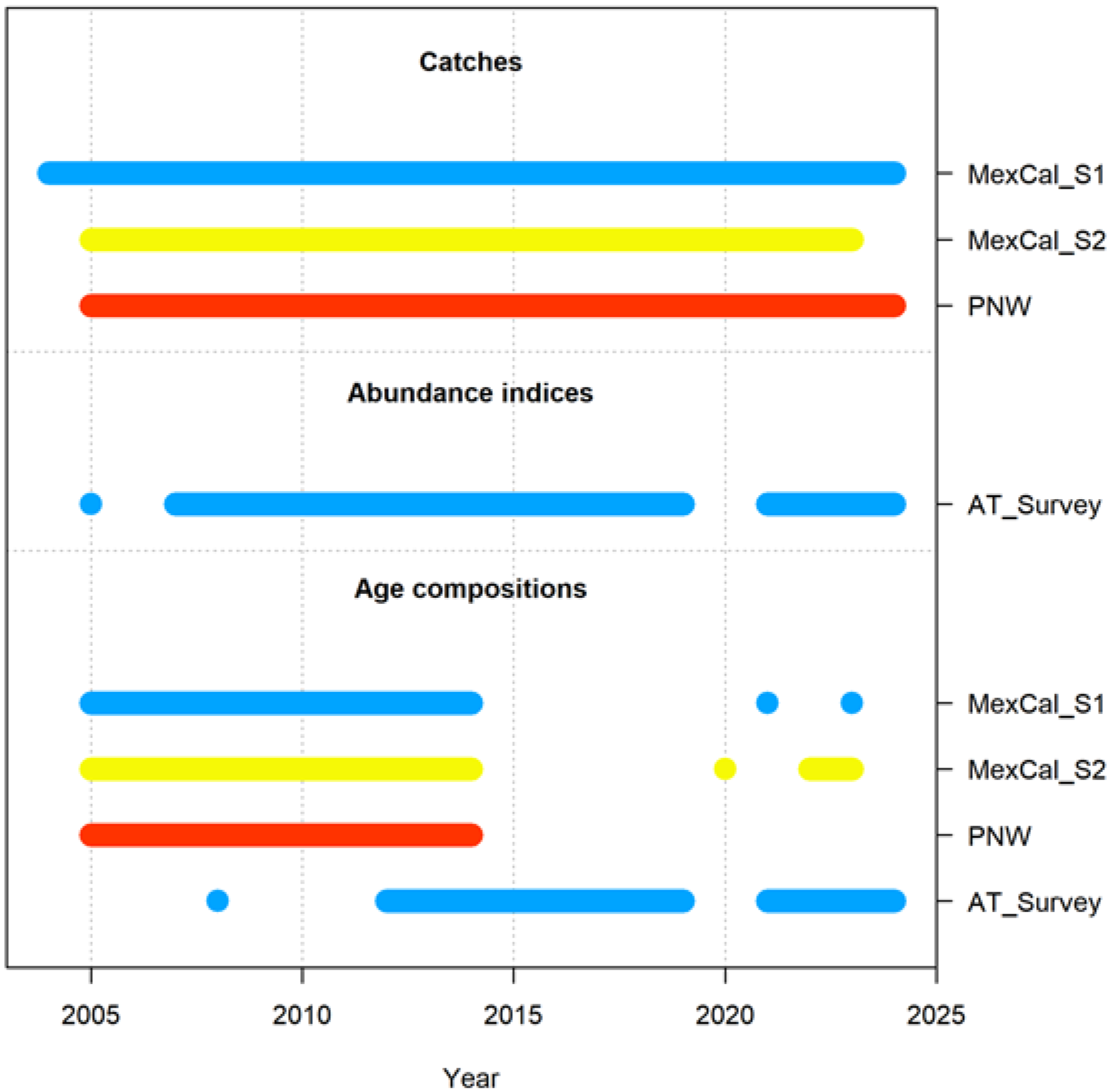


Figure 2. Data used in the model for each fleet and across years.

3.2. Fishery-Independent Data

A survey biomass estimate was computed using the 2024 survey data (Stierhoff et al., in prep). The survey data includes the core area survey performed on the *R/V Reuben Lasker*, and a nearshore cooperative survey using the *F/V Lisa Marie* and *F/V Long Beach Carnage* vessels. Observations from the acoustic-trawl survey indicated continued low biomass levels in the core survey area, and ~99% of the observed biomass occurred in the nearshore area observed by the acoustic-purse seine fishing vessels (Table 6). Nearly all of the biomass seen in the nearshore was observed in two strata along Central California (Stierhoff et al., in prep), and these high-biomass strata co-occurred with the highest proportion observed of Japanese sardine (*S. melanostictus*) along the West Coast (Longo et al., in prep). This update assessment does not use genetics data to separate Pacific and Japanese sardine stocks, thus total NSP biomass estimates include both wherever they co-occurred in the NSP habitat.

The survey age-composition and weights-at-age data were computed for the 2024 fishery and survey (Figure 2). However, the STAT has concerns about including the survey biological data. The sample sizes were low and the few biologically sampled sardine for the core survey area (80 individuals) represented the core survey biomass of ~337 mt. The vast majority of the total biomass was observed in two nearshore strata in Central California, sampled by the fishery purse seine nets, and yielded only 98 aged specimens collected from two purse seine sets in one of those strata. Of those nearshore specimens, the ages range from 2 to 5 years old with a mode at 4. Both the weights-at-age and age-composition data were processed consistently with CPS methodology (as documented in Kuriyama et al., 2022, Appendix A). The weights-at-age from the nearshore specimens are smaller than those of sardine in the north and smaller than those in previous years (Figure 3). The differences in weights-at-age may be due to the small sample size of Pacific sardine mixed with Japanese sardine (Longo et al., in prep). The STAT included the age and weights-at-age data consistent with a standard update assessment, although these data may not be representative of the Pacific sardine NSP. Model sensitivities to these data sources are documented in Appendix A.

Table 6. Biomass estimates from the 2024 AT core and nearshore surveys (from Stierhoff et al., in prep).

Region	Number	Area	Transects	Distance	Clusters	Individuals	Biomass estimate (mt)	$CI_{L, 95\%}$	$CI_{U, 95\%}$	CV
Core	3	3,877	9	392	3	61	20	5	43	51
Core	4	1,885	6	203	1	1	3	0	6	60
Core	5	8,768	18	861	4	570	314	42	865	74
Core	Total	14,530	33	1,456	8	632	**337**	64	892	69
Nearshore	1	238	14	53	4	149	34,060	5,601	48,627	32
Nearshore	2	317	12	49	3	101	43,223	4,787	126,693	76
Nearshore	3	84	3	13	1	549	129	0	270	81
Nearshore	4	103	4	16	1	1	0	0	1	84
Nearshore	5	66	4	10	1	1	0	0	1	72
Nearshore	Total	808	37	141	10	801	**77,412**	21,736	155,856	45
TOTAL		15,338	70	1597	18	1433	**77,750**	21,800	156,748	45

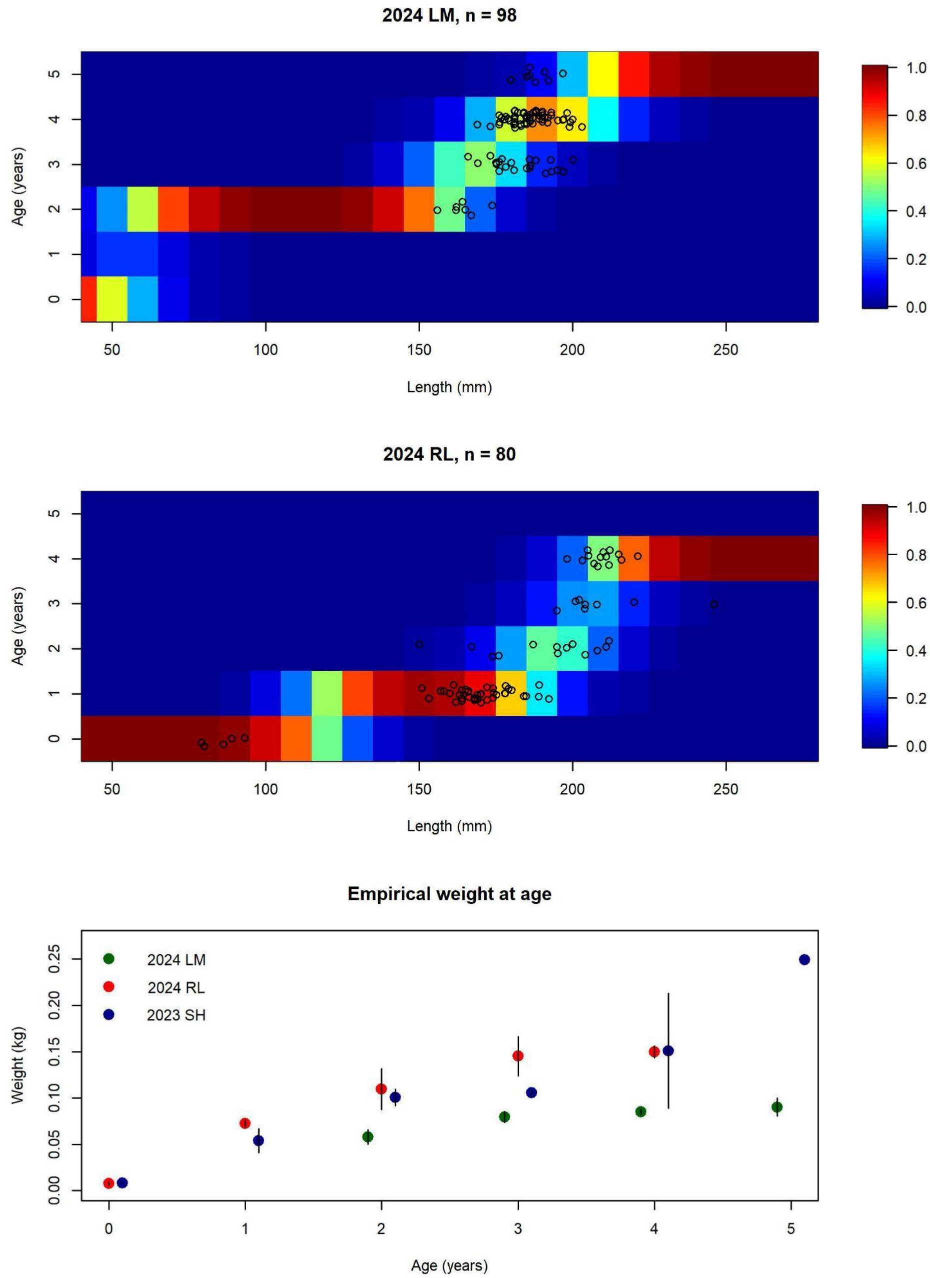


Figure 3. Top two panels: age-length keys generated from sardine sampled in 2024 by *FV Lisa Marie* (LM) and *FSV Reuben Lasker* (RL) with pairs of length and age observations overlaid (jittered black circles). Bottom panel: Mean weights-at-age for the LM and RL 2024 data sets, with the 2023 counterparts for comparison (SH). The colored dots represent the mean weights-at-age for all the aged sardine available in the respective samples. The vertical lines cover the 95% confidence intervals for the mean.

3.3. Biological parameter data

The biological data remains the same for this 2025 update assessment as for the 2024 benchmark assessment (Kuriyama et al., 2024).

3.4. Ecosystem data

The CalCOFI sea surface temperature (SST) data were used to generate a mean SST for 2024, consistent with the 2024 benchmark assessment (Kuriyama et al., 2024). The 3-year running mean of SST was used to inform the E_{MSY} calculation (documented in Kuriyama et al., 2024, Section 5.3).

4. Methods

The base model for this update assessment uses the same model parameterization as the 2024 benchmark assessment (described in Kuriyama et al., 2024), as stipulated by the Council's Terms of Reference for Update Assessments (PFMC, 2024c). The update assessment was conducted using Stock Synthesis (SS v.3.30.22, consistent with the 2024 benchmark). Steepness remained fixed at 0.65, an additional recruitment deviation was estimated in the main time period to fit to data from 2024, and the bias-correction parameters were tuned. Catchability for the 2024 AT survey was fixed at 1. Time-varying fishery selectivities and survey selectivity blocks were extended to 2024 (2dAR for both MexCal fleets, block for survey; Table 7). Otherwise, selectivity configurations are the same as documented in section 4.5.4 of the 2024 benchmark assessment (Kuriyama et al., 2024). Fishing mortality was estimated by fleet and year. The forecasted fishing mortality was updated based on most recent catch and fishing mortality rates (Table 8).

Due to the STAT's concerns regarding the age-composition and weights-at-age data for the 2024 AT survey, a suite of alternative models was explored and are documented in Appendix A to demonstrate the uncertainty around recruitment and forecasted 2025 biomass.

The base model converged with a positive-definite hessian, small gradients, and 20 jitters at 5% did not uncover a better solution.

Table 7. Table comparing the 2024 benchmark model configurations to the 2025 update.

Model configuration details	Benchmark	Update
Time period	2005-2023	2005-2024
Fishery fleets	3, commercial	3, commercial
Survey fleets	1, AT	1, AT
Natural mortality (M)	Estimated (prior)	Estimated (prior)
Growth	Fixed (WAA)	Fixed (WAA)
Spawner-recruit relationship	Beverton-Holt	Beverton-Holt
Equilibrium recruitment (R0)	Estimated	Estimated
Steepness (h)	Fixed (0.65)	Fixed (0.65)
Total recruitment variability (sigmaR)	Fixed (1.2)	Fixed (1.2)
Final year recruitment deviations estimated	2023	2024
SR regime offset	Estimated	Estimated
Catchability (q)	Fixed (1 for 2005-2014; 0.73 for 2015-2019; variable 2020-2023)	Fixed (1 for 2005-2014; 0.73 for 2015-2019; variable 2020-2024)
Selectivity	Estimated	Estimated
Fishery selectivity	Dome-shaped and asymptotic	Dome-shaped and asymptotic
Age-compositions	Yes	Yes
Form	Age-specifc, random walk (MexCal) / Logistic (PNW)	Age-specifc, random walk (MexCal) / Logistic (PNW)
Time-varying	Yes (2dAR) through 2023	Yes (2dAR) through 2024
Survey selectivity	Asymptotic	Asymptotic
Age-compositions	Yes	Yes
Form	Age-specific, asymptotic	Age-specific, asymptotic
Time-varying	Yes (age-0)	Yes (age-0)
	Random walk (option 17)	Random walk (option 17)
Data weighting	No	No

Table 8. Catch values and associated estimated F values added to the update assessment.

		MexCal S1		MexCal S2		PNW	
Calendar Y-S	**Model Y-S**	**Catch**	**F (yr^{-1})**	**Catch**	**F (yr^{-1})**	**Catch**	**F (yr^{-1})**
2024-1	2023-2	0.00	0.00	398.87	0.04	0.14	0.00
2024-2	2024-1	267.06	0.04	0.00	0.00	0.09	0.00

5. Results

Summary biomass (age 1+) for the 2025 fishing year is forecasted in mt (Table 9, Figure 4), and recruitment is forecasted in thousands of age-0 fish (Table 9, Figure 5). Model diagnostics, fits to data, and parameter distributions are included in Appendix B, as well as available in the supplemental Stock Synthesis electronic document files appended to this assessment.

Table 9. Base model estimated age-1+ biomass (mt) and age-0 recruits (thousands).

Model year	Seas	1+ Biomass	Recruits
2005	1	810,272	0
2005	2	681,529	0
2006	1	1,134,490	9,405,600
2006	2	891,316	0
2007	1	892,637	4,756,060
2007	2	818,387	0
2008	1	923,450	2,997,970
2008	2	584,832	0
2009	1	522,415	4,737,310
2009	2	452,127	0
2010	1	394,246	6,481,010
2010	2	290,105	0
2011	1	455,695	424,305
2011	2	369,161	0
2012	1	289,618	111,344
2012	2	167,814	0
2013	1	149,725	144,046
2013	2	79,969	0
2014	1	73,233	510,016
2014	2	39,882	0
2015	1	58,874	567,224
2015	2	40,864	0
2016	1	52,065	183,401
2016	2	32,702	0
2017	1	47,499	315,672

2017	2	25,831	0
2018	1	46,912	609,893
2018	2	26,242	0
2019	1	43,126	563,073
2019	2	28,207	0
2020	1	44,651	2,230,190
2020	2	29,325	0
2021	1	145,641	610,498
2021	2	54,255	0
2022	1	64,580	389,308
2022	2	53,826	0
2023	1	62,214	209,191
2023	2	57,007	0
2024	1	36,190	289,283
2024	2	50,418	0
2025	1	30,158	1,391,300
2025	2	42,224	0

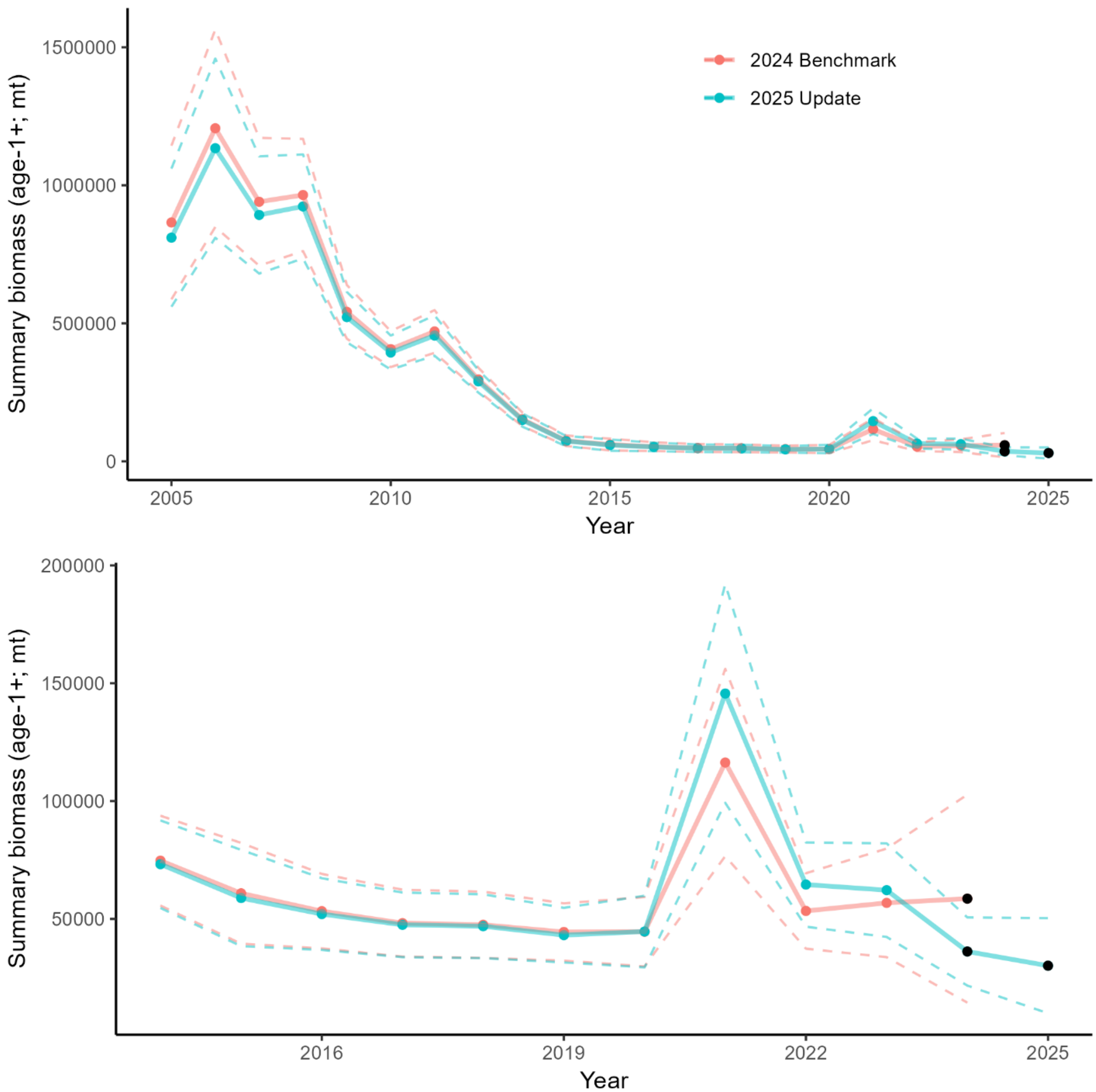


Figure 4. Time series of summary biomass (age-1+; mt) for the 2024 benchmark assessment (red) and 2025 update assessment (blue). The top panel shows values from 2005-2025, the bottom shows 2014-2025. Dotted lines represent 95% confidence intervals. Black points indicate forecasted age-1+ biomass.

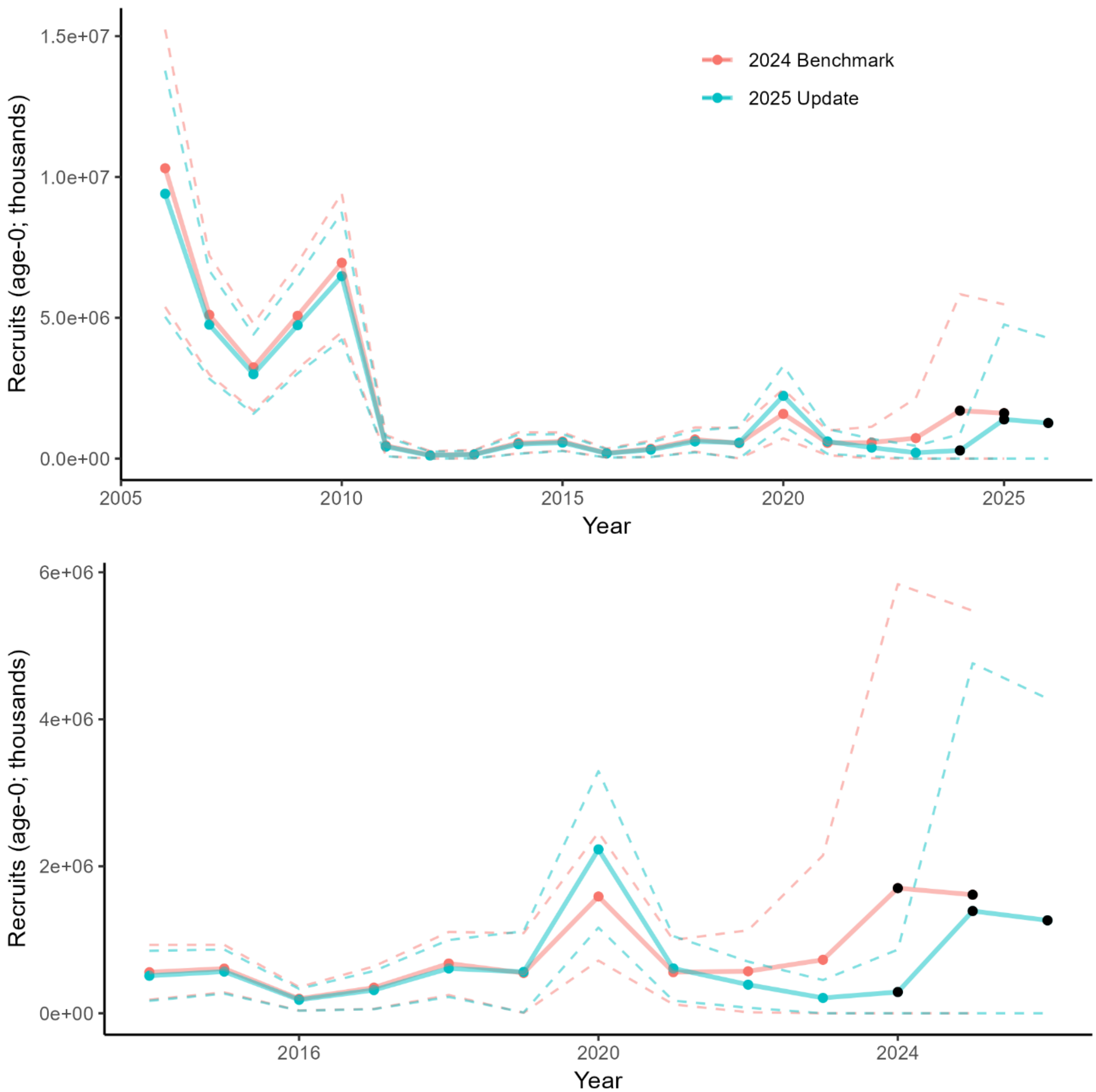


Figure 5. Time series of recruits entering the population (thousands of age-0 fish) for the 2024 benchmark assessment (red) and 2025 update assessment (blue). The top panel shows values from 2005-2026, the bottom shows 2014-2026. Dotted lines represent 95% confidence intervals. Black points indicate values based on recruitment values from the stock-recruit relationship.

6. Exploitation Status

Exploitation rate is defined as the calendar year catch divided by the total mid-year biomass (July-1, ages 0+). Based on the latest model and historic catches, the U.S. exploitation rate was about 2% in 2024 (Table 10, Figure 6). Mexico and Canada had an annual exploitation rate of 0%, thus the total exploitation rate for Mexico, USA, and Canada was about 2% of the total biomass. These exploitation rates are similar to those reported in the 2024 benchmark assessment (0.8% in 2023).

Table 10. Annual exploitation rate (calendar year landings / July total biomass) of the NSP by country and calendar year.

Calendar Year	Mexico	USA	Canada	Total
2005	0	0.05	0	0.06
2006	0	0.06	0	0.06
2007	0.02	0.11	0	0.13
2008	0.01	0.08	0.01	0.1
2009	0.01	0.11	0.03	0.15
2010	0.01	0.11	0.05	0.16
2011	0.04	0.09	0.04	0.17
2012	0.01	0.31	0.07	0.39
2013	0	0.39	0	0.39
2014	0	0.29	0	0.29
2015	0	0.05	0	0.05
2016	0	0.01	0	0.01
2017	0	0.01	0	0.01
2018	0	0	0	0
2019	0	0.01	0	0.01
2020	0	0.01	0	0.01
2021	0	0	0	0
2022	0	0.01	0	0.01
2023	0	0.01	0	0.01
2024	0	0.02	0	0.02

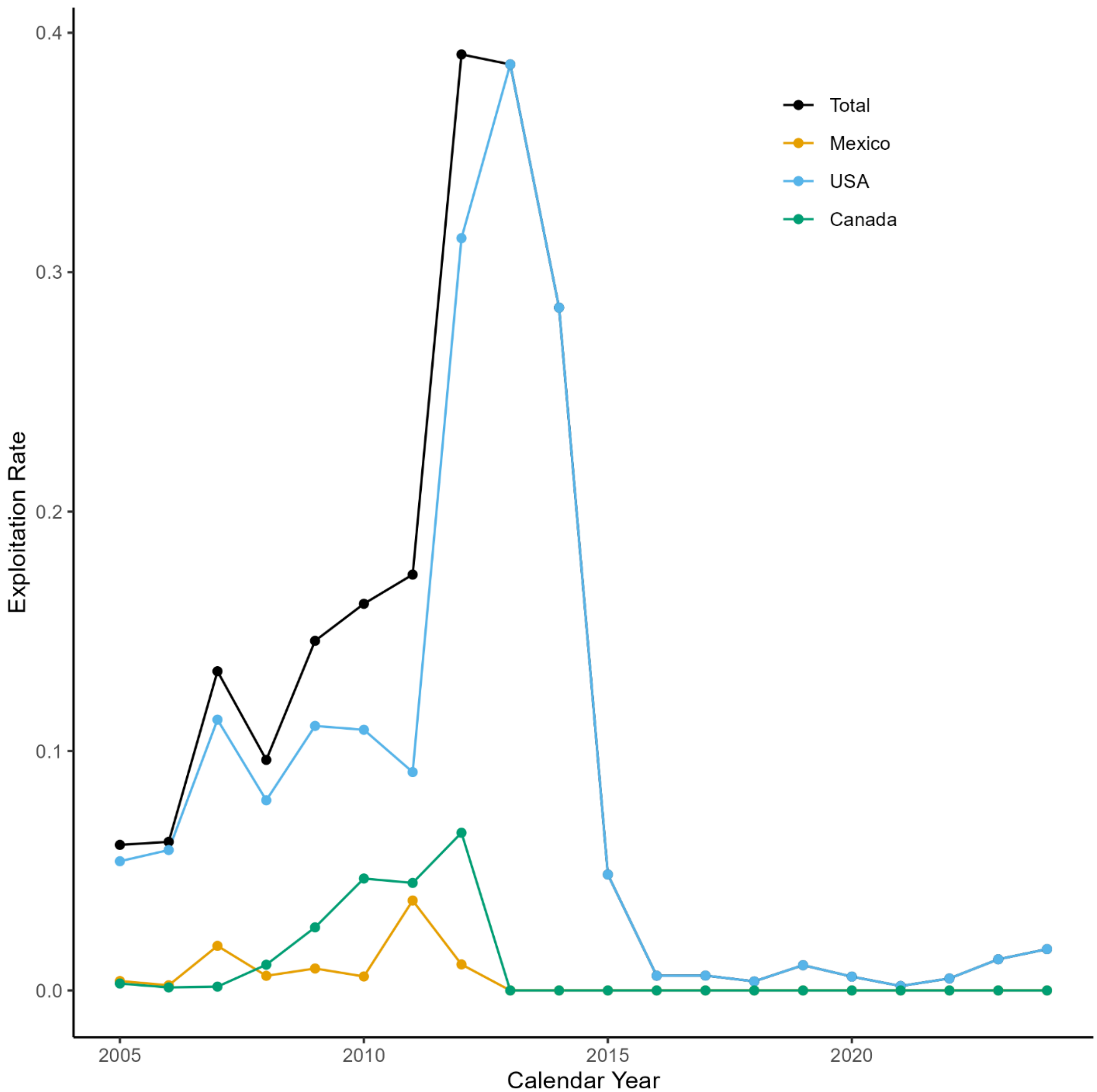


Figure 6. Annual exploitation rates (calendar year landings / July total biomass) for NSP in the base model. (Note that since Canada and Mexico exploitation rates are zero after 2013, the total exploitation rate is equal to the US exploitation rate.)

7. Harvest Control Rules

The harvest guidelines are shown in Table 11, based on a CalCOFI sea-surface temperature (SST) of 15.69 °C (average for 2022-2024), resulting in an E_{MSY} of 0.1771, and forecast age 1+ biomass of mt. The stock is below the 150,000 mt management threshold. For the current base model, the OFL is 4,645 mt, and the harvest guideline is 0 mt for 2025.

Table 11. Pacific sardine harvest control rules for fishing year 2025-2026.

Harvest Control Rule Formulas									
OFL = BIOMASS * E_{MSY} * DISTRIBUTION; where E_{MSY} is bounded 0.00 to 0.25									
$ABC_{P\text{-}star}$ = BIOMASS * $BUFFER_{P\text{-}star}$ * E_{MSY} * DISTRIBUTION; where E_{MSY} is bounded 0.00 to 0.25									
HG = (BIOMASS – CUTOFF) * FRACTION * DISTRIBUTION; where FRACTION is E_{MSY} bounded 0.05 to 0.20									
Harvest Guideline Parameters									
BIOMASS (ages 1+, mt)	30,158								
P-star	0.45	0.4	0.35	0.3	0.25	0.2	0.15	0.1	0.05
ABC $Buffer_{Tier\ 1}$	0.9230	0.8508	0.7822	0.7158	0.6505	0.5847	0.5164	0.4417	0.3504
ABC $Buffer_{Tier\ 2}$	0.8519	0.7239	0.6118	0.5124	0.4231	0.3419	0.2667	0.1951	0.1228
ABC $Buffer_{Tier\ 3}$	0.7778	0.6025	0.4627	0.3504	0.2595	0.1858	0.1258	0.0771	0.0373
CalCOFI SST (2022-2024)	15.69								
E_{MSY}	0.1771								
FRACTION	0.1771								
CUTOFF (mt)	150,000								
DISTRIBUTION (U.S.)	0.87								
Harvest Control Rule Values									
OFL =	**4,645**								
$ABC_{Tier\ 1}$ =	4,288	3,952	3,634	3,325	3,022	2,716	2,399	2,052	1,628
$ABC_{Tier\ 2}$ =	3,957	3,363	2,842	2,380	1,965	1,588	1,239	906	570
$ABC_{Tier\ 3}$ =	3,613	2,799	2,149	1,628	1,205	863	584	358	173
HG =	**0**								

8. Recent Management Performance

A thorough description of PFMC management actions for sardines, including HG values, may be found in the most recent CPS SAFE document (PFMC, 2024b). U.S. landings in recent years have remained below the annual catch limits (or annual catch targets, when applicable; Table 1). The 2024-2025 annual catch target for Pacific sardine was 5,500 mt for Pacific sardine (Table 1). Landings-to-date of the northern subpopulation in the U.S. were 267 mt for 2024-2025, less than 5% of the annual catch limit, with no NSP landings in Canada or Mexico (Table 2).

Available information concerning bycatch and discard mortality of Pacific sardine, as well as other members of the small pelagic fish assemblage of the California Current Ecosystem, is presented in NMFS (2019a). Limited information from observer programs implemented in the past indicated minimal discard of Pacific sardine in the commercial purse seine fishery that targets the small pelagic fish assemblage on the U.S. Pacific coast. It is generally acknowledged that the small purse seine fishery for coastal pelagic fishes discards negligible volumes of sardine.

9. Uncertainties

The concentration of sardine biomass around a relatively small area in nearshore Central California and near absence in the core area shows a continued deviation from historical patterns of distribution, and warrants close monitoring over the next few years leading up to the 2027 benchmark. In addition, the relatively high proportion of Japanese sardine overlapping with this singular high-biomass area should continue to be monitored. Of particular importance in monitoring the results from the ongoing genetics analysis is information on the potential for hybridization between Japanese sardine and Pacific sardine. While successful hybridization has the potential to increase total sardine biomass on the West Coast, unsuccessful hybridization could either have no impact or a depensatory effect on both species (e.g., via cross-fertilization resulting in non-viable zygotes).

10. Regional Management Considerations

Pacific sardine, as well as other species considered in the CPS FMP, are not managed formally on a regional basis within the U.S., due primarily to the extensive distribution and annual migration exhibited by these small pelagic stocks. A form of regional (spatial/temporal) management has been adopted for Pacific sardine, whereby seasonal allocations are stipulated in attempts to ensure regional fishing sectors have at least some access to the directed harvest each year (PFMC, 2014).

11. Research and Data Needs

The alternative models in Appendix A highlight a source of uncertainty around the stock-recruit relationship for Pacific sardine. The STAT recommends exploring whether the arithmetic mean is the best way to characterize and projected recruitment events for Pacific sardine in the 2027 benchmark assessment.

Research on Japanese sardine potential interactions with Pacific sardine including spawn timing, locations, recruitment, and the results of hybridization with Pacific sardine is critical for improved understanding of the potential recruitment outcomes for these stocks in the near-term. In addition, current research regarding the high and low recruitment phases of Pacific sardine through time, including possible impacts by the environment on recruitment success would improve and strengthen our ability to more accurately forecast population biomass.

The distinction between the NSP and Southern Subpopulation (SSP) of Pacific sardine remains a continued source of investigation and research.

Given that ~99% of the sardine biomass was seen in the nearshore component of the survey, it is important to continue collecting survey data in the nearshore to assess the full scope of the US West Coast sardine populations.

Acknowledgements

We recognize and sincerely thank the many groups and individuals that contribute to the Pacific sardine assessment.

Thanks to our State partners at the California Department of Fish and Wildlife (Trung Nguyen), Oregon Department of Fish and Wildlife (Greg Krutzikowsky), and Washington Department of Fish and Wildlife (Lisa Hillier) that helped verify PacFIN commercial catch and sample data.

Aerial surveys were a collaboration between CWPA and CDFW, piloted by Mike Greenhill, Mike Breiling, and Vadim Alekseev. The CWPA observer (industry spotter pilot) was Devin Reed. Aerial survey data and analysis were provided by Kirk Lynn (CDFW) and Emmanis Dorval (SWFSC).

Thank you to our collaborators on the nearshore survey, including captains, crew, NGOs and state partners. The participants for the *Lisa Marie* and *Long Beach Carnage* included Capts. Rick Blair, Rich Ashley, Tom Brinton, Johny Marcopoulos, and F/V crew. California Wetfish Producers Association collaborators included Mark Fina, Diane Pleschner-Steele, and Joel van Noord. West Coast Pelagic Conservation Group included Andy Blair, Mike Okoniewski, and Greg Shaughnessy. State partners included Kristen Hinton and Jennifer Topping from WDFW, and Sandy Diaz, Leeanne Laughlin, Heather Lee, Dane McDermott, Trung Nguyen, and Chelsea Protasio from CDFW.

Exempted fishing permit point sets and biological sampling were contributed by crews including the F/V King Philip (Anthony Russo), F/V Trionfo (Neil Guglielmo), F/V Provider (Jamie Ashley), F/V Eileen (Corbin Hanson and Nick Jurlin), the F/V Triton (Peter Ciaramitaro), F/V Cape Blanco (Corbin Hanson) and F/V Sea Wave (Andy Russo).

Port samples for the Ensenada, Mexico fishery were collected by INAPESCA (Ensenada). Recent landings data from the Ensenada fishery were kindly provided by Concepción Enciso-Enciso (INAPESCA-Ensenada).

Thanks to numerous staff from the SWFSC for the ongoing collection and processing of surface-water trawl samples and acoustic data used in this assessment. Data were collected, analyzed, and provided by members of the Life History Group (Brad Erisman, Brittany Schwartzkopf, Bryan Overcash, Emmanis Dorval, Kelsey James, Lanora Vasquez del Mercado, Owyn Snodgrass and Zach Skelton) and Advanced Survey Technologies Group (Alice Beittel, David Murfin, Josiah Renfree, Kevin Stierhoff, Scott Mau, and Steve Sessions).

Thanks to the CalCOFI staff across the SWFSC and Scripps Institution of Oceanography (SIO), who faithfully execute quarterly surveys to monitor the California Current conditions and provide SST measurements for this assessment and sardine management.

Thanks to Ian Taylor and Jason Cope (NWFSC) for providing alternative model support. And a final thank you to the stock assessment team at the SWFSC for their continuous support (Huihua Lee and Steve Teo).

References

Cheng, M.L., Thorson, J.T., Ianelli, J.N. and Cunningham, C.J., 2023. Unlocking the triad of age, year, and cohort effects for stock assessment: demonstration of a computationally efficient and reproducible framework using weight-at-age. *Fisheries Research*, 266, p.106755.

Kuriyama, Peter T., Caitlin Allen Akselrud, Juan P. Zwolinski, and Kevin T. Hill. 2024. Assessment of the Pacific sardine resource (*Sardinops sagax*) in 2024 for U.S. management in 2024-2025. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-698. https://doi.org/10.25923/jyw3-ys65

Kuriyama, Peter T., Juan P. Zwolinski, Steve L.H. Teo, and Kevin T. Hill. 2022. Assessment of the Northern anchovy (*Engraulis mordax*) central subpopulation in 2021 for U.S. management. U.S. Department of Commerce, NOAA Technical Memorandum NMFS-SWFSC-665. https://doi.org/10.25923/jv24-1539

Longo, G., James, K., Hinton, K., Topping, J., and Craig, M. *In prep*. Update on the presence of Japanese Sardine (*Sardinops melanosticta*) in the California Current Large Marine Ecosystem 2024. U.S. Dep. Commer., NOAA Tech. Memo.

Pacific Fishery Management Council (PFMC). 2014. Pacific sardine STAR panel meeting report. Pacific Fishery Management Council, Portland, Oregon.

Pacific Fishery Management Council (PFMC). 2024a. Coastal pelagic species fishery management plan. Pacific Fishery Management Council, Portland, Oregon.

Pacific Fishery Management Council (PFMC). 2024b. Status of the Pacific Coast Coastal Pelagic Species Fishery and Recommended Acceptable Biological Catches. Stock Assessment and Fishery Evaluation. Pacific Fishery Management Council, Portland, Oregon.

Pacific Fishery Management Council (PFMC). 2024c. Terms of Reference for the Coastal Pelagic Species Stock Assessment Review Process. Pacific Fishery Management Council, Portland, Oregon. 40 p.

Stierhoff, K. L., Renfree, J. S., and Zwolinski, J. P. *In prep.* Distribution, biomass, and demographics of coastal pelagic fishes in the California Current Ecosystem during summer 2024 based on acoustic-trawl sampling. U.S. Dep. Commer., NOAA Tech. Memo.

United States. 1976. *Magnuson-Stevens Fishery Conservation and Management Act,* Public Law 94-265, 94th Congress.

United States. 2006. *Magnuson-Stevens Fishery Conservation and Management Reauthorization Act,* Public Law 109-479, 109th Congress.

Appendix A: Alternative models to the 2025 update assessment base model

Appendices to the update assessment

A.1. Introduction

When adding new data to the 2025 update assessment, the STAT found a projected doubling in biomass for 2025 when the survey biological data (weights-at-age and age-composition data) were excluded. Given concerns about the representativeness of the biological data for the 2024 survey, the STAT traced the origins of this projection and discovered that this model artifact stems from excluding the survey age-composition data, which informs the model of the relative abundance-at-age. The STAT took a two-fold approach to exploring this problem: 1) to understand the progressive impact of including 2024 survey age-composition and weights-at-age inputs (data-driven), and 2) to attempt to correct the model artifact by excluding survey biological data (better data choice) with some modeling changes (model-driven).

In the first case, the STAT tested the impacts of stepwise adding 2024 weights-at-age data and age-composition data from the 2024 AT survey, then updating the recruitment deviations. Most of these biological data stem from two nearshore strata in Central California (Stierhoff et al., in prep) and overlaps with areas indicating high proportions of Japanese sardine in the overall sardine biomass (Longo et al., in prep.). In particular, the weights-at-age were smaller than expected compared with samples collected farther north and in previous years, and the ages were estimated between 2 to 5 years old, with a mode at 4 (Figure 3). It is unlikely that the population as a whole is well-represented by these 98 individuals. The results from these configurations should be taken as an example of how the model behaves differently when grounded in current year survey age-composition data.

To examine possible modeling artifacts resulting from excluding the age-composition data, the STAT added a regime parameter on the stock-recruit relationship. Through our model explorations, the STAT was able to diagnose the modeling artifact as an assignment of biomass to a large recruitment event in 2024 without age-composition data to indicate otherwise. However, there is a dearth of age-0 individuals that would support a large recruitment in the data we do have from 2024. The large recruitment event produced by the model was a result of reverting to a mean stock-recruit relationship that produces an estimated recruitment much higher than is indicated in recent years (Figure B.11). The STAT was able to add a block of years on the estimated stock-recruit relationship to restrict it to values found in recent years and supported by data. Without a deeper dive into recruitment events, the STAT constructed three possible regime blocks: 2021-2022 as the most recent years of recruitment, 2015-2022 that covers the closure period and likely a lower-recruitment regime in the environment, and the full time series 2005-2022 that applies all stock-recruit observations within the modeled period, but excludes anything that would be used to inform the stock-recruit relationship in the pre-model build-up years (1999-2004; Figure A.1).

A.2. Alternative model configurations:

Each model configuration examined is described below and summarized in Table A.1. A note on model version syntax: the letter in the model version suffix is updated for each model with a change to the data used, and the model version numeric suffix is updated for models with a change to the model structure.

A.2.1 Data differences from the base model

While the STAT thought that the 2024 biological data (age-composition and weights-at-age) were not the best representation of the NSP, we did want to generate model configurations that showed the impact on the model results when biological data for the current year is included stepwise, and to illustrate the impact of the large recruitment model artifact when the survey biological data are excluded.

Model 2025.1a: no survey biological data included

No 2024 AT survey biological data was included, meaning the 2023 weights-at-age data was assumed to continue for 2024, no 2024 AT survey age-composition data were included, and the last year of main recruitment deviations was set to 2023 (consistent with not including updated information about recruitment through the survey biological data). No other model parameterization was changed from the base model described in the main text.

Model 2025.1b: 2024 WAA only

This model configuration uses the previous model (2025.1a), but includes the 2024 weights-at-age data.

Model 2025.1c: 2024 survey data, early recdev

This model configuration uses the 2025.1b model and adds the 2024 age-composition data, keeping the last year of main recruitment deviations at 2023 instead of updating it to 2024.

Model 2025.1d: base model

This model configuration is the base model described in the main text, and uses the 2025.1c model and updates the final year of main recruitment deviations to 2024, for the full update assessment.

A.2.2 Model configuration differences from the base model

This set of models was developed to address the issues observed when not including 2024 biological survey data, and provide a range of plausible modeled population dynamics.

Model 2025.2a: early recdev

This model configuration uses the 2025.1a no survey biological data model, but changes the last year of recruitment deviations from 2023 to 2022. The stock-recruit bias correction is updated and forecast recruitment beings in 2023 for this and the following three model configurations (2025.3a, 2025.4a, and 2025.5a).

Model 2025.3a: recent regime

This model configuration updates model 2025.2a to use a new stock-recruit regime parameter. The blocking of this parameter calculates a stock-recruit relationship for recent years (2021-2022) and applies this stock-recruit relationship to the remaining model years and the forecast year.

Model 2025.4a: closure regime

This model configuration updates model 2025.2a to use a new stock-recruit regime parameter, similarly to 2025.3a, but the block period includes the full fishery closure period: 2015-2022, which may represent a lower-recruitment regime for Pacific sardine.

Model 2025.5a: full time series (ts) regime

This model configuration updates model 2025.2a to use a new stock-recruit regime parameter, similarly to 2025.3a and 2025.4a, but the block period includes the full modelled time series: 2005-2022. This configuration excludes any influence that the pre-model period (1999-2004), which builds up the model biomass, might have on the stock-recruit relationship.

A.3. Results

A.3.1 Data models

All of the models with age-composition data entered for 2024 (2025.1c-e) do not show a forecasted doubling of biomass for 2025, and all show a 2024 estimated recruitment between about 290 million-380 million age-0 recruits, rather than the more than 2 billion estimated recruits for 2024 in the 2025.1a model (Table A.2). This illustrates that the high recruitment and biomass estimates in the models 2025.1a and 1b stem solely from the exclusion of age-composition data for 2024.

A.3.2. Model change models

Simply setting the last year of recruitment deviations to 2022 did not change the high projected recruitment for 2024 (model 2025.2a). However, when the STAT added a regime parameter to the stock-recruitment settings, the 2024 recruitment decreased, though it was variable between the three regime models (2025.3-5a; Table A.2). Despite variability in the modeled recruitment for 2024, the forecasted 2025 biomass ranged from about 42,500-62,400 mt– between the nearly 94,000 mt forecasted in the no 2024 survey data model (2025.1a) and the approximately 30,00 mt forecasted in the base model (2025.1d).

The likelihoods and corresponding AIC values of the regime models were very similar, with the full time series likelihood just slightly below the closure and recent regime configurations (recent regime likelihood: 229.382; closure regime likelihood: 229.374; full time series likelihood: 228.249; Table A.3). The base model likelihood is included in Table A.3, but the effective degrees of freedom from a Stock Synthesis model are difficult to characterize and methodology to do so is currently under development. Therefore, only the three models that are structurally the same (their only change is to the starting regime block year) are compared in this analysis.

A.4. Discussion

The STAT wanted to demonstrate the range of forecasted values given different combinations of data. We felt it was important to develop a plausible model that also excludes the potentially unrepresentative survey biological data (age-composition or weights-at-age from 2024). Without 2024 age-composition data to anchor the model, the stock-recruit relationship is reverting to a mean value, which results in a larger than expected recruitment in 2024 and subsequent doubling of forecasted biomass for 2025. Given there is little evidence in our current data for a large recruitment event, the STAT developed a suite of alternative models that use the regime parameter on the stock-recruit relationship to examine three plausible alternatives: 1) the stock-recruit relationship follows recent recruitment patterns seen in 2021-2022, 2) the relationship follows the mean pattern since the fishery closure (2015-2022), or 3) the relationship follows the mean pattern since the start of the modeled data (2005-2022) and excludes years prior to the model beginning that build up the stock (1999-2004). Given the similar results between the three stock-recruit regime models, the STAT finds that these models (2025.3-5a) are biologically plausible and represent a range of uncertainty around the 2025 forecasted biomass.

References

Longo, G., James, K., Hinton, K., Topping, J., and Craig, M. *In prep*. Update on the presence of Japanese Sardine (Sardinops melanosticta) in the California Current Large Marine Ecosystem 2024. U.S. Dep. Commer., NOAA Tech. Memo.

Stierhoff, K. L., Renfree, J. S., and Zwolinski, J. P. *In prep.* Distribution, biomass, and demographics of coastal pelagic fishes in the California Current Ecosystem during summer 2024 based on acoustic-trawl sampling. U.S. Dep. Commer., NOAA Tech. Memo.

Tables and Figures

Table A.1. Descriptions of the base model and each alternative model configuration. All models include bias correction.

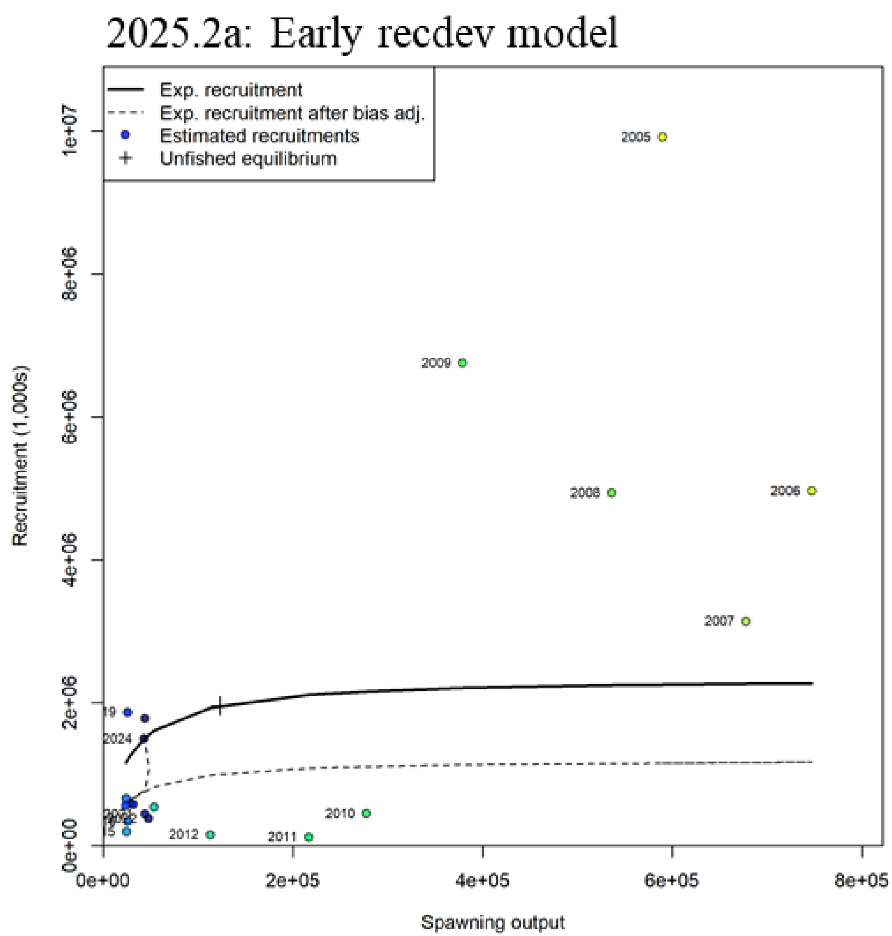
Model Names	**Change type**		**Model name**	**Previous Model**
2025 no survey bio	Data	2023 WAA used for 2024, no 2024 age comp, last recdev = 2023, age0 selex = 2024	2025.1a	
2024 WAA only	Data	add 2024 WAA, no age comp, last recdev = 2023, age0 selex = 2024	2025.1b	2025.1a
2024 survey data, early redev	Data	2024 WAA, 2024 age comp, last recdev = 2023, age0 selex = 2024	2025.1c	2025.1b
2024 Base	Base	2024 WAA, 2024 age comp, last recdev = 2024, age0 selex = 2024	2025.1d	2025.1c
early recdev	Model	base + recdev = 2022, age0 selex = 2024	2025.2a	2025.1a
recent regime	Model	early rec dev + regime = 2021-2022	2025.3a	2025.2a
closure regime	Model	early rec dev + regime = 2015-2022	2025.4a	2025.2a
full ts regime	Model	early rec dev + regime = 2005-2022	2025.5a	2025.2a

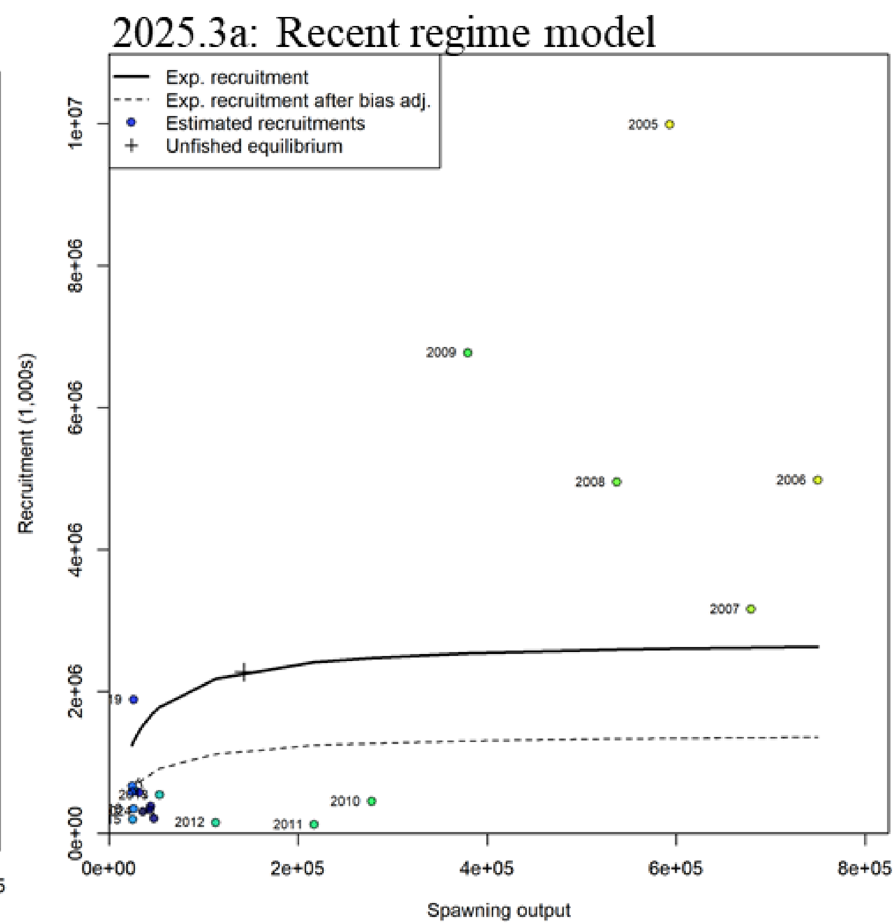
Table A.2 Model results from the base and each of the alternative model configurations. Biomass and OFL are reported in metric tons (mt) and recruitment is reported in thousands of individuals.

Model	Model name	2023 1+bio	2024 1+bio	2025 1+bio	2023 recr	2024 recr	2025 recr	OFL
no_survey_bio	2025.1a	57,318	48,865	93,972	373,932	2,037,160	1,515,520	14,475
data_2024_waa_only	2025.1b	59,381	44,205	84,562	574,699	2,094,550	1,581,900	13,026
data_2024_notuning	2025.1c	62,217	36,200	30,382	209,485	296,964	1,301,960	4,680
base	2025.1d	62,214	36,190	30,158	209,191	289,283	1,391,300	4,645
early_recdev	2025.2a	57,521	49,191	77,477	380,191	1,441,230	1,481,420	13,385
regime_recent	2025.3a	55,677	43,263	42,504	212,428	334,468	310,398	6,547
regime_closure	2025.4a	55,241	44,529	62,391	274,397	1,024,460	978,206	9,611
regime_full_ts	2025.5a	53,382	45,381	57,219	355,201	830,794	759,118	8,814

Table A.3 The number of parameters*, likelihood, and AIC reported for the alternative regime models, with the base model included for reference. *Note: the effective degrees of freedom from a Stock Synthesis model are difficult to characterize.

Model	Model number	N params*	Likelihood	AIC
regime recent	2025.3a	155	229.38	299.13
regime closure	2025.4a	155	229.37	299.13
regime full ts	2025.5a	155	228.25	299.14
base	2025.1a	157	239.68	303.04


2025.2a: Early recdev model
Exp. recruitment
Exp. recruitment after bias adj.
Estimated recruitments
Unfished equilibrium
Recruitment (1,000s)
Spawning output
2005
2009
2008
2006
2007
2010
2012
2011
2024


2025.3a: Recent regime model
Exp. recruitment
Exp. recruitment after bias adj.
Estimated recruitments
Unfished equilibrium
Recruitment (1,000s)
Spawning output
2005
2009
2008
2006
2007
2010
2012
2011

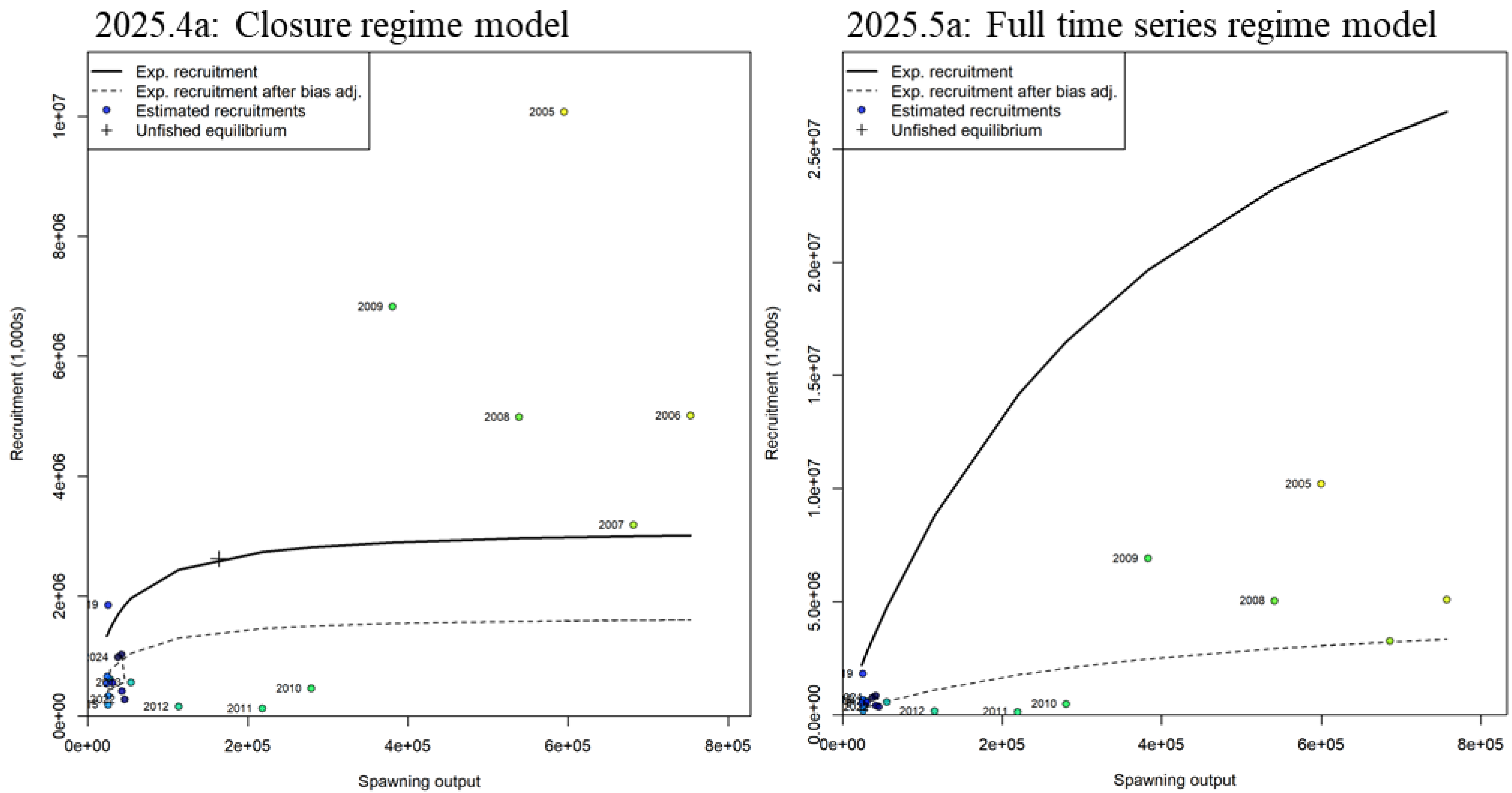


Figure A.1. Stock-recruit curves for the modeling-based alternative models (2025.2-5a). Each stock-recruit curve shows the mean expected recruitment (solid curve), expected recruitment after bias adjustment (dashed line), and annual stock-recruit data (labeled points).

Appendix B. Additional model validation and diagnostic tables and figures.

Weight-At-Age Model Reporting and Diagnostics.

Table B.1: MexCal S1 conditional weight-at-age model results. Bolded values represent the selected model.

Model	Parameter	Parameter estimate	St dev	AIC	dAIC	Pos-def Hessian
None	rho_a			-16.06	-41.1	TRUE
None	rho_c			-16.06	-41.1	TRUE
None	rho_y			-16.06	-41.1	TRUE
None	log_sigma2	0.04	0.16	-16.06	-41.1	TRUE
a	rho_a	0.2	0.14	-15.95	-41.21	TRUE
a	rho_c			-15.95	-41.21	TRUE
a	rho_y			-15.95	-41.21	TRUE
a	log_sigma2	0.04	0.16	-15.95	-41.21	TRUE
c	rho_a			-22.77	-34.39	TRUE
c	rho_c	0.43	0.13	-22.77	-34.39	TRUE
c	rho_y			-22.77	-34.39	TRUE
c	log_sigma2	0.04	0.16	-22.77	-34.39	TRUE
a_c	rho_a	0.02	0.15	-20.78	-36.38	TRUE
a_c	rho_c	0.42	0.15	-20.78	-36.38	TRUE
a_c	rho_y			-20.78	-36.38	TRUE
a_c	log_sigma2	0.04	0.16	-20.78	-36.38	TRUE
y	rho_a			-49.96	-7.2	TRUE
y	rho_c			-49.96	-7.2	TRUE
y	rho_y	0.71	0.1	-49.96	-7.2	TRUE
y	log_sigma2	0.03	0.16	-49.96	-7.2	TRUE
y_a	rho_a	0.23	0.09	-52.77	-4.39	TRUE
y_a	rho_c			-52.77	-4.39	TRUE
y_a	rho_y	0.71	0.1	-52.77	-4.39	TRUE
y_a	log_sigma2	0.03	0.16	-52.77	-4.39	TRUE
y_c	**rho_a**			**-57.16**	**0**	**TRUE**
y_c	**rho_c**	**0.32**	**0.1**	**-57.16**	**0**	**TRUE**
y_c	**rho_y**	**0.65**	**0.1**	**-57.16**	**0**	**TRUE**
y_c	**log_sigma2**	**0.02**	**0.16**	**-57.16**	**0**	**TRUE**
y_a_c	rho_a	0.04	0.12	-55.25	-1.92	TRUE
y_a_c	rho_c	0.3	0.14	-55.25	-1.92	TRUE
y_a_c	rho_y	0.65	0.1	-55.25	-1.92	TRUE
y_a_c	log_sigma2	0.02	0.16	-55.25	-1.92	TRUE

Table B.2: MexCal S2 conditional weight-at-age model results. Bolded values represent the selected model.

Model	Parameter	Parameter estimate	St dev	AIC	dAIC	Pos-def Hessian
None	rho_a			-16.06	-41.1	TRUE
None	rho_c			-16.06	-41.1	TRUE
None	rho_y			-16.06	-41.1	TRUE
None	log_sigma2	0.04	0.16	-16.06	-41.1	TRUE
a	rho_a	0.2	0.14	-15.95	-41.21	TRUE
a	rho_c			-15.95	-41.21	TRUE
a	rho_y			-15.95	-41.21	TRUE
a	log_sigma2	0.04	0.16	-15.95	-41.21	TRUE
c	rho_a			-22.77	-34.39	TRUE
c	rho_c	0.43	0.13	-22.77	-34.39	TRUE
c	rho_y			-22.77	-34.39	TRUE
c	log_sigma2	0.04	0.16	-22.77	-34.39	TRUE
a_c	rho_a	0.02	0.15	-20.78	-36.38	TRUE
a_c	rho_c	0.42	0.15	-20.78	-36.38	TRUE
a_c	rho_y			-20.78	-36.38	TRUE
a_c	log_sigma2	0.04	0.16	-20.78	-36.38	TRUE
y	rho_a			-49.96	-7.2	TRUE
y	rho_c			-49.96	-7.2	TRUE
y	rho_y	0.71	0.1	-49.96	-7.2	TRUE
y	log_sigma2	0.03	0.16	-49.96	-7.2	TRUE
y_a	rho_a	0.23	0.09	-52.77	-4.39	TRUE
y_a	rho_c			-52.77	-4.39	TRUE
y_a	rho_y	0.71	0.1	-52.77	-4.39	TRUE
y_a	log_sigma2	0.03	0.16	-52.77	-4.39	TRUE
y_c	**rho_a**			**-57.16**	**0**	**TRUE**
y_c	**rho_c**	**0.32**	**0.1**	**-57.16**	**0**	**TRUE**
y_c	**rho_y**	**0.65**	**0.1**	**-57.16**	**0**	**TRUE**
y_c	**log_sigma2**	**0.02**	**0.16**	**-57.16**	**0**	**TRUE**
y_a_c	rho_a	0.04	0.12	-55.25	-1.92	TRUE
y_a_c	rho_c	0.3	0.14	-55.25	-1.92	TRUE
y_a_c	rho_y	0.65	0.1	-55.25	-1.92	TRUE
y_a_c	log_sigma2	0.02	0.16	-55.25	-1.92	TRUE

Table B.3: PNW conditional weight-at-age model results. Bolded values represent the selected model.

Model	Parameter	Parameter estimate	St dev	AIC	dAIC	Pos-def Hessian
None	rho_a			-35.5	-86.23	TRUE
None	rho_c			-35.5	-86.23	TRUE
None	rho_y			-35.5	-86.23	TRUE
None	log_sigma2	0.03	0.15	-35.5	-86.23	TRUE
a	rho_a	0.67	0.11	-63.98	-57.75	TRUE
a	rho_c			-63.98	-57.75	TRUE
a	rho_y			-63.98	-57.75	TRUE
a	log_sigma2	0.02	0.15	-63.98	-57.75	TRUE
c	rho_a			-47.28	-74.46	FALSE
c	rho_c	0.88	0.08	-47.28	-74.46	FALSE
c	rho_y			-47.28	-74.46	FALSE
c	log_sigma2	0.02	0.16	-47.28	-74.46	FALSE
a_c	rho_a	0.19	0.14	-86.76	-34.97	TRUE
a_c	rho_c	0.66	0.12	-86.76	-34.97	TRUE
a_c	rho_y			-86.76	-34.97	TRUE
a_c	log_sigma2	0.02	0.15	-86.76	-34.97	TRUE
y	rho_a			-111.17	-10.56	TRUE
y	rho_c			-111.17	-10.56	TRUE
y	rho_y	0.83	0.07	-111.17	-10.56	TRUE
y	log_sigma2	0.01	0.16	-111.17	-10.56	TRUE
y_a	**rho_a**	**0.28**	**0.08**	**-121.74**	**0**	**TRUE**
y_a	**rho_c**			**-121.74**	**0**	**TRUE**
y_a	**rho_y**	**0.7**	**0.07**	**-121.74**	**0**	**TRUE**
y_a	**log_sigma2**	**0.01**	**0.16**	**-121.74**	**0**	**TRUE**
y_c	rho_a			-121.42	-0.32	TRUE
y_c	rho_c	0.33	0.1	-121.42	-0.32	TRUE
y_c	rho_y	0.63	0.09	-121.42	-0.32	TRUE
y_c	log_sigma2	0.01	0.16	-121.42	-0.32	TRUE
y_a_c	rho_a	0.16	0.12	-121.27	-0.47	TRUE
y_a_c	rho_c	0.18	0.15	-121.27	-0.47	TRUE
y_a_c	rho_y	0.64	0.09	-121.27	-0.47	TRUE
y_a_c	log_sigma2	0.01	0.16	-121.27	-0.47	TRUE

Table B.4: Comparison of the new weight-at-age values for each fishery fleet with those in the 2024 benchmark (A: MexCal S1 fleet; B: MexCal S2 fleet; C: PNW fleet). The numbers represent the difference between the update base model configuration and 2024 benchmark configuration (update - benchmark).

MexCal S1 Fleet

A	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
2005	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0000	0.0137	0.0185	0.0223	0.0269	0.0324
2006	0.0000	0.0000	0.0000	0.0000	0.0061	0.0061	-0.0024	0.0091	0.0192	0.0266	0.0330
2007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0086	0.0087	0.0054	0.0121	0.0218	0.0307
2008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0157	0.0210	0.0205	0.0179	0.0209	0.0280
2009	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0119	0.0026	0.0166	0.0233	0.0256	0.0292
2010	0.0000	0.0000	0.0000	0.0000	-0.0052	0.0046	-0.0011	0.0071	0.0183	0.0268	0.0321
2011	0.0041	0.0000	0.0000	0.0000	0.0000	-0.0014	0.0019	0.0063	0.0133	0.0228	0.0315
2012	-0.0047	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0060	0.0123	0.0196	0.0283
2013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0109	0.0165	0.0218	0.0282
2014	0.0000	0.0106	0.0439	0.0000	0.0000	0.0000	0.0000	0.0000	0.0104	0.0201	0.0280
2015	-0.0029	-0.0109	0.0019	0.0326	0.0536	0.0587	0.0340	0.0139	0.0045	0.0068	0.0139
2016	-0.0028	-0.0048	-0.0039	0.0083	0.0258	0.0398	0.0448	0.0374	0.0260	0.0188	0.0192
2017	-0.0030	-0.0054	-0.0046	0.0007	0.0108	0.0225	0.0319	0.0388	0.0385	0.0339	0.0302
2018	-0.0036	-0.0064	-0.0084	-0.0048	0.0035	0.0127	0.0214	0.0294	0.0365	0.0398	0.0398
2019	-0.0047	-0.0074	-0.0123	-0.0124	-0.0041	0.0054	0.0144	0.0224	0.0299	0.0369	0.0420
2020	-0.0070	-0.0081	-0.0166	-0.0218	-0.0138	-0.0035	0.0070	0.0165	0.0248	0.0322	0.0393
2021	0.0000	0.0000	0.0000	0.0000	-0.0391	-0.0467	-0.0298	-0.0024	0.0127	0.0281	0.0405
2022	-0.0027	-0.0048	-0.0137	-0.0256	-0.0258	-0.0199	-0.0102	0.0010	0.0122	0.0226	0.0322
2023	0.0000	0.0000	0.0000	0.0000	0.0073	-0.0143	-0.0275	-0.0229	-0.0054	0.0102	0.0255
2024	0.0031	0.0049	0.0010	-0.0077	-0.0133	-0.0148	-0.0119	-0.0054	0.0035	0.0136	0.0238
2025	0.0006	0.0027	0.0025	-0.0015	-0.0060	-0.0085	-0.0079	-0.0040	0.0029	0.0116	0.0212

MexCal S2 Fleet

B	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
2005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0019	-0.0032
2006	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0011	0.0003	0.0028	0.0018	-0.0010	-0.0029
2007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0002	0.0004	0.0022	0.0029	0.0015
2008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011	0.0003	0.0000	0.0001	0.0012	0.0022
2009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0010	0.0021	0.0027	0.0025	0.0023	0.0024
2010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0001	0.0012	0.0022	0.0027
2011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005
2012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0016	-0.0013	-0.0020	-0.0035	-0.0039
2013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	-0.0008	-0.0024
2014	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0032	0.0062	0.0050	0.0043	0.0032
2015	0.0004	-0.0030	-0.0012	0.0057	0.0258	0.0466	0.0560	0.0589	0.0583	0.0512	0.0418
2016	0.0004	-0.0002	-0.0019	-0.0027	-0.0014	0.0064	0.0188	0.0304	0.0394	0.0454	0.0471
2017	0.0003	-0.0002	-0.0009	-0.0020	-0.0030	-0.0036	-0.0014	0.0041	0.0117	0.0198	0.0272
2018	-0.0001	-0.0010	-0.0016	-0.0023	-0.0030	-0.0038	-0.0045	-0.0043	-0.0023	0.0014	0.0066
2019	0.0001	-0.0025	-0.0046	-0.0050	-0.0052	-0.0054	-0.0057	-0.0059	-0.0060	-0.0054	-0.0037
2020	0.0000	0.0000	0.0000	0.0000	-0.0102	-0.0231	-0.0300	-0.0334	-0.0350	-0.0332	-0.0300
2021	-0.0047	-0.0148	-0.0165	-0.0183	-0.0207	-0.0214	-0.0209	-0.0196	-0.0179	-0.0161	-0.0142
2022	0.0000	0.0000	0.0000	-0.0053	-0.0074	-0.0123	-0.0193	-0.0260	-0.0311	-0.0343	-0.0352
2023	0.0132	0.0131	0.0108	-0.0153	-0.0375	-0.0434	-0.0462	-0.0466	-0.0452	-0.0426	-0.0393
2024	0.0004	0.0054	0.0096	0.0116	0.0016	-0.0154	-0.0285	-0.0376	-0.0432	-0.0459	-0.0464
2025	0.0004	-0.0002	0.0015	0.0044	0.0074	0.0057	-0.0022	-0.0127	-0.0229	-0.0314	-0.0377

PNW Fleet

C	Age										
Year	0	1	2	3	4	5	6	7	8	9	10
2005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2009	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2015	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2019	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2023	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2024	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2025	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Base Model Diagnostic Figures

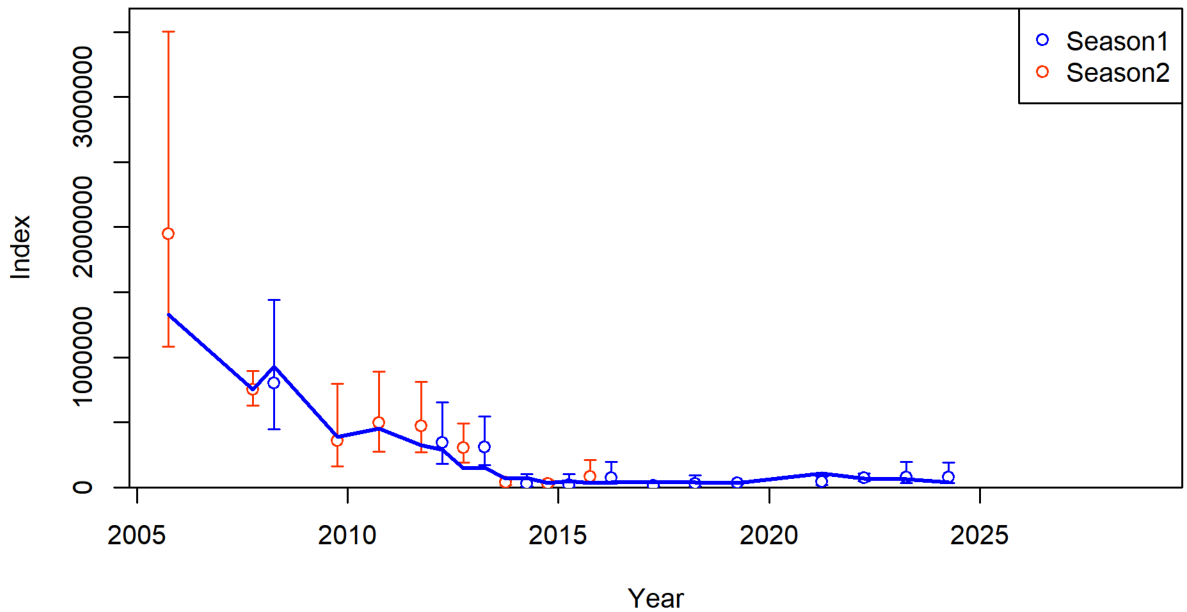


Figure B.1. Fit to index data for the AT Survey. Lines indicate 95% uncertainty intervals around index values based on the model assumption of lognormal error. Thicker lines (if present) indicate input uncertainty before the addition of an estimated additional uncertainty parameter.

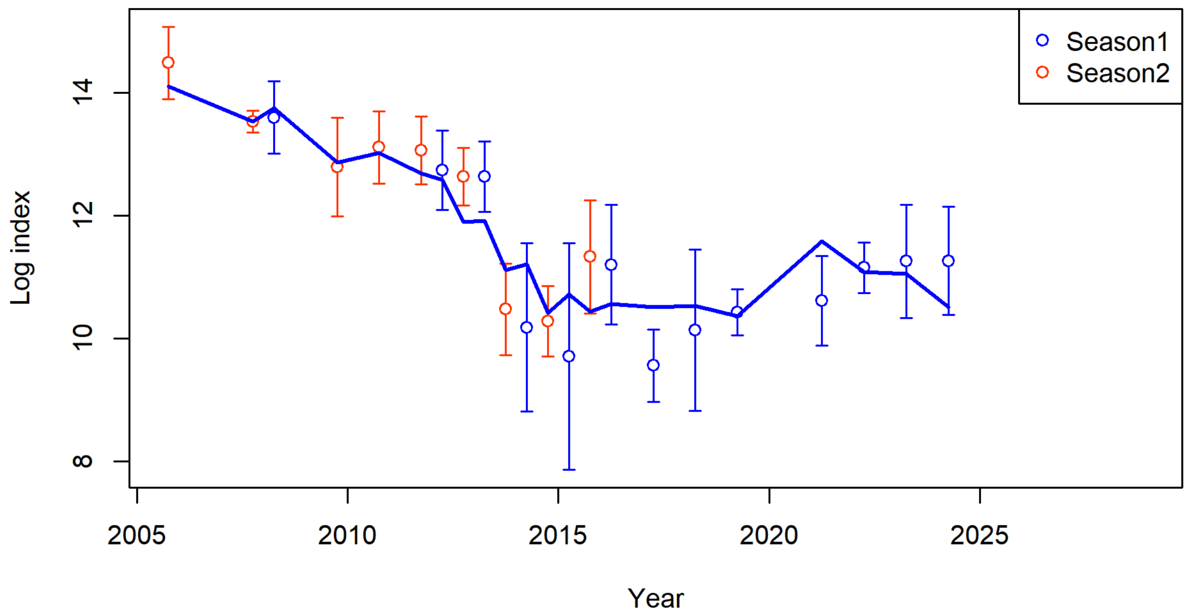


Figure B.2. Fit to log index data on log scale for AT Survey. Lines indicate 95% uncertainty intervals around index values based on the model assumption of lognormal error. Thicker lines (if present) indicate input uncertainty before the addition of an estimated additional uncertainty parameter.

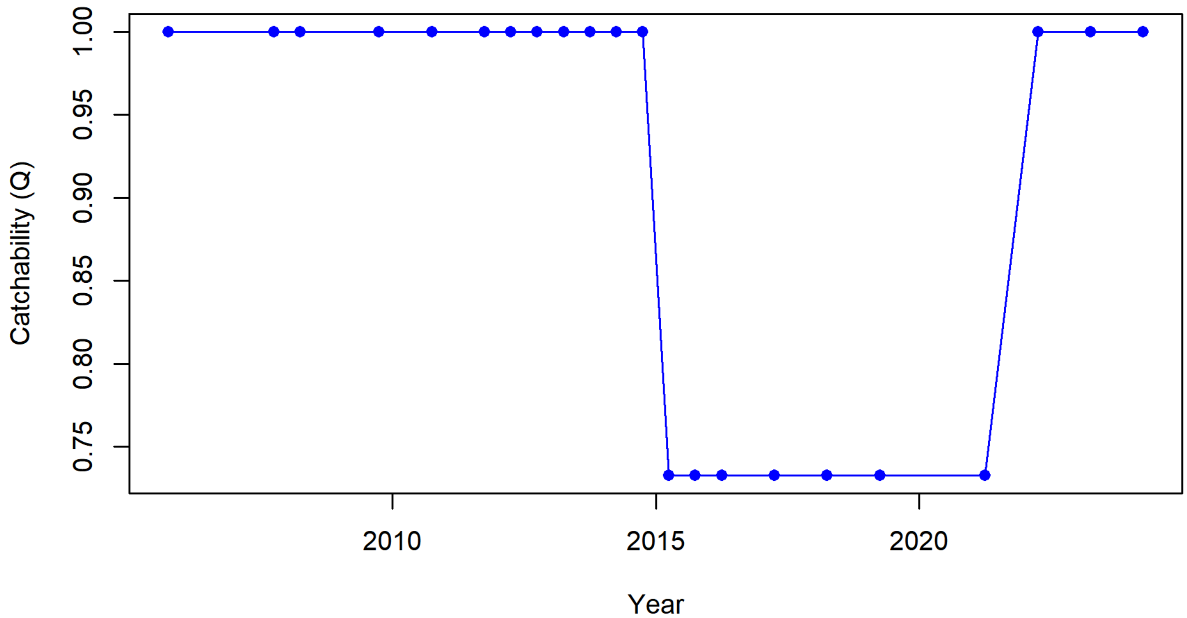


Figure B.3. Catchability (Q) values input to the assessment. Between 2015-2021, these values were calculated as a ratio of the AT survey observations and the aerial survey observations.

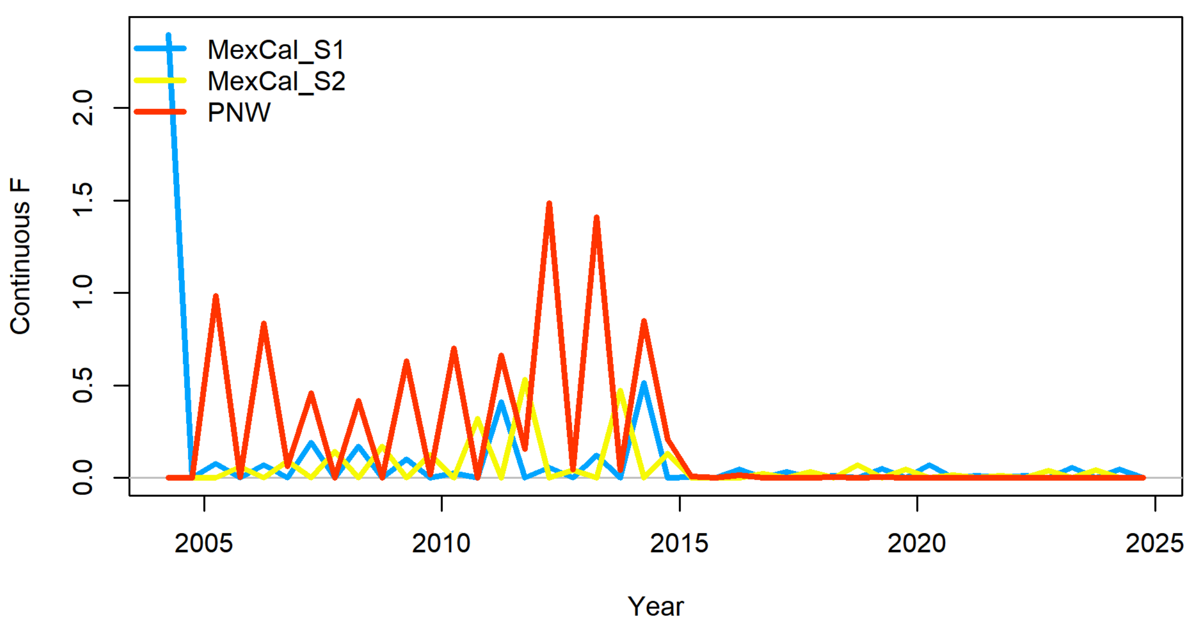


Figure B.4. Instantaneous fishing mortality time series for each fishery fleet.

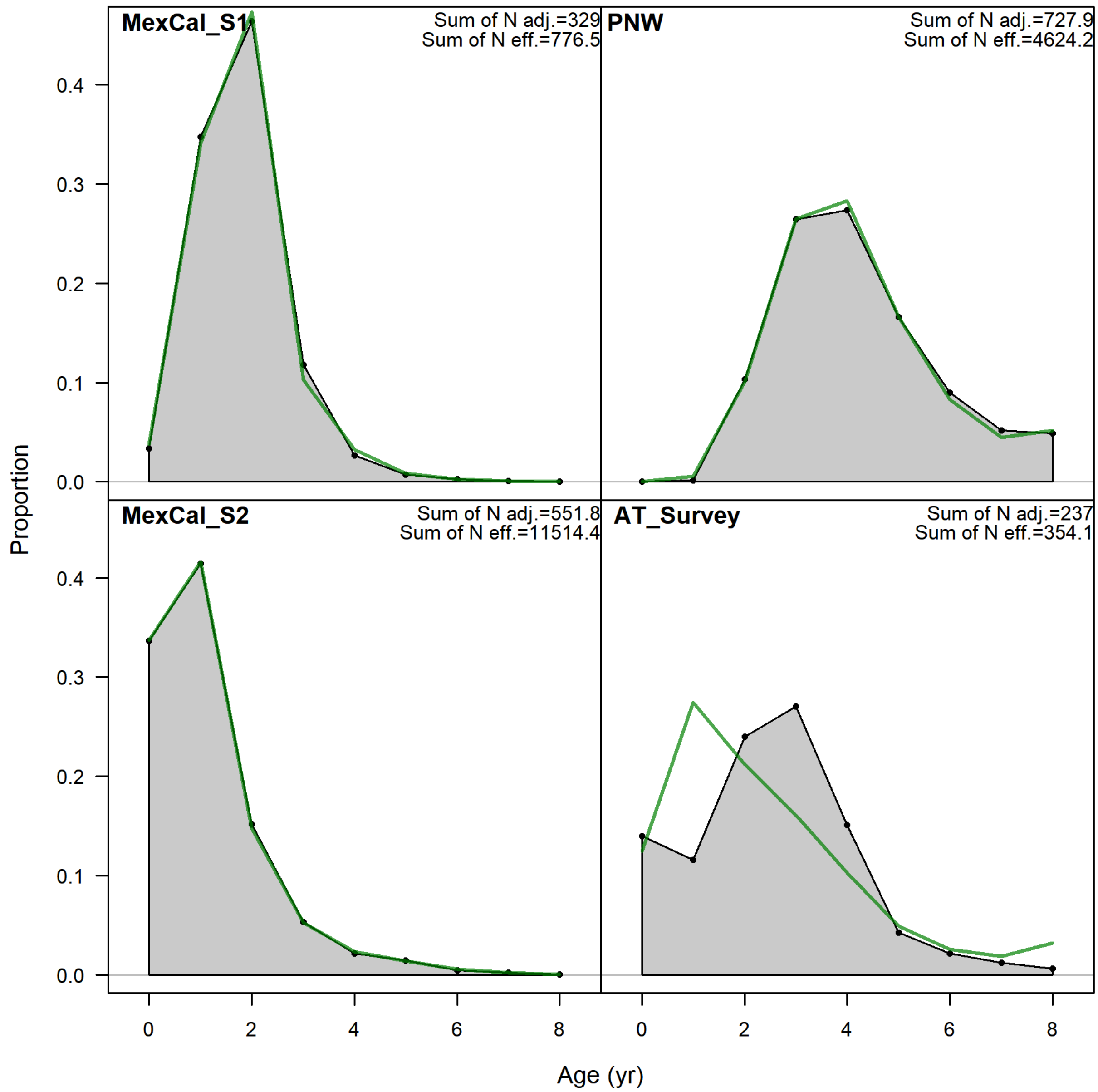


Figure B.5. Base model fits to the age-composition data, aggregated across time by fleet.

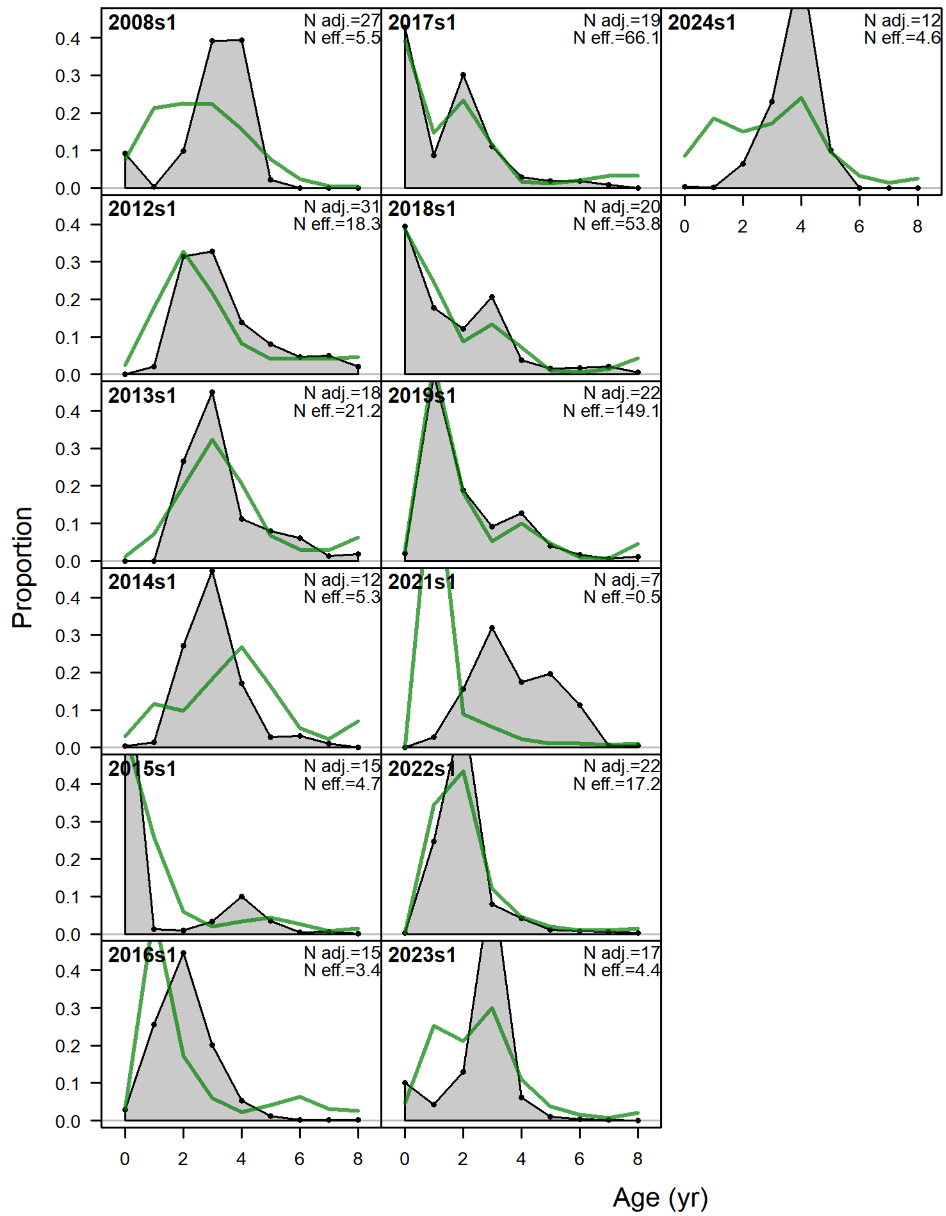


Figure B.6. Fits to the AT survey age-compositions by year.

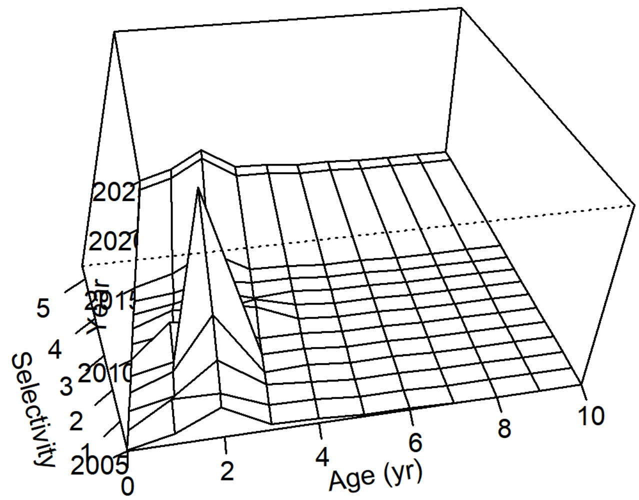


Figure B.7. Time-varying age-based selectivity patterns for the MexCal S1 fishery.

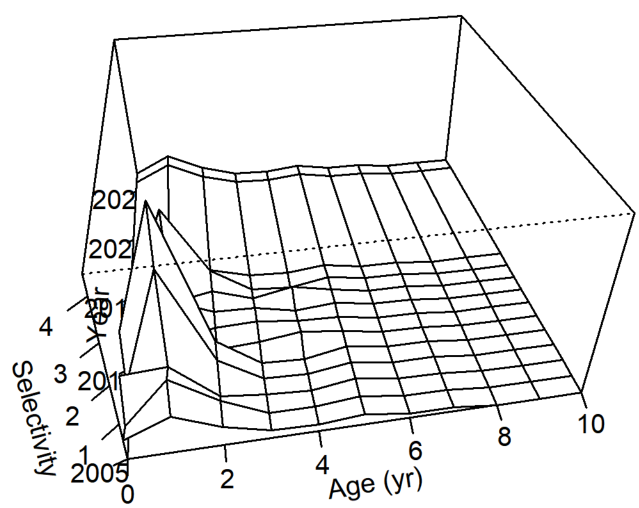


Figure B.8. Time-varying age-based selectivity patterns for the MexCal S2 fishery.

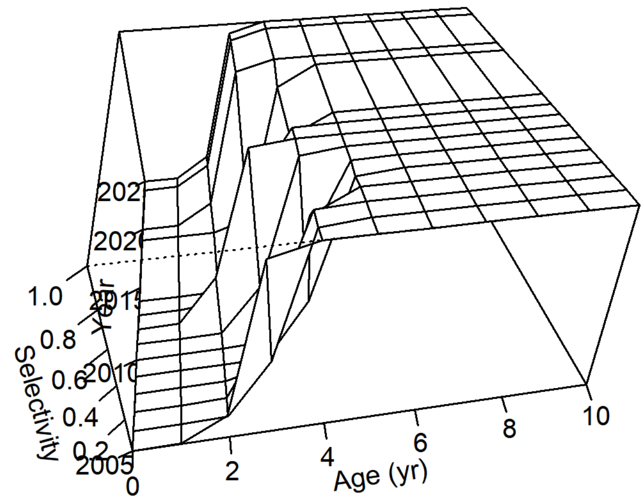


Figure B.9. Time-varying age-based selectivity patterns for the PNW fishery.

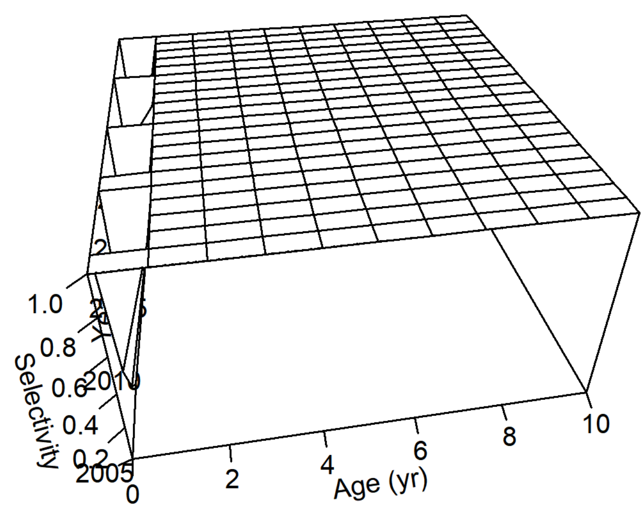


Figure B.10. Time-varying age-based selectivity patterns for the combined AT survey and nearshore survey.

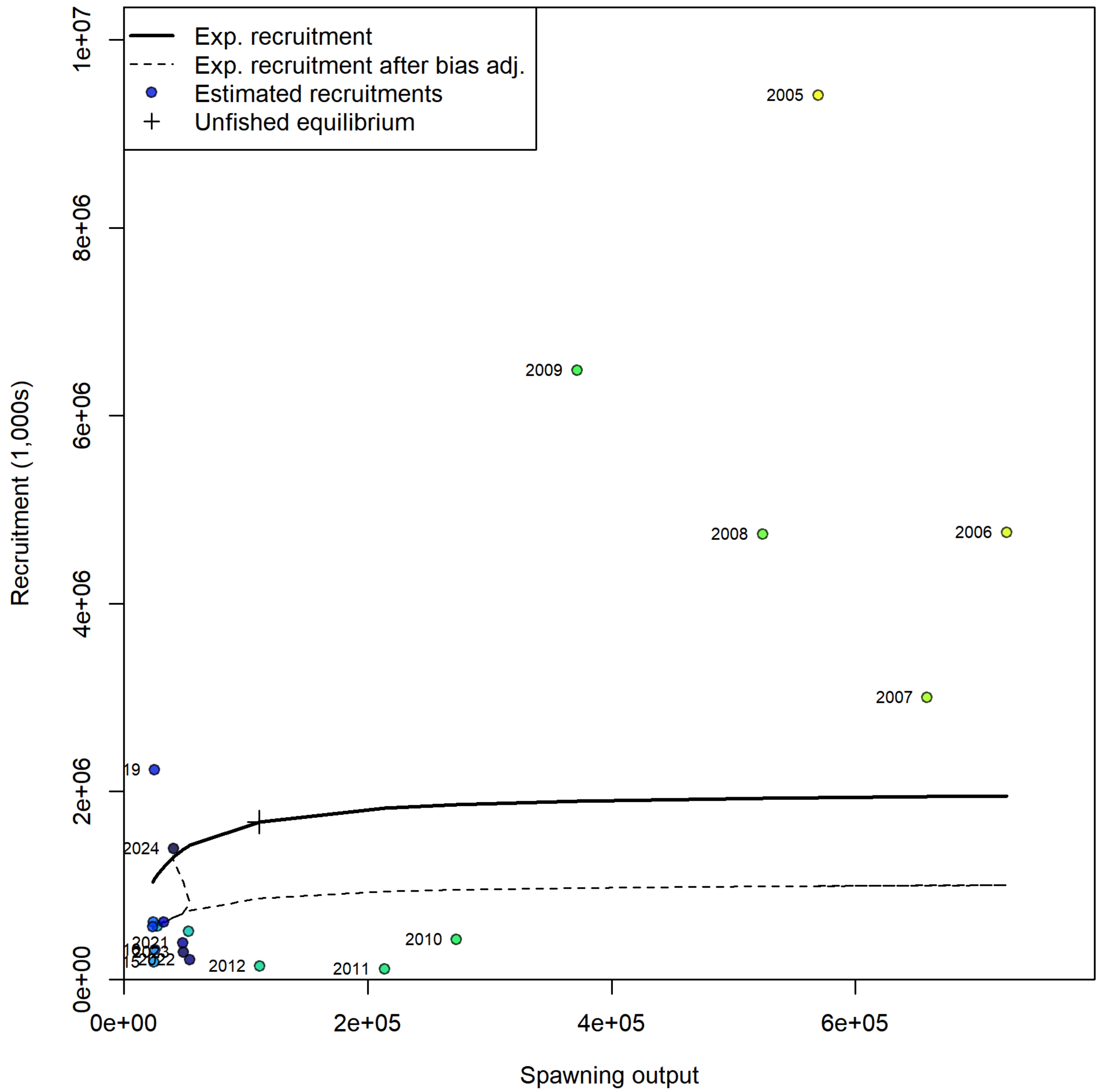


Figure B.11. The stock-recruit curve (solid black line) and bias-adjusted curve (dashed line) with individual years (points).

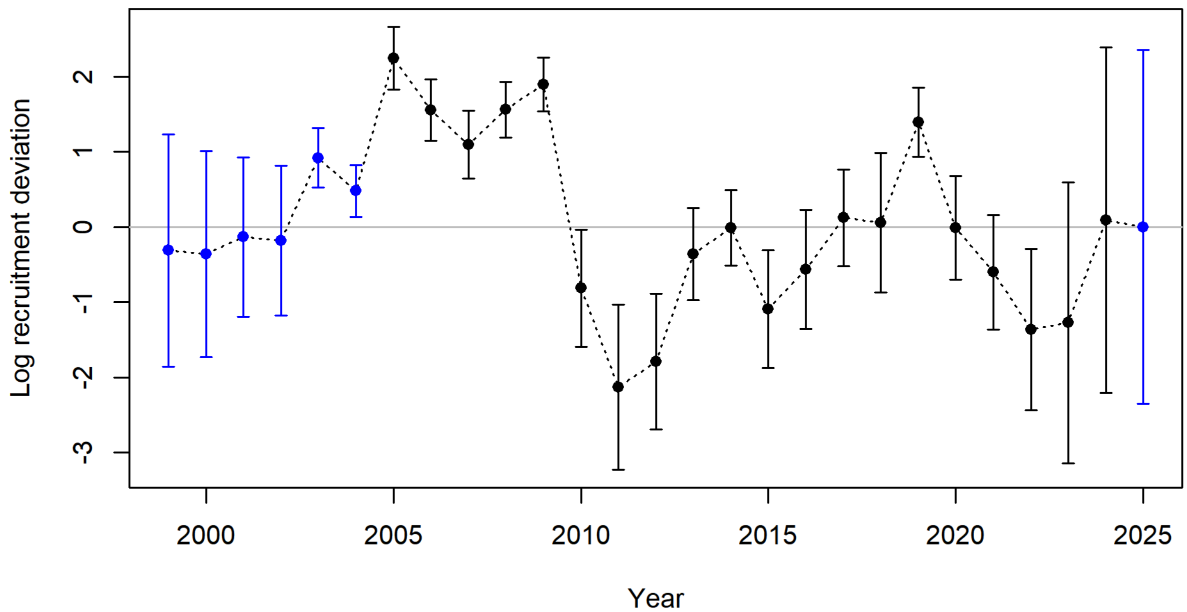


Figure B.12. Recruitment deviations with 95% CI bars. The last year of estimated recruitment deviations is 2024.

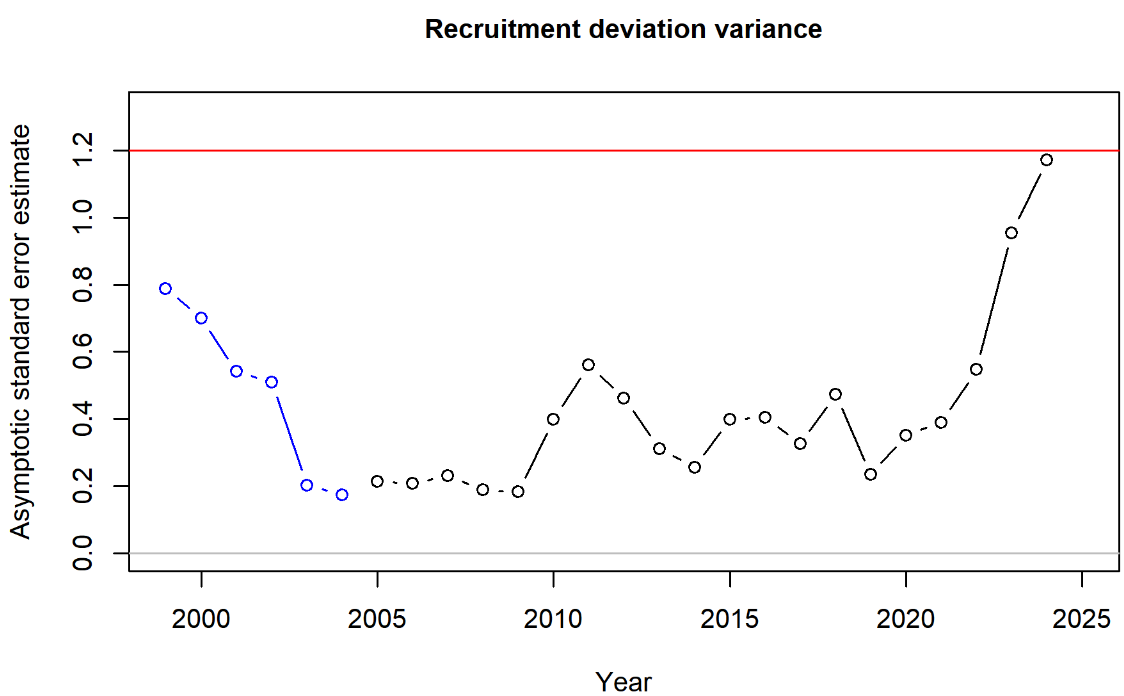


Figure B.13. Asymptotic standard errors for estimated recruitment deviations.

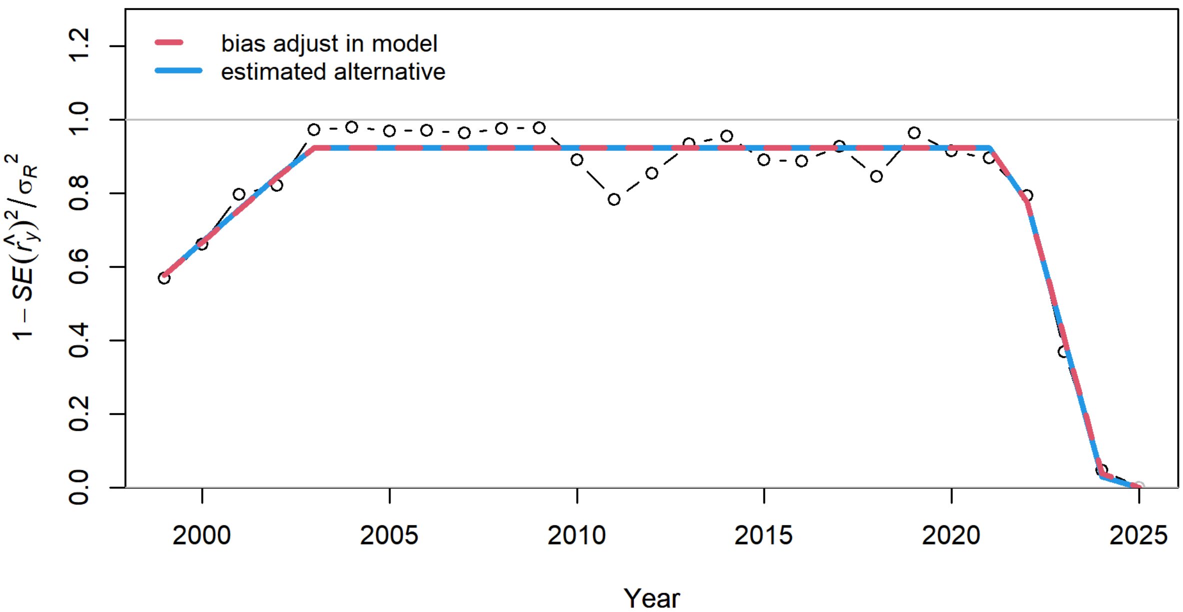
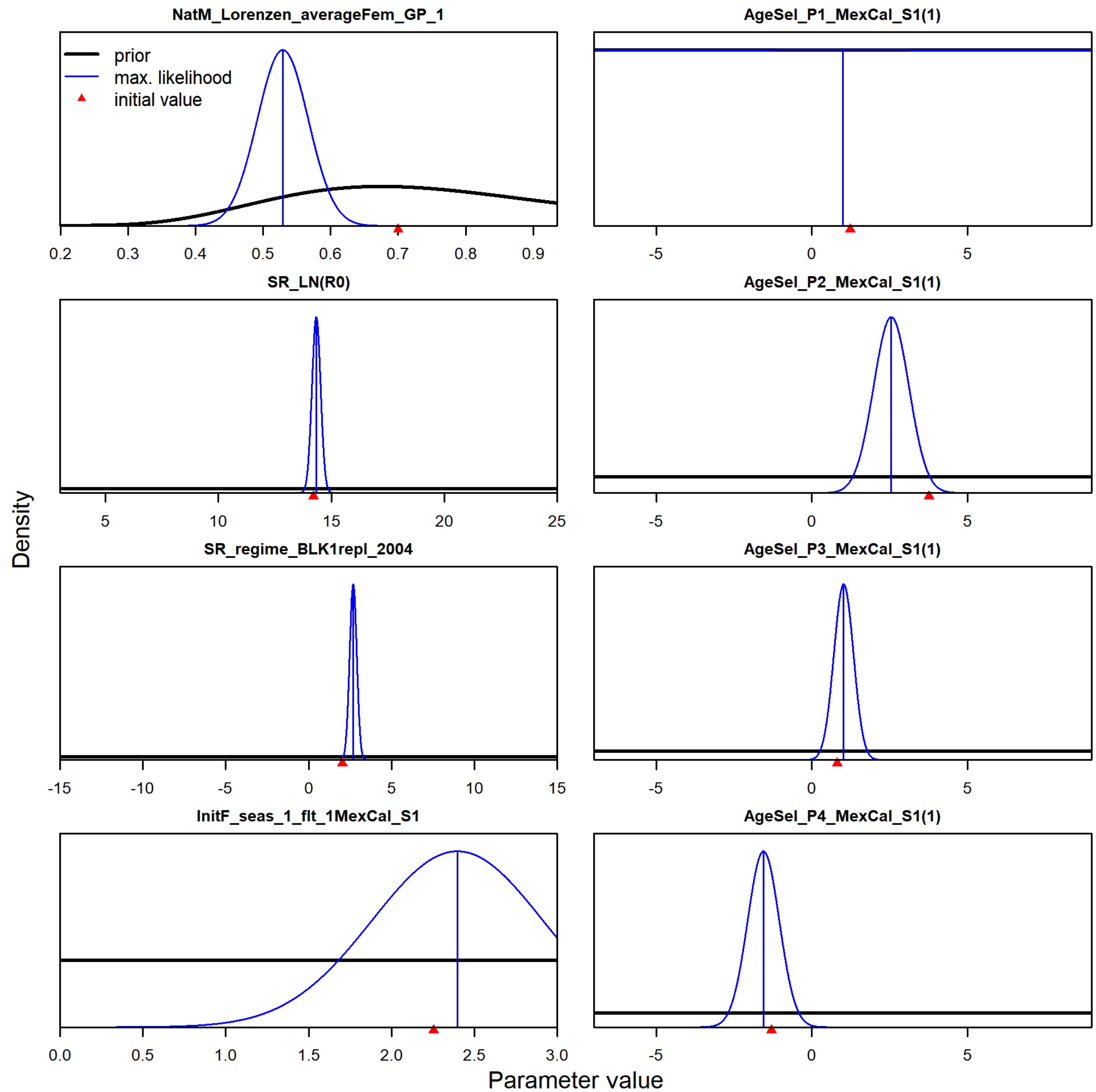
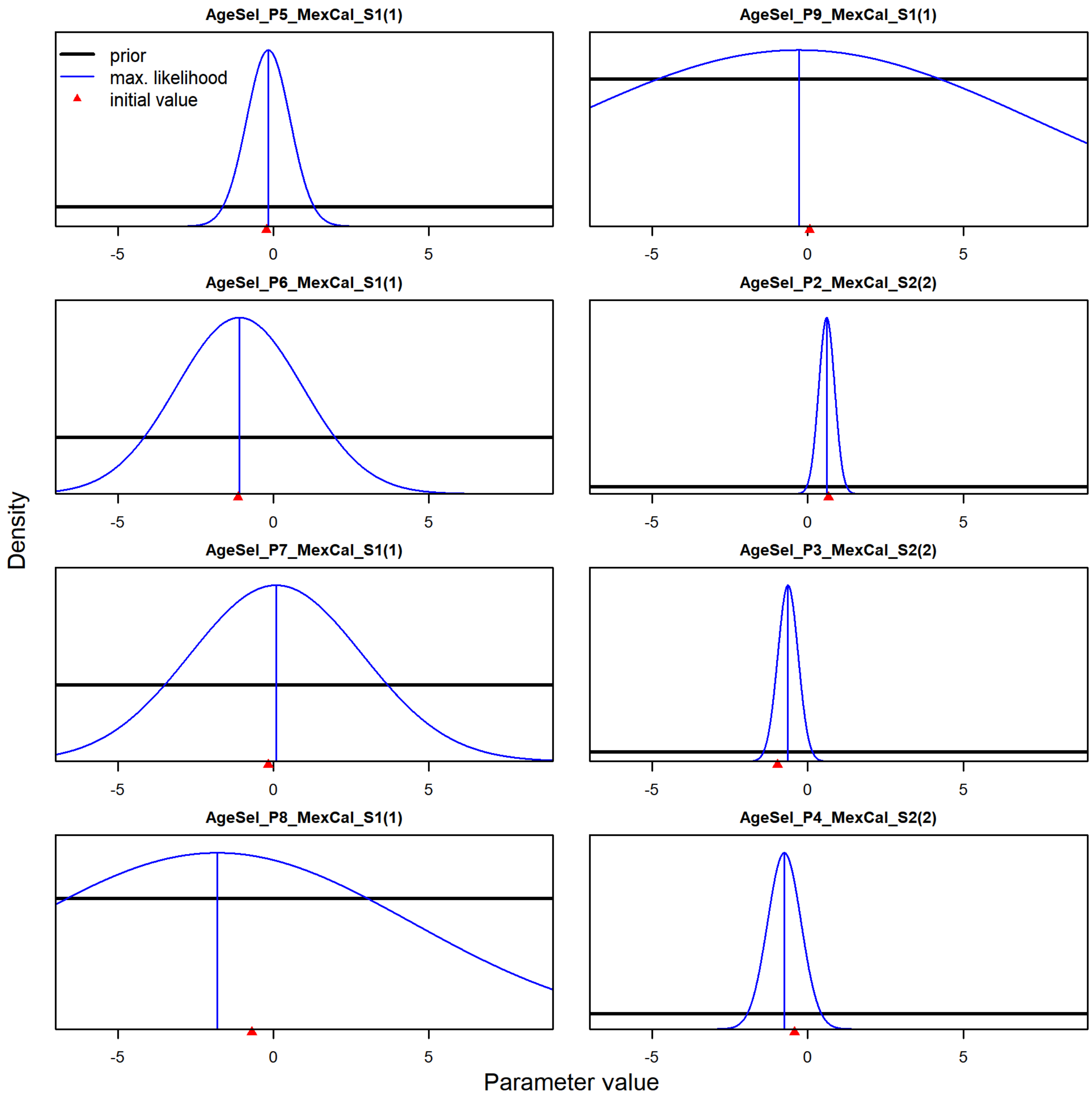
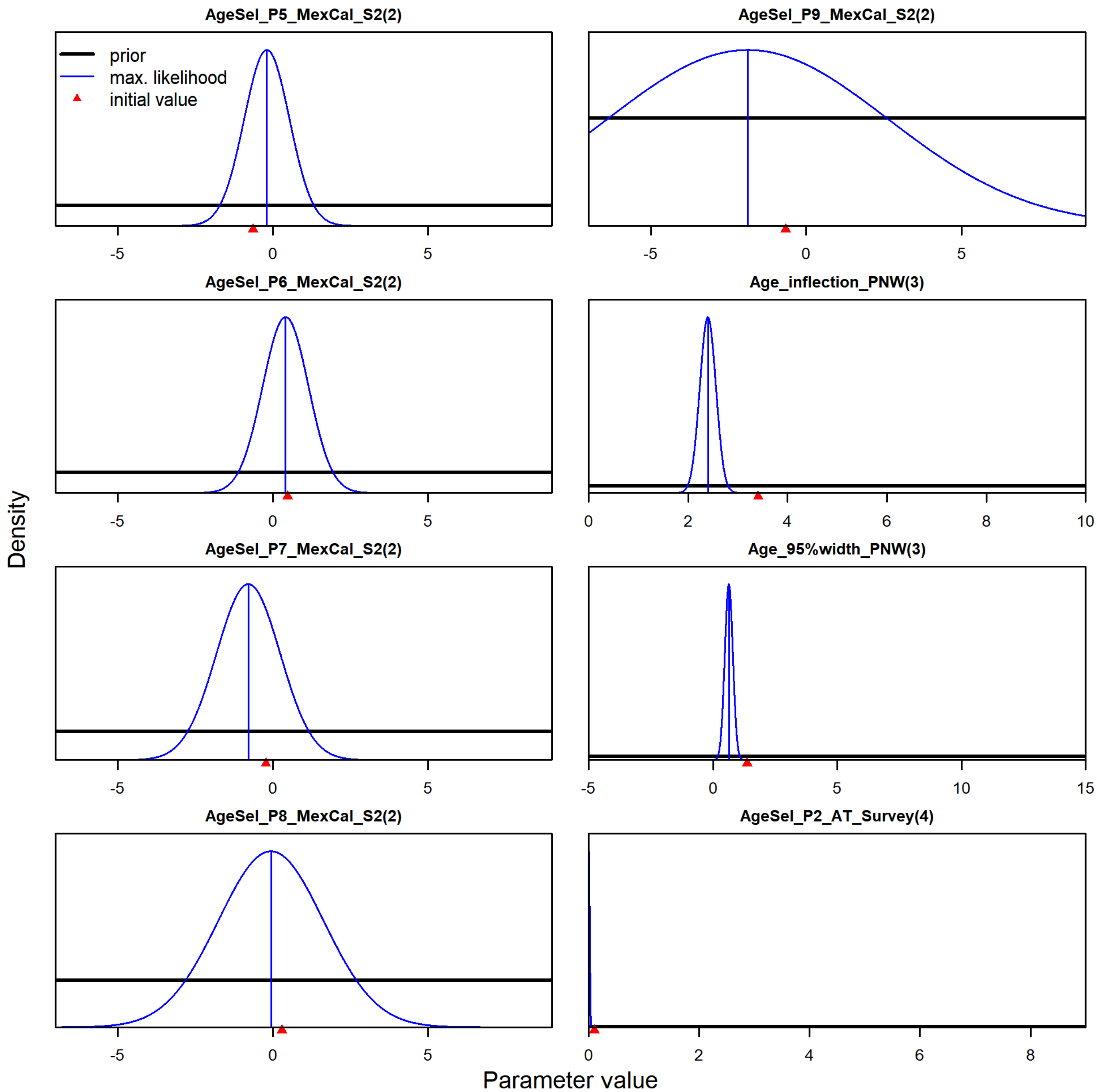
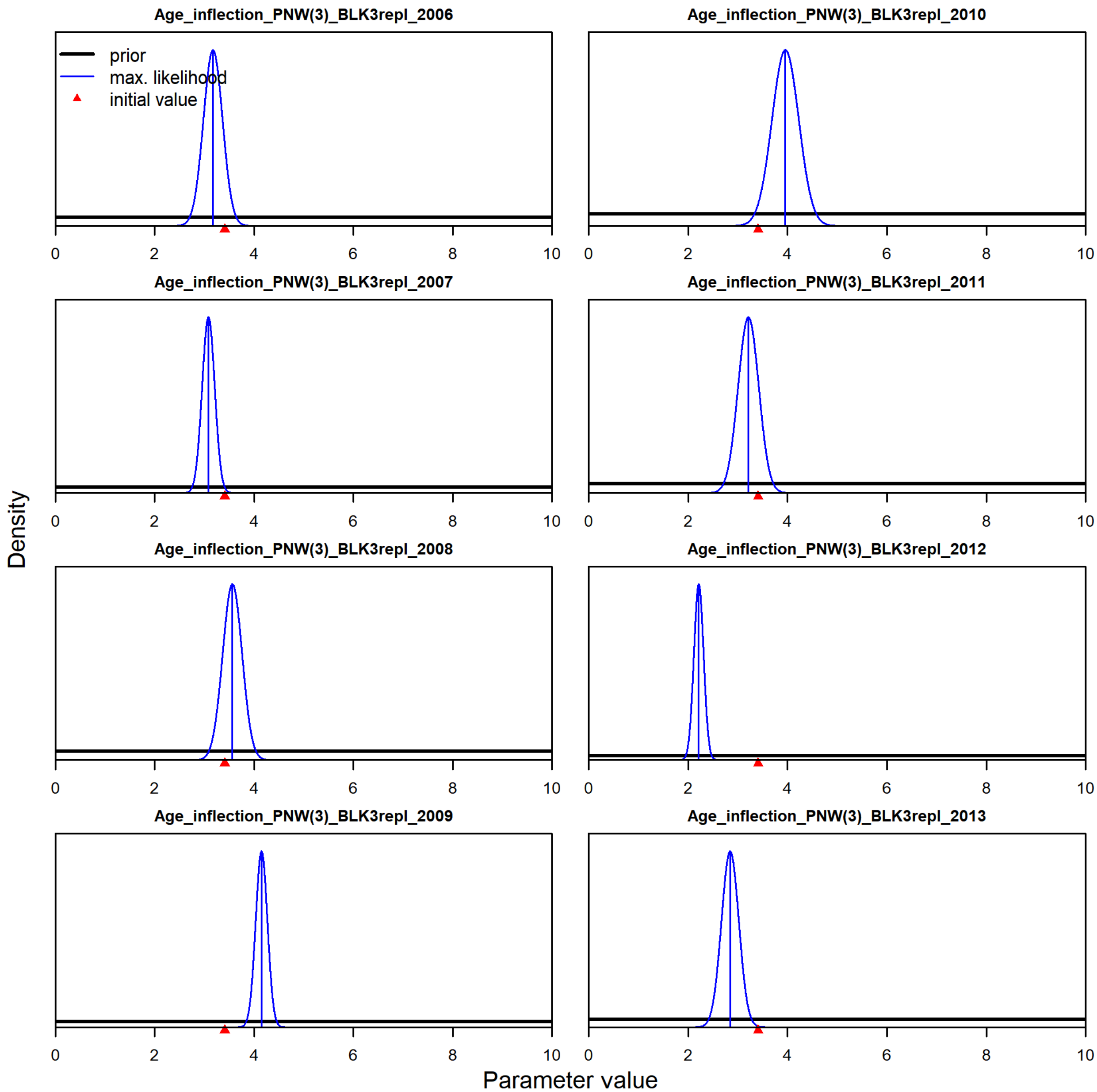


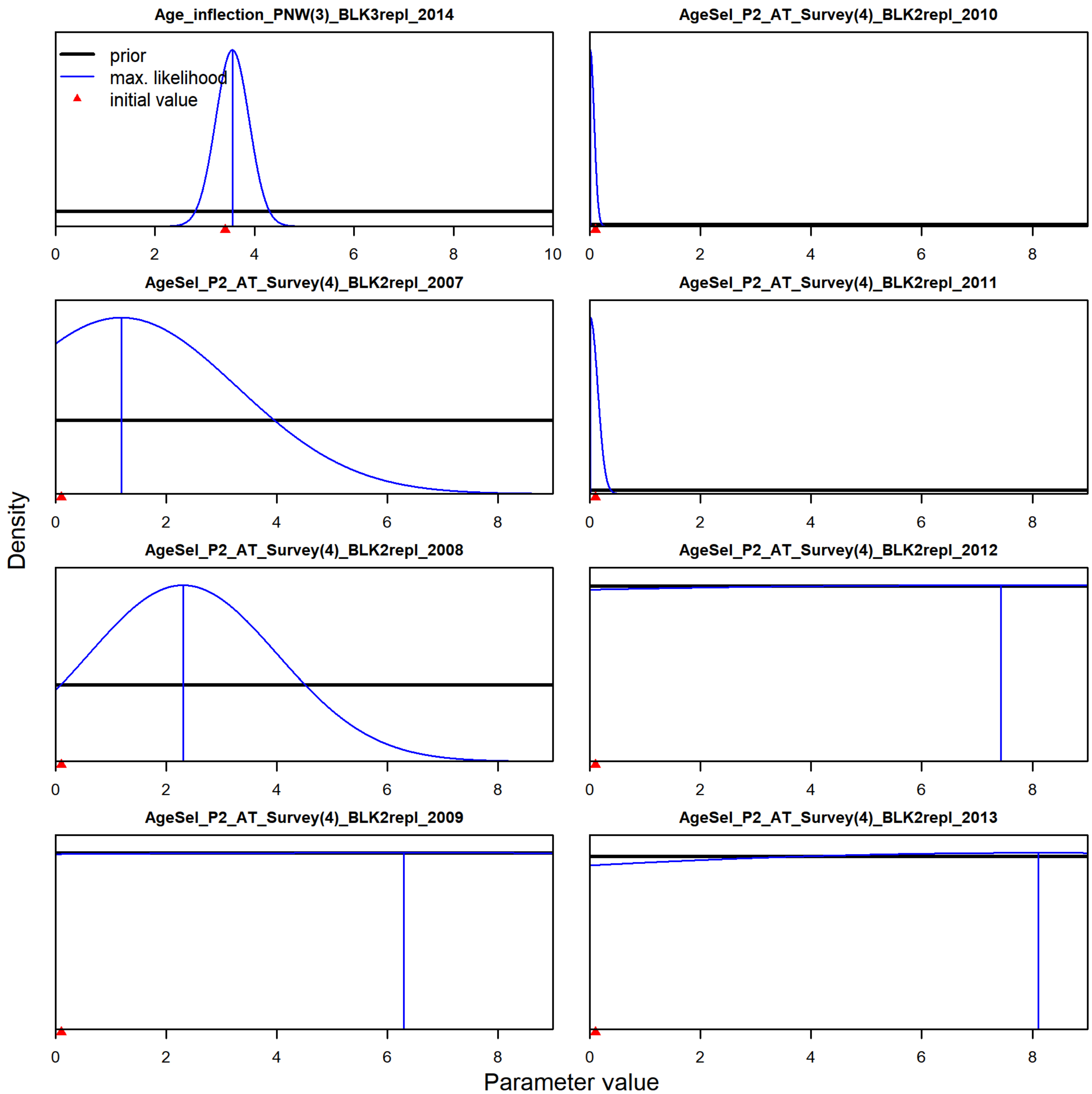
Figure B.14. Transformed recruitment deviations variance, where points are transformed variances, the red line shows current settings for bias adjustment specified in control file, and the blue line shows least squares estimate of alternative bias adjustment relationship for recruitment deviations.


NatM_Lorenzen_averageFem_GP_1
prior
max. likelihood
initial value
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
AgeSel_P1_MexCal_S1(1)
-5
0
5
SR_LN(R0)
5
10
15
20
25
AgeSel_P2_MexCal_S1(1)
SR_regime_BLK1repl_2004
-15
-10
-5
0
5
10
15
AgeSel_P3_MexCal_S1(1)
InitF_seas_1_flt_1MexCal_S1
0.0
0.5
1.0
1.5
2.0
2.5
3.0
AgeSel_P4_MexCal_S1(1)
Density
Parameter value

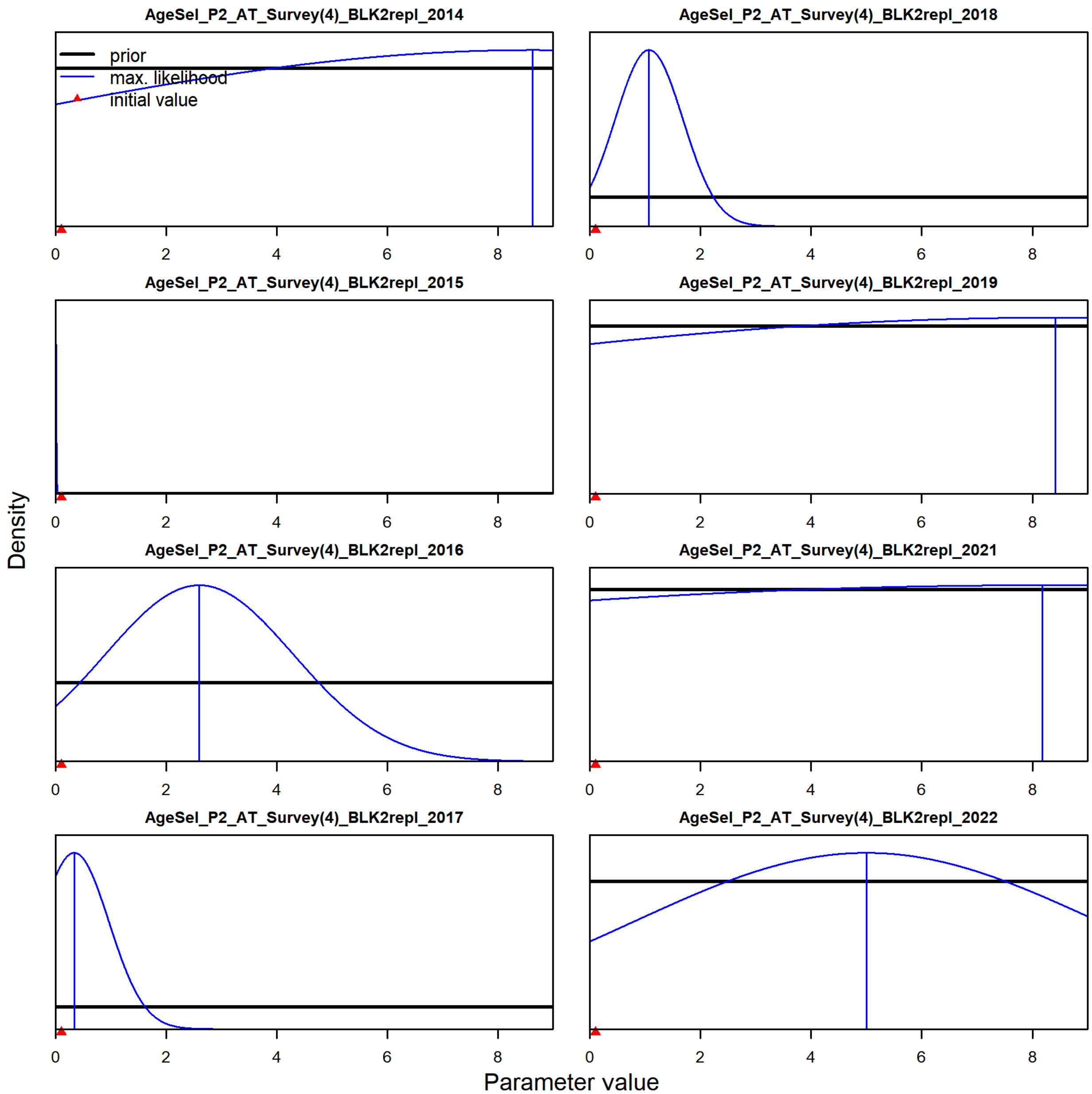

AgeSel_P5_MexCal_S1(1)
prior
max. likelihood
initial value
AgeSel_P9_MexCal_S1(1)
AgeSel_P6_MexCal_S1(1)
AgeSel_P2_MexCal_S2(2)
AgeSel_P7_MexCal_S1(1)
AgeSel_P3_MexCal_S2(2)
AgeSel_P8_MexCal_S1(1)
AgeSel_P4_MexCal_S2(2)
-5
0
5
Density
Parameter value


AgeSel_P5_MexCal_S2(2)
prior
max. likelihood
initial value
AgeSel_P9_MexCal_S2(2)
AgeSel_P6_MexCal_S2(2)
Age_inflection_PNW(3)
AgeSel_P7_MexCal_S2(2)
Age_95%width_PNW(3)
AgeSel_P8_MexCal_S2(2)
AgeSel_P2_AT_Survey(4)
Density
Parameter value


Age_inflection_PNW(3)_BLK3repl_2006
prior
max. likelihood
initial value
Age_inflection_PNW(3)_BLK3repl_2010
Age_inflection_PNW(3)_BLK3repl_2007
Age_inflection_PNW(3)_BLK3repl_2011
Age_inflection_PNW(3)_BLK3repl_2008
Age_inflection_PNW(3)_BLK3repl_2012
Age_inflection_PNW(3)_BLK3repl_2009
Age_inflection_PNW(3)_BLK3repl_2013
0
2
4
6
8
10
Density
Parameter value



Age_inflection_PNW(3)_BLK3repl_2014
prior
max. likelihood
initial value
AgeSel_P2_AT_Survey(4)_BLK2repl_2010
AgeSel_P2_AT_Survey(4)_BLK2repl_2007
AgeSel_P2_AT_Survey(4)_BLK2repl_2011
AgeSel_P2_AT_Survey(4)_BLK2repl_2008
AgeSel_P2_AT_Survey(4)_BLK2repl_2012
AgeSel_P2_AT_Survey(4)_BLK2repl_2009
AgeSel_P2_AT_Survey(4)_BLK2repl_2013
Density
Parameter value


AgeSel_P2_AT_Survey(4)_BLK2repl_2014
prior
max. likelihood
initial value
AgeSel_P2_AT_Survey(4)_BLK2repl_2018
AgeSel_P2_AT_Survey(4)_BLK2repl_2015
AgeSel_P2_AT_Survey(4)_BLK2repl_2019
AgeSel_P2_AT_Survey(4)_BLK2repl_2016
AgeSel_P2_AT_Survey(4)_BLK2repl_2021
AgeSel_P2_AT_Survey(4)_BLK2repl_2017
AgeSel_P2_AT_Survey(4)_BLK2repl_2022
Density
Parameter value
0
2
4
6
8

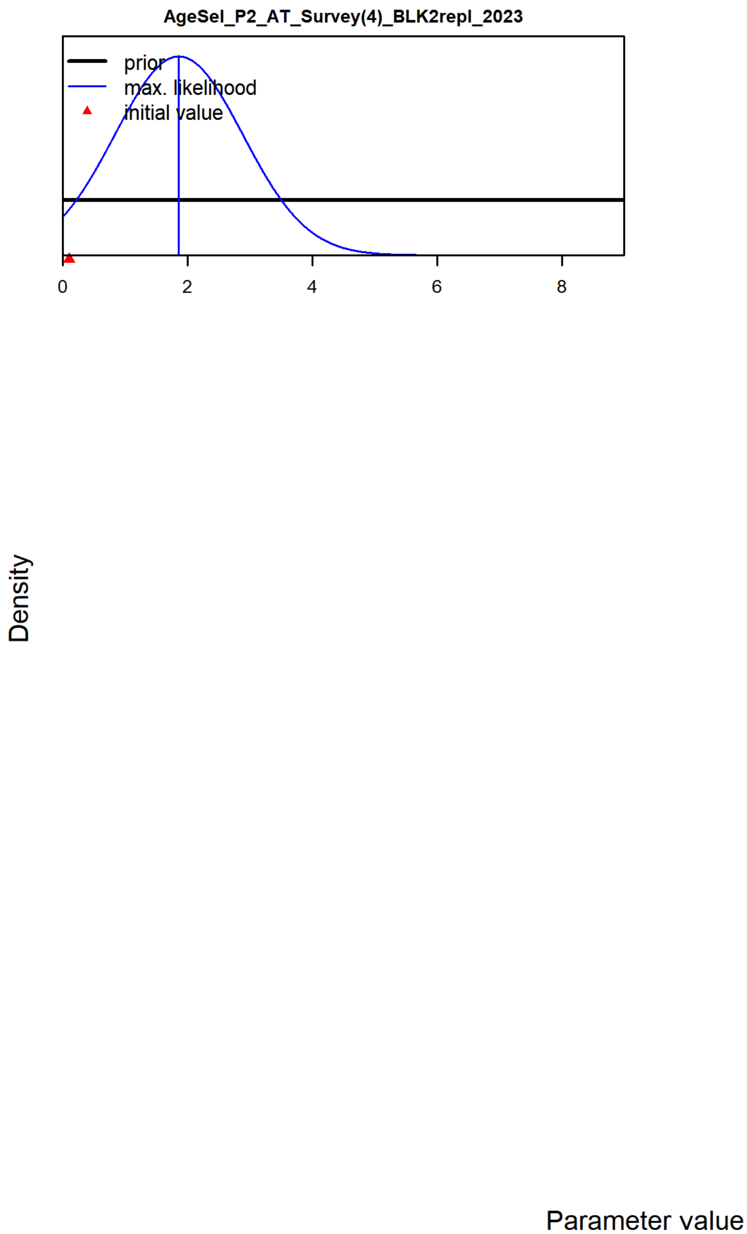


Figure B.15. Parameter prior distributions.

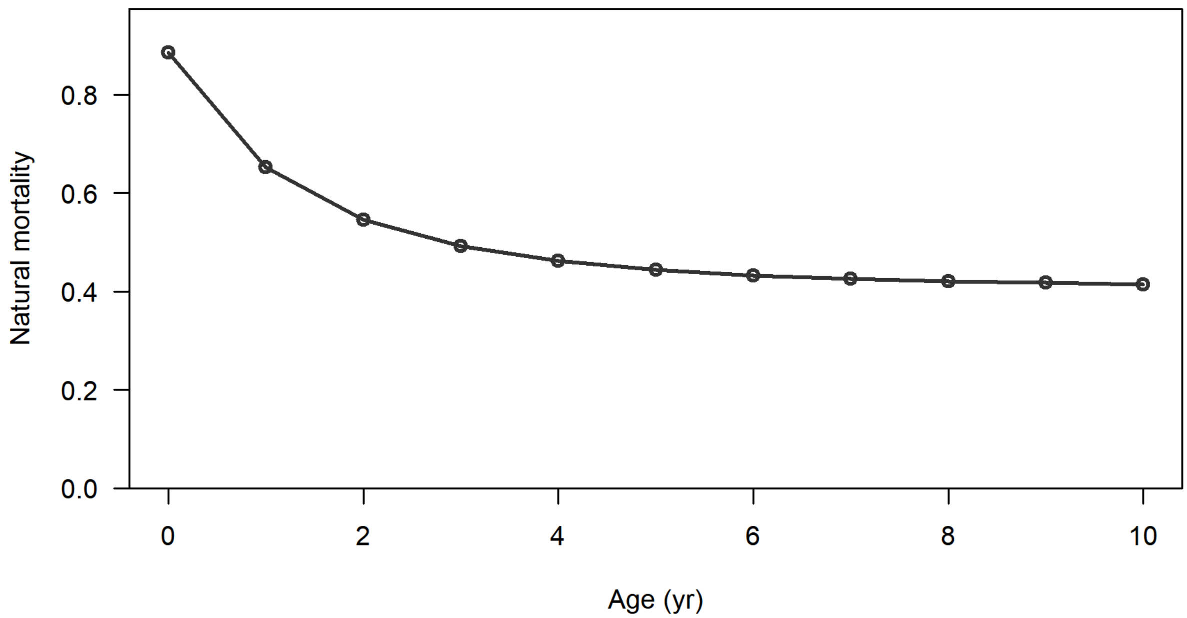


Figure B.16. Natural mortality at age.