Agenda Item F.2.b
Attachment 1
Pacific Sardine Assessment Executive Summary
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ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2011 FOR U.S. MANAGEMENT IN 2012

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EXECUTIVE SUMMARY

Stock

Pacific sardine (*Sardinops sagax caerulea*) range from southeastern Alaska to the Gulf of California, México, and are thought to comprise three subpopulations. In this assessment, we presumed to model the northern subpopulation which ranges seasonally from northern Baja California, México, to British Columbia, Canada, and up to 300 nm offshore. All U.S., Canada, and México (Ensenada) landings were assumed to be taken from a single northern stock. Future modeling efforts may explore a scenario where Ensenada and San Pedro catches are parsed into the northern and southern stocks using some objective criteria.

Catches

The assessment includes sardine landings from six major fishing regions: Ensenada, southern California, central California, Oregon, Washington, and British Columbia.

Calendar year	ENS	SCA	CCA	OR	WA	BC	Total
2000	67,845	46,835	11,367	9,529	4,765	1,721	142,063
2001	46,071	47,662	7,241	12,780	10,837	1,266	125,857
2002	46,845	49,366	14,078	22,711	15,212	739	148,952
2003	41,342	30,289	7,448	25,258	11,604	978	116,919
2004	41,897	32,393	15,308	36,112	8,799	4,438	138,948
2005	55,323	30,253	7,940	45,008	6,929	3,232	148,684
2006	57,237	33,286	17,743	35,648	4,099	1,575	149,588
2007	36,847	46,199	34,782	42,052	4,663	1,522	166,065
2008	66,866	31,089	26,711	22,940	6,435	10,425	164,466
2009	55,911	12,561	25,015	21,482	8,025	15,334	138,328
2010	56,821	29,382	4,306	20,853	12,381	22,223	145,965

Data and assessment

This assessment was conducted using 'Stock Synthesis' version 3.21d and includes fishery and survey data collected from mid-1993 through mid-2011. The model uses a July-June 'model year', with two semester-based seasons per year (S1=Jul-Dec and S2=Jan-Jun). Catches and biological samples for the fisheries off Ensenada, southern California, central California were pooled into a single 'MexCal' fleet, in which selectivity was modeled separately for each season (S1 & S2). Catches and biological samples from Oregon, Washington, and British Columbia were modeled as a single 'PacNW' fleet. Four indices of relative abundance were included in the base model: daily egg production method and total egg production estimates of spawning stock biomass off California (1994-2011), aerial survey estimates of biomass off Oregon and Washington (2009-2011), and acoustic estimates of biomass observed from California to Washington (2006-2011). Catchability coefficient (q) for the acoustic survey was fixed at 1 in the base model. All other survey qs were freely estimated.

Unresolved problems and major uncertainties

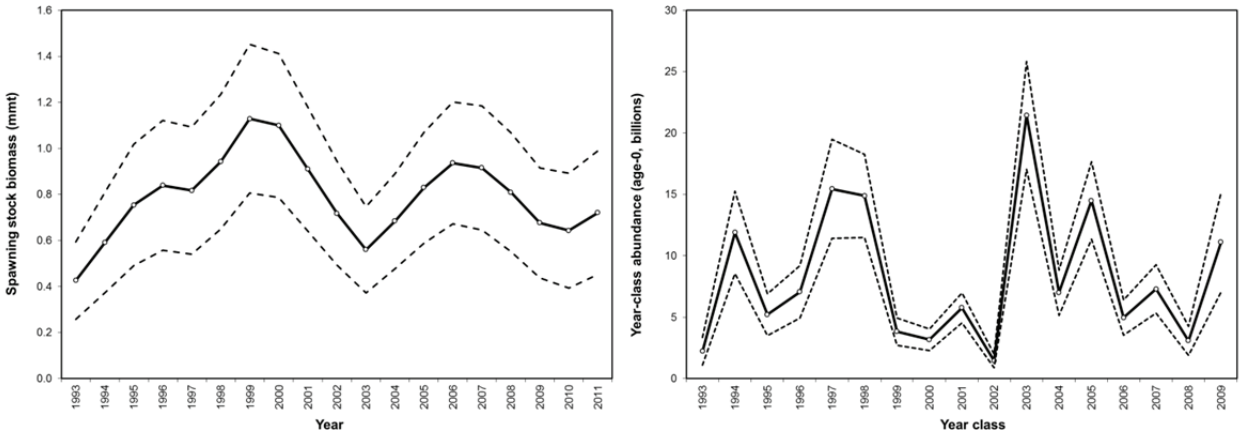
As in the past, the sardine model can be sensitive with regard to scaling of population estimates. While model likelihoods were robust to large changes in scale (i.e., flat likelihood surface), some model scenarios (e.g. extended time series, or treating Canadian fishery separately) resulted in implausibly high fishing mortality rates at the start and/or end of the modeled time series. In the 2009 and 2010 assessments, the scaling problem was addressed by fixing the aerial survey

catchability coefficient (q) to equal 1. For the current assessment, model scaling and stability was improved, in part, by simplifying overall model structure (e.g. fewer time-varying elements and fleets) and reducing the number of estimated parameters. Final base model stability was further improved by fixing q for the acoustic time series to equal 1. The acoustic biomass survey was chosen due to the more synoptic nature and longer time series available for the survey. A more detailed listing of modeling issues and uncertainties may be found in the body of this report as well as the STAR (2011) panel report.

Spawning Stock Biomass and Recruitment

Recruitment was modeled using the Ricker stock-recruitment relationship (σ_R=0.62). The estimate of steepness was high (h=2.96), and virgin recruitment (R_0) was estimated to be 6.2 billion age-0 fish. Virgin SSB was estimated to be 0.969 mmt. Spawning stock biomass (SSB) increased throughout the 1990s, with peaks at 1.13 mmt in 1999 and 0.936 mmt in 2006. Recruitment (year-class abundance) peaked at 15.5 billion fish in 1997, 14.9 billion in 1998, 21.4 billion in 2003, and 14.5 billion in 2005. The 2009 year class was estimated to be 11.1 billion fish, higher than the recent average.

Model year	SSB (mt)	SSB Std Dev	Year class abundance (billions)	Recruits Std Dev
2000	1,099,300	156,590	3.176	0.441
2001	910,030	134,710	5.774	0.611
2002	717,380	112,480	1.453	0.280
2003	559,170	93,958	21.444	2.198
2004	683,570	103,390	7.007	0.927
2005	828,760	120,630	14.502	1.573
2006	936,130	132,590	4.968	0.714
2007	915,230	134,720	7.299	0.987
2008	809,350	128,620	3.081	0.584
2009	675,810	119,320	11.107	2.028
2010	642,830	124,630	---	---
2011	720,420	134,540	---	---

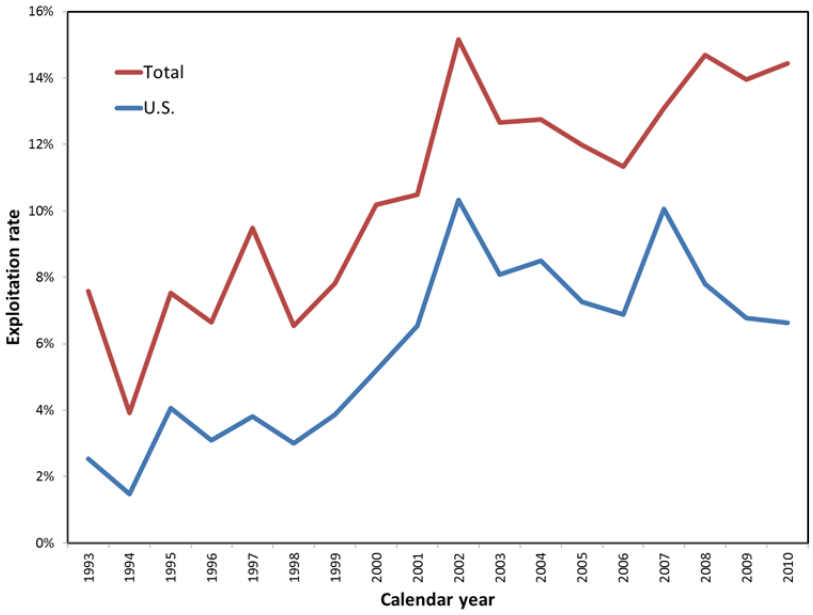


Stock biomass

Stock biomass, used for calculating harvest specifications, is defined as the sum of the biomass for sardine ages 1 and older. Biomass increased rapidly throughout the 1990s, peaking at 1.45 mmt in 1999 and 1.27 mmt in 2006. Stock biomass was estimated to be 988,385 mt as of July 2011.

Exploitation status

Exploitation rate is defined as calendar year catch divided by total mid-year biomass (July-1, ages 0+). U.S. exploitation rate has averaged 7.6% since 2000 and is currently about 6.6%. Total coast-wide exploitation rate has averaged 12.8% since 2000 is currently about 14.5%.



Calendar year	U.S. rate	Total rate
2000	5.20%	10.19%
2001	6.54%	10.48%
2002	10.32%	15.16%
2003	8.08%	12.67%
2004	8.50%	12.75%
2005	7.26%	11.98%
2006	6.88%	11.34%
2007	10.06%	13.09%
2008	7.79%	14.70%
2009	6.77%	13.95%
2010	6.62%	14.45%

Harvest Specifications

Harvest Guideline for 2012

Using results from the final base model ('X5'), the harvest guideline for the U.S. fishery in calendar year 2012 would be 109,409 mt. To calculate the HG for 2012, we used the harvest control rule defined in Amendment 8 of the Coastal Pelagic Species-Fishery Management Plan (PFMC 1998). This formula is intended to prevent Pacific sardine from being overfished and maintain relatively high and consistent catch levels over the long-term. The Amendment 8 harvest guideline for sardine is calculated:

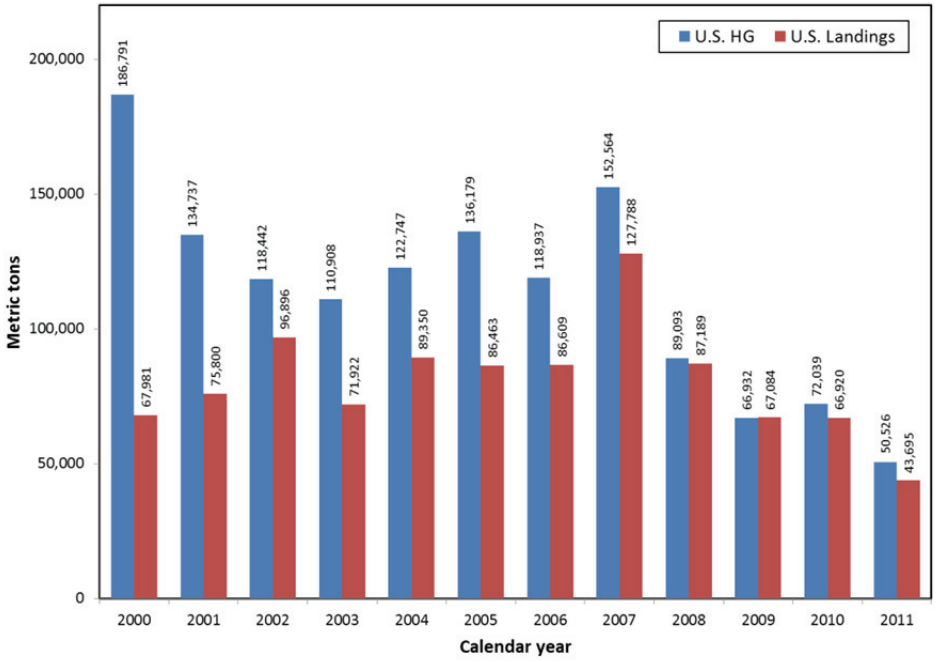
$$HG_{2012} = (BIOMASS_{2011} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2012} is the total U.S. (California, Oregon, and Washington) harvest guideline for 2012, $BIOMASS_{2011}$ is the estimated July 1, 2011 stock biomass (ages 1+) from the assessment (988,385 mt), CUTOFF is the lowest level of estimated biomass at which harvest is allowed (150,000 mt), FRACTION is an environmentally-based percentage of biomass above the CUTOFF that can be harvested by the fisheries, and DISTRIBUTION (87%) is the average portion of BIOMASS assumed in U.S. waters.

The following formula has been used to determine FRACTION value:

$$FRACTION = 0.248649805(T^2) - 8.190043975(T) + 67.4558326;$$

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding seasons (July-June). Under Option J (PFMC 1998), F_{MSY} is constrained and ranges between 5% and 15%. Based on T values observed throughout the period covered by this stock assessment, the appropriate exploitation fraction has consistently been 15%; and this remains the case under current conditions (T_{2011} = 17.7 °C). U.S. harvest guidelines and catches since 2000 are displayed below.



OFL and ABC

The Magnuson-Stevens Reauthorization Act requires fishery managers to define an overfishing limit (OFL), allowable biological catch (ABC), and annual catch limit (ACLs) for species managed under federal FMPs. By definition, ABC and ACL must always be lower than the OFL based on uncertainty in the assessment approach. The PFMC's SSC recommended the '*P**' approach for buffering against scientific uncertainty when defining ABC, and this approach was adopted under Amendment 13 to the CPS-FMP.

The estimated biomass of 988,385 (ages 1+, mt), an F_{MSY} of 0.1985 based on a relationship between temperature and F_{MSY}, and an estimated distribution of 87% of the stock in U.S. waters results in a U.S. OFL of 170,689 mt for 2012. For Pacific sardine, the SSC has recommended that scientific uncertainty (σ) be set to the maximum of either (1) the CV of the biomass estimate for the most recent year or (2) a default value of 0.36, which was based on uncertainty across full sardine assessment models. Model CV for the terminal year biomass was equal to 0.187 (σ =0.185); therefore scientific uncertainty (σ) was set to the default value of 0.36. The Amendment 13 ABC buffer depends on the probability of overfishing level chosen by the Council (*P**). Uncertainty buffers and ABCs associated with a range of discreet *P** values are presented in the table below.

Harvest Formula Parameters	Value			
BIOMASS (ages 1+, mt)	988,385			
*P** (probability of overfishing)	0.45	0.40	0.30	0.20
$BUFFER_{P^*}$ (Sigma=0.36)	0.95577	0.91283	0.82797	0.73861
F_{MSY} (upper quartile SST)	0.1985			
FRACTION	0.15			
CUTOFF (mt)	150,000			
DISTRIBUTION (U.S.)	0.87			

Harvest Control Rules	MT
OFL = BIOMASS * F_{MSY} * DISTRIBUTION	170,689
$ABC_{0.45}$ = BIOMASS * $BUFFER_{0.45}$ * F_{MSY} * DISTRIBUTION	163,140
$ABC_{0.40}$ = BIOMASS * $BUFFER_{0.40}$ * F_{MSY} * DISTRIBUTION	155,810
$ABC_{0.30}$ = BIOMASS * $BUFFER_{0.30}$ * F_{MSY} * DISTRIBUTION	141,325
$ABC_{0.20}$ = BIOMASS * $BUFFER_{0.20}$ * F_{MSY} * DISTRIBUTION	126,073
HG = (BIOMASS - CUTOFF) * FRACTION * DISTRIBUTION	109,409