Agenda Item D.1
Attachment 1
June 2022

Assessment of the Northern anchovy (*Engraulis mordax*) central subpopulation in 2021 for U.S. management.

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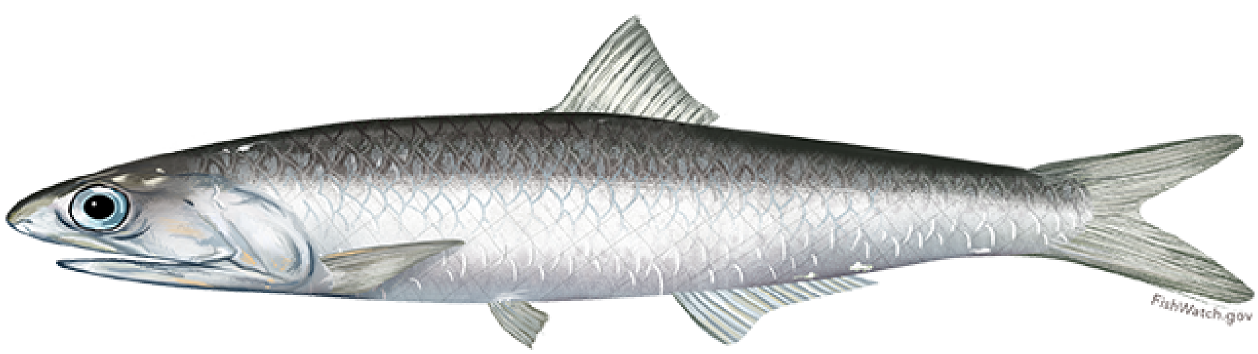

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Assessment of the Northern anchovy (*Engraulis mordax*) central subpopulation in 2021 for U.S. management.

Contents

Executive Summary

The following northern anchovy (*Engraulis mordax* Girard) stock assessment was reviewed at the STAR Panel in December, 2021.

Stock

This assessment focuses on the central subpopulation of northern anchovy (CSNA), a small, short-lived coastal pelagic fish, which ranges from roughly northern California, USA to central Baja California, Mexico. There is a northern subpopulation, which ranges from waters off British Columbia, Canada to Cape Mendocino, CA, USA, and a southern subpopulation, which is found in waters off central Baja California to the Gulf of California, Mexico. The subpopulations have been found to have distinct meristic and serological characteristics (McHugh 1951, Vrooman et al. 1981). CSNA are typically found in waters ranging from 11° to 29° C (Lo 1985), and the three subpopulations do not seem to be genetically distinct (Lecomte et al. 2004). This assessment is focused on fishery and survey information available for CSNA.

Catches

The assessment includes CSNA landings from three major fishing regions: central California, USA (CCA), southern California, USA (SCA), and Ensenada, Mexico (ENS). Landings from each region over the model year-semester combinations are shown beginning in 2015 below in Table ES-1.

Table ES-1: CSNA landings (mt) for the three major fishing regions: central California, USA (CCA), southern California, USA (SCA), and Ensenada, Mexico (ENS). The values are reported for each calendar year-semester (Y-S) and model Y-S.

Calendar Y-S	Model Y-S	CCA	SCA	ENS
2015-2	2015-1	9,325	645	25,751
2016-1	2015-2	384	4,633	1,389
2016-2	2016-1	3,446	170	3,619
2017-1	2016-2	119	236	6,845
2017-2	2017-1	5,098	138	8,881
2018-1	2017-2	6,112	34	18,152
2018-2	2018-1	11,277	91	24,020
2019-1	2018-2	3,680	21	17,090
2019-2	2019-1	6,323	146	18,048
2020-1	2019-2	3,612	14	19,803
2020-2	2020-1	1,895	114	20,934
2021-1	2020-2	1,601	78	19,803
2021-2	2021-1	206	59	7,782

Data and Assessment

The integrated assessment model was developed using Stock Synthesis (SS version 3.30.17), and includes fishery and survey data collected from mid-2015 through 2021. The model is based on a June-May biological year (aka 'model year'), with two semester-based seasons per year (S1=Jun-Dec and S2=Jan-May). Catches and biological samples for the fisheries off ENS, SCA, and CCA were pooled into a single MexCal fleet, for which selectivity was modeled separately in each semester (S1 and S2). A single AT survey index of abundance from ongoing SWFSC surveys (2015-2021) was included in the model.

The base model incoporates the following specifications:

- Sexes were combined; ages 0-3+;
- One fishery (MexCal), with seasonal selectivity patterns (S1 and S2);
- MexCal fleets had age-based selectivity (time-varying and 2dAR option in Stock Synthesis 3);
- Length-based selectivity fixed at 1 for all lengths and for the AT survey and two semester-based fishing fleets;
- AT survey age compositions with effective sample sizes set to 1 per cluster (externally);
- Fishery age compositions with effective sample sizes calculated by dividing the number of fish sampled by 25 (externally) and lambda weighting=1 (internally);
- Beverton-Holt stock-recruitment relationship with steepness set to 0.6;
- Initial equilibrium ("SR regime" parameter) estimated with the 'lambda' for this parameter set to zero (no penalty contributing to total likelihood estimate);
- Natural mortality (M) estimated;
- Recruitment deviations estimated from 2015-2021;
- Virgin recruitment estimated, and total recruitment variability (σ_R) fixed at 1;
- Initial fishing mortality (F) estimated for the MexCal S1 fleet and assumed to be 0 yr^{-1} for the other fleets;
- AT survey biomass 2015-2021, partitioned into two (spring and summer) surveys, with catchability (Q) set to 0.579 for spring (0.580 for spring 2020 based on aerial survey estimate) and 0.930 for summer;
- AT survey age-based selectivity is assumed to be uniform (fully-selected) above age-1 and estimated annually for age-0.

Spawning Stock Biomass and Recruitment

Time series of estimated spawning stock biomass (SSB, mmt) from the base model and associated 95% confidence intervals are displayed in Figure ES-1 and Table ES-2. The initial level of SSB was estimated to be 92,598 mt. The SSB has continually increased since 2015, and the SSB was projected to be 3,548,420 mt in January 2022 from the base model.

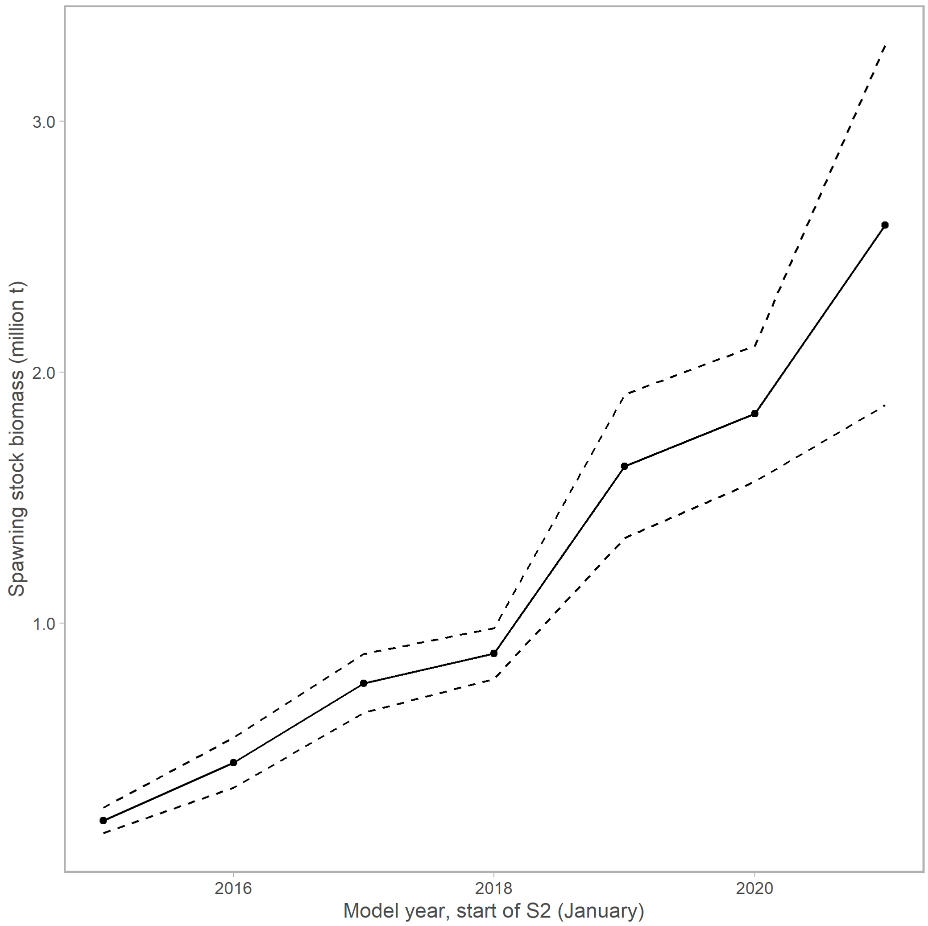

Figure ES-1: Spawning stock biomass time series (95% CI dashed lines).

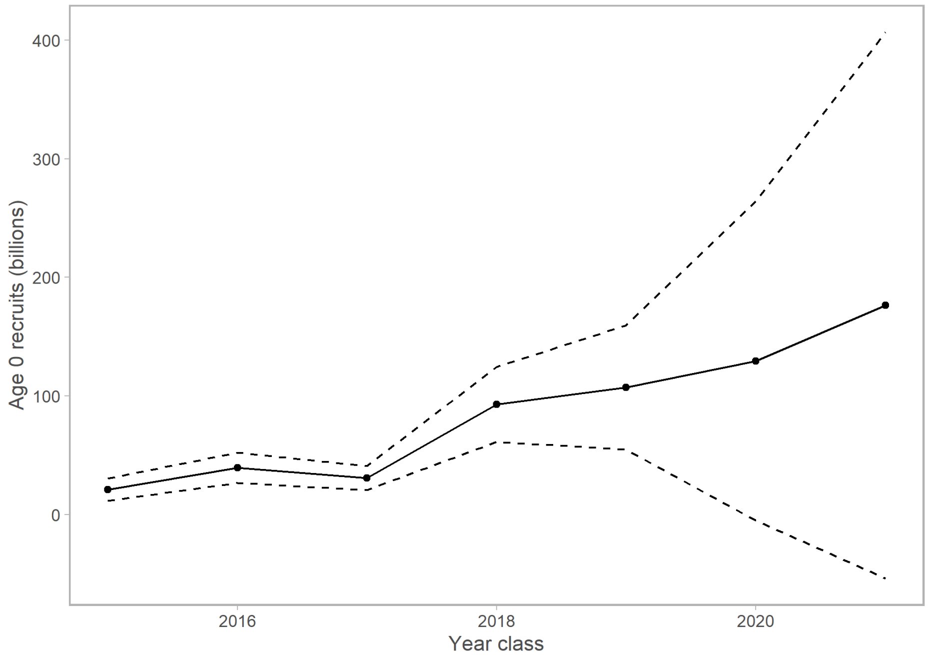

Figure ES-2: Estimated recruitment (age-0, billions of fish) time series.

Time series of estimated recruitment (age-0, billions of fish) abundance is presented in Figure ES-2 and Table ES-2 in the base model. The initial level of recruitment (R_0) was estimated to be 25,745,900 age-0 thousands of fish. As indicated for SSB above, recruitment has increased throughout the base model time period.

Table ES-2: Spawning stock biomas (SSB) and recruitment (1000s of fish) estimates and asymptotic standard errors for the base model. SSB estimates were calculated at the beginning of semester 2 of each model year (January). Recruits were age-0 fish calculated at the beginning of each model year (June).

Calendar Y-S	Model Y-S	SSB	SSB sd	Recruits	Recruits sd
–	VIRG-1	0	0	0	0
–	VIRG-2	10,685,800	12,514,700	269,708,000	247,391,000
–	INIT-1	0	0	0	0
–	INIT-2	92,598	52,012	0	0
2015-2	2015-1	0	0	25,745,900	7,001,730
2016-1	2015-2	213,162	50,714	0	0
2016-2	2016-1	0	0	21,009,800	9,480,240
2017-1	2016-2	443,476	99,593	0	0
2017-2	2017-1	0	0	39,546,800	12,836,000
2018-1	2017-2	759,613	117,717	0	0
2018-2	2018-1	0	0	30,643,300	10,092,800
2019-1	2018-2	879,476	101,516	0	0
2019-2	2019-1	0	0	92,894,400	31,484,800
2020-1	2019-2	1,625,280	285,553	0	0
2020-2	2020-1	0	0	107,169,000	52,421,600
2021-1	2020-2	1,835,140	270,099	0	0
2021-2	2021-1	0	0	129,427,000	134,584,000
2022-1	2021-2	2,586,700	718,182	0	0
2022-2	2022-1	0	0	176,376,000	230,134,000
2023-1	2022-2	3,548,420	2,003,880	0	0

Stock Biomass for PFMC Management

Stock biomass, used for calculating annual harvest specifications, is defined as the sum of the biomass for CSNA ages one and older (age-1+, mt) at the start of the management year. Time series of estimated stock biomass from the base model are presented in Figure ES-3 and Table ES-3. As discussed above for both SSB and recruitment, a similar trend of increasing stock biomass has been observed since 2015. The base model stock biomass was estimated in 2021 to be 2,090,640 mt and is projected to be 2,879,010 mt in June 2022.

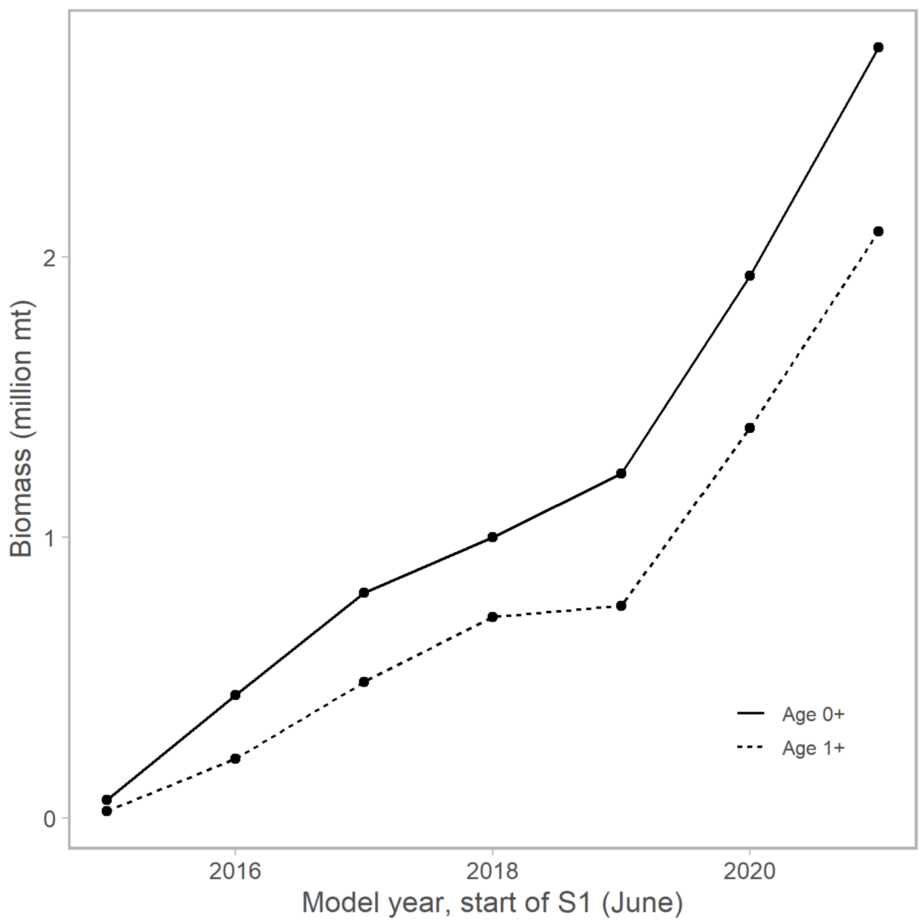

Figure ES-3: Estimated total biomass (age-0+ fish; mt) and stock biomass (age-1+ fish; mt) time series for the base model.

Table ES-3: Total (age-0+) and summary (age-1+) biomass values (mt) estimated on June 1 of each year.

Year	Age-0+	Age-1+
2015	64,830	24,810
2016	437,939	211,662
2017	803,290	484,605
2018	1,001,840	716,804
2019	1,227,790	757,029
2020	1,933,090	1,389,990
2021	2,746,530	2,090,640

Exploitation Status

Exploitation rate is defined as the calendar year CSNA catch divided by the total mid-year biomass (June-1, ages-0+). Based on the base model estimates, the U.S. exploitation rate has averaged about 3% since 2015, peaking at 15% in 2015. The total exploitation rates were 1% in 2021, largely driven by catches from Mexico. Exploitation rates for CSNA, calculated from the base model, are presented in Figure ES-4 and Table ES-4.

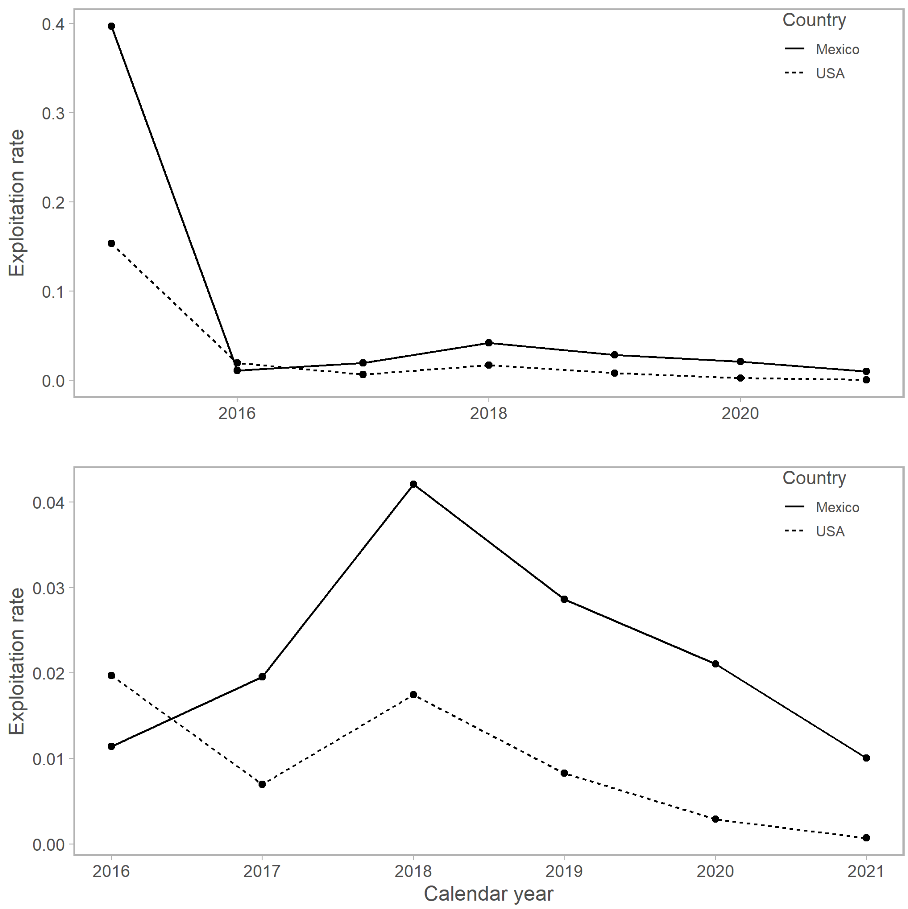

Figure ES-4: Annual exploitation rates (calendar year landings / June total biomass) for the base model.

Table ES-4: Annual exploitation rate (calendar year landings / June total biomass) by country and calendar year.

Calendar Year	Mexico	USA	Total
2015	0.40	0.15	0.55
2016	0.01	0.02	0.03
2017	0.02	0.01	0.03
2018	0.04	0.02	0.06
2019	0.03	0.01	0.04
2020	0.02	0.00	0.02
2021	0.01	0.00	0.01

Ecosystem Considerations

Juvenile anchovies, generally distributed inshore, are vulnerable to a variety of predators, including birds and some recreationally and commercially important species of fish (Szoboszlai et al. 2015, Koehn et al. 2016). As adults offshore, anchovies are fed upon by numerous marine fishes (some of which have recreational and commercial value), marine mammals, and birds such as the California brown pelican (Koehn et al. 2017).

Ecosystem linkages to CSNA productivity are poorly understood. Until recently, it has generally been assumed that anchovy increase productivity under cooler ocean conditions and sardine under warmer ocean conditions (Chavez et al. 2003), but the current CSNA boom began amid two marine heat waves seems to contradict this assumption (Thompson et al. 2019). Sardine and anchovy under warm and cold ocean regimes were thought to fluctuate asynchronously (Chavez et al. 2003), although analysis of sardine and anchovy time series across the world did not find evidence of widespread asynchrony (Siple et al. 2020). Environmental drivers may be density-dependent as no physical or biological variable correlated to CSNA biomass for time series dating from 1951 to 2015 have been found (Sydeman et al. 2020).

Harvest Control Rules

The CPS FMP includes a default harvest control for stocks without a stock-specific harvest control rule (HCR). The default HCR, which is currently used for CSNA, includes an OFL based on species-specific MSY proxy. The default ABC control rule consists of a 75 percent reduction from OFL to ABC. The ACL is determined by the PFMC and may be equal or lower than the ABC.

F_{MSY} was estimated in the base model, which assumed a fixed steepness value of 0.6, to be 0.493 (see Appendix E). Note that F_{MSY} was calculated to be catch/summary age-1+ biomass and not the fully selected fishing mortality corresponding to MSY. In this case, F_{MSY} can exceed 1 because selectivity for age-0 fish is non-zero.

The STAT preferred the short-term model based on the period of greatest data availability for the AT survey from 2015 to 2021, and the fact that the longer-term model was less stable. A ten-year time series of biomass estimates is required under the anchovy management framework adopted in COP 9, schedule 3 for determination of the average biomass component of the OFL. The biomass estimates resulting from the shorter-term revised base model provide fewer years for estimating the average biomass. Surveys for short-term biomass are better informed given data availability in the recent past, and more years of data can be added to update the OFL and ABC with a longer-term average biomass from a longer time series. The management quantities can be informed with the current short-term assessment model but could be revisited when additional data are available from 2015 to 2025, and assessment considerations are addressed. Final recommendations will come from the SSC.

Management Performance

The CSNA fishery has been managed by the Pacific Fishery Management Council since 1978. Regulations currently described in the fishery management plan (FMP) designate the northern anchovy fishery as 'monitored', not 'actively managed', due to relatively low fishery demand (PFMC 1990). The FMP is currently being revised to remove the 'active' and 'monitored' management categories, and more regular assessments of the CSNA are anticipated. The default MSY control rule in the FMP gives an ABC for the entire stock equal to 25 percent of the MSY catch. An estimated 82 percent of the stock is assumed to be resident in U.S. waters. ABC in U.S. waters is 25,000 mt. NMFS issued a new rule in response to a 2020 court decision (Oceana, Inc. v. Ross et al.), implementing an OFL of 119,153 mt, an ABC of 29,788 mt, and an ACL of 25,000 mt. The fishery has not caught this default amount since the onset of federal management. Harvests in major fishing regions from Ensenada to Central California (CCA) are provided in Table ES-1 and Figure ES-5. The U.S. HG/ACL values and catches since the onset of federal management are presented in Table ES-5.

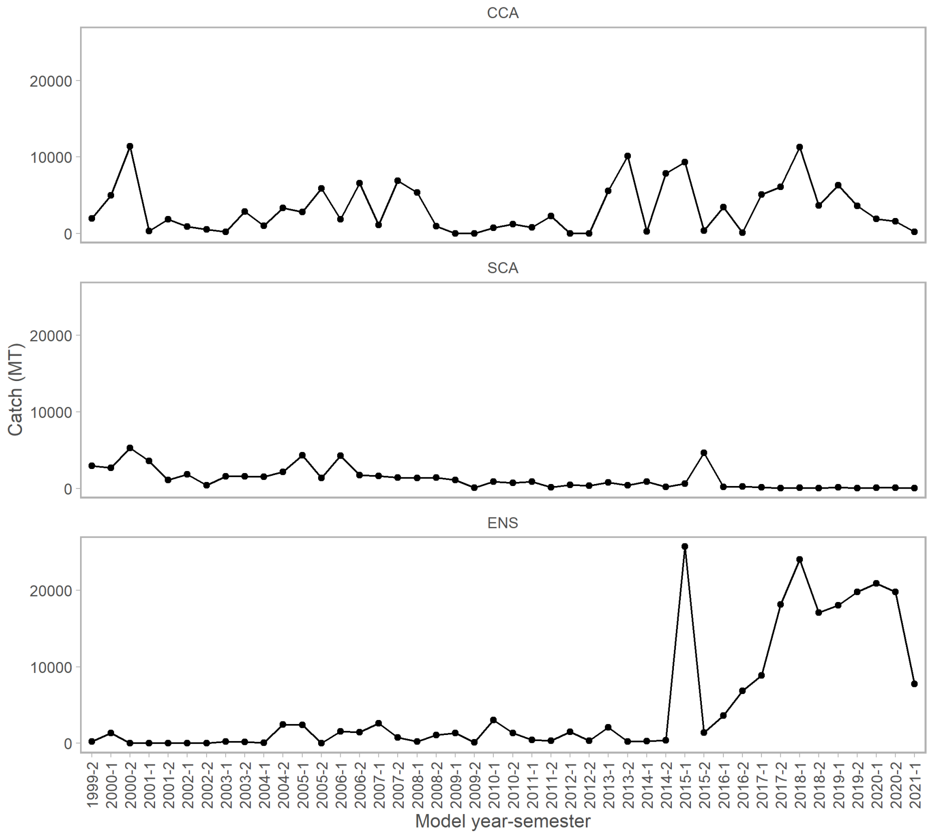

Figure ES-5: CSNA landings (mt) by major fishing region (Central California, Southern California, and Ensenada, Mexico).

Table ES-5: US CSNA landings (mt) by model year (beginning June 1). CSNA has been considered a monitored species with an OFL of 100,000 mt and ABC and ACL equal to 25,000 mt in most years. The 2021 ABC was 29,788 mt.

Model year	OFL	ABC/ACL	US Landings	Percentage ACL
1999	100,000	25,000	4,915	20
2000	100,000	25,000	24,363	97
2001	100,000	25,000	6,884	28
2002	100,000	25,000	3,617	14
2003	100,000	25,000	6,174	25
2004	100,000	25,000	8,096	32
2005	100,000	25,000	14,383	58
2006	100,000	25,000	14,437	58
2007	100,000	25,000	11,049	44
2008	100,000	25,000	9,120	36
2009	100,000	25,000	1,184	5
2010	100,000	25,000	3,604	14
2011	100,000	25,000	4,073	16
2012	100,000	25,000	787	3
2013	100,000	25,000	16,843	67
2014	100,000	25,000	9,191	37
2015	100,000	25,000	14,987	60
2016	100,000	25,000	3,971	16
2017	100,000	25,000	11,382	46
2018	100,000	25,000	15,069	60
2019	94,290	23,573	10,095	43
2020	94,290	23,573	3,688	16
2021	119,153	25,000	265	1

Research and Data Needs

Nearshore biomass, particularly the area inshore of the past AT survey footprint, will likely be an uncertainty when the anchovy population declines to low levels. There have been methodological improvements to the AT nearshore survey and aerial survey, and such refinements should continue.

The distribution of anchovy across the US-Mexico border will be a research need, particularly when the population drops to low levels. The summer 2021 AT survey was able to survey in Mexican waters, and hopefully such efforts will be able to continue.

Ageing consistency remains a research need that the SWFSC and CDFW are committed to working on in the future.

Habitat separation may be one research need, although northern and central subpopulation anchovy seem to be well separated given recent survey cruise reports (e.g. Stierhoff et al. 2019).