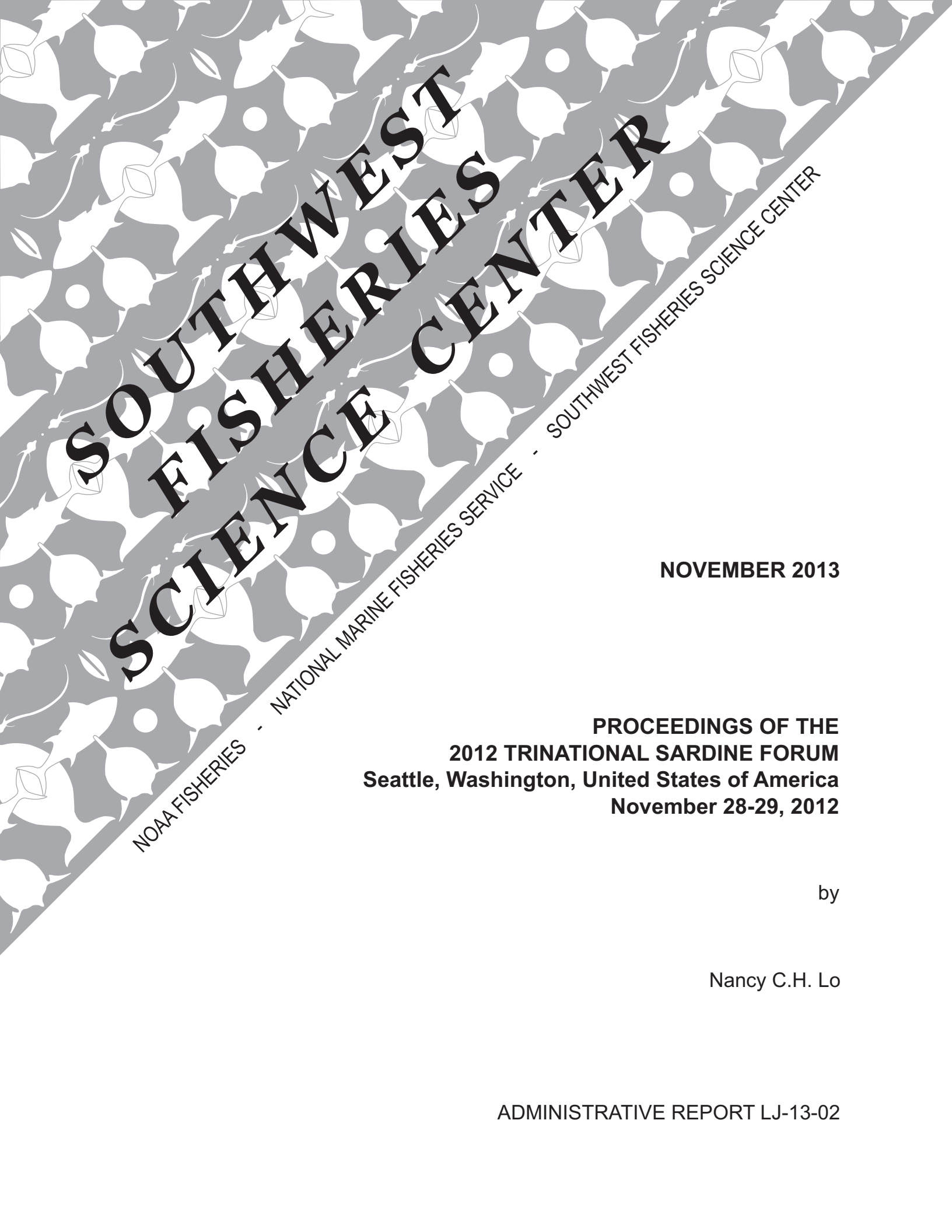




SOUTHWEST FISHERIES SCIENCE CENTER

NOAA FISHERIES - NATIONAL MARINE FISHERIES SERVICE - SOUTHWEST FISHERIES SCIENCE CENTER

NOVEMBER 2013

**PROCEEDINGS OF THE
2012 TRINATIONAL SARDINE FORUM
Seattle, Washington, United States of America
November 28-29, 2012**

by

Nancy C.H. Lo

ADMINISTRATIVE REPORT LJ-13-02

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Southwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic & Atmospheric Administration
8901 La Jolla Shores Drive
La Jolla, California 92037, United States of America

Ocean Associates Inc. (OAI) contracted to SWFSC.
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2012 Trinational Sardine Forum participants at the Hotel Deca

4507 Brooklyn Ave NE, Seattle, Washington, USA

<http://swfsc.noaa.gov/tsf.aspx>

TABLE OF CONTENTS

INTRODUCTION.....	1
PLENARY SESSION HIGHLIGHTS	
Regional Sardine Fisheries Reports	
Canada	
British Columbia.....	2
México	
Bahía Magdalena.....	4
Ensenada and Gulf of California	10
United States	
California.....	10
Oregon.....	11
Washington.....	12
WORKING GROUP REPORTS	
WG1: Regional Biomass	15
WG2: Stock Structure, Age Structure, and Adult Sampling	36
WG3: Industry Trends and Issues.....	38
CONCLUSION.....	43
ACKNOWLEDGMENTS.....	44
REFERENCES.....	44
ACRONYMS	46
APPENDICES	
Appendix I: List of Participants.....	48
Appendix II: English Agenda.....	51
Appendix III: Contributed Abstracts and Summaries, Oral Presentations.....	54

INTRODUCTION

On November 27 and 28, 2012, the Northwest Fisheries Science Center (NWFSC) held the 13th annual Trinational Sardine Forum (TSF) at the Hotel Deca, 4507 Brooklyn Ave NE Seattle, Washington, USA. Close to thirty five participants attended from Canada, Mexico, and the United States; and represented government agencies, academic institutions and industry (Appendix I). Special thanks go to both the logistics and the program committee members (Appendix II).

Dr. Mark Strom, Deputy Director of Northwest Fisheries Science Center (NWFSC), delivered the opening remarks. He mentioned that while both Dr. John Stein and Dr. Francisco (Cisco) Werner, the directors of NWFSC and SWFSC, were unable to attend, they both expressed the importance of the forum in the development of cooperative research across international lines. The Trinational Sardine Forum's open atmosphere has resulted in knowledge across countries and allows for international cooperation with science, a significant aspect in times of budget restraint. Dr. Strom acknowledged Robert Emmett, the meeting's organizer for 2012, for all his work and mentioned he was not able to attend at the last moment. He also recognized Nancy Lo's commitment in her inability to stay away from the Trinational Sardine Forum despite her retirement early in 2012. Dr. Strom closed his remarks by wishing the participants a successful meeting with viable results.

The "Regional Sardine Fisheries Reports" session followed opening remarks. Representatives from Canada, Mexico, California, Oregon, and Washington presented current data, aging methods and industry information. The "Research Plans and Reports" session followed thereafter. Presented papers covered a range of topics, including: "Development of a Prediction System for California Current Ocean Conditions," "Measurements of natural mortality for Pacific sardine," and "Recent shift in the California population of Pacific sardine (*Sardinops sagax*) detected in otolith features"(Appendix III).

Unlike previous years, 2012's Trinational Forum did not include a Special Session and Focus Issue but instead focused on the Working Group sessions which began on the second day. Instead of breakout sessions, attendees participated in all three Working Group plenary sessions. These were designed to facilitate interaction and the flow of ideas among the participants regarding three current issues: Regional Biomass, Stock Structure, and Industry Trends and Issues.

PLENARY SESSION HIGHLIGHTS

Regional Sardine Fisheries Reports

Canada

British Columbia - Jordon Mah (DFO)

Most Pacific sardine (*Sardinops sagax*) found off the west coast of the United States and Canada occur in waters off California during peak winter and spring spawning periods. Large aggregations of sardine migrate from key spawning habitat to more northern waters prior to and during summer and fall months to forage. This is when they can be found in British Columbia waters before returning south in the winter.

The Canadian Pacific Sardine fishery is an opportunistic fishery that depends on the migration of sardine into Canadian waters. The 2012 fishery was open from June 1, 2012 to February 9, 2013, although the last sardine landing for the 2012 season occurred on November 12, 2012. The first landing of the 2011 season occurred on July 4, 2012.

The Department of Fisheries and Oceans Canada (DFO) established the Total Allowable Catch (TAC) for commercial harvest of Pacific sardine in British Columbia based on 2011 biomass estimates of the Northeast Pacific population from a U.S. led stock assessment (988,385 metric tons) and an estimated migration rate of sardine into Canadian waters (18.4%), upon which a Pacific Region Pacific sardine harvest rate is established. A 15% harvest rate has been applied to the Canadian harvest control rule since 2002, which is equivalent to what has been applied to the U.S. harvest control rules.

For the 2012 season, the TAC was set at 27,279 tons. The TAC was equally divided amongst 50 licenses over two license categories, commercial and communal commercial, with each license receiving an equal quota of 545.6 tons. All 50 available licenses were issued for the season.

Since 2007, harvesters have been permitted to designate multiple licenses to a single vessel which allows for increased in-season flexibility for harvesters and has helped to increase the amount of catch landed since it was implemented. For example, 8% of the TAC was harvested in 2007 compared to 96% in 2010. Table 1 shows the catch history from 2002 to 2012.

There were 13 active vessels that participated in the fleet in 2012, with all of the catch occurring on the west coast of Vancouver Island. In total, 19,129 tons of Pacific sardine have been harvested to November 21, 2012. In addition to sardine, fishers are also permitted to harvest 10 tons of chub and jack mackerel, which must also be recorded in the logbook and validated at dockside. The purpose of the mackerel allowance is not to create a directed fishery, but rather to decrease wastage of mackerel that is normally encountered when fishing for Pacific sardine. All other by catch must be released.

For the 2012 season, the sardine industry fleet has advised that the sardine were abundant along the west coast of Vancouver Island (WCVI) and offshore, but they arrived later than usual (due to oceanographic conditions), and the size was smaller than in recent years. As a result, some buyers were unable to process

and market the smaller sardine which resulted in some vessels shutting down earlier than expected for the season.

All catch (target and by catch) in the fishery is monitored through a third party service provider that is funded by industry. The monitoring program has several requirements, including hailing into and out of the fishery, submission of logbooks with catch and effort information, 100% dockside validation of catch, and at-sea observers. At-sea observer coverage varies depending on the fishing location and date. There is a minimum of 25% at-sea observer coverage across the Pacific Region with the possibility of increased at-sea observer coverage in areas of high concern for wild salmon populations in the WCVI. In addition, there are robust time and area closures along the WCVI to protect returning wild salmon stocks. The “Salmon By catch and Discard Management Framework” was introduced in 2012 and provides further detail on the bycatch management measures for the sardine fishery. The framework can be found in the 2012-2015 Pacific Sardine Integrated Fisheries Management Plan available on the DFO website.

DFO has established priorities for the management of Canadian fisheries. The Department is working to ensure the monitoring program meets Canada’s catch monitoring standards while being cost effective for harvesters, improves cooperation and compliance with conditions of license, and continues developing shared stewardship arrangements for cost sharing of science and management activities. DFO continues to work with industry to reduce levels of incidental catch through an improved monitoring program and by utilizing selective fishing practices.

Table 1. Annual summary of catch and effort in Canadian waters from 2002 to 2012 with individual vessel quota (IVQ), total allowable catch (TAC) and actual catch

YEAR	IVQ (mt)	TAC (mt)	CATCH(mt)	% of TAC
2002	180	5,000	822	16%
2003	180	9,000	1,006	11%
2004	300	15,000	4,259	28%
2005	304	15,200	3,266	21%
2006	270	13,500	1,558	12%
2007	396	19,800	1,507	8%
2008	250	12,491	10,435	84%
2009	364	18,196	15,334	84%
2010	463	23,166	22,223	96%
2011	438	21,917	20,719	95%

2012*	546	27,279	19,129	70%
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*Data are preliminary to November 21, 2012

Discussion:

Many questions were raised during the discussion sessions regarding inlet fishing, decline of northern most near shore region, chub mackerel catch, salmon bycatch, etc.

Rather than fishing off shore, as is the case for most years, the fishers chose to fish close to the processing plants in the calm water and within the inlet area. Apparently, the highest catch was by the two loading stations. While fishers are now allowed to fish one mile off the coast or 30-40 miles away from the coast, this was not allowed during the 2012 period. Canada does not estimate biomass within the inlets as the larger biomass is offshore (half mile away from the coast) and the sardine move in and out of the inlets, as per their dynamic nature, making such estimations unreliable.

In 2012, there was a sharp decline of sardine in the north nearshore area. This decline was due to the larger fish coming late in August and stopping at Cape Scott, rather than traveling further north. This uncommon behavior seems to be in conjunction with La Niña. The fish seemed to stay off Westport and lot of fish came into Canadian waters later in the season. . The industry only caught 70% of the Canadian TAC in 2012 due to the small size of the fish and the little to no market for such catch. Out of the 50 licences issued to 13 vessels, only 39 licences were fished.

Two other species, mackerel and sardine, are often found among sardine catch. Canadian fishers are allowed to catch up to 10t of mackerel per year. While they are not caught every year, many mackerel were mixed with sardine in 2012. Salmon are also often caught, and those similar in size to sardine sometimes get past the excluder systems and are separated at dockside. A total of 183 Chinook salmon were caught this year, with 98t of sardine caught per Chinook. However, due to the creation of a sardine monitoring program Working Group, live releases of the Chinook were higher than in previous years. The sardine monitoring program Working Group, which includes a salmon stock assessment staff, designed time and area closures so that the bycatch of salmon would be released in open water, rather than in the closed areas, so as to not negatively affect the salmon spawning population.

The Canadian commercial sardine fishing season dates for 2013 were confirmed as June 1, 2013 to February 9, 2014. Fishing licences do not have to be stacked prior to the start of the season and licenses may be issued throughout the year.

México

Bahía Magdalena – R. Félix-Uraga, F. N. Melo-Barrera, C. Quiñónez-Velázquez, E. Álvarez-Transviña, and R. García-Morales (CICIMAR – IPN, La Paz) presented by Kevin Hill (SWFSC)

The 2011 total landings of small pelagic fishes in Bahia Magdalena were 62,141 mt, and 709 fishing trips were carried out. The Pacific sardine, *Sardinops sagax*, caught in this year was 54,729 mt and represented 88.1% of the total catch (Figure 1).

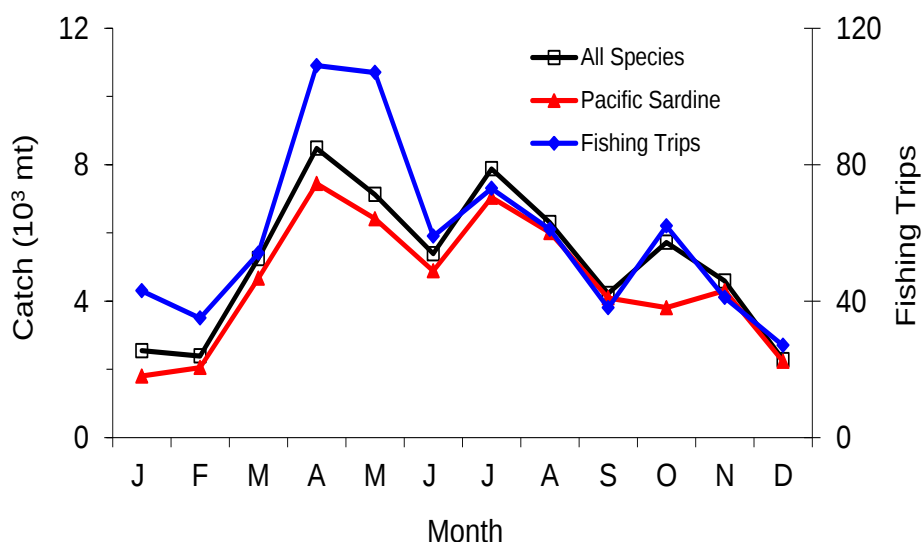


Figure 1. Monthly catch and effort in Bahia Magdalena, 2011

Other species landed were herrings (*Opisthonema* sp) (8.2%), round herring (*Etrumeus teres*) (1.4%), Chub mackerel (or Pacific mackerel) (*Scomber japonicus*) (0.6%), *Cetengraulis mysticetus* (0.5%), and a mixture of other species (1.3%) (Figure 2).

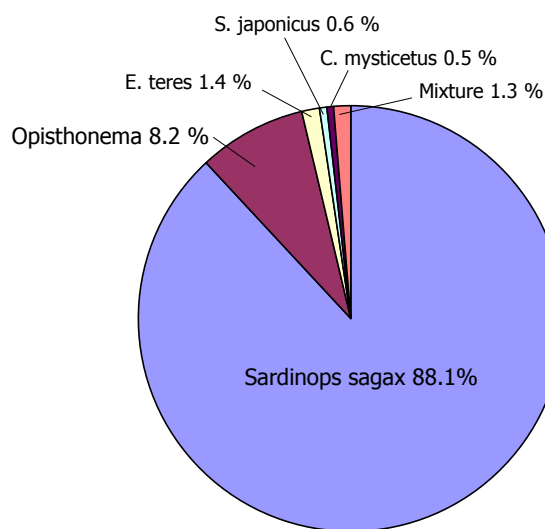


Figure 2. Catch composition of small pelagic fishes in Bahia Magdalena, 2011.

Pacific sardine were caught throughout the year, with a peak in April (8,476 mt) and a minimum in December (2,281 mt); and 67% recorded from March to August. Landings of Pacific sardine in 2011 did

not show the typical pattern for this fishing area, as catches in May and June were lower than the average monthly catch for Bahia Magdalena (Figure 1).

Sizes of *S. sagax* varied between 135 to 205 mm SL, but the bulk (65 %) was among 175 to 190 mm SL. Practically all the sardine caught were above the minimum legal size (Figure 3).

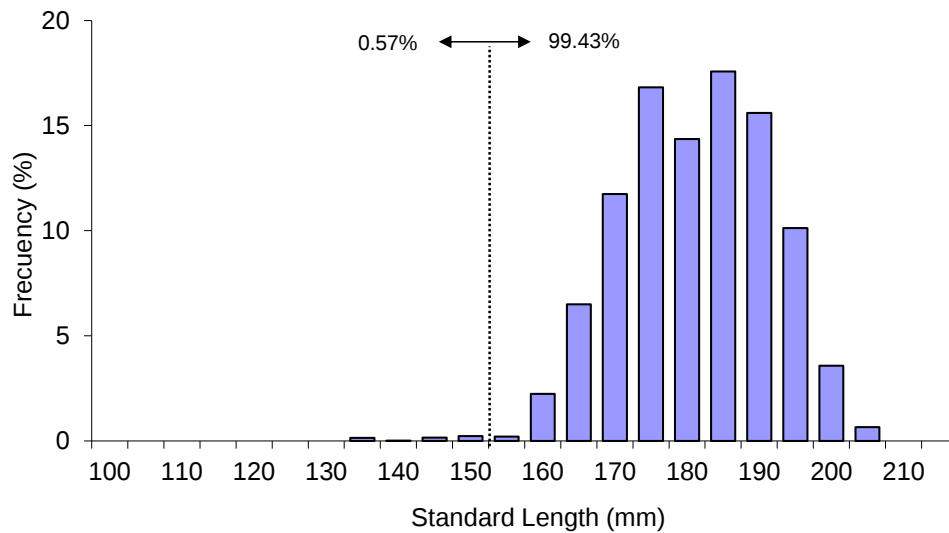


Figure 3. Size composition of Pacific sardine in Bahia Magdalena during 2011.

Six age groups have been found (0-5), with 2 yr olds (47%) and 1 yr olds (30%) being the most abundant (Figure 4).

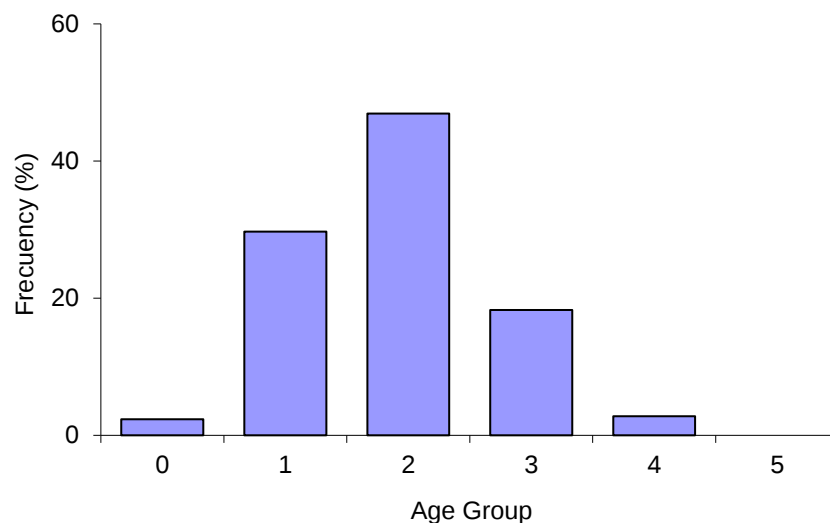


Figure 4. Age composition of Pacific sardine in Bahia Magdalena during 2011.

The 2011 maturity cycle of the Pacific sardine does not show the typical pattern of the reproductive cycle for Bahia Magdalena, where usually the maximum occurs between February through August. Instead, reproductively active sardine were found practically throughout the year and especially in the second half. In previous years, the reproductive activity was minimum during this period (Figure 5).

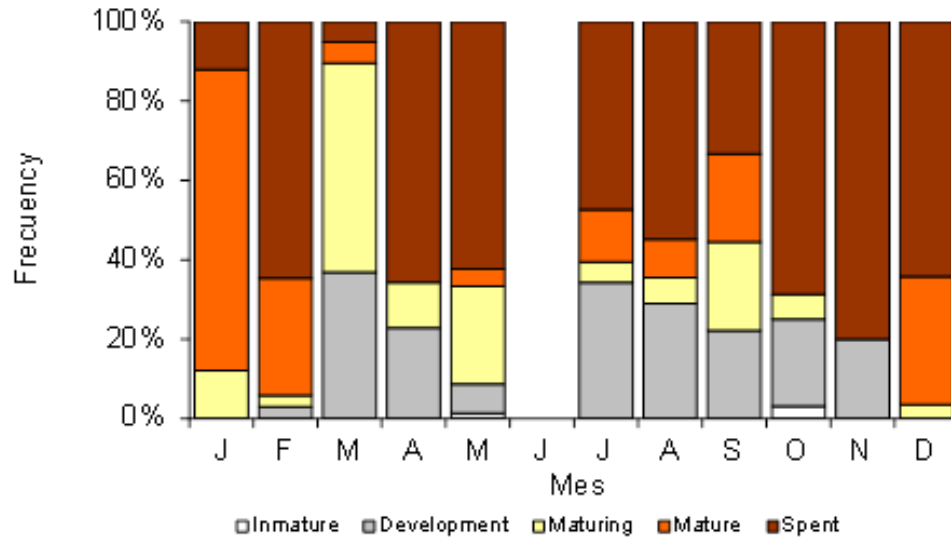


Figure 5. Maturity of Pacific Sardine in Bahia Magdalena during 2011.

From January to August of 2012, 43,130 mt of small pelagic fishes were caught in 549 fishing trips. Pacific sardine catch totaled 35,675 mt, representing 82.7% of total landings (Figures 6 and 7).

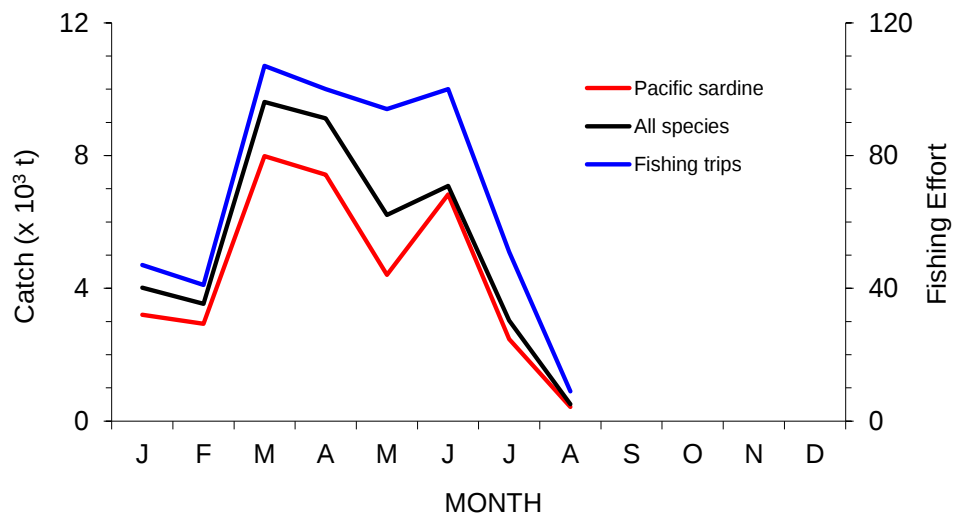


Figure 6. Monthly catch and effort in Bahia Magdalena, 2012 (Jan-Aug)

Others species caught in these months were herring (*Opisthonema* sp) (6.0%), round herring (*Etrumeus teres*) (7.1%), anchoveta (*Cetengraulis mysticetus*) (0.1%), Pacific mackerel (*Scomber japonicas*) (0.6%) and a mixture of other species (3.4%) (Figure 7).

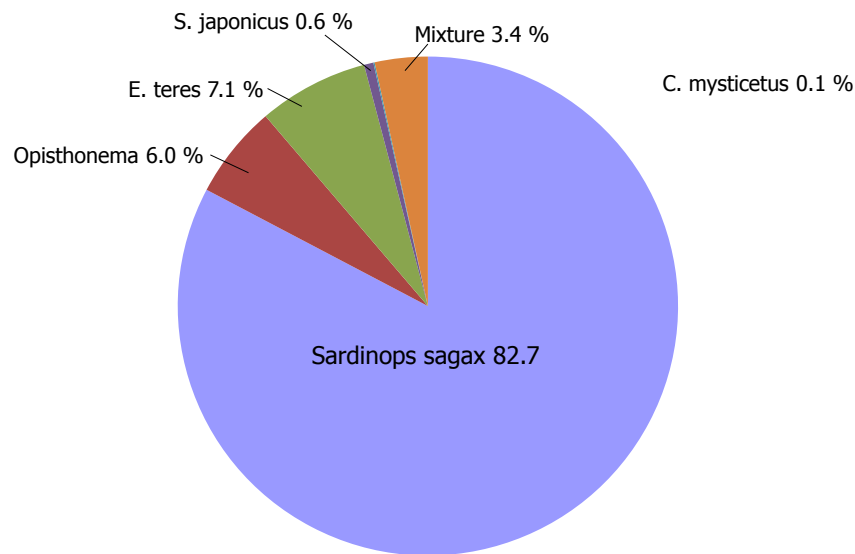


Figure 7. Catch composition in Bahia Magdalena (January to August, 2012).

Size of Pacific sardine varied between 135-215 mm SL. The smallest sardine, the minimum legal size, represented only 6.8% (Figure 8).

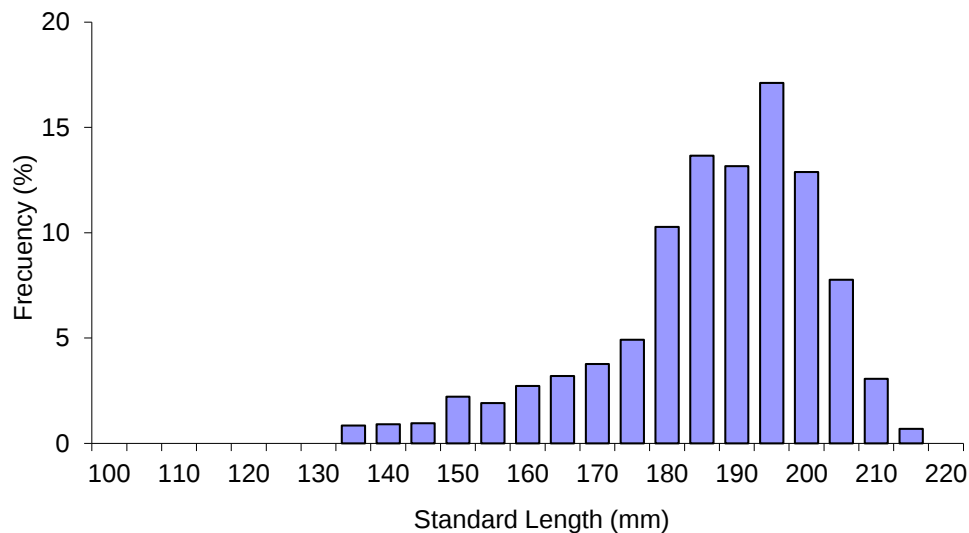


Figure 8. Size composition in Bahia Magdalena (January to August, 2012).

Six age groups have been found (0-5) with the groups 2 (36%) and 3 (34%) being the most abundant in 2012. Compared with previous years, age groups 4 and 5 were relatively abundant (Figure 9) while age groups 1 and 2 were most abundant in 2011 (Figure 4).

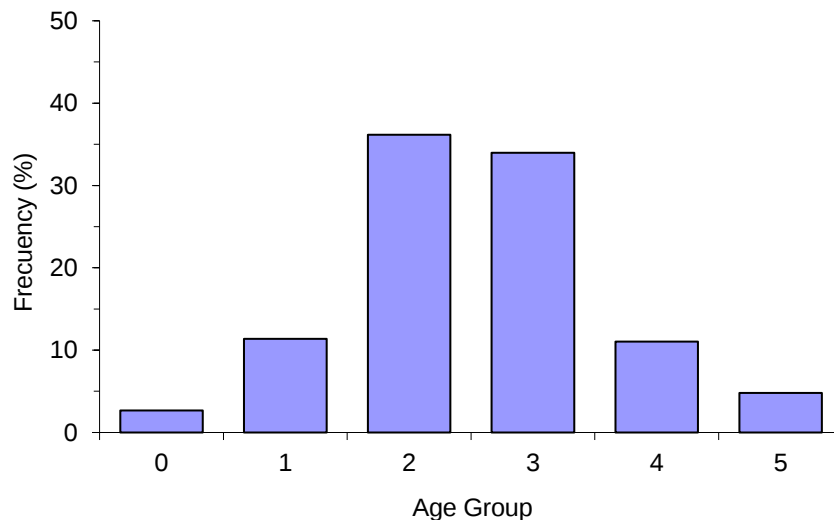


Figure 9. Age composition in Bahia Magdalena (January to August, 2012).

During January to February most of the sardine were in reproductive activity (Figure 10).

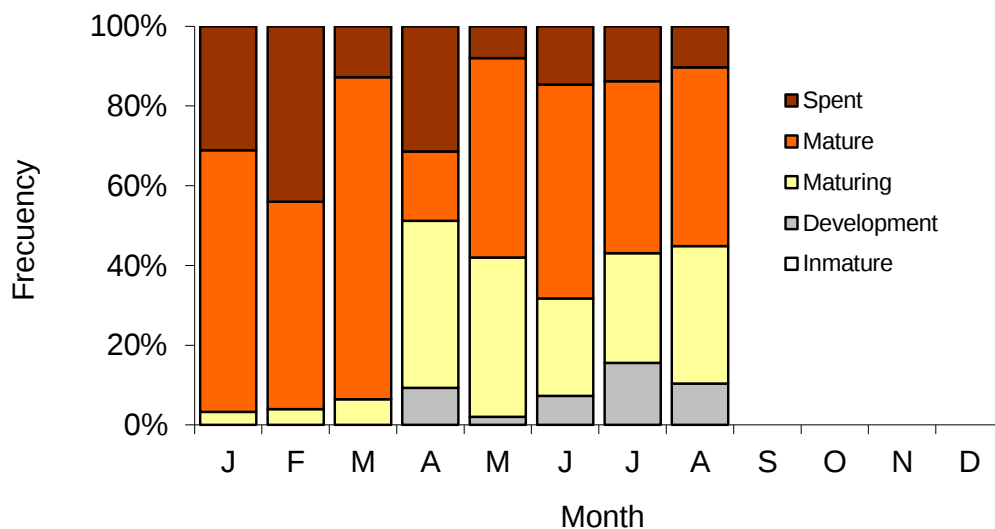


Figure 10. Maturity of Pacific Sardine in Bahia Magdalena (January to August, 2012).

Discussion:

This age shift between 2011 and 2012 may have been caused by several factors. The most notable is the difference in the time period and sample sizes of data collected between 2011 and 2012; since the fishing during July through September in 2011 was during a discrete time period and the sample sizes were smaller. The shift may have been due to no new recruitment in the Pacific Northwest for this year.

Finally, the age shift may reflect ageing techniques resulting in over-counting of annuli. This would account for the blips in the length at age data for the assessment.

The 2012 fishing year started early in June off Pacific Northwest (PNW). The Industry saw a variety in sizes and some with roe, indicating the fishing was on a spawning or post spawning stock. Since spawning creates quality issues, the Industry encouraged its fleet to find a different stock. PNW usually spawn in May-June (e.g. Emmett's egg data), and June seems to be the peak spawning for the females. Most of the active fish that were in areas where fishermen don't usually fish.

Ensenada –Report not received

Gulf of California–Report not received

United States

California –Chelsea Protasio (CDFW) represented by Dale Sweetnam (SWFSC)

A total of 21,990 metric tons (mt) of Pacific sardine were landed in California in 2012. This was a 20% decline from 2011 landings (27,688 mt). Although California saw a decrease in landings, there was a substantial increase in the coast-wide harvest guideline (HG), almost doubling from 47,825 mt in 2011 to 94,409 mt in 2012. The HG is based on a west coast stock biomass estimate of 988,385 mt of sardine (age 1+). Unlike the previous four years, the HG did not limit the amount of fishing during the season. Significant declines in sardine biomass estimates over the previous four seasons had resulted in a derby style fishery, where there had been a race to catch sardine. With the increase in HG, the fishery was able to fish more days and the derby style was not seen in 2012.

Nearly four-fifths of California's landings occurred in southern California ports (17,749 mt), while 4,241 mt were landed in the Monterey ports. Ex-vessel value ranged from \$225-145/ mt in Monterey and \$180-127/ mt in southern California ports. Sardine landed in Monterey ports tend to be larger than the sardine landed in southern California ports. The average length of sardine in Monterey ports was 194 mm with a weight of 102 grams; average length in southern California ports was 169 mm with a weight of 69 grams. This represents an increase from 2011, when Monterey sardine averaged 186 mm in length and 94 grams in weight and sardine from San Pedro averaged 147 mm and 51 grams. The most recently available age data from 2011 continue to show a pattern of younger fish in the southern California area compared to previous years. The age data from 2007 – 2009 had shown a predominance of 1-yr-old fish whereas 2010 – 2011 data has shown a change to nearly equal amounts of 0 and 1-yr-old fish. Monterey data from 2007 – 2009 produced mainly 2-yr-old fish and 2010 – 2011 also produced mainly 2-yr-old fish, with equal numbers of 0 and 3-yr-old fish.

Under the current HG, Pacific sardine are allocated coast-wide in U.S. waters over three periods: January 1 – June 30 (35% of total allocation), July 1– September 14 (40%), September 15 – December 31 (25%). The seasonal allocation for the first period of 2012 was 33,039 mt. During this period, limited

landings were made in California due to the scarcity of sardine in desirable fishing locations and the allocation was not met. After the end of the allocation period, 12,061 mt of sardine remained un-harvested and rolled over into the second allocation period.

During the second allocation period, 51,025 mt was available starting on July 1. Landings in California were minimal with most fishermen concentrating on the abundance of market squid with higher ex-vessel prices in both Monterey Bay and the Southern California Bight. Only 3,116 mt were brought into California ports during the period that closed early August 22, after 53 days.

The third allocation period opened on September 15 with 30,567 mt available for harvest and was open until the end of the season, December 31. Fishermen in California were still concentrating on market squid until its fishing season closed on November 21. After the closure of squid, sardine were still not found in desirable fishing locations and therefore minimal landings were seen in California. The majority of the California landings during the third period (2,498 mt out of 3,001 mt landed in California) came from the southern California ports.

Discussion:

A question was raised regarding the purpose of the aerial survey. The idea was to do a biomass estimate in the Southern California area in July and August before fish move north. It is interesting to compare fish caught by the fishery with the survey results at the same time. Many marine mammals were around during the entire survey. The survey also covered the inshore area. There were still some spotter pilots working for the fishing fleets and the logbooks might be available. The *R/V Ocean Starr* acoustic trawl survey did not observe much sardine in the same area. Most of the older fish moved up north, so only small fish stayed in the bight. Fishermen targeted squid instead.

Oregon– Jill Smith and Cyreis Schmitt (ODFW), presented by Lorna Wargo (WDFW)

The Pacific sardine fishery in Oregon operates as a day fishery with vessels based primarily in Astoria where processing plants for sardine operate. In addition to the timing of peak availability of sardine in northwest waters, environmental factors greatly affect when vessels fish. Aircraft are often used to assist in locating schools for sardine and weather and tides are major factors affecting when vessels are able to transit in and out of the Columbia River. Twenty of the 25 vessels in the Oregon limited entry permit fishery made landings into Oregon during 2012. As of November 1, 2012, the fishery remained open and active, although both fishing and processing activity decreased as the third fishing period progressed. As of late October, sardine landings into Oregon totaled approximately 40,000 metric tons (mt). A preliminary estimate of the mean weight of these landings is 58 mt. Small, incidental amounts of Pacific mackerel and jack mackerel, approximately 1,400 mt and 80 mt, respectively, were also landed.

Sardine were landed in Oregon during all three allocation periods. In the previous four years, allocation periods closed early because allocation limits were reached. However in 2012, allocation limits were higher and, as of November 1, only the second period allocation limit was reached before the fishing period ended.

Pacific mackerel is up from the average and the catch is 1300mt in 2012. There was no anchovy in 2012. The fishery Salmon bycatch numbers were: 135 salmon with 50% dead, 0.0033 salmon/mt. No Eulachon were caught as bycatch in this fishery. Oregon sardine biological data had a mean standard length of 208 mm and weight of 154g. The average age of sardine was little over 5 for 2011.

Neither Oregon nor Washington had observer coverage in 2012. In Washington, it was discontinued based on low rate of salmon bycatch in the sardine fishery. Washington had 20% coverage from 2000-2004. Oregon has done trial observer coverage in the past.

Washington – Lorna Wargo and Carol Henry (WDFW); Alan Sarich (Quinault Indian Nation)

Pacific sardine are the primary coastal pelagic species harvested in Washington waters. The Washington sardine fishery opens annually by rule on April 1. In 2012, the first landing was made on June 15. Nine of the 16 Washington permanent limited entry licenses were actively fished. Additionally, one temporary annual permit was issued and fished in 2012. In combination, the total number of limited entry licenses and temporary annual permits cannot exceed 25. Temporary annual permits are issued at the discretion of the director.

Landings

A total of 34,655.1 metric tons of sardine were landed into Washington during the 2012 season. The season remained open through December 31, 2012, but weather and colder waters prevented fishermen from successfully fishing after mid-October. Of the 591 landings, 39% were made in July, 25% were made in August and 19% were made in September. The average landing was about 59 mt. All landings were made into either Westport or Ilwaco. Total ex-vessel value for 2012 was \$7.7 million which is a 280% increase from the second highest grossing year which was 2010 with \$2.7 million.

The Quinault Indian Nation entered the sardine fishery this year with a harvest set aside of 9,000 metric tons. Fishing within the usual and accustomed (U&A) area, Point Chehalis to Destruction Island, landings for the 2012 season totaled 1,294.2 metric tons. Landings were made in July, August, September and October (one landing).

Total state and tribal landings for Washington were 35,959.3 metric tons.

Logbook

Pacific sardine are the targeted catch in the Washington fishery; but anchovy, mackerel, and squid can also be retained and landed. In 2012, the only other CPS landed was 636 mt of mackerel. Logbook data also showed salmon released in the sardine fishery.

A total of 752 sets were made according to logbook records. Of the 752 sets, 95% were in waters adjacent to Washington, and approximately 73% of the sets were between the Columbia River and the Copalis River. By rule, no fishing may occur within state waters or within 3 miles of the coastline. The average catch per successful set was 54 metric tons. Less than 7% of the sets produced catches of 100 metric tons or greater.

Biological Data

Forty-five samples of 25 sardine each were collected randomly from landings at Ilwaco and Westport for a total annual sample of 1,125 sardine across all nine participants in the fishery and throughout all five months fished (June-October). Sardine were sampled for length, weight, sex, maturity; and otoliths were collected for aging. Sexual maturity is determined by using the California Department of Fish and Game (CDFG) Standard Maturity Guide for Wetfish, which is based on Hjort (1910, 1914) State of Sexual Organs. Sexual maturity codes 1- 4 are used and described as follows:

Code Description

- (1) Virgin individuals.
- (2) Maturing virgins or recovering spent. Males intermediate; no milt present.
- (3) Yoked oocytes visible. Milt is present and oozing in males.
- (4) Hydrated oocytes present.

Of the sampled sardine, 43% percent were male and 57% were female. The majority of sardine sampled were maturity code 2 for both males and females. No maturity code 4 was seen in the samples and only a few maturity codes 1 (Table 1).

Table 1. Sex and sexual maturity of sardine sampled in 2012.

Sex	Maturity Code	Maturity Code	Maturity Code
	1	2	3
Male (43%)	1%	39%	3%
Female (57%)	<1%	54%	3%

For the 2012 season, the average length of sardine sampled was 208 mm and the average weight was 149.9 grams. Monthly, the length of sardine sampled varied from a 206 mm average to 209 mm average. The monthly average weights exhibited a greater range, averaging from 137.8 g to 159.3 g (Table 2).

Table 2. Average size and length of sampled sardine by month

Month	Length (mm)	Weight (g)	Sample Size
June	207	137.8	175

July	209	159.3	375
August	208	152.7	175
September	206	143.2	250
October	209	152.3	125

Sardine samples are collected throughout the summer and fall as long as there are landings. Basic biological data (length, weight, sex, maturity) can be obtained immediately but aging of the sardine is more complex so ages are not typically available until the following spring. Otoliths are used for aging sardine and are collected immediately at the time the sardine is sampled. At the end of the fishing season all the otoliths are sent to age readers in Olympia, Washington.

WORKING GROUP REPORTS

Working Group 1: Regional Biomass, Nancy Lo (SWFSC)

Report for Working Group 1- Regional estimates of biomass of 2011 and recommendations

Partial list of members: Tim Baumgartner, Martin E. Hernandez-Rivas, Sandy McFarlane, Jake Schwartz, Linnea Flostrand, Vanessa Hodes, Jennifer Boldt, Robert Emmett, Andrew Claiborne, Yanira Green-Ruiz, Darrell Kapp, Nancy C. H. Lo, Beverly Macewicz, Juan Zwolinski, Dave Demer, Rick Brodeur, Manuel Nevárez, Enrique Morales, Kevin Hill, Marisa Litz, and Cheryl Morgan

1. Coast-wide survey, CalCOFI, and IMECOCAL April cruises, 2012

Objectives: To estimate spawning biomass and biomass of Pacific sardine from Baja California, Mexico to Vancouver Island, British Columbia, Canada.

1.1. California DEPM-acoustic and CalCOFI, March-April cruises, 2012

The spring 2012 CPS-Sardine DEPM-acoustic survey was conducted aboard one NOAA research vessel, *Bell M. Shimada* (April 11-April 30) and a chartered research vessel, the R/V *Ocean Starr* (March 26-April 29). The R/V *Ocean Starr* covered the area off the west coast of the US from Cape Flattery, Washington to Point Conception, California with most of the stations off California located within the area from north of San Francisco to Point Conception (CalCOFI lines 56.3 to 80.0 from April 5 to April 28) (Figure 1). The *Shimada* covered the area from San Diego, California (CalCOFI line 93.8) to Monterey Bay (CalCOFI line 68.3). The NOAA ship *Shimada* also occupied the primary CalCOFI lines, 76.7 to 93.3, from March 23 to April 7 for the spring CalCOFI cruise. During the DEPM and CalCOFI surveys, CalVET tows, Bongo tows, and CUFES were conducted aboard both vessels while surface trawls were conducted only during the DEPM-acoustic surveys. Data from DEPM-acoustic surveys on both ships were included in the estimation of spawning biomass of Pacific sardine. Data from the CalCOFI survey during March, 2012, were not used due to the low number of sardine egg or larval catches from all nets (Lo et al. 2013).

In addition to sardine eggs and yolk-sac larvae collected with the CalVET net, yolk-sac larvae collected with the Bongo net have been included to model the sardine embryonic mortality curve since 2000. Beginning in 2001 (Lo 2001), CUFES data from the ichthyoplankton surveys have been used only to map the spatial distribution of the sardine spawning population, with the survey area post-stratified into high-density (Region 1) and low-density (Region 2) areas according to the sardine egg density from CUFES collections. Staged eggs from CalVET tows and yolk-sac larvae from CalVET and Bongo tows in the high-density area have been used to model embryonic mortality in the high density area and the daily egg production, P_0 , for the whole survey area.

For adult samples, the survey plan was to use the *Shimada* and the *Ocean Starr* to conduct 3 – 5 trawls a night either near regular CalCOFI stations or at random sites on the survey line regardless of the presence of sardine eggs in CUFES collections. At night a Nordic 264 rope trawl with 3.0 m² foam core doors was

towed for 30 minutes at the surface (0 – 11 meters). The trawl was modified for surface trawling with Polyform floats attached to the head rope and trawl wings. The trawl was modified with a marine mammal excluder device placed midsection just forward of the codend. In addition, on both vessels, the first trawl of the night (about a half hour after sunset) was towed without the Polyform floats to depths about 15 to 35 meters to potentially catch fish that might still be moving up toward the surface from daytime depths since darkness had not fully descended. For the whole CPS-Sardine DEPM-acoustic survey, trawling occurred from April 5 to April 30, 2012 and 21 of the 95 trawls conducted at night were positive for Pacific sardine. A single trawl in northern California just above CalCOFI line 56.7 collected sardine. The other 20 trawls with sardine were located in the south below latitude 37.4°N (Figure 1).

Since 2009, in addition to the estimates of spawning biomass based on the past procedure where P_0 was weighted by the size (km²) of each region and the adult parameters were estimated from all trawl samples in the entire survey area, an alternative estimator based on stratified sampling for each parameter was also included (Hill et al. 2009) for years when adequate adult samples were available (1986, 1987, 1994, 2004, 2005, 2007 – present). As such, the original time series of spawning biomass may not be comparable due to slightly different estimation procedures and the refined survey designs over time. This alternative method was also used to estimate the female spawning biomass that is now used as a data time series for stock assessment computations. Here, the time series of spawning biomass, female spawning biomass, and total egg production is reported based on both the traditional method and the stratified estimation procedure.

The spawning biomass of the Pacific sardine (*Sardinops sagax*) in April 2012 was estimated using the daily egg production method (DEPM) calculated by two methods: 1) the traditional method where the egg production (P_0) was a weighted mean while each adult parameter was an unstratified estimate, and 2) a stratified procedure where the estimate of total spawning biomass is the sum of the estimated spawning biomass in each of two regions representing high and low spawning activity. The two estimates of the spawning biomass were 282,110 mt (CV = 0.43) and 255,391 mt (CV = 0.32), respectively, for the standard DEPM survey area of 270,991 km² off the west coast of North America from north of San Francisco to San Diego, California (CalCOFI line 60.0-95.0). The daily egg production estimate (P_0 , an average weighted by area) was 0.84/.05m² (CV = 0.27). In the standard DEPM area, the estimates of female spawning biomass calculated by the two methods were 120,902 mt (CV = 0.36) and 113,178 mt (CV = 0.27), respectively. Samples taken north of CalCOFI line 60 found no eggs in either CalVET tows or CUFES collections, and one trawl out of three caught sardine north of CalCOFI line 60 during the *R/V Ocean Starr* cruise. Hence, coast-wide estimates of sardine spawning biomass and female spawning biomass were not calculated.

The estimated daily specific fecundity was 16.14 (number of eggs/population weight (g)/day) using the following estimates of reproductive parameters from 126 mature female Pacific sardine collected from 16 positive trawls: F , mean batch fecundity, 38,682 eggs/batch (CV = 0.06); S , fraction spawning per day, 0.138 females spawning per day (CV = 0.24); W_f , mean female fish weight, 141.6 g (CV = 0.04); and R , sex ratio of females by weight, 0.429 (CV = 0.12). Since 2005, trawling has been conducted randomly or at CalCOFI stations, which resulted in sampling adult sardine in both high (Region 1) and low (Region 2) sardine egg-density areas. During the 2012 survey, the number of tows positive for mature female sardine was the same in Regions 1 and 2 (8 trawls in each region). In addition, two tows in each region contained a sole male sardine.

The estimates of spawning biomass of the Pacific sardine off California in 1994 – 2012 based on the traditional method are 127,000 mt, 80,000 mt, 83,000 mt, 410,000 mt, 314,000 mt, 282,000 mt, 1.06 million mt, 791,000 mt, 206,000 mt, 485,000 mt, 300,000 mt, 600,000 mt, 837,000 mt, 392,000 mt, 117,000 mt, 185,000 mt, 108,000 mt, 383,000 mt, and 282,000 mt (for the standard DEPM area), respectively. These estimates of spawning biomass indicate that there has been considerable fluctuation during this time (the peaks occurred in 2000 and 2006) and that biomass has declined in 2008-2010, increased in 2011 and declined in 2012 to the level of 2004 (about 300,00 mt). The time series of spawning biomass was one of the fishery-independent inputs to the annual stock assessment of the Pacific sardine from 1985 – 2008. Since 2009, the time series of spawning biomass was replaced by female spawning biomass for years when sufficient trawl samples were available and the total egg production for other years was used as inputs to the stock assessment of Pacific sardine.

In addition to the spawning biomass time series for Pacific sardine, two other time series for the biomass are available: one is from the acoustic data which have been collected since early 1990s (Zwolinski et al. 2012) and the other one was from the NW fisheries industry supported aerial survey since 2008 (Wespestad et al. 2008; Emmett and Lo 2009; Schweigert et al. 2010; Rodriguez-Sanchez et al. 2010; Hill et al. 2012).

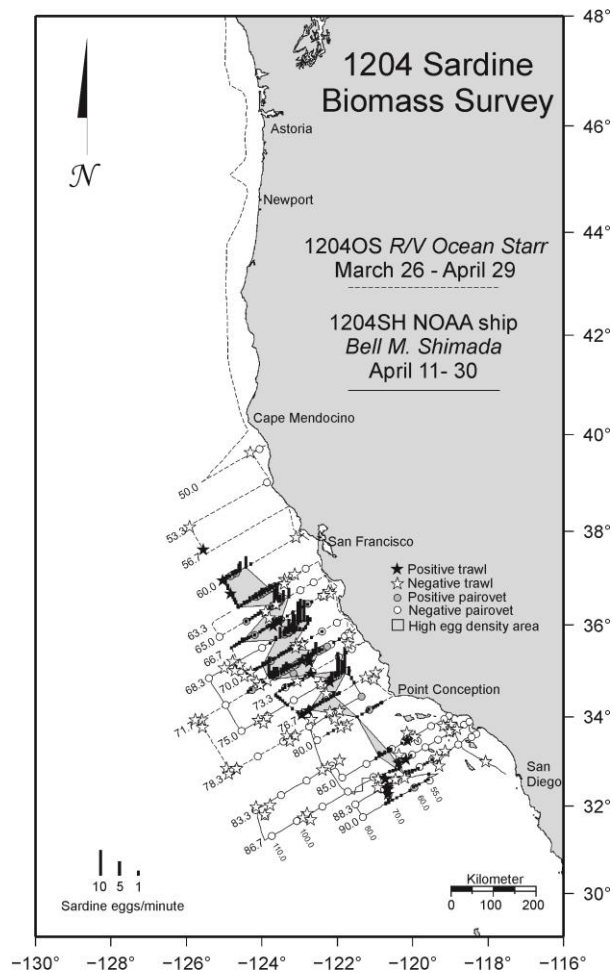


Figure 1. Location of sardine eggs collected from CalVET, a.k.a. Pairovet; (solid circle is a positive catch and open circle is zero catch) and from CUFES (stick denotes positive collection), and trawl locations (solid star is catch with sardine adults and open star is catch without sardine) during the 2012 survey aboard two vessels: the R/V Ocean Starr (dash line) and the NOAA ship Shimada (solid line). Shaded area is Region 1, the high egg-density area, and the rest of survey area is Region 2.

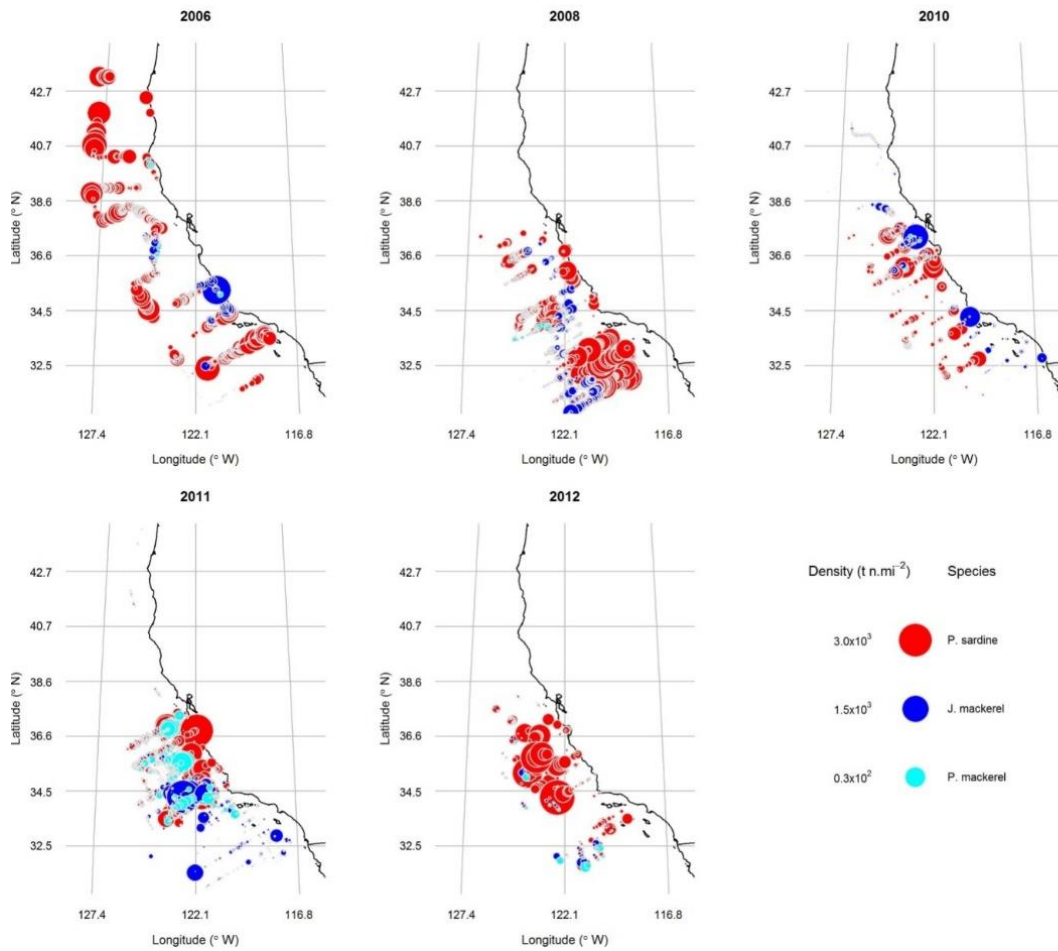


Figure 2: Distribution and abundance of sardine and mackerel off the west coast of the United States during springs of 2006, 2008, 2010, 2011 and 2012, estimated from our acoustic-trawl surveys (11). Survey results show that in 2012 sardine were the dominant epipelagic fish species (courtesy of Zwolinski).

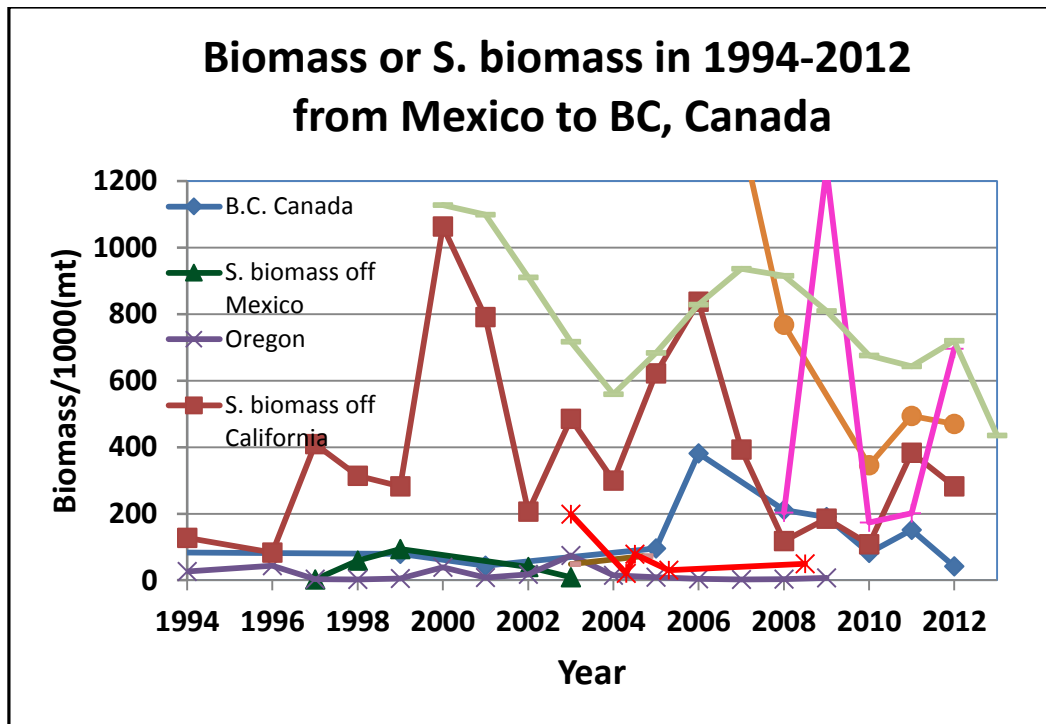


Figure 3: Time series of estimates of biomass and spawning biomass (s. biomass) from 1994-2012 from Mexico to British Columbia and spawning stock biomass (SSB) from 2011 stock assessment. Note the biomass estimate from the acoustic survey (ATM) in 2006 was 1.9 million mt with large variance

1.2 IMECOCAL in 2012

No updates

2. Pacific Sardine Biomass Estimates and Associated Information off Northern Oregon and Southern Washington in 2012.

Objectives: To estimate biomass of Pacific sardine off Oregon since 1994.

Surveys

Unlike previous years (Lo and Schott 2012), only one pelagic fish study off Oregon and Washington in 2012 was conducted, the BPA Columbia River Plume Study. The Plume study collected fish during daytime using surface trawls from northern Washington to Newport, Oregon in May, June and September.

Estimations of the sardine population size off the Columbia River in 2012 were not taken as they had been in the past. The annual bi-weekly surveys off the mouth of the Columbia River were discontinued in

2012 because of funding constraints. Here the survey reported length frequency of Pacific sardine captured during daytime surface trawling off Oregon and Washington in 2012.

Sardine Catches

The Plume Study in May captured only one sardine. In June and September 2012, sardine were found mostly off WA in both cool and warm waters (Figure 4). Length frequency histograms indicate that only one large size class of sardine was captured (Figure5). No 0-age sardine were captured, indicating that sardine did not successfully spawn and recruit off Oregon in 2012, similar to what occurred in 2011.

Oceanographic Conditions in 2012

Cool ocean conditions continued off the Pacific Northwest in 2012. Ocean sea surface temperatures were cool in June 2012 (Figure 6), when sardine have previously been found to spawn (Emmett et al. 2005).

Past surveys have found that during years with anomalous cold ocean conditions sardine do not successfully spawn and recruit off the Pacific Northwest. Relatively good sardine spawning and recruitment has been observed when June sea surface temperatures are warm, such as in 2003-2005 and 2009 (Figure6). However, the ocean in June 2012 was anomalously cool and had a negative Pacific Decadal Oscillation (PDO) condition. Hypothetically, the cool ocean conditions again limited the spawning/recruitment opportunities for sardine off the Pacific Northwest in 2012.

Conclusion

Similarly to 2011, no 0-age sardine were captured in 2012. This indicates that sardine did not successfully spawn and recruit off the Pacific Northwest in 2012, likely due to relatively cool ocean conditions and negative PDO.

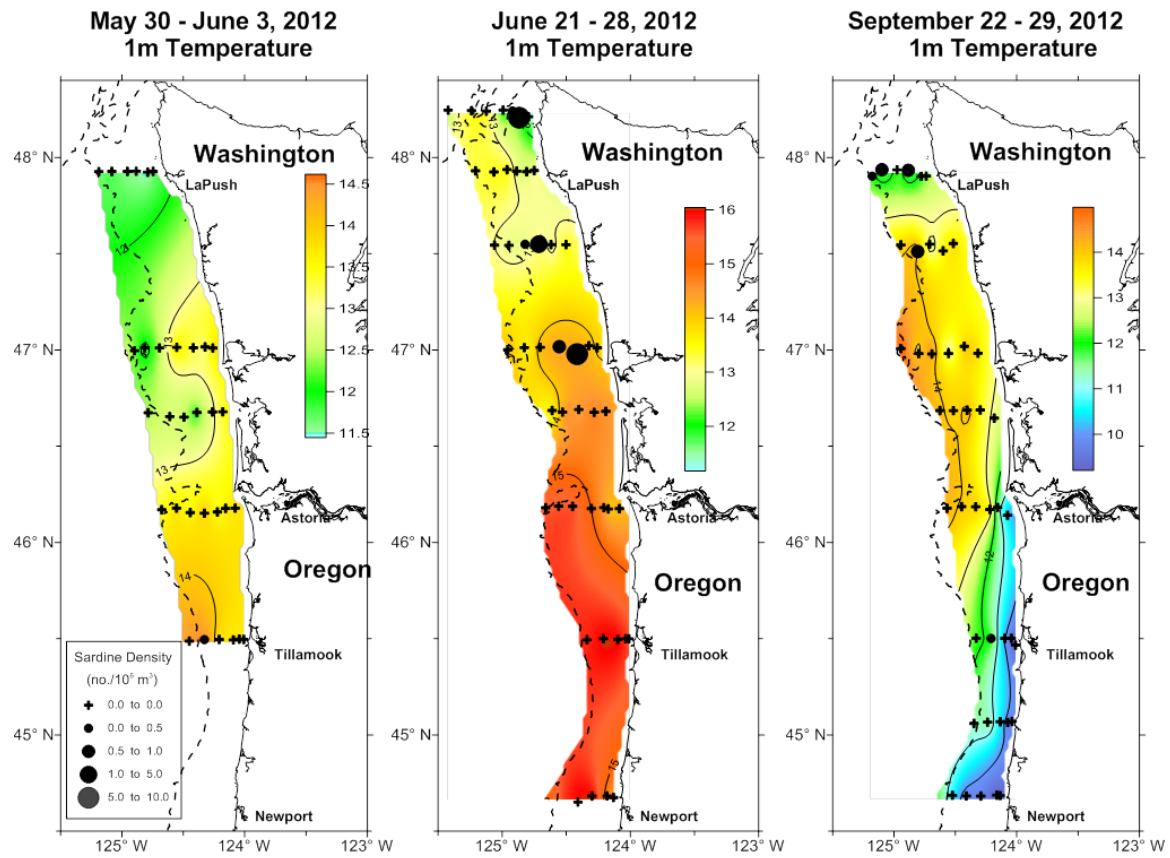


Figure 4. Sea surface temperatures and densities of Pacific sardine captured by surface trawl in 2012.

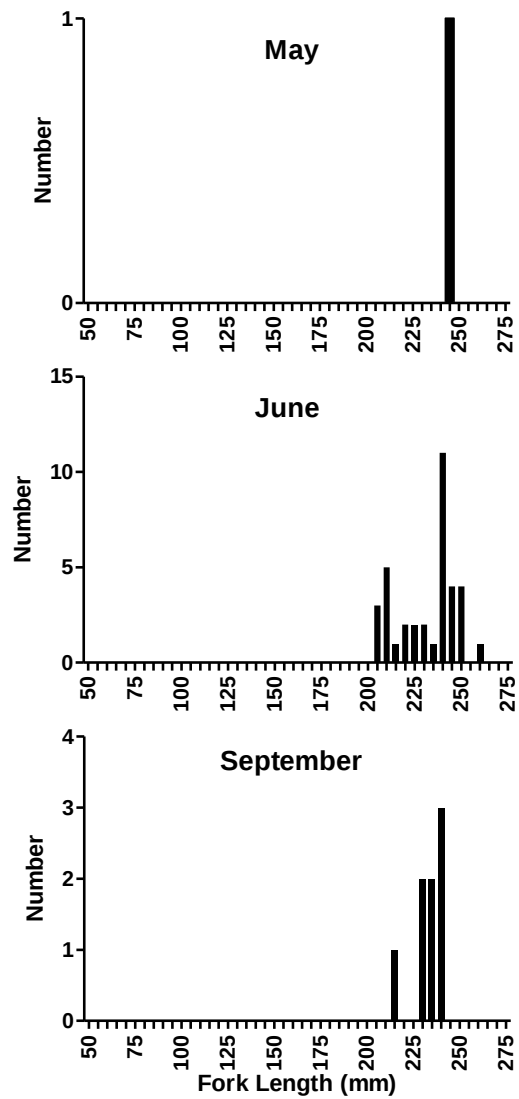


Figure 5. Length frequency distribution of Pacific sardine captured by surface trawl off Oregon and Washington in 2012.

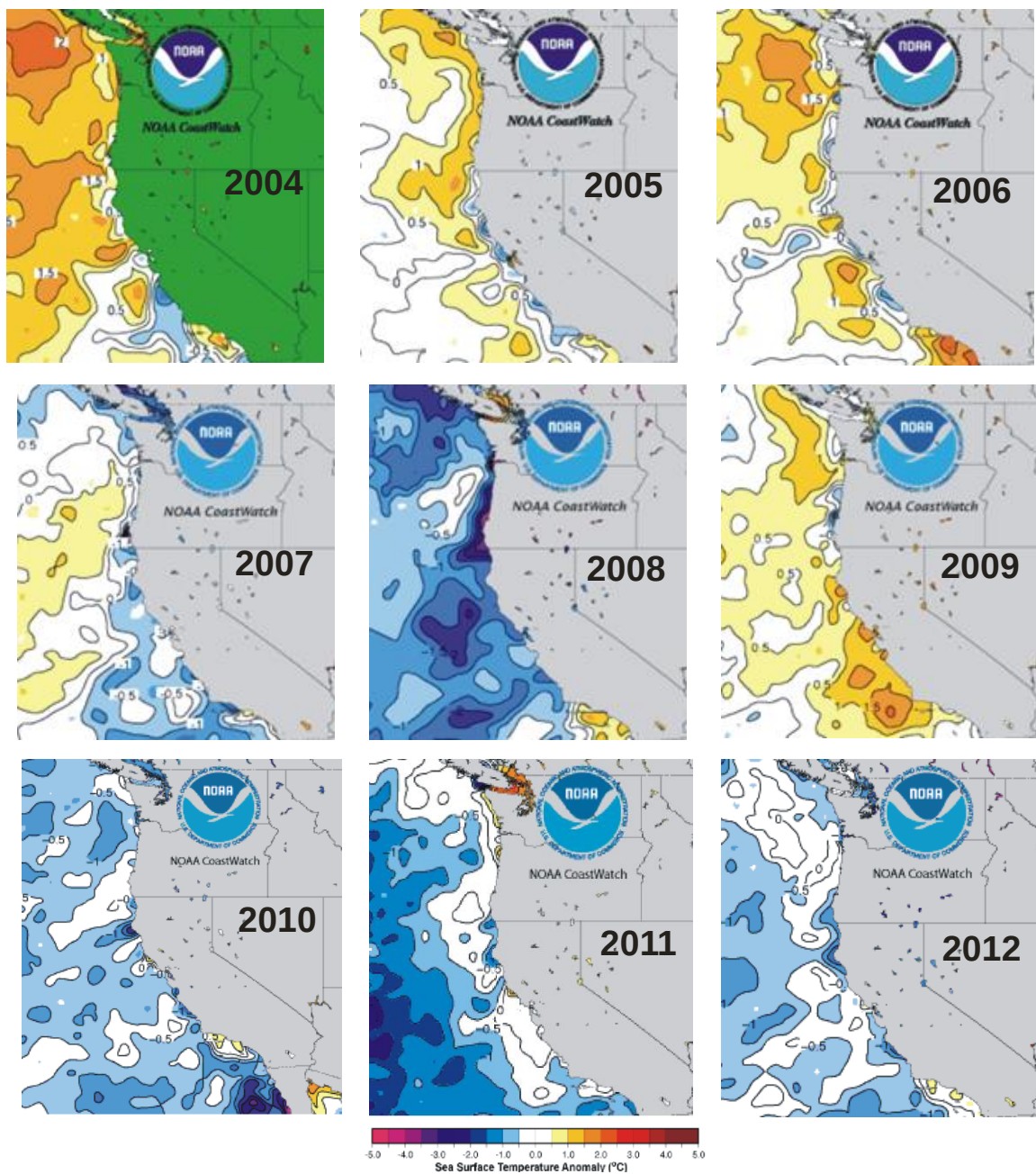


Figure 6. June sea surface temperature anomalies from 2004-2012.

3. Canadian sardine trawl density and biomass estimates associated with the summer Canadian trawl survey off the west coast of Vancouver Island, 2012.

Objectives: The summer west coast of Vancouver Island surface trawl survey is conducted to collect information on sardine: 1) distribution, 2) abundance, 3) size and age structure, and 4) species associations ~ sardine diet and predation.

Summary Objectives

This report provides a brief update on Pacific sardine observations from the 2012 WCVI trawl survey with an emphasis on regional distribution, catch densities, biomass estimates, and fork lengths. Information on fork lengths from commercial purse seine July and August samples in or near WCVI inlets is also provided.

Survey background

The summer west coast of Vancouver Island surface trawl survey is conducted to collect information on sardine: 1) regional distribution, 2) abundance, 3) size and age structure, 4) species associations (sardine diet and predation), and 5) oceanographic conditions. Surveys have been conducted most summers since 1992 (McFarlane and MacDougall 2001, DFO 2012). Fishing is done by a mid-water trawl towed near the surface (e.g. <30 m) using floats on the headlines at average speeds approximating 4.5 to 5.5 knots. Since 2006, sampling has been conducted at night (Schweigert et al 2009; DFO 2012).

The 2012 survey was conducted between July 18 and August 2 and sampling sites were based on intersections of a regional grid (~ 5x5 km) extending approximately 2 to 57 km from shore with a range in latitude of 50.7-48.5° extending southward to 10km from the US border (Figure 7). The region was further subdivided into 8 sub-regional strata to aid in the planning of sampling coverage across the region and for future exploration of possible stratification schemes for calculating estimates. Assignment of sampling stations was done by applying proportional probabilities to strata so that each would receive approximately equal sampling intensity. For planning purposes, it was expected that ~70 unique stations would be sampled within a previously defined “core” region (designated initially for the 2011 season).

Biomass estimates for the region have been calculated using mean sardine catch densities (metric ton /km³) extrapolated over regional or sub-regional surface volume estimates (Schweigert and McFarlane 2001; Schweigert et al 2009; DFO 2012). For each tow, a catch density estimate is calculated as the total weight of sardine divided by an estimate of the volume of water swept while fishing. The volume of water is determined by multiplying the length and width dimensions of the trawl net mouth by the effective fishing distance covered during the tow (distance over ground between end of net deployment and beginning of net retrieval). The core area of the survey region is approximately 16,740 km² and catch densities are assumed to represent sardine distributions in the top 30m of the region, therefore the region’s surface volume is estimated at ~ 502.2 km³ (Figures 7 and 8, Flostrand et al 2011).

WCVI catch densities and biomass estimates in 2012

In 2012, a total of 88 trawl tows were made (Figure 7, Table 1). Four trawl stations were sampled within inlets and 4 stations were sampled seaward of the core region. Replicate sampling was conducted at 13 different stations inside the core region. The incorporation of replicate sampling was to collect information on temporal variation during the survey period representing a time difference of approximately 1 week (Table 2). Excluding inlet sampling, 67 different stations were sampled within the core region and 71 different stations were sampled with the inclusion of the seaward stations.

Compared to previous survey year observations, overall catch densities in 2012 were considerably lower and no sardine were caught in the northwest and southeast sub-regions (Figures 7 and 8, Table 1). For the 13 sites where replicate sampling occurred, the first set of observations had a lower proportion of positive sardine tows but the mean density and variance were greater than the second set of observations (Table 2), due in part to one particularly high density tow.

WCVI 2012 Biological Samples & Sardine Lengths

Sardine collected during the 2012 WCVI survey were measured for fork length (to the nearest millimeter), weight (to the nearest gram) and information on sardine sex, diet, otoliths/age and predator size and stomach contents was also collected (Table 3). Randomly selected fresh length samples were taken from 32 tows (100-140 fish per sample sex combined). For pooled (unweighted) sample data, the range in fork length for most sardine was 19-26 cm, with a mean of 22.9 cm and a peak mode at ~21-22 cm and a secondary mode at ~ 23-24 cm.

For comparison, sardine fork length data from July and August commercial purse seine catch samples from or near WCVI inlets are also summarized (Table 4). For July and August, 34 and 23 fresh samples were taken, respectively (100 fish per sample). For pooled (unweighted) sample data, the range in fork length for most sardine was also 19-26 cm, with means of 22.3 cm and peak modes at ~ 21-22cm for both months. Only July data show a secondary mode at ~ 23-24 cm.

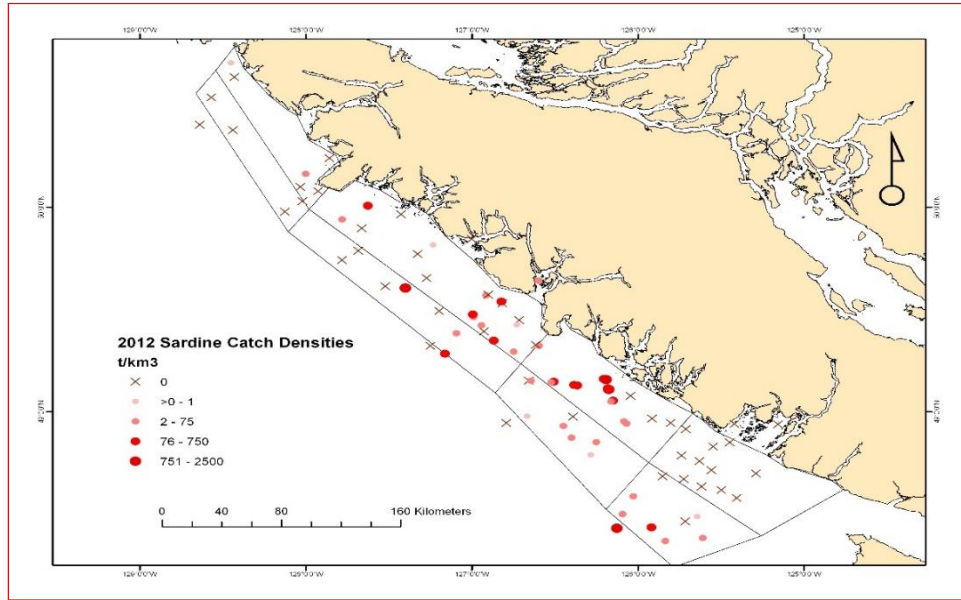


Figure 7. West coast of Vancouver Island 2012 surface trawl locations (July 18-August 2) and approximate Pacific sardine catch densities for night sampling.

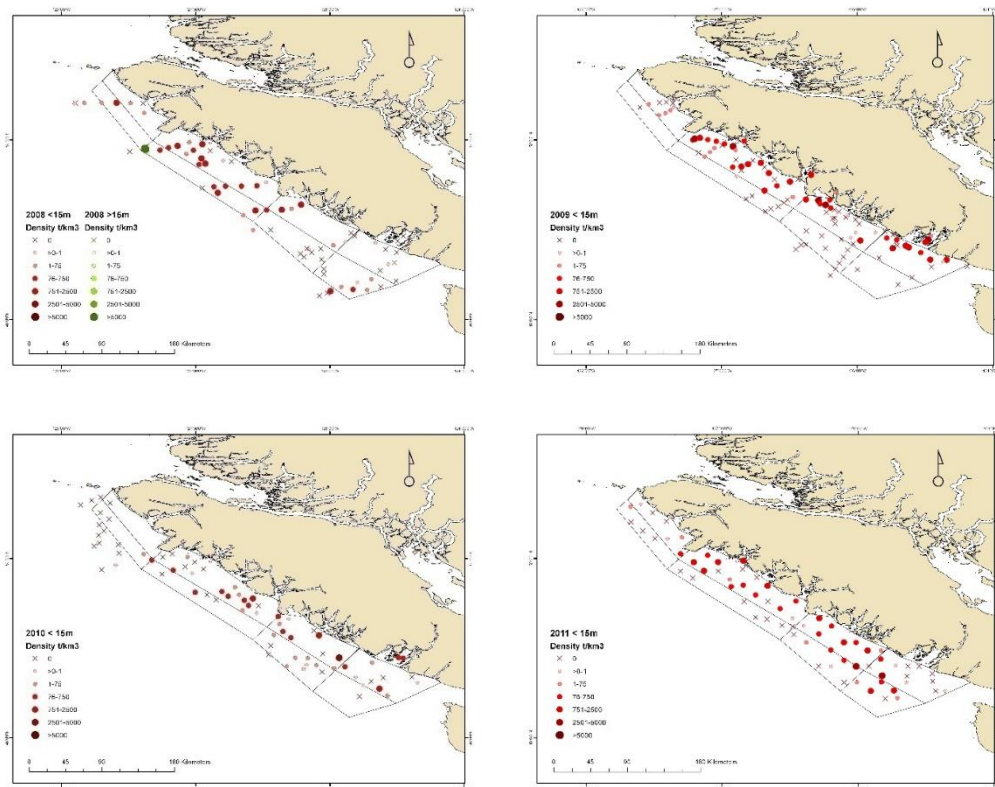


Figure 8. West coast of Vancouver Island 2008-2011 surface trawl locations and approximate Pacific sardine catch densities for night sampling (Flostrand et al 2011, DFO 2012).

Table 1. Pacific sardine west coast of Vancouver Island mean sardine catch densities and biomass estimates from night surface trawl surveys. No survey was conducted in 2007.

YEAR	2006	2008	2009	2010	2011	2012*
WCVI						
SAMPLING						
Tows with sardine /						
total number of tows	42/45	44/71	53/109	40/72	41/68	31/71
Core survey region						
Tows with sardine/						
total number of tows	41/44	40/60	47/95	37/57	41/68	30/67
SARDINE						
DENSITY						
(mt/km³)						
Mean	759.9	420	378.3	163.2	301.0	80.4
CV	0.23	0.33	0.23	0.39	0.27	0.43
BIOMASS (mt)						
Mean	381,617	210,924	189,977	81,964	151,162	40,376

*2012 estimates are preliminary and have not been formally reviewed

Table 2. Sardine trawl density replicate observations for 13 stations in the WCVI core survey region in 2012.

Shoreward reference	1 st Replicate			2 nd Replicate		
	Tow #	Date	Density (t/km ³)	Tow #	Date	Density (t/km ³)
Nootka	25	July 22	0.00	73	July 30	0.61
Nootka	26	July 23	0.00	74	July 30	252.45
Nootka	27	July 23	22.05	75	July 31	0.00
Nootka	28	July 23	22.57	76	July 31	458.04
Esperanza	30	July 23	49.23	72	July 30	0.00
Nootka/Esperanza	32	July 24	0.00	77	July 31	4.38
Esperanza/Clayoquot	36	July 24	0.00	79	July 31	17.86
Esperanza/Clayoquot	37	July 24	159.60	80	July 31	19.44
Clayoquot	38	July 24	87.22	81	July 31	143.70
Clayoquot	39	July 25	735.18	82	Aug 1	890.41
Clayoquot	40	July 25	1910.03	83	Aug 1	91.03
Clayoquot	41	July 25	194.90	84	Aug 1	36.09
Long Beach	50	July 27	7.53	85	Aug 1	12.69
Average, n=13 tows			245.36	148.21		
sample CV			2.20	1.76		
Proportion (non-zero)			0.69	0.85		

Table 3. Summary of biological samples taken onboard the W.E. Ricker July 18-August 2, 2012 (fresh and preserved combined).

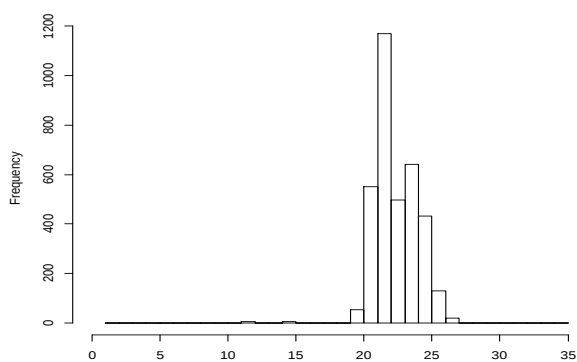
Sample Type	# Tows Sampled	# Fish per Sample	#Fish Total
Length	32	20-100	4209
Sex	29	20-100	3463
Weight	31	100	2927
Otolith/Age	14	50	700
Maturity	0	0	0
Sardine Stomachs	13	20	260
Fresh predator stomachs	46	1-40	305
Total number of sardine sampled (fresh and frozen): 4209			

Table 4. Summary fork length (cm) statistics from pooling fresh (at sea recorded) sample data for the WCVI trawl survey and July and August commercial WCVI purse seine catch samples with %ile as percentile.

Sample source	Sets	Fish	% Female	Mode	Min	25%ile	Median	Mean	75%ile	Max
Trawl survey	32	3509	53.9%	21-22	11.3	21.7	22.5	22.9	24.1	33.7
July seine (WCVI)	34	3400	51.7%	21-22	19.7	21.4	22.0	22.3	23.3	29.5
Aug seine (WCVI)	23	2300	49.3%	21-22	20.2	21.6	22.0	22.3	22.7	28.3

A Research trawl survey (WCVI)

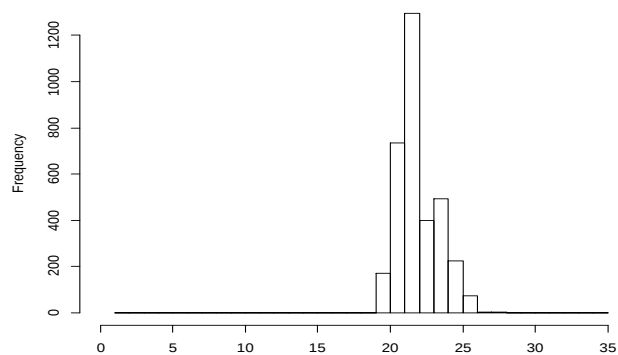
32 samples (~3500 fish)



Fork length (cm)

B July commercial seine (WCVI)

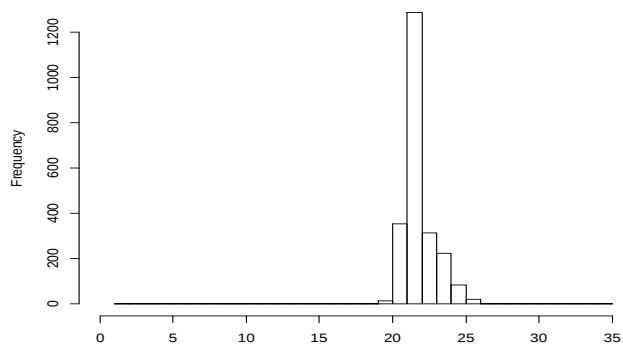
34 samples (3400 fish)



Fork length (cm)

C August commercial seine (WCVI)

23 samples (2300 fish)



Fork length (cm)

Figure 9. Fork length frequency distributions representing fresh sardine collected in 2012 from the WCVI summer surface trawl survey between July 18 and August 2 (panel A) and from commercial purse seine catches in July (panel B) and August (panel C).

Monthly Average Sea Surface Temperature Anomalies

Plots of monthly average Sea Surface Temperature anomalies for July, August and September taken from Fisheries and Oceans Canada SST internet archives (<http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/sst-tsm/index-eng.htm>) are included to consider in association with the spatial distributions and densities of sardine observed during the 2006 and 2008 to 2012 WCVI surveys (Figures 7, 8 and 10). Average monthly August and September SSTs in 2012 were generally cool, especially off the WCVI.

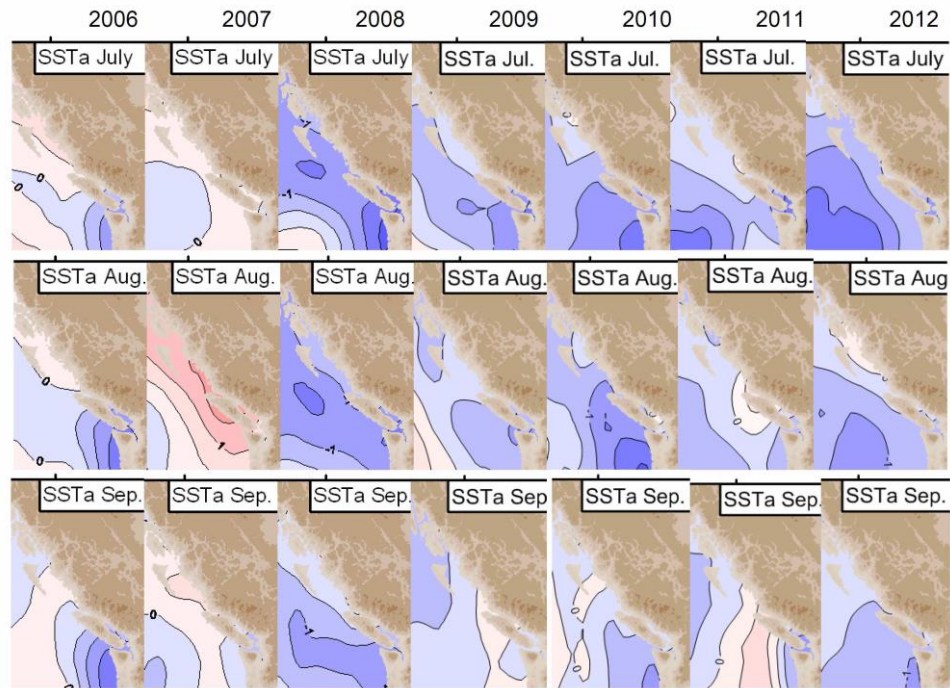


Figure 10: Mean monthly sea surface temperature anomalies for waters surrounding Vancouver Island in June, August and September of 2006 to 2012. Information from: <http://www.pac.dfo-mpo.gc.ca/science/oceans/data-donnees/sst-tsm/index-eng.htm>

Working Group 1 Plenary Session:

All biomass estimate time series (Figure 3) show a decrease in 2012 except the aerial survey which went up. The 2012 survey indicated that spawning took place off California as only one CUFES sample and trawl north of 38° N caught sardine. For future coast-wide summer surveys, the area south of California may need to be included to ascertain the spatial distribution and abundance of Pacific sardine.

Mike Okoniewski raised a question regarding the relationship between the spawning biomass and the recruitment. Nancy Lo indicated that egg- larvae data was collected, while recruitment was estimated from the stock assessment. The biological process from larval stage to recruitment is unknown and the juvenile surveys need to be conducted for the recruitment. Kevin Hill noted that no relationship was found between the recruitment time series from the model and the egg production which is likely due to mortality. It would be great if industry can provide funding for further explorations. Note, the industry did not catch juveniles.

Accomplishments in 2012:

Canada

- 2012 Survey was conducted from July 19- August 1 on the Ricker with night trawling with acoustics.
- Prepare for the methodology review for stock assessment in May 29-31, 2012.
- Conduct Inlet Trawl Survey: to obtain a representative biomass density.

US

- 2012 Coast-wide survey in spring and summer
- Aerial surveys off NW and California by the industry

Mexico (no report)

Future Plans:

Canada

- 2013 summary trawl survey from August 6-16.

US

- **Tagging experiment of sardine using electronic acoustic receivers (first suggested at the 2008 TSF) to be done on a chartered boat in July. In June, fake tags will be used for experiment. A total of 100 tags will be used for real release of sardine.**

The pre-release tagging experiment should continue in the California laboratory. NWFSC was not able to conduct the experiment in 2010, though an attempt was made. It was suggested to stabilize sardine in the Santa Cruz laboratory.

- **Early recruit survey. Possible use of Japanese surface trawl discussed during 2010 TSF.**

A Japanese mid-water trawl has a fixed form with a depressor bar beneath the net. It was suggested to examine data collected by Tony Koslow's group or at the ground-fish trawl survey as small sardine were caught in both cases. However, according to Kevin Hill, the ground-fish data are noisy and sampling protocol has been changed over time and needs to be standardized.

- **Collect data from salmon surface trawls off Oregon during May-June-Sept 2012 or future surveys.**
- 2013 aerial survey by US NW industry
- 2013 coast-wide survey in spring and summer (SaKe: **s**ardine and **h**ake survey): exchange of protocol of trawl-acoustic surveys among three countries and points of contacts are needed. For future hake survey, trawl doors need to be reset.

Discussion

The Industry expressed concern that some components of the PNW and Canada sardine population measurement are not as reliable as they could be. They asked that the upcoming SAKE survey, a combined sardine and hake survey, would take this concern into account. They also argued that the ATM survey produces biomass estimates less than that from the 2012 industry aerial survey, which, the industry believed, produced some of their best sightings ever. One option for the ATM would be to add sonar to the NOAA survey vessel in order to help explain the discrepancy between the aerial survey, fishery data and ATM. Having a second ship or fishing vessel, with sonar to concentrate on sardine behavior patterns such as vessel avoidance and location in the water column, would be a step forward. Everyone is aware of limited resources; however, discrepancies of this magnitude deserve further and immediate attention.

Another issue raised by the Industry is that the trawl for ATM is done at night, which is problematic as some CPS species shift from day to night. As with the aerial survey, it is likely that the acoustic survey can be performed at different times and would find different results. It was also thought that acoustics might be able to avoid some of the poor conditions which make photography difficult at times for the aerial survey.

However, the Industry argued that the acoustic survey would come with its share of issues. Since these PNW and Canadian sardine are largely near the surface in daylight hours, it may be impossible to use a downsounder to accurately quantify the PNW sardine without an upper water column searching sonar with forward and side-scanning capability. The industry indicated that the possible underestimate of biomass from the acoustic survey is that the acoustic survey may miss fish near surface. These aspects have to be considered. One could stratify the survey into two areas, inshore and offshore, while using smaller boats in the inshore area and ensuring fishermen had good collaboration during fishing. However, in the past there was no direct coordination with the survey vessel so to date no multiple vessel experiment has been conducted. This is worth consideration.

Dave Demer asserted the reliability of techniques used during ATM surveys. He further argued that sending a vessel in the inshore areas to make up for the sole use of acoustics and its own complications is unlikely. The SWFSC has traditionally conducted two sardine surveys a year, each in spring and summer,

with the area in the spring covered offshore. Demer argued that the biomass estimates from both surveys were not statistically different. The results for the time series for the ATM are consistent and showed plausible estimates of natural mortality. The trajectory of two cohorts from 2006 to 2012 can be explained, and there was nothing inconsistent in the ATM. Demer further argued that the biomass estimate from the aerial survey may be biased upward because Pacific mackerel and jack mackerel co-exist with sardine in Canada and Oregon, yet aerial surveys attribute other species to schools of sardine.

There seems to be a fundamental difference of opinion between the industry and Dave Demer. While the industry expressed their belief the conservative estimates of the acoustic survey will result in loss of economic stability for fishers, Dave Demer rebutted that the results are not expressing a personal opinion, but were based on the scientific data. Demer trusts the ATM estimates from the evidence of the stock assessment. He argued that these data are plausible results based on scientific parameters. All the observations from sardine surveys conducted by the SWFSC and Canada indicated declining stock, and northern migration, thus the survey results are scientific observations, not opinion.

Another question was raised regarding the trawl survey off Canada, and the fact that the biomass in the inlets was not covered by the survey area. The answer was that the sardine move in and out of the Canadian inlets frequently, so there is no need to do a survey within that area. The Canadians indicated that they need more accurate surveys and their aim of conducting surveys is to get an unbiased estimate of sardine abundance.

While there are obvious disagreements between the Industry and some scientists, both parties felt that this forum brings is incredibly helpful in bringing everyone together to make sustainable decisions.

The three sources of bias in the ATM mentioned by the industry should be examined as a starting point. As to the aerial survey, point sets were taken after the transects were flown during the aerial survey. Thus the data from the point sets and data collected from the aerial survey may not be synchronized and could be another source of bias for the biomass from the aerial survey.

Working group 2: Stock structure, Age structure, and Adult Sampling. John Hyde (SWFSC)

The sardine stock structure is the ongoing question. Stock structure issues are addressed through tools such as catch and ichthyoplankton data, morphometry, artificial tagging, natural tagging, and genetic analyses. An example of how these tools are used can be found in the examination of the temporal shift in spawning areas. When the stock is smaller it concentrates around Baja California. In addition, there is the three- stock hypothesis: cold, temperate and warm stocks. Differences found in body morphology give some support for separation in those three stocks. A lot of this is variable on the condition factor of the fish and other factors. There are variations in vertebral counts with higher numbers in higher latitudes in faster growing fish. Otolith morphometry demonstrates some differences between cold and temperate stocks, otherwise known as the frill factor.

Two of the most common ways to assess the migration of sardine include tagging studies and examination of otoliths. Tagging studies have shown a lot of movement up and down the coast, much of this from historical data. Parasite presence shows an overall signal of north to south movement along the west coast. Oxygen isotope studies are underway looking at whole otolith isotopes. Currently the core of the otoliths are being examined, and results show a chaotic signal in the sardine otoliths. There are no clear results yet. In the earlier work there is a temporal shift, perhaps different stocks moving in and out.

Sardine stock structure poses two challenges for population genetics: historical signals and variation in blood type. Previous hypothesised stock membership results were messy and showed immense variation. These issues have not been resolved as no new hypothesised stock membership results have been done since. Pair wise population comparison demonstrated barely significant separation. The future will most likely bring more tagging, more genetics, more morphometric studies, and more otolith chemistry. Sharon Herzka is currently working on oxygen isotopes.

Working Group 2 Plenary Session:

Future Plans:

In both 2011 and 2012, the forum discussed the use of small acoustic tags to detect and track the movements and behavior of sardine. Due to logistical limitations in the northwest, it was suggested that initiating a 6-month study using dummy tags in La Jolla to monitor mortality could be beneficial. The first step was to project a sample size, while considering the major issues of tagging mortality and predation. The tag detection needed to be the most stable of the current receivers arrays along the coast to be the most useful for sardine within the POST network.

A tagging project must take into considering the limited amount of money while answering the most important questions. One of the biggest questions to consider was determining the rates of detection for salmon by the arrays, since having an idea of detection rates would provide an idea of natural mortality. Knowing this, surveys would be able to calculate how many tags would be needed for sardine. This answer depends on the species. Salmon are easier to tag; tagging and detection can be done at the mouth

of the bay. The detection range of these tags can be from 500m to 1km but are typically less for the size of tags needed for sardine.

There are 20 years of data defining where spawning happens in the Pacific Ocean. The movement of the high density area over time shows that the sardine move offshore into warmer water. The sardine drift pattern is being worked on offshore and down the California current down into Ensenada.

The migration rate could be better established through the deployment of tags since they are internal with unique ID's; so there could be multiple releases in various areas to understand regional behaviors.

PIT (Passive Integrated Transponder) tagging is also a possible option. PIT tagging might be a way to spend less, as the tags are cheaper and tag readers could be installed at processing plants. This type of tagging is essentially the same idea used in the 30's and 40's. This method of tracking would show the dynamics of sardine movement, especially in and out of inlets in areas like Canada. However, as processing facilities aren't as widely spread along the coast as they once were, the results would only provide a small window as opposed to a total coastline review. Another issue with PIT tags is that there is no way to follow information in between the time of deployment and when the tag is retrieved.

Another method of determining sardine movement is through the examination of sardine otoliths and how they range in age from where they were caught. Otolith exchanges between Canada and the US were discussed as well as the creation of a photo atlas. Discussion regarding otolith morphology as a biological curiosity occurred. The SWFSC is continuing their otolith work in 2013.

Discussion

In order to get at a better understanding of the inshore-offshore component, there has been discussion of coast-wide inshore work with live bait fishers concurrently with coast-wide surveys. This didn't happen in 2012, however, the SWFSC has been collecting samples monthly from bait fishermen in San Diego and now has a ~ 10 year archive of otoliths and tissue samples.

Sharon Herzka's group is continuing their studies of otolith microchemistry, focused particularly on oxygen isotopes of otolith cores as a proxy for salinity and temperature during early life stages. There also has been discussion on daily ring ageing and ROMS modeling to further interpret these data. Mexico was doing some work on this in 2011.

Examination of larval and juvenile daily growth increments could be done to look for differential growth between putative northern and southern stocks but currently no one is explicitly looking at this.

As age-size structure changes due to environmental and fishing forces, there is the question of whether larger female sardine produce more and better quality offspring. This has been shown in several demersal fishes and could be an important aspect to consider. No work to date has been done to examine this in sardine.

Working Group 3: Industry Trends and Issues, Mike Okoniewski (Pacific Seafood)

The 2012 USA sardine harvest was largely successful in Oregon and Washington in 2012. Fish in California were difficult to catch during part of 2012. Anecdotal reports, especially early in the season, noted that sardine in Southern California waters were driven into near-shore kelp beds by a super-abundance of marine predators. When sardine go into areas that are shallow or have heavy concentrations of kelp it effectively blocks the seine fleet and eliminates fishing opportunity.

Canada experienced relatively small fish for some duration. This was unusual and often did not line up to buyer's expectations of larger Canadian sardine. Certain processors were not able to utilize or buy the smaller fish for their markets for part of the season. From anecdotal reports it appears that Canada will harvest a number that comes relatively close to the 2012 TAC, however this needs to be confirmed by DFO.

Purposes and Needs:

The predominant issue for 2013 confronting industry in the USA is a severe drop in quota. This was largely due to a lack of fish (13,335mt) recorded by the Acoustic-Trawl (ATM) survey in the northern Oregon and Washington waters from July 21-August 10th (Hill et al. 2012). This was an ironic proposition to the PNW fishermen who caught 49,000mt in the same waters from July 1-August 22 and in an overlapping time frame. In addition, the NW Aerial survey recorded the largest number of sardine schools in this area in some years.

The cut in USA quota would amount to a loss of revenue of roughly \$32,000,000-\$40,000,000 in FOB export wholesale value. In addition it would truncate the season to a point that it may be difficult to find boats willing to fish for the expected short interval. This impediment to fleet participation is largely a Pacific NW issue and may have little impact in the California seasonal fisheries. Cuts to revenue streams affect the entire spectrum of west coast fishing communities that rely on CPS fisheries.

Impact to the Canadian sardine industry: Canada utilizes the biomass and HG information from the NMFS sardine stock assessment. They arrive at their own Canadian TAC through a careful, deliberative, and scientific process that can best be described by their own scientists and fishery managers. The Trilateral Forum may provide an opportunity for further inquiry into that process if there are specific questions.

The 2012 Canadian Quota was 27,280mt. The DFO announced a 25,477mt sardine quota for 2013 on June 1.

Impact to U.S. sardine industry: Customers that relied on production from the USA will likely attempt to find fish from other areas of the world as their primary source and will rely more on USA production to backfill any supply gaps they encounter. This strategy has already been announced by certain customers.

Impact to the Mexican sardine industry: The Chair cannot comment on Mexico except to say that some former USA customers have taken a portion or all of their sardine purchases south of the U.S. border.

USA Issues and trends:

The issues remain largely the same as in past years: Sardine and seafood buyers prefer consistency of supply in volume and quality to the highest degree possible. Inconsistency causes disruption and is harmful to business profitability at every level of the supply chain. Sardine fishermen have business decisions to make in regards to the economic viability of fishing for short periods. Short seasons and inconsistent supply have the effect of driving away potential fishing fleets and customers while simultaneously driving up production costs.

U.S. fishermen feel that the NMFS ATM and DEPM survey methods still are not up to the task. They argue that these survey methods are not recording, and possibly even disrupting the sardine schools and spawning activity they are attempting to measure. The industry-sponsored aerial survey can only see fish when visual conditions are at an optimum level. In 2013 photographic conditions were excellent, but due to the time constraints necessary to process the data for the stock assessment, the aerial survey had to cut its point set activity short and was not able to produce the robust survey result that seemed implicit from the large numbers of schools photographed.

Again the ATM survey result of very limited biomass in the PNW is in stark contrast to actual recorded landings and the Aerial survey. This further brings into question the adequacy of the ATM survey methods in the PNW. More frustrating is that certain alarmists in the NGO sector and at NMFS have now begun predicting the imminent collapse of the sardine biomass based on present harvest practices and their absolute belief in the NMFS survey data. Nancy Lo noted that the difference between the biomass estimate from ATM survey (13,334 mt) in the PNW from July 21-August 10 and the actual recorded landing (49,000mt) from July 1-August 22 is likely due to different dates of data collection. The comparison would be more meaningful to use landing data off Oregon and Washington during the ATM survey period: July 21-August 10.

USA Industry remedies: In lieu of the fact that industry was (and is) convinced there is a large amount of biomass that is currently not being seen by the NMFS sponsored sardine surveys, the Industry launched an aerial survey that was intended to be conducted in a coordinated and collaborative manner. Some form of linkage or overlap with the ATM survey has never really occurred. Many in industry believe that the acoustic method has promise, but the necessity for the acoustic down-sounder to be mounted relatively low in the water column means that there is little chance it will be able to legitimately record PNW (or Canadian) sardine biomass. It is also believed that unless the NOAA ship possesses “side scanning” scientific sonar it will not be able to accurately measure the PNW sardine biomass.

Other issues include the current practice of sample trawling at night but doing the acoustic work during the day. There is much evidence that the CPS species in the PNW remain near the surface during the day (sardine) but change radically at night, to a near-total CPS species reversal. One NOAA scientist suggested that perhaps seine vessels could be used for day sampling as the surface trawl during daylight hours is ineffective.

Another idea included using a seine vessel with side scan sonar to accompany the NOAA vessel on some transects to gather information on sardine vessel avoidance and vertical position in the water column. This and the use of a camera-equipped airplane could be used to contrast what the ATM vessel is recording with a down sounder vs. sonar observation and/or photography.

Why the scientific surveys are important to industry: Simply put, industry livelihoods are dependent on the data outcomes of the surveys. Industry has a vested interest in accurate information. Mike Okoniewski believes that the effort to do stock status surveys needs to move to a collaborative basis. Funding cuts to NMFS research efforts and NOAA ship operations are a part of the issue. In addition the Industry feels it is time to work together to gather the most accurate and informative data possible. Industry support may help stave off some funding cuts. This support is more difficult to garner if fishermen's information and knowledge is not included in survey design and strategy.

Both science and the industry remain optimistic that they will be able to establish an effective and collaborative working relationship that will lead to a more comprehensive and improved understanding of this dynamic species. The SaKe survey that was put forward through enormous effort by the NW & SW Science Centers, Industry, DFO, and the West Coast and Alaska Congressional delegations was an affirmative step forward.

The most obvious challenge to the USA short seasons & low quota is having enough fishing time and quota to make any form of profit. Compounding this challenge are the following:

1. Attracting & retaining skilled crew to work in a short season.
2. Customer retention when they realize they can no longer meet their supply needs.
3. Attracting fleet to fish in an abbreviated season. (Largely confined to the PNW)

Working group 3 Plenary Session

Fishermen from each area summarized the fishing conditions in 2012:

1. Washington: 2012 was a good fishing year. Boats went out in May. There were issues with weather, quality, and some spotter planes. Fishing continued until the end of October due to the weather conditions. The fishing was very good close to the plant. The quality issues were early in the season, so fishers were asked to fish in different areas. The Quinault tribe had an allocation for the first time. The tribal fisheries had good quality and steady catches, and this is expected to continue.

Sardine caught in late May to early June had a lot of breakage; they were post-spawn and soft. A large percentage was roe bearing females. They weren't holding up to the rigors of loading and offloading. These earlier fish didn't meet the specification for either the bait or canning fishery. The bait fishery requires sardine with a specific oil content. This was early so there was no opportunity cost or competitive catch working on the quota. Late in the season the fleet would be more reluctant to venture farther once the other plants were open.

Competing with the pink salmon fishery is a challenge to the fishermen. In 2012, there were no problems retaining a fleet because there was a lot of fishing opportunity. However, when the quota goes down for sardine and other fisheries are more appealing, the fishermen would lose their sardine fleet.

2. Canada: SIAB (Sardine Integrated Advisory Board) members summarised the Canadian sardine fishery. 2012 was not a great year for BC. They needed larger fish and higher in oil. The cold water of 7° C in April affected the migration and delayed everything. The sardine didn't go past Cape Cook, and didn't split size groups. There was no market for fish of the poor quality at the beginning of the season. The fish seemed to be stalled below the border. The fish sizes were small when the PNW had larger fish. Instead of going in to Barkley Sound, fish went above Estevan. Nootka Sound probably had 200,000t in the inlet. The fish in our samples averaged 70-75 fish per bucket, with 170-180g fish mixed with 110-130g fish. The mixed sizes were not preferred by the fish market, thus it was difficult for the fishing operation. The late migration of sardine which did not reach far north as in the past was likely due to oceanographic conditions. Total number of Canadian licences was fewer than 10 this year.

It was cold in July, but the water warmed prior to the Canadian trawl survey and from mid-August to October. The conditions were quite different than previous years. With water cooled and then warmed, it was hard to know if the fish were offshore or still down south. However, once the warm water appeared, the sardine did too.

During the July 15th Salmon opening, sardine are usually present in the northern fishery. There was no sardine in the north in 2012. This was also reflected in the Canadian Tuna fishery. The whole area north of Cape Cook was flown and no whales were visible. The only humpback whales feeding on the sardine were down south. SST showed that Hecate Strait and the east coast of the Charlottes were particularly warm during the Salmon survey. This demonstrated that the migration has more to do with the temperature earlier in the year, as the example of 2012's cold April waters shows.

During the fishing season, temperatures reached 13°-17°C: 12.5°-13° south of Barkley, 14.5-15°C north of Barkley, and warmer in the inlets. Note that more humpback whales were observed in Washington than the past.

3. At Astoria, Oregon, catching sardine for longline tuna bait is the main focus. Taiwan has cut down their longline fleet in lieu of milk fish and eel, thus the demand for sardine has diminished. There are also issues with fat content and the percentage of oil with the European market.
4. In California, the fishery was small and slow between January and July. Since then fishermen have caught minimal sardine because of the squid fishery and small sardine. There were anecdotal reports of the population crowded in shallow water. Maybe after the squid fishery is shut down sardine will perk up.

The take home message from the fishing industry at this session is that a low level of harvest guideline makes it hard to run a fishing business because it affects fleet, fishers, and offload facilities.

Looking at size distribution between years, this year's 12-22cm range didn't have the usual sharp peak. The length range of sardine in last year was 15-20cm.

Industry is looking toward the future, and will have to be more involved in looking at generating more funds to get the research done that is needed. SaKe survey is a good direction to be going. The industry needs the science to support the fishery and science needs industry to obtain funding.

An aerial survey is planned for 2013.

CONCLUSION

The one and half day Forum, despite being a small meeting, provided another opportunity to share information across national lines. We wish there would be more participants from Mexico.

This forum included the regular sessions: regional Pacific sardine fisheries, research plans and reports (including many contributed papers), and three working group discussions; without a special session and focus issue like previous forums. The highlights of the forum were the plenary sessions of three working groups, which stimulated relevant questions and open discussions.

The Pacific sardine stock assessment indicates a general decline in the stock productivity since the late-1990s and early 2000s with around 1-million mt. Recruits (age-0) declined from 14 billion fish in 1997-99 to a level of 1.5 billion fish in fishing year 2011 (July 1, 2011-June 30, 2012), with the strongest 2003 year class of 22 billion fish. The spawning stock biomass has been declining from 1 million mt in early 2000 to 0.4 million mt in the 2012 season. The commercial landings of the U.S. peaked in 2007 with 127,788 mt and have been declining since. The total landings in 2012 were 98,027 mt, doubling the landing in 2011. The commercial catch off B.C., Canada has been increasing from 1.7 thousand mt in 2000 to 21 thousand mt in 2011. The commercial catch off Ensenada has been stable with annual total catch being around 50 thousand mt and increasing to 70 thousand mt in 2011(Hill et al. 2012). The harvest guideline (HG) proposed for 2012 (109,409 mt) is lower than the 2007 HG (152,564 mt), but higher than the quota allocated in 2008-2011. Since 2008, the commercial catch of the U.S. fishery has been close to the HG issued under federal management. Industry is looking forward to the future and needs to make an effort to generate funding for further research, such as the SaKe survey and indicated that science needs to support the fishery. An aerial survey is planned for 2013.

The forum concluded with ‘Thanks to everyone for attending the forum’ by Dr. Russ Vetter (*SWFSC*). Dr. Nancy Lo (*SWFSC affiliate*) also said ‘Good bye’ to everyone, as most likely this will be her last time to attend the TSF. The 2013 Trilateral Sardine Forum will be held in Ensenada, Mexico in early December. Please visit <http://swfsc.noaa.gov/tsf.aspx> or <http://swfsc.noaa.gov> for updated information.

ACKNOWLEDGMENTS

Special thanks to Vanessa Hodes, DFO for providing the meeting notes and Stephanie Flores, SWFSC, for organizing and editing the report. We thank William Watson and Barbara Javor of SWFSC for reading an early draft of the report.

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ACRONYMS (not all were used in this report)

CCGS	Canadian Coast Guard Ship
CDFG	California Department of Fish and Game
CIAD	Centro de Investigación en Alimentación y Desarrollo
CICESE	Centro de Investigación Científica y de Educación Superior de Ensenada
CICIMAR-IPN	Centro Interdisciplinario de Ciencias Marinas – Instituto Politecnico National
CIBNOR	Centro de Investigacion Biologico del Noroeste
CONAPESCA	Comisión Nacional de Acuacultura y Pesca
CRIP	Centro Regional de Investigación Pesquera
DFO	Department of Fisheries and Oceans, Canada
FACIMAR	Facultad de Ciencias del Mar
IMECOCAL	Investigaciones Mexicanas de la Corriente de California
INAPESCA (INP)	Instituto Nacional dela Pesca
IPN	Instituto Politécnico Nacional
IVQ	Individual Vessel Quota
NEFP	New Emerging Fisheries Policy
NMFS	National Marine Fisheries Service
NWFSC	Northwest Fisheries Science Center
ODFW	Oregon Department of Fish and Wildlife
PICFI	Pacific Integrated Commercial Fisheries Initiative
PSC	Pacific Seafood Co
PCSCA	Pacific Coast Shrimpers Cooperative Association

SAFS	School of Aquatic and Fishery Sciences, University of Washington
SARDI	South Australia Research and Development Institute
SIO	Scripps Institution of Oceanography, University of California San Diego
SWFSC	Southwest Fisheries Science Center, National Marine Fisheries Service
UBC	University of British Columbia
WDFW	Washington Department of Fish and Wildlife
WSP	Wild Salmon Policy

APPENDIX I

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APPENDIX II

ENGLISH AGENDA

2012 TriNational Sardine Forum

November 28-29, 2012

Seattle, Washington, USA

Tuesday, November 27th

Afternoon: Arrival in Seattle. Travel to Hotel Deca

18:00-21:00 Non-hosted welcome gathering in the Hotel Deca lobby

Wednesday, November 28th

8:00 Registration

9:00 Welcome and opening remarks: Mark Strom, NWFSC

9:20 Meeting Logistics: Lorna Wargo, WDFW

9:30 Regional Sardine Fishery Report: British Columbia for 2012 by Jordan Mah, DFO

10:00 Break

10:20 2012 Washington State and Quinault Indian Nation Sardine Fisheries: Lorna Wargo and Alan Sarich, presented by Lorna Wargo, WDFW

10:40 2012 Oregon Sardine Fishery Report: Jill Smith and Cyreis Schmitt, presented by Lorna Wargo

11:00 2012 California Sardine Fishery Report: Chelsea Protasio, CDFG presented by Lorna Wargo, DFW

11:20 The Sardine Fishery In Bahia Magdalena, 2011-2012: R. Félix-Uraga, F. N. Melo-Barrera, C. Quiñonez-Velázquez¹, E. Álvarez-Trasviña, M. E. Hernández-Rivas and V. D. Hernández-Valdéz¹ and presented by Kevin Hill

11:45 Lunch

13:00-14:40 Research Plans and Reports:

1. Stock structure (genetics, microchemistry, traditional approaches, others): John Hyde, SWFSC
2. Regional Biomass estimates: Nancy Lo

3. West coast of Vancouver Island 2012 sardine trawl survey: Linnea Flostrand, Vanessa Hodes, Jennifer Boldt, Jake Schweigert
4. Acoustic-trawl surveys of sardine during spring and summer 2012: David A. Demer, Juan P. Zwolinski, Beverly J. Macewicz, George R. Cutter Jr., Kyle A. Byers, Josiah S. Renfree, and Thomas S. Sessions
5. Stock assessment: Kevin Hill, SWFSC

14:40 Break

15:00-17:00 Contributed papers:

1. The Impact of Spatial Structure Assumptions on the Pacific Sardine Assessment: Felipe Hurtado-Ferro¹, André E. Punt¹& Kevin T. Hill²¹ University of Washington, School of Aquatic and Fishery Sciences ²NOAA, National Marine Fisheries Service
2. Development of a Prediction System for California Current Ocean Conditions: Isaac Kaplan and Greg Williams, NOAA Northwest Fisheries Science Center, Samantha Siedlecki, Nicholas Bond, Albert Hermann, Phil Levin, Jan Newton, William Peterson Measurements of natural mortality for Pacific sardine: Juan P. Zwolinski and David A. Demer, SWFSC
3. 2012 DEPM adult parameters of Pacific sardine (*Sardinops sagax*): results and comparison to previous years: Bev Macewicz, Dave Griffith, and Nancy Lo, SWFSC
4. Recent shift in the California population of Pacific sardine (*Sardinops sagax*) detected in otolith features: Barbara Javor, SWFSC, presented by John Hyde.
5. Growth and maturation of Pacific sardine off California from 2004 to 2010: Emmanis Dorval, Kevin Hill, Jenny McDaniel, Beverly Macewicz, SWFSC and Dianna Porzio, CDFG

17:00 Adjourn

18:30-21:00 Dinner at Ivar's Fish House

Thursday, November 29th

8:00 Working Group (WG) breakout sessions: WG1) Regional biomass: Nancy Lo WG2) Stock structure, age structure and adult sampling: John Hyde WG3) Industry trends and issues: Mike Okoniewski

9:30 Plenary Sessions results of WG discussions

11:00 Closing Remarks: Russ Vetter and Nancy Lo

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APPENDIX III

CONTRIBUTED ABSTRACTS AND SUMMARIES

ORAL PRESENTATIONS

(In alphabetical order)

ACOUSTIC TRAWL SURVEYS OF SARDINE DURING SPRING AND SUMMER 2012

David A. Demer (1), Juan P. Zwolinski (2), Beverly J. Macewicz (1), George R. Cutter Jr. (1), Kyle A. Byers (1), Josiah S. Renfree (1), and Thomas S. Sessions (1)

1. Southwest Fisheries Science Center

2. Ocean Associates Incorporated

The abundances, distributions, and demographics of Pacific sardine (*Sardinops sagax*) in the California Current ecosystem (CCE) have been surveyed using the acoustic-trawl method (ATM) during spring 2006, 2008, 2010, 2011, and 2012, and summers 2008 and 2012. Based on the scientific literature and results of the 2006-2011 ATM surveys, oceanographic conditions in the north Pacific have shifted to a colder period, sardine biomass has declined in the CCE, survey-trawl catches with sardine increasingly include other pelagic fish species, and the abundance of mackerel (*Trachurus symmetricus* and *Scomber japonicus*) is increasing in the survey area. Here, these observations are reviewed considering new information from the spring and summer 2012 surveys. Estimates are provided for the 2012 distributions and abundances of sardine and mackerels, estimates of uncertainty, and density-weighted sardine length distributions. The summer ATM survey was conducted as part of the first international sardine-hake survey off the west coasts of the USA and Canada. The 2012 sardine stock assessment was updated with data from both of the 2012 surveys.

GROWTH AND MATURATION OF PACIFIC SARDINE OFF CALIFORNIA FROM 2004 TO 2010

Emmanis Dorval¹, Kevin Hill¹, Jenny McDaniel¹, Beverly Macewicz¹, Diana Porzio²

1. NOAA Southwest Fisheries Science Center

2. California Department of Fish and Game

The northern Pacific sardine (*Sardinops sagax*) stock ranges from northern Baja California (Mexico) to British Columbia (Canada), but the core spawning area of this stock is located off California. The stock is fully exploited throughout its range, with the Ensenada (Mexico) and California fisheries targeting smaller and younger fish (0-4 years old) and the Pacific Northwest fishery exploiting larger and older fish (4-8 years old). During the last decade the spawning stock biomass steadily declined from a peak of 1,128,220 mt in 1999 to a low of 642,833 mt in 2010. This period of stock decline coincided with the expansion of the range of the population from California to the Pacific Northwest. Although growth rate and maturity at length were previously estimated for sardine collected in 1994, to our knowledge no studies have determined whether the decline in abundance and the northward migration have impacted growth and maturation of the sardine population off California. In this study, we used the von Bertalanffy growth model to estimate growth parameters of sardine collected during the Southwest Fisheries Science Center DEPM (i.e., Daily Egg Production Method) spring surveys from 2004 to 2010. As Pacific sardine were aged by multiple readers, we developed random-effects models to account for the effects of ageing imprecision on the estimation of the three parameters (i.e., k , L_{∞} , t_0) of the growth equation. Maturation status of females sardine was determined based on histological analysis of ovary samples. Further, fish were grouped in two aggregated cohorts, including fish that were born after 2003 and before 2004. Growth rate of fish collected during the 2004-10 period was estimated to be 0.20 ± 0.02 , which was much slower than the growth rate estimated for fish collected in 1994 ($k = 1.19 \pm 0.04$) when the stock was recovering from the 1940's collapse. In contrast, length at 50% maturity (L_{50}) was estimated to be 148.96 mm for fish collected during the 2004-10 period, which varied slightly from L_{50} estimated for fish collected in 1994 (i.e., 153.8mm). Similarly, age at 50% maturity varied little among the two aggregated cohorts, and was estimated to be 0.59 for fish collected during the 2004-2010 period. These results suggest that Pacific sardine mature during the first semester of their life, and they exhibit compensatory growth rate off California, but with no significant effects on size and age at maturity.

THE IMPACT OF SPATIAL STRUCTURE ASSUMPTIONS ON THE PACIFIC SARDINE ASSESSMENT

Felipe Hurtado-Ferro (1), André E. Punt (1), Kevin T. Hill (2)

1. University of Washington, School of Aquatic and Fishery Sciences

2. NOAA Southwest Fisheries Science Center

The conventional model of the dynamics of the northern subpopulation of Pacific sardine (*Sardinops sagax caerulea*) is that it concentrates in a “core” area off southern California and northern Mexico during periods of low abundance, but expands its range to the north during periods of high abundance. The stock assessment, conducted using the Stock Synthesis 3 (SS3) framework, uses this model and assumes a spatially-aggregated stock with constant growth across the entire coast and fleets with different selection patterns. However, seasonal length-dependent migration has been described in the literature, as well as the possible presence of two stocks, rather than one.

A simulation-based approach, using operating models including several hypothetical scenarios of spatial structure and seasonal movement, is used to evaluate the performance of SS3. Specifically, we evaluated (1) how much error can arise because assessments of sardine are conducted using a spatially-aggregated stock assessment method when this assumption is violated, and (2) whether moving to a spatially-structured stock assessment could reduce this error. We found that the assessment model is sensitive to the presence of seasonal migrations and the occasional persistence in the Pacific Northwest of Pacific sardine, while relatively insensitive to the presence of a southern (Mexican) subpopulation in the area in which the northern subpopulation is usually found. We also found that an assessment model that includes several fleets (i.e. 2009-2010 model configuration) is more flexible than a model with fewer fleets (i.e. 2011-2012 model configuration) when dealing with spatial uncertainty. A spatially-explicit model using the same data available for the current assessment model was not able to converge.

RECENT SHIFTS IN THE CALIFORNIA POPULATION OF PACIFIC SARDINE (*Sardinops sagax*) DETECTED IN OTOLITH FEATURES

Barbara Javor

NOAA Southwest Fisheries Science Center

The causes of declining stocks and lengths of Pacific sardine along the west coast of the U.S.A. during the early 2000s have not been identified with certainty, but clues might be found within the fish themselves. An investigation of the otoliths from two California populations of immature sardine during 2006-2012 revealed a persistent increase in morphologies resembling otoliths from warmer Mexican waters that began in mid-2008. The relative decrease in northern-race juvenile otoliths correlated with declining spawning stock biomass estimates. The shift in juvenile otolith phenotypes did not appear in the adult population in 2009-2012. There was no difference in the sexual maturity between adult sardine with southern- and northern-type otoliths in annual spring surveys (2004-2012). Regressions of otolith weight vs. standard length of adults in annual surveys were similar, indicating growth rates were likely unaffected by the shift in the juvenile population. The persistent relative increase of southern-race juveniles in California without similar representation in the adult stock requires further investigation. Such population shifts may be intrinsic in the natural oscillations of Pacific sardine. Otolith morphology, particularly in immature sardine, should be considered as a validating factor in stock assessment estimates.

DEVELOPMENT OF A PREDICTION SYSTEM FOR CALIFORNIA CURRENT OCEAN CONDITIONS

Isaac Kaplan and Greg Williams

NOAA Northwest Fisheries Science Center

**Collaborators: Samantha Siedlecki, Nicholas Bond, Albert Hermann, Phil Levin, Jan Newton,
William Peterson**

NOAA Northwest Fisheries Science Center

We will discuss a new project that will forecast ocean conditions 6-9 months in advance. We aim to link these forecasts to ocean conditions that are relevant to sardine. Predictions will include ocean temperature, salinity, chlorophyll, nutrients, oxygen, and zooplankton. The oceanographic modeling links CFS (Climate Forecast System) to a ROMS (Regional Ocean Modeling System). We will predict presence/absence or density of sardine life stages on the basis of predicted ocean conditions, recognizing that Trinational Sardine Forum participants have fitted similar relationships between sardine survey data and observed ocean conditions. We will compare hindcasts to recent observations of physical variables as well as sardine densities. Forecasts will be communicated as part of the California Current Integrated Ecosystem Assessment and via the NANOOS public website (www.NANOOS.org). We seek feedback regarding this new effort.

2012 DEPM ADULT PARAMETERS OF PACIFIC SARDINE (*Sardinops sagax*): RESULTS AND COMPARISON TO PREVIOUS YEARS

Beverly Macewicz, Dave Griffith, and Nancy Lo

NOAA Southwest Fisheries Science Center

Four adult parameters are needed for estimation of spawning biomass: S) daily spawning fraction or the number of spawning females per mature female per day, F) the average batch fecundity (number of eggs spawned in a batch), Wf) the average weight of mature females (g), and R) the proportion of mature female fish by weight (sex ratio). Daily specific fecundity (number of eggs per population weight (g) per day) is (RSF)/Wf). For the standard DEPM area (CalCOFI lines 60-95 about San Diego to San Francisco), 126 mature female Pacific sardine, collected from 16 positive trawls, contributed to the following 2012 results: Wf = 141.6 g (CV = 0.04); F = 38,682 eggs/batch (CV = 0.06); S = 0.138 females spawning per day (CV = 0.24); and R = 0.429 (CV = 0.12). We compared the adult parameters from 2012 to results from 2004-2011. The average mature female weight was higher than 2005-2011 (65.34, 67.41, 81.62, 102.21, 112.4, 129.51, and 127.59 grams respectively) but lower than 2004 (166.99 g). The daily spawning fraction in 2012 (0.138 females spawning per day) was similar to 2004 (0.131) and higher than 2005-2011 (fraction spawning ranging between 0.07 and 0.119). Because lighter fish produce less eggs per batch than heavier fish every year, it is difficult to compare average batch fecundity, although it seems that females in 2012, that were slightly larger on average, produced less eggs per batch than the previous two years: 274 eggs/g-female in 2012 vs. 301 eggs/g-female in 2011 and 302 eggs/g-female in 2010. In 2004 the adult samples were taken primarily in the high sardine egg density area, but beginning in 2005 adult Pacific sardine samples for reproductive output were taken in both high (Region 1) and low (Region 2) sardine egg density areas. Daily spawning fraction was higher in Region 1 than Region 2. Female size (weight in grams) was either similar or larger in Region 1, except for 2012 and 2009 when females were smaller.

MEASUREMENTS OF NATURAL MORTALITY FOR PACIFIC SARDINE

Juan P. Zwolinski (1) and David A. Demer (2)

1. Ocean Associates Incorporated

2. NOAA Southwest Fisheries Science Center

The abundances and distributions of the migrating portion of the “northern” stock of Pacific sardine (*Sardinops sagax*) in the California Current Ecosystem (CCE) were surveyed using an acoustic-trawl method (ATM) during spring 2006, 2008, 2010, and 2011. To assess the stock, an integrated simulation model (Stock Synthesis) uses these and other survey data, and numerous fixed or estimated parameters including a constant value for an instantaneous natural mortality coefficient (M). Here, the 2006-2011 ATM-estimated sardine abundances and demographics are combined to directly assess the length-structured sardine biomass, estimate M , and forecast the sardine stock biomass for 2012. The biomass-weighted fish-length distributions from the ATM surveys indicate that the sardine stock was dominated by 2003 and 2005 year classes (2003/2005 cohort) from 2006 to 2010, and by a 2009 cohort in 2011. The lack of significant recruits between 2006 and 2010 allowed the decline of the sardine-stock biomass to be tracked, providing bootstrap estimates of total mortality distributions. By subtracting deaths due to fishing, distributions of M were estimated for each inter-survey period (i.e., 2006-2008, 2008-2010, and 2010-2011), and for the entire survey period, 2006-2011.