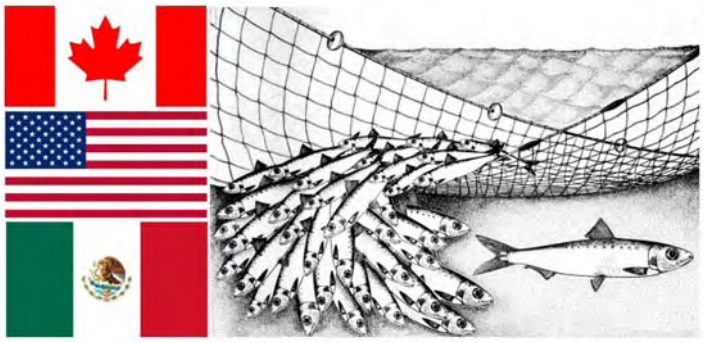
Proceedings of the
2009
TRINATIONAL SARDINE FORUM
FORO TRINACIONAL DE LA SARDINA
Xth ANNUAL MEETING

Mechanisms of variation of sardine abundance in the California Current system

Mecanismos de variación en la abundancia de sardina en el sistema de la Corriente de California



CICIMAR- Instituto Politécnico Nacional
La Paz, Baja California Sur, México
November 17-20, 2009

Ruben Rodríguez-Sánchez[1*], Héctor Villalobos[1], and Sharon Z. Herzka[2]

[1] CICIMAR- IPN
Av. IPN s/n, Playa Palo de Sta. Rita
23096 La Paz, B.C.S., México
***** rrodrig@ipn.mx

[2] CICESE
Km 107 Carretera Tijuana-Ensenada
22860, Ensenada, B.C., México

NOVEMBER 2010

Participants of the 2009 Trinational Sardine Forum (Xth meeting) held in La Paz, B.C.S., Mexico.

CONTENTS

INTRODUCTION …… 1
ACKNOWLEDGEMENTS …… 2

PLENARY SESSION HIGHLIGTHS
Regional Sardine Fisheries Reports …… 3
MEXICO
Gulf of California …… 4
Bahia Magdalena …… 6
Ensenada …… 10
UNITED STATES
California …… 12
Oregon …… 14
Washington …… 15
Assessment of the Pacific sardine resource in 2009 for U.S. management in 2010: Executive Summary …… 17

REPORT FOR WORKING GROUP 1: Regional Estimates of Biomass 2009 and Recommendations …… 22
Coast-wide survey, CalCOFI, and IMECOCAL April cruises, 2009 …… 22
Pacific Sardine Biomass Estimates and Associated Information off Northern Oregon and Southern Washington …… 26
Canadian Trawl Survey of Pacific Sardine Abundance in B.C. Waters During 2009 …… 40
Work Group 1 2009 Recommendations …… 45
.
REPORT FOR WORKING GROUP 2: Stock Structure, age structure, and adult sampling …… 47

REPORT FOR WORKING GROUP 3: Industry Trends and Issues …… 48

APPENDIX I: List of Participants …… 49

APPENDIX II: Agenda …… 51

APPENDIX III: Contributed Abstracts and Summaries …… 56

APPENDIX IV: Workshop on the role of Pacific sardine in the California Current System …… 95

INTRODUCTION

The Xth Trinational Sardine Forum (TSF) was held in La Paz, Baja California Sur, México, on November 17-20, 2009. The theme of the 2009 TSF was ¨Mechanisms of variation of sardine abundance in the California Current system¨. The meeting took place at El Galeon Room, Hotel Marina, and was attended by 47 participants representing the fishery industry, scientist, governments, and academia from Canada, United States and México (Appendix I).

The Forum was inaugurated by two special guests, Lic. Juan Antonio Angulo, Director de Fomento Pesquero y Acuacultura of Secretaria de Pesca y Acuacultura del Estado de B.C.S.; and Lic. Ramón Alejo Parra Ojeda, Director General de Asuntos Jurídicos del Gobierno del Estado. Both speakers expressed the importance of understanding the ecology, oceanography, and biology of Pacific sardine and the impact of fisheries on sardine populations. Each touted the benefits of the Forum as a venue for sharing academic experience, fostering international cooperation, identifying research priorities and exchanging ideas. A welcome statement was pronounced by Dr. Rafael Cervantes, Director of CICIMAR, and Dra. Nancy Lo of NOAA- South West Fishery Science Center gave a brief history of the Forum and outline the objectives at its inception. Finally, the opening remarks and instructions were presented by Dr. Ruben Rodriguez-Sanchez, Chair of the Forum.

Dr. Daniel Lluch Belda lecture was titled ¨Reexamining and old hypothesis¨, he remembered that 20 years ago he and other colleges proposed a hypothesis to explain the large fluctuations in the abundance of sardine populations at the California Current System, synchronic with those of several other areas of the world oceans. Since then many other hypothesis have emerged, but citing to Alheit (in press), ¨…the direct association of shifts in the dynamics of small pelagic fish and their ecosystems are still largely obscure…¨. Thus, he suggested appropriate to reexamine the old hypothesis, and particularly some parts of it such as synchrony, migrations and others at the various scales of change.

Followed Dr. Lluch-Belda´s key note presentation, the Forum moved into Regional Sardine Reports and then contributed papers (Appendix II and III). Seven posters were also displayed at the meeting hall for the duration of the Forum.

A Sardine Workshop entitled ¨the role of Pacific sardine in the California Current System¨ follow the Trinational Sardine Forum (November 19-20). The workshop was convened by Sandy McFarlane and Jake Schweigert of the Department of Fisheries and Oceans, Canada, focusing on the development of a trophodynamic model to enable the prediction of future changes in abundance and distribution of Pacific sardine in the California Current system. It was held in the Multimedia Room at Centro Interdisciplinario de Ciencias Marinas (CICIMAR), La Paz, B.C.S., Mexico.

The TSF Executive Committee represents all three countries: Nancy Lo (USA), Sharon Herzka (Mexico), Robert Emmett (USA), and Jake Schweigert (Canada), were present hosting the meeting. The 2010 TSF will be held in Harbour Towers Hotel, Victoria, British Columbia, Canada (November 16-17, 2010). The theme of the 2010 TSF will be ¨Sardine and its role in the ecosystem¨. A Workshop on Ecopath modelling of Pacific sardine in the California Current system will follow the TSF (November 18, 2010). The workshop is convened by Sandy McFarlane and Jake Schweigert.

ACKNOWLEDGEMENTS

Putting on the Xth Annual TSF takes a host of people. Special thanks go to the TSF Program Committee Drs. Nancy Lo and Sharon Herzka. Ing. Joel Ávila Secretarío de Pesca y Acuacultura del Estado de B.C., provided financial support for the meeting. Ing. Cesar Garcia, Grupo Pando, provide the wine offered in the banquet. Pedro Gonzalez and Indra Alvarez, CICIMAR, were instrumental in setting up all meeting logistic. Gregoria Hernandez and Ulianov Jakes-Cota greatly assisted with registration/meeting logistics.

PLENARY SESSION HIGHLIGHTS

REGIONAL SARDINE FISHERY REPORTS

La pesquería de peces pelágicos menores en el Golfo de California, México; Temporada de pesca 2007-2008

The small pelagic fishery in the Gulf of California, Mexico Fishing season 2007-2008

Manuel O. Nevárez Martínez[1], Ma. Ángeles Martínez Zavala[1], J. Pablo Santos Molina[1], Myrna L. Anguiano Carrazco[1] y Ángel R. Godínez Cota[1].

[1]Centro Regional de Investigación Pesquera Guaymas, Instituto Nacional de la Pesca. Calle 20 No. 605 Sur, Guaymas, Sonora. C. P. 85400.

E-mail: nevarez@prodigy.net.mx

RESUMEN

Los peces pelágicos menores del Golfo de California sostienen la pesquería masiva más importante de México. La captura se sustenta en varias especies de sardinas, anchovetas y macarela, aunque la sardina monterrey (*Sardinops caeruleus*) históricamente ha sido la especie objetivo. Aquí se presenta el comportamiento de las capturas durante la temporada de pesca 2007-2008. Durante esta temporada, se registró una captura total de 538,669 t, de las cuales 90.71% fue de sardina monterrey, 4.78% fue sardina crinuda (*Opisthonema spp*.), 2.28% fue sardina bocona (*Cetengraulis mysticetus*), un 1.09% fue anchoveta (*Engraulis mordax*), un 0.74% fue macarela (*Scomber japonicus*), un 0.13% fue japonesa (*Etrumeus teres*) y la sardina piña (*Oligoplites spp*.) aporto el 0.04%. Entre los meses de noviembre del 2007 a julio del 2008, las capturas oscilaron entre 43,750 y 72,100 toneladas por mes, en gran medida a que hubo una muy elevada disponibilidad de sardina monterrey en áreas aledañas a Guaymas y Yávaros y en la zona frente a Santa Rosalía-Mulegé. La temperatura superficial del mar fue relativamente fría, presentándose anomalías negativas en los meses de octubre a marzo. Por otro lado, el patrón de vientos fue normal, pues en ese mismo periodo los vientos soplaron con componente norte, los cuales promueven las surgencias a lo largo de las costas de Sonora. Esos rasgos ambientales podrían explicar (al menos en parte) el comportamiento de las capturas durante 2007-08 y el significativo incremento en los desembarcos con respecto a las últimas temporadas de pesca.

ABSTRACT

Small pelagic fish of the Gulf of California sustain the most important large-scale fishery in Mexico. The catch is sustained by several species of sardines, anchovies and mackerel, although historically the Pacific sardine (*Sardinops caeruleus*) has been the primary target species. We describe the characteristics of the catch for the 2007-2008 fishing season. The total catch registered was

538,669 t, of which 90.71% was Pacific sardine, 4.78% was “Crinuda” sardine (*Opisthonema spp*.), 2.28% was “Bocona” (an anchovy, *Cetengraulis mysticetus*), 1.09% was northern anchovy (*Engraulis mordax*), 0.74% was mackerel (*Scomber japonicus*), 0.13% was round herring (*Etrumeus teres*), and 0.04% was “Piña” sardine (*Oligoplites spp*.). Between November 2007 and July 2008, monthly catches fluctuated between 43,750 t and 72,100 t per month, due mostly to very high availability of Pacific sardine close to Guaymas and Yavaros. During that period, sea surface temperatures were relatively cold, with negative anomalies between October and March. During those months, the wind patterns were “normal”; winds with a northern component promoted upwelling along the coast of Sonora coast. Those environmental features could explain (at least partly) the behavior of the catches during 2007-2008 and the substantial increase in landings compared with previous fishing seasons.

Magdalena Bay Pacific Sardine Fishery, 2008-2009

Félix-Uraga, R [1]., F. N. Melo-Barrera[1], & C. Quiñonez-Velázquez[1],

[1]Centro Interdisciplinario de Ciencias Marinas-IPN, Departamento de Pesquerías y Biología Marina. La Paz, Baja California Sur. Becarios COFAA y EDI.

E-mail: rfelix@ipn.mx

SUMMARY

The sardine fishery in Bahía Magdalena, BCS, is comprised of seven fishing boats with a carrying capacity of 60 to 120 tons. The composition of the catch is comprised of *Opistonema libertate, Cetengraulis mysticetus, Scomber japonicus* and *Sardinops sagax*. The Pacific sardine, *S. sagax*, represents 85% of the mean annual catch. Although fishing is carried out throughout the year, the Pacific sardine is more abundant between April and August. The yields of Pacific sardine in this fishing area have shown interannual variations. Between 1972 and 1993, the catch averaged 10,000 t year^{-1}, from 1994 to 1999 the average annual catch increased to 35,000 t, and between 2000 to 2007 the annual catch had been higher than 40,000 (Fig.1).

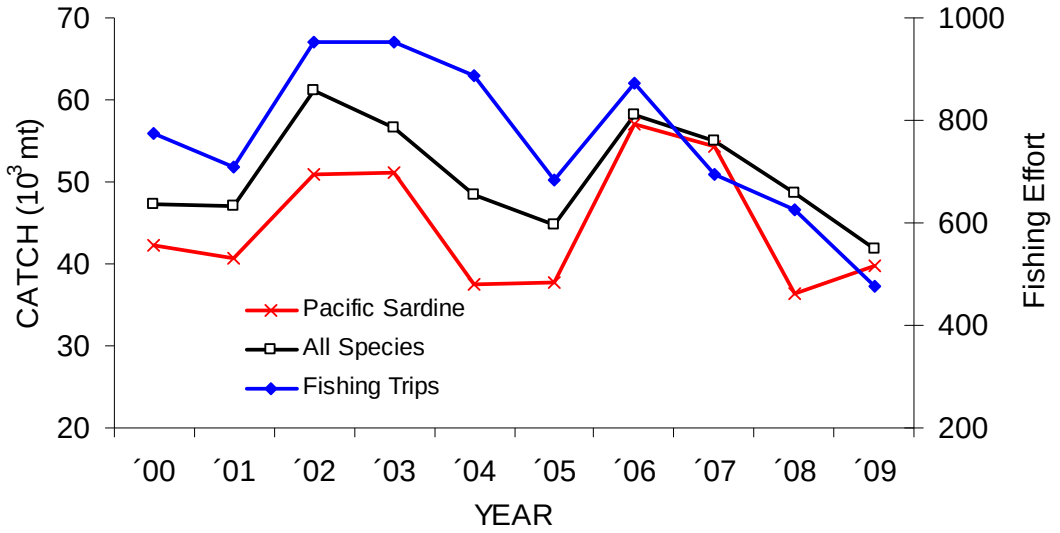


Figure 1. Annual variation in the catch of small pelagics in Bahia Magdalena, BCS, Mexico. For 2009, only data from January to August are included.

During 2008, 627 fishing trips were conducted and 48,710 t of small pelagic fishes were caught in Bay Magdalena. The catch of Pacific was 36,338 t, and represented 74.5% of the total catch (Fig. 2). The other species caught by the fishery were *Opisthonema* sp (14.2% of total), *Cetengraulis mysticetus* (6.9%), *Etrumeus teres* (0.8%) and *Scomber japonicus* (1.5%). Pacific sardine were caught throughout the year, although 75% of the annual catch was landed from May to September and 58% of the fishing trips took place during those months.

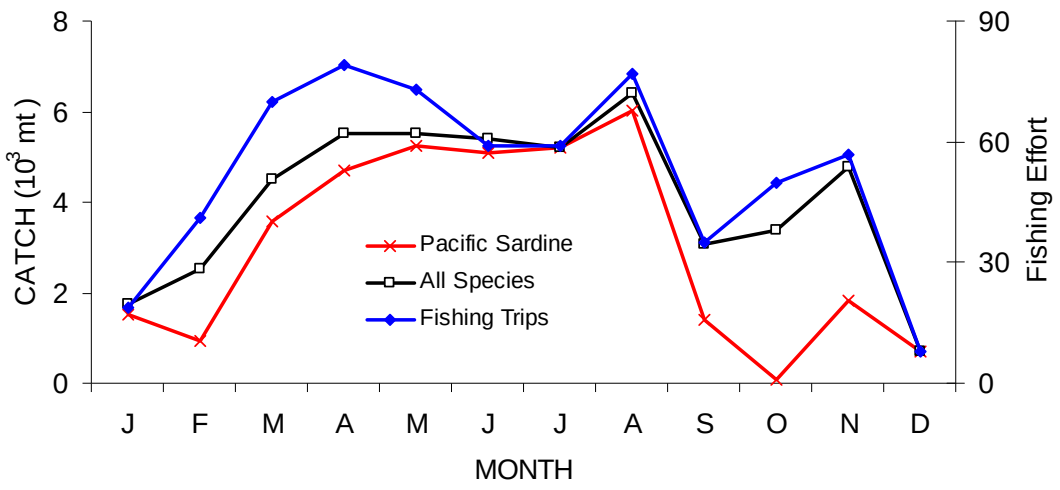


Figure 2. Monthly catch and fishing effort in Magdalena Bay fishery during 2008.

For 2008, the size of Pacific sardines ranged between 140-210 mm standard length (SL). Practically all sardines landed (99.8%) were above the minimum legal size (150 mm SL) (Fig. 3). Six age groups (0 to 5) were found, although age groups 1 and 2 were the most abundant (55% and 35%, respectively) (Fig. 4).

From January to August 2009, 36,000 t of small pelagic fishes were caught during 399 fishing trips. The catch of Pacific sardines was 34,170 t and represented 94.9% of the total catch. *C. mysticetus* comprosed 3.6% of the total biomass landed. Sizes of *S. sagax* ranged between 125-200 mm SL and ages between 0 to 4 years old. During this period, one-year old sardines were most abundant and sardines larger than minimum legal size represented 55% of the total catch.

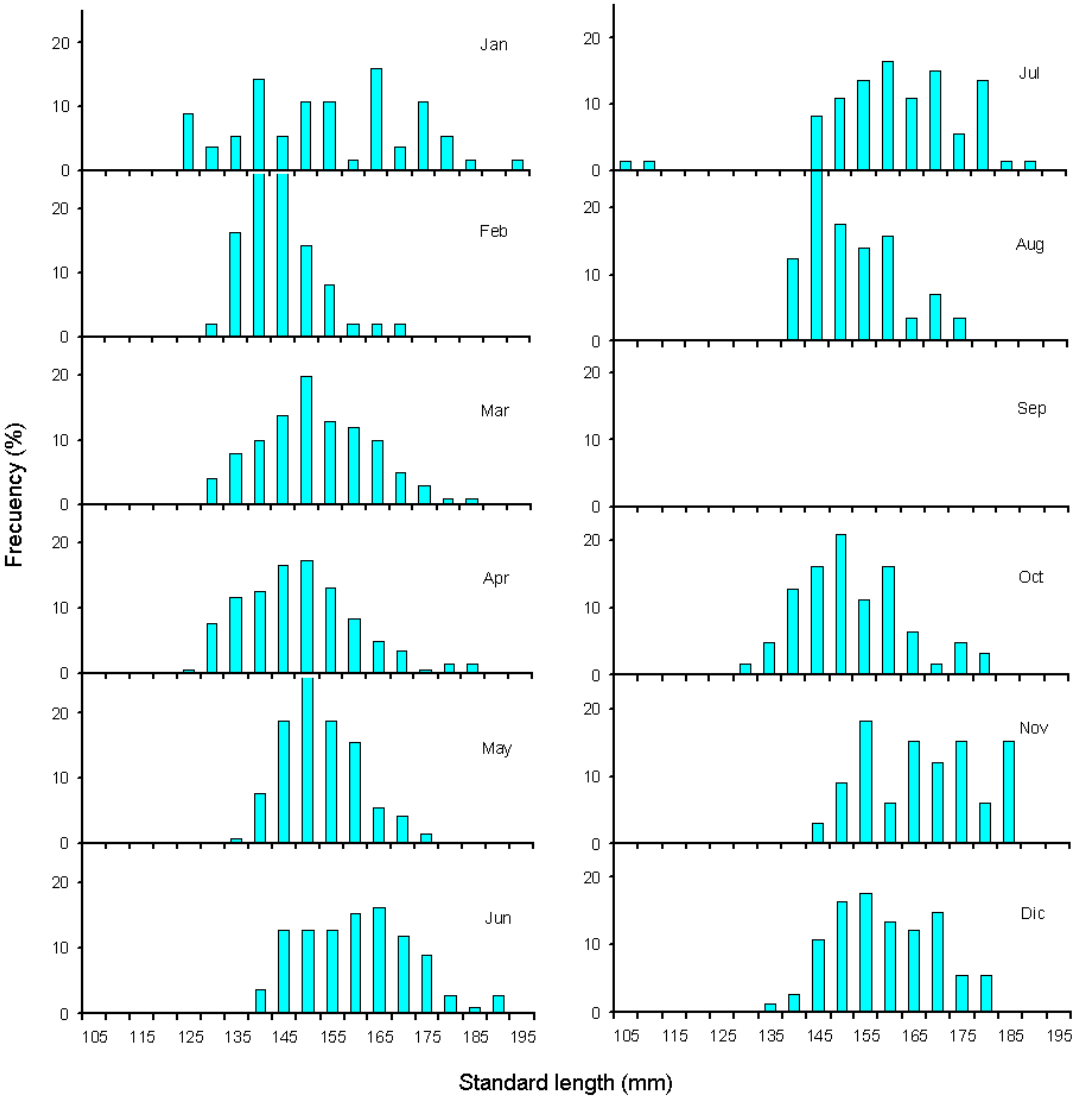


Figure 3. Monthly size structure variations of Pacific sardines caught in Bahia Magdalena during 2008.

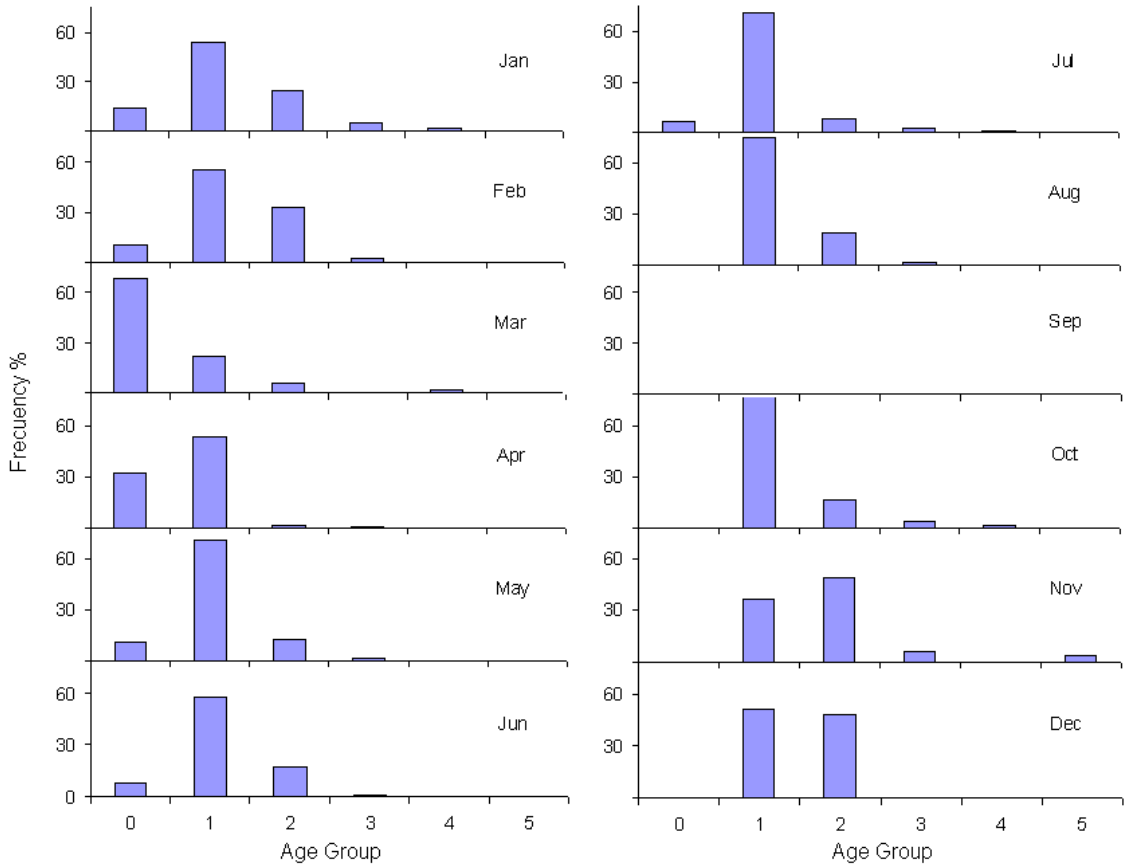


Figure 4. Monthly variations in age structure of Pacific sardines caught in Bahia Magdalena during 2008.

La pesquería de pelágicos menores en Ensenada, Baja California, Temporada de pesca 2008

Small pelgacis fishery in Ensenada, Baja California, 2008 fishing season

Eva Cotero Altamirano y Alfredo Cota Villavicencio
Centro Regional de Investigación Pesquera de Ensenada, INAPESCA.

E-mail: cecotero@yahoo.com

RESUMEN

Este trabajo presenta la situación de la pesquería de pelágicos menores que se desarrolla en la costa noroccidental de la Baja California para el año de 2008. Se toma como base los reportes de la flota de las capturas diarias y los muestreos diarios de las descargas, especialmente de sardina monterrey que es la especie objetivo de la pesquería, del resto de las especies se tiene escasa información. Se capturaron un total de 55,094.2 toneladas durante el 2008, correspondiendo un 98.4% a la sardina, 0.23% fue macarela del Pacifico y 1.3% fue anchoveta. Operaron un total de 15 embarcaciones con una capacidad de bodega promedio de 150 toneladas, realizándose un total de 1,162 viajes nominales. La composición por tallas muestra organismos con tallas promedio por encima de la talla mínima legal que es de 150 mm de longitud patrón; siendo las hembras las que presentaron tallas mayores sobre todo en los meses de verano (>160 mm de longitud patrón). Los meses más importantes en la reproducción fueron los meses de enero a marzo, con el máximo en febrero, mientras que la talla de primera madurez fue de 170 mm. La fecundidad estimada varió entre 8,633 y 27,064 con un promedio de 15,106 ovocitos (para hembras entre 150 y 190 mm). Durante el año 2008 se observaron condiciones térmicas mixtas.

ABSTRACT

This work reports on the small pelagic fishery along the northeastern coast of Baja California during 2008. The data were obtained from daily landing reports and from dock sampling of daily landings. Most of the information reported is specific to Pacific sardines, as there is limited information for other species. A total of 55,094.2 tons were captured during 2008, of which 98.4% were sardines, 0.23% were mackerel and 1.3% was anchovy. Fifteen boats with a capacity of 150 tones were in operation, and 1,162 trips were conducted. The size structure of Pacific sardines indicated that the average size captured was above the 150 mm SL legal size limit. Females were larger than males, particularly during the summer months (>160 mm SL). The months that were most important for reproduction were January-March, with a peak in February. Size at first maturity was 170 mm SL. Estimates of fecundity ranged between 8,633 and 27,064, with

a mean of 15,106 ovocytes for females between 150-190 mm SL. During 2008, the thermal conditions in the area were mixed.

California Sardine Landings for 2009

Dale Sweetnam and Briana Brady
California Department of Fish and Game

E-mail: Dale.Sweetnam@noaa.gov

A total of 37,660 metric tons (mt) of Pacific sardine were landed in California ports in 2009. This represents a 35% decline from 2008 landings (57,800 mt) due to a reduction of the harvest guideline (HG). Based on a west coast stock biomass estimate of 662,886 mt of sardines (age-1+), the 2009 season HG was set at 66,932 mt, nearly a 25% decrease from the HG set in 2008. The annual HG was attained within 77 fishing days.

Significant declines in sardine biomass estimates for the 2008 and 2009 seasons have resulted in the HG limiting landings instead of market demand. This has created a derby style fishery, as the allocated HG is caught before the allocation period or season has ended. This increases the amount of in-season monitoring and coordination between the states and agencies in order for management of the fishery to be effective.

Nearly two-thirds of California landings occurred in Monterey ports (24,725 mt), while 12,935 mt were landed in southern CA ports. Ex-vessel value ranged from $130-150/ mt in Monterey ports and between $120-140/ mt in southern CA ports. Sardines landed in Monterey ports tended to be larger than those landed in southern CA ports. The average length of sardines in Monterey ports was 166 mm with a weight of 64 grams; average length in southern CA ports was 151 mm and a weight of 49 grams.

Under the current HG, Pacific sardines are allocated coastwide in U.S waters during three periods 1 January - 30 June (35%), 1 July – 14 September (40%), 15 September – 31 December (25%). The seasonal allocation for the 1st period was 23,006 mt. During this period, fishermen fished harder during this time period than last year because they thought that the allocation amount would be used as quickly as it was in the previous 3rd allocation period in September. The fishery period was closed after 51 days; however, 2,266 mt remained un-harvested after the closure because bad weather prevented some vessels from fishing while other vessels left to fish market squid in Ventura.

During the second allocation period, a total of 28,559 mt was available starting 1 July. In July in Monterey, fishing primarily took place of off Capitola and Moss Landing. Weather prohibited vessels from locating sardine in the last days of the allocation in Monterey. Heavy marine layer prevented the spotter plane from flying and most vessels returned empty or with very small loads. A total of 8,665 mt was landed prior to the fishery closing on 18 July. In southern CA, sardine landings started slower than expected, but steadily increased through the first weekend. Some vessels instead brought in large loads of squid – there were

some complaints about the difficulty in finding larger schools of sardines. Most fishing took place along the coast with 2,677 mt landed.

The third allocation period opened on 15 September with 15,886 mt available for harvest, and was closed on 23 September. The majority of the landings (4,200 mt out of 4,771 mt landed in California) came from Monterey area ports. Most of the southern CA boats headed south from Monterey the weekend before the closure to fish for market squid.

Oregon Fishery report

Greg Krutzikowsky and Jill Smith

Oregon Departament of Fish and Wildlife

E-mail: greg.krutzikowsky@state.or.us

After a hiatus beginning in 1948 the Oregon directed sardine fishery was revived in 1999. It ramped up quickly with catches averaging ~40,000 mt from 2004 through 2007 before the Harvest Guideline was reduced in 2008. The directed sardine fishery landed 20,298 metric tons into Oregon in 2009. This accounted for 34% of 59,232 mt allocated to the coastwide directed fishery in waters off California, Oregon, and Washington. Twenty of the 25 vessels permitted in Oregon made 373 sardine landings during the 2nd and 3rd allocation periods, July 1- September 14 and September 15 to December 31, respectively. The reduced harvest guideline resulted in shortened fishing seasons for the second year in a row. Like the first allocation period from January 1-June 30 during which sardines were landed only in California, the second and third periods were closed early because the harvest allocation was projected to be reached before the period was finished. The fishery was open for 28%, 22%, and 7% of the available days in each of the three allocation periods, respectively. Oregon landings ranged from <10 mt to >100 mt with landings between 40 and 50 mt being most common. The ex-vessel value for sardines landed in Oregon was approximately $5 million, down slightly from approximately $5.7 million in 2008. All sardines were landed in Astoria and fishing was a daytime operation. Many vessels utilized spotter aircraft when possible. Tides and weather are major factors that affect fishery operations. The main area of catch, north and south of the Columbia River, was similar to previous years. Non-target species landings by the sardine fishery were low in other coastal pelagic species, specifically Pacific and jack mackerel, which accounted for >98% of other species landed by weight. Logbook information indicated that 248 salmon were caught and 53% of those were released alive. The mean weight of 1125 sardine sampled from Oregon landings was 125.9 g and the mean standard length was 198.1 mm.

Several changes to management of the Oregon sardine fishery were put into place for 2009. These include:

- The minimum landing requirements for permit renewal was eliminated for years that the coastwide harvest guideline is set at ≤100,000 mt.
- Catch sharing was restricted to catching vessels and limited to 20% of landing
- Requirements for the owner/operator be aboard a vessel were eliminated
- A provision for a lottery system to issue available permits not in use.

Washington Fishery Report

Lorna Wargo-Washington Department of Fish and Wildlife

E-mail: Lorna.Wargo@dfw.wa.gov.

In Washington, the sardine fishery has been managed as an emerging or developmental fishery since 2000. Under emerging fishery rules, sardine licenses could not be sold or traded. Participation in the Washington fishery was not limited until 2003, when a cap of 25 licenses was set in response to rapid expansion of the fishery in the Pacific Northwest.

Through legislation in 2009 regulation of Washington's fishery was moved from emerging to standard rules. Standard rules are used to manage established fisheries and allow licenses to be sold or leased. The number of licenses was capped at 16, and an individual or corporation can hold no more than two. Additional sardine licenses, good for one year only, may be issued at the director's discretion following criteria established in rule.

In 2009, sixteen fishers were eligible to receive a Washington sardine license.

A total of 8,009 mt of sardines were landed in the directed fishery in Washington in 2009, distributed over 173 landings with 59% landed in July and 41% in August. The average landing into Washington was about 46 mt. All landings were made into Westport or Ilwaco with the majority of the catch (95%) occurring in waters adjacent to Washington. A total of 238 sets were made with 203 (85%) of them successful. The average catch per successful set was about 44 mt.

An incidental harvest of nearly 14 mt of sardine was caught in anchovy-directed fishing in Washington in July and August.

The fishery typically opens on April 1; however, the first landings into Washington have usually been around late June or early July. Due to the reduced quota in 2009 and to accommodate its portioning into three periods, the fishery opened on July 1.

Only six of the 16 permit holders participated in the July portion of the 2009 fishery. Another two vessels joined the sardine fishery in August. These two vessels were new entrants, having just obtained sardine licenses when the fishery moved from emerging to standard rules in July.

Ex-vessel price per pound in the fishery averaged $0.08 - $0.11 across the season. Vessels fishing out of Ilwaco and Westport sometimes use spotter planes. In general, pilots receive about 10-15% of the landing revenue.

	2009	2008	2007	2006	2005	2004
Landings (mt)	8,009	6,432	4,663	4,362	6,714	8,911
# Landings	173	150	106	108	207	236
# Vessels	8	5	6	7	11	14

WDFW staff coordinated the collection of biological samples with Oregon Department of Fish and Wildlife (ODFW) staff to ensure sample coverage was evenly distributed throughout the Northwest fishery. Each state (Washington, Oregon, and California) is asked to collect a minimum of one sample of twenty-five sardines per 1,000 mt landed. WDFW collected twelve samples of twenty-five sardines each, extracting otoliths and determining sex and maturity of 300 fish.

Age data for 2009 are not yet available. Sardine ages in the Washington fishery have ranged from one to 10 years; the dominant age class has ranged from two to five years.

In 2008, ages ranged from three to nine years with age-4 and age-5 fish dominant at 35 and 43 percent respectively. In 2005, 2006 and 2007, the dominant age classes were age-4, age-3 and age-2 respectively.

Sex and maturity were determined by using the California Department of Fish and Game (CDFG) Standard Maturity Guide for Wetfish, which is based on Hjort, J. (1914) State of Sexual Organs. Sexual maturity codes 1-4 were used for the sardine samples:

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.

Most of the samples analyzed in 2009 were females (54%), with the highest subcategory overall being females with a sexual maturity of two. All sardines sampled had a maturity level of one or two. Typically there are also a very small number of sardines with a maturity level of three although none were found in Washington's landings this year. A maturity level of four has never been found in the Washington sardine fishery.

Assessment of the Pacific sardine resource in 2009 for U.S. management in 2010: Executive Summary

Kevin T. Hill[1], Nancy C. H. Lo[1], Beverly J. Macewicz[1], Paul R. Crone[1], and Roberto Felix-Uraga[2]

1. NOAA National Marine Fisheries Service, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, California,

   USA 92037

2. CICIMAR-IPN. Ave. IPN s/n A.P. 592, Col. Playa Palo Sta. Rita C.P. 230096, La Paz, Baja California Sur, México

The Pacific sardine northern subpopulation is assessed each year in support of the Pacific Fishery Management Council (PFMC) process that, in part, establishes an annual harvest guideline ('HG', or 'ABC') for the U.S. fishery. The latest assessment was conducted using the 'Stock Synthesis 3' (SS3) model, and includes fishery and survey data from updated and new sources. The draft assessment was reviewed by a Stock Assessment Review Panel 21-25 September, 2009, and the revised assessment will be presented to the PFMC in early November 2009. The outcome of these reviews may form the basis for U.S. Pacific sardine management in 2010.

Data and assessment

The assessment was conducted using 'Stock Synthesis' version 3.03a (Methot 2009). Fishery data include catch and biological samples for four fisheries off Ensenada, Southern California, Central California, and the Pacific Northwest. Two indices of relative abundance are included in the final base model: Daily Egg Production Method and Total Egg Production estimates of spawning stock biomass (1986-2009), both based on annual surveys conducted off California. Finally, the tuned base model was run with the addition of the 2009 aerial survey estimate of absolute abundance (q=1) to derive population quantities for 2010 management.

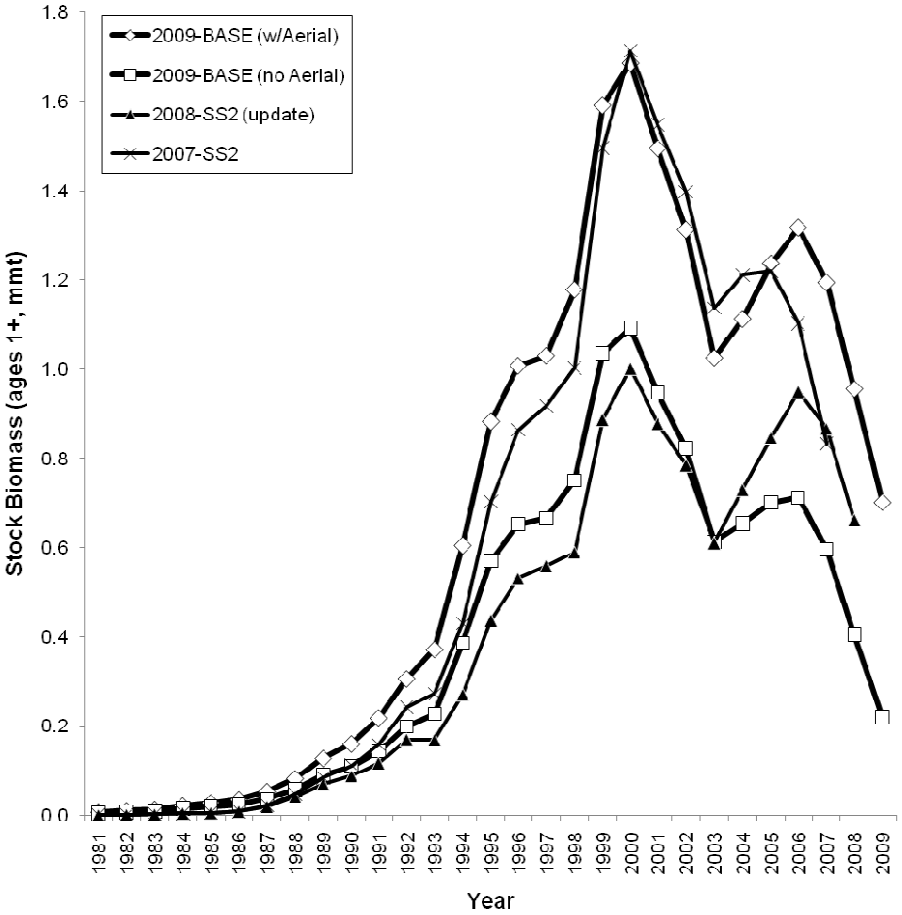
The final base model had the following specifications:

- Model Year based on the July 1 birth date assumption (July 1-June 30 time span);
- Assessment years 1981-2009; Two semesters per year (S1=Jul-Dec; S2=Jan-Jun);
- Four fisheries (ENS, SCA, CCA, PNW), with annual selectivity patterns for ENS and PNW and seasonal selectivity patterns for SCA and CCA (S1 & S2).
- Use of length-frequency and conditional age-at-length data for all fisheries;

- Length-based, double-normal selectivity with time-blocking:
    - ENS, SCA_S1, & SCA_S2: 1981-91, 1992-98, 1999-09;
    - CCA_S1 & CCA_S2: 1981-92, 1993-98, 1999-09;
    - PNW: 1981-03, 2004-09;
- $M = 0.4yr^{-1}$ for all ages and years;
- Two periods for growth estimation: 1981-90 and 1991-09;
- Ricker stock-recruitment relationship; $\sigma_R = 0.89$; Steepness estimated;
- Initial recruitment (R_1) estimated; recruitment devs estimated from 1975 to 2007;
- Hybrid continuous-F fishing mortality option;

Stock biomass and recruitment

Stock biomass, used for management purposes, is defined as the sum of the biomass for sardine ages 1 and older. Stock biomass increased rapidly through the 1980s and 1990s, starting at 8,210 mt in 1981 and peaking at 1.69 mmt in 2000. Stock biomass has subsequently declined to the present (July 1, 2009) level of 702,024 mt. Biomass from the base model is compared to final values from SS2 assessments used for management in 2008 and 2009 (Figure 1). Stock biomass and recruitment from the 2009 base model (w/Aerial) was very similar to results from the final 2007 assessment. Both the 2009-Base and final 2007 models scaled higher than the 2008 update and the 2009 base model that excluded the aerial survey:



Recruitment was modeled using the Ricker stock-recruitment relationship. The estimate of steepness was high (h=2.32). Virgin recruitment (R_0) was estimated at 4.94 billion age-0 fish for the base model. Recruitment increased rapidly through the mid-1990s, peaking at 16.79 billion fish in 1997, 22.01 billion in 1998, and 18.62 billion fish in 2003. Recruitments have been notably lower since 2005. Recruitments for 2008 and 2009 were derived from the spawner-recruit curve.

Exploitation status

Exploitation rate is defined as calendar year catch divided by total mid-year biomass (July-1, ages 0+). Exploitation rate was relatively high during the early recovery period (mid-1980s), but declined and stabilized as the stock underwent the most rapid phase of recovery. Exploitation rate has subsequently increased in recent years as the stock has again declined. Ensenada catch during 2009 is unknown (unavailable), so is assumed the same as 2008. Total exploitation rate is currently less than 16%:

Calendar Year	ENS	SCA	CCA	PNW	Total
2000	4.0%	2.7%	0.7%	0.9%	8.3%
2001	2.9%	3.0%	0.5%	1.6%	8.0%
2002	3.6%	3.7%	1.1%	2.9%	11.3%
2003	3.5%	2.5%	0.6%	3.2%	9.8%
2004	3.5%	2.7%	1.3%	4.1%	11.5%
2005	4.2%	2.3%	0.6%	4.2%	11.2%
2006	4.3%	2.5%	1.3%	3.1%	11.1%
2007	3.0%	3.8%	2.8%	3.9%	13.6%
2008	5.6%	3.2%	2.7%	4.1%	15.6%
2009	7.1%	1.8%	3.5%	3.4%	15.8%

Recommendation for U.S. management in 2010

The U.S. HG (or ABC) is based on the control rule defined in the CPS-FMP:

$$HG_{2010} = (BIOMASS_{2009} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2010} is the total U.S. (California, Oregon, and Washington) harvest guideline in 2010, $BIOMASS_{2009}$ is the estimated July 1, 2009 stock biomass (ages 1+) from the assessment (702,024 mt), CUTOFF is the lowest level of estimated biomass at which harvest is allowed (150,000 mt), FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries (see below), and DISTRIBUTION (87%) is the average portion of BIOMASS assumed in U.S. waters. Based on the current (T_{2009}) SST estimate of 17.92 °C, the F_{msy} exploitation fraction should remain at 15%. Based on results from the base model, the harvest guideline for the U.S. fishery in calendar year 2010 would be 72,039 mt. U.S. ABCs for previous years follow:

Calendar Year	U.S. ABC	U.S. Landings
2000	186,791	67,985
2001	134,737	75,733
2002	118,442	96,876
2003	110,908	69,931
2004	122,747	92,723
2005	136,179	90,016
2006	118,937	91,039
2007	152,564	127,789
2008	89,093	87,184
2009	66,932	65,652

REPORT FOR WORKING GROUP 1
Regional estimates of biomass of 2009 and recommendations

Partial list of members: Martin E. Hernandez-Rivas, mrivas@ipn.mx; Sandy McFarlane, mcfarlanes@dfo-mpo.gc.ca; Jake Schwartz, SchweigertJ@pac.dfo-mpo.gc.ca; Vanessa Hodes, Vanessa.Hodes@pac.dfo-mpo.ca; Robert Emmett, robert.emmett@noaa.gov; Andrew Claiborne; Green-Ruiz, motagreen@yahoo.com.mx; Darrell Kapp, dkapp@netos.com; Nancy C. H. Lo, Nancy.Lo@noaa.gov, Beverly Macewicz, Bev.Macewicz@noaa.gov; Rick Brodeur, Rick.Brodeur@noaa.gov; Manuel Nevariz, nevarezm@gys.megared.net.mx; Enrique Morales, embojorq@ipn.mx; Kevin Hill, Kevin.Hill@noaa.gov

1. Coast-wide survey, CalCOFI, and IMECOCAL April cruises, 2009

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

Activities**:**

California DEPM and Calcofi, MARCH-APRIL CRUISES, 2009

The DEPM (daily egg production method) survey was conducted aboard the chartered fishing vessel *F/V Frosti* (April 15-May 9) to cover the area from San Diego to San Francisco (CalCOFI line of 95.0 to 63.3). During the DEPM survey, CalVET tows, Bongo tows and CUFES and trawls were conducted. Prior to the DEPM survey, the spring CalCOFI survey was carried out aboard R/V *David Starr Jordan* from March 7-22 to cover six lines of 93.3 to 76.6 and only CalVET and Bongo tows were taken. Only data from the DEPM survey were used in estimation of spawning biomass of Pacific sardine because the spring CalCOFI cruise was conducted prior to the peak spawning time of Pacific sardine.

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), the 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 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 the embryonic mortality curve in the high density area and later converted to the daily egg production, P_0, for the whole survey area.

For adult samples, the survey plan was to conduct 3-5 trawls a night at the regular CalCOFI stations if possible on the survey line regardless of the presence of sardine eggs in CUFES collections from April 15 - May 8, 2009. A Nordic 264 rope trawl with 3.0 m^2 foam core doors was towed at the surface at night for a duration of 30 minutes. 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 extruder device placed midsection just forward of the codend. Pacific sardines were caught in 34 of the 61 trawls that were conducted at night near the surface (0-6 fathoms) (Fig. 1).

In 2009, in addition to the estimates of spawning biomass based on the past procedure by which, the P_0 was a weighted average with weights being the area size (km^2) of each region, whereas the adult parameters were estimated from all trawl samples in the entire survey area, an alternative estimator based on the stratified sampling for each parameter was also included (Hill et al. 2009) for years when adequate adult samples were available, e.g. 1986,1987,1994,2004,2005,2007-2009. The original time series of spawning biomass may not 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, an input time series for the stock assessment. The time series of spawning biomass based on the original method and the stratified estimates were report in Lo et al (2009).

The spawning biomass of the Pacific sardine (*Sardinops sagax*) in April - May 2009 was estimated by the original procedure of the daily egg production method (DEPM) to be 185,084 mt (CV = 0.26) for an area of 274,895 km^2 off California from San Diego to south of San Francisco (CalCOFI lines 95.0-63.3). The daily egg production estimate (P_0) was 0.59/.05m^2 (CV = 0.22), with the majority of eggs found south of Point Conception. The daily specific fecundity was calculated as 17.53 (number of eggs/population weight (g)/day) using the estimates of reproductive parameters from 467 mature female Pacific sardine collected from 29 positive trawls: F, mean batch fecundity, 29,790 eggs/batch (CV = 0.06); S, fraction spawning per day, 0.11 females spawning per day (CV = 0.15); W_f, mean female fish weight, 112.4 g (CV = 0.04); and R, sex ratio of females by weight, 0.602 (CV = 0.04).

The estimates of spawning biomass of the Pacific sardine off California in 1994 - 2008 were 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, 392,00 mt, 117,000 mt and 185,000mt (for the standard DEPM area), respectively. Therefore, the estimates of spawning biomass have been fluctuating, peaking in 2000 and 2006 and have been declining over the last three years.

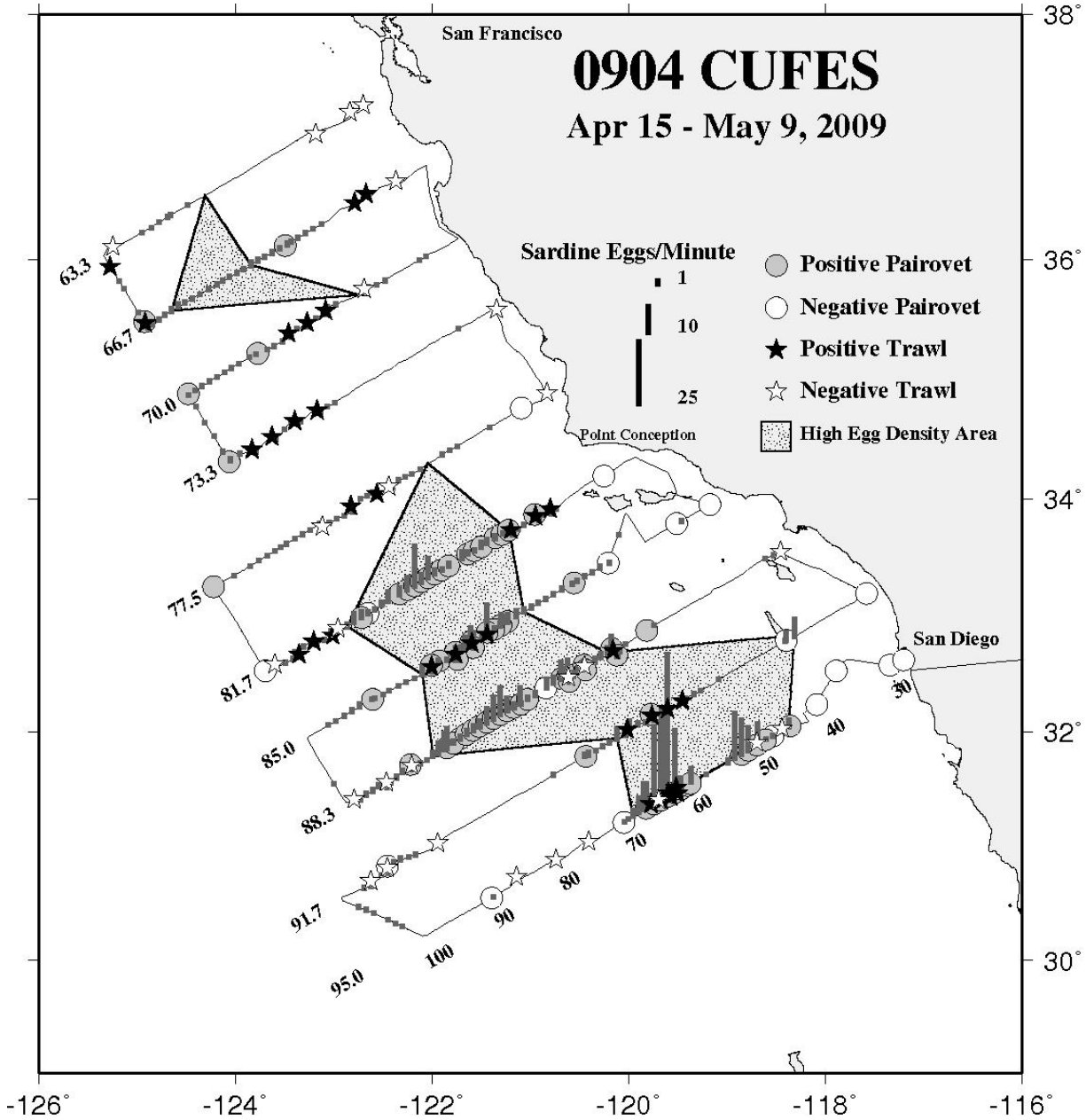


Figure 1. Location of sardine eggs collected from CalVET, a.k.a. Pairovet; (solid circle is a positive catch and open circle is zero catch) and from CUFES (stick denotes positive collection), and trawl locations (solid star is catch with sardine adults and open star is catch without sardines) during the 2009 survey. Region 1 is high density area. Dates of cruises refer to the first and last tow.

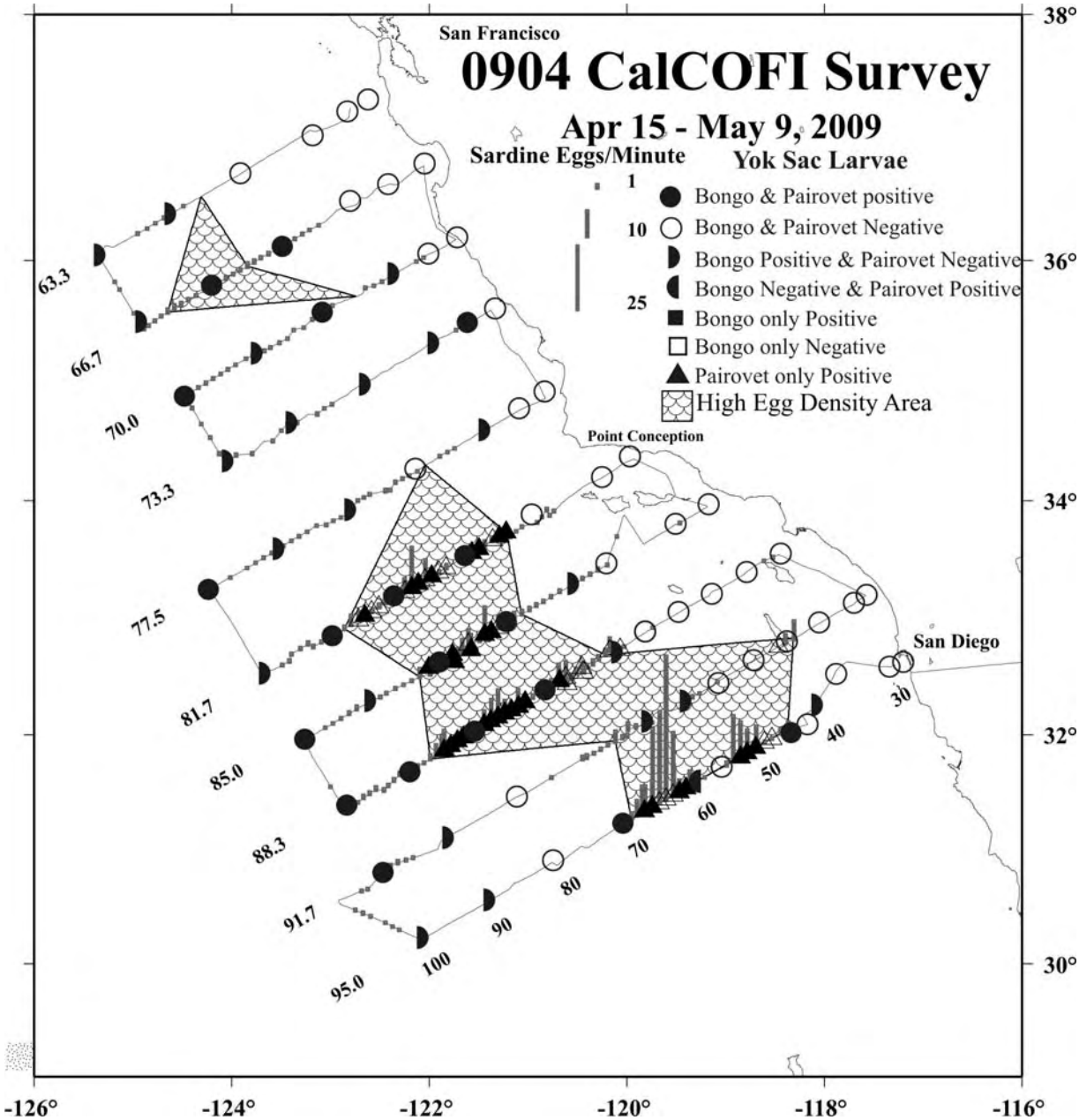


Figure 2. Location of sardine yolk-sac larvae collected from CalVET (or Pairovet; circle and triangle) and from Bongo (circle and square) during the 2009 survey. Solid symbols are positive and open symbols are zero catch.

1.2 IMECOCAL in 2009

Spawning biomass was estimated for years: 1997-1999, 2002 and 2003 as 2662, 59,000, 94,000, 48,000 and 9,200mt. The first three estimates were computed from sardine larval data and the 2002 and 2003 spawning biomasses were estimated from CUFES egg samples from IMELCOCAL surveys (Lo et al. 2006).

In 2009, two cruises were conducted in 2009 each in April and October. CUFES and Bongo samples were taken.

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

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

Robert Emmett, NOAA Fisheries, Northwest Fisheries Science Center, Newport, OR
and
Paul Bentley, NOAA Fisheries, Northwest Fisheries Science Center, Hammond, OR

Andrew Claiborne, Pacific States Marine Fisheries Commission, Newport, OR.

Surveys:
Two surface trawl surveys collected Pacific sardines (*Sardinops sagax*) off Oregon/Washington in 2009:

a) The Predator/Forage Fish Survey off the Columbia River/Willapa Bay: night surface trawls twice per month from May to August.
b) The BPA (Bonneville Power Administration) Columbia River Plume Study: daytime surface trawls from northern Washington to Newport, Oregon in June and September.

Population estimates and size/age structure of Pacific sardine:

Sardine population estimates in the Columbia River region were calculated using the same methodology as past years (volume swept methodology). Sardines captured during the Predator/Forage Fish Survey are usually most abundant in July and August. As such, July or late July/early August information was used to make population estimates. During each cruise (2 days, 9 to 12 trawls every two weeks) the mean number/m^3 was calculated using the number captured divided by the volume swept. Total density in the study area (Fig. 3) was calculated by multiplying mean sardine/m^3 by 1.52×10^{11} [area of the study area (7,600 km^2) x 20 m]. Average weight of sardines captured was calculated from mean length.

The sardine biomass estimates off the Columbia River region in late was 5,739 MT in early July, 1,303 in mid July, and 13,807 in late July (Table 1). These estimates are above all July 2008 estimates for similar time periods. Sardine estimates for late July (13,807 MT) were much higher than the last two years and similar to abundance estimates made in 2001. However, wide

fluctuations in population estimates were observed. This is expected because sardines have very patchy distributions and they show large movements both within and outside the study area.

The length/frequency data (Fig. 4) indicate that sardines in the Columbia River area in 2009 were composed primarily of one large size class. However, the average size slightly decreased each month. We suspect the change in size was due either to an influx of smaller sardines into the study area, or the movement of larger sardines out of the area. This is similar to what we observed in 2008. Overall, average sardine lengths in July 2009 were very similar to that of 2007 and 2008 (Table 1).

Overall, sardines off the Columbia River averaged 222.7 mm FL and 122.8 g in 2009. However, they ranged in weight from a little less than 70 g (an individual captured in May 2009) to 160 g (Fig. 5). During the season, sardine weights were initially relatively low, rose significantly in early June, declined in late June, were very high by July, but declined by August.(Fig. 6). Plotting upwelling and weight by age indicates that average mass/age class appears to be strongly related to upwelling (Fig. 7).

The broad coastal surveys during Oregon/Washington in 2009 showed sea surface temperatures that were relatively warm in June (Fig. 8). Coastal sardine catches also showed essentially one large size-class in May and June, but primarily one very small size class (0-age sardines) in September 2009 (Fig. 9). This is much different than 2008 when no 0-age sardines were captured in September (Fig. 10). The occurrence of 0-age sardines in September off Oregon/Washington indicates that sardine spawned successfully off the Northwest in 2009. This may be related to the warmer ocean conditions in June and September.

One-year-old sardines generally range from 125 to 175 mm FL in September. In 2009, this size/age class was completely absent from our September sample collections (Fig. 10). This indicates that, as reported in 2008, sardine 0-age recruitment in 2008 was very poor and is now reflected as the near complete absence of one-year-old sardines observed in our sample collections 2009.

Pacific sardines collected during off the Columbia River region in 2009 were primary 4-year-old-fishes (i.e., 2005 year class). However, early in the year sardine were larger and older fish from the 2004 year class (i.e., 5-year-olds) (Fig. 11). We captured no sardines that were 1- or 2-year-olds (2007 or 2008 year classes) off the Columbia River in 2009.

There were no significant differences in the weights of 3- to 6-year-old sardines caught off the Columbia River in 2009 (Fig. 12). However, the few 7-year-old we captured weighed significantly more than the other age classes.

Sea surface temperatures were relatively cold in May, relatively warm in June, and July, and very warm in August 2009, compared to past years (Fig. 13). Past reports have noted that warm ocean conditions in May/June appear to be conducive for successful spawning and recruitment of Pacific sardine off the Oregon/Washington coast. The observed sardine recruitment in 2009 supports the hypothesis that warm ocean conditions in May/June and perhaps August are important for sardine to successfully spawn and recruit off the Pacific Northwest.

Sardine catch and length/frequency data indicate that sardines were probably more abundant off the Columbia River in 2009 than in 2007 and 2008. Sardines off Oregon/Washington also appeared to have spawned and recruited successfully in 2009. These findings suggests that the sardine population in the northern California Current may increase in future years because of the additional sardine biomass originating from Northwest spawning in 2009, similar to what was observed in 2005.

Finally, while conducting surface trawling operations off Oregon/Washington during August and September 2009, many Humboldt squid (*Dosidicus gigas*) were captured. During many of these trawls both Humboldt squid and small 0-age sardines were captured in the same trawl. We suspect that Humboldt squid were eating 0-age sardines. As such, any additional sardine biomass production coming from successful spawning in the Pacific Northwest may not translate into increased adult biomass if the predation by Humboldt squid is very high. At this time we do not have enough information estimate the effect of Humboldt squid predation on the sardine population or other fish populations.

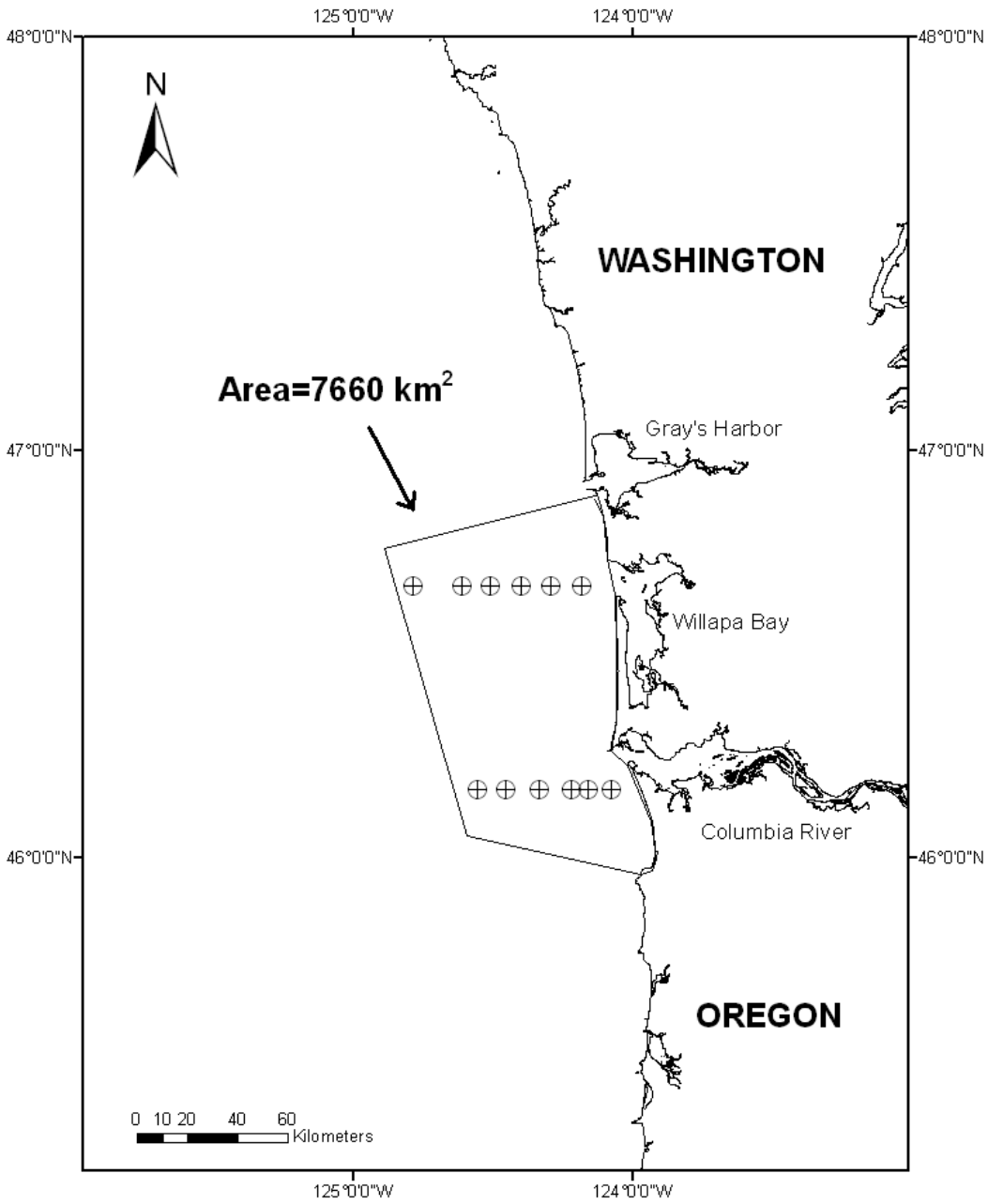


Figure 3. Location of the 12 surface trawl locations sampled at night approximately every 10-14 days near the Columbia River from May through August 1998-2009 during the Predator/Forage Fish Surveys.

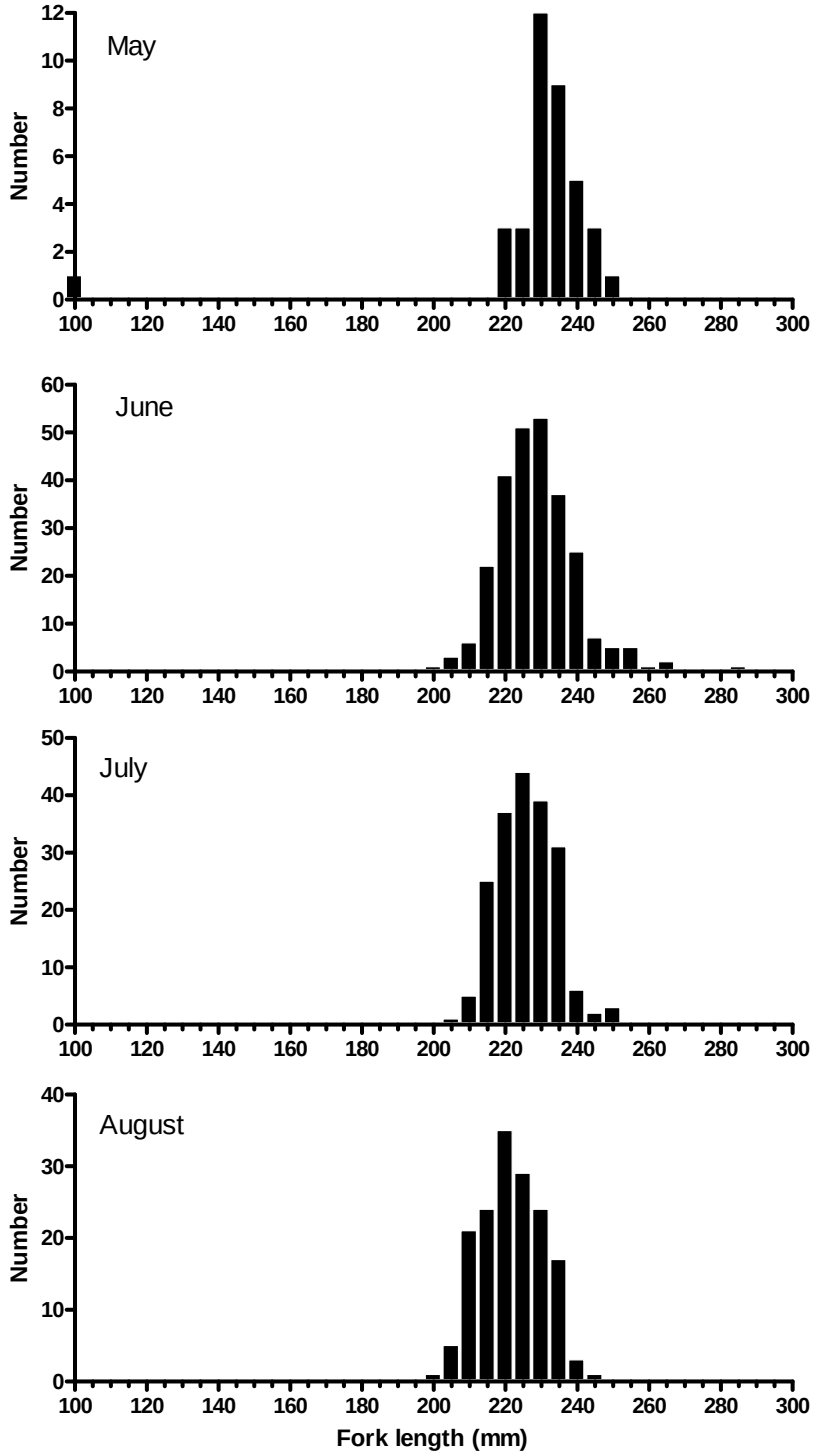


Figure 4. Length frequency of Pacific sardine (*Sardinops sagax*) captured off the Columbia River in 2009 during the Predator/Forage Fish Survey.

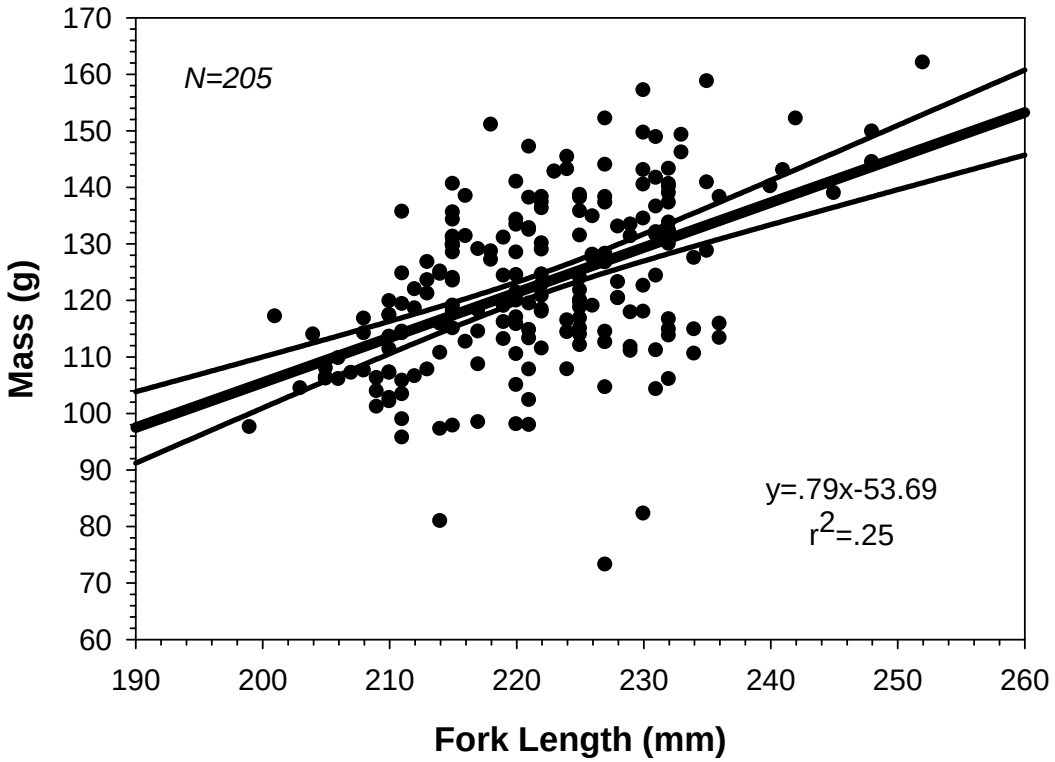


Figure 5. Mass (g) and fork length (mm) of Pacific sardine (*Sardinops sagax*) captured during eight cruises off the Columbia River May to August 2009.

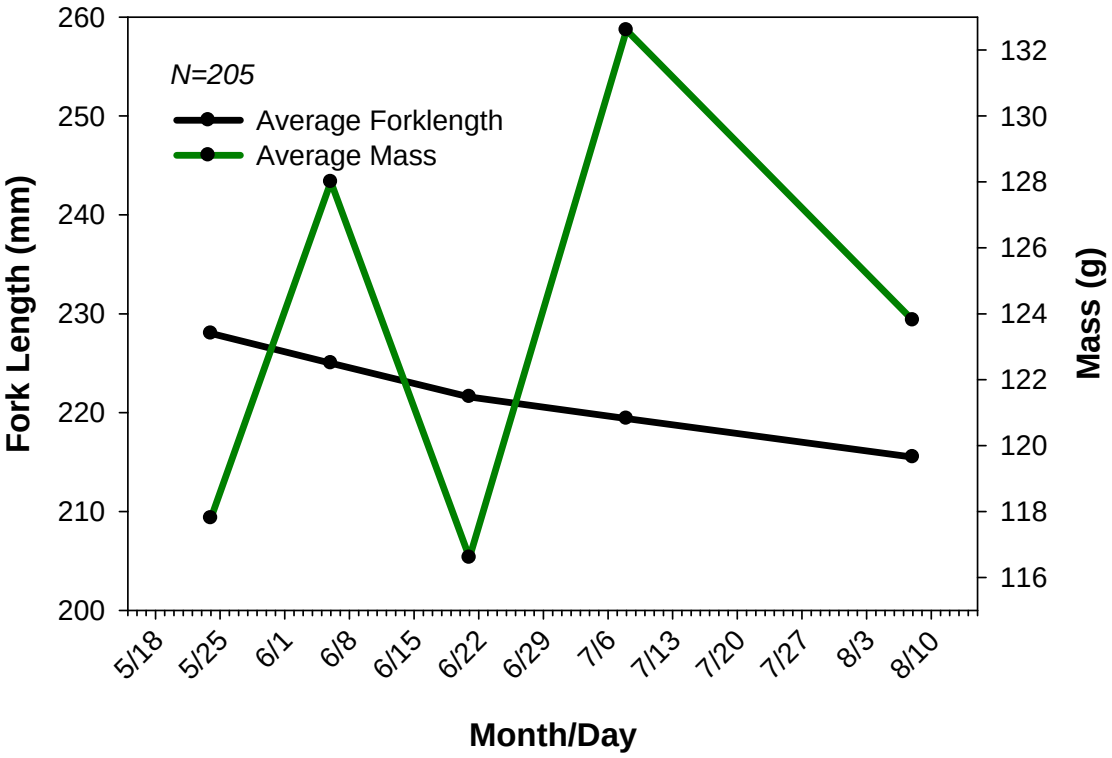


Figure 6. Average fork length (mm) and mass (g) by Julian day of Pacific sardine (*Sardinops sagax*) captured during eight cruises off the Columbia River May to August 2009.

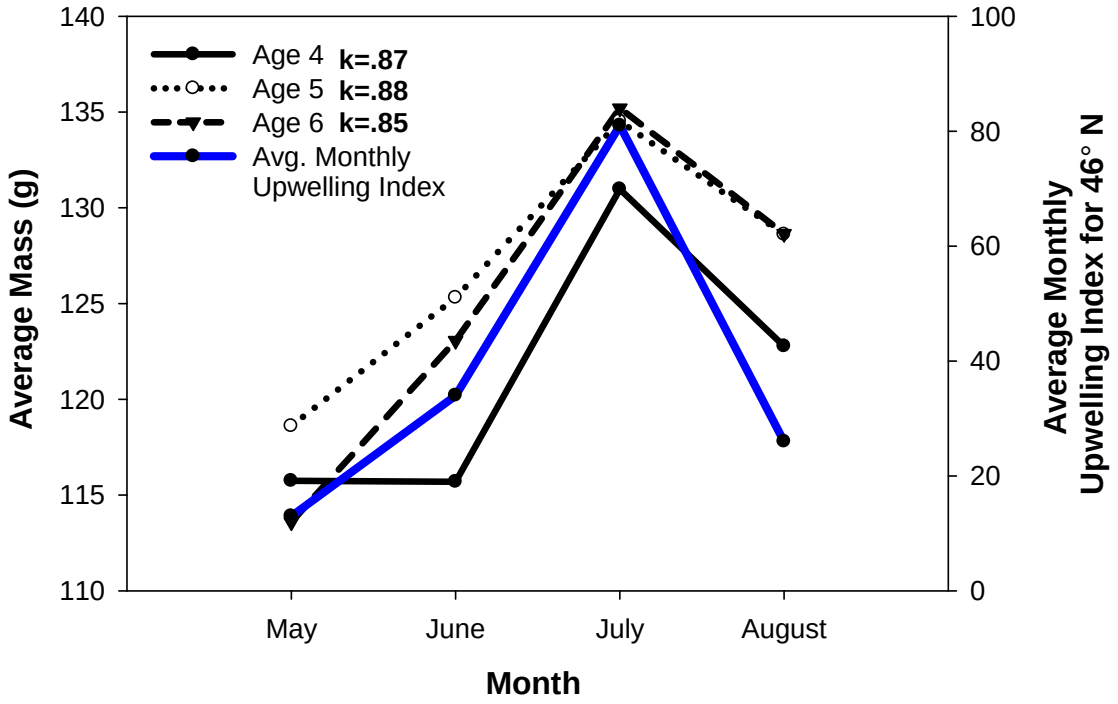


Figure 7. Average mass (g) by month of Pacific sardine (*Sardinops sagax*) captured during eight cruises off the Columbia River May to August 2009. Also shown is the average monthly Upwelling Index for 46° N. K values indicate correlation coefficient between average mass and Upwelling Index.

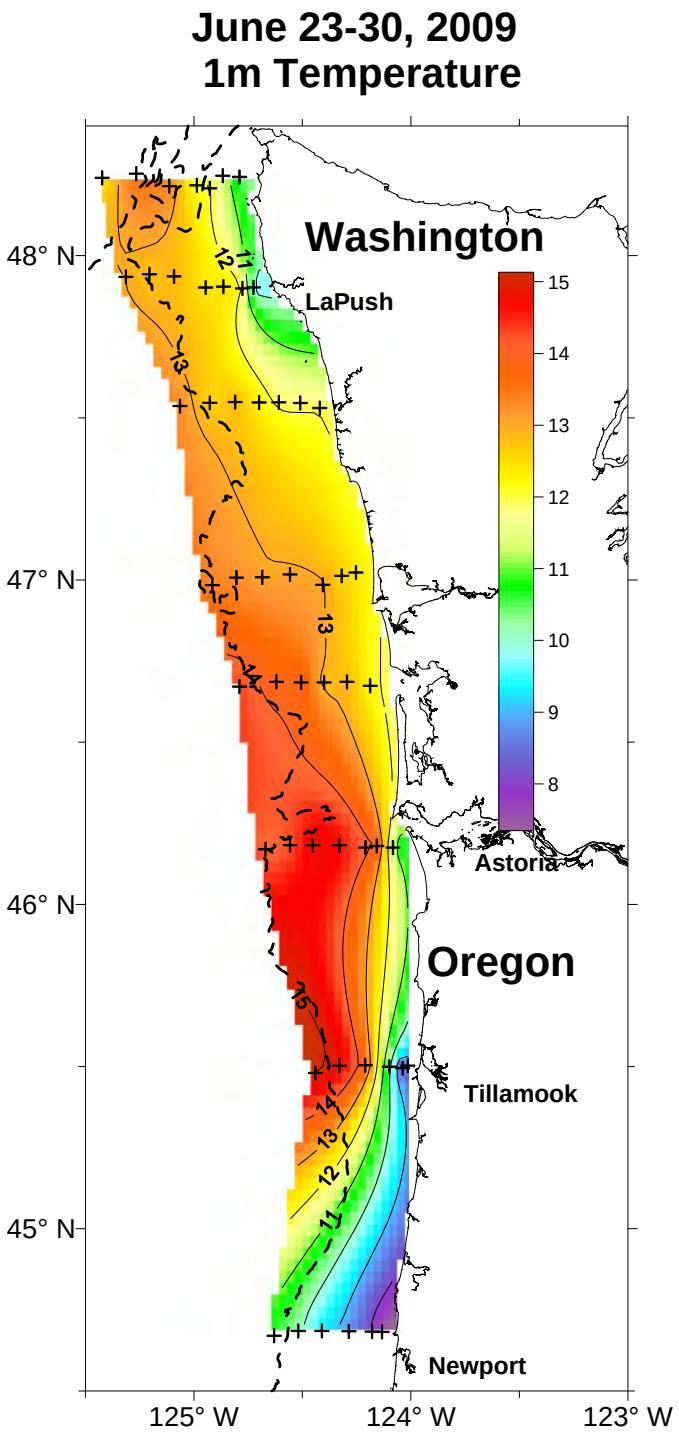


Figure 8. Location of stations sampled annually in May, June and September off Oregon/Washington during the BPA plume study in 2009. Also shown are sea surface temperatures during late June in 2009.

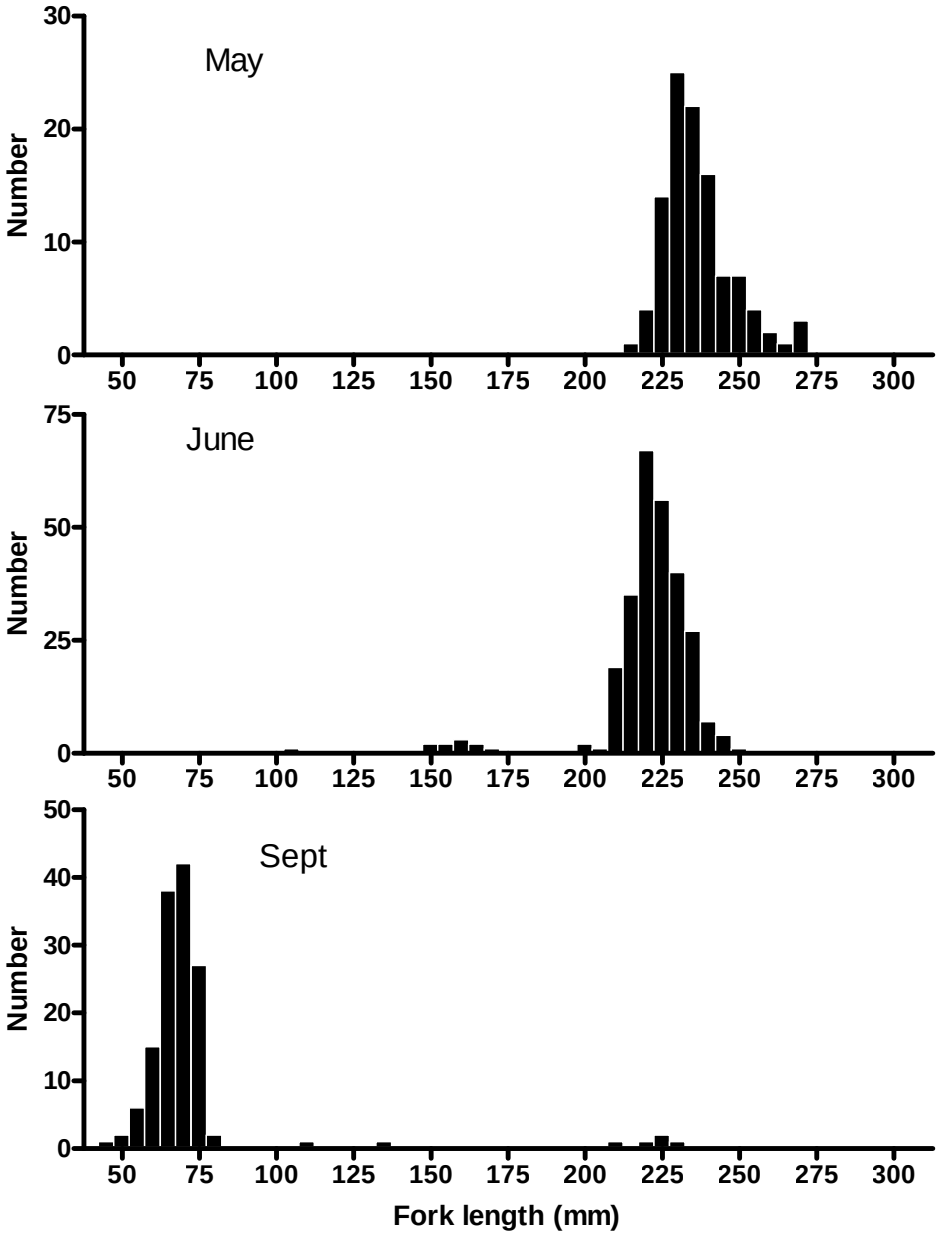


Figure 9. Length frequency of Pacific sardine (*Sardinops sagax*) captured off Oregon/Washington in May, June and September 2009 during BPA plume study.

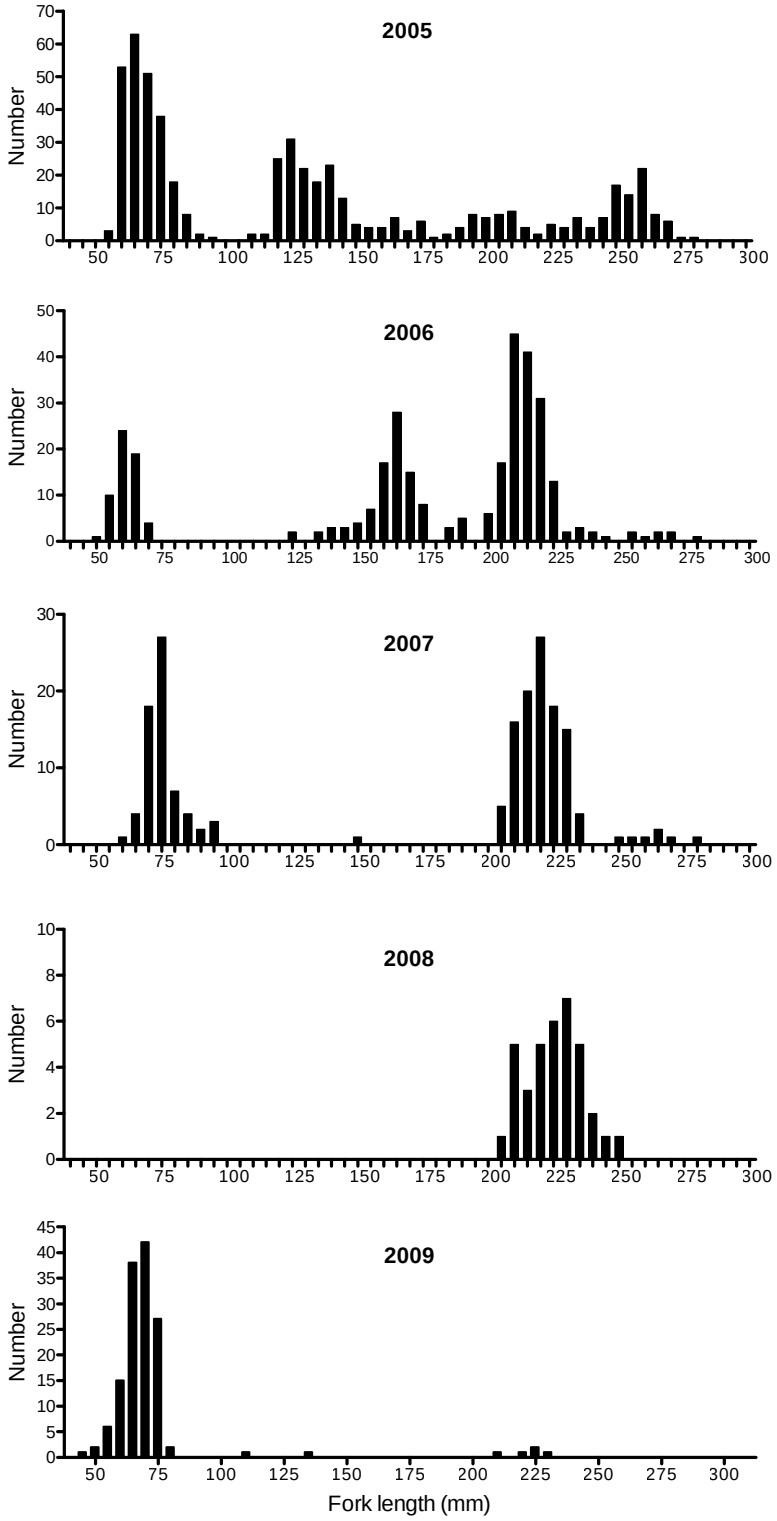


Figure 10. Length frequency of Pacific sardine captured during September 2004 – 2009 off the Oregon/Washington coast during the BPA plume study.

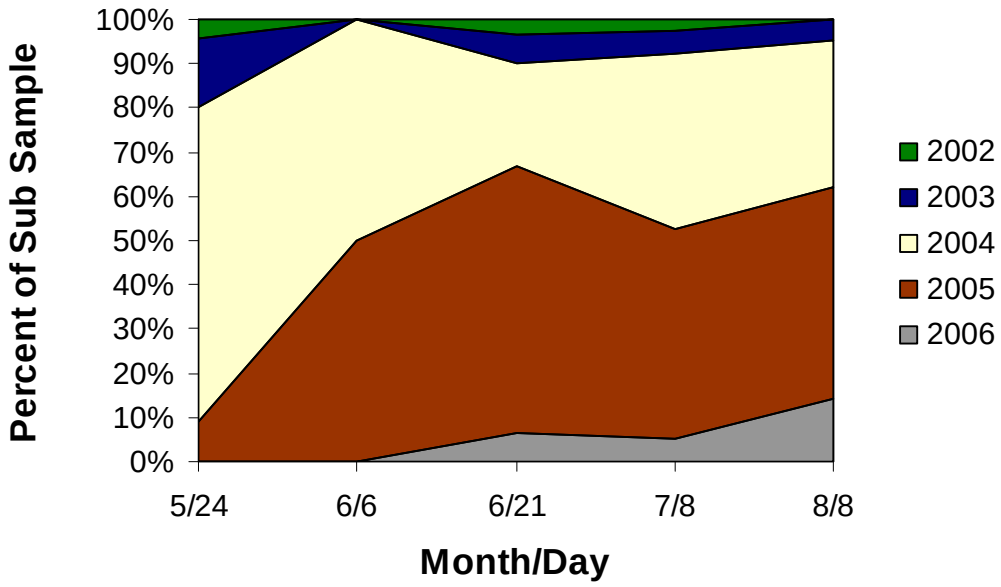


Figure 11. Percent year class by Julian day of Pacific sardine (*Sardinops sagax*) captured during eight cruises off the Columbia River May to August 2009.

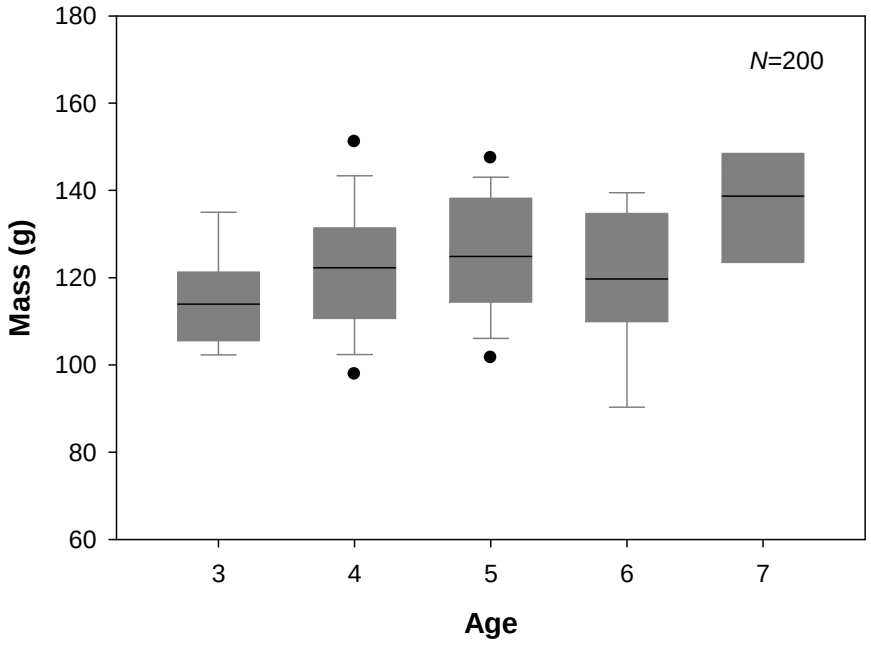


Figure 12. Box plot of mass (g) by age (years) of Pacific sardine (*Sardinops sagax*) captured during eight cruises off the Columbia River May to August 2009. Black lines indicates the mean value, boxes represent the 90th percentile with error bars, and dots represent outliers.

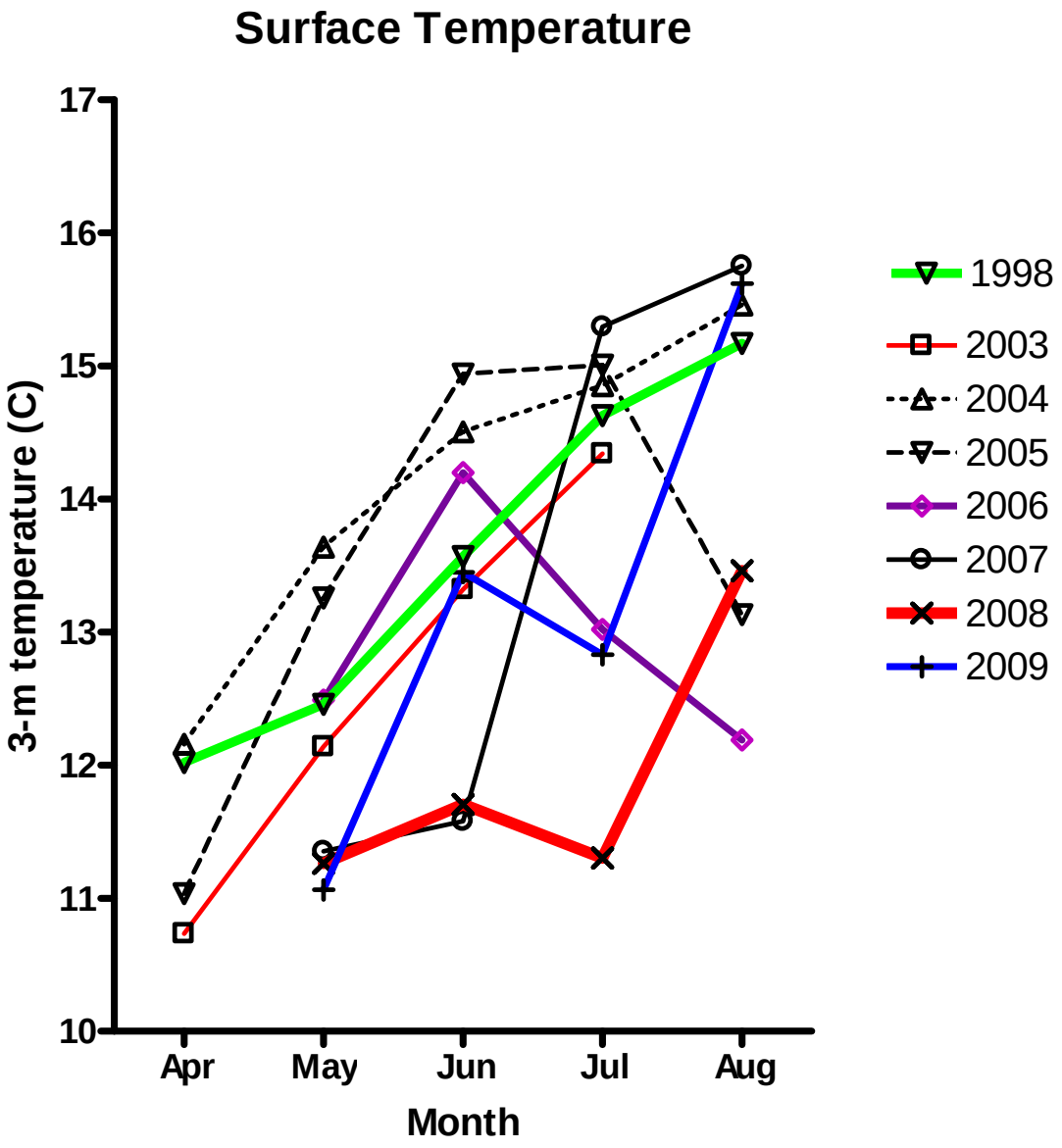


Figure 13. Average monthly surface temperatures (3 m depth) off the Columbia River 1998-2009.

Table 1. Statistics on Pacific sardine (*Sardinops sagax*) captured off the Columbia River region since 1999.

Estimated Number of Pacific Sardine off S Wash/N Oregon			
Year	early July	Mid July	Late July/early August
1999	6,361,531	4,298,041	110,264,191
2000	246,539,570	293,661,085	no trawls after 22 July 2000
2001	13,547,385	61,691,990	89,693,132
2002	207,891,576	18,538,962	non taken
2003	10,259,428	847,269,268	73,626,122
2004	11,672,862	79,086,033	173,551,785
2005	156,052,620	No Trawls	103,173,678
2006	5,948,632	3,829,993	106,931,506
2007	32,381,019	No Trawls	26,078,994
2008	22,652,434	8,112,418	50,674,438
2009	47,733,543	11,054,110	125,167,373
Average Length of Pacific Sardine			
Year	early July	Mid July	Late July/early August
1999	246	239	235
2000	237	243	
2001	233	241	242
2002	247	247	
2003	251	249	237
2004	108 and 256	135 and 251	143 and 245
2005	189	No Trawls	190
2006	207	210	215
2007	222	No Trawls	218
2008	223	222	221
2009	225	224	218
Average weight of Pacific Sardine (g) Calculated from average length			
Year	early July	Mid July	Late July
1999	154	143	137
2000	140	149	
2001	133	146	148
2002	156	156	
2003	165	160	140
2004	22 and 248	41 and 236	48 and 220
2005	73	No Trawls	74
2006	95	99	106
2007	115	No Trawls	110
2008	117	116	114
2009	120	118	110
Biomass of Pacific Sardine off S Wash/N Oregon (metric tons)			
Year	Early July	Mid July	Late July/early August
1999	985	613	14,984
2000	34,475	43,845	No Trawls
2001	1,802	8,980	13,289
2002	32,529	2,892	No Trawls
2003	1,690	211,098	10,290
2004	2,705	5,533	36,574
2005	11,399	No Trawls	7,621
2006	564	378	11,285
2007	2,857	No Trawls	1,012
2008	2,646	938	5,765
2009	5,739	1,303	13,807

Canadian Trawl Survey of Pacific Sardine Abundance in B.C. Waters During 2009

Objectives: To provide information on the distribution and presence and absence of sardine, biological parameters, and feeding behavior and to estimate a minimum biomass of Pacific sardine off Vancouver Island from the July survey each year since 1996.

Background:

From 1992 to 1996 small numbers of sardines were captured in both commercial and research sets targeting Pacific hake off the southwest coast of Vancouver Island. Since 1997, large numbers of sardines have been captured in surface water research sets targeted on sardine off the west and northeast coasts of Vancouver Island, Queen Charlotte Sound, and in a small commercial fishery for sardines in inlets surrounding Vancouver Island. From 1997 to 1999, sardines were found in the Strait of Juan de Fuca, in the Strait of Georgia, along the west coast of Vancouver Island, Hecate Strait, and off southeast Alaska. Sardine distribution in 2000 was concentrated on the WCVI and ranged as far south as Barkley Sound and as far north as mainland British Columbia, north of Vancouver Island. From 2001 to 2003, sardine distribution became progressively concentrated near shore along the southwest Vancouver Island coast and progressively less prevalent in research cruises. By 2004, sardines were rarely captured offshore or along the research grid; however, large catches of sardines were made in inlets and the shallows along the WCVI, and in 2004 in Queen Charlotte Sound inlets. In 2005, the survey was directed at developing a relationship between day sets and night sets to be used to calibrate future surveys. Sardine distribution in 2006 extended along the entire west coast of Vancouver Island (Fig. 14), suggesting a return to distribution patterns seen in the late 1990s. The estimated abundance in 2006 was the highest recorded since the inception of the research surveys. Sardine distribution in 2008 was along the entire west coast of Vancouver Island (WCVI) extending from inshore to offshore; estimated abundance was lower than in 2006 but still significantly higher than previous years.

Activities

Research cruises have obtained sardine samples since 1997. The 2009 survey is the 8th survey directed at estimating abundance in offshore waters along the WCVI. This report summarizes sardine data collected during a research cruise conducted from July 21 to August 6, 2009.

The 2009 research cruise was carried out aboard the R/V W.E. Ricker, and all fish were captured using a model 250/350/14 mid water rope trawl (Cantrawl Pacific Ltd., Richmond, British Columbia). Fish were measured for fork lengths recorded to the nearest millimeter. Biological samples were also collected for sex, stomachs and otoliths (Table 2).

From July 21 to August 6, 2009, a total of 109 sets were made in surface waters (<30m) off the west coast of Vancouver Island (Fig. 15). Of these, 53 sets contained sardines. All sets were made at night.

Similar to most of the previous surveys, the 2009 cruise covered only five of the six WCVI areas (due to time constraints). This year, sardines were present in all five areas (Fig. 15). Sardine abundance was highest in areas 3 and 6 (both 38% of total), slightly lower (21%) in area 4 and very low (0.2% and 3%) in areas 2 and 5 (Fig. 15).

Biomass estimates were calculated according to the method described in Beamish et al. (2000). The west coast of Vancouver Island was partitioned into major "regions" and total volume was determined to allow biomass estimates to be calculated regionally. Volume swept during each set was determined by multiplying the area of the mid-water trawl net used during the fishing operations by the distance traveled during fishing.

Biomass estimates from 2005 are combined day and night. Biomass estimates for 2006, 2008 and 2009 are night fishing estimates. All other years are day fishing biomass estimates (Figure 16). Table 3 presents only estimates from 2006, 2008 and 2009 as our intent is to use only the night estimates in future analysis as we move towards a three year running average to calculate migration rate into Canadian waters.

In 2009, sardines were common in all major surveyed areas similar to 2008, however they were closer to shore than 2008 where they extended to the western boundary of the survey areas (Figure 14 and 15). The bulk of the commercial fishery (to September 27th) has occurred in areas 9 (Central coast), 25 and 23 (WCVI). The most northerly catch was from area 8-5 along the Central coast. The Canadian commercial sardine landings in 2009 to Sept 27 were approximately 12, 642 tonnes. The average sardine fork length off the WCVI in 2009 was 24cm (Figure 17).

Table 2. Summary of biological samples taken onboard the W.E. Ricker July 21-August 6, 2009.

2008 Pacific Sardine Sample Survey	
Sample Type	**# of Sardines**
Weight	**996**
Length/Sex	**4278**
Length Frequency	**3423**
Stomach	**978**
Otolith	**975**

Table 3. Pacific sardine biomass estimates from 2006, 2008 and 2009 (for estimates by area for other survey years, see previous tri-national reports).

Year	Area	Total volume (km3)	Average swept volume	Average weight of individual sardine per area (kg)	Average # sardines per area	Average kg of sardines per area	**Total # fish**: total volume* avg # sardine per area/avg swept volume	**Abundance MT** = total fish per area*average weight per area/1000
2006	2	66.6	0.0019	0.145	1577	228.22	56775178	8215.6
	3	119.7	0.0018	0.124	1422	176.14	94789660	11741.3
	4	83.9	0.0015	0.137	11035	1510.34	624522615	85476.6
	5	71.8	0.0012	0.126	9193	1154.16	532879953	66905.2
	6	127.7	0.0019	0.146	4328	632.31	283786165	41464.3
							Total:	213803.0
2008	2	66.6	0.0018	0.145	1476	213.4	55542719	8028.8
	3	119.7	0.0013	0.153	9149	1397.6	835039507	127569.0
	4	83.9	0.0015	0.145	5005	726.0	271697198	39412.4
	5	71.8	0.0012	0.138	24	3.3	1454369	200.8
	6	127.7	0.0016	0.140	1329	186.3	104423951	14641.3
							Total:	189852.3
2009	2	66.6	0.0012	0.177	55	10	3065311	541.8
	3	119.7	0.0012	0.169	4523	765	446906415	75607.6
	4	83.9	0.0012	0.172	3296	568	236450899	40767.7
	5	71.8	0.0011	0.163	570	93	36974883	6034.3
	6	127.7	0.0011	0.163	4167	679	463130010	75413.0
							Total:	198364.5

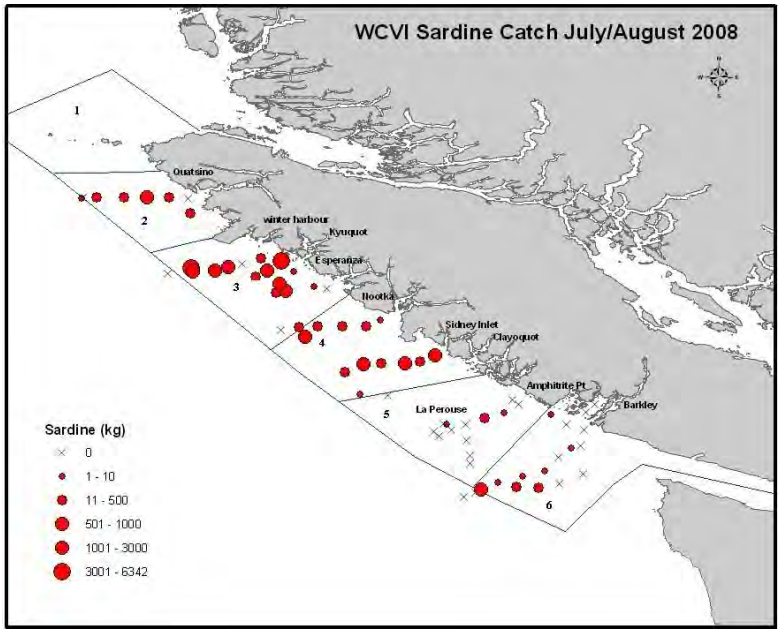


Figure 14. Set locations for the 2008 Pacific sardine cruise off the WCVI, July 31 to August 8 with region numbers.

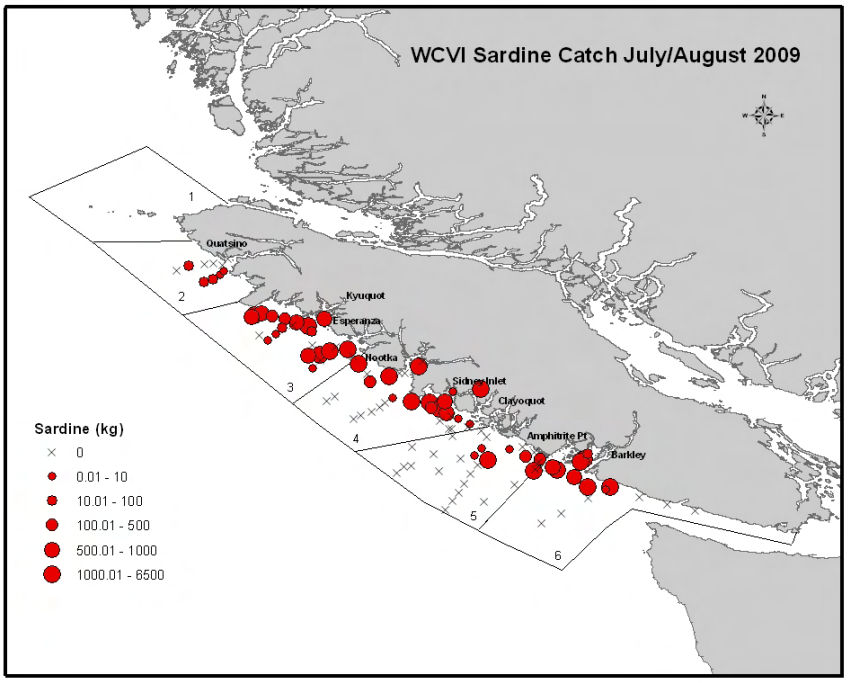


Figure 15. Set locations for the 2009 Pacific sardine cruise off the WCVI, July 21 to August 6 with region numbers.

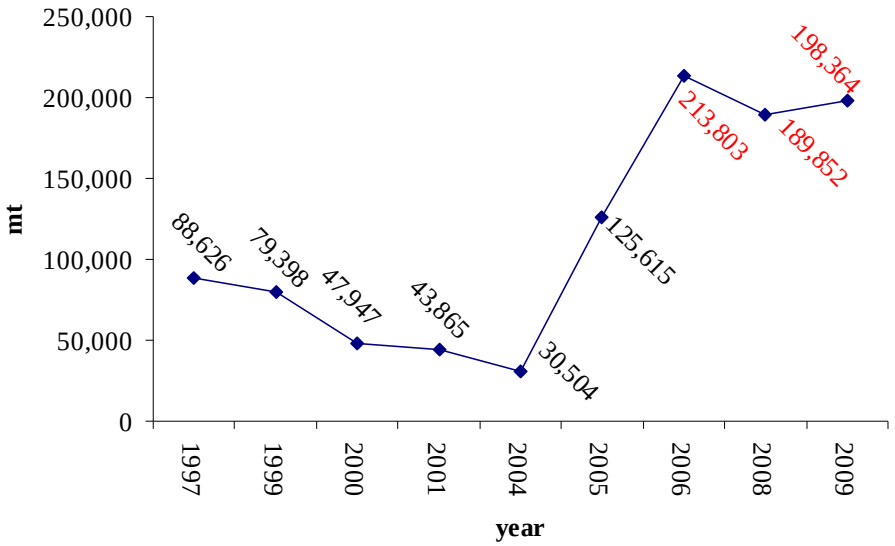


Figure 16. Pacific sardine biomass estimates from WCVI trawl surveys. 1997-2004 are daytime estimates. During 2005 a day/night comparison survey was conducted. 2006, 2008, and 2009 (shown in red) are nighttime estimates.

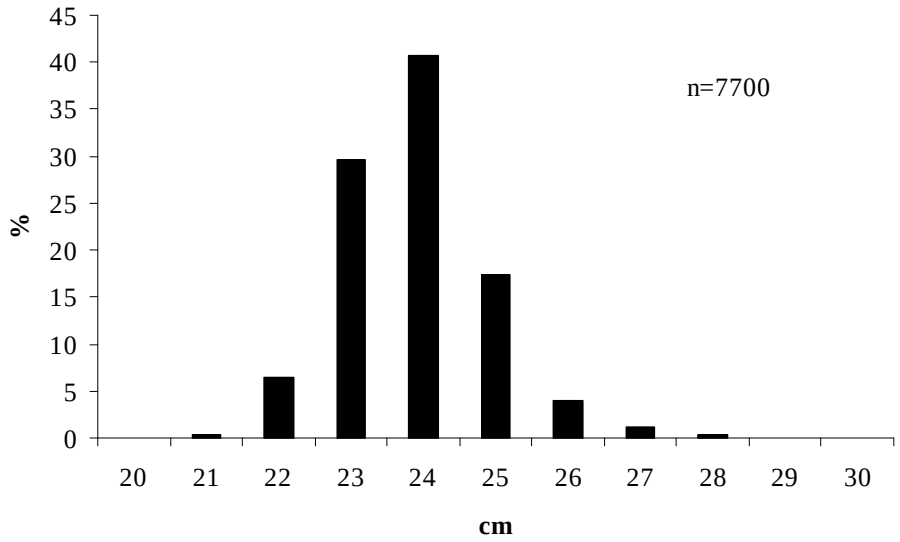


Figure 17. Pacific sardine fork length frequency from the 2009 Pacific sardine cruise off the WCVI, July 21 to August 6, 2009.

Work Group 1 2009 Recommendations

US

- A 2010 coastwide survey with 2 vessels was planned
- Acoustic data were processed for 2008, followed by processing data of 2009 and previous years. Advance Survey technologies Group (AST) group of Southwest Fisheries Science Center headed by Dave Demer is continuing to work on ground truth of the acoustics.
- LIDAR is still being considered to be used in future surveys. No definite plans were made at this moment.
- An aging workshop in La Jolla will be held before or after the small pelagic fish workshop in Ensenada.
- Tagging experiment of sardine using electronic acoustic receivers will still be considered eventhough in 2009, due to a problem to keep sardines alive in the area of Newport, it was not possible to use electronic acoustic receivers to monitor fish movement. Tim Baumgartner indicated that John Paine is conducting tagging herring experiment and may work with him to test surgical implants

Canada

- Survey is normally conducted from the last week of July-the first week of August on the Ricker with night trawling without acoustics. No CUFES samples will be taken because no eggs would be expected.
- It was proposed that vessel and gear comparisons be made between US and Canada (r/v Ricker and f/v Frosti) with Robert Emmet and Jake Schweigert as coordinators

Mexico

- Budget was requested for acoustic survey in Gulf and in Pacific using 2 vessels (BIP XI and a new vessel) in March.
- Four IMECOCAL cruises (January, April, July, and October) start in north (Ensenada) to south hopefully at end of March, Tim Baumgartner will coordinate work with Manuel Nevariz, for acoustic operation
- A request was made to add CalVet sampling in January and April because eggs have been found offshore even when no active females were observed in commercial catch.
- A stock assessment workshop in Ensenada will be held in May 2010.

References

Hill, Kevin. T, Nancy C.H. Lo, Beverly J. Macewicz, Paul R. Crone,Christina Show and____. 2009. Assessment of the Pacific sardine resource in 2009 for U.S. Mmanagement in 2010.

Hunter, J. R. and D. Pleschner-Steele. 2003. Minutes of the 2002 trinational sardine forum San Pedro, California, U.S.A December 5-6, 2002. Admin Rpt LJ-03-05, 54p.

McFarlane, G.A. and R.J. Beamish. 2001. The reoccurrence of sardines off British Columbia characteristics the dynamic nature of regimes. Prog. in Oceanog. 49, 151-165

McFarlane, G.A. and L.A. MacDougall. 2001. Biological information for Pacific sardine, (*Sardinops sagax*) captured during research cruises, 1992 – 2000. Can. Tech. Rep. Fish. Aquat. Sci 2372. 149p.

Lo, Nancy C.H. , J.R. Hunter, and R Charter. 2001. Use of a continuous egg sampler for ichthyoplankton survey: application to the estimation of daily egg production of Pacific sardine (*Sardinops sagax*) off California. Fish. Bull. U.S. 99:554-571.

Lo, Nancy C.H., 2001. Daily egg production and spawning biomass of Pacific sardine *(Sardinops sagax*) of California in 2001. National Marine Fisheries Service, Southwest Fisheries Science Center, Admin. Rep. LJ-01-08, 32 pp.

Lo, Nancy C.H., Anne C. Allen and Sharon Herzka. 2006. Minutes of the 2005 Trinational Sardine forum. National Marine Fisheries Service, Southwest Fisheries Science Center, Admin. Rpt. LJ-06-05. 118pp.

Lo. Nancy C.H. , B. Macewicz and Richard L Charter. 2007. Spawning biomass of Pacific sardine(*Sadinops sagax*) of California in 2007. NOAA Technical Memorandum NMFS, NOAA,DOC. NOAA-TM-NMFS-SWFSC-411.31pp.

Lo. Nancy C.H. , B. Macewicz and David Griffith. 2008. Spawning biomass of Pacific sardine(*Sadinops sagax*) of California in 2008. NOAA Technical Memorandum NMFS, NOAA,DOC. NOAA-TM-NMFS-SWFSC-___.31pp.

Lo, N.C.H., Y.A. Green Ruiz, M.J. Cervantes, H.G. Moser, R.J. Lynn. 1996. Egg production and spawning biomass of Pacific sardine (*Sardinops sagax*) in 1994, determined by the daily egg production method. Calif. Coop. Oceanic Fish. Invest. Rep. 37:160-174.

Macewicz, D. J., J. J. Castro-Gonzales, CE. Cortero Altamirano, and J. R. Hunter. 1996. Adult reproductive parameters of Pacific sardine (*Sardinops sagax*) during1994. Calif. Coop. Oceanic Fish. Invest. Rep. 37:140-151.

REPORT FOR WORKING GROUP 2
Stock Structure, age structure, and adult sampling

Prepared by John Hyde

- SWFSC - Otolith morphometrics and stable isotope studies finishing up, manuscripts in preparation. Heterogeneity found among sample collections but a number of caveats exist (i.e. change in morphology with age, ontogenetic habitat shifts).
- CICESE – Continuing δ^{18}O study of sardine otoliths as a marker of natal origin and creation of an δ^{18}Oisoscape along the coast.
- Analysis of 20 neutral microsatellite markers has failed to uncover strong evidence for population heterogeneity with the strongest differences often found between adjacent sampling areas. Perhaps markers under selective pressure, such as those found in cod, should be evaluated.
- Continued work on parasites as population markers by Becca Baldwin and Kym Jacobson is continuing and producing some interesting results.
- Valuable age-structure as well as age of first reproduction information for the Bahia Magdalena sardine fishery were reported.
- Continued collection of adults and juveniles from all population areas are needed to improve current studies.
- SWFSC is planning another California Current ecosystem survey in April, 2010.
- SWFSC is bringing in a postdoctoral researcher to examine physiology and gene expression of sardine in relation to temperature. This work should help understand the effects of climate on sardine health and should aid in the delineation of environmentally adapted stocks.
- Planned otolith ageing workshop in June, 2010.

REPORT FOR WORKING GROUP 3
Industry Trends and Issues

Prepared by: Don Pepper, Canadian Pacific Sardine Association

A one-day Workshop was held post- Trinational Forum under the aegis of the Industry and Ecosystem Modeling groups. The objective was to integrate industry's perceived needs for an ecosystem study with the data requirements of an ecosystem modeling exercise. Participation was excellent with all major scientific institutions and industry present. The result was a commitment to supply environmental and other data to the Canadian scientists. This data would be available to all researchers but its primary purpose would be as input into an ecosystem modeling exercise using sardines as an indicator species.

Various computer models were reviewed and ECOSYM was seen as appropriate, subject to a detailed review. Once the data has been received and collated in Canada the next step would be assessing how it could be used in a model. Canada will initiate this aspect of the project. This is expected to take place in the summer of 2010. A review of the project will be presented to the next Trinational in 2010.

On May 19th, the Ecosystem group and the Industry Group met in a special day-long Workshop session to initiate a new project. Also present were representatives from almost all the fisheries agencies from the three nations. The purpose is to construct an eco-system model of the Califorina Current using sardines as an indicator species. The first step is to assemble all the available environmental and biological data into a standard format. The lead agency is to be the Canadian Department of Fisheries at the Nanaimo Pacific Biological Station (PBO). All the agencies present agreed to submit their data to PBO.

PBO will be contacting the various agencies and supplying templates for their input. It is hoped that the data will be useful in constructing a robust ecosystem model of sardines as an indicator species in the California Current. Various ecosystem models were briefly discussed and a consensus emerged to use the ECOPATH model as this has been used by researchers with some success. This aspect will be explored with the University of BC Fisheries Center as they have significant expertise in the use of this model.

The Canadian Pacific Sardine Association will supply some funds towards this project. A wide range of methodological problems remain but these will obviously be addressed once the modeling exercise starts in the summer. It is hope to have some preliminary results, or at least an update, at the Trinational to be held in Canada in late 2010.

Appendix I: List of Participants Xth TRINATIONAL SARDINE FORUM

CANADA		
Andres Cisneros	University of British Columbia	a.cisneros@fisheries.ubc.ca
John Lenic	Canadian Pacific Sardine Association	jalenic@telus.net
Vanessa Hodes	Fisheries and Oceans Canada	Vanessa.hodes@dfo-mpo.gc.ca
Linnea Flostrand	Fisheries and Oceans Canada	Linnea.flostrand@dfo-mpo.gc.ca
Jake Schweigert	Fisheries and Oceans Canada	jake.schweigert@dfo-mpo.gc.ca
Gordon McFarlane	DFO/Pacific Sardine Association	sandy.mcfarlane@dfo-mpo.gc.ca
Cynthia Johnston	Fisheries and Oceans Canada	cynthia.johnston@dfo-mpo.gc.ca
Mitch Ponak	Canadian Pacific Sardine Association (CPSA)	kanopfish@shaw.ca
Chris Wick	Canadian Pacific Sardine Association (CPSA)	chris@ndseafoods.com
Don Pepper	Canadian Pacific Sardine Association (CPSA)	dapepper@me.ca
UNITED STATES		
Doyle Hanan	H&A, Inc.	drhanan@cox.net
Russ Vetter	NOAA - Southwest Fisheries Science Center	russ.vetter@noaa.gov
Michael Okoniewski	Pacific Seafood-Pacific Fisheries Mangement Council-CPS Advisory Panel	mokoniewski@pacseafood.com
Roszella Sanford	NOAA	Roszella.Sanford@noaa.gov
Samuel Herrick	NOAA	sam.herrick@noaa.gov
Beverly Macewicz	NOAA-Southwest Fisheries Science Center	bev.macewicz@noaa.gov
Gregory Krutzikowsky	Oregon Department of Fish and Wildlife	greg.krutzikowsky@state.or.us
John Ferguson	NOAA Fisheries	john.ferguson@noaa.gov
Sam McClatchie	NOAA-Southwest Fisheries Science Center	sam.McClatchie@noaa.gov
Nancy Lo	NOAA - Southwest Fisheries Science Center	Nancy.Lo@noaa.gov
John Hyde	NOAA - Southwest Fisheries Science Center	John.Hyde@noaa.gov
Mike Burner	Pacific Fishery Management Council	mike.burner@noaa.gov
Christina Show	NOAA - Southwest Fisheries Science Center	christina.show@noaa.gov
Kevin Hill	NOAA - Southwest Fisheries Science Center	Kevin.Hill@noaa.gov
Juan Zwolinski	NOAA - Southwest Fisheries Science Center	juan.zwolinski@noaa.gov
Robert Emmett	NOAA - Northwest Fisheries Science Center	robert.emmett@noaa.gov
Kym Jacobson	NOAA - Northwest Fisheries Science Center	kym.jacobson@noaa.gov
Rebecca Baldwin	Cooperative Institute for Marine Resources Studies, Oregon State University	rebecca.baldwin@oregonstate.edu
Lindsay Joshua	NOAA Fisheries - Sustainable Fisheries Division	joshua.lindsay@noaa.gov
MEXICO		
Manuel Nevarez-Martinez	INAPESCA - CRIP Guaymas	manuel.nevarez@prodigy.net.mx
Yanira A. Green-Ruiz	INAPESCA-CRIP Mazatlan	motagreen@yahoo.com.mx

Appendix I: List of Participants Xth TRINATIONAL SARDINE FORUM

Ragnar Gutierrez	Productos Marinos ABC	ragnar@pmabc .com.mx
Ruben Rodriguez-Sanchez	CICIMAR-IPN	rrodrig@ipn.mx
Sharon Herzka	CICESE	sherzka@cicese.mx
Jorge A. Ceron	CICESE	jceron@cicese.mx
Salvador Lluch-Cota	CIBNOR	slluch@cibnor.mx
Rene Funes-Rodriguez	CICIMAR-IPN	rfunes@ipn.mx
Roberto Felix-Uraga	CICIMAR-IPN	rfelix@ipn.mx
Felipe N. Melo Barrera	CICIMAR-IPN	fmelo@ipn.mx
Gabriela Garcia-Alberto	CICIMAR-IPN	gabigaralb@gmail.com
Daniel Luch-Belda	CICIMAR-IPN	dlluch@ipn.mx
Hector Villalobos-Ortiz	CICIMAR-IPN	hvillalo@ipn.mx
Rosa Isabel Ochoa-Baez	CICIMAR-IPN	rochoa@ipn.mx
Julian Rene Torres Villegas	CICIMAR-IPN	
Christian Salvadeo	CICIMAR-IPN	chsalvadeo@yahoo.com.mx
Tim Baumgartner	CICESE	tbaumgar@cicese.mx
Benjamin Baron S.	CICESE	bbaron@cicese.mx

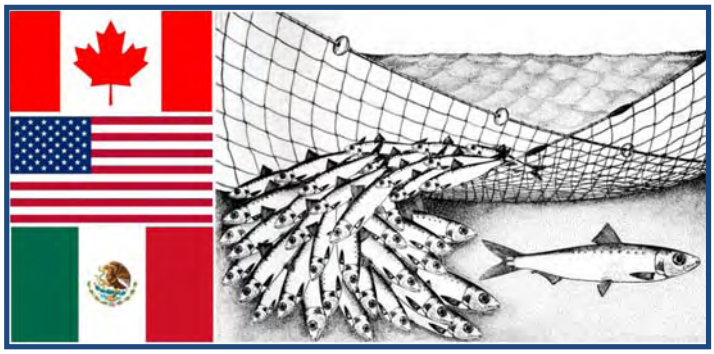
APPENDIX II

AGENDA

TRINATIONAL SARDINE FORUM/ FORO TRINACIONAL DE LA SARDINA

Xth ANNUAL MEETING

Theme: "Mechanisms of variation of sardine abundance in the California Current system".



CICIMAR- Instituto Politécnico Nacional

La Paz, Baja California Sur, México

November 17-20, 2009

Agenda

Monday November 16th

Arrival in La Paz, Baja California Sur, Mexico

Host Hotel: Hotel Marina (Km 2.5 Road La Paz-Pichilingue)

Tuesday, November 17th (Galeón Room, Hotel Marina)

08:00 Registration

09:00 Welcome, statements from special guests and inauguration

09:30 Meeting logistics and opening remarks

09:40 **Keynote address:** "Reexamining an old hypothesis": Dr Daniel Lluch- Belda, CICIMAR

10:40 Break

11:00 Regional Sardine Fisheries Reports

11:00	Gulf of California:	Manuel Nevarez et al. (CRIP-INP-Guaymas)
11:20	Bahía Magdelena:	Félix-Uraga, Melo-Barrera, C. Quiñonez-Velázquez (CICIMAR)
11:40	Ensenada:	Eva Cotero (CRIP-INP-Ensenada)
12:00	California	Dale Sweetnam (CDFG)
12:20	Oregon	Greg Krutzikowsky and Jill Smith (ODFW)
12:40	Washington	Greg Krutzikowsky (in lieu of L.Wargo-DFW)
13:00	Canada	Cynthia Johnston (DFO)

13:20-14:40 Lunch

14:40 Research Plans and Reports

14:40 Regional estimates -Nancy Lo

15:00 Stock Assessment- Kevin Hill

15:20 Contributed Papers

15:20 Pacific Sardine Biomass Estimates and Associated Oceanographic Conditions Off Northern Oregon and Southern Washington in 2009-Robert Emmett, Paul Bentley

15:40 Acoustic estimation of sardine biomass in the Gulf of California during the spring of 2009 - Héctor Villalobos, Manuel O. Nevárez-Martínez, José Pablo Santos-Molina, Jean Jacques Lévénez, Erwan Josse, Ma. de los Ángeles Martínez Zavala,Mercedes Jacob-Cervantes, Alejandro Balmori-Ramírez

16:00 Towards improved acoustic surveys of sardine in the California Current Ecosystem: a review of coastal pelagic species and equipment and methods currently used to assess their distributions and abundances -Juan P. Zwolinski, George R. Cutter, David A. Demer

16:20 Reassessment of the stock-recruitment and temperature-recruitment relationships for Pacific sardine (*Sardinops sagax*) - Sam McClatchie, Ralf Goericke, Guillermo Auad, Kevin Hill

16:40 Break

17:00 Environmental influence in stock-recruitment relationships of the Pacific sardine (*Sardinops sagax*) of the Northeastern Pacific Ocean **-** Gabriela Galindo-Cortes, Juan Antonio De Anda-Montañez, Francisco Arreguín-Sánchez, Silvia Salas, Eduardo Francisco Balart

17:20 Climate Variability and Sardine Recruitment Success in the California Current - Tim R Baumgartner,, Guillermo Auad, Kevin T Hill, Arthur J Miller

17:40 Modeling climate-to-fish-to-fishers interactions: progress, issues, and some solutions - Enrique N. Curchitser, Kenneth A. Rose, Kate Hedstrom, Jerome Fiechter, Shin-ichi Ito, Bernard A. Megrey, Salvador Lluch-Cota

18:00 Comparing the influence of oceanographic fronts on interannual changes in the distribution and relative abundance of sardine in the California and Southern Benguela Current systems - Rubén Rodríguez-Sánchez, Carl van der Lingen, Marlene Manzano, Larry Hutchings, Héctor Villalobos

18:30 - 20:30 Welcome reception and poster presentations

Posters:

Pacific sardine (Sardinops sagax) spawning fraction and batch fecundity data from 1986 to 2009: age, size, or temperature relationships - Beverly J. Macewicz

The effect of the sea tide cycles in the monterey sardine fishery in Bahia Magdalena - Carlos Robinson-Mendoza, Casimiro Quiñónez -Velázquez, Jaime Gómez-Gutiérrez

Annual changes in abundance of the *Sardinops sagax* early stages in Bahía Magdalena - René Funes-Rodríguez, Alejandro Zárate-Villafranco, Alejandro Hinojosa-Medina, Rubén Rodríguez-Sánchez

Oxygen consumption of the Pacific sardine: cold and temperate group - Benjamín Baron, Mónica Hernández, Marisol Simon D.

A review of the population structure of Pacific sardine *Sardinops sagax* (Jenyns, 1842) based on morphometric and genetic analysis - Francisco J. García-Rodríguez, Silvia A. García-Gasca, José De La Cruz-Agüero, Víctor M. Cota-Gómez

Age and growth of Pacific sardine (S*ardinops caeruleus*) off the west coast of Baja California in 2007 - Y. A. Green-Ruiz, A. Cota-Villavicencio, M. Jacob-Cervantes, P. Santos-Molina, A. Verde-Hernàndez, R. Sánchez-Medina, S. Rodríguez-Aguayo.

Can there be stable, cooperative exploitation of a transboundary fish stock under climate variability? The case of Pacific sardine in the California Current - Gaku Ishimura, Andrés M. Cisneros-Montemayor, Sam Herrick, U. Rashid Sumaila

Wednesday, November 18th (Galeón Room, Hotel Marina)

09:00 Contributed Papers (continuation)

09:00 Inter-annual variability of age structure of Pacific Sardine in the West Coast of Baja California Sur, Mexico (southern portion of California Current System 1981-2008) - Felipe Neri Melo-Barrera, Roberto Félix-Uraga, Casimiro Quiñónez-Velázquez, Griselma Rubio Castro.

09:20 Annual variability of growth of the Pacific sardine in Magdalena Bay, 1981-2008 - Roberto Félix-Uraga, Felipe Neri Melo-Barrera, Gabriela García-Alberto, Casimiro Quiñonez-Velázquez, Cristhian Robles-Cota.

09:40 Analysis of the first maturity size of the Pacific sardine in the west coast of the peninsula of Baja California - Gabriela García-Alberto, Roberto Félix-Uraga, Felipe Neri Melo-Barrera.

10:00 An Introduction to the Historical Pacific Sardine Database - Christina Show, Kevin Hill

10:20 Trophic role of sardine in the Gulf of California - Christian Salvadeo, Salvador Lluch-Cota , Pablo Del Monte-Luna, Daniel Lluch-Belda

10:40 Break

11:00 2009 aerial survey - Doyle Hanan

11:20 La temporalidad de la reproducción de la sardina monterrey (*Sardinops sagax*) en la costa occidental de la península de Baja California en 2007. René Torres-Villegas, Rosa Isabel Ochoa-Báez, Ilinova Maravilla-Ulloa

11:40 Trophically-transmitted parasites of Pacific sardines: A comparative analysis of host size, host species and regions-Rebecca Baldwin, Kym C. Jacobson, Robert Emmett

12:00 Larval *Anisakis* spp. (Phylum Nematoda) in Pacific Sardines: Does Genetic Analysis of the Worms Provide Information on the Biology and Migration of Sardines in the California Current System?- Kym C. Jacobson, Rebecca Baldwin, Mary Beth Rew

12:20 Discrimination of Pacific sardine subpopulations using $\delta^{18}O$ values of otolith cores to calculate larval rearing temperature: Preliminary results-Jorge A. Cerón, Sharon Z. Herzka, Casimiro Quiñonez-Velazquez, Paula Perez-Brunius, Timothy Baumgartner

12:40 Examination of Population Connectivity in Sardine (*Sardinops sagax caeruleus*) in the North East Pacific Using Microsatellite Markers- John Hyde, Carol Kimbrell, Barbara Javor, Eric Lynn

13:00-14:30 Lunch

14:30 Workgroups. Reports and analysis

WG1: Regional biomass

WG2: Stock structure, age structure and adult sampling

WG3: Industry trends and issues

WG4: Biological and economical modeling

17: 00 Closing remarks – Future Plans

APPENDIX III

Abstracts of Contributed Papers and Posters

Contents

Keynote address **5**

REEXAMINING AND OLD HYPOTHESIS 6

Daniel Lluch-Belda[1]

Regional Biomass **7**

CLIMATE VARIABILITY AND SARDINE RECRUITMENT SUCCESS IN THE CALIFORNIA CURRENT 8

TIM R BAUMGARTNER[1], GUILLERMO AUAD[2], KEVIN T HILL[3] AND ARTHUR J MILLER[2]

PACIFIC SARDINE BIOMASS ESTIMATES AND ASSOCIATED OCEANOGRAPHIC CONDITIONS OFF NORTHERN OREGON AND SOUTHERN WASHINGTON IN 2009 9

Robert Emmett and Paul Bentley

REASSESSMENT OF THE STOCK-RECRUITMENT AND TEMPERATURE-RECRUITMENT RELATIONSHIPS FOR PACIFIC SARDINE (SARDINOPS SAGAX) 10

Sam McClatchie[1], Ralf Goericke[2], Guillermo Auad[3], Kevin Hill[1]

ACOUSTIC ESTIMATION OF SARDINE BIOMASS IN THE GULF OF CALIFORNIA DURING THE SPRING OF 2009 11

Héctor Villalobos[1,*], Manuel O. Nevárez-Martínez[2], José Pablo Santos-Molina[2], Jean Jacques Lévénez[3], Erwan Josse[3], Ma. de los Ángeles Martínez Zavala[2], Mercedes Jacob-Cervantes[2] and Alejandro Balmori-Ramírez[2]

Stock structure **12**

TROPHICALLY-TRANSMITTED PARASITES OF PACIFIC SARDINES: A COMPARATIVE ANALYSIS OF HOST SIZE, HOST SPECIES AND REGIONS 13

Rebecca Baldwin[1,2]*, Kym C. Jacobson[3], Robert Emmett[3]

DISCRIMINATION OF PACIFIC SARDINE SUBPOPULATIONS USING $\Delta^{18}O$ VALUES OF OTOLITH CORES TO CALCULATE LARVAL REARING TEMPERATURE: PRELIMINARY RESULTS 14

Cerón, Jorge A.[1]* Herzka, Sharon Z.[1] Quiñonez-Velazquez, Casimiro[2] Perez-Brunius, P.[1] and Baumgartner, T.[1]

ANNUAL VARIABILITY OF GROWTH OF THE PACIFIC SARDINE IN MAGDALENA BAY, 1981-200815

Roberto Félix Uraga[1,a,*], Felipe Neri Melo Barrera[1,a], Gabriela García Alberto[1], , Casimiro Quiñonez Velázquez[1,a a] & Cristhian A. Robles Cota[1,a].

ENVIRONMENTAL INFLUENCE IN STOCK-RECRUITMENT RELATIONSHIPS OF THE PACIFIC SARDINE (SARDINOPS SAGAX) OF THE NORTHEASTERN PACIFIC OCEAN..... 16

Gabriela Galindo-Cortes[1*], Juan Antonio De Anda-Montañez[1], Francisco Arreguín-Sánchez[2], Silvia Salas[3], Eduardo Francisco Balart[1]

ANALYSIS OF THE FIRST MATURITY SIZE OF THE PACIFIC SARDINE IN THE WEST COAST OF PENINSULA OF BAJA CALIFORNIA 17

García-Alberto, Gabriela[1], Félix-Uraga, Roberto[1,a] & Melo-Barrera, Felipe Neri[1,a]

EXAMINATION OF POPULATION CONNECTIVITY IN SARDINE(SARDINOPS SAGAX CAERULEUS) IN THE NORTH EAST PACIFIC USING MICROSATELLITE MARKERS 18

John Hyde[1*], Carol Kimbrell[1], Barbara Javor[1], Eric Lynn[1]

LARVAL ANISAKIS SPP. (PHYLUM NEMATODA) IN PACIFIC SARDINES: DOES GENETIC ANALYSIS OF THE WORMS PROVIDE INFORMATION ON THE BIOLOGY AND MIGRATION OF SARDINES IN THE CALIFORNIA CURRENT SYSTEM? 19

Kym C. Jacobson[1]*, Rebecca Baldwin[2,3], Mary Beth Rew[2]

INTER-ANNUAL VARIABILITY OF AGE STRUCTURE OF PACIFIC SARDINE IN THE WEST COAST OF BAJA CALIFORNIA SUR, MEXICO (SOUTHERN PORTION OF CALIFORNIA CURRENT SYSTEM 1981- 2008)..... 20

Felipe Neri Melo-Barrera[1,a,*], Roberto Félix-Uraga[1,a], Casimiro Quiñónez-Velázquez[1,a] & Griselda Castro-Rubio[1]

AN INTRODUCTION TO THE HISTORICAL PACIFIC SARDINE DATABASE 21

Christina Show[1]*, Kevin Hill[1]

SPAWNING SEASON IN THE PACIFIC SARDINE (SARDINOPS SAGAX) IN 2007 ALONG THE WEST COAST OF THE BAJA CALIFORNIA PENINSULA, MEXICO..... 22

J. René Torres-Villegas [1], Rosa Isabel Ochoa-Báez [1, 2, 3]and Ilinova Maravilla-Ulloa [1]

TOWARDS IMPROVED ACOUSTIC SURVEYS OF SARDINE IN THE CALIFORNIA CURRENT ECOSYSTEM: A REVIEW OF COASTAL PELAGIC SPECIES AND EQUIPMENT AND METHODS CURRENTLY USED TO ASSESS THEIR DISTRIBUTIONS AND ABUNDANCES..... 23

Juan P. Zwolinski[*], George R. Cutter, David A. Demer

Biolical & Economial Modeling 24

MODELING CLIMATE-TO-FISH-TO-FISHERS INTERACTIONS: PROGRESS, ISSUES, AND SOME SOLUTIONS 25

Enrique N. Curchitser[1*], Kenneth A. Rose[2], Kate Hedstrom[3], Jerome Fiechter[4], Shin-ichi Ito[5], Bernard A. Megrey[6], and Salvador Lluch-Cota[7]

COMPARING THE INFLUENCE OF OCEANOGRAPHIC FRONTS ON INTERANNUAL CHANGES IN THE DISTRIBUTION AND RELATIVE ABUNDANCE OF SARDINE IN THE CALIFORNIA AND SOUTHERN BENGUELA CURRENT SYSTEMS..... 26

Rubén Rodríguez-Sánchez[1*], Carl van der Lingen[2], Marlene Manzano[3], Larry Hutchings[2] and Héctor Villalobos[1]

TROPHIC ROLE OF SARDINE IN THE GULF OF CALIFORNIA 27

Christian Salvadeo [1,*], Salvador Lluch-Cota [2], Pablo Del Monte-Luna [1] and Daniel Lluch-Belda [1]

Posters 28

ANNUAL CHANGES IN ABUNDANCE OF THE SARDINOPS SAGAX EARLY STAGES IN BAHÍA MAGDALENA 29

René Funes-Rodríguez[1,*], Alejandro Zárate-Villafranco[1], Alejandro Hinojosa-Medina[1] and Rubén Rodríguez-Sánchez[1]

THE EFFECT OF THE SEA TIDE CYCLES IN THE MONTEREY SARDINE FISHERY IN BAHÍA MAGDALENA 30

Carlos Robinson Mendoza[1]; Casimiro Quiñónez Velázquez[2]; Jaime Gómez Gutiérrez[2]

A REVIEW OF THE POPULATION STRUCTURE OF PACIFIC SARDINE SARDINOPS SAGAX (JENYNS, 1842) BASED ON MORPHOMETRIC AND GENETIC ANALYSIS 31

Francisco J. García-Rodríguez[1*], Silvia A. García-Gasca[2], José De La Cruz-Agüero[1] and Víctor M. Cota-Gómez[1]

AGE AND GROWTH OF PACIFIC SARDINE (SARDINOPS CAERULEUS) OFF THE WEST COAST OF BAJA CALIFORNIA IN 2007. 32

Y. A. Green-Ruiz.[1*], A. Cota-Villavicencio[2], M. Jacob-Cervantes[1], P. Santos-Molina[3], A. Verde-Hernàndez[1] R. Sánchez-Medina[2] y S.Rodríguez-Aguayo[4]

PACIFIC SARDINE (SARDINOPS SAGAX) SPAWNING FRACTION AND BATCH FECUNDITY DATA FROM 1986 TO 2009: AGE, SIZE, OR TEMPERATURE RELATIONSHIPS. 33

Beverly J. Macewicz

CAN THERE BE STABLE, COOPERATIVE EXPLOITATION OF A TRANSBOUNDARY FISH STOCK UNDER CLIMATE VARIABILITY? THE CASE OF PACIFIC SARDINE IN THE CALIFORNIA CURRENT 34

Gaku Ishimura[1,2,*], Andrés M. Cisneros-Montemayor[1,**], Sam Herrick[3] and U. Rashid Sumaila[1]

Regional Reports 35

MAGDALENA BAY PACIFIC SARDINE FISHERY, 2008-2009 36

Félix-Uraga, R.[1], F. N. Melo-Barrera[1] & C. Quiñonez-Velázquez[1]

ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2009 FOR U.S. MANAGEMENT IN 2010: EXECUTIVE SUMMARY 37

Kevin T. Hill[1], Nancy C. H. Lo[1], Beverly J. Macewicz[1], Paul R. Crone[1], and Roberto Felix-Uraga[2]

Keynote address

Reexamining and old hypothesis

Daniel Lluch-Belda

Centro Interdisciplinario de Ciencias Marinas (CICIMAR - I.P.N.) La Paz, B.C.S., México.
dlluch@ipn.mx

This description of the *Regime Problem* in 1989[i] considered three principal aspects: 1) sardine populations grow and decline in synchrony at distant and disconnected areas of the world oceans; 2) sardine and anchovy populations alternate abundance between them; 3) sardines are associated to warm periods, while anchovies develop during cold ones. At that time we stated that *"the mechanisms which initiate, sustain, and terminate outbursts of sardine or anchovy populations are not yet clear"*. As of today, *"the direct association of shifts in the dynamics of small pelagic fish and their ecosystems … are still largely obscure"*[ii]. Later, we proposed a hypothesis[iii] to explain those mechanisms; here it is reviewed for the purpose of critically examining its components after almost 20 years.

I first discuss the concept of Regime originally thought to consist of sustained lapses of warm and cold conditions and arrive to the conclusion that they rather are prolonged periods of change, warming and cooling, separated by abrupt changes in the direction of change, the Regime Shifts. Based on this and on the differential intensities of fishing, I claim that basic synchrony remains.

Looking at other scales of variation, it is here suggested that: 1) high frequency (<10 yrs, El Niño – La Niña) variation forces changes in the distribution of sardines; 2) seasonally, sardine schools expand north and south from a permanent distribution area; and 3) when reaching a productive area, if there are adequate conditions of temperatures and productivity, a local population is established.

Finally, it is proposed that: 1) sardines schools don't migrate, they randomly swim, feeding and spawning on the way; 2) temperature limits their dispersion from year round highly productive areas; 3) if reaching an area with adequate temperature and high productivity during a favorable regime, new population is formed with a different ecophenotype; and finally 4) the newly formed population may then disperse further on a seasonal basis

---

[i] Lluch-Belda, D., R.J.M. Crawford, T. Kawasaki, A.D. MacCall, R.H. Parrish, R.A. Schwartzlose and P.E. Smith (1989). World-wide fluctuations of sardine and anchovy stocks: The regime problem. S. Afr. J. Mar. Sci. **8**: 195-205

[ii] Alheit, J., C. Roy and S.Kifani. 2009. Decadal-scale variability in populations. In D. Chekley, J. Alheit, Y. Oozeki and C. Roy (eds) Climate Change and Small Pelagic Fish. Cambridge U. Press.

[iii] Lluch-Belda, D., S. Hernández-Vázquez and R.A. Schwartzlose (1991). A hypothetical model for the fluctuations of the California sardine population. Long-term Variability of Pelagic Fish Populations and their Environment. T. Kawasaki et. al, Pergamon Press**:** 293-300.

Regional Biomass

Climate variability and sardine recruitment success in the California Current

Tim R Baumgartner[1], Guillermo Auad[2], Kevin T Hill[3] and Arthur J Miller[2]

1. Departamento de Oceanografía Biológica, División de Oceanología, CICESE, Ensenada, B.C. MEXICO
2. Climate Research Division, Scripps Institution of Oceanography, UCSD, La Jolla, CA USA
3. Coastal Fisheries Division, Southwest Fisheries Science Center, NMFS, NOAA, La Jolla, CA USA

We investigate the relationship between recruitment success of the springtime spawning stock of the Pacific sardine and the climate and ocean conditions in the central region of the California Current system by means of a statistical model set up to reflect sensitivity of specific life stages to seasonal climate forcing. The series of sardine recruitment success is taken from annual stock assessments over the period 1982-2007 by the Southwest Fisheries Science Center of NOAA-NMFS. Ocean climate variability is represented by monthly values of the Pacific Decadal Oscillation index (PDOI; from http://jisao.washington.edu/pdo/), plus monthly indices of coastal upwelling and Ekman pumping off central California (from http://las.pfeg.noaa.gov/las6_5/servlets/dataset).

We selected a suite of four seasonal indices for each climate variable (a total of 12 climate indices) by prescreening successive, overlapping 3-month means of each of the three climate series from evaluation of their lagged correlations with the series of annual sardine recruitment success. This prescreening process identifies seasonal periods of the three forcing variables that exert the strongest influence on each of the life stages in the recruitment process specified as 1) environmental conditioning of prespawning adults, 2) spawning and larval growth/mortality, 3) juvenile growth/mortality, and 4) the stage of recruitment to the adult population that together extend over a span of 27 months. We use a stepwise regression procedure to develop a general linear model for annual recruitment success by selecting 5 of the original 12 seasonal climate variables that optimizes the level of skill and degrees of freedom of the model estimates.

The model results indicate that the interannual variability of the PDOI is strongly linked to recruitment success through its positive association with environmental conditioning of prespawning adults and with the stage of spawning and larval development (*i.e.*, warming episodes over the NE Pacific tend to be associated with recruitment success). Model results further indicate that a decadal scale increase in Ekman pumping after 1990 had a significant negative effect on recrutment success mainly through its negative influence at the stage of juvenile growth. Likewise, two of the four coastal upwelling series, those corresponding to the stages of juvenile growth and then recruitment, were also inversely related to recruitment success over the period of 1982-2007.

The talk will conclude with a preliminary interpretation of linkages between the climate variables and the sardine recruitment success through regional ocean dynamics that regulate the seasonal variability in the state of the sardine habitat.

Pacific sardine biomass estimates and associated oceanographic conditions off northern Oregon and southern Washington in 2009

Robert Emmett and Paul Bentley

NOAA Fisheries, Northwest Fisheries Science Center
Newport, OR

Two fishery oceanographic surveys, which collect juvenile and adult sardines and measure environmental conditions off Washington/Oregon, were conducted in 2009. These surveys have been conducted annually since 1998. Preliminary information from the Predator Survey (nighttime surface trawls) indicates that June, July and August 2009 sardine biomass estimates (using an area swept methodology) were very similar to 2008. However, highest sardine catches, and thus biomass estimates, occurred in August 2009. Monthly age analysis revealed that most (80%) of sardines were born in 2004-2005, years when sardine successfully spawned off Oregon. Ocean temperatures were much warmer than 2008. The limited sardine recruitment success the last couple of years off the Pacific Northwest may influence future adult sardine abundance in this region, but exactly how much, is presently uncertain.

Reassessment of the stock-recruitment and temperature-recruitment relationships for Pacific sardine (*Sardinops sagax*)

Sam McClatchie[1], Ralf Goericke[2], Guillermo Auad[3], Kevin Hill[1]

1. Southwest Fisheries Science Center, National Marine Fisheries Service, 8604 La Jolla Shores Drive, La Jolla, California 92037 − 1508, U.S.A.
2. Integrative Oceanography Division, Scripps Institution of Oceanography, La Jolla, CA 92093-0218
3. Climate Research Division, Scripps Institution of Oceanography, La Jolla, CA 92093-0218

* Contact author: Sam.McClatchie@noaa.gov

Keywords: sardine, Scripps, pier, temperature

The harvest guideline for Pacific sardine (*Sardinops sagax*) incorporates an environmental parameter based on averaged surface temperatures at the Scripps Institution of Oceanography Pier (SIO pier) that would be invoked after a series of cool years to reduce commercial catches using a precautionary decision rule. We test whether SIO pier temperatures are representative of temperatures in the offshore spawning habitat using data from 1916 to 2007. SIO pier surface temperatures are warmer than 10m-depth Southern California Bight (SCB) temperatures, and the difference has increased since the late 1970s. Sardine currently spawn up to 250 km offshore in the SCB and we present evidence based on adult size and egg distributions that larger sardine spawners have moved offshore. Given the offshore trends in sardine spawning, offshore temperatures would provide a more relevant environmental input to surplus production models than the SIO pier temperatures. We revisit the stock-recruit and temperature-recruit relationships underpinning the currently used environmental parameter for sardine assessment and found that the temperature-recruit relationship no longer holds for the SIO pier or the offshore when time series are updated with data from more recent years. In contrast, the stock-recruit relationship was still valid when recent data were added. We demonstrate that the environmental proxy derived from SIO pier temperature, which has never affected the harvest guideline it's inception, is no longer relevant to sardine spawning, or by inference to recruitment success of Pacific sardine, and should be removed from the sardine stock assessment.

Acoustic estimation of sardine biomass in the Gulf of California during the spring of 2009

Héctor Villalobos[1,*], Manuel O. Nevárez-Martínez[2], José Pablo Santos-Molina[2], Jean Jacques Lévénez[3], Erwan Josse[3], Ma. de los Ángeles Martínez Zavala[2], Mercedes Jacob-Cervantes[2] and Alejandro Balmori-Ramírez[2]

1. CICIMAR-IPN. Av. Instituto Politécnico Nacional s/n. Col. Playa Palo de Santa Rita, La Paz, B.C.S. México
2. Instituto Nacional de Pesca (CRIP Guaymas, Mazatlán)
3. IRD Center of Brittany, B.P. 70-29280, Plouzané, France

* Contact author: hvillalo@ipn.mx

Keywords: California sardine, acoustics, biomass estimations, Gulf of California

We present the results of an acoustic survey carried out in the Gulf of California from April 30 to May 21, 2008. Acoustic sampling was conducted onboard the R/V "BIP XI" mostly during nighttime (17:00 to 3:00) using a SIMRAD EK60 echosounder with a 38 kHz split beam transducer. Survey design was adapted to depth conditions in both margins of the gulf. In the eastern margin, a series of parallel transects extending to the 200 m isobath and spaced 10 nautical miles (nm), were made perpendicular to the coast of Sonora, from Agiabampo Bay in the south to Puerto Lobos in the North. In the western margin, zig-zag transects covered from Loreto to Isla Angel de la Guarda. The acoustic information was recorded for later analysis. Along transects, 39 identification trawls were made using a 4 layer midwater trawl with a bag of ¾ inch mesh size.

The processing and analysis of stored digital echograms was carried out using Movies+ software (Berger *et al.*, 2007). Echograms were inspected for errors (bottom correction, removing parasite or double bottom echoes) before conducting echointegration by depth layers to obtain the nautical area scattering coefficient values (s_A) by elementary sampling unit (ESU) of 1 nm. The largest proportion of acoustic energy was distributed north of I. Tiburón and I. Angel de la Guarda, although a significant portion was also observed off the coast of Sonora, north of Guaymas. 18 out of 19 hauls were positive for California sardine, with individuals averaging 140 mm of standard length and 40 g of weight. Based on these data, a first exercise of California sardine' acoustic biomass estimation in this area is presented.

References

Berger, L., C. Durand and C. Marchalot, 2007. *MOVIES+ User Manual version 4.3. Rapport Technique DNIS/ESI/DLE/DTI/00-051, IFREMER.*

Stock structure

Trophically-transmitted parasites of Pacific sardines: A comparative analysis of host size, host species and regions

Rebecca Baldwin[1,2]*, Kym C. Jacobson[3], Robert Emmett[3]

1. Cooperative Institute for Marine Resources Studies, Oregon State University
2. Department of Fisheries and Wildlife, Oregon State University
3. NOAA Fisheries, Northwest Fisheries Science Center

* Contact author: Rebecca.Baldwin@oregonstate.edu

Keywords: Pacific sardines, parasite community ecology

Previously, we reported on a project using macroparasites acquired through infected prey to assess the migration patterns of Pacific sardine within the California Current System (CCS). Approximately 2500 sardines were collected from 2005 through 2008 between 50° to 31° North latitude, and 120° to 125° West longitude. To date, eleven parasite species have been recovered from approximately 1200 sardines, with five parasite species identified as potential biological tags. A comparison of the macroparasite communities of sardines caught from 2005 to 2008 identified three different parasite communities suggesting that Pacific sardines are not migrating throughout the entire study region. In this presentation. we will describe the macroparasite communities of sardines in relation to fish length for sardines caught off of southern, central and northern California (SL range 101 – 262 mm) versus sardines caught off of the Pacific northwest (SL range (122 – 272 mm). In addition, we will present a comparison of the macroparasite communities of non-migratory northern anchovy (*Engraulis mordax*) collected off of Washington and southern California in 2007 as a baseline for the macroparasite communities of migratory sardines. We will also discuss a comparative analysis of the macroparasite communities of sardines from two different fishing efforts (research and commercial) off of northern Oregon – southern Washington during the summer of 2007.

Discrimination of Pacific sardine subpopulations using δ18O values of otolith cores to calculate larval rearing temperature: preliminary results

Cerón, Jorge A.[1]* Herzka, Sharon Z.[1] Quiñonez-Velazquez, Casimiro[2] Perez-Brunius, P.[1] and Baumgartner, T.[1]

1. Centro de Investigación Científica y de Educación Superior de Ensenada CICESE. Km. 107 Carretera Tijuana-Ensenada, Ensenada, Baja California 22860 México.
2. Centro Interdisciplinario de Ciencias Marinas I.P.N., CICIMAR. Playa El Conchalito s/n Apdo. Postal 592. La Paz, Baja California Su, C.P. 2300, México.

* Contact author: jceron@cicese.mx

The implementation of management strategies for marine fish populations relies on the identification of subpopulations, as well as the characterization of their spatial and temporal distribution relative to environmental conditions. This is particularly important for species whose level of exploitation varies along its distribution and that exhibit extensive migrations. Despite the research effort conducted on the Pacific sardine (*Sardinops sagax*) during the last century, there is still uncertainty regarding its population structure, the natal origin of individuals, the amount of mixing between subpopulations and its migratory ability. The oxygen isotopic composition ($\delta^{18}O$) of the otolith carbonate of marine fishes has been successfully used as a natural tracer of stock structure and natal origin, as well as to reconstruct the thermal history of individuals and infer migration patterns. Previous studies found a high degree of variability in the $\delta^{18}O$ values of whole otoliths of young sardines captured in the Mexican Pacific and Gulf of California (up to 2 ‰). The high level of variation was considered consistent with mixing during the first year of life. However, whether mixing occured at the subpopulation level or among subpopulations is not clear.

Otolith $\delta^{18}O$ values permanently record the temperature and salinity under which the carbonate formed. The otoliths of individuals that have grown in waters with different temperature and/or salinity regimes can thus exhibit differing isotopic values. Further, if the isotopic composition of the water (δ_w) in a given area is known or can be estimated based on salinity, $\delta^{18}O$ values can be used to calculate the temperature of carbonate formation. However, isotopic values derived from whole otoliths integrate the temperature to which an individual was exposed throughout life. The temporal resolution that can therefore be obtained from whole otoliths is limited.

Our ongoing research is implementing cutting-edge technology to obtain and analyze carbonate subsamples from the cores of the otoliths of Pacific sardines. Our overall goal is to reconstruct the temperature to which individual sardines were exposed to during the larval and early juvenile period to (1) identify spawning subpopulation, (2) evaluate whether there is evidence of mixing among the northern and southern Pacific subpopulations and (3) infer migration patterns.

This presentation will exemplify the potential of this technique to contribute to the present-day understanding of Pacific sardine subpopulations. We present preliminary data obtained from otolith cores of sardines caught by the fishing fleet of El Sauzal, Baja California, in February 2008 and in Magdalena Bay in May and November of 2006. We evaluate the level of variability in $\delta^{18}O$ values of otolith cores relative to previous results obtained from whole-otolith analyses. We also estimate temperature based on $\delta^{18}O$ values and δ_w estimates. Lastly, we infer the spawning population based on age and temperature estimates.

Annual variability of growth of the Pacific sardine in Magdalena Bay, 1981-2008

Roberto Félix Uraga[1,a,*], Felipe Neri Melo Barrera[1,a], Gabriela García Alberto[1], , Casimiro Quiñonez Velázquez[1,a a] & Cristhian A. Robles Cota[1,a].

1. Centro Interdisciplinario de Ciencias Marinas CICIMAR-IPN. Av. Instituto Politécnico Nacional s/n Col. Playa Palo de Santa Rita.

a Becarios COFAA y EDI

* Contact author: rfelix@ipn.mx

The inter-annual variability of the individual growth of the Pacific sardine in Magdalena Bay during 1981 to 2008 was analyzed. The average size by age group (0-5) was estimated, showing a great inter-annual variability during this period. The estimates of the parameters $\mathbf{L}_\infty$ y **k** of the von Bertalanffy growth model, also presented inter-annual changes and an inverse variability among them. These variations are related, at least partly, to the changes in the sea surface temperature and to their population abundance. When comparing the variability of the average sizes by age group of each cohort, we could observe the effects of a compensatory growth in Pacific sardine, since in the cohorts with small average sizes for age group 0 showed a higher growth rate than cohorts with large average sizes for group 0. The effect of the compensatory growth was bigger during the relatively cold years and vice versa. Finally, the recruitment estimates (age group 0) to the fishery in Magdalena Bay presented an inverse relationship to body size, since when peaks of recruitment were observed, the average sizes of age group 0 were smallest, and vice versa.

Environmental influence in stock-recruitment relationships of the Pacific sardine (*Sardinops sagax*) of the Northeastern Pacific Ocean

Gabriela Galindo-Cortes[1*], Juan Antonio De Anda-Montañez[1], Francisco Arreguín-Sánchez[2], Silvia Salas[3], Eduardo Francisco Balart[1]

1. Centro de Investigaciones Biológicas del Noroeste, S.C., Mar Bermejo No. 195, Col. Playa Palo de Santa Rita, Apartado Postal 128, 23090, La Paz, BCS, México
2. Centro Interdisciplinario de Ciencias Marinas, IPN, Av. IPN s/n, Col. Playa Palo de Santa Rita s/n, Apartado Postal 592, 23096, La Paz, BCS, México
3. Centro de Investigación y de Estudios Avanzados del IPN, Unidad Mérida, Antigua Carretera a Progreso Km. 6, Apartado Postal 73, Cordomex, 97310 Mérida, Yucatán, México

* Contact author: ggalindo@cibnor.mx

Keywords: Pacific sardine; models; stock-recruitment; California Current; oceanographic variables

The Pacific sardine (*Sardinops sagax*) currently is the basis for an important fishing industry that extends the length of the northeastern Pacific Ocean (NPO). The recruitment of juveniles in the NPO has been variable in recent decades, which is attributed to variations in the spawning stock biomass (SSB) and to the oceanographic conditions within the California Current system (CCS). In this study, different stock-recruitment (SR) functions were fitted for recruitment data and SSB of *S. sagax* in three regions of the NPO. Six SR models, with one to three parameters, were used. Two information criteria (Akaike (AIC) and Bayesian (BIC)) were used to select the best suitable SR relationships. The SR relationship with the best performance supported prior evidence that recruitment of Pacific sardine in Magdalena Bay (MB) has a strong component of density-dependent compensation of the Ricker type, which implies that at high SSB, subsequent recruitment is low and, for the northern regions Ensenada (EN) and North Pacific (NP), the recruitment appears to be regulated by an effect depending on the abundance of the pre-recruits and compensatory mortality, which is governed by food limitation and competition among the juveniles, that is, similar to the Beverton-Holt model. Upon incorporation of data on four environmental variables into the SR models, these data differentially affected the recruitment of the sardine throughout the CCS, *e.g.*, high temperatures in MB negatively affected recruitment, whereas in EN and NP, the effect was positive. The best environmental-SR models by region, in agreement with AIC and BIC, were that of Ricker with temperature for MB and that of Beverton-Holt with either the upwelling index or the Southern Oscillation index for EN and NP, respectively.

Analysis of the first maturity size of the Pacific sardine in the west coast of peninsula of Baja California

García-Alberto, Gabriela[1], Félix-Uraga, Roberto[1,a] & Melo-Barrera, Felipe Neri[1,a]

1. Age and Growth Laboratory. Centro Interdisciplinario de Ciencias Marinas-IPN. La Paz, B.C.S., México. e-mail: gabigaralb@gmail.com

a Becarios EDI, COFFA

Keywords: *Sardinops sagax*, density-dependence, first reproduction size (L_{50}), NOM-003-PESC-1993.

The determination of the reproductive cycle and maturity size (L_{50}) are relevant issues to the knowledge of biology of species, and to establish criteria to take decisions on fishery management. In this work, we analyze the variability of L_{50} of Pacific sardine in Magdalena Bay (MB) and Ensenada (EN) México, and its relationship with the sea surface temperature and catch. We take monthly samples from commercial landing of S. *sagax*, between 1981 and 2005 for MB and from 1989 to 2002 for EN. In each sample, the standard length (SL), sex and maturity stage (using a macroscopic scale) were recorded for 100 individuals (at least). The value of L_{50} was obtained using a logistic model using the frequency of mature organism by intervals of size of 5mm SL; the parameters were obtained by a non lineal method. To estimate L_{50}, we only use sardines from January to June, because it represent the principal reproductive period. In MB the L_{50} range from 150.2 mm (1983) to 185.3 mm LP (1993). For En L_{50} show its minimum in 1994 (171.4 mm SL) and its maximum in 1992 (219.7 SL). In both zones, the inter-annual variability of L_{50} may be due to environmental changes, mainly El Niño and La Niña phenomena, which significantly affect the availability of resource. In MB, we founded a significant correlation between L_{50} and catches, (R=0.52) and with the abundance of the young-of-year, this could be a density-dependence effect, that is, when the abundance is low; the L_{50} decreases, and vice versa. However, for EN, the correlation was inverse, but non-significant (R=-0.28). It is necessary to emphasize that, the sizes of first maturity estimated in this work, are greater than the minimum legal size (150 mm, LP NOM-003-PESC-1993), these differences may be due to the way how determined the maturity. The Pacific sardine is a species with a plasticity such that allows them to have a great capacity to respond to changes in the environment and the fishing, changing their biological characteristics, such as the size of first maturity.

Examination of population connectivity in sardine(*Sardinops sagax caeruleus*) in the North East Pacific using microsatellite markers

John Hyde[1*], Carol Kimbrell[1], Barbara Javor[1], Eric Lynn[1]

1. NOAA Fisheries, Southwest Fisheries Science Center, 3333 N. Torrey Pines Ct., La Jolla, CA 92037 USA
* Contact author: john.hyde@noaa.gov

Keywords: sardine, genetics, stock structure

Sardine (*Sardinops sagax caeruleus*) have long been a major part of the commercial fishery along the west coast of North America. Collapse of sardine populations in the 1940's and 50's devastated commercial fishers and processing. Though large-scale population fluctuations are now known to occur naturally, overfishing may increase the severity of population declines. In recent years the demand for aquaculture feed has placed increased fishing effort on sardine populations. With increasing exploitation of this resource comes the need to ensure proper management of the fishery. Despite extensive tagging studies in the 1930's and 40's the stock structure and dynamics of sardine populations remains poorly understood. Studies of egg and larval abundance suggest that at least two distinct spawning habitats exist, supporting the existence of separate regional stocks. However, genetic studies have yet to yield clear answers to this problem. Genetic stock structure is expected to be minimal when dealing with species that are highly abundant and exhibit migratory behavior. In such cases larger sample sizes and more genetic markers are often necessary to separate the low-level genetic differentiation from the background noise. In an attempt to better address this issue we examined sardine collected at multiple sites from Canada into the Gulf of California using 17 microsatellite markers. Using these data we test previous stock hypotheses and the utility of these markers to monitor the migratory dynamics of these stocks.

Larval *Anisakis spp*. (Phylum Nematoda) in Pacific sardines: does genetic analysis of the worms provide information on the biology and migration of sardines in the California Current System?

Kym C. Jacobson[1]*, Rebecca Baldwin[2,3], Mary Beth Rew[2]

1. NOAA Fisheries, Northwest Fisheries Science Center
2. Oregon State University Cooperative Institute for Marine Resources Studies
3. Department of Fisheries and Wildlife, Oregon State University

* Contact author: Kym.Jacobson@noaa.gov

Keywords: parasite genetics, marine

To identify potential subpopulation structure or migration of Pacific sardines in the California Current System (CCS), we began a population genetic analysis of the mitochondrial *COX2* gene in the larval nematode *Anisakis* spp.. This work complements the macroparasite community analysis of the same individual fish. We also included larval *Anisakis* from less migratory fish species for a genetic baseline in the northern region of the CCS. A total of 220 *Anisakis* spp. recovered from 2005 through 2008 were included in the analysis: n = 188 from Pacific sardines; n = 48 from juvenile salmonids (*Oncorhynchus* spp.); and n= 5 from northern anchovy (*Engraulis mordax*). We identified 141 unique haplotypes comprising three genetically distinct species of *Anisakis* :*A. simplex s.s.*; *A. pegreffii*; and *A. simplex* 'C'. All three *Anisakis* species were recovered from sardines, and to date only one *A. pegreffii* was identified from a northern anchovy. Except for one *A. simplex* 'C', all nematodes recovered from juvenile salmonids were *A. simplex s.s.* There was no regional pattern evident for the 27 shared haplotypes; perhaps a result of the dispersal of nematode eggs by cetacean definitive host resulting in high gene flow within the CCS. To confirm the presence of genetically distinct but morphologically identical *Anisakis* species, we have begun a genetic analysis of the ribosomal ITS gene, a more conserved region of the gene, previously used to identify cryptic species of *Anisakis*. Future research will focus on the population genetic structure of the Clupeid -specific trematode, *Myosaccium ecaude* which does not require cetaceans to complete its life-cycle.

Inter-annual variability of age structure of Pacific sardine in the West Coast of Baja California Sur, Mexico (southern portion of California Current System 1981- 2008)

Felipe Neri Melo-Barrera[1,a,*], Roberto Félix-Uraga[1,a], Casimiro Quiñónez-Velázquez[1,a] & Griselda Castro-Rubio[1]

1. Laboratorio de Edad y Crecimiento. Centro Interdisciplinario de Ciencias Marinas Instituto Politécnico Nacional.
a. Becarios COFFA, EDI
* Contact author: fmelo@ipn.mx

Keywords: Age structure, El Niño, recruitment,

Pacific sardine (*Sardinops sagax)* represents most economically important fish species in the California Current System. The age determinations studies are essential to properly deal with fisheries forecasts and management. The assessment of the age structure of the stock provides information about the state of health of the resource. We evaluated the variation in age structure of this specie in Magdalena Bay, Mexico during 1981-2008. The sample consisted of 20,120 specimens ranging from 80 to 220 mm of standard length (96-265 mm of total length), sampled monthly from April 1981 to June 2008. Annual banding patterns in more than 20,000 otoliths were examined for age estimation. The age structure range for zero to six age year groups; the maximum observed ages for males and females were 6 and 8 years, respectively. The 1-year old specimens are the most conspicuous in the samples (34%) followed by organisms of the 2-age group. The young-of-year (YOY) organisms represent 24% of catch, and individuals of 5-8 years of life were very scarce. The general sex ratio male:female was 1:1, although in some years the females were more abundant than males. There were no differences during study period in the age structure due to the sex. However, differences in age structure between males and females were detected in 1981, 1988, 2000 and 2004. The recruitment occurs mainly in October to December reaching 40% of catches. We detected large recruitments of YOY in 1981, 1985, 1993, 1999, and 2003-04 to the fishery; this could be associated to El Niño and La Niña events, since one or two years after to El Niño event, the catch are dominated by 0-age groups. There were no symptoms of overfishing, since, that years with catches dominated by YOY were followed by years where the sardines of one and two years old were the most abundant.

The stock of Pacific sardines exploited in Magdalena Bay can be considered stable, with significant variations, associated with phenomena of scale inter-annual, like El Niño events.

An introduction to the historical Pacific sardine database

Christina Show[1]*, Kevin Hill[1]

1. Fisheries Resources Division, Southwest Fisheries Science Center, La Jolla, CA
* Contact author: christina.show@noaa.gov

Keywords: Database, Age, Length.

The California Department of Fish and Game has been collecting data from commercial catch since 1919 to study the causes underlying changes in abundance of this species. The data collection were undertaken later jointly by other agencies such as the U.S. Fish and Wildlife Service, the Fisheries Research Board of Canada, the Washington State Department of Fisheries and Fish Commission of Oregon, etc.

Much of the data were collected from the sardine catches in all ports along the Pacific Coast from Canada to California and were reported on a regular basis with age and length composition by area and by season in a tabular form. All of these data have been digitized from their original files and hard copy reports, compiled and incorporated into a Microsoft Access relational database. Our objective is to make these data available in a centralized data warehouse as a time series for easy access by the stock assessment researchers. Biologists who study life structural sardine population dynamics will be able to use this information in developing recommendations for assessing and managing this important species.

In this talk, we will give a brief overview of all access Tables contained in this relational database and present an overall descriptive statistics from the age and length compositions without interpretation of the data.

Spawning season in the Pacific sardine (*Sardinops sagax*) in 2007 along the west coast of the Baja California peninsula, Mexico.

J. René Torres-Villegas [1], Rosa Isabel Ochoa-Báez [1, 2, 3] and Ilinova Maravilla-Ulloa [1]

1. Laboratorio de Morfofisiología. CICIMAR-IPN. Av. IPN s/n Playa Palo de Santa Rita s/n. 23096. La Paz Baja California Sur, México.
2. Becario de la Comisión de Operación y Fomento de las Actividades Académicas.
3. Becario del Sistema de Estímulos al Desempeño de la Investigación del IPN.

Key words: Pacific sardine, reproduction, DEPM, reproductive seasonality, Sardina monterrey, reproducción, DEPM, temporalidad reproductive

There are data showing that the spawning season in the Pacific sardine in Bahia Magdalena was interrupted. However, there is not evidence if a major atresia was a local process or has a large scale influence. In order to describe changes in spawning season of the Pacific sardine along the west coast of Baja California peninsula, a sampling was conducted simultaneously aboard boats of the commercial fleets of Ensenada BC and Bahia Magdalena BCS during winter 2007-2008. Gonad growth was followed using gonadosomatic (IGS) and relative gonadic (IGR) indices. Histological analysis of the ovaries showed that the reproductive season starts first in Bahia Magdalena and one month later in Ensenada. Spawn was monitored using active female and spawning frequencies. Spawning peak had a one month lag between BC and BCS. Spawn was sustained by young fish, and no significant differences in length were found between both sampling areas. Major atresia was found in the ovaries early in spawning season in both sampling areas. Spawning peak was reduced in February in BC and in March in BCS were spawning peak is normally high. Evidence suggests an interruption of spawning in females in BC and BCS. Major atresia was not a local process at least inside the area where the commercial fleet has influence along the west coast of Baja California.

Towards improved acoustic surveys of sardine in the California Current Ecosystem: a review of coastal pelagic species and equipment and methods currently used to assess their distributions and abundances

Juan P. Zwolinski*, George R. Cutter, David A. Demer

Southwest Fisheries Science Center, 8604 La Jolla Shores Drive La Jolla, CA 92037-1508
* Contact author: juan.zwolinski@noaa.gov

Keywords: Sampling design, habitat, species identification, bias, precision

After almost 40 years of low abundances, the stock of Pacific sardine (*Sardinops sagax*) off the northwestern coast of North America showed signs of recovery in the 1980s. The sardine reoccupied pre-collapse habitats between northern California and British Columbia and the fishery restarted. The sardine biomass peaked at over 1.7 million metric tons (t) in 2000 and post-collapse catches reached a maximum of 141,000 t in 2002. Since then, catches greater than 100,000 t have been maintained while the total sardine biomass has steadily decreased. To preclude another collapse of the Pacific sardine stock in the California Current Ecosystem (CCE), fishery management efforts must be supported by accurate stock assessments incorporating fishery-independent survey data. Management of sardine stocks in other areas of the world are successfully carried out using data from both the daily egg production method (DEPM) and acoustic-trawl surveys. The National Marine Fisheries Service pioneered the DEPM and has recently prioritized the application and refinement of the acoustic-trawl technique in the CCE. Preliminary estimates of sardine abundance from a coastwide acoustic survey in 2006 were consistent with those from corresponding stock assessments based on DEPM data. However, the acoustic surveys had high coefficients of variation (ca. 80%) due to sparse sampling of the entire west coast of the U.S., and potential biases due to uncertainties related to the identification of echoes from target species (SID) and target strength (TS) estimation. Summarized here is the current knowledge of sardine stocks worldwide, the various management efforts employed, and the state-of-the-art in protocols for effective acoustic-trawl surveys. This information provides the foundation for a suggested protocol for efficiently surveying Pacific sardine in the CCE. Emphasis is placed on the most advantageous timing and location of the limited sampling resources. Future efforts to refine this protocol should focus on the identification of essential oceanographic habitat for sardine in the CCE, and improvements to SID and TS estimation.

Biological & Economical Modeling

Modeling climate-to-fish-to-fishers interactions: progress, issues, and some solutions

Enrique N. Curchitser[1*], Kenneth A. Rose[2], Kate Hedstrom[3], Jerome Fiechter[4], Shin-ichi Ito[5], Bernard A. Megrey[6], and Salvador Lluch-Cota[7]

1. Institute of Marine and Coastal Sciences, Rutgers University. 71 Dudley Rd. New Brunswick, NJ 08901.U.S.A.
2. Department of Oceanography and Coastal Sciences. Louisiana State University. Baton Rouge LA 70803. U.S.A.
3. Arctic Region Supercomputing Center. 909 Koyukuk Dr Suite 105. Fairbanks AK 99775. U.S.A.
4. Ocean Sciences Department. University of California. Santa Cruz, CA 95064. U.S.A.
5. Tohoku National Fisheries Research Institute, Fisheries Research Agency. 3-27-5, Shinhamacho. Shiogama-city Miyagi 985-0001. Japan
6. Alaska Fishseries Science Center-NOAA. 7600 Sand Point Way NE. Seattle WA 98115. U.S.A.
7. CIBNOR. Mar Bermejo # 195 Col. Playa Palo de Santa Rita. La Paz B.C.S. 23090 México

* Contact author: enrique@marine.rutgers.edu

An ecosystem approach to understanding large-scale patterns in exploited systems caused by both climate change and human activity increasingly relies on the use of numerical models. In the past, physical, lower and higher trophic level models were developed, tested, and implemented independently of each other. Recently, the advances in physics and biology have created the needed pieces for a comprehensive (end-to-end) ecosystem model, including humans as a dynamical component. The challenge is to integrate all the components, and examples of fully-coupled end-to-end models are relatively rare. This is partly due to the perception that blending separate yet complex sub-models is impractical because of demanding computational requirements and partly due to the respective communities working independently. We present our progress to date on the development of an end-to-end model modeling framework within the widely-used ROMS (Regional Ocean Modeling System) circulation model. The NEMURO Nutrient-Phytoplankton-Zooplankton (NPZ) submodel provides the lower trophic level dynamics, and a multi-species individual-based submodel simulates fish population and community dynamics, including fishing fleets as one of the predator species. All of these models exist in various forms, but the individual sub-models have never been harmonized together into one integrated analysis tool useful for synthesis, integration, and prediction. This model framework was designed to investigate the effects of climate and fishing on marine ecosystems within one model that includes dynamical feedbacks among the different systems. We describe the conceptual and technical challenges involved in assembling and implementing such a model and we will present some early results of a test-bed (proof of principle) application developed to study the low-frequency fluctuations of sardine and anchovy.

Comparing the influence of oceanographic fronts on interannual changes in the distribution and relative abundance of sardine in the California and Southern Benguela Current systems

Rubén Rodríguez-Sánchez[1*], Carl van der Lingen[2], Marlene Manzano[3], Larry Hutchings[2] and Héctor Villalobos[1]

1. Centro Interdisciplinario de Ciencias Marinas (CICIMAR - I.P.N.) La Paz, B.C.S., México
2. Marine and Coastal Management (MCM), Cape Town, South Africa.
3. Centro de Investigaciones Biológicas del Noroeste (CIBNOR). La Paz, B.C.S., México.

* Contact author: rrodrig@ipn.mx

Marked changes in the distribution and relative abundance of sardine *Sardinops sagax* populations in the California and Southern Benguela Current systems have been reported, with these changes occurring over recent decades during periods of steadily increasing population size in both systems. Such distributional changes may be environmentally-mediated, and this paper assess whether mesoscale frontal activity could be a mechanism underlying latitudinal and longitudinal shifts in sardine distribution in the California and Southern Benguela Current systems, respectively. That the location and occurrence of oceanographic fronts may affect sardine distribution patterns is based on preliminary results from the California Current system (CCS), where the latitudinal distribution of monthly abundance indices of young California sardine seems to follow seasonal changes in advection, suggesting that recruitment is related to the location of the frontal zone where the California Current (CalC) and the inshore California Countercurrent (CcC) converge. Over the period 1980 to 1997 sardine in the CCS showed a progressive northward shift in the location of highest relative abundance, suggesting northward changes in the location of favorable conditions for young sardines along the frontal zone between Baja California and California. We proxied interannual variability along the frontal zone by developing monthly time-series of the frequency of SST fronts in different areas along the California–Baja California coast using the single-image, edge-detection method applied to monthly satellite data from the AVHRR Pathfinder v5, and the relationship between sardine abundance and SST front frequency indices suggests that recruitment increases where optimal front-frequency levels are found and declines where they are suboptimal. Interannual changes in the distribution of sardine along the frontal zone suggest a progressive, interannual increase in northward advection of the CcC following the 1976–1977 regime shift, whereas southward advection via the CalC weakened. We use a similar approach to assess whether the eastward shift in the distribution of Southern Benguela sardine was also environmentally mediated by examining frontal activity data from different areas of the Agulhas Bank, where seasonal and interannual variation in interactions between a major surface boundary current (the westward-flowing Agulhas Current) and an eastward-moving, coastal counter-current also occur.

Trophic role of sardine in the Gulf of California

Christian Salvadeo [1,*], Salvador Lluch-Cota [2], Pablo Del Monte-Luna [1] and Daniel Lluch-Belda [1]

1. Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional
2. Centro de Investigaciones Biológicas del Noroeste

* Contact author: chsalvadeo@yahoo.com.mx

Keywords: Trophic relation, small pelagic fish, top predators, Gulf of California

Sardine is considered a key throphic component in the upwelling-controlled ecosystems (i.e. wasp waist) where it occurs, particularly as the main food source for some important predators, including commercial fishes and emblematic birds and marine mammals. We reviewed this condition for the Gulf of California by gathering available information on the trophic spectra for those predators. We found that the sardine is an important component in the diet of striped marlin (*Tetrapturus audax*), several marine birds, small cetaceans like common dolphins (*Delphinus sp.*), medium size whales like Bryde's whale (*Balaenoptera edeni*) and California sea lions (*Zalophus californianus californianus*); however, for other like hammerhead sharks (*Sphirna zigaena*), dolphin fish (*Coryphaena hipporus*) and jumbo squid (*Dosidicus gigas*), sardines are a second component of their diet and for many others, predation is based on mesopelagic fish (mictophids) and medium size squids, not on sardine. We discuss observed and potential diet changes as related to climate variability.

Posters

Annual changes in abundance of the *Sardinops sagax* early stages in Bahía Magdalena

René Funes-Rodríguez[1,*], Alejandro Zárate-Villafranco[1], Alejandro Hinojosa-Medina[1] and Rubén Rodríguez-Sánchez[1]

1. CICIMAR-IPN. Av. IPN. s/n. Col. Playa Palo Sta. Rita. A. P. 592. La Paz, Baja California Sur., México CP. 23096.
*. Contact author: rfunes@ipn.mx

Keywords: Sardine, eggs and larvae, Magdalena, Mexican Pacific

Seasonal patterns in abundance of early stages of *Sardinops sagax* were analyzing in Bahía Magdalena for the periods 1982–89 and 1997–2009. In this area, reproductive activity of sardine occurs principally in a wide sea surface temperature (SST) interval (13 – 25.0 °C), with a maximum activity between 18 – 20 °C. Early stages occurs principally during winter season diminishing drastically in summer, limited by temperature at inlet waters, that usually is elevated (>25 °C). The occurrence of a well defined winter reproductive peak in Magdalena has been also reported using annual records of gonadosomatic index and histological data, with a secondary peak during summer, apparently related to cool conditions. Nevertheless, inter-annual variability of climatic and oceanographic conditions can change the importance of the early stages abundance winter peak, as well as, regional extension in the reproductive activity in time and space. Thus, during El Niño's years, early stages although scarce are present in Magdalena suggesting the local activity of some proportion of the sardine population, but during cool conditions, with the incorporation of the migratory population, spawning activity may become more important, inclusive into the Gulf of California, that is similar with this know for sardine reproductive activity in Magdalena, suggesting the hypothesis of connectivity. Preliminary results shown that sardine eggs and larvae abundances are statistically correlated with commercial catches in Magdalena and follow a similar variation during anomalous warm or cool years.

References

Torres-Villegas J. R., Ochoa-Báez R. I., Perezgómez-Álvarez L., García-Melgar G. 1995. Comparison of seasonal variability in the reproduction of Pacific Sardine (*Sardinops sagax*) from Baja California Sur, México, in the years 1982-1992. Sci. Mar. 59 (3-4): 255-264.

The effect of the sea tide cycles in the monterey sardine fishery in Bahía Magdalena

Carlos Robinson Mendoza[1]; Casimiro Quiñónez Velázquez[2]; Jaime Gómez Gutiérrez[2]

1. Instituto de Ciencias del Mar y Limnología, UNAM, Ciudad Universitaria, México D.F. CP 04500, México
2. Centro Interdisciplinario de Ciencias Marinas, Instituto Politécnico Nacional. Av. Instituto Politécnico Nacional s/n. La Paz, BCS CP 23096, México

Keywords: Bahía Magdalena, *Sardinops sagax*, hydroacoustic, CPUE, tidal front

The total catch, CPUE y number of fishing trips of the monterey sardine (*Sardinops caeruleus)* fishery during 2001-2005 in Bahía Magdalena BCS has a temporal variability significantly associated to the environmental conditions that occur during neap tides (< 1.2 m) and spring tides (> 1.8 m). During the neap tides were done a larger number of fishing trips obtaining the largest total catches in comparison with the spring tide periods. Using an hydroacoustic echosounder and continuous records of high resolution (<50 m) of 4-m depth temperature, oxygen dissolved concentration, and fluorescence recorded in July 2004 is possible to explain why in neap tides exists larger sardine availability for the fishery industry. The distribution and abundance of small pelagic fish detected with hydroacoustic techniques show that the period to find successive sardine schools is significantly larger during spring tides than during neap tides when sardine schools are widely distributed near the mouth of Bahía Magdalena. During spring tides exist frequent and pronounced environmental horizontal gradients (that indicate the presence of tidal fronts) under environmental conditions highly heterogeneous. High densities of phytoplankton and zooplankton were frequently observed associated to the tidal front region. During neap tides the horizontal surface gradients were considerably smaller in magnitude and less frequently detected (relatively homogeneous environmental conditions). The higher number of fishing trips and total catch obtained during neap tides likely is caused to the fact that the sardine distribution is highly disperse under environmental and feeding availability relatively homogeneous conditions (when the fishermen recognize and name this period like “la sardine is plana” or is flat). During spring tides the small pelagic fish tend to concentrate near the tidal front making relatively more difficult to locate the schools by the fishing, particularly during nighttime fishing. We demonstrated that the sardine behavior is highly associated with the environmental and feeding conditions as a function of the tidal phases that directly influence the availability and probability of encounter between fishing vessels and sardine schools.

A review of the population structure of Pacific sardine *Sardinops sagax* (Jenyns, 1842) based on morphometric and genetic analysis

Francisco J. García-Rodríguez[1*], Silvia A. García-Gasca[2], José De La Cruz-Agüero[1] and Víctor M. Cota-Gómez[1]

1. Centro Interdisciplinario de Ciencias Marinas- Instituto Politécnico Nacional (CICIMAR-IPN), Departamento de Pesquerías y Biología Marina. Av. Instituto Politécnico Nacional s/n, Col. Playa Palo de Santa Rita, 23096. La Paz, Baja California Sur, México.
2. Centro de Investigación en Alimentación y Desarrollo, A.C. Av. Sábalo-Cerritos s/n. Estero del Yugo. Apdo. Postal P 711. Mazatlán, Sinaloa, México

* Contact author: fjgarciar@ipn.mx

Keywords: Sardines, *Sardinops*, morphometric, genetic, Mexico

Several studies regarding the Pacific sardine *Sardinops sagax* (Jenyns, 1842) have been focused to identify the composition and boundaries of stocks. They have recently included the use of morphometric data and genetic analysis based on DNA information (De La Cruz-Agüero y García-Rodríguez, 2004; Félix.Uraga *et al*., 2005; Lacomte *et al*., 2004).

In this study, geometric morphometric based on body landmarks and molecular analysis using the Control Region of mtDNA were applied to review the population structure of sardines along the Pacific coast of the Baja California Peninsula. Samples from commercial fishing unloaded in Ensenada (ENS), Baja California State, and Bahía Magdalena (BM), Baja California Sur State, Mexico were obtained during 2006-07. A total of 275 sardines from ENS and 119 from BM were used in morphometric analysis and 53 sequences from ENS and 106 from BM were used for genetic comparisons.

Morphometric results showed differences between the groups suggesting the existence of different morphotypes. The percentage of molecular variance explained mainly by differences between groups was significantly different from zero. However, the distribution of haplotypes along the groups did not show a clear phylogeographic pattern. Additionally, mismatch distributions support relatively similar historical demographic events.

We found evidences of phenotypic groups existing in the Pacific coast of the Peninsula; however, current molecular data did not clearly support the existence of a genetically structured population.

References

De La Cruz-Agüero, J., y F.J. García-Rodríguez. 2004. Morphometric stock structure of the Pacific sardine *Sardinops sagax* (Jenyns, 1842) off Baja California, Mexico. *In*: Morphometrics: Applications in Biology and Paleontology, A. M. Elewa, ed. New York, NY. Springer-Verlag, pp. 115–124.

Félix-Uraga, R., V.M. Gómez-Muñoz, C. Quiñonez-Velázquez, F.N. Melo-Barrera, K.T. Hill y W. García-Franco. 2005. Pacific sardine (*Sardinops sagax*) stock discrimination off the West coast of Baja California and Southern California using otolith morphometry. *California Cooperative Oceanic Fisheries Investigations Reports*. 46: 113-121.

Lecomte, F., W.S. Grant, J.J. Dodson, R. Rodríguez-Sánchez y B. Bowen. 2004. Living with uncertainty: genetic imprints of climate shifts in East Pacific anchovy (*Engraulis mordax*) and sardine (*Sardinops sagax*). *Molecular Ecology*. 13: 2169-2182.

Age and growth of pacific sardine (*Sardinops caeruleus*) off the west coast of Baja California in 2007.

Y. A. Green-Ruiz.[1*], A. Cota-Villavicencio[2], M. Jacob-Cervantes[1], P. Santos-Molina[3], A. Verde-Hernàndez[1] R. Sánchez-Medina[2] y S.Rodríguez-Aguayo[4]

1. INAPESCA, CRIP- MAZATLÁN
2. INAPESCA CRIP- ENSENADA
3. INAPESCA CRIP- GUAYMAS
4. Estudiante 8° semestre licenciatura. Servicio Social FACIMAR-UAS

* motagreen@yahoo.com.mx

Keywords: Age, growth, Pacific sardine, Baja California.

One of the most important fisheries in the Northwest is that of small pelagic where Pacific sardine is a major component (84.3% in 2007). In order to increase knowledge of this species and have benchmarks of population behavior, useful as indicators in the management of the fishery, a study of age and growth was performed, based on the analysis of otoliths of Pacific sardine captured by the commercial fleet on the west coast of Baja California in 2007. Of 652, 29% were female, 57% males and 14% did not determine sex. As no significant difference between sexes, age-length data were analyzed as a population. The minimum size was 99 mm and maximum of 240 mm. Were determined 4 age groups 1, 2, 3 and 4; the dominant group was 2 with 33%, followed by groups 3 and 1. The von Bertalanffy growth parameters were: L_∞ = 208 mm standard length, k = 0.51/año and t_0 = -0.901 years. Two important outcomes of this research are the library of images of otoliths of sardine and updating the database INAPESCA of length and age composition of the sardine fishery of the west coast of Baja California, with direct application in the age-structured models to estimate the abundance of sardine in this area and the population projection matrix models.

Pacific sardine (Sardinops sagax) spawning fraction and batch fecundity data from 1986 to 2009: age, size, or temperature relationships.

Beverly J. Macewicz

Southwest Fisheries Science Center
National Marine Fisheries Service, NOAA
E-mail address: Bev.Macewicz@noaa.gov

Keywords: Batch fecundity, Spawning, Histology, Age

Ovarian histology provides critical information on mature sardines to analyze the adult female reproductive parameters (batch fecundity and spawning fraction) needed for spawning biomass estimation by the daily egg production method (DEPM):

Batch fecundity, the number of oocytes to be released during a spawning event. Estimation of batch fecundity is by the gravimetric method using whole oocyte preparations from females that have not begun releasing that batch. Hydrated oocytes can be counted with confidence because they provide the best visual identification (fluid uptake and yolk coalescence results in larger and translucent appearing oocytes). Histological preparation can identify the migrating nucleus and lipid droplet coalescence (Figure 1) earlier than can be seen visually in whole oocyte preparations (blocked by the dense yolk globules). The elongated granulosa cell in *S. sagax* follicles have provided an extra clue that can be seen in whole preparations. Hence, we can count MN oocytes and have increase the number of females we use for batch fecundity estimation.

Spawning fraction. Our sampling of *S. sagax* occurs during the night between 18:00 and 06:00. During these hours, we can determine 4 spawning events (nights) based on histological criteria (Figure 1 and 2): A) will spawn tomorrow night, advanced stage MN oocytes ; B) spawning the night of capture, hydrated oocytes and/or POF without deterioration or barely begun degeneration; C) spawned last night, POF aged about 18-30 hours old; and D) spawned 2 nights before capture, POF aged about 42-56 hrs old. The postovulatory follicle of *S. sagax* has large granulosa cells that degenerate over a longer time period. This fact with a thicker theca-connective cell layer has allowed better identification of older POFs (42-56 hrs after spawning). POFs > 66 hrs are less evident (number and size), may be confused with late stage β atresia, and are not used to estimate a spawning event.

Data from 1986 to 2009 on batch fecundity and the number of mature females spawning per night (spawning events A-D) is examined and preliminary results by size classes (Table 1, Figure 3), age (Table 2, Figure 4) and sea surface temperature is reported.

Can there be stable, cooperative exploitation of a transboundary fish stock under climate variability? The case of Pacific sardine in the California Current

Gaku Ishimura[1,2,*], Andrés M. Cisneros-Montemayor[1,], Sam Herrick[3] and U. Rashid Sumaila[1]**

1. Fisheries Centre, University of British Columbia, Vancouver, Canada.
2. Center for Sustainability Science, Hokkaido University, Hokkaido, Japan.
3. NOAA Southwest Fisheries Science Center, La Jolla, USA.

* Contact author: gakugaku@sgp.hokudai.ac.jp
** Contact author: a.cisneros@fisheries.ubc.ca

Keywords: Climate fluctuation, game theory, cooperative exploitation.

Climate variability significantly affects food and habitat availability and quality for fish and other marine organisms. The abundance of fishery resources or their migration and distribution patterns along their range can vary as a result. These changes in local availability and distribution are critical for the management of transboundary fish stocks which are shared exclusively by multiple countries (Munro, 2004). The UN Law of the Sea places a duty on such countries to cooperatively manage their shared resources. However, it does not impose requirements for these countries to reach cooperative agreements, or penalties for deviating from previous agreements. It thus becomes vital to reach stand-alone stability of cooperative exploitation, where no country has an incentive to deviate from a once-reached agreement.

In the case of the California Current Ecosystem (CCE) sardine stock, we have analyzed this issue using a game-theoretic approach. The abundance and distribution of this stock is known to fluctuate according to ocean climate variability in the CCE (Chavez *et al.*, 2003). During warm temperature regimes, the stock is distributed from southern British Columbia (Canada), along the Pacific coast of the United States, and all the way to the Baja California Peninsula (Mexico). During cold regimes however, the resource is not only less abundant, but is concentrated in southern California (USA) and northern Baja California (Rodriguez-Sanchez *et al.*, 2002). A model was developed to calculate the biomass distribution and population dynamics of the CCE sardine stock given different ocean temperatures. This was then linked with a multi-player bio-economic model to analyze the economic performance of the three countries given these biological scenarios and different possible cooperation schemes. Special attention was placed on identifying stable and unstable cooperation strategies.

References

Chavez, F.P., Ryan, J., Lluch-Cota, S.E. and M. Ñiquen C. (2003). From anchovies to sardines and back: Multidecadal change in the Pacific Ocean. *Science*, 299: 217–221.

Rodriguez-Sanchez, R., Lluch-Belda, D., Villalobos, H. and S. Ortega-Garcia. (2002). Dynamic geography of small pelagic fish populations in the California Current System on the regime time scale (1931-1997). *Can. J. Fish. Aquat. Sci.*, 59: 1980–1988.

Munro, G. (2004). *Game theory and the development of resource management policy: The case of international fisheries. The 6th Meeting on Game Theory and Practice. Zaragoza, Spain 10-12 July,* http://www.iamz.ciheam.org/GTP2006/FinalpapersGTP2006/58final.pdf

Regional Reports

Magdalena Bay Pacific sardine fishery, 2008-2009

Félix-Uraga, R.[1], F. N. Melo-Barrera[1] & C. Quiñonez-Velázquez[1]

1. Centro Interdisciplinario de Ciencias Marinas-IPN, Departamento de Pesquerías y Biología Marina. La Paz, Baja California Sur. Becarios COFAA y EDI.

* Contact author: rfelix@ipn.mx

During 2008, 627 fishing trips were carried out and 48,710 t of small pelagic fishes were caught in Bay Magdalena, Mexico. Pacific sardine *Sardinops sagax*, catch was 36,338 t and represented 74.5% of total catch. Others species were *Opisthonema* sp (14.2%), *Cetengraulis mysticetus* (6.9%), *Etrumeus teres* (0.8%) and *Scomber japonicus* (1.5%). Pacific sardine was caught along the year, although 75% of catch of this specie was landed from May to September and 58% of fishing trips were carried out at same time. Size of Pacific sardine ranged between 140-210 mm of standard length (SL). Practically all the sardines landed (99.8%) were above the minimum legal size (150 mm SL). Six age groups (0 to 5) were found, although groups one and two were the most abundant (55% and 35%, respectively). From January to August 2009, 36,000 t of small pelagic fishes has been caught by 399 fishing trips. Pacific sardine catch was 34,170 t and represented 94.9%. From the other species, *C. mysticetus* was 3.6% of total landed. Sizes of *S. sagax* ranged between 125-200 mm SL and ages haven't still been determined. Sardines larger than minimum legal size represented 55% of the total catches until date above mentioned.

Assessment of the Pacific sardine resource in 2009 for U.S. management in 2010: Executive Summary

Kevin T. Hill[1], Nancy C. H. Lo[1], Beverly J. Macewicz[1], Paul R. Crone[1], and Roberto Felix-Uraga[2]

1. NOAA National Marine Fisheries Service, Southwest Fisheries Science Center, 8604 La Jolla Shores Drive, La Jolla, California,
USA 92037
2. CICIMAR-IPN. Ave. IPN s/n A.P. 592, Col. Playa Palo Sta. Rita C.P. 230096, La Paz, Baja California Sur, México

The Pacific sardine northern subpopulation is assessed each year in support of the Pacific Fishery Management Council (PFMC) process that, in part, establishes an annual harvest guideline ('HG', or 'ABC') for the U.S. fishery. The latest assessment was conducted using the 'Stock Synthesis 3' (SS3) model, and includes fishery and survey data from updated and new sources. The draft assessment was reviewed by a Stock Assessment Review Panel 21-25 September, 2009, and the revised assessment will be presented to the PFMC in early November 2009. The outcome of these reviews may form the basis for U.S. Pacific sardine management in 2010.

Data and assessment

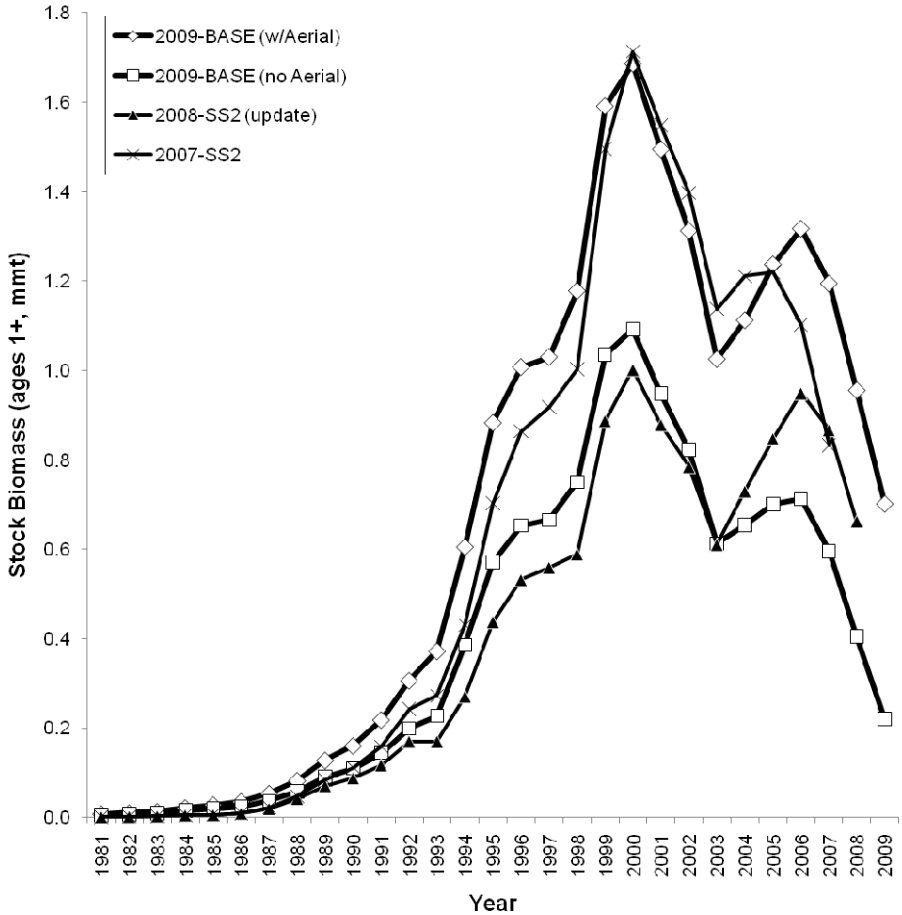
The assessment was conducted using 'Stock Synthesis' version 3.03a (Methot 2009). Fishery data include catch and biological samples for four fisheries off Ensenada, Southern California, Central California, and the Pacific Northwest. Two indices of relative abundance are included in the final base model: Daily Egg Production Method and Total Egg Production estimates of spawning stock biomass (1986-2009), both based on annual surveys conducted off California. Finally, the tuned base model was run with the addition of the 2009 aerial survey estimate of absolute abundance (q=1) to derive population quantities for 2010 management.

The final base model had the following specifications:

- Model Year based on the July 1 birth date assumption (July 1-June 30 time span);
- Assessment years 1981-2009; Two semesters per year (S1=Jul-Dec; S2=Jan-Jun);
- Four fisheries (ENS, SCA, CCA, PNW), with annual selectivity patterns for ENS and PNW and seasonal selectivity patterns for SCA and CCA (S1 & S2).
- Use of length-frequency and conditional age-at-length data for all fisheries;
- Length-based, double-normal selectivity with time-blocking:
    - ENS, SCA_S1, & SCA_S2: 1981-91, 1992-98, 1999-09;
    - CCA_S1 & CCA_S2: 1981-92, 1993-98, 1999-09;
    - PNW: 1981-03, 2004-09;
- M = 0.4yr^{-1} for all ages and years;
- Two periods for growth estimation: 1981-90 and 1991-09;
- Ricker stock-recruitment relationship; σ_R = 0.89; Steepness estimated;
- Initial recruitment (R_1) estimated; recruitment devs estimated from 1975 to 2007;
- Hybrid continuous-F fishing mortality option;

Stock biomass and recruitment

Stock biomass, used for management purposes, is defined as the sum of the biomass for sardine ages 1 and older. Stock biomass increased rapidly through the 1980s and 1990s, starting at 8,210 mt in 1981 and peaking at 1.69 mmt in 2000. Stock biomass has subsequently declined to the present (July 1, 2009) level of 702,024 mt. Biomass from the base model is compared to final values from SS2 assessments used for management in 2008 and 2009 (Figure 1). Stock biomass and recruitment from the 2009 base model (w/Aerial) was very similar to results from the final 2007 assessment. Both the 2009-Base and final 2007 models scaled higher than the 2008 update and the 2009 base model that excluded the aerial survey:



Recruitment was modeled using the Ricker stock-recruitment relationship. The estimate of steepness was high (h=2.32). Virgin recruitment (R_0) was estimated at 4.94 billion age-0 fish for the base model. Recruitment increased rapidly through the mid-1990s, peaking at 16.79 billion fish in 1997, 22.01 billion in 1998, and 18.62 billion fish in 2003. Recruitments have been notably lower since 2005. Recruitments for 2008 and 2009 were derived from the spawner-recruit curve.

Exploitation status

Exploitation rate is defined as calendar year catch divided by total mid-year biomass (July-1, ages 0+). Exploitation rate was relatively high during the early recovery period (mid-1980s), but declined and stabilized as the stock underwent the most rapid phase of recovery. Exploitation rate has subsequently increased in recent years as the stock has again declined. Ensenada catch during 2009 is unknown (unavailable), so is assumed the same as 2008. Total exploitation rate is currently less than 16%:

Calendar Year	ENS	SCA	CCA	PNW	Total
2000	4.0%	2.7%	0.7%	0.9%	8.3%
2001	2.9%	3.0%	0.5%	1.6%	8.0%
2002	3.6%	3.7%	1.1%	2.9%	11.3%
2003	3.5%	2.5%	0.6%	3.2%	9.8%
2004	3.5%	2.7%	1.3%	4.1%	11.5%
2005	4.2%	2.3%	0.6%	4.2%	11.2%
2006	4.3%	2.5%	1.3%	3.1%	11.1%

2007	3.0%	3.8%	2.8%	3.9%	13.6%
2008	5.6%	3.2%	2.7%	4.1%	15.6%
2009	7.1%	1.8%	3.5%	3.4%	15.8%

Recommendation for U.S. management in 2010

The U.S. HG (or ABC) is based on the control rule defined in the CPS-FMP:

$$HG_{2010} = (BIOMASS_{2009} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2010} is the total U.S. (California, Oregon, and Washington) harvest guideline in 2010, $BIOMASS_{2009}$ is the estimated July 1, 2009 stock biomass (ages 1+) from the assessment (702,024 mt), CUTOFF is the lowest level of estimated biomass at which harvest is allowed (150,000 mt), FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries (see below), and DISTRIBUTION (87%) is the average portion of BIOMASS assumed in U.S. waters. Based on the current (T_{2009}) SST estimate of 17.92 °C, the F_{msy} exploitation fraction should remain at 15%. Based on results from the base model, the harvest guideline for the U.S. fishery in calendar year 2010 would be 72,039 mt. U.S. ABCs for previous years follow:

Calendar Year	U.S. ABC	U.S. Landings
2000	186,791	67,985
2001	134,737	75,733
2002	118,442	96,876
2003	110,908	69,931
2004	122,747	92,723
2005	136,179	90,016
2006	118,937	91,039
2007	152,564	127,789
2008	89,093	87,184
2009	66,932	65,652

[i] Lluch-Belda, D., R.J.M. Crawford, T. Kawasaki, A.D. MacCall, R.H. Parrish, R.A. Schwartzlose and P.E. Smith (1989). World-wide fluctuations of sardine and anchovy stocks: The regime problem. S. Afr. J. Mar. Sci. **8**: 195-205

[ii] Alheit, J., C. Roy and S.Kifani. 2009. Decadal-scale variability in populations. In D. Chekley, J. Alheit, Y. Oozeki and C. Roy (eds) Climate Change and Small Pelagic Fish. Cambridge U. Press.

[iii] Lluch-Belda, D., S. Hernández-Vázquez and R.A. Schwartzlose (1991). A hypothetical model for the fluctuations of the California sardine population. Long-term Variability of Pelagic Fish Populations and their Environment. T. Kawasaki et. al, Pergamon Press**:** 293-300.

APPENDIX IV

Workshop on the role of Pacific sardine in the California Current System

(November 19-20 2009; Multimedia Room, CICIMAR)

Co-convenors: Sandy McFarlane and Jake Schweigert (DFO)

Workshop objectives:

The return or increase of large numbers of Pacific sardine (Sardinops sagax) to waters off Mexico, California, Oregon, Washington and Canada since the middle to late 1980s, has stimulated great interest in understanding the factors which influence both the numeric and geographic elements of sardine populations.

Sardines respond to changes in their prey resources in a variety of ways and over a range of levels of ecological organization, from the individual to the population. Understanding these responses is important for gauging the usefulness of sardines as indicators of ecosystem change and determining their role in the ecosystem. In addition, ecosystem management strategies require an understanding of the inter-specific relationships between small pelagics and key predators in the regulation of marine ecosystems.

As a first step toward understanding the role of sardines in the ecosystem and exploring mechanisms underlying the expansion and contraction of sardine population(s) in the CCS, we will bring together scientists associated with the Tri-national Sardine Forum in a workshop format to identify a process for moving towards our ultimate goal of ecosystem model development. The overarching goal of this proposed work is to develop a tropho-dynamic model which will enable us to predict future changes in abundance and distribution of sardine in the California Current System (CCS). As a first step in understanding the role of sardines in the system and exploring mechanisms underlying the expansion and contraction of sardine population(s) in the CCS we will bring together scientists associated with the Tri-national Sardine Forum in a workshop format to identify a process for moving towards our ultimate goal of model development.

Since many of the workshop participants have access to and are collecting relevant data to develop a tropho-dynamic model we expect this workshop will begin the process of data collection and synthesis of diet and predation information (what they eat and who eats them) both spatially and temporally. We expect that the participants will come prepared to identify relevant data bases available for each area (where they reside, contacts, etc.) as well as data gaps/needs; discuss formatting requirements; and timelines for completing data compilation and development of a coastwide diet and predation data base. In addition, we will outline future steps (workshops) required to move towards final model development.

Workshop agenda

Thursday, November 18th (Multimedia Room, CICIMAR)

Workshop on the role of Pacific sardine in the California Current system

Co-convenors: Sandy McFarlane and Jake Schweigert

9:00-9:15 Introductions

9:15-10:00 Workshop Objectives

Sandy McFarlane: Role of Pacific Sardine overview

10:00-10:30 Review of available sardine datasets by region.

Linnea Flostrand: Canadian data presentation

Presenter to be announced: Washington
Oregon
California
Mexico

Participants from each region to present an overview of available data similar to what was outlined in the example spreadsheets. Data such as:

Data Type: diet, predation or other biological data
Data Formats: review formats of existing databases
Data Source: commercial fishery, research surveys, etc.
Does the data encompass a time series or just a snapshot?

10:30-11:00 Coffee

11:00-12:00 Continuation of dataset reviews by region.

12:00-13:30 Lunch

13:30-13:45 Jake Schweigert: Overview of potential models

13:45-14:00 Francisco Arreguin-Sanchez: presentation

14:00-15:00 Determine which data to capture and agree on data formats

15:30 Coffee

15:30-17:00 Discussion

Friday, November 19th (Multimedia Room, CICIMAR)

9:00-10:00 Outline data gaps and needs

Establish a data acquisition process and confirm data formatting

10:00-10:30	Coffee
10:30-12:00	Identify custodian of the database Discuss deadlines. Confirm process for data acquisition Discuss future work including workshops Workshop 1. Building a conceptual model. Workshop 2. Ecosystem model development.
12:00	Adjourn