MINUTES OF THE 2005 TRINATIONAL SARDINE FORUM

Ensenada, Baja California, México
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2005 Trinational Sardine Forum participants at the Centro Social, Cívico y Cultural Riviera, Boulevard Lázaro Cárdenas, Ensenada, México.

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INTRODUCTION

The 6th Trinational Sardine Forum (TSF) was held in Ensenada, Baja California, México, on November 14-15, 2005. The meeting took place at the Salón Casino, Centro Social, Cívico y Cultural Riviera (Riviera Social, Civic and Cultural Center) and at the Hotel Cortez, and was attended by 83 participants representing the fishing industry, scientists, governments, and academia from Canada, México, and the United States (Appendix I). Special thanks go to those individuals who helped with the local logistics, particularly Sharon Herzka, Orlando Amoroso, and Lic. Martín Gutiérrez. We also thank Quim.César Mancillas Amador, Municipal President of Ensenada, Dr. Federico Graef Ziehl, Director of the Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Dr. Axayáctl Rocha, Head of CICESE's Department of Biological Oceanography, Dr. Tim Baumgartner of CICESE and IAI-EPCOR, and Mr. Orlando Amoroso, SPPSOA, who provided the financial aid to make this Forum possible.

The Forum was inaugurated by City Council Member Ing. Nélida Pelayo Ponce, Coordinator of the Local Fisheries Commission. Two special guests made statements, including Dr. Federico Graef Zielh, Director, CICESE, and Dr. William W. Fox, Jr., Director, Southwest Fisheries Science Center, National Marine Fisheries Service. All speakers expressed the importance of understanding the oceanography, ecology, and biology of Pacific sardines and the impact of their extraction on sardine populations and industry. Each touted the benefits of the Forum as a venue for sharing academic experience, fostering international cooperation, identifying research priorities and exchanging ideas. In particular, Dr. Fox mentioned a newly established observing program: the Pacific Coast Ocean Observing System (PaCOOS), which extends the CalCOFI model and may involve Canada, México and the United States. The PaCOOS observing system will be built over the next decade (www.pacoos.org) and will target the California Current Large Marine Ecosystem. Its goal is to "provide the information needed for management of fishery resources, protected marine mammals, marine birds, and turtles, and to forecast the ecosystem consequences of fisheries removals, environmental variability and climate change". In addition, he mentioned that the upcoming 2006 coast-wide survey will provide an important data gathering opportunity.

Dr. John Hunter of Scripps Institution of Oceanography gave a brief history of the Forum and outlined the objectives at its inception. The main research goals of the first Forum in November 2000 were to: (1) improve knowledge of age structure and determine age-specific reproductive effort; (2) monitor shifts in maturity; (3) conduct coast-wide biomass surveys and add regional surveys to fill in knowledge gaps; and (4) identify movements (stock structure). In the last five years, substantial progress has been made in all these areas, except for age-specific reproductive effort (Hunter and Baumgartner 2001, 2002; Hunter and Pleschner-Steele 2003).

Some of the accomplishments highlighted by Dr. Hunter include fulfilling the central mission of the TSF: to hold regular informal meetings with participants from the three countries, provide a platform for sharing research results and planning collaborations, present regional views of the fishery, and construct an integrated vision of the status of the Pacific sardine throughout its the geographic range. The Forum has also promoted the use of both traditional and new methodologies to examine Pacific sardine stock structure. In addition, since the first meeting, the goal of conducting a coast-wide inventory of the stock has been continually reiterated. It has not been possible to survey the entire range concurrently, and thus each country has worked with its own regional data. However, in April 2006 a coast-wide survey will be conducted that will hopefully establish a precedent and be repeated annually.

Dr. Hunter also emphasized the importance of defining the role of the Pacific sardine in the ecosystem, including the consequences of its variability in population size and geographic range. He suggested conducting workshops on specific topics such as the ageing workshop held previously, and organizing a formal fishery commission with representatives from the three nations.

The opening statements and historical overview of the TSF were followed by the two sessions: "Regional Sardine Fisheries Reports" and "Research Plans and Reports." Most of the scientific papers presented were oriented toward documenting patterns in the regional fisheries and understanding the reproductive capability, stock structure and migratory patterns of the Pacific sardine using various techniques. Posters were also on display around the meeting hall for the duration of the Forum. This year, there were two new features. The first was a session on "Contributed Papers," and the second a new working group on "Industry Trends and Issues," which was introduced by Orlando Amoroso and Martín Gutiérrez (Asociación de Armadores de Pelágicos Menores de Ensenada) toward the end of the first day.

In the evening, special guest Mr. Felipe Charat, of Maricultura del Norte, provided an overview of the company's tuna farming operating procedures. Of particular interest was the reliance of tuna farming on fresh sardines, which are fed to the tuna to obtain the high-quality product demanded by the Japanese market.

The second day of the meeting began with a presentation by Dr. Roger Hewitt, Director of the Fisheries Resources Division at the Southwest Fisheries Science Center. He discussed the focus issue of the Forum, a coast-wide survey to be held in April 2006 from Baja California to British Columbia. The survey is essential to obtain a clear picture of the overall biomass and reproduction patterns of the Pacific sardine along the west coast of North America, and to pave the road for future collaborations among the three countries. Participants were asked to provide recommendations on logistics and procedures for the survey to their working groups. After the focus issue presentation, the working group break-out sessions took place, followed by the plenary session in which working group results were presented. Finally, the Forum drew to an end with the promise of reconvening in the fall of 2007.

The executive committee of the Trinational Sardine Forum represents all three countries: Nancy Lo (United States), Sharon Herzka (México), Robert Emmett (United States), and Jake Schweigert (Canada). The committee members take turn organizing and hosting the meeting. Next year's Forum will be held in Vancouver, Canada and will be hosted by Jake Schweigert and Bob Emmett.

PLENARY SESSION HIGHLIGHTS

Regional Sardine Fisheries Reports

México

Gulf of California

(Manuel Nevárez-Martínez, CRIP-Guaymas and Enrique Morales Bojorquez, CRIP-La Paz)

The Gulf of California has a large fishing industry and the catch of small pelagics is monitored monthly. Peak fishing occurs in winter and spring. The time series of landings show that the Pacific sardine catch mirrors the variability in total landings of small pelagics. In recent years, there has been a decrease in the availability of sardine that matches a decrease in the total landings of small pelagics in the Gulf. There are two competing hypotheses to explain the decline in catch: over-fishing and a change in the environment. The decline has been associated with a pattern of average temperature and abnormal winds. The winds have been weaker and less persistent, particularly between October and February. Strong winds during these months are important for generating upwelling along the coast of Sonora.

Bahía Magdalena

(Casimiro Quiñónez-Velázquez, CICIMAR)

The number of fishing trips for Pacific sardine out of Bahía Magdalena has declined in the last three years, from 991 in 2003, 858 in 2004, to 604 in 2005. During this time, 139,200 metric tons (mt) was landed, of which 83% was Pacific sardine (*Sardinops sagax*), 12% was thread herring (*Opisthonema spp.*), 2% anchoveta (*Cetengraulis mysticetus*), 2% round herring (*Etrumeus teres*), and 0.4% Pacific mackerel (*Scomber japonicus*).

The Pacific sardine was captured throughout the year, except for January 2004. From 2003-2005 interannual differences in CPUE were observed. The months of highest catch were April-October (>4,000 mt/month) in 2003, July-November (>3,000 mt/month) in 2004, and March-July (>4,000 mt/month) for 2005. The 2004 season was unusual in that few Pacific sardines were caught before July and those caught later in the summer were small. A variation in the overall sex ratio and in the proportion of adults with mature gonads was also observed. In 2004, there were more fish with mature gonads in the early months, and none were found to be mature in the later months.

In 2003 and 2005, the standard length (SL) of Pacific sardines caught increased throughout the summer. In 2004, however, a very different length and age distribution was observed. From February-May, age-1 fish were predominant. In June, two modes of

SL were identified with a break point at 150 mm SL, and age-2 fish were the most common. During the second half of the year 100% of the fish caught were <150 mm SL, and age-0 fish were dominant. This unusual size and age distribution was observed until April 2005, after which the lengths and ages followed a pattern similar to that documented in 2003.

The large abundance of age-0 fish in 2004 is an indication that they are from the Baja California stock. These results are presented in CalCOFI Reports volumes 45 and 46.

Ensenada – No presentation, but please see the abstract in Appendix III by Celia Eva Cotero.

United States

California
(Kelly O'Reilly, CDFG)

<u>2004 Fishing Season</u>

The fishing season for Pacific sardine off California takes place throughout the year, and the harvest guideline is based on the previous year's stock biomass estimate. There are two fishing sub-areas: the northern sub-area extends from 39ºN latitude up to the Canadian border. The southern sub-area is from 39ºN down to the Mexican border, which spans approximately the coast of California. The 2003 biomass estimate for northern Baja California and U.S. waters was 999,871 mt. Thus, the 2004 U.S. harvest guideline was set at 122,747 mt, split between the two sub-areas. The northern sub-area was allotted 40,916 mt and the southern sub-area 81,831 mt. This allocation scheme (one third in the northern area, two thirds in the southern area) was applied for the first 8 months of the year. After September 1, the unharvested portion was pooled and reallocated so that 20% was available to the north and 80% to the south. On December 1st, the total remaining unharvested catch was open to the entire coast. By the end of the year, 81% of the harvest guideline was landed.

<u>California commercial landings from 1994-2004:</u>

California landings have varied between 13,000 mt in 1994 to 58,000 mt in 2002. In 2004 the total landings were over 44,000 mt. During the same period, the market squid (*Loligo opalescens*) landings were much more variable than that of the Pacific sardine. Market squid are more valuable, and when they are available they are preferentially targeted by fishermen. In the last few years, the Pacific sardine landings have been much higher than those of either northern anchovy (*Engraulis mordax*) or Pacific mackerel (*Scomber japonicus*). These landing statistics do not include estimates of bait barge catches, so landings are somewhat underestimated. Because bait barge boats do not have to submit landings receipts, there is no way to monitor them at this time.

A breakdown of the catch by gear type is as follows: 99% of Pacific sardines caught were landed by round haul gear. Of this, 69% was landed by purse seine and 30% by drum seine. In 2004, 53% of the total catch was landed in Los Angeles, 35% in Monterey and 11% in Ventura. All other areas comprised less than 1% of the landings.

2005 Fishing Season

In 2004, the Pacific sardine biomass estimate was 1,090,587 mt, and the U.S. harvest guideline for 2005 was set at 136,179 mt. As in 2004, one third was allocated to the northern sub-area, and two-thirds to the southern sub-area. From January to July 2005, 96% of the landings occurred in Los Angeles, 3% in Ventura, 0.8% in Monterey, and 0.1% in San Diego.

On September 1, the uncaught harvest allocation was pooled (85,000 mt) and reallocated, with 20% assigned to the northern sub-area and 80% to the southern sub-area. On December 1, the remaining allocation will be available coast-wide.

The harvest allocation rules for 2006 have changed. The FMP was amended with the goal of making the allocation distribution more equitable. Beginning January 1, 2006, 35% of the harvest guideline (118,937 mt) will be allocated coast-wide. On July 1, 2006, 40% of the harvest guideline plus any un-harvested portion from the initial allocation will be allocated coast-wide. Then, on September 15, 25% of the harvest guideline and any un-harvested portion from the previous allotment will be allocated coast-wide.

This is a very different scheme than those used in the past, but it should allow for more equitable distribution of the allocation. In 2004, 19% of the allocation was not harvested. If the quota from the previous year is not reached and the allowable quota for the following year is reduced, then this may indicate that factors other than fishing are reducing the biomass.

Northwest

(Jean McCrae, ODFW, and Michele Culver, WDFW)

Through mid-October of 2005, over 45,119 mt have been landed in Oregon and 6,892 mt in Washington. The September-through-November allocation for the northern sub-area was reached in mid-October and the northern fishery closed until December 1. This year, the first landings occurred in April, although the fishery did not start in earnest until mid-June, which has been the typical starting time in past years. As in the past, August was the peak harvest month and September the second highest.

In 2005, the main catch area was much farther north than in past years, during which the majority (59% - 75%) of the harvest activity occurred off Oregon, with the remainder occurring off Washington as far north as the mouth of Willapa Bay. This year, based on logbook data through mid-September, almost 2/3 of the harvest came from Washington. Vessels went as far north as the Canadian border to find larger-sized fish. In general, Pacific sardines were much smaller this year than they have been in the past. Larger fish began showing up toward the end of the season.

The Washington fishery continues to be managed under its "experimental" fishery designation; 16 permits were issued in 2005. The Oregon fishery is managed under the Developmental Fishery program; 20 permits were issued in 2005. The Oregon Fish and Wildlife Commission will consider in December whether to move the Oregon fishery out of Developmental Fisheries and into a limited entry system.

The websites for tracking each state's landings are as follows:
Oregon: www.dfw.state.or.us/mrp/finfish/cps.asp;
Washington: wdfw.wa.gov/fish/commercial/sardines/index.htm

Canada

British Columbia
(Christa Hrabok, DFO)

Pacific sardines supported a large fishery in Canada from 1917-1947, until the stock collapsed. In May 2002, sardines were de-listed by the Committee on the Status of Endangered Wildlife in Canada as a species of special concern. Historically, Pacific sardines have been distributed as far north as southeast Alaska, but have more recently been caught off Vancouver Island. This year the sardines moved away from Vancouver to the north coast area.

In 2005 the Department of Fisheries and Oceans Canada (DFO) is finishing the third year of a three-year sardine fishery management plan, and a total of 50 licenses were issued: 25 commercial and 25 communal commercial licenses. The total allowable catch (TAC) was set at 17,903 mt. The season is from July 10, 2005 through February 9, 2006. Consultations were held with First Nations to increase their participation levels. Participants in the fishery are required to fund a monitoring program, and to share the costs of stock assessment and managing the fishery through a joint agreement with DFO for $100,000.

<u>Fisheries activities</u>:
Of the 50 licenses available, 13 of the 25 commercial licenses were fished, and 5 of the 25 communal commercial licenses were fished. The catch for the season thus far is 3,200 mt. The largest total catch was in 2004, at 4,258.8 mt.

The majority of the fish were caught in the southern part of the northern-most area during September, and next biggest catch was in August. The west coast of Vancouver Island is usually the most successful fishing area, but this year large fishes were difficult to find, so there was more exploratory fishing and as a result many new fishing areas were discovered. Still, the total catch is much lower than 2004. Bycatch is usually less than 1% of the total catch rate. This year bycatch diversity increased, but was mostly dogfish and herring.

Length Frequencies July – October:

Small fish of 100 g were caught in all months. The largest fish this year were caught in Area 12 (Queen Charlotte Strait, northeast of Vancouver Island). In both 2003 and 2004 there was a large amount of big fish. However, in 2005 nearly of all the catch was comprised of small fish. The smaller fish were caught everywhere, but particularly inshore, and the larger fish, when found, were only offshore.

Industry Perspective:

Less than half the fishermen fished this year. The market was strong for big fish, but they were very hard to find. The industry's biggest concerns are: 1) the catch of small, 100 g fish, which seem to be 2-3 years old although they haven't been aged yet; and 2) the need to identify locations of spawning.

2006 Fishery Management Planning

There is a need to develop a new, integrated Fishery Management Plan that includes information on access to licenses, First Nation participation, use of the fish, scientific surveys, and a monitoring program.

Ongoing and future research by DFO includes: (1) industry surveys to assess abundance and distribution of fish; (2) age methodology studies; (3) diet studies; (4) trawl surveys for biomass estimates; (5) fat content monitoring (an industry concern); and (6) modeling studies to examine decadal-scale fluctuations.

Introduction to Working Group 3: Industry Trends and Issues

Mr. Orlando Amoroso announced the formation of a new working group focusing on fishing industry trends and issues in the evening of the first day. Mr. Felipe Charat, president of Maricultura del Norte, the invited speaker, then described the operation of his Pacific bluefin tuna (*Thunnus thynnus*) ranches and the role that Pacific sardine play in the industry.

The tuna are captured at sea via purse seine, and then transferred through open doors in the seine into a tow pen net. This net is 50 m in depth, with weights on the bottom to prevent a cone shape during towing. The net is towed at 1 knot per hour back to the pens at the mariculture facility. This can take up to three weeks, however towing at a greater speed causes stress to the fish. Observers check the condition of the fish everyday, and remove any dead fish to prevent attracting predators. The observers also estimate the weight of the fish they are towing. The density of fish per kilogram that can be maintained in each holding pen at the ranch is used to calculate the number of fish to transfer into each pen.

Once the fish are inside the pens, they are fed fresh sardines twice a day, six days a week. Maricultura del Norte is one of the few companies in the world to use only fresh sardine. They maintain strict standards to ensure the best possible tuna products.

To harvest the tuna, workers lift by hand each fish out of the water by the gills. It is killed quickly and humanely, and in such a way as to maintain the highest quality of meat by maintaining blood temperature and minimizing lactic acid. The amount of time from when a fish is lifted from the water to being auctioned off in Japan can be as little as 70 hours.

Tuna ranches in Ensenada produce approximately 500,000 t of bluefin tuna annually. To achieve this volume they consume sardine equal to the yearly catch of 2.5 sardine boat loads, and thus are not monopolizing the Ensenada sardine catch. The industry right now employs 1,000 people directly, and about 2,500 indirectly, and its annual revenue is approximately 80 million dollars U.S. One advantage that the Mexican tuna ranching industry has over other countries, such as Australia and those in the Mediterranean is the availability of fresh sardine at a low cost.

Mr. Charat praised the exchange of scientific information provided by the Forum, however cautioned the participants to remember that scientific knowledge can also be potentially harmful when used emotionally to obtain specific objectives.

Focus Issue: 2006 Coast-Wide Synoptic Survey
(Roger Hewitt, Southwest Fisheries Science Center)

The need for a coast-wide survey spanning the entire range of Pacific sardine was identified during the first Trinational Sardine Forum and it has been reiterated at each succeeding TSF. This synoptic survey is planned for April-May 2006, spanning from Baja California to British Columbia.

The objectives of the survey are to: 1) describe the spatial distribution of eggs, larvae, and adults; 2) obtain measurements of instantaneous egg production and adult fecundity required for estimating spawning biomass; 3) collect environmental data that may be useful for describing spawning habitat, and 4) collect specimens for use in genetics and microchemistry, and for the evaluation of size at maturity, age, and fecundity.

The survey will include regularly spaced stations along a series of inshore/offshore transects based on an extended CalCOFI pattern. The pattern is set up for two ships to run for 30 days each. The R/V *David Starr Jordan* will travel from San Diego, California north to Cape Mendocino from April 1-30. The R/V *Oscar Dyson* will depart near Cape Flattery and sail south towards Cape Mendocino from April 7 through May 9.

Primary station observations will include pelagic trawls of adult fish, plankton net samples of fish eggs, fish larvae and zooplankton, and vertical profiles of temperature, salinity, oxygen and chlorophyll. Transect observations will include continuous egg pump samples, continuous multi-frequency acoustic surveys of adults and possibly juvenile fish, and continuous measurements of sea surface and meteorological conditions.

In addition, the R/V *El Puma* and the R/V *Altair* of México have been secured by Instituto Nacional de la Pesca (INP) for 20+ days to cover the area off Baja California.

Nine people will be required on each ship to conduct basic measurements, not including acoustic technicians and marine mammal and seabird observers. David Griffith of Southwest Fisheries Science Center is the survey coordinator, and will be the main point of contact throughout the cruise (david.griffith@noaa.gov). He will shortly release a cruise announcement that will include dates, port calls, personnel lists, and a description of operations. Soon thereafter he will provide a cruise manual with detailed protocols on operations.

Dr. Hewitt acknowledged that these are very ambitious cruises which the Southwest Fisheries Science Center cannot complete alone. His team is looking for collaboration, particularly because a CalCOFI cruise will be running concurrently and three ships will need to be staffed.

Recommendations for the coast-wide survey

Plenary Session:

1. Call for proposals for ancillary projects to the coast-wide survey.
2. Calibration between the R/V *David Starr Jordan* and R/V *El Puma* for CUFES samples are needed. The R/V *El Puma* does not have CUFES installed and needs to get one on loan from SWFSC.
3. Trawl samples and acoustics information are two other data sources for the Pacific sardine biomass estimates. All trawls will be taken at pre-determined stations at night regardless of the appearance of eggs to ensure unbiased estimates of biomass. A protocol for the acoustics is being worked out by David Demer with multiple frequencies to sample the upper 10 m when the sea is calm.
4. Questions were raised regarding the optimal layout of transect lines north of Cape Mendocino. The CalCOFI pattern is to be followed due to its simplicity. Ideally, this coast-wide survey will be conducted annually, however a July survey is also desirable. In the future, an airborne LIDAR may be added to the survey to complement side-scan sonar by detecting schools in the upper 30 m.

Working Group 1: Regional Biomass:

CANADA

1. Month of the year

Canadian researchers' participation requires the application for ship time a minimum one year in advance. In order for Canada to participate in a survey in April 2007 the application for ship time should be submitted in November, 2005. Canadian vessels can collect trawl and bongo samples, but do not have CalVET and CUFES. NMFS would need to provide both nets. Canada would be able to participate in a July 2007 survey, for 7-10 days of ship time, although this ship time would be a part of their regular survey.

2. Acoustic sonar and trawl surveys

Inter-calibration among the sonar systems and among trawl samples is necessary. During a 2005 survey off Canada, sonar was used to obtain estimates of relative abundance. As to the compatibility among multiple vessels, it is necessary to inter-calibrate the sonar for the different instruments, multi-beam, single beam, and the algorithm used. However, the compatibility may be constrained by the transducers that are already on each vessel. For trawl surveys, differences may exist in towing speeds and area covered by the trawl due to the area of the net opening. It is necessary to standardize the towing speed even if the same net-tow is used.

3. Sample and data processing

The funding for sorting and data processing of ichthyoplankton samples would have to come from an agreement with industry, for instance with Don Pepper. If Canada gets the funding, the work has to be performed by contracted personnel, as there is no expertise at the Department of Fisheries and Oceans. Sub-sampling is recommended to save money and time. The funding situation is also similar for México; the funding will have to come from the industry and a small amount may be provided by the Mexican government.

MÉXICO

For the coast-wide survey, INP is likely to obtain ship time for the R/V *El Puma,* which belongs to the Universidad Nacional Autónoma de México (UNAM). The R/V *El Puma* will be used to do the trawling and ichthyoplankton sampling. Yanira Green Ruiz of INP, Mazatlan, will be responsible for processing egg and larval samples, including staging eggs and sorting larvae. Eva Cotero of CRIP-Ensenada will process the adult samples and estimate reproductive parameters. Carlos Robinson from the Fisheries Ecology Laboratory, UNAM is doing an acoustic survey this month, but is using an Isaac-Kidd net. The R/V *Francisco de Ulloa* is the vessel used for routine IMECOCAL surveys in January, April, July and October to collect data from CUFES and physical oceanography.

UNITED STATES

If funding is an issue, the coast-wide survey could be conducted every 2-3 years, as was initially recommended during the first Trinational Sardine Forum.

1. Sample and data processing

For the 2006 April cruise, we need to have a time table in place for processing the specimens and to build up the data files necessary for analyses. At the very least, the ichthyoplankton samples and trawl samples from Central California should be ready by June or July, and the adult samples need to be processed by July-August. An estimate of spawning biomass needs to be finished by the end of August in order to be used as an input in the September stock assessment. In addition to samples needed for biomass estimates, aging of adults from all areas needs to be completed to assess the population age distribution by area. It is recommended that Pablo Santos Angeles from CRIP-Guaymas or Casimiro Quiñónez-Velázquez from the Centro Interdisciplinario de Ciencias Marinas (CICIMAR) read the otoliths from Mexican waters. Moreover, samples of other species along the west coast, particularly small pelagics need also to be sorted, identified, and the information incorporated into a database.

2. Future July coast-wide survey

The biennial Pacific hake survey, conducted by the Northwest Fisheries Science Center (NWFSC) in July, can be considered as a platform to collect Pacific sardine trawls at night after finishing with the Pacific hake work (Lo et al. 2005). One of the original ideas of the Trinational Sardine Forum was to involve industry, and for the industry to provide ship time in kind. As an example, in this working group, it was recommended last year that Canada would survey the inlets, and that Canadian industry would provide the ships and money to do the survey. This was accomplished in 2005.

Working Group 2: Stock Structure, Age Structure and Adult Sampling:

1. Maintain good records of oceanography throughout the survey because oceanographic conditions dictate otolith microchemistry and accurate oceanographic

data facilitate the otolith analysis.

2. Data to delineate the spawning grounds for Pacific sardine are needed to increase the resolution of genetic analyses, as there is likely to be mixing on the feeding grounds. The synoptic survey may not detect the ripple effect of warming water temperature on spawning, for it is believed that the Gulf of California population spawns in November-December, the Magdalena Bay population in February, Ensenada in March, and San Pedro in April. These are not necessarily separate stocks.
3. It is important to know the location and habitat of small Pacific sardines and the year classes to which they belong, so as to try to provide forecasts for fishermen.
4. Two very important issues are which specimens to save for subsequent analyses and how to handle the data management. Samples preserved in ethanol are useful for many things, but not for otolith microchemistry or reproductive histology. Prior to the coast-wide survey, a plan on what samples are to be collected and how they will be handled must be developed. The storage and analysis of such a large number of specimens will likely require additional funding.

Tim Baumgartner commented that planning for their portion of the coast-wide survey is underway, and that México will have 20 days of ship time. The point of contact for cruise information will be Enrique Morales Bojorquez. They don't yet know the area they will cover, but are pleased to be involved. Baumgartner also raised a concern about inter-calibrating the egg pumps. He suggests that people who work frequently with the egg pumps should work together to calibrate the CUFES aboard the R/V *Francisco de Ulloa* and the R/V *David Starr Jordan*. So far, they have been unable to successfully employ the overboard method aboard the R/V *Francisco de Ulloa*.

WORKING GROUP REPORTS

Working Group 1- Regional Estimates of Biomass of 2004 and Recommendations

CalCOFI AND IMECOCAL, April cruises, 2005

Objectives: To estimate spawning biomass of Pacific sardine from Baja California, México to San Francisco, CA, U.S.

Activities:

<u>CalCOFI, April cruises, 2005</u>

The 2005 CalCOFI survey was extended north to CalCOFI line 60.0 (San Francisco) in winter and spring. The R/V *New Horizon* cruise (April 15 - May 1) occupied the six regular CalCOFI lines (93.3 - 76.6) and the R/V *David Starr Jordan* cruise (March 28 - April 26) occupied 12 additional lines (83.3- 60.0). Therefore, the total number of lines occupied by both vessels was 18, with each line spaced 20 or 40 nm apart (Figure 1). Bongo samples were taken only at regular CalCOFI survey stations aboard both the R/V *New Horizon* in the south and the R/V *David Starr Jordan* in the north (Figure 2). On the southern 6 lines CalVET tows were taken only at regular CalCOFI survey stations. On the additional 12 lines CalVET tows were taken at 4 nm intervals on each line after the egg density from each of two consecutive CUFES samples exceeded 1 egg/min. Similarly, CalVET tows were stopped after the egg density from each of two consecutive CUFES samples was less than 1 egg/min. The threshold of 1 egg/min was reduced from the number used in years prior to 2002 (2 eggs/min) to increase the area identified as the high density area and, subsequently, to increase the number of CalVET samples. This adaptive allocation sampling was similar to the 1997 survey (Lo et al. 2001). For adult samples, the trawl survey was conducted aboard the R/V *David Starr Jordan* from March 28 to April 26 during the April CalCOFI survey (Figure 1). Adult Pacific sardines were dispersed or in small schools. We conducted trawling near the surface (0-6 fathoms depth) at night in potential adult Pacific sardine areas as identified by the presence of Pacific sardine eggs in CUFES collections. In total, 19 trawls were taken, of which 14 were positive for Pacific sardine. Among 251 female Pacific sardines randomly selected for histological analysis of maturity and spawning, 76 were immature and 175 were mature.

The daily egg production of Pacific sardine off California from San Diego to San Francisco was estimated to be 1.916/0.05m^2 (CV = 0.416). The spawning biomass was estimated to be 621,266.08 metric tons (mt, CV = 0.54) for an area of 253,620 km^2, using the daily specific fecundity (number of eggs/population weight g/day) of 15.64. For the years prior to 2002, the daily specific fecundity used was 23.55. In 2002, 22.94 was used, and in 2004, 21.86. In 2005, trawl samples were taken in both high and low density areas to ensure the accuracy of estimates of adult reproductive parameters (Figure 1). The area (253,620 km^2) is smaller than those in previous years: 2004 (320,620 km^2) and 2003 (365,906 km^2). Estimates of the female Pacific sardine reproductive parameters were (EPM program of Chen et al. 2003): *F*, mean batch fecundity, 55,710.71 eggs/batch

(CV = 0.04); S, spawning fraction, 0.131 per day (CV = 0.17); and W_f, mean female fish weight, 166.99 grams (CV = 0.02). The average interval between spawning (or spawning frequency) was about 8 days (inverse of spawning fraction or 1/0.131), and the daily specific fecundity was 21.86 eggs/gm/day. The estimates of spawning biomass of Pacific sardine in 1994 - 2005 are 127,000 mt, 80,000 mt, 83,000 mt, 410,000 mt, 314,000 mt, 282,000 mt, 1.06 million mt, 791,000 mt, 206,000 mt, 485,000 mt, 300,000 mt, and 600,000 mt respectively. Therefore, the estimates of spawning biomass have been fluctuating and increasing since 1994.

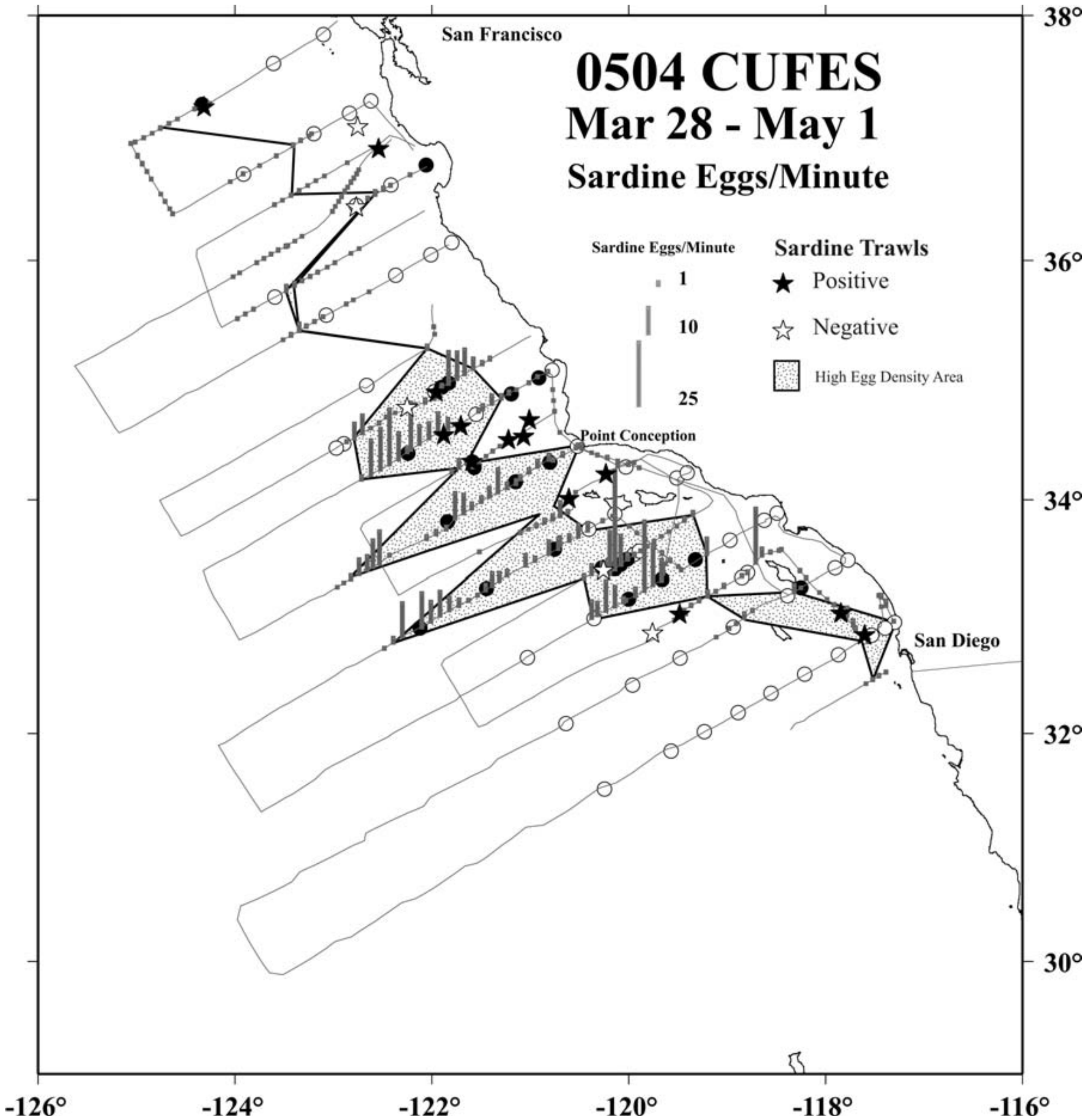


Figure 1. Pacific sardine eggs from CalVET (or Pairovet; solid circle denotes positive catch and open circle denotes zero catch) and from CUFES (stick denotes positive collection) and positive trawl samples (stars) in March-May 2005 survey. Region 1 is stippled area.

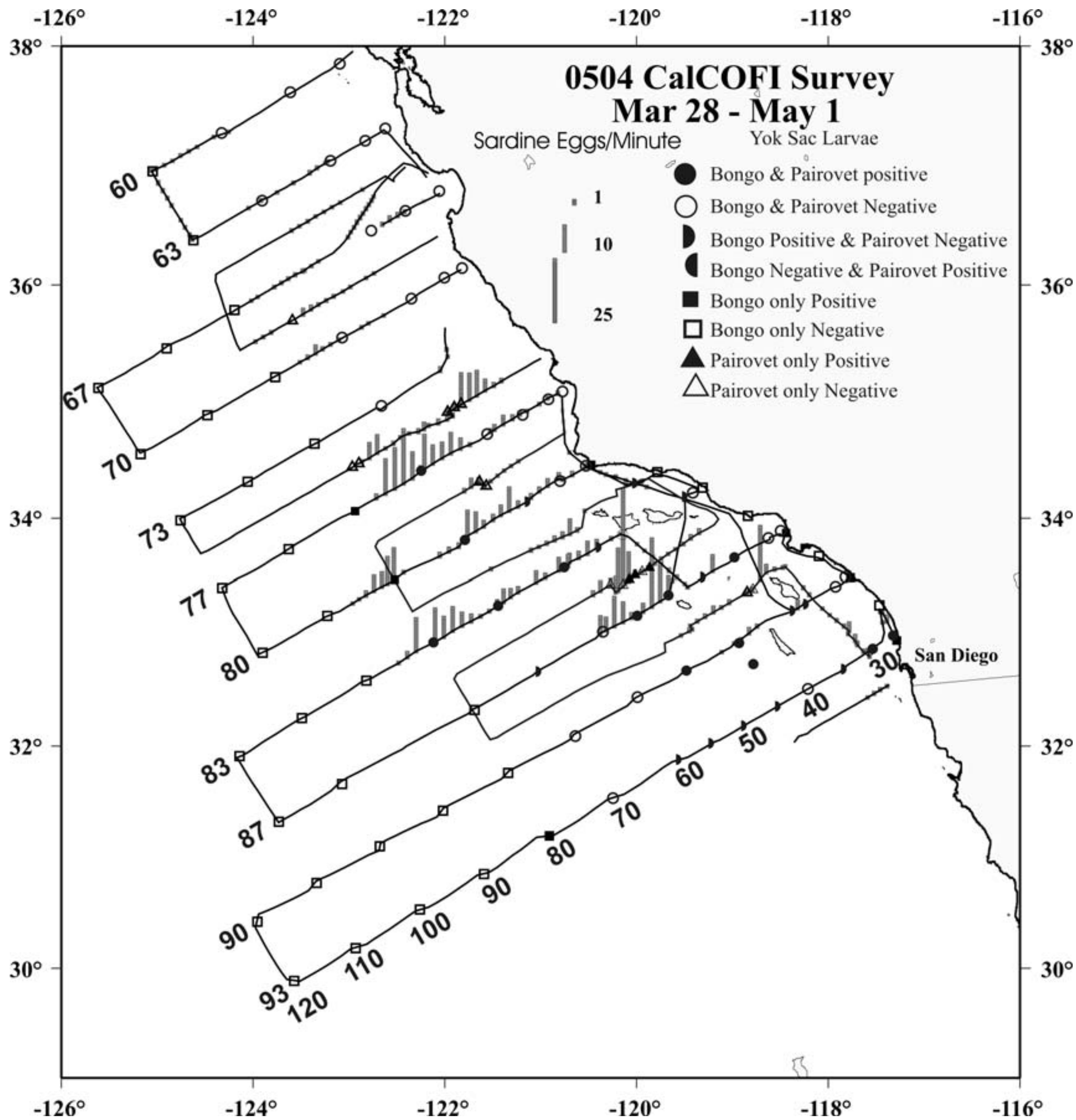


Figure 2. Pacific sardine yolk-sac larvae from CalVET (or Pairovet; circle and triangle) and from Bongo (circle and square) in April 2005 survey. Solid symbols are positive and open symbols are zero catch. The numbers on line 93 are station numbers.

<u>Northwest winter (February, March) trawl and acoustic surveys</u>

Twenty of forty-nine trawl samples were positive for Pacific sardine. No July cruise was conducted in 2005 (see abstract of Macewicz for more details).

<u>Aerial Surveys</u>

Beginning in March 2004, a statistically designed aerial survey was conducted off Central California. In addition to the fixed grid that the pilots fly over, they are also allowed to search over schools freely, in a similar manner to the flying pattern used during their routine operation to search for schools for commercial boats. The data from this survey will be used to obtain fishery-independent estimates of recruits, which will be compared with the estimates of recruits made during routine spotter pilot surveys. As of now, three pilots have conducted seven surveys (Figure 3). The initial analyses indicated that the estimate of tonnage/block was 236 and 76 for 2003 and 2004, respectively, based on the strip-transect method (Buckland et al. 1993) and 31 and 6.28 based on the generalized linear model.

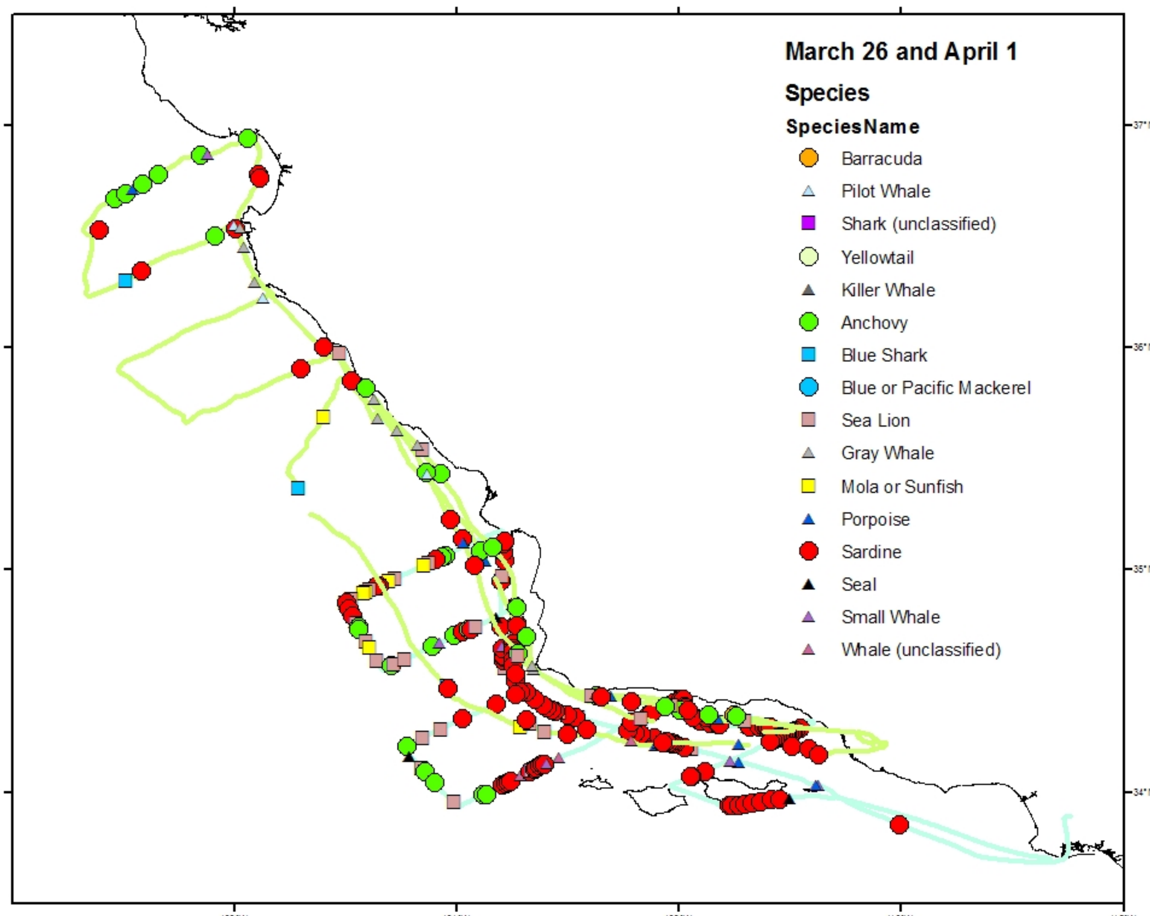


Figure 3. Sightings of different fish and marine mammals from one aerial survey in March and April, 2005.

<u>IMECOCAL</u>
Abstract by Tim Baumgartner (See Appendix IV for full text)

The Daily Egg Production Method (DEPM) was used to estimate spawning biomasses of the Pacific sardine off northern and central Baja California with data collected from IMECOCAL cruises during April, 2002, and April, 2003. The DEPM analyses were restricted to the area of spawning stock that is a southern extension of the stock found off Alta California (U.S.A.) so that comparisons can be reasonably drawn between biological parameters of the two regions. Ichthyoplankton data used in this study were obtained from egg densities collected by the CUFES (Continuous Underway Fish Egg Sampler) system and CalVET net tows from the R/V *Francisco de Ulloa*. The adult parameters were estimated from biological sampling of the landings made from the area around Ensenada. The estimate of spawning biomass off Baja California for 2002 is significantly higher than that for 2003, and is associated with correspondingly higher egg production and larger spawning area of the targeted stock. Our mid-range estimates of the spawning biomasses are approximately 48,000 ± 30,500 metric tons for April, 2002 and 9,200 ± 5,900 metric tons for April, 2003.

One of the goals of this study has been to identify the uncertainties in the DEPM that result from the current practices in the ichthyoplankton collection and analyses from the IMECOCAL cruises, and from the limitations in collection of the adult reproductive parameters. Based on the analyses in this study we strongly recommend that the IMECOCAL surveys integrate a procedure of adaptive sampling with CalVET net tows based on the occurrence of Pacific sardine eggs in the CUFES samples. It is also imperative that steps be taken to ensure annual adult samples from the offshore areas to provide more realistic estimates of the adult reproductive parameters.

NWFSC Biomass Surveys off Northern Oregon and Southern Washington

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

Activities:

Egg surveys

Egg surveys were conducted from only 1994-1998.

Adult surveys

Since 2001, no offshore survey has been conducted to capture adults in June because locations and timing of spawning were unknown. Effort was concentrated on the following three nearshore trawling surveys off Oregon and Washington:

1. BPA Columbia River plume study - daytime surface trawl from northern Washington to Newport, Oregon in May, June, and September.
2. Predator/baitfish study off the Columbia River - night surface trawl surveys off the Columbia River every 10 days from late April through early August.
3. Lower Columbia River purse seine survey - every 2 weeks from April through September.

In past years a monthly purse seine study in the Columbia River estuary documented use of the estuary by sub-yearling and yearling Pacific sardines (item 3). Vessel problems caused this project to be canceled in 2004. This project was not carried out in 2005 (see below).

This section reports the preliminary estimates of biomass of Pacific sardine based on July samples from night surface survey trawls during a predator/baitfish study off the Columbia River from Willapa Bay, Washington, down to Tillamook Head, Oregon, in 1999-2004 (Figure 4). The survey area was approximately 20,000 km^2, from above Gray's Harbor to Cape Falcon and out 35 nm. Night surface trawls were conducted every 10 days from late April through July. During each survey, 12 surface trawls were conducted: 6 on 2 lines (Willapa Bay and the Columbia) at 6 distances from shore, 0-10, 10-20, 20-30, 30-40, 40-50, and 50-60 km, which constitute six strata. A 264 rope trawl with a mouth opening of 360 m^2 was used. The net sampled down to 20 meters depth. Total volume within the survey area was calculated using the depth of the net fished times the survey area, for a total of 4 x 10^{11} m^3.

Pacific sardine population estimates in the Columbia River region were calculated using the same method as in previous years (volume swept methodology). Sardines captured during the Predator/Forage Fish Survey are usually most abundant in July. As such, only July information is used to make population estimates. We usually have three 2-day surface trawl surveys off the Columbia River in July. However, in 2005 only two surveys were conducted because of poor weather conditions in mid-July. For each cruise the mean number/m^3 was calculated using the number captured divided by the volume swept. Total density in the study area was calculated by multiplying mean Pacific sardine/m^3 by the volume (4 x 10^{11} m^3) of the study area. Average weight of sardines captured was calculated from mean length. In July 2005, unlike 2004, only one size class was evident.

The Pacific sardine biomass estimates for 2005 ranged from 29,996 metric tons (mt) in early July to 20,054 mt in late July (Table 1). These estimates are much less than the late July estimates in 2004 (96,247 mt). However, wide fluctuations in population estimates can be expected because Pacific sardines have very patchy distributions, and show large movements both within and outside the study area.

The length/frequency data (Figure 5) indicate an abundance of small Pacific sardines. Average length in July 2005 was much smaller than previous years (Table 1). Many of these were probably one-year-olds in 2005. Large numbers of 0-age sardines were captured in fall 2004 off the Oregon/Washington coast. These 0-age Pacific sardine appeared to have over-wintered in Oregon/Washington coastal waters during winter 2004-2005. There were no indications that older Pacific sardines were over-wintering off Oregon. Many 0-age Pacific sardines were captured in September 2005 off Oregon (BPA survey; Figure 6). We suspect that these sardines will over-winter in Oregon/Washington coastal waters.

Large Pacific sardine (>220 mm FL) were only found in May, June, and September and were not very abundant. We suspect that many larger sardines may have migrated farther north, out of our study area, in 2005.

The ocean was again very warm in spring 2005 (Figure 7). Warm ocean conditions in May/June appear to be conducive for successful spawning and recruitment of Pacific sardine off the Oregon/Washington coast. Spring surface temperatures in 2004 and 2005 were warmer than temperatures in 1998, an El Niño year.

These data indicate that Pacific sardines successfully spawned off Oregon May/June 2005. New recruits from this year's spawning will probably add significant biomass to the Pacific sardine population in the California Current.

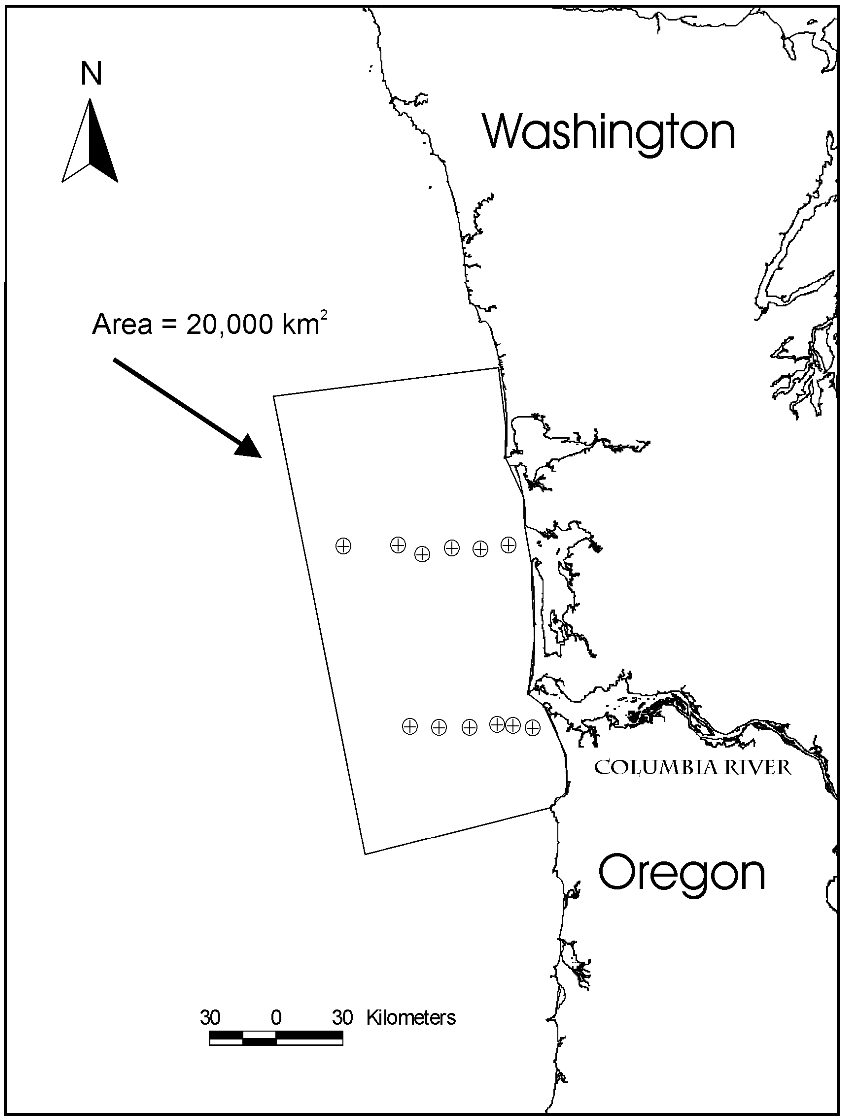


Figure 4. Location of the 12 surface trawls sampled at night approximately every 10 days from late April through early August, 1999-2004.

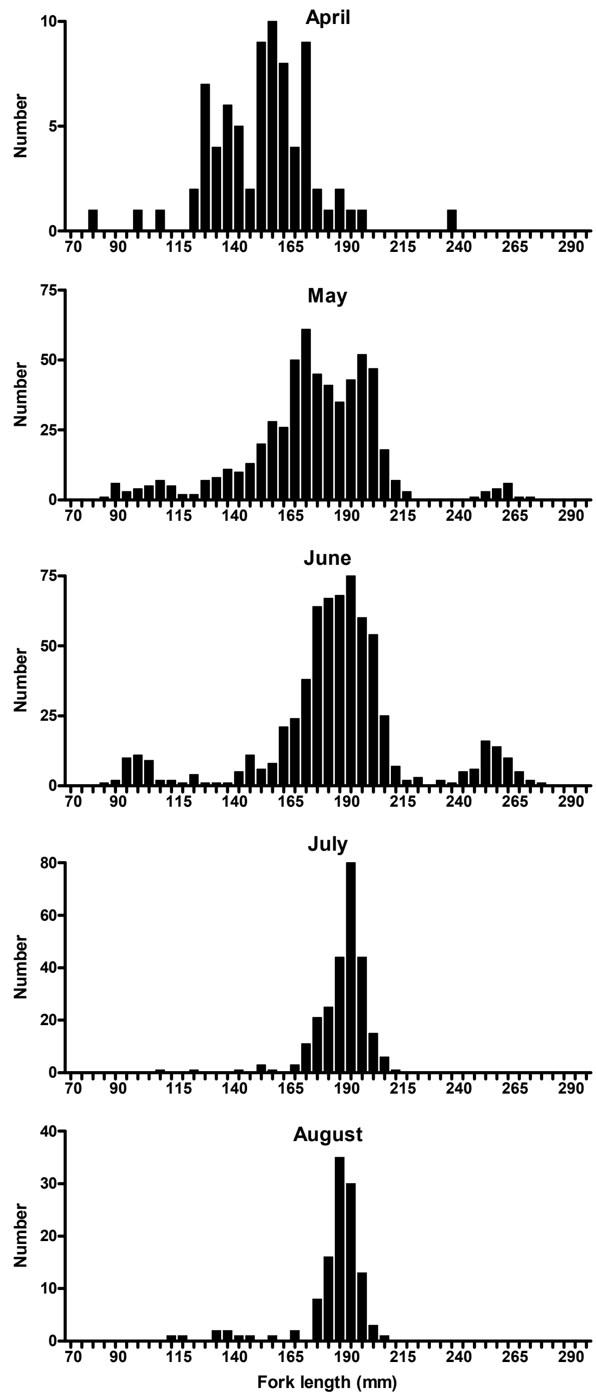


Figure 5. Length frequency of Pacific sardine captured off the Columbia River in 2005.

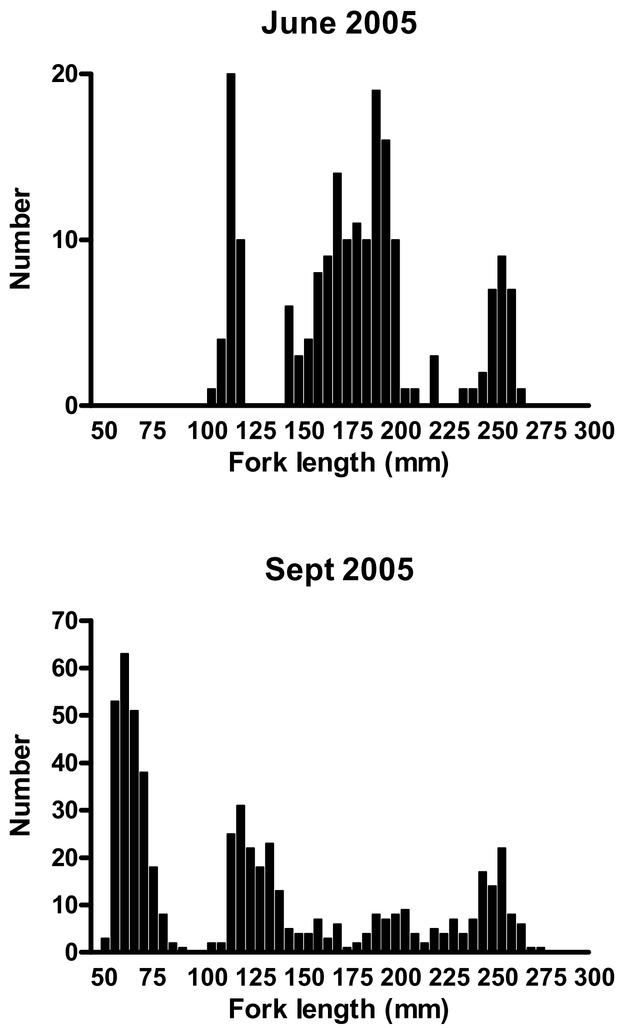


Figure 6. Length frequency of Pacific sardine captured off Oregon/Washington.

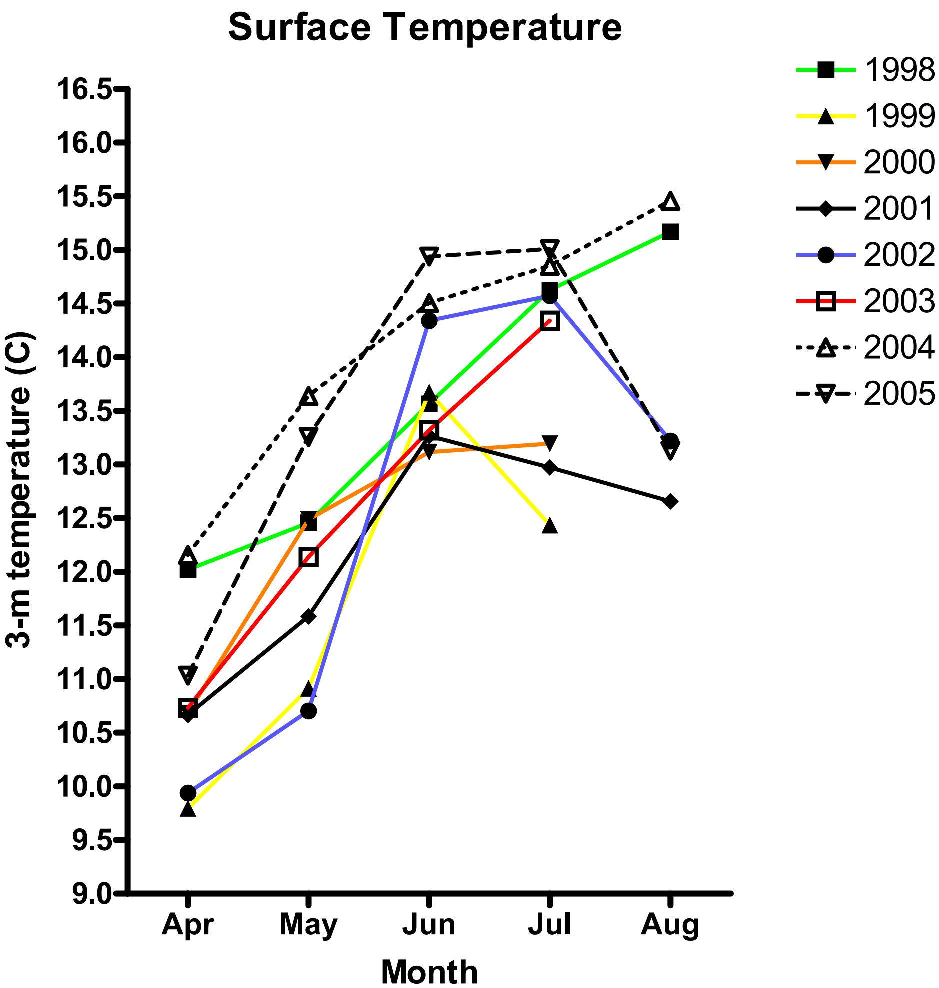


Figure 7. Average monthly surface temperatures (3 m depth) off the Columbia River.

Table 1. Statistics on Pacific sardine captured off the Columbia River region since 1999.

Number of Pacific sardine off S Washington/N Oregon

Year	Early July	Mid July	Late July/Early August
1999	16,738,383	10,282,076	667,488,503
2000	644,545,899	766,670,243	no trawls after 22 July 2000
2001	35,637,249	162,221,196	235,583,259
2002	544,696,457	48,770,214	non taken
2003	26,997,079	2,177,182,868	193,544,001
2004	30,713,861	208,021,190	454,430,085
2005	**410,664,790**	**No Trawls**	**271,509,680**

Average fork length (mm) 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**

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**

Biomass of Pacific sardine off S Wash/N Oregon (metric tons)

Year	Early July	Mid July	Late July/Early August
1999	2,585	1,471	91,200
2000	90,129	114,467	
2001	4,740	23,612	34,904
2002	85,229	7,607	
2003	4,448	542,448	27,049
2004	7,118	14,561	96,247
2005	**29,996**	**No Trawls**	**20,054**

Canadian Trawl surveys

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

Activities:

Surveys of Pacific Sardine Abundance in B.C. Waters during 2005

Four independent research surveys were planned between August 4 and October 5, 2005 to assess the relative abundance of Pacific sardine in British Columbia waters, including the annual trawl survey conducted by Fisheries and Oceans Canada (DFO), and three surveys conducted with vessels chartered from the sardine fleet using commercial purse seine vessels.

The annual DFO trawl research cruise was not conducted (given in Figure 8 for reference) as the ship, R/V *W.E. Ricker,* was under repair. Instead, a comparative day/night trawl survey aboard the commercial vessel *Frosti* was conducted on the west coast of Vancouver Island (WCVI). Set track lines were surveyed offshore of Nootka and Barkley Sounds (Figure 9). The track lines were trawled during the day and night off Nootka Sound first and then at Barkley Sound. The trawls were repeated to complete another day/night series off Nootka Sound followed by a daytime series off Barkley Sound. The final night time survey could not be completed.

In total, 53 sets were made over a 9 day period: 8 day and 14 night sets off Barkley Sound; 16 day and 15 night sets off Nootka Sound. Initial findings indicate that Pacific sardine schools tend to aggregate in the daytime with catches being fewer, but larger. At night Pacific sardine appear to disperse with many smaller schools being encountered (Figures 9 & 10).

A total of 6,180 fish were sampled. Fish were weighed to the nearest gram and measured for fork lengths to the nearest millimeter. Fish were also sampled for sex and maturity with otoliths and stomachs extracted for future laboratory analysis. Weights ranged from 60 to 280 grams with the largest fish caught at Nootka Sound. Fork lengths ranged from 95 to 300 mm with the largest fish being caught at Nootka Sound (Table 2). Length frequencies for both Nootka and Barkley Sounds are shown in Figure 11.

Ages ranged from one to seven years old in both the Nootka and Barkley areas (Figure 12). Females tended to be older in the Nootka area while there was a pretty even mix of ages and sex in the Barkley Sound area. There was a large contingent of age two fish in both areas, with it being more predominant in the Nootka Sound area.

In general, jack mackerel (*Trachurus symmetricus)* and Pacific herring (*Clupea pallasi)* were the predominant bycatch species in sardine trawl catches. Salmon species, particularly chinook salmon *(Oncorhynchus tshawytscha)*, but also coho salmon *(Oncorhynchus kisutch)*, pink salmon (*Oncorhynchus gorbuscha)*, sockeye salmon (*Oncorhynchus nerka)* and chum salmon (*Oncorhynchus keta)* were commonly caught. Other species captured along with Pacific sardine included: ocean sunfish, (*Mola mola),* blue shark (*Prionace glauca),* soupfin shark (*Galeorhinus zyopterus),* Pacific hake (*Merluccius productus),* euphausiids (Euphausiacea), jellyfish (*Scyphozoa* spp*.),* yellowtail rockfish (*Sebastes flavidus),* and spiny dogfish (*Squalus acanthias).* Bycatch estimates are presented in Table 3.

Pacific sardine spawn off the coast of California and then make an annual migration north to the coast of British Columbia in summer to feed. The extent of the migration into Canadian waters varies annually but on average appears to be about 10 percent of the total coast-wide population. Understanding the factors that affect the timing and degree of migration into British Columbia would provide the sardine industry with more consistent harvesting opportunities and market stability. An annual scientific survey to estimate the biomass of Pacific sardine in British Columbia could also help to better estimate the migration rate. Unfortunately, the hydro-acoustic technology required for such a survey is not currently available in the sardine fleet. As a result, a one-year feasibility study was proposed to develop guidelines for conducting future hydro-acoustic surveys to assess Pacific sardine biomass in the Canadian zone using scientific acoustic equipment.

The surveys were conducted utilizing standard sonar and sounding equipment and plotters to capture the size and location of surveyed Pacific sardine schools. When a school was encountered, the vessel sounder and sonar attempted to assess the dimensions of the school and to estimate relative fish density. The survey vessels made seine sets to collect biological samples in inshore and offshore areas as fish availability permitted.

The three industry-sponsored Pacific sardine surveys, WCVI Inlets, Northern Index Sites, and WCVI Offshore Encounter/Response Survey, were conducted between August 4 and October 5, 2005 (Figure 13). The surveys are described below.

<u>WCVI Inlets</u>: A 16-day survey of the major inlets on the west coast of Vancouver Island, from Areas 23 to 27, the offshore areas at the mouths of the inlets and in Area 12 (east side at the north end of Vancouver Island) was conducted along defined transects to obtain relative abundance and biological data.

<u>Northern Index Sites</u>: A 12-day survey of northern index sites was conducted to assess the relative abundance and northern distribution of Pacific sardine. The index sites ranged from Areas 6 to 12.

<u>WCVI Offshore Encounter-Response</u>: An 8-day encounter-response survey was conducted to assess large concentrations of Pacific sardine and determine the feasibility of obtaining acoustic assessments of total biomass. The survey attempted to map out school dimensions and qualitatively assess fish density.

In total, 37 sets were made during the course of the three surveys with 33 biological samples being retained during the combined 36 days of survey time. Total Pacific sardine catches ranged from 4 metric tons (mt) to 50 mt (Figures 14 & 15). Fish were sampled on-board for fork and standard lengths, weight, sex, and maturity. Frozen samples were also preserved for otolith and stomach data. A Scientific Committee on Oceanic Research (SCOR) net was used to collect plankton samples and a Seabird-19 was used for CTD casts.

Standard lengths of 3,348 fish ranged from 150 mm to 270 mm and fork lengths ranged from 162 mm to 287 mm with the largest fish being captured in Rivers Inlet, Area 9. The average standard length was 197 mm and the average fork length was 211 mm. Weights of 3,294 fish ranged from 43 g to 340 g with the heaviest fish being caught at the most northern site in Area 6. The average weight was 118 g.

Male to female ratios were examined over the entire coast in relation to length. Males tend to be more heavily represented in the small size range. South of Estevan Point, Vancouver Island, the male to female sex ratio was 46:54. North of Estevan Point the ratio was almost 50:50 and in the north mainland coast it was 48:52 (Figure 16).

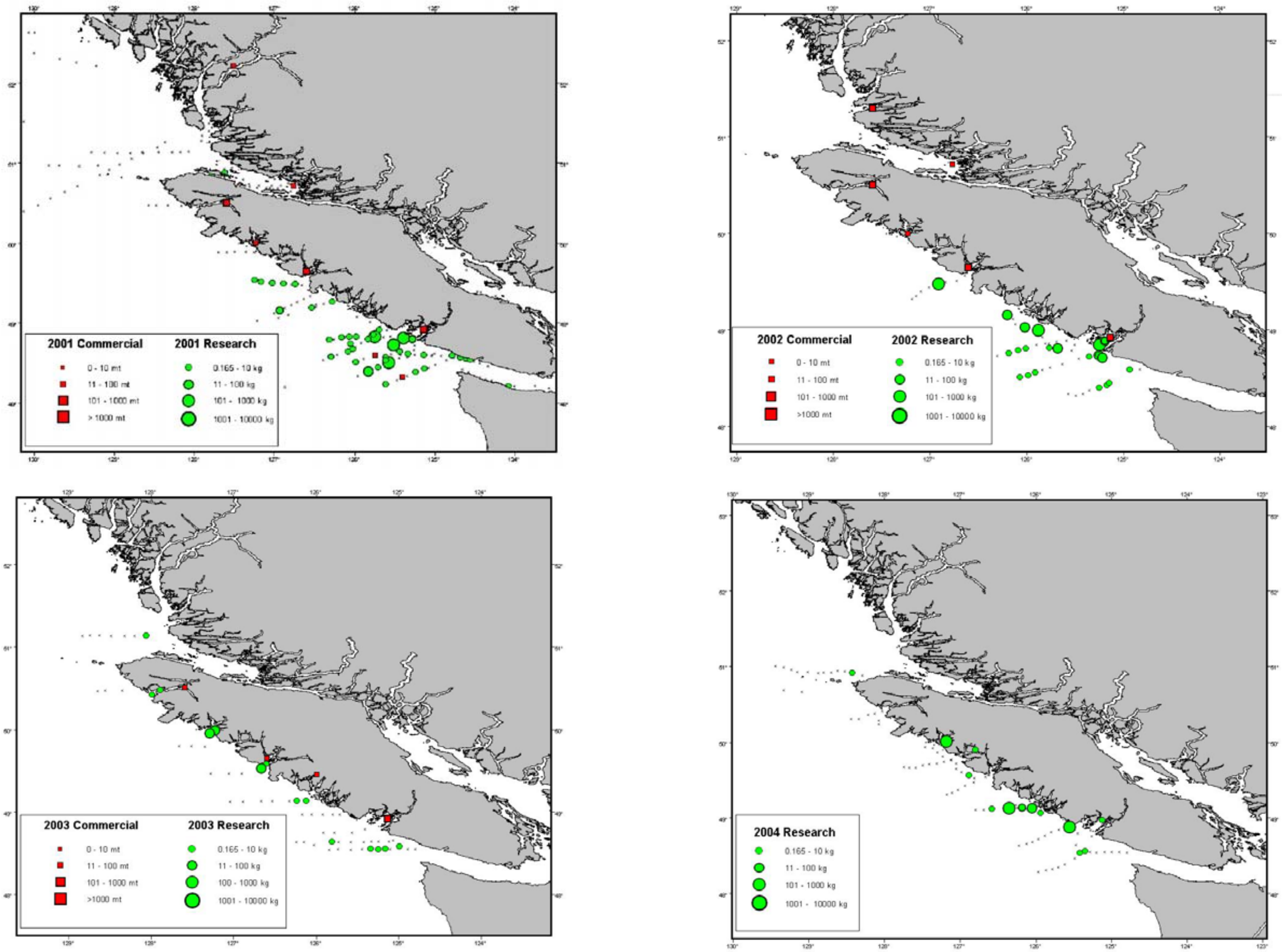


Figure 8. Distribution of relative abundance of Pacific sardine in trawl research surveys 2001-2004 off the west coast of Vancouver Island (Green = Research catch; Red = Commercial catch).

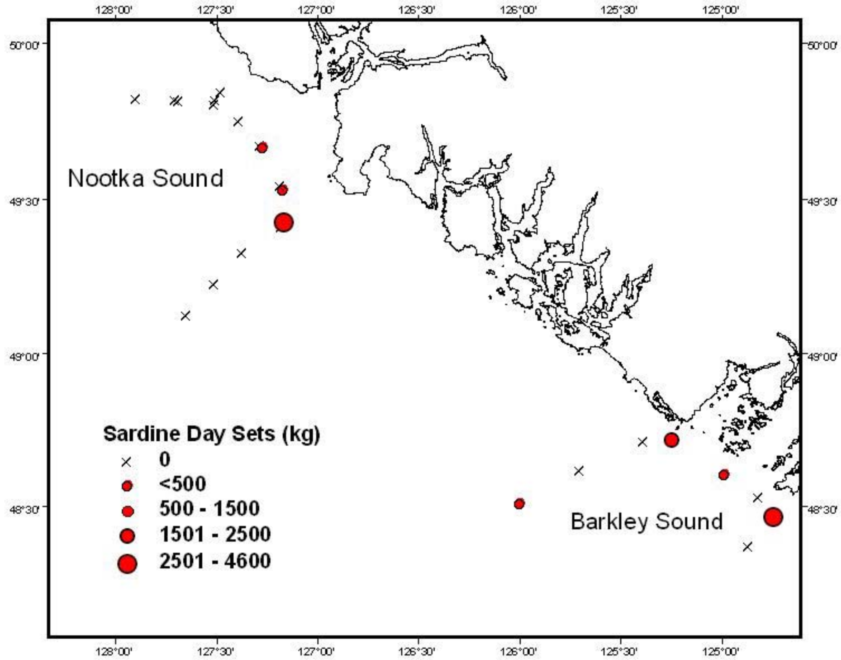


Figure 9. Set location and catch size along Nootka Sound and Barkley Sound transects for day cruises on the trawl research cruise aboard the F/V *Frosti.*

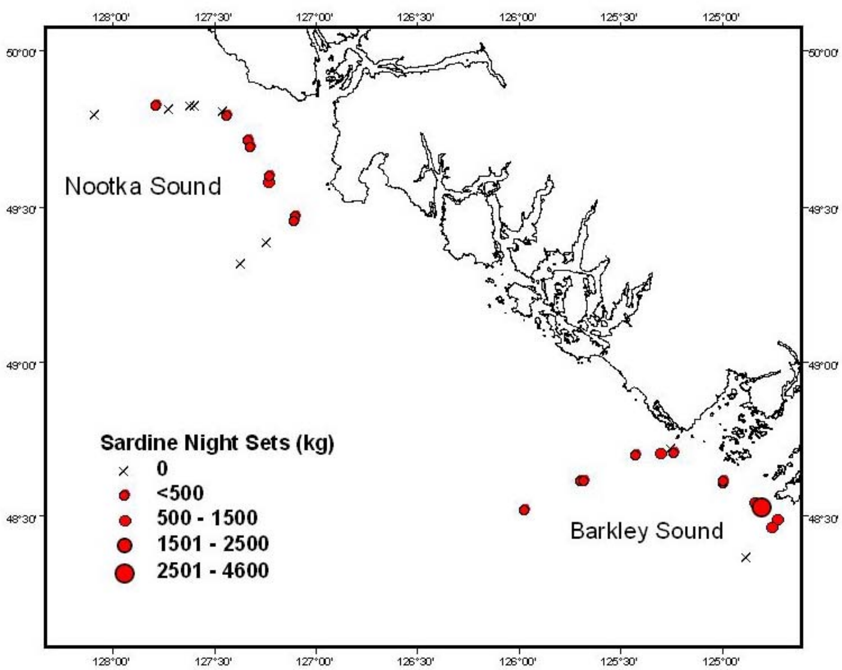


Figure 10. Set location and catch size along Nootka Sound and Barkley Sound transects for night cruises on the trawl research cruise aboard the F/V *Frosti.*

Table 2. Summary of Pacific sardine samples by sample type from the 2005 Pacific sardine survey conducted on the F/V *Frosti.*

set	location	time of day	# of sardines sampled	otolith pairs	stomach	full length	sex	maturity	weight
2	Nootka	Night	225	75	50	225	225	205	225
4	Nootka	Night	241	75	75	241	241	241	242
5	Nootka	Night	255	75	75	255	255	255	255
6	Nootka	Night	173	75	75	173	173	94	173
7	Nootka	Night	175	75	75	175	175	175	175
8	Barkley	Night	6			6	6	6	6
9	Barkley	Night	445	55	48	445	445	445	445
10	Barkley	Night	40			40	40	40	40
12	Barkley	Night	475	75	75	474	475	475	475
13	Barkley	Night	361	60	60	361	361	361	360
14	Barkley	Night	288			288	288	288	288
17	Nootka	Day	2			2	2	2	2
22	Barkley	Day	25			25	25	25	25
25	Barkley	Day	449	49	49	449	449	449	449
27	Barkley	Day	10	10	0	10	10	10	10
28	Barkley	Day	415	75	75	415	415	415	415
32	Nootka	Day	485	85	75	485	485	485	485
42	Nootka	Night	300	50	50	300	300	300	300
43	Nootka	Night	200			200	200	0	200
44	Nootka	Night	301	50	50	301	301	301	301
47	Barkley	Night	40			40	40	40	40
48	Barkley	Night	349	49	49	349	349	349	349
49	Barkley	Night	305			305	305	305	305
50	Barkley	Night	253	51	51	253	253	253	253
51	Barkley	Night	140			140	140	140	140
52	Barkley	Night	222	50	50	222	222	222	222

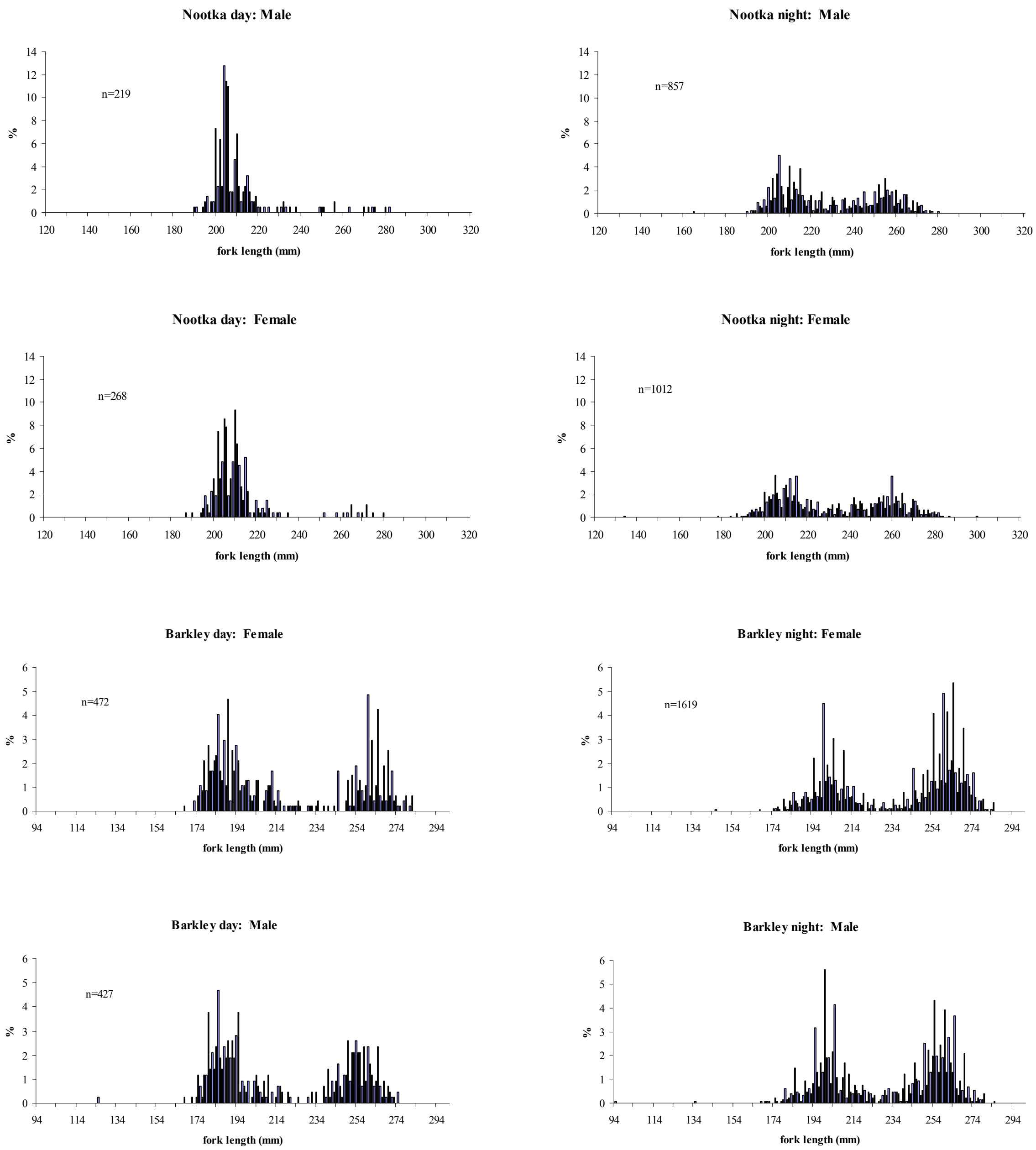


Figure 11. Comparing male and female Pacific sardine length frequencies for Nootka Sound and Barkley Sound for both day and night cruises on the trawl research cruise aboard the F/V *Frosti*.

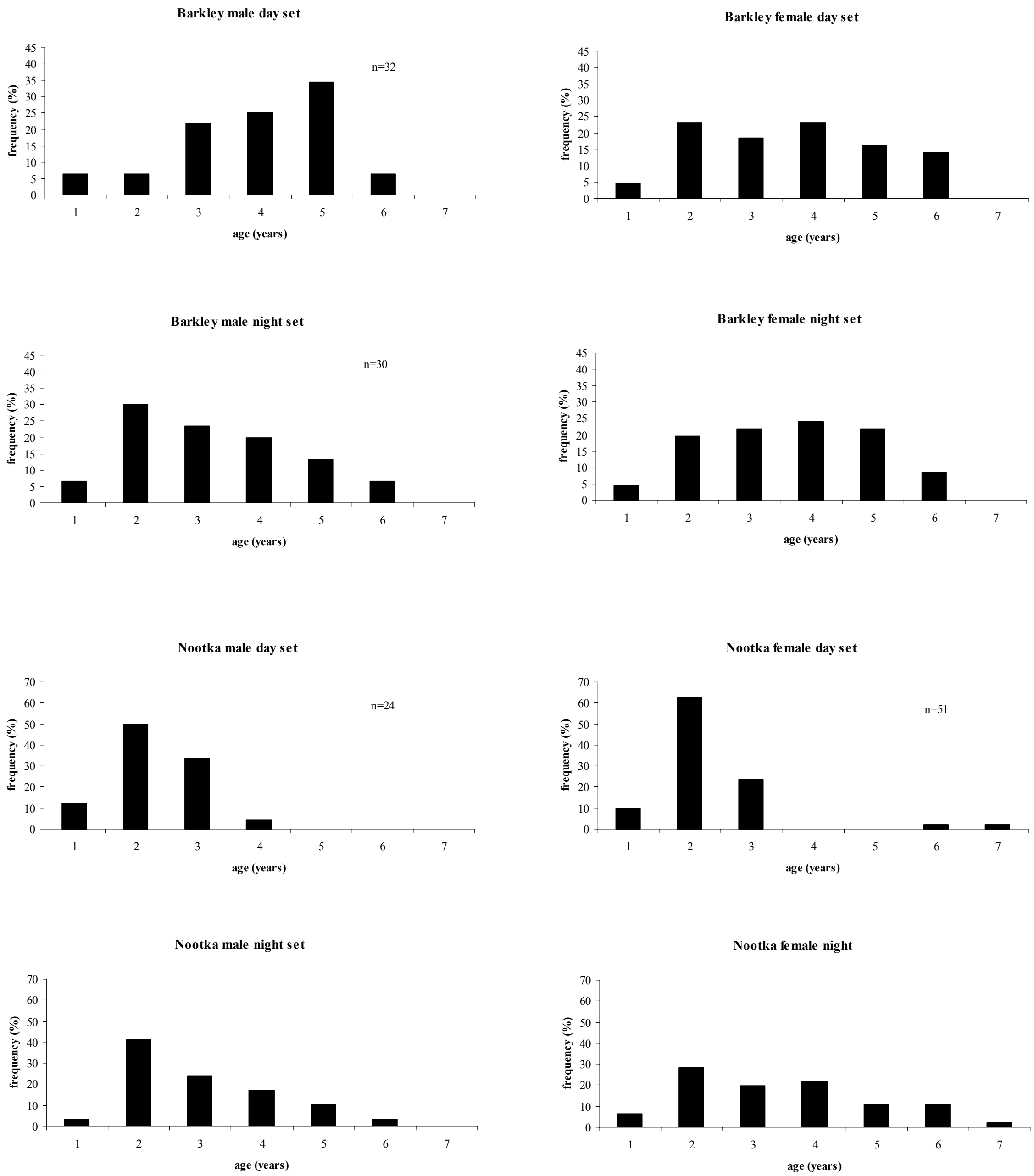


Figure 12. Comparing male and female Pacific sardine age frequencies along Nootka Sound and Barkley Sound transects for both day and night cruises on the trawl research cruise aboard the F/V *Frosti*.

Table 3. Summary of incidental catch by weight (kg) from the Pacific sardine survey on the F/V *Frosti* in August of 2005. Species with a catch weight of 1 kg and less are not shown.

set	sunfish	jack mackerel	blue shark	soupfin shark	pink salmon	chinook salmon	sockeye salmon	chum salmon	coho salmon	herring	hake	euphausid	yellowtail rockfish	jellyfish	dogfish
1	29.44	89.60	52.33		5.70										
2	9.90	68.04		25.07	1.90	40.35	2.98		2.34		952.54				
3															
4						20.42			26.41	36.40	30.00				
5				27.52	3.17	50.80		4.10	4.70	3.36	141.92				
6	6.74	2.34				31.91	2.07	11.65	4.86	trace	5.96				
7	5.17	1.91				139.00	2.56	50.92	10.78						
8				52.59					4.44						
9					12.99	30.16	3.55		8.29	281.63					
10		17.89			1.79	11.67	3.30		6.11			trace			
11						1.97			0.45	472.72					
12		2.33			1.04	9.55			27.71	438.40	2.78				
13						7.96	4.75		8.82	621.40	trace				
14					3.31	207.95	8.22		15.62						
15	11.82		2.68									3.81			
16		101.23				9.80	2.52		10.86						
17						24.63	5.68	5.72	18.57						
18					20.58	56.19	58.28		43.05					133.54	
19					5.25				12.34		0.86			700.00	
20					10.98	31.68	2.18	5.24	43.20					50.00	
21		5.90				1.90								trace	
22	5.00	143.34			1.86	66.66		16.14	38.94						1.74
23		58.60				14.22			45.44						
24		1.94							3.01						
25						13.78									
26		38.84				43.86			43.86						
27					3.55	10.25			25.54		trace				
28					trace	trace									
29		1.83				46.46			119.46						553.31
30	16.63	2.17												42.83	
31		2.09												27.17	
32		trace			trace	trace	trace	trace	trace						
33		25.31			1.70	50.51			40.10						
34		1.58			4.44	55.34	16.82		17.58					24.20	
35						48.76	4.94		11.89					3.70	
36					1.70	4.78			16.82					6.19	
37		536.68													
38		75.55	7.29										3.98	19.66	
39		22.13				27.87					0.65			24.49	
40		44.40				107.78		10.50		1.01	17.51	trace		4.63	
41		2.36		24.12	4.40	27.65		3.78	63.18	13.01	14.18				1.56
42					7.92	20.32				40.96	17.99				
43					7.04	7.27	2.64		10.83	108.07	7.21				
44		35.96			12.50		4.33		17.84		22.86				
45		15.84				13.45					13.06	26.15			
46		52.72										41.50		27.60	
47					1.58	30.89			16.63						
48		trace				12.92	2.50			63.80					
49									2.12	283.59	1.32				
50		trace				30.08	3.17		15.83	185.60					
51					trace										
52					0.93	18.79	6.02		7.44		1.12				
53		528.10			17.29	44.45	6.57		44.87	124.67	13.60				
Total	16.63	1344.89	7.29	24.12	59.50	500.86	46.99	14.28	265.13	820.71	109.50	67.65	3.98	180.47	1.56

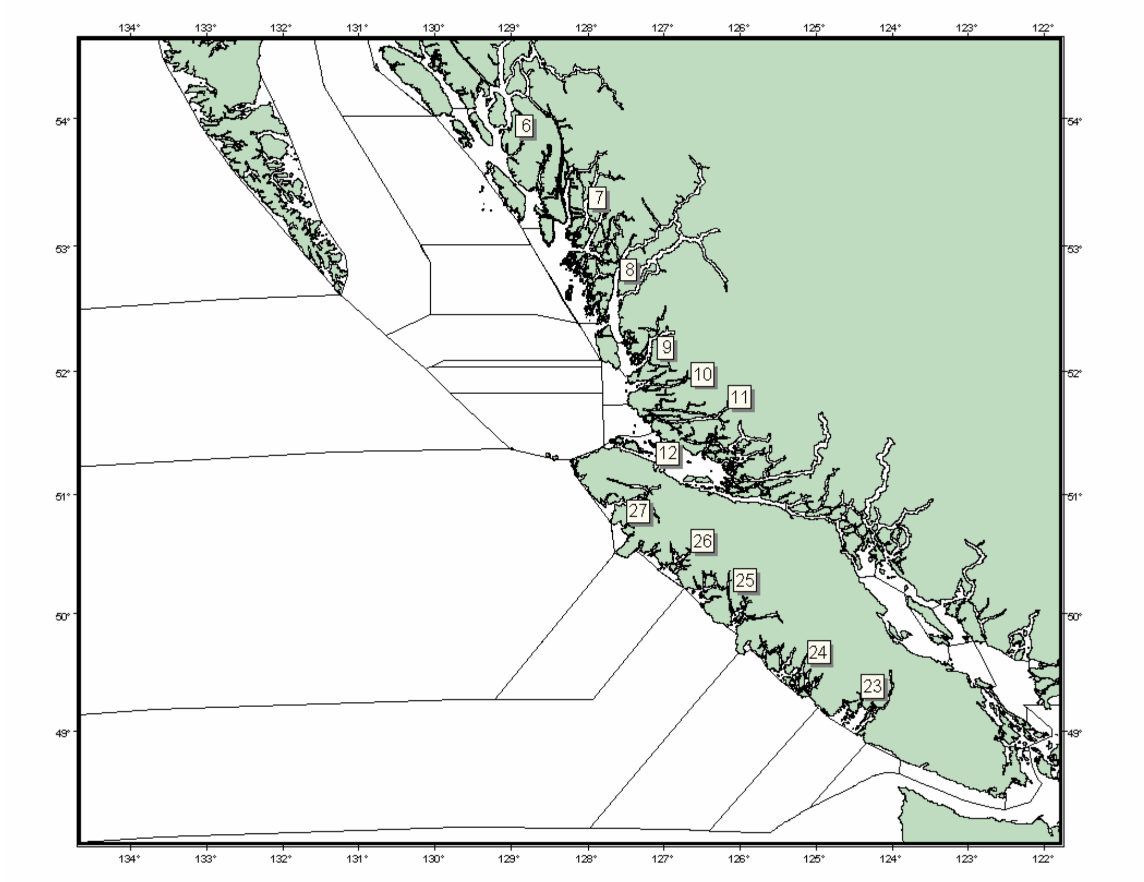


Figure 13. Management areas, denoted by numbers, on the British Columbian coast. The WCVI Inlets survey included areas 23-27 and the Vancouver Island coast in area 12, the Northern Index Sites survey included areas 6-12, and the WCVI Offshore Encounter-Response survey was conducted offshore from sites 23-27.

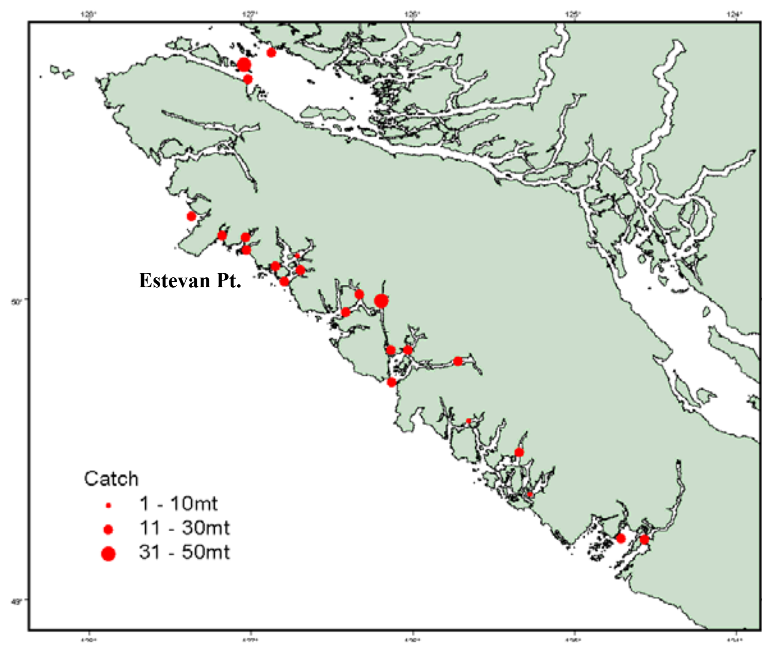


Figure 14. Catch size and location from the WCVI Inlet Industry survey.

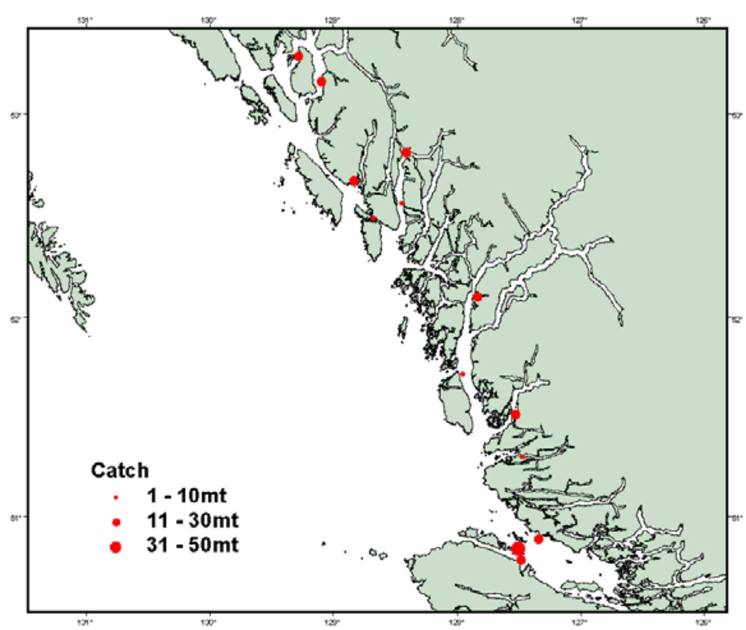
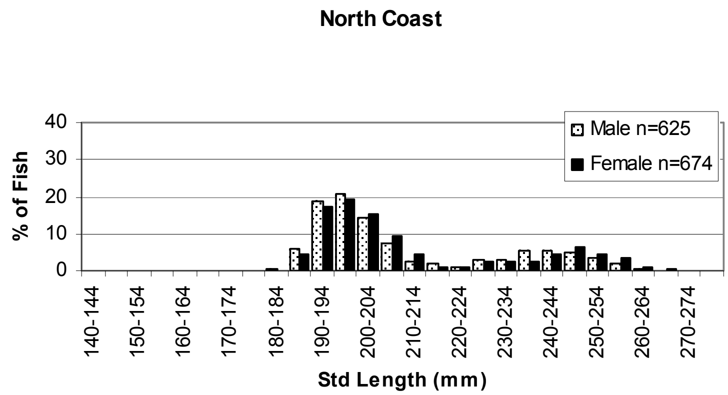
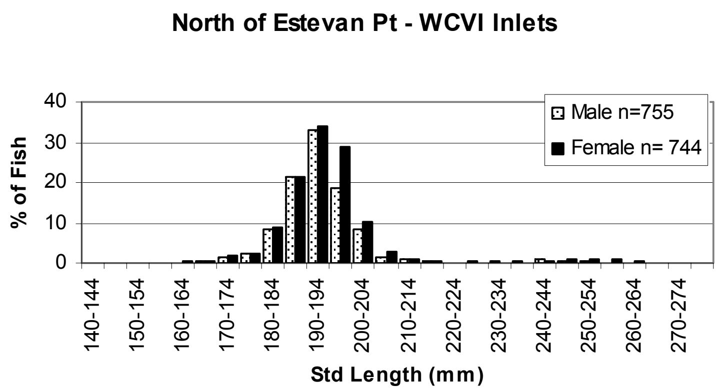


Figure 15. Catch size and location from the Northern Index Industry survey.





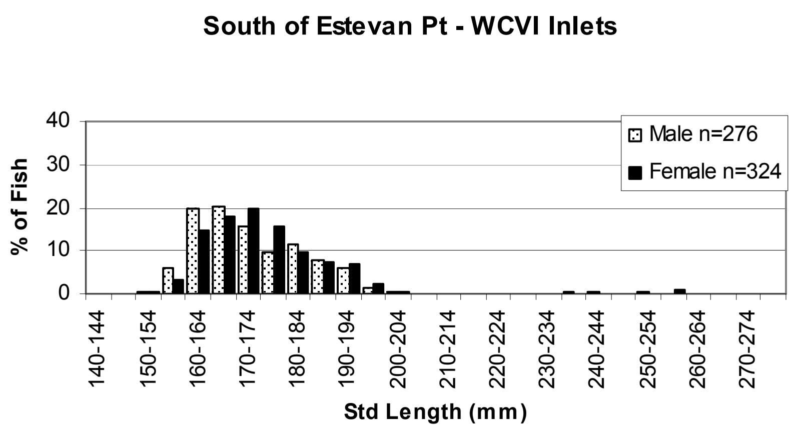


Figure 16. Comparing male and female Pacific sardine length frequencies along the entire coast for the three 2005 Industry sardine surveys.

IMECOCAL, January survey in South Baja California and Gulf of California

Objectives: To estimate spawning biomass of Pacific sardine in southern Baja California, México and in the Gulf of California, and to investigate the migration of Pacific sardine between the two (Hunter and Baumgartner 2002).

See report by Tim Baumgartner, Appendix IV.

Working Group 1 Future Plans and Recommendations

MÉXICO

1. Continue monitoring the fishery

   In Ensenada, sampling programs will be continued to monitor the fishery and obtain estimates of biological parameters each month: daily samples from the fishery catch and adult samples to get reproductive parameters. During the peak spawning period, sampling is intensified: 1-2 samples per day, around 30 fish per sample.

   In Bahía Magdalena, programs also exist to monitor the commercial catch from the fishery. Adult samples are taken for length and weight one day per week. For biological data, three samples per month are taken. During spawning season, the number of samples is increased and samples are also taken aboard commercial vessels. This year, however, no observers are sent to commercial vessels to collect samples in Ensenada. Some commercial captains do take samples for CRIP, but most of the sampling is done in port. The same type of monitoring is also done in the Gulf of California, which is coordinated and paid for by industry.

2. Increase the amount of ship time for IMECOCAL

   Dr. Cotero indicated that the ship time for IMECOCAL was reduced to 10 days for the last October cruise from the standard 21-22 days for each IMECOCAL cruise (January, April, July, October), and it will be the same this year. The vessel now does not go as far offshore, and the number of CUFES samples has been reduced from 800 to 400. The IMECOCAL survey emphasizes physical oceanography rather than biological samples. Nevertheless, more ship days for IMECOCAL are needed.

3. Lack of trawl surveys

   Due to the budget constraints and no access to the commercial fishery, very few adult samples have been collected. There is no trawl vessel based in Ensenada. Drs. Cotero and Baumgartner are working together to obtain adult samples along with ichthyoplankton for the biomass estimate. Eggs obtained using CUFES during IMECOCAL were counted by researchers at CRIP, Ensenada. Determining spawning biomass is not a primary objective of IMECOCAL, and the April cruise will be a special case.

4. Surveys in February-March, 2006 off western Baja California

   In addition to the coast-wide survey in 2006, México may conduct an ichthyoplankton survey on the west coast of Baja California from Ensenada to Bahía Magdalena in February, after the regular January IMECOCAL. However, this is uncertain due to a lack of funding. One of the coordinators of the cruise is Tim Baumgartner. A tuna trawler may be chartered to do the survey during February for one month in Baja California and during March for one month in Baja California Sur from Punta Eugenia to Bahía Magdalena.

CANADA

1. A scientific workshop was again proposed to create a biological, economic and oceanographic model for Pacific sardine biomass estimates. Jake Schweigert has suggested that Don Pepper take the lead in organizing this workshop in 2006.

2. It is likely that the general abundance surveys done by purse seine beginning in 2005 (including inlets, and supported by industry) will continue on a yearly basis. This is in addition to the routine trawl survey that Sandy McFarlane conducts in July or early August.

3. Researchers plan to continue monitoring biological parameters of the population from the commercial catch and take samples.

U.S.A.

1. Extend the survey pattern offshore in California waters for the biennial Pacific hake survey conducted by the Northwest Fisheries Science Center. The survey runs from Point Conception to Canada to obtain trawl samples of adult Pacific sardine at night and to collect Pacific sardine eggs using CUFES and CalVET nets. The NWFSC may have time after the Pacific hake survey is over to take some trawls for Pacific sardine and northern anchovy.

2. Restore the Northwest trawl-acoustic surveys during February-March and in July in the future. The Northwest July survey was not conducted in 2005 due to the unavailability of ship time.

3. Organize a workshop to evaluate the Northwest trawl surveys conducted by SWFSC and to discuss the proper timing and the use of other survey methods such as LIDAR and acoustics during the coast-wide survey.

4. During the DEPM survey each April, it may be possible to ask coastal pelagic species observers to collect adult samples (March-May) in the Southern California Bight and Monterey to increase sample size.

WORKING GROUP 2: Stock Structure, Age Structure and Adult Sampling

Working Group 2 convened at the Hotel Cortez at 10:00 November 15, 2005. The overall discussion focused on: 1) new starts and accomplishments to date; 2) sampling logistics for the upcoming coast-wide survey; and 3) where to go from here in terms of students, research projects, and most importantly, funding.

First the group discussed the papers and posters presented the previous day, as well as the collected wisdom of the scientists present. Good starts have been made in the areas of otolith morphology, otolith microchemistry (elemental and stable isotope analyses), genetic comparisons of various populations, and the use of the stable isotope composition of Pacific sardine soft tissues as indicators of trophic structure and relationships. All of the studies have provided useful first steps in the understanding of regional differences in environment and its expression in Pacific sardine phenotype. To date, no single study has been able to compare differences throughout the full range of Pacific sardine distribution from the Gulf of California to British Columbia. Rather, work is progressing via smaller projects, often Masters and Ph.D. theses that will eventually be combined into a larger overview. It was agreed that the Trinational Sardine Forum is working well as a means of standardizing analytical approaches such that regional data can eventually be combined into a coast-wide synthesis. The working group approach has been important in developing a means of sharing samples and standardizing sampling and analytical protocols. Members of the working group have written joint proposals to various bi-national funding agencies with reasonable success.

In the case of otolith microchemistry, it is clear that there are regional signals, particularly in the Mexican portion of the study area, where temperature and salinity ranges can be more extreme and where oceanographic conditions are different. Laboratory studies that attempted to confirm the underlying hypothesis that otolith microchemistry reflects water chemistry and not temperature or diet have been mostly completed on captive Pacific sardine and bear out the basic assumptions, except that some trace elements such as phosphorous may be labile and can leave the otolith. The next step is to determine the degree of seasonal and yearly variation in different elemental and isotope signals to determine which approaches best reflect the region of birth so that their utility in tracking migration and in identifying natal stocks can be fully exploited with a minimum of cost and analytical time. Stable oxygen isotope signals that may reflect water temperature seem to be particularly promising, while some trace metal signals seem less easy to interpret.

Genetic analyses are underway that rely on mitochondrial DNA sequences and nuclear microsatellite markers. A preliminary study of microsatellite variability from three regions of the coast was presented with the surprising result that genetic variability at the northern extent of the range was quite large. This preliminary result is inconsistent with the idea that Canadian populations are extirpated under unfavorable climate conditions and were only recently repopulated. Confirmation of this result will be important in the coming year.

A central problem faced by all of the members of the working group is the identification of funds to carry out this work. Despite broad scientific interest and a consensus that it is critical to management, research on Pacific sardine stock structure tends to be more exploratory and is often carried out in primarily academic institutions. To date, projects have been funded by small grants rather than broad institutional support. Finally, the problem of aging Pacific sardine otoliths to improve population dynamics studies was again agreed to be a particularly important need and one best supported by federal fisheries organizations rather than academia. However, no funding sources have been identified among the various national and state fisheries agencies.

Future Plans and Recommendations

The working group as a whole was very pleased with the progress made since the last meeting, and made the following recommendations for the future:

1. It is important to learn where the spawning grounds for the Pacific sardine are as this would greatly increase resolution obtained with genetic studies. Knowing the feeding grounds is not as useful, as there is likely mixing among potential subpopulations during the adult stage.

2. The group has been impressed with South African and Japanese fishery management. These nations seem to have a handle on the small recruits and can tell the fisherman that a year class is coming. We should pay attention during the trawl survey to the smaller fish and where the year classes are.

3. A goal for next year's Forum will be to lay out a fine scale sampling scheme once the genetics and the microchemistry are more worked out. This would help elucidate migration patterns more clearly and establish adequate sampling protocols. For instance, having port sampling stations or bait barge sampling throughout the entire latitudinal range would help us to learn where the recruits are.

4. A useful study would be to raise Pacific sardine from different regions in captivity and discover if gill raker and vertebral counts are genetically inherited or if they are functions of water temperature.

WORKING GROUP 3: Industry Trends and Issues
(Don Pepper, Pacific Sardine Association)

The industry working group focused on the role of the Forum and its relevance to industry. We posed the rhetorical question: what's in it for us? This provided us with the conclusion that there are tangible benefits in the form of scientific knowledge. The Forum is useful also because it avoids, indeed excludes, management and allocation issues.

The Forum gives industry "organized science," that is, science that is useful to industry. This is in the form of a biological model of the Pacific sardine stocks. From this it is hoped that a long-term predictive model that incorporates timing and distribution of stocks can be developed. Ultimately, industry's needs are simple: How many fish are there? Where and when are they located? And can we make a profit from fishing them?

The role of the Trinational Sardine Forum needs to be reviewed. At present, it is actually an informal arrangement that functions excellently (due to the professional attitude of the participants) which might be said to function in a semi-formal way given that it has a highly structured set of proceedings. However, it appears it is time for the Forum to evolve. There are various reasons for this. Primarily, as the Pacific sardine fishery develops there is a need for the industry to be comfortable in making long-term investments in the infrastructure necessary for a successful and stable fishery. This is especially true in the Canadian context. There is a common goal among government, industry and the Trinational Sardine Forum, which has to be a sustainable and profitable fishery.

From this, the challenge is to examine the mandate of the Forum to incorporate these long-term objectives. It is essential for industry and government to plan for the future. The Forum is a mechanism to provide this. It is hoped that the next session in Canada can address this problem. Given the success of the Forum to date, the industry participants are confident this can be achieved. The industry will be providing an impetus for a better Trinational Sardine Forum that builds upon the goodwill and success of its past achievements.

Future Plans and Recommendations

The working group members agree with Dr. Hunter in that a limit exists to how much can be done in the informal setting of the Trinational Sardine Forum, and they believe the time has come to move forward with a more formal arrangement. The following points were also put forth:

1. Orlando Amoroso (U.S.), Don Pepper (Canada), and Lic. Martín Gutiérrez (México) will work together to increase industry interest in next year's Forum in Canada.

2. What is really needed from the scientists is a predictive model that could suggest how many fish there are, what they're eating, where they are, and the age distribution, so that the industry can efficiently plan. The information should be specific for each of the three countries.

3. Industry deals with government, and by statute, has to look at the science first. So, industry participants want to be on top of the science and push it in the direction that is useful to them.

4. The technical methods for harvesting Pacific sardine have changed over the years, and it would be beneficial to have more discussion about this.

5. The industry participants would like a full day at the Forum devoted to their specific interests, the format of which will be worked out at a later time.

6. There should be a commercial side of Pacific sardine fishing being addressed at the Forum, and industry members should be invited to give talks on this issue.

7. There are banks and financial institutions supporting the industry in each country. In the future we should consider inviting them to the Forum. Increasing their awareness might increase their investment in the industry.

8. The U.S. has access to advanced technology, while México is at a technological disadvantage. Participants suggested that members of the industry be invited that can discuss and provide new technologies to the fleet.

9. Industry participants hope that with the Forum in Canada next year there will be good discussion and sharing of technology, without revealing trade secrets. For example, there has been research done on how a Pacific sardine rots, which is important information in the food industry to help improve sardine quality.

10. Tuna aquaculture is very advanced in México, and industry participants would like to see technical and operational issues on aquaculture presented more often.

11. The position of the industry participants from México is that there is room for scientific presentations at the TSF, but issues of management and quotas should be left for each country to pursue individually.

CONCLUSIONS

This two full day Forum was indeed a success. In addition to the regular sessions on regional Pacific sardine fisheries, research plans and reports, working group breakouts and a poster session, a session on contributed papers was added to increase the diversity of the Forum (see the program). Since our first Forum in 2000, substantial progress has been made in the areas regarding age structure, monitoring shifts in maturity, conducting coast-wide biomass surveys and regional surveys to fill gaps, and stock structure. In particular, the coast-wide survey, the focus issue of this Forum, will be realized in 2006. Another feature of the Forum is the newly formed working group on industry trend and issues.

The stock assessment of the Pacific sardine indicated a general decline in the stock productivity since the mid-1990s. Recruits (age 0) declined from 9.5 million fish in 1994-95 to a level between 3.5 and 6.5 million fish in recent years, although the biomass has been stable at around 1 million mt since the late 1990s. The commercial landings off Ensenada and the U.S. were similar to previous years. However, the catch in the Gulf of California is decreasing, and in Bahía Magdalena, the fishing effort has declined during 2003-2005. Similarly, off Canada, the catch in 2005 was much lower than 2004 and the fish was smaller (100 g). Much effort in 2005 was devoted to exploration and many new fishing areas in the northern part of Canada were discovered.

The coast-wide survey is to be conducted in April-May 2006. The Fisheries Resources Division of NMFS has secured ship time on two NOAA research vessels for this survey in addition to the regular CalCOFI survey in April. The INP, México, will also provide ship time, most likely on the R/V *El Puma* and the R/V *Altair* to cover the Baja California area. Although Canada is unable to provide ship time, they will provide sea-going personnel. The results of this survey will shed much light on the Pacific sardine off the west coast of North America in terms of the spatial distribution, the biomass, the size and age structure, and the verification of different population stock structures based on morphology, genetics, and microchemistry. In addition, we are likely to discover other biological characteristics of the population from Baja California to British Columbia, and will investigate linkages to oceanographic and environmental conditions.

The new working group on industry trends and issues was created to address the needs of the industry, and was well supported with many participants from the industry of the three countries attending (Appendix I). It is apparent that scientists from government and academia as well as industry representatives all have common goals: 1) better understanding of the status of the Pacific sardine population; 2) the location, timing and abundance of the fish; and 3) the ability to predict these factors in the future. One goal unique to industry is to find a way to make a profit from a sustainable population on a long-term basis. The industry representatives felt that the Forum needs to evolve and have a more formal structure to achieve these goals. However, these goals require the collaboration among all three nations as well as adequate funding and manpower in order to conduct extensive sea surveys, to develop a predictable economic, biological and oceanographic model, and to create a more formal Forum.

The 2006 Forum will be held in Vancouver, Canada in late October or early November. (http://swfsc.nmfs.noaa.gov/frd/Trinational/index.htm; if this link is no longer active, please visit http://swfsc.noaa.gov).

ACKNOWLEDGEMENTS

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APPENDIX I

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Ensenada, México
November 14-15, 2006

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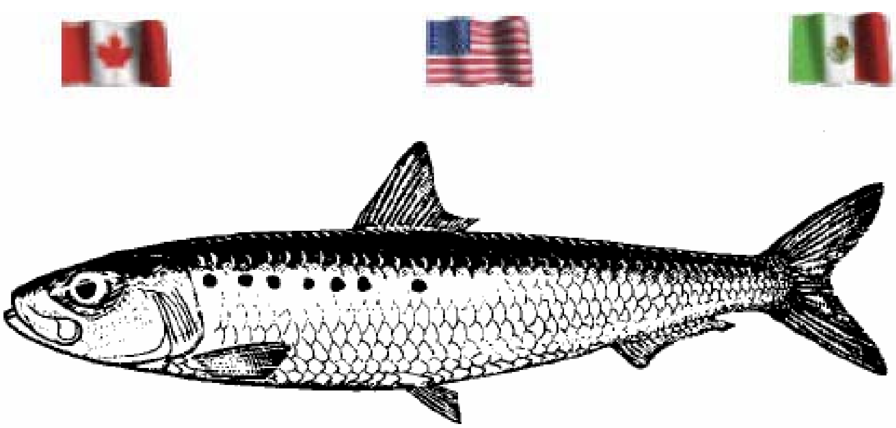
APPENDIX II
English and Spanish Agendas

TRINATIONAL SARDINE FORUM
FORO TRINACIONAL DE LA SARDINA



6th ANNUAL MEETING
Riviera Social, Civic and Cultural Center,
Centro Social, Cívico y Cultural Riviera,
Boulevard Lázaro Cárdenas, and Hotel Cortez, Ensenada, México
November 14th and 15th, 2005

Table of Contents

2005 Trinational Sardine Forum Agenda

<u>Sunday, November 13th</u> Hotel Cortez.

18:00-21:00 Welcome gathering at poolside and restaurant, Tim Baumgartner

<u>Monday, November 14th</u> The Casino Room, the Riviera Social, Civic and Cultural Center, Boulevard Lázaro Cárdenas, Ensenada, Mexico

8:30 Registration

9:00 Welcome and Opening Remarks, *Nancy Lo (SWFSC)*

9:05 Inauguration by Quim. César Mancillas Amador, Municipal President of Ensenada, and City Council Member Ing. Nélida Pelayo Ponce, Coordinator of the Local Fisheries Commission.

Statements from special guests:

9:15 Federico Graef Zielh, Director General, Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)

9:25 Dr. William W. Fox, Jr., Director, Southwest Fisheries Science Center, National Marine Fisheries Service (SWFSC- NMFS)

9:35 History and objectives of the forum, *John Hunter (SIO)*

9:50 Meeting Logistics, *Nancy Lo (SWFSC)* and *Sharon Herzka (CICESE)*

REGIONAL SARDINE FISHERIES REPORTS

10:00 Gulf of California
Manuel Nevárez (CRIP-Guaymas)

10:15 Bahía Magdalena
C. Quiñónez-Velázquez, R. Felix-Uraga and F.N. Melo-Barrera (CICIMAR)

10:30 Ensenada (N. Baja)
Alfredo Cota Villavicencio (CRIP-Ensenada)

10:45 California
Kelly M. O'Reilly (CDFG)

11:00 Northwest
Jean McCrae (ODFW) and Bruce Culver (WDFW)

11:15 Canada
Christa Hrabok (DFO)

11:30 Discussion

11:45 Break

RESEARCH PLANS AND REPORTS

12:00 Stock structure - General introduction
R. Vetter (SWFSC)

12:10 A molecular genetic perspective of sardines from Canada to the Gulf of California: Measuring levels of mitochondrial and nuclear polymorphisms
C. Gutiérrez and A. Rocha (CICESE)

12:30 Potentials of otolith trace-elements and stable isotopic ratios for identifying stock structure of Pacific sardines
E. Dorval, B. Javor, L. Robertson, and R. Vetter (SWFSC)

12:50 Analysis of carbon and oxygen stable isotope ratios of otoliths of young sardines in Mexican waters: toward the characterization of stock structure and migration patterns
S. Valle, S. Herzka, T. Baumgartner (CICESE)

13:10 Lunch at the Riviera ($10.00/person)

14:30 Structure, growth, and biomass of Pacific sardine along the western coast of Baja California
C. Quiñónez-Velázquez, R. Felix-Uraga y F.N. Melo-Barrera. (CICIMAR)

14:50 Can carbon and nitrogen isotopes be used to infer trophic level and movement in Pacific sardine
D. Field (SWFSC)

15:10 Biomass estimates
N. Lo (SWFSC) and T. Baumgartner (CICESE)

15:30 Stock assessment
K. Hill (SWFSC)

15:50 Results of U.S. Northwest surveys
B. Macewicz (SWFSC)

16:10 Oregon/Washington
R. Emmett (NWFSC)

16:30	Break
16:45	Canada *J. Schweigert (DFO)*
17:05	N. Baja *E. Cotero (CRIP-Ensenada), Y. Green (CRIP-Mazatlán), T. Baumgartner (CICESE)*

CONTRIBUTED PAPERS

17:25	California sea lion predation on Pacific sardine in the Southern California Bight during 1981-2002 *M. Lowry (SWFSC)*
17:40	On the origin and larval abundance of *Sardinops sagax* in the California Current *M. E. Hernández Rivas (CICIMAR), W. Watson (SWFSC), R. L. Charter (SWFSC), A. Hinojosa-Medina (CICIMAR), S. Patricia Jiménez-Rosenberg (CICIMAR), and R. Funes-Rodríguez (CICESE)*
17:55	Growth of juvenile Pacific sardine (*Sardinops sagax*) in the California Current in 2004-2005 *M. Takahashi (SIO)*
18:10	Finding methods of predicting sardine-climate shifts: Analysis of the fishery, physical variables and possible economic benefits *S. Herrick, J. Norton, and J. Mason (SWFSC*)
18:25	Mixture distributions and their applications in catch-at-age methods. *Enrique Morales (CRIP-INP)*
18:40	Daily specific fecundity of the Monterrey sardine in Bahia Magdalena. *Rene Torres (CICIMAR)*

INTRODUCTION TO WORKING GROUP 3:

19:00	Industry trends and issues *O. Amoroso & M. Gutierrez*
	Tuna ranch operations/sardine products Invited speaker: *Mr. F. Charat, President of Maricultura del Norte*
19:30- 21:30	Dinner-Hotel El Cid ($15.00) # 993 Avenida López Mateos (2 blocks from the Hotel Cortez)

<u>Tuesday, November 15th</u> ***<u>Hotel Cortez</u>***

9:00 Focus Issue: 2006 BC to BC Coast-wide April survey
R. Hewitt (SWFSC)
Baja Inn Room

10:00 Working group discussions
WG 1: Regional biomass - *Nancy Lo*
WG 2: Stock structure, age structure and adult sampling – *Russ Vetter*
WG 3: Industry trends and issues - *Orlando Amoroso & Lic. Martín Gutierrez*
Baja Inn and Mixteco Rooms

13:00 Lunch at the Hotel Cortez ($10.00/person)

15:00 Plenary Sessions for reporting results of WG discussions
Baja Inn Room
PS 1: Coast wide survey
PS 2: Industry trends and issues
PS 3: Other issues

18:00 Closing remarks
Baja Inn Room

Nancy Lo (*SWFSC*) and Sharon Herzka (*CICESE*)

18:30 Transportation to San Diego departing from Hotel Cortez

POSTER SESSION (November 14 and 15):

Posters will be displayed around the meeting hall for the duration of the forum.

Preliminary results on the use of otolith elemental analysis to identify natal origin, migration patterns and stock structure of Pacific sardines in Mexican waters
S. Valle, S. Herzka, and T. Baumgartner (CICESE)

Sardine Otolith Chemistry
E. Dorval and B. Javor (SWFSC)

<u>Wednesday, November 16th</u>

AM (time to be determined) Field trip to Maricultura del Norte tuna ranch if weather permits -- CANCELED
O. Amoroso, M. Gutiérrez, and R. Cortez

14:00 Transportation to San Diego departing from Hotel Cortez

Working Groups/Contributors/Committees

WORKING GROUPS:
The principal goal of the working groups is to promote coast-wide cooperation in producing information needed regarding the biology and dynamics of the population:

WG1: Regional biomass - Nancy Lo
WG2: Stock structure, age structure and adult sampling - Russ Vetter
WG3: Industry trends and issues - Mr. Orlando Amoroso & Lic. Martín Gutiérrez

CONTRIBUTORS:
XVIII Municipal Government of Ensenada
General Director and Department of Biological Oceanography, CICESE
Mr. Orlando Amoroso, Purse seine owner
IAI-EPCOR

PROGRAM COMMITTEE:
Dr. Nancy Lo, Southwest Fisheries Science Center (SWFSC-NOAA), La Jolla, California
Dra. Sharon Z. Herzka, Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)

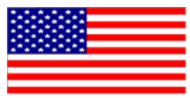
LOGISTIC COMMITTEE:
Mr. Orlando Amoroso, Purse Seine Owner
Sr. Raúl Cortez, Pesquera Cortez
Dra. Sharon Z. Herzka (CICESE)
Lic. Martín Gutiérrez, Presidente, Asociación de Armadores de Pelágicos Menores y Representante de B.C. para la Red de Innovación de la Cadena Productiva de Peces Pelágicos
Menores de B.C., B.C.S, Son. y Sin.

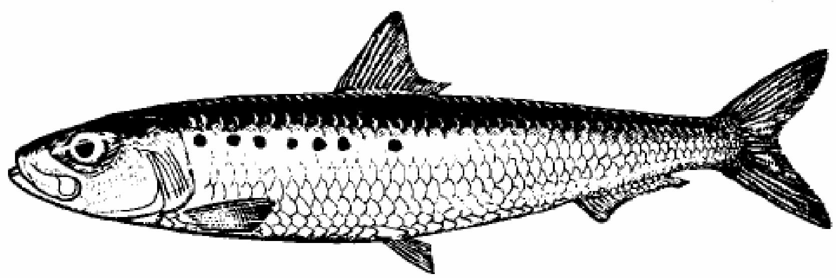
EXECUTIVE COMMITTEE:
Nancy Lo
Sharon Herzka
Robert Emmett
Jake Schweigert

ACRONYMS

CDFG	California Department of Fish and Game
CICESE	Centro de Investigación y de Educación Superior de Ensenada
CICIMAR	Centro Interdisciplinario de Ciencias Marinas
CONAPESCA	Comisión Nacional de Acuacultura y Pesca
CRIP	Centro Regional de Investigación Pesquera, Instituto Nacional de la Pesca
DFO	Department of Fisheries and Oceans, Canada
NWFSC	Northwest Fisheries Science Center, National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
SIO	Scripps Institution of Oceanography, University of California San Diego
SWFSC	Southwest Fisheries Science Center, National Marine Fisheries Service
WDFW	Washington Department of Fish and Wildlife

6to FORO TRINACIONAL DE LA SARDINA

14 de noviembre: Salón Casino, Centro Social, Cívico y Cultural Riviera, Boulevard Lázaro Cárdenas, Ensenada, México

15 de noviembre: Hotel Cortez, # 1089 Avenida López Mateos Ensenada, México

Tabla de Contenidos

Foro Trinacional de la Sardina
Agenda 2005

Domingo 13 de noviembre

6:00 - 9:00 PM Bienvenida en el Hotel Cortez.

Lunes 14 de noviembre

Salón Casino, Centro Social, Cívico y Cultural Riviera
Boulevard Lázaro Cárdenas, Ensenada, México.

8:30 AM	Registro de participantes
9:00	Bienvenida – *Nancy Lo (SWFSC)*
9:05	Inauguración del Foro por el Presidente Municipal de Ensenada, Quim. César Mancillas Amador e Ing. Nélida Pelayo Ponce, Coordinadora de la Comisión de Pesca del Ayuntamiento

Breves discursos por parte de invitados especiales:

9:15	Dr. Federico Graef Zielh, Director General, Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE)
9: 25	Dr. William Fox, Director, Southwest Fisheries Science Center, National Marine Fisheries Service
9:35	Historia y Objetivos del Foro: *Dr. John Hunter, SIO*
9:50	Logística – *Dras. Nancy Lo (SWFSC) and Sharon Herzka (CICESE)*

Reportes Regionales Pesqueros

10:00	Golfo de California *M. Nevárez (CRIP-INP, Guaymas)*
10:15	Bahía Magdalena *C. Quiñónez, R. Felix-Uraga y F.N. Melo-Barrera (CICIMAR)*
10:30	Ensenada *A.C. Villavicencio (CRIP-INP, Ensenada)*

10:45	California *K.M. O'Reilly (CDFG)*
11:00	Noroeste *J. McCrae (ODFW) and B. Culver (WDFW)*
11:15	Canadá *C. Hrabok (DFO)*
11:30	Discusión
11:45	Receso

Planes y Reportes de Investigación

12:00	Introducción a la estructura de stocks *R. Vetter (SWFSC)*
12:10	Perspectiva genética de la sardina desde Canadá hasta el Golfo de California: I. Evaluación de niveles de polimorfismo mitocondrial y nuclear *C. Gutiérrez y A. Rocha (CICESE)*
12:30	Potencial del análisis de elementos e isótopos estables para identificar la estructura de stocks de la sardina del Pacífico *E. Dorval, B. Javor, L. Robertson y R. Vetter (SWFSC)*
12:50	Análisis de isótopos estables de carbono y oxígeno de los otolitos de sardinas jóvenes en aguas Mexicanas: hacia la caracterización de estructura de stocks y patrones de migración *S. Valle, S. Herzka, T. Baumgartner (CICESE)*
1:10 PM	**Comida en el Riviera ($10.00/persona)**
2:30	Estructura por edades, crecimiento y biomasa de la sardina del Pacífico en la costa occidental de Baja California *C. Quiñónez-Velázquez, R. Felix-Uraga y F.N. Melo-Barrera (CICIMAR)*
2:50	Pueden utilizarse los isótopos estables para inferir nivel trófico y movimiento en la sardina del Pacífico? *D. Field (SWFSC)*
3:10	Estimaciones de biomasa *N. Lo (SWFSC) y T. Baumgartner (CICESE)*
3:30	Evaluación de stocks

K. Hill (SWFSC)

3:50 Resultados de los censos del Noroeste
B. Macewicz (SWFSC)

4:10 Oregon/Washington
R. Emmett (NWMFS)

4:30 Receso

4:45 Canadá
J. Schweigert (DFO)

5:05 Baja California Norte
E. Cotero (CRIP-INP, Ensenada), Y. Green (CRIP-INP, Mazatlán), T. Baumgartner (CICESE)

Contribuciones Especiales

5:25 Depredación de sardina del Pacífico por lobos marinos en el Southern California Bight 1981-2002
M. Lowry (SWFSC)

5:40 Sobre el origen y abundancia de larvas de *Sardinops sagax* en la Corriente de California
M. E. Hernández-Rivas (CICIMAR), W. Watson (SWFSC), R.L. Charter (SWFSC), A. Hinojosa-Medina (CICIMAR), S.P. Jiménez-Rosenberg (CICIMAR), R. Funes-Rodríguez (CICIMAR)

5:55 Crecimiento de juveniles de sardina del Pacífico (*Sardinops sagax*) en la Corriente de California (2004-2005)
M. Takahashi (SIO)

6:10 Métodos de predicción de cambios climáticos asociados a la sardina: Análisis de pesquerías, variables físicas y beneficios económicos posibles
S. Herrick, J. Norton, J. Mason (SWFSC)

6:25 Distribuciones mixtas y su aplicación a métodos de edad-captura
E. Morales (CRIP-INP, La Paz)

6: 40 Fecundidad diaria específica de la sardina Monterrey en Bahía Magdalena
R. Torres (CICIMAR)

Introducción al Grupo de Trabajo 3

7:00	O. Amoroso (San Pedro Purse Seine Owner) y M. Gutiérrez (Asociación de Armadores de Pelágicos Menores de Ensenada) Operaciones de ranchos atuneros/ Productos de sardina *Invitado especial:* Sr. Felipe Charat, Maricultura del Norte
7:30	Cena – Hotel El Cid, Avenida Lopez Mateos, #993 ($15.00)

Martes 15 de noviembre **Hotel Cortez, Avenida Lopez Mateos # 1089**

9:00 AM	Discusión general sobre el Censo México-E.U.A.-Canadá Abril 2006 *R. Hewitt (SWFSC)* ***Salón Baja Inn***
10:00	Discusiones por grupos de trabajo GT1) Biomasa regional -*Nancy Lo* GT2) Estructura de stocks, estructura de edades y muestreo de adultos - *Russ Vetter* GT3) Retos y tendencias en la industria- *O. Amoroso & M. Gutiérrez* ***Salones Baja Inn y Mixteco***
1:00 PM	**Comida en *Salón Baja Inn* ($10.00/persona)**
3:00	Sesiones Plenarias y presentación de resultados de los grupos de trabajo PS 1) Censos PS 2) Retos y tendencias en la industria PS 3) Otros ***Salón Baja Inn***
6:00	Clausura Nancy Lo (SWFSC) y Sharon Herzka (CICESE)

Sesión de carteles

Los carteles estarán disponibles durante la duración del Foro.

Resultados preliminares sobre el uso del análisis de elementos en otolitos para la identificación de origen natal, patrones de migración y estructura de stocks de la sardina en México - *S. Valle, S. Herzka, T. Baumgartner (CICESE)*

Química de otolitos de sardina - *B. Javor (SWFSC)*

6:30 PM Transporte a San Diego

Miércoles 16 de noviembre

2:00 PM Transporte a San Diego

GRUPOS DE TRABAJO
La meta principal de los grupos de trabajo es promover cooperación trinacional para la realización de un censo poblacional exhaustivo que se realizará en el 2006 para recabar información sobre la biología y dinámica de esta especie.

Coordinadores de grupos:
GT1) Biomasa regional -Dra. Nancy Lo
GT2) Estructura de stocks, estructura de edades y muestreo de adultos - Dr. Russ Vetter (SWFSC)
GT3) Tendencias y retos del sector industrial - Sr. Orlando Amoroso (San Pedro Purse Seine Owner) & Lic. Martín Gutiérrez (Presidente, Asociación de Armadores de Pelágicos Menores de Ensenada).

Patrocinadores:
XVIII Ayuntamiento de Ensenada
Dirección general del CICESE
Departamento de Oceanografía Biológica, CICESE
Mr. Orlando Amoroso, San Pedro Purse Seine Owner
Programa Interamericano para el Cambio Global (IAI-EPCOR)

Coordinadores del programa:
Dra. Nancy Lo, Southwest Fisheries Science Center (SWFSC-NOAA), La Jolla, California
Dra. Sharon Z. Herzka, Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE), Ensenada, México

Comité organizador:
Sr. Orlando Amoroso, San Pedro Purse Seine Owner
Sr. Raúl Cortez, Pesquera Cortez
Lic. Martín Gutiérrez, Presidente, Asociación de Armadores de Pelágicos Menores de Ensenada
Dra. Sharon Z. Herzka (CICESE)

Comité Ejecutivo Foro Trinacional de la Sardina:
Nancy Lo
Sharon Herzka
Robert Emmett
Jake J. Schweigert

SIGLAS

CDFG	California Department of Fish and Game
CICESE	Centro de Investigación y de Educación Superior de Ensenada
CICIMAR	Centro Interdisciplinario de Ciencias Marinas
CONAPESCA	Comisión Nacional de Acuacultura y Pesca
CRIP	Centro Regional de Investigación Pesquera, Instituto Nacional de la Pesca
DFO	Department of Fisheries and Oceans, Canada
NWFSC	Northwest Fisheries Science Center, National Marine Fisheries Service
ODFW	Oregon Department of Fish and Wildlife
SIO	Scripps Institution of Oceanography, University of California San Diego
SWFSC	Southwest Fisheries Science Center, National Marine Fisheries Service
WDFW	Washington Department of Fish and Wildlife

APPENDIX III

CONTRIBUTED ABSTRACTS AND SUMMARIES
(In alphabetical order)

REPRODUCTIVE BIOLOGY OF *Sardinops caeruleus* IN THE WESTERN COAST OF BAJA CALIFORNIA

Celia Eva Cotero A.[1] and Héctor Valles Ríos[2]

[1]CRIP ENSENADA
[2]SAGARPA –Instituto Nacional de la Pesca
cecotero@yahoo.com
hualles@telnor.net

The small pelagic fishery represents an important food source, and creates employment opportunities and economic benefits for the countries which use these fishes as marine resources. In Mexico, traditionally small pelagic fish catches are used for fish meal, fish oil, as well as for canned sardine production. Recently, sardine has been fresh frozen for exportation and fresh sardine is utilized in the tuna ranch industry.

Mexico signed the Code of Conduct for responsible fisheries in which one promises to maintain a monitoring system of the principal fisheries like small pelagic fishes, with the objective of continuing a sustainable use of fisheries resources through the National Fishery Institute, which is scientific advisor to the Fishery Authority, in the Regional Fishery Research Center (CRIP initial letters in Spanish).

In terms of the reproduction dynamics of population, some important parameters of fundamental importance in fishery are the age or body size at sexual maturity, since the growth and the sexual maturity reveal a consistent pattern as response to both fishing pressure and environmental conditions. The continuous monitoring of the fishing operations, through analyzing the obtained biological variables from the catches, provide information about its work flow, and give us some evidence of the causes of variability in the abundance. Such information permits us to determine the effect of fishing on the resource. Samples from the commercial fleets were obtained and most gonads specimens were processed with histological techniques after collection. Slide sections were examined with a compound microscope and were analyzed emphasizing the different oocytes classes, the presence of postovulatory follicles, and the characteristics in atretic stages. With these peculiarities the individuals were identified to their maturity stages and thus represented the reproductive behavior of the Monterrey sardine of the western coast of Baja California during 2003 to 2004. The body size of individuals considered either ripening or resting mature. The ripe mature was used to estimate the length at which 50% are sexually mature (L_{50}) by fitting the data to the logistic equation. We observed the length-frequency distribution to be between 115 to 225 mm, the principal months of catches in June and July, the L_{50} at 180 mm, in 2004, and the peak spawning both years in January to February.

CAN $\delta^{13}C$ AND $\delta^{15}N$ BE USED TO INFER TROPHIC LEVEL AND MOVEMENT IN PACIFIC SARDINE?

David Field and Russ Vetter

National Oceanographic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center
La Jolla, CA 92037

We address the use of $\delta^{13}C$ and $\delta^{15}N$ signatures in tissues and scales of the California sardine, *Sardinops sagax caerulea*, as an indicator of regional stock structure. Examining fish caught at different coastal locations throughout the California Current (Magdalena Bay, Ensenada, San Diego, Canada) and offshore of southern and central California indicates that fish from Magdalena Bay are distinguishable from fish caught in other locations. We determined the isotopic response of scales, liver, and red and white muscle tissue of sardines raised on three different food types to assess the timescales of change expected if fish were to move to another location and feed on a diet with different isotopic composition. The growth rates of fish fed squid, copepods, and pellets differed. While isotopic signatures tended towards the composition of their diet in all cases, isotopic change varied strongly with growth. The isotopic composition of liver varied most rapidly while that of scales was the least variant. Additionally, there was very little difference in the outer edge of the scales (representing recent growth) relative to the inner core (representing more juvenile growth) due to the continuous thickening of the organic matrix of the scale after deposition of skeletal hydroxyapatite. While the expected change in isotopic signature varies with growth and diet composition, there is a strong potential to discriminate fish from Bahia Magdalena that have migrated to other regions within several months using $\delta^{15}N$.

A MOLECULAR GENETIC PERSPECTIVE OF SARDINE FROM CANADA TO THE GULF OF CALIFORNIA

Carina Gutiérrez-Flores, Carol Kimbrell, Eric Lynn, Eric Saillant, Ricardo Pereyra, Russell Vetter, John Gold, & Axayacatl Rocha-Olivares

Stock identification is required for any management strategy. This is of particular relevance in species exploited over most of their distribution such as the Pacific sardine, a small schooling pelagic fish inhabiting the California Current System and the Gulf of California. The identification of genetically differentiated demographic units and the understanding of geographical patterns of genetic diversity will shed light on levels of population connectivity and will help to estimate the contribution of subpopulations to regional catches. Stock delineation of Pacific sardines has been controversial. In general, morphological characters suggest the existence of three and maybe four groups. Recent evidence suggests the existence of three phenotypic groups with thermal affinities and seasonal distributional shifts. On the other hand, available biochemical and molecular genetic studies suggest the existence of a single panmictic population. Here we present results based on one mitochondrial (mtDNA control region, n=180) and four nuclear loci (microsatellites, n=173) from eight regions along the northeastern Pacific to assess patterns of genetic diversity and population structure. We found high levels of mitochondrial haplotypic diversity ($h > 0.88$) and evidence of a diversity gradient with low diversity at the edges (Washington $h = 0.85$ and Magdalena Bay $h = 0.86$) and the highest centered on California ($h = 0.98$). This pattern would be compatible to a basin model of expansions and contractions in the abundance of the Pacific sardine with a refuge zone located in California. However, we found the highest haplotype diversity in the northern limit of the species distribution (Vancouver, $h = 0.99$), which contradicts this model and suggests that it may not apply to the entire range, if at all. The mitochondrial pattern was not corroborated by the nuclear data characterized by high heterozygosities (H > 0.89). Preliminary analyses showed no evidence of genetic structure in the mtDNA data set, however a small but significant differentiation was detected in microsatellite loci ($F_{st} = 0.002$, $p < 0.05$). Genetically differentiated groups consisted in Vancouver, Cedros Island and a third group integrated by Ensenada, Magdalena Bay and Gulf of California. Our results are in partial agreement with previous hypotheses of genetic structure, such as the groups based on thermal affinities, and also include unsuspected findings, such as the genetic distinction of sardines from Vancouver. This study shows the power of using multiple molecular markers able to detect demographic processes at different temporal and spatial scales.

FINDING METHODS OF PREDICTING SARDINE-CLIMATE SHIFTS: ANALYSIS OF THE FISHERY, PHYSICAL VARIABLES AND POSSIBLE ECONOMIC BENEFITS

S. F. Herrick, Jr., J. G. Norton, J. Mason and C. Bessey

National Oceanographic and Atmospheric Administration
National Marine Fisheries Service
Southwest Fisheries Science Center
La Jolla, CA 92037

In previous work we show that accumulated anomalies of physical indices are proportional to the $\log_e$ transform of California sardine landings weights and that the accumulated anomaly curves change the sign of their slope, showing maxima or minima, when climates (un) favorable to successful completion of the sardine life cycle change. Here we find unique aspects of the periods when the climate changed for sardines in the 1930-2004 period. Only one 50-70 year cycle is examined, but the ubiquity of the important signals in measurements taken independently within the sardine's environment and at locations separated by thousands of kilometers supports the argument that the events affecting the ocean-climate of the California Current region and consequently sardine life-cycle are large-scale and persist over multi-decadal periods. When using the relationships reported to analyze future changes in climates affecting sardines, we can also monitor the progress of the climate regime shift in the physical environment and in the harvestable sardine populations on a year -by-year basis. The ability to analyze climate shifts and monitor their progress from the fisheries and environmental viewpoints can be of great value in making resource management, social and business decisions. Decisions affecting transboundary issues within the United States (U.S.) and between the U.S. and its Pacific neighbors are clarified. The methods presented will add an analysis of low frequency events to the current management oriented analyses of interannual events, which are part of the existing Pacific Fishery Management Council sardine management plan.

ASSESSMENT OF THE PACIFIC SARDINE (*Sardinops sagax caeruleus*) POPULATION FOR U.S. MANAGEMENT IN 2006

Kevin T. Hill, Nancy C. H. Lo, Beverly J. Macewicz, and Roberto Felix-Uraga
(http://swfsc.ucsd.edu/frd/Coastal%20Pelagics/Sardine/Hill_etal_2006_TM-386.pdf)

A Pacific sardine stock assessment is conducted annually in support of the Pacific Fishery Management Council (PFMC) process that, in part, establishes an annual harvest guideline (quota) for the U.S. fishery. In June 2004, the PFMC, in conjunction with NOAA Fisheries, organized a Stock Assessment Review (STAR) Panel in La Jolla, California, to provide peer review of the methods used for assessment of Pacific sardine and Pacific mackerel. The report was initially prepared in draft form for the STAR panel's consideration, and was updated for the 2005 management cycle (Conser et al. 2004). Many of the STAR panel review recommendations as well as considerable new data were incorporated into that stock assessment update. The assessment was again updated by Hill et. al (2006) for 2006 management; as such, it was reviewed by the Pacific Fishery Management Council (PFMC) and its advisory bodies, and the results were adopted by the PFMC for setting the U.S. harvest guideline in 2006.

The assessment was conducted using age-structured assessment program (ASAP), a forward simulation, likelihood- based, age-structured model developed in AD Model Builder. New information has been incorporated into the update, including: (1) new landings data from the Ensenada fishery for the period January 2000 through June 2005; (2) an additional year of landings and biological data from the California and Pacific Northwest fisheries; (3) a new daily egg production method, or DEPM-based estimate of spawning stock biomass (SSB) based on the April 2005 survey off California; and (4) addition of enhanced aerial spotter survey data from the Southern California Bight, which have been used to recalculate this time series of relative abundance through 2004-05.

Results from the final base model indicate a general decline in stock productivity (recruits per spawning biomass) which began in the mid-1990s. Recruit (age-0) abundance increased rapidly from low levels in 1982-83, peaking at 9.5 billion fish in 1994-95 (Figure 1). Recruitment has subsequently declined to between 3.5 and 6.5 billion fish per year since that time, with the recent exception of a strong 2003 year class (YC). Recruit abundance is poorly estimated for the most recent years, however, the 2003 YC was estimated to be 10 billion fish. There was a large proportion of 2003 YC in the catch, as well as relatively high abundance in fishery-independent trawl surveys off California and the Pacific Northwest. Stock biomass (ages 1+) peaked at 1.48 million metric tons (mmt) in 1996-97, declining to 0.81 mmt in 2003-04 (Figure 2). As of July 2005, stock biomass was estimated to be 1.06 mmt.

The primary motivation for conducting this annual assessment is to provide the scientific basis for the Pacific Fishery Management Council's (PFMC) sardine management process. This process -- centered on an environmentally-based control rule -- establishes U.S. coast-wide harvest guidelines (HG) for Pacific sardine for the fishing year beginning on January 1 of each year. Based on the Pacific sardine biomass estimate from this assessment (1,061,391 mt) and current environmental conditions, the PFMC control rule suggests a 2006 HG for U.S. fisheries of 118,937 mt. This HG recommendation is 13% lower than the HG adopted for calendar year

2005, but 22,049 mt higher than the largest recent harvest by the U.S. However, when viewed on a coast-wide basis, the combined harvests of México, Canada, and the U.S.A. (Table 1) may be meeting or exceeding levels sustainable by the stock.

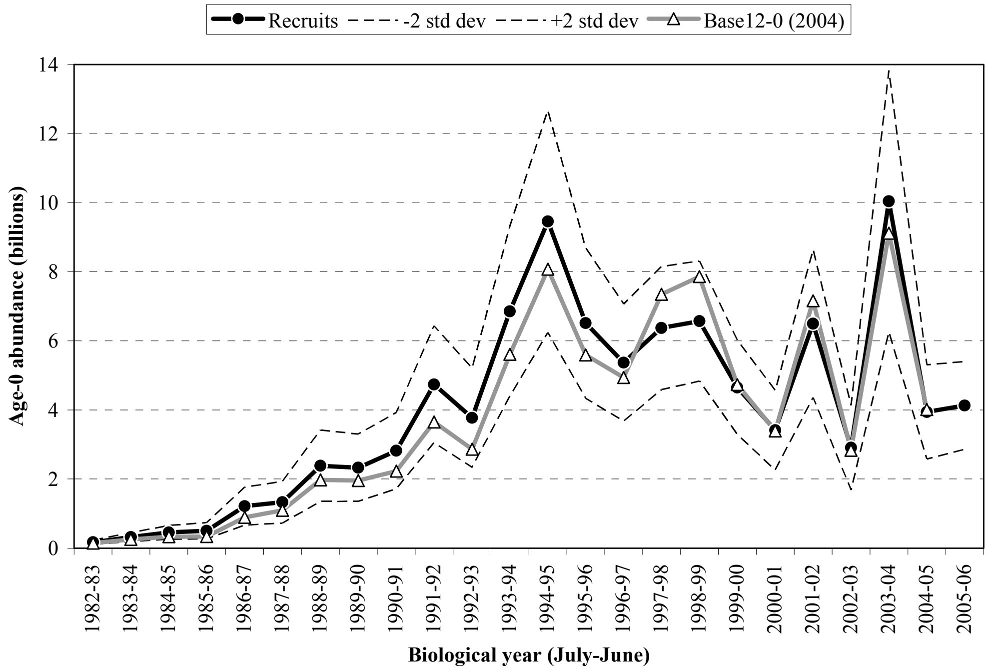


Figure 1. Pacific sardine recruitment estimates (age 0 abundance in billions) from the ASAP baseline model (solid circles) along with a 2-standard error uncertainty envelope (dashed lines). Corresponding estimates from Conser et al. (2004) are shown for comparison (triangles).

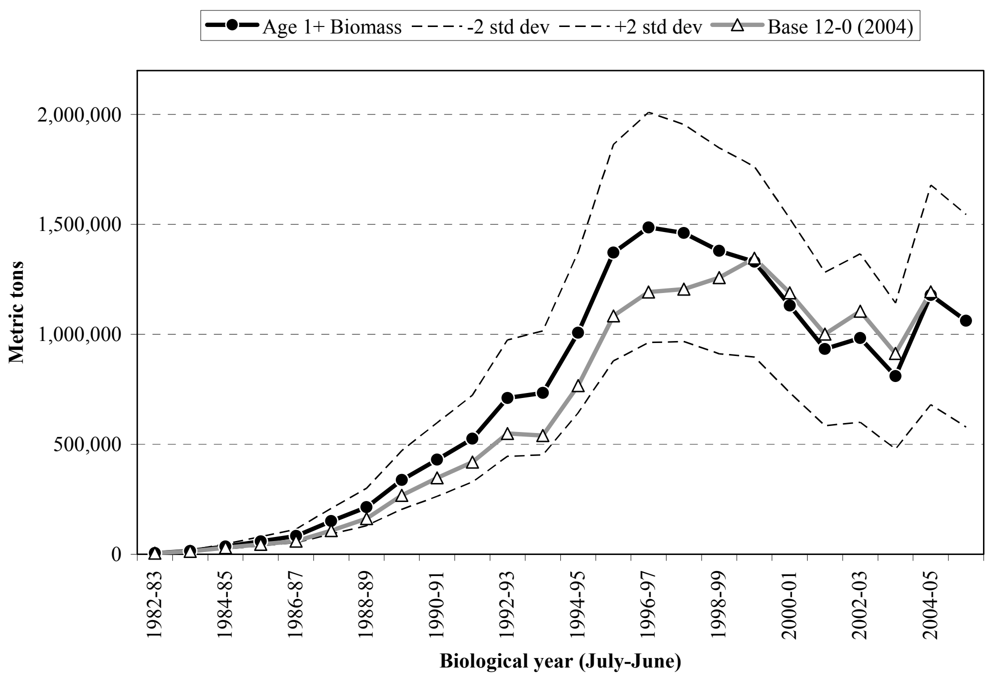


Figure 2. Pacific sardine stock (ages 1+) biomass estimates from the ASAP baseline model (solid circles) along with a 2-standard deviation uncertainty envelope (dashed lines). Corresponding estimates from Conser et al. (2004) are shown for comparison (triangles).

Table 1. Coast-wide harvest (mt) of Pacific sardine for calendar years 1983 through 2004.

Calendar Year	Ensenada, México (mt)	U.S.A. (mt)	British Columbia, Canada (mt)	Total (mt)
1983	274	1	0	274
1984	0	1	0	1
1985	3,722	6	0	3,728
1986	243	388	0	631
1987	2,432	439	0	2,871
1988	2,035	1,188	0	3,223
1989	6,224	837	0	7,061
1990	11,375	1,664	0	13,040
1991	31,392	7,587	0	38,979
1992	34,568	17,950	0	52,518
1993	32,045	15,345	0	47,390
1994	20,877	11,644	0	32,520
1995	35,396	40,327	25	75,748
1996	39,065	32,553	88	71,706
1997	68,439	43,245	34	111,718
1998	47,812	42,956	745	91,514
1999	58,569	60,039	1,250	119,858
2000	67,845	67,985	1,718	137,549
2001	46,071	75,800	1,600	123,472
2002	46,845	96,896	1,044	144,785
2003	41,342	71,864	954	114,159
2004	41,897	89,338	4,259	135,494

OTOLITH TRACE ELEMENTS AND STABLE ISOTOPIC RATIOS IN PACIFIC SARDINES (*Sardinops sagax*): ARE THEY USEFUL FINGERPRINTS FOR IDENTIFYING STOCK STRUCTURE?

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Variability in the physical environment, such as water chemistry and temperature, is likely to be recorded in fish otoliths, providing natural chemical tags to identify stock structure, population movement, and mixing rates. A fundamental assumption of otolith chemistry is that their calcium carbonate matrix is metabolically inert, thus once deposited the concentration of elements will not change. We are assessing the stable isotope ($\delta^{18}O$ and $\delta^{13}C$) and trace element (Mg, P, Mn, Sr, and Ba) chemical composition of *Sardinops sagax* otoliths from wild-caught and cultured young fish to identify factors that might be useful to differentiate populations throughout their geographic range.

Young-of-the-year fish were collected for otolith analysis from Bahia Magdalena (Baja California Sur, Mexico, June-Nov, 2004), San Diego (2003-2005), Oregon-Washington (2003-2004), and Vancouver Island (Canada, Jan. 2005). In addition, young sardines from San Diego were caught and maintained in laboratory tanks for several experiments to determine the effects of diet and growth rate on otolith chemistry (2003-2004). One experiment quantified the effects of three diets: (1) commercial pellets (a mixed, balanced diet), (2) frozen copepods, and (3) frozen squid. Another experiment compared growth effects in a sample of pellet-fed juveniles that were of uniform size at the time of capture.

Stable isotopes ($\delta^{18}O$ and $\delta^{13}C$): In the 5-month feeding experiment, no significant differences in $\delta^{18}O$ signatures were detected, but $\delta^{13}C$ varied slightly with both diet and time. The most pronounced differences in stable isotope ratios were observed in coast-wide comparisons from samples across the geographic range of the sardines (Figure 1). The carbon and oxygen isotope ratios co-varied as expected, but the $\delta^{18}O$ signatures of the Pacific Northwest sardines were predicted to be higher than those of fish from Southern California and Mexico based on environmental temperature. A possible reason for the lower $\delta^{18}O$ signatures in the Pacific Northwest samples may be related to low salinities in the Columbia River plume. Further analyses of $\delta^{18}O$ signatures in a broader collection of juvenile sardines are necessary to determine whether this chemical tag will be useful for identifying populations.

Trace elements: Using solution-based inductively coupled plasma-mass spectroscopy (ICP-MS), elemental concentrations of dissolved otoliths were compared to otolith weight. In the growth experiments, Ba/Ca and Sr/Ca ratios were relatively stable over time with little effect of diet or growth. Mn/Ca ratios increased with otolith weight, indicating the otoliths preferentially took up Mn during growth. Mg/Ca ratios were high in small juveniles, but those ratios decreased with growth (Figure 2). The decrease in the Mg/Ca ratios with otolith size was not predicted from the theoretical ratio expected if no further Mg was trapped in the otoliths as they grew, indicating that Mg was probably labile. P/Ca ratios also decreased with otolith size, suggesting that P was also probably labile. Such losses in elements have not been reported before in fish otoliths.

In the coast-wide comparison of trace element ratios in otoliths, Mg/Ca ratios appeared to decrease with otolith size in California and Pacific Northwest sardines, but not in fish captured in Bahia Magdalena (Figure 3). A similar pattern for both P/Ca and Ba/Ca ratios was observed in the coast-wide comparison. No smaller juveniles from Mexico were available in this survey to determine whether the same decreasing trends occur in the southern stocks. A comparison of Mg/Ca and P/Ca ratios in otoliths of juveniles from the Pacific Northwest showed these two components co-varied ($R^2 = 0.796$; Figure 4). It is likely both Mg and P are not tightly bound in the otolith cores in these sardines. The loss of Mg and P from the otolith core counters the basic assumption that the microchemistry of these structures is an inert record of fish life history.

Statistical comparisons of the Sr/Ca, Ba/Ca, and Mn/Ca ratios of the otoliths in the coast-wide survey (Figure 5) indicate that trace element analysis may be a useful tool for differentiating the geographic origin of the juvenile signals in otolith cores in spite of the limited utility of Mg and P as trace constituents.

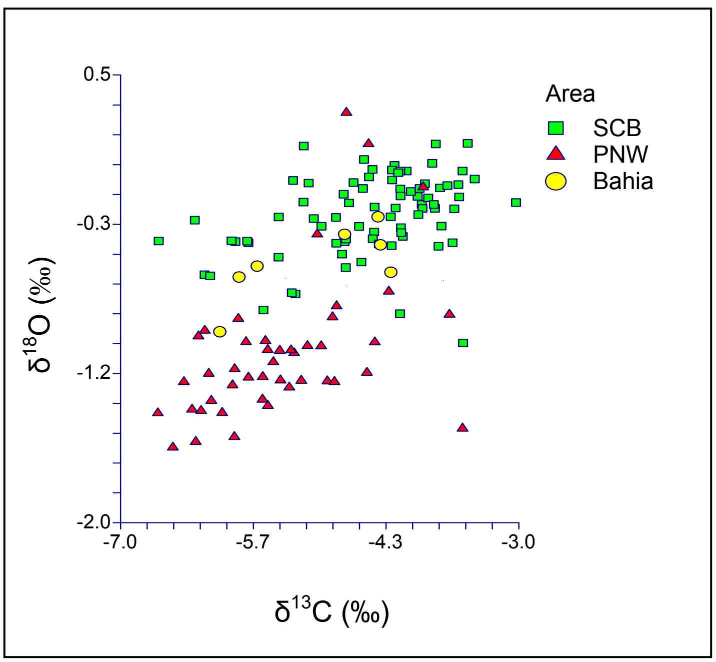
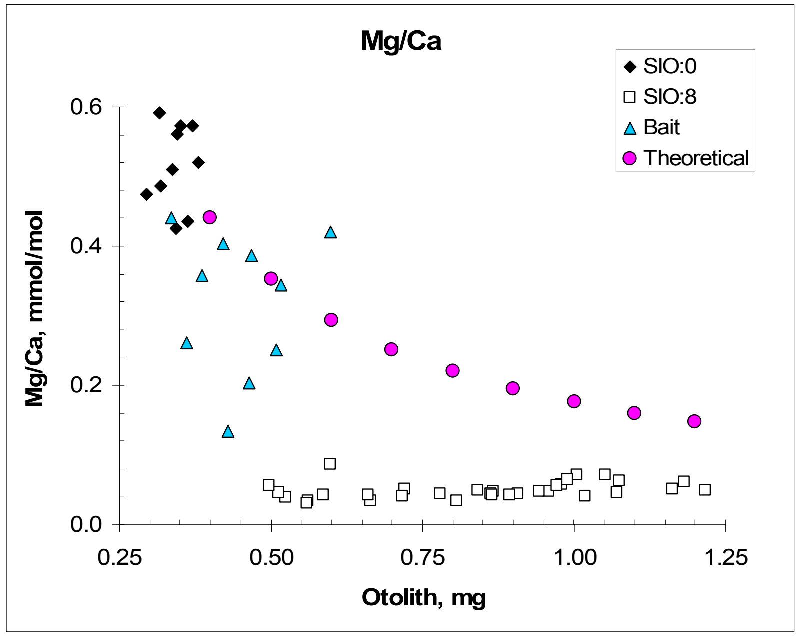


Figure 1. Stable isotope compositions of young-of-the-year sardine otoliths from three geographical areas: Southern California Bight (SCB, squares), Pacific Northwest (PNW [Oregon and Washington], triangles), and Mexico (Bahia Magdalena, Baja California Sur, circles).

Figure 2. Mg/Ca ratios vs. otolith weight of juvenile sardines collected in Nov. 2004 in San Diego and maintained for 8 mos in an aquarium. The initial juveniles were of similar size (67.3 ± 3.7 mm standard length; diamonds). After 8 mos on the pellet diet, they ranged in size from 71-142 mm (squares). The theoretical Mg/Ca ratios (circles) are those expected if no further Mg was incorporated into the growing otoliths (based on the average ratio of Time 0 fish). San Diego bait sardines (triangles) collected in Feb. 2005 are shown for comparison.



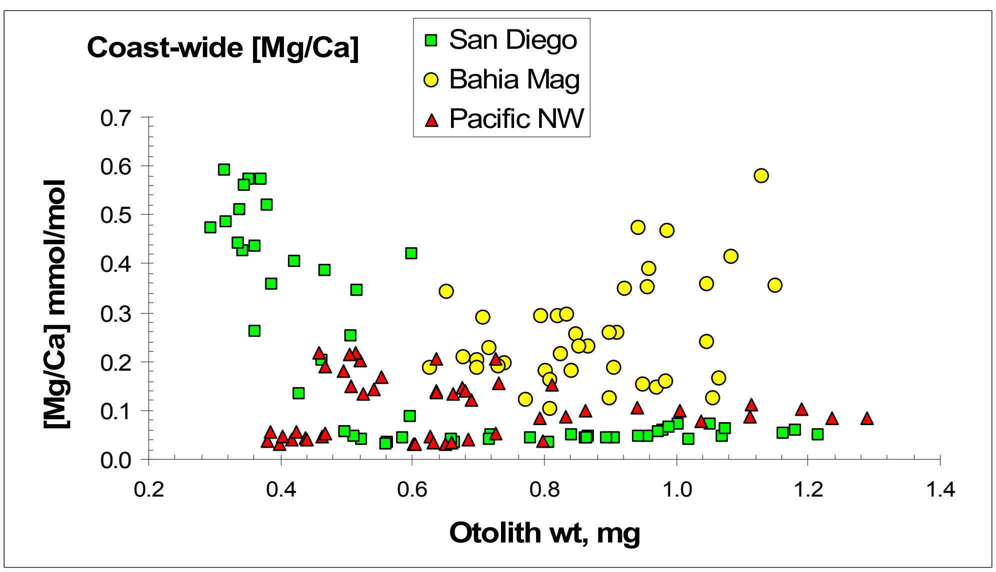


Figure 3. Mg/Ca (mmol/mol) ratios vs. otolith weight in young-of-the-year sardine otoliths from three geographical regions (same symbols as Figure 1). The data for San Diego (squares) are further detailed in Figure 2. The low ratios in Pacific Northwest sardines (Mg/Ca < 0.1 between otolith weights of 0.35-0.8 mg) were all from one sample (near Newport, OR, in March, 2004).

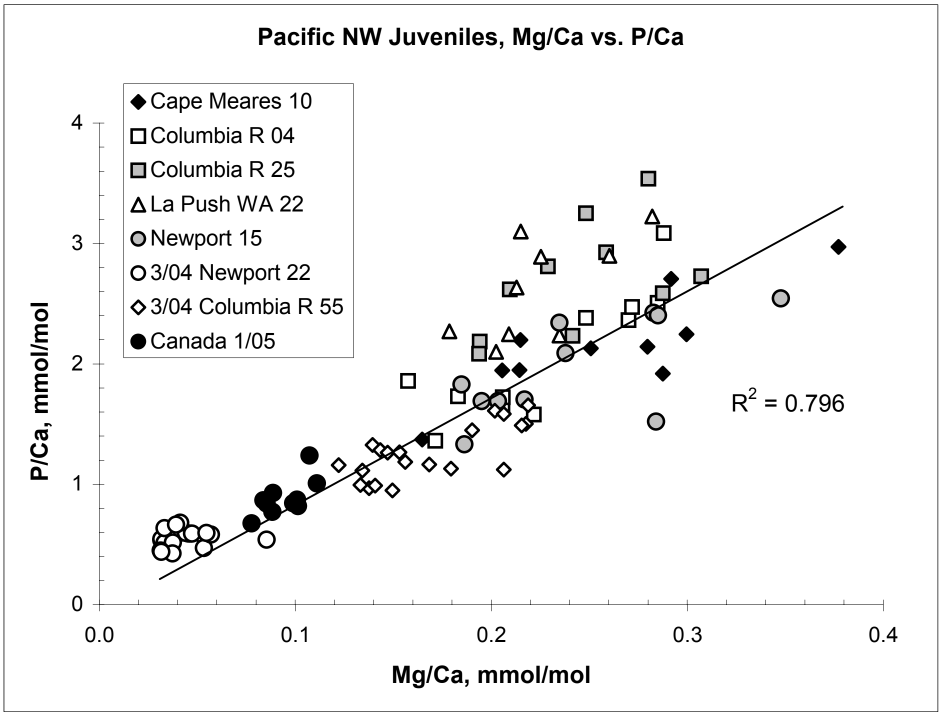


Figure 4. Mg/Ca vs. P/Ca ratios in juvenile sardine otoliths from the Pacific Northwest.

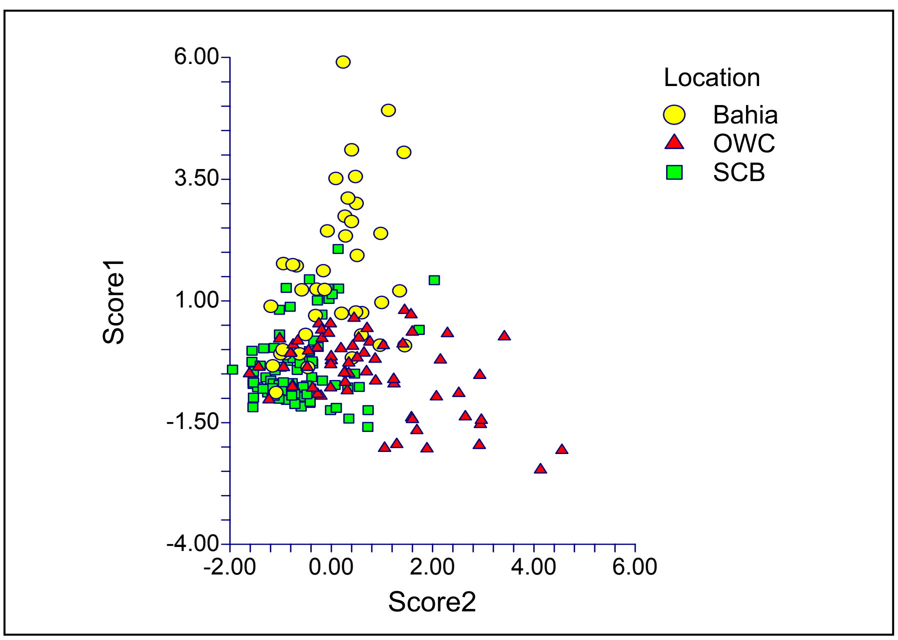


Figure 5. Coast-wide comparison of trace element ratios in juvenile sardine otoliths (Sr/Ca, Ba/Ca, and Mn/Ca only), canonical variates scores. Squares = Southern California Bight; triangles = Pacific Northwest (Oregon, Washington, and British Columbia); Circles = Bahia Magdalena, BCS, Mexico.

CALIFORNIA SEA LION PREDATION ON PACIFIC SARDINE IN THE SOUTHERN CALIFORNIA BIGHT DURING 1981-2002

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California sea lion (*Zalophus californianus*) fecal samples (n = 10,057) collected during summer 1981 through spring 2002 from rookeries at Santa Barbara Island, San Clemente Island, and San Nicolas Island were analyzed to document consumption of prey species by sea lions in the Southern California Bight. Seven primary prey species were identified out of 133 species found in the diet: Market squid (*Loligo oplalescens*), Pacific whiting (*Merluccius productus*), northern anchovy (*Engraulis mordax*), jack mackerel (*Trachurus symmetricus*), shortbelly rockfish (*Sebastes jordani*), Pacific sardine (*Sardinops sagax*), and Pacific mackerel (*Scomber japonicus*). Pacific sardine began to appear consistently in the diet in the 1990's and was negatively correlated (r = -0.47) with the presence of northern anchovy in the diet. Presence of sardine in fecal samples was highly correlated with proportion positive CalCOFI ichthyoplankton tows containing sardine larvae (r = 0.68) and eggs (r = 0.69), and were also correlated with the estimated biomass of age 0 sardine (r = 0.50), age 1 sardine (r = 0.40), age 2 sardine (r = 0.54), age 3 sardine (r = 0.54), and with aerial fish spotter sardine biomass estimates (r = 0.51). Sardine otolith length was measured in 1,853 otoliths and, after correcting for erosion, a regression equation estimated that California sea lions in the SCB consumed sardines between 81 mm and 345 mm standard length, with a mean of 183 mm. Standard length of sardine consumed by sea lions in the SCB were not significantly different between rookery-islands ($P = 0.17$), but there were significant seasonal differences ($P < 0.001$) and significant rookery-island*season interactions ($P < 0.001$).

INITIAL RESULTS FROM FOUR PACIFIC SARDINE (*Sardinops sagax*) SURVEYS OFF THE COASTS OF OREGON AND WASHINGTON

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Surveys

A total of four surveys were completed over a two year period. Two of these were performed during the summers of 2003 and 2004 (July 6 - 25,) and two during the winters of 2004 and 2005 (February 29 - March 19, 2004 and March 2-21, 2005). The basic design of each survey consists of forty-two primary stations positioned on seven transect lines. Each line was spaced sixty miles apart ranging from 42° N to 48° N latitude and extending offshore to 128° W longitude. Stations were spaced at approximately thirty mile intervals. Station activities included a pairovet net tow, a CTD cast to 100 meters, weather observations and a thirty minute surface trawl using a Nordic 264 mid-water trawl with foam core trawl doors. Sardines collected in each trawl were randomly sampled, standard length and body weight were measured, otoliths were collected, and ovaries were preserved. These fish were assigned a maturity code based on a system developed during previous Trinational Sardine Forums (Table 1). In addition, during the summer surveys, the continuous fish egg sampler (CUFES) was used to sample the surface waters for sardine eggs. These surveys benefited by the cooperation and support provided by the Fishing Industry, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, and the Northwest Fisheries Science Center.

Table 1. Gross anatomical classification system for female and male Pacific sardine gonads.

Female - Ovary

1 - Clearly Immature: oocytes not visible, ovary is very small, translucent/clear, and thin but with rounded edges (torpedo shape).

2 - Intermediate: Individual oocytes are not visible to unaided eye (no visible yolk or hydrate oocytes in the ovaries) but ovary is not clearly immature. Includes possible maturing and regressed ovaries.

3 - Active: Yolked oocytes visible, any size or amount as long as you can see them by the unaided eye in ovaries. This includes the smaller opaque oocytes (around 0.4-0.5 mm) to the large yellowish oocytes (about 0.6-0.8mm). If hydrated oocytes are also present, then classify ovary as “4".

4 - Hydrated oocytes present, yolked oocytes may, or not, also be seen; any amount of hydrated oocytes (large and transparent) qualifies for this class from few to many or even if loose or “oozing/running” from ovary.

Male – Testis

1 - Clearly Immature: testis is very small, knife-shaped, translucent/clear, thin with a flat ventral edge

2 - Intermediate: no milt evident and is not a clear immature; includes maturing or regressed testes

3 - Milt is present: either oozing from pore, in the duct, or when testis is cut with a knife

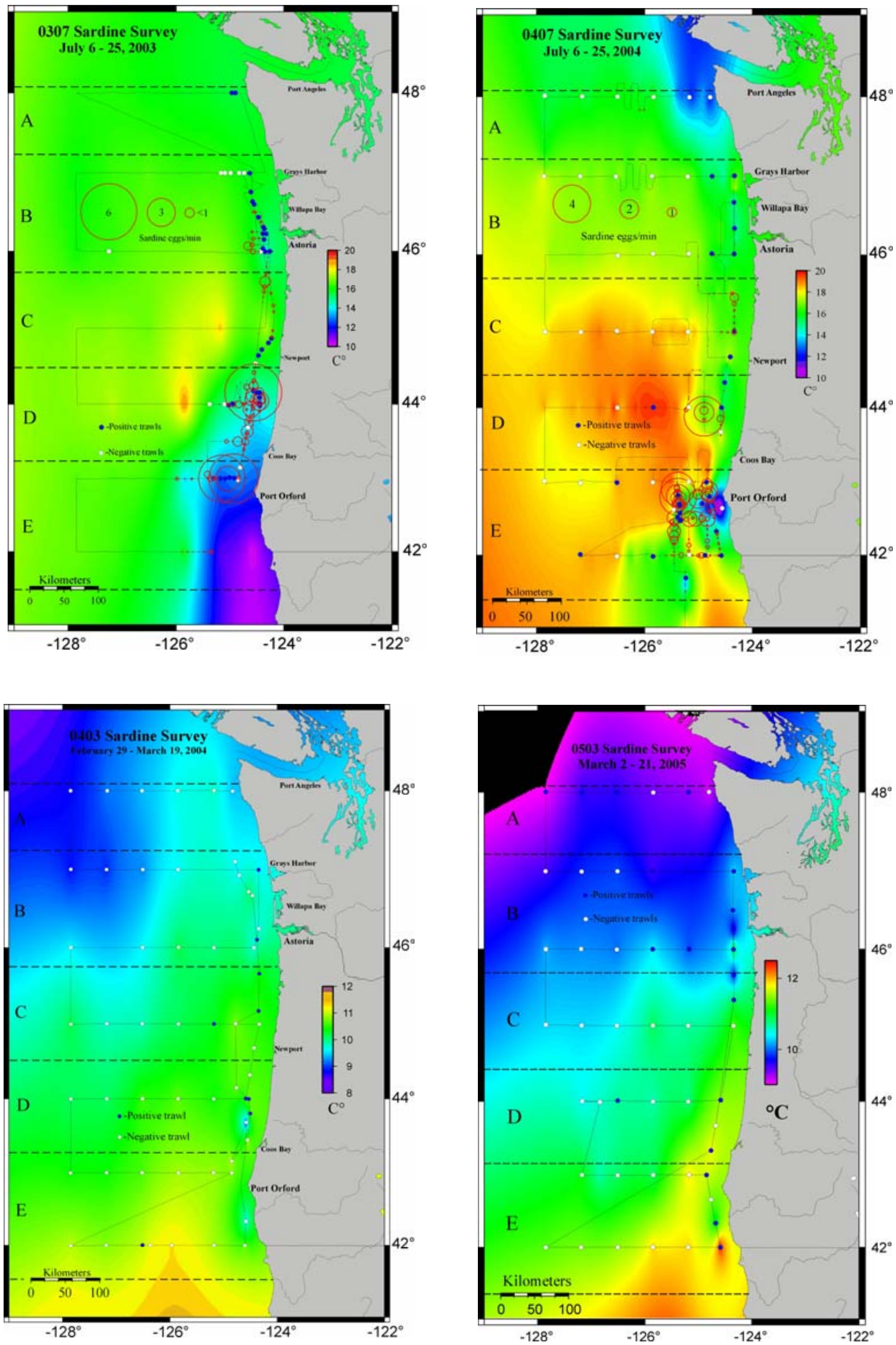

Figure 1. Summer (July) and winter (March) sardine surveys off the Northwest. Maps show sea surface temperature, ship tract-lines, trawl locations, and during the two summer surveys the sardine egg density (eggs/min) in CUFES samples.

Results

A total of 214 surface trawls were successfully completed in which 92 were positive for adult or sub-adult sardine (Figure 1). The average sea-surface temperature of the trawling locations was 15.5°C in July 2003, 10.4°C in March 2004, 16.3°C in July 2004, and 10.6°C in March 2005. Although average sea-surface temperature of trawls was higher during the second year of the surveys, the average sea-surface temperature of positive sardine trawls was similar by season: summer averaged 15.4°C for 36 positive in 2003 and 15.6°C for 27 in 2004; winter averaged 10.4°C for 9 in 2004 and 10.4°C for 20 in 2005.

The majority of sardine eggs, collected in CUFES samples, were found near to the coast and south of Newport, Oregon during both summer surveys (Figure 1). Maximum sardine egg densities measured during the summer off the Northwest (0.85 – 1.144 eggs/minute) were approximately 1% to 2% of the densities seen during April in the southern distribution (40 – 127 eggs/minute).

Sardines were present year round off the Northwest coast. Analysis of sardines measured in the random samples of the trawls indicated that the winter surveys showed almost the complete absence of large sardine such as those seen in the summer surveys (Figure 2). Although sardines have not been aged, it is possible to follow the 2003 year class in the standard length distributions by large peaks at 107 mm SL in 0403, 134 mm in 0407 and about 167 mm in 0503 (Figure 2 and Table 2).

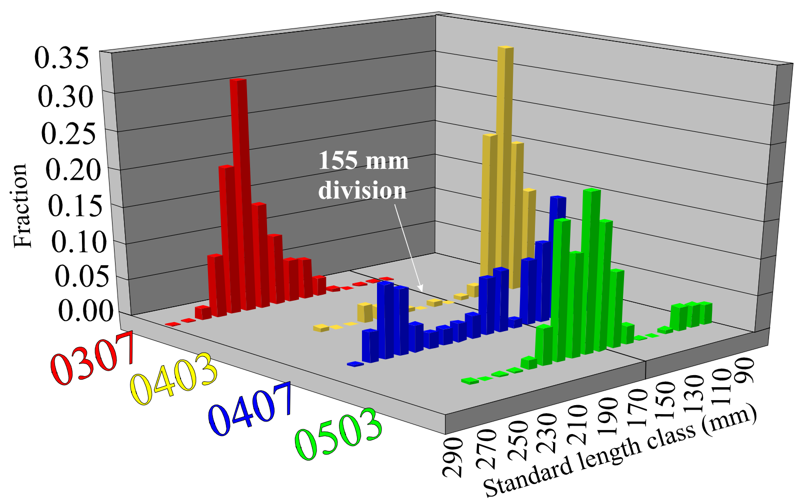

Figure 2. Sardine standard length distribution by 10 mm classes for the trawl random samples in each of the 4 surveys; label indicates midpoint of class and sexes (male, female, and indeterminate) were combined. All sardines below 155 mm (black line) were visually assessed as immature (codes 1) or sex was impossible to determine without a microscope.

Table 2. Mean standard length (SL), and mean fresh whole-body weight (W) percentage below and above 155 mm for the random specimens of Pacific sardine (male, female, and indeterminate) in each research survey.

		Sardines less than 155 mm			**Sardines 155 mm and larger**		
Survey	***N*** total random	%	Mean SL (mm)	mean W (g)	%	Mean SL (mm)	mean W (g)
July 2003 (0307)	1316	0.15	154	50	99.85	235	187
March 2004 (0403)	224	95.1	106	13	4.9	201	102
July 2004 (0407)	713	39.0	134	30	61.0 peak a 28 peak b 33	215 181 243	148 82 205
March 2005 (0503)	520	22.5	123	24	77.5 peak a 45 peak b 32	177 167 189	64 53 79

Maturity analysis of females in the random samples indicated that female sardines were larger and a larger percent were mature (histological verification) during the July surveys (Table 3) than the March surveys. If the random specimens in a trawl did not contain 25 possible mature females (visual codes 2, 3 and 4) additional "random mature" females were collected. All females verified as mature by histological analysis were further classified by reproductive state (Table 4). A high proportion of the mature females were inactive with regressed ovaries and unable to spawn again in the near future during all four surveys, maybe because off the Northwest their main activity is feeding and growth rather than massive egg production. Pacific sardine in the Northwest do spawn during the summer months but the rate is less than their rate off California (0.111 – 0.174 per day). We noted during the second winter that a large warm water protrusion was occurring in the south (Figure 1); in this area some of the mature female sardines had ovaries containing yolking oocytes and were classed as active but non-spawning (i.e. histological analysis determined that they had not spawned within the last 3 days nor were they going to spawn in the next 2 days, otherwise maybe they might spawn in 3days to 3 weeks).

Table 3. Maturity and average size of Pacific sardine females in random samples of trawls conducted during four research surveys off the Northwest.

Survey dates (*N* random females)	**Maturity Class**	**Percent**	**Mean standard length in mm**	**Mean whole body weight in grams**
July 6 – 25, 2003	Immature	0.7	204	124
(690)	Mature	98.3	238	194
Feb. 29-March 19, 2004	Immature	97.2	108	14
(108)	Mature	2.8	207	105
July 6 – 25, 2004	Immature	62.2	147	43
(410)	Mature	37.8	240	200
March 2 – 21, 2005	Immature	89.2	161	51
(241)	Mature	10.8	195	87

Table 4. Reproductive classification and standard length (SL) of mature females caught in each Northwest research survey.

	July 2003	March 2004	July 2004	March 2005
Number of mature females	793	3	214	37
Inactive Fraction	0.628	0.667	0.654	0.703
mean SL	231mm	206mm	236mm	196mm
Active Fraction	0.372	0.333	0.346	0.297
mean SL	249mm	209mm	249mm	221mm
Fraction of mature spawning	0.073	0.0	0.028	0.0
Fraction of active mature spawning	0.197	0.0	0.081	0.0
fraction spawning per day	0.065		0.027	

We examined possible latitudinal trends in Pacific sardine egg production and female reproductive state and surface temperature. The survey area was separated into the following 5 areas:

Zone	Latitudinal Zone °N	Approximate location
A	47.26 to 48.10	La Push, WA
B	45.76 to 47.25	Astoria, OR – Grays Harbor, WA
C	44.51 to 45.75	Newport, OR
D	43.26 to 44.50	Coos Bay, OR
E	41.76 to 43.25	Port Orford, OR

In the southern areas of the July surveys, we found increasing egg densities and a higher active fraction of the mature females (Table 5). In addition the most southern zone (E) with the coldest sea surface temperatures had the highest egg densities and fraction active. The temperatures in this zone are most similar to the temperatures during peak spawning off California.

Table 5. Pacific sardine reproduction and average temperatures[a] by latitudinal zones during July.

July 2003					July 2004			
Zone	ave. ºC Egg samples	Average Egg/min	Fraction active mature	ave.ºC active female	ave. ºC Egg samples	Average Egg/min	Fraction active mature	ave.ºC active female
A	NA	0.022	0.046	15.5	15.9	0.094	0	--
B	16.7	0.174	0.161	15.5	16.2	0.039	0.030	15.7
C	16.5	0.237	0.191	15.7	16.2	0.156	0.205	15.7
D	16.0	0.524	0.661	15.8	16.8	0.454	0.159	15.9
E	14.4	0.654	0.716	14.1	16.2	0.626	0.226	13.6

[a] temperature at location of CUFES samples with sardine eggs were averaged and temperature for each trawl location with active mature females was weighted by the number of active females and averaged

OREGON & WASHINGTON SARDINE FISHERY
2005 PRELIMINARY SUMMARY

Jean McCrae[1] and Michele Culver[2]

[1]Oregon Department of Fish and Wildlife
[2]Washington Department of Fish and Wildlife

In 2005, over 45,119 mt have been landed into Oregon and 6,892 mt into Washington through mid October. The September-through-November allocation for the northern sub-area was reached in mid October and the northern fishery closed until December 1. This year, the first landings occurred in April; although, the fishery didn't get started in earnest until mid-June, which has been the typical starting time in past years. As in the past, August was the peak month of harvest, with September having the second highest.

The main area of catch in 2005 was much farther to the north than in past years. In past years, the majority (59% - 75%) of the harvest activity occurred off Oregon, with the remainder of the activity occurring off Washington as far north as the mouth of Willapa Bay. This year, based on logbook data through mid-September, almost 2/3 of the harvest came from off Washington. Vessels went as far north as the Canadian border to find larger size fish. In general, sardines were much smaller this year than they have been in the past. Larger fish began showing up at the end of the season.

The Washington fishery continues to be managed under their "experimental" fishery designation; 16 permits were issued in 2005. The Oregon fishery is managed under their Developmental Fishery program; 20 permits were issued in 2005. The Oregon Fish and Wildlife Commission will consider in December whether to move the Oregon fishery out of Developmental Fisheries and into a limited entry system.

The websites for tracking each state's landings are:
for Oregon, www.dfw.state.or.us/mrp/finfish/cps.asp;
and for Washington, wdfw.wa.gov/fish/commercial/sardines/index.htm

AGE STRUCTURE, GROWTH AND BIOMASS OF THE PACIFIC SARDINE FROM THE SOUTH CALIFORNIA TO BAHIA MAGDALENA (MEXICO)

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[3]Instituto Nacional de la Pesca, El Sauzal, BC, México.

On the basis of the existence of three stocks of Pacific sardine (*Sardinops sagax*) along the eastern Pacific coast, from the south of California (San Pedro) until Bahia Magdalena, B.C.S., the data of standard length (SL), age, and biomass estimation were analyzed. The series of data analyzed were: from 1983 to 2002 for San Pedro, from 1989 to 2002 for Ensenada, B.C., and from 1981 to 2002 for Bahia Magdalena. The sardine lengths varied from 138 to 231 mm SL and were assigned to up to 8 age groups. A positive gradient in average size by age from the south was detected and it was more evident when it was considered for stock. The same pattern was observed in the individual growth (von Bertalanffy). The biomass was estimated (VPA) for two of the stocks, for the cold stock (south of California to Ensenada) and for the temperate stock (Ensenada to Bay Magdalena). A constant increment was detected in the biomass up to 1999 (316,000 t) for the cold stock and up to 1996 (398,000 t) for the temperate stock and later on the biomass descended to 238,000 t (cold stock) and 217,000 (temperate stock) for the 2000.

ESTRUCTURA POR EDADES, CRECIMIENTO Y BIOMASA DE LA SARDINA DEL PACIFICO DESDE EL SUR DE CALIFORNIA (EUA) A BAHIA MAGDALENA (MEXICO)

C. Quiñonez-Velázquez[1], R. Félix-Uraga[1], F. N. Melo-Barrera[1], K. T. Hill[2] y W. García-Franco[3]

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Bajo el supuesto de la existencia de tres grupos poblacionales (stocks) de sardina del Pacifico (*Sardinops sagax*) en la costa oriental del Pacifico, desde el sur de California (San Pedro) hasta Bahía Magdalena, BCS, se analizan los datos de longitud estándar (LE), edad y se estima la biomasa por stock. La serie de datos analizada para San Pedro incluye los años de 1983 a 2002, para Ensenada, BC, de 1989 a 2002 y para Bahía Magdalena de 1981 a 2002. La talla de la sardina varió de 138 a 231 mm y se asignaron hasta 8 grupos de edad. Se detectó un gradiente positivo de sur a norte (zona de pesca) de la talla promedio por edad y fue más evidente cuando se estimó por stock, el mismo patrón se observó en el crecimiento individual (von Bertalanffy). Se estimó la biomasa (APV) para dos de los stocks, para el stock frío (sur de California a Ensenada) y para el templado (Ensenada a Bahía Magdalena). Se detectó un incremento constante en la biomasa hasta 1999 (316,000 t) para el stock frío y hasta 1996 (398,000 t) para el stock templado y posteriormente la biomasa descendió a 238,000 t (stock frío) y 217,000 (stock templado) para el 2000.

THE FISHERY OF PACIFIC SARDINE IN MAGDALENA BAY, 2003-2005

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From January 2003 to October 2005 in Bahia Magdalena, B.C.S. 2,453 fishing trips were carried out and 139,200 t of sardine was captured (all the species), of which 83% was of Pacific sardine *Sardinops sagax*. The rest of the catch was represented by the thread herring *Opisthonema spp.* with (12%), anchoveta *Cetengraulis mysticetus* (2%), round herring *Etrumeus teres* (2%) and macarela *Scomber japonicus* (0.4%).

The Pacific sardine was fished in every month of the year, except in January 2004. A change was observed in the seasonality of the yields of the fishing, where the months of bigger capture of Pacific sardine went from April to October during 2003 (>4,000 t/month), from July to November during 2004 (>3,000 t/month) and from March to July during 2005 (>4,000 t/month). The thread herring was hardly caught at all during the second half of 2004 and it represented 20% of the catch. It was practically absent in 2005 (0.6% of the capture), while the capture of anchoveta increased significantly (12%).

Eighty-five percent of the Pacific sardine lengths were less than 150 mm SL during 2004, and from July to December 100% of the sardines were smaller than 150 mm SL. The age-1 fish were predominant from February to May. In June of 2004, the fish we sampled exhibited a wider range of sizes and ages than the rest of the year. Two modes in length were identified: one less than 150 mm and one greater than 150 mm SL. The age-2 fish were dominant. During the second half of the year the sizes were less than 150 mm, and age-0 fish were most prevalent. This pattern in the structure of sizes and age continued until April 2005, after which the percentage of the smallest sardines decreased up to 17% in September, similar to the pattern observed during 2003.

Nevertheless, even with this reduction in the average size of the Pacific sardine during the last two years, a similar decrease has not been detected in the catch. The predominance of small fishes (age-0) may be associated with reproductive success in 2004.

LA PESQUERIA DE SARDINA DEL PACIFICO EN BAHIA MAGDALENA

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Desde enero 2004 a septiembre 2005 se realizaron 1,331 viajes de pesca en Bahía Magdalena, B.C.S. y se capturaron 77,705 t de sardina (todas las especies), de las cuales el 83% fueron de sardina del Pacifico *Sardinops sagax*. El resto estuvo representado por la sardina crinada *Opisthonema* sp con (12%), bocona *Cetengraulis mysticetus* (2%), japonesa *Etrumeus teres* (2%) y macarela *Scomber japonicus* (0.4%).

La sardina del Pacifico se pescó en todos los meses del año, excepto en enero 2004. Se observó un cambio en la estacionalidad de los rendimientos de la pesca, los meses de mayor captura de sardina del Pacifico fueron de julio a noviembre durante 2004 (>3,000 t/mes) y de marzo a julio durante 2005 (>4,000 t/mes). La crinuda, prácticamente no se capturo durante la segunda mitad del 2004 y representó el 20% de la captura y estuvo prácticamente ausente en 2005 (0.6% de la captura).

El 85% de las tallas de la sardina Monterrey en Bahía Magdalena durante 2004 estuvieron por debajo de 150 mm LE, de julio a diciembre el 100% de las sardinas tuvieron talla menor a 150 mm de LE. El grupo de edad 1 fue el predominante de febrero a mayo. En junio se registro el intervalo de tallas y edades mas amplio del año con dos modas en talas bien definidas una en tallas menores a 150 mm y la otra en tallas mayores a 150 mm LE, el grupo-2 de edad fue dominante. Durante la segunda mitad del año las tallas fueron menores a 150 mm de LE predominando los individuos del grupo-0. Este patron en la estructura de tallas y edad continúo hasta abril de 2005, posteriormente el porcentaje de sardinas menores a 150 mm LE se redujo hasta 17% en septiembre.

No obstante esta reducción en la talla promedio de la sardina Monterrey durante los últimos dos años no se ha detectado una disminución en su captura. Posiblemente la dominancia de organismos pequeños sea el resultado de clases anuales fuertes.

GROWTH OF JUVENILE PACIFIC SARDINE (*Sardinops sagax*) IN THE CALIFORNIA CURRENT IN 2004 – 2005

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Growth rates and hatch dates of early juvenile Pacific sardine (*Sardinops sagax*) were estimated from daily increments of otoliths. I compared values for late juveniles and pre-recruits in the 2004 year class. Early juveniles (60 – 70 mm SL) were collected by beach seine at La Jolla Shores, San Diego, in November, 2004. Hatch date distributions of the early juveniles ranged from late May to early June. Mean width of otolith increments (IW) increased to ca. 8 µm at 70 days after hatching (d), and then decreased to 2.3 ± 0.7 µm at 150 d. The late juveniles (110-159 mm SL) and pre-recruits (160-185 mm SL) were obtained from CalCOFI cruise 0504 JD, which was conducted in offshore waters from San Diego to San Francisco. IWs of fish collected as late juveniles and pre-recruits increased similarly as IWs for fish collected as early juveniles up to age 70 d, and thereafter decreased to 3.9 ± 1.1 µm at age 150 d for fish collected as late juveniles and to 4.1 ± 0.7 µm for fish collected as pre-recruits. The pre-recruits had the widest IWs during the juvenile (> 70 d) stage for fish collected in all three developmental stages. These data indicate that faster growing juveniles of the Pacific sardine survived longer and had greater probability of successful recruitment to the adult stage than slower growing juveniles.

ANALYSIS OF CARBON AND OXYGEN STABLE ISOTOPE RATIOS OF OTOLITHS OF YOUNG SARDINES IN MEXICAN WATERS: TOWARD THE CHARACTERIZATION OF STOCK STRUCTURE AND MIGRATION PATTERNS

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The relative abundance of the stable isotopes of carbon and oxygen ($\delta^{18}O$ and $\delta^{13}C$) in the otolith carbonate of teleost fishes can be used to reconstruct some of the environmental characteristics to which individuals are exposed during their life cycle. We measured $\delta^{18}O$ and $\delta^{13}C$ in the otoliths of young (< 1.5 yrs) Pacific sardines (*Sardinops sagax caeruleus*) collected in Mexican waters to evaluate whether they can be used as natural tracers of natal origin and migration patterns and to evaluate stock structure. Samples were collected in the Pacific (Ensenada, Isla de Cedros, Bahia Magdalena) and the Gulf of California (Cabo Tepoca, Bahia de los Angeles, Santa Rosalia) between May and June of 2004 (Group 1 samples). To evaluate whether there was temporal variability in otolith $\delta^{18}O$ and $\delta^{13}C$, additional samples were collected in the Pacific between October 2004 and February 2005 and in the Gulf between December 2004 and April 2005 (Group 2 samples). Estimates of the sea surface temperatures (SST) to which each sampling population was exposed were derived from satellite-based measurements averaged over the time period corresponding to otolith-based ages. Otoliths from ten individuals per location and time were processed using standard methods and analyzed for $\delta^{18}O$ and $\delta^{13}C$.

There were differences in the $\delta^{18}O$ and $\delta^{13}C$ of fishes collected in the Pacific and Gulf of California. For the Pacific, highest average $\delta^{18}O$ values (0.31 ± 0.33 ‰, mean ± sd) were found in fishes collected in Ensenada in June 2004. The lowest average value was found for Bahia Magdalena samples during the same time of year (-1.66 ± 0.47‰). There was an inverse relationship between $\delta^{18}O$ values and SST estimates for all fishes collected in the Pacific, which agrees with theoretical predictions ($r^2 = 0.64$). In contrast, there was a low correlation between SST estimates and $\delta^{18}O$ values of sardines captured in the Gulf ($r^2 = 0.28$). This may be attributed to a lower range of average SST estimates for the central Gulf of California (20.9-24.3 ^oC) compared to the Ensenada-Bahia Magdalena region of the Pacific (15.1-20.1 ^oC).

For $\delta^{13}C$, the lowest values (-5.93 ± 0.59‰) corresponded to fishes captured in Isla de Cedros in February of 2005, while the highest values were found in December of 2004 in Ensenada (-4.11 ± 0.37‰). For both the Pacific and Gulf samples, there was a low correlation between SST and $\delta^{13}C$ ($r^2 = 0.06$ and 0.23, respectively). This probably reflects the influence of metabolic and growth rate variations on otolith $\delta^{13}C$ values.

Based on a 1-way Analysis of Variance (ANOVA) of Group 1 fishes, there was a significant difference in $\delta^{18}O$ values among sampling populations ($F = 48.77$, $p<0.0001$). The same analysis applied to Group 2 fishes did not yield differences among populations ($F= 1.45$, $p = 0.225$). Nevertheless, when all samples were analyzed, there were significant differences in $\delta^{18}O$ between Pacific and Gulf samples ($F = 11.32$, $p<0.000$). Likewise, ANOVA results of $\delta^{13}C$ values indicated that there were significant differences among groups as well as regions (Group 1: $F=20.82$, $p <0.0001$; Group 2: $F=11.83$, $p< .0001$). Interestingly, the otoliths of samples collected in Bahia Magdalena in May and October 2004 were significantly different in their $\delta^{18}O$ and $\delta^{13}C$ values, suggesting that these two sampling populations were exposed to different environmental conditions during growth.

Principal Component Analysis was used to evaluate whether it was possible to distinguish among sampling populations. Otolith $\delta^{18}O$ and $\delta^{13}C$, standard length, age, otolith length and weight, salinity and sampling date data for all locations and dates were included in the analysis. PCA results indicated a clear separation between Pacific and Gulf samples, although the data corresponding to fishes collected in Bahia Magdalena in October 2004 formed an additional group. The first principal component explained 36.17% of the variability (variable loadings were otoliths weight: 0.18, SST: 0.17, age: 0.16), while the second explained 23.38% (variable loading were sampling date: 0.27, salinity: 0.17). The stable isotopes of oxygen and carbon loaded significantly on the third principal component (0.44 and 0.24, respectively). Hence, most of the group separation observed in the analysis was attributed to differences in size at age and environmental conditions, and not to otolith stable isotope ratios. Nevertheless, the existence of differences in otolith $\delta^{18}O$ and/or $\delta^{13}C$ values among fishes captured in different areas of the Mexican Pacific suggests that stable isotope analyses of sardine otoliths could potentially be used to characterize natal origin and migration patterns among regions such as Bahia Magdalena, the Pacific and the Gulf of California.

PRELIMINARY RESULTS ON THE USE OF OTOLITH ELEMENTAL ANALYSIS TO IDENTIFY NATAL ORIGIN, MIGRATION PATTERNS AND STOCK STRUCTURE OF PACIFIC SARDINES IN MEXICAN WATERS

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Otoliths are small stones located in the inner ear of bony fishes that are involved in sound detection and balance, and which are comprised mostly of calcium carbonate. They grow throughout life by periodic ring formation. During otolith growth, certain elements are incorporated from the surrounding water and/or food sources. Individuals whose otoliths formed under differing environmental conditions may thus exhibit distinguishable elemental signatures. A promising approach in the measurement of otolith trace elements is Laser Ablation Inductively Coupled Plasma Mass Spectrometry. LA-ICPMS uses a laser to target specific areas of an otolith to obtain minute subsamples of material corresponding to different stages of the life cycle of an individual. The use of laser ablation has the potential to be of aid in the identification of natal origin, migration patterns and stock structure of teleost fishes.

We evaluated whether the abundance of specific elements in otoliths of Pacific sardines (*Sardinops sagax caeruleus*) captured in Mexican waters varies as a function of life cycle stage by comparing the elemental composition of the nucleus (representing the larval stage) with the otolith margins (corresponding to time before capture) at the individual level. In addition, we compared the elemental composition of the otolith margins of young sardines captured in various locations between May 2004 and May 2005 to evaluate whether elemental analysis of otoliths has potential for differentiating among sardine subpopulations.

We collected sardines in 12 locations in 4 major regions within the known areas of distribution of Pacific sardine in Mexican waters (Ensenada to the Gulf of California). Most locations were sampled twice within a one-year period. All individuals were less than 1.5 yrs of age based on otolith ageing. Otoliths from ten sardines were analyzed for each time and location. Otoliths were processed and cleaned using standard methods, polished to reveal the core, recleaned and analyzed using a New Wave UP 213-nm laser ablation unit attached to a Thermoquest Finnigan Element 2 – ICPMS at Scripps Institution of Oceanography in La Jolla, California. Ablations were made within the nucleus (n=2) and 100 um from the margin (n=2). NIST Reference Materials 612, 614 and 616 were sampled at the beginning and end of each day and used to standardize for machine drift and among-day variations. Elemental abundances were standardized to ^{48}Ca. Here, we report the standardized abundance of the following isotopes: ^{24}Mg, ^{26}Mg, ^{55}Mn, ^{86}Sr, ^{88}Sr, ^{118}Sn, and ^{138}Ba.

No differences were found among replicate standardized abundances of target isotopes within either the nucleus or otolith margins (Student's t test $p > 0.05$). Data corresponding to each otolith nucleii and margin was therefore averaged and the site- and time-specific mean ± sd of each elemental concentration calculated.

Samples from Ensenada (December 2004), Isla de Cedros (February 2005) and Bahia Magdalena (May 2004) did not exhibit significant differences between the nucleus and margins for any target isotopes (Wilcoxon Matched Paired test, $p > 0.05$). There were significant differences in at least some elemental abundances measured in the nucleii and margins in samples collected at these three locations at other times. Likewise, there were significant differences among at least some elements for samples collected within the Gulf of California (Bahía de Los Angeles, Santa Rosalía and Cabo Tepoca from May 2004 and Guaymas from May 2005), except for those collected in Punta Borrascosa (December, 2004). This suggests that the composition of sardine otoliths can reflect variations in the abundance of elements in the environment through time and/or ontogenetic effects.

There were differences in standardized abundances of some of elements measured in otolith margins for samples collected in different locations. For example, the $^{138}Ba/^{48}Ca$ ratio of samples collected in Ensenada, Isla de Cedros and Bahia Magdalena exhibited significant differences among locations (1-Way ANOVA; $F = 6.49$ $p = 0.00010$). In contrast, there were no differences in $^{138}Ba/^{48}Ca$ among Gulf samples ($F = 0.34$ $p = 0.88$). Moreover, margin $^{138}Ba/^{48}Ca$ of sardines collected in Bahía Magdalena in October 2004 differed significantly from that of other sardines captured in the Pacific (HSD test $p = 0.024$), and had similar values to those of individuals collected in the Gulf of California (HSD test $p = 0.80$). In contrast, $^{138}Ba/^{48}Ca$ ratios from individuals captured in Bahia Magdalena in May 2004 were similar to those of fishes collected in the Pacific at about the same time. This suggests that otoliths from the two populations of sardines sampled in Bahia Magdalena formed under different environmental conditions conditions, and may have different natal origins.

A Discriminant Function Analysis that included the standardized ratios of all isotopes analyzed was performed to evaluate whether groups of sardines with different compositions could be discerned based on their capture location. There was a clear separation of the elemental composition of fishes captured in the Gulf and Pacific. In addition, when Pacific samples were analyzed separately, the individuals from Bahia Magdalena collected in October 2004 could be clearly discriminated. The results obtained thus far suggest that subsequent studies using LA-ICPMS could potentially be used to evaluate whether there is migration among the Pacific, Gulf of California and Bahía Magdalena, and potentially identify the natal origin of fishes from these areas.

THE PELAGIC FISHERY IN BAJA CALIFORNIA

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The total catches for 2004 were 47,709 metric tons; 1,797 for anchovy; 1,529 Pacific mackerel; and 44,382 for Pacific sardine. The most important period was from August to November, with a peak in the month of October of 8,180 metric tons (Figure 1).

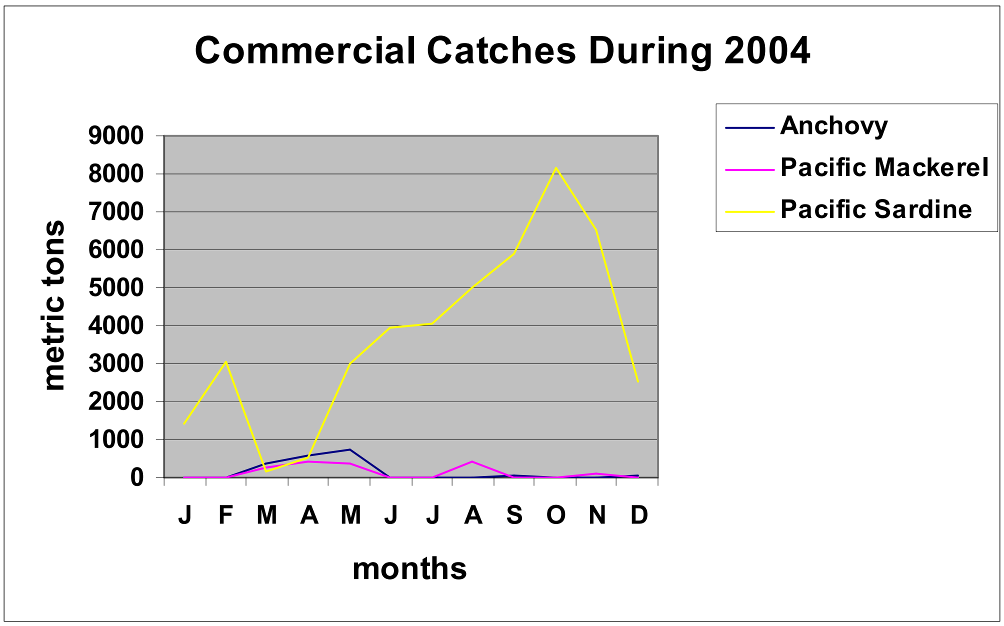

Figure 1

APPENDIX IV

Report for Working Group 1, Trinational Sardine Forum, November, 2005

SPAWNING BIOMASS ESTIMATES FOR THE PACIFIC SARDINE (*Sardinops sagax caeruleus*) OFF BAJA CALIFORNIA, MÉXICO, DURING APRIL, 2002, AND APRIL, 2003

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ABSTRACT

The Daily Egg Production Method (DEPM) was used to estimate spawning biomasses of the Pacific sardine off northern and central Baja California (*Sardinops sagax caeruleus*) with data collected from IMECOCAL cruises during April, 2002, and April, 2003. The DEPM analyses were restricted to the area of spawning stock that is a southern extension of the stock found off Alta California (USA) so that comparisons can be reasonably drawn between biological parameters of the two regions. Ichthyoplankton data used in this study were obtained from egg densities collected by the CUFES (Continuous Underway Fish Egg Sampler) system and CalVET net tows from the R/V *Francisco de Ulloa*. The adult parameters were estimated from biological sampling of the landings made from the area around Ensenada. The estimate of spawning biomass off Baja California for 2002 is significantly higher than that for 2003, and is associated with correspondingly higher egg production and larger spawning area of the targeted stock. Our mid-range estimates of the spawning biomasses are approximately 48,000 ± 30,500 metric tons for April, 2002 and 9,200 ± 5,900 metric tons for April, 2003.

One of the goals of this study has been to identify the uncertainties in the DEPM that result from the current practices in the ichthyoplankton collection and analyses from the IMECOCAL cruises, and from the limitations in collection of the adult reproductive parameters. Based on the analyses in this study we strongly recommend that the IMECOCAL surveys integrate a procedure of adaptive sampling with CalVET net tows based on the occurrence of sardine eggs in the CUFES samples. It is also imperative that steps be taken to insure annual adult samples from the offshore areas to provide more realistic estimates of the adult reproductive parameters.

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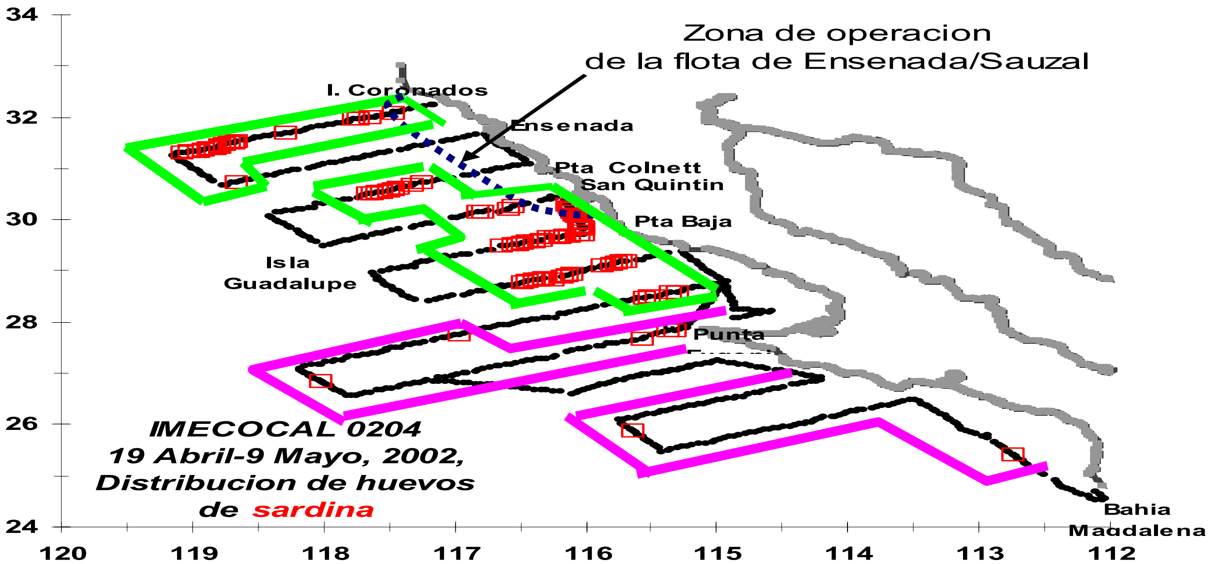
1. Introduction

The Daily Egg Production Method (DEPM; Lasker, 1985) has been used by the Southwest Fisheries Science Center (NOAA-NMFS) each year since 1994 to estimate spawning biomasses of the Pacific sardine in the region from San Francisco to the Mexican border during the springtime CalCOFI cruises (Lo et al., 2005a). The springtime cruises are centered on the month of April and are presumed to capture the peak of the sardine spawning off California. DEPM estimates of spawning biomass require both egg production estimates from ichthyoplankton survey data plus reproductive parameters from adult females. The initial 1994 biomass survey was undertaken with collaboration of Mexican fisheries scientists and included collection of ichthyoplankton and adults off central and northern Baja California as well as off California (Lo et al., 1996).

Since that initial 1994 study, there have been no estimates of sardine biomass off Baja California using DEPM except for a preliminary attempt using ichthyoplankton data from the April, 2002, IMECOCAL survey with rough estimates of egg production and adult parameters. The results were included in the report of Working Group 2 of the 2004 Trinational Sardine Forum (Lo et al., 2005b). Note that the installation of a CUFES system on board the CICESE vessel *Francisco de Ulloa* in 2000 along with CalVET tows at each of the IMECOCAL stations have made the application of the DEPM feasible off Baja California although the method is still limited by uncertainty in the calibration between CUFES and CalVET measures, and the means of collection of adults. The biomass estimates were initiated with data from April, 2002 since the trackline coverage of the April surveys of 2000 and 2001 were incomplete. To complement the ichthyoplankton surveys, CICESE also began a program of regular monitoring of sardine landings in 2002 to obtain estimates of reproductive parameters.

This study is designed to reveal the principal uncertainties in the DEPM that result from current practices in the ichthyoplankton collection and analyses from the IMECOCAL cruises and the limitations in collection of adult parameters off Baja California. Identification of these uncertainties in the biomass estimates points to additional efforts needed to provide a complete set of ichthyoplankton and adult information in a program of biomass evaluation for Pacific sardine (and other species) off Baja California. A specific objective of this study is to improve the initial effort of the biomass estimate of April, 2002 and compare it to the biomass estimate for April of the following year, 2003. Results of this study also allow us to compare the biomass estimates off Baja California with the corresponding estimates off Alta California.

The egg concentration data from the IMECOCAL surveys off Baja California collected by CUFES and by CalVET tows aboard the R/V *Francisco de Ulloa* were used to estimate rates of daily egg production of sardines for the spring (April) cruises during 2002 and 2003. The underway CUFES samples along the tracklines of the IMECOCAL surveys are indicated by the black points in Figure 1 with samples positive for sardine eggs plotted as open red squares. Information on the reproductive states of the adult sardines off northern Baja California during these periods is taken from fishery landings in the Ensenada area which operates generally inshore of the principal spawning grounds defined by the IMECOCAL surveys as shown in Figure 1. These data are used in the absence of directed sampling on adults offshore in the areas of egg collections by the IMECOCAL surveys.



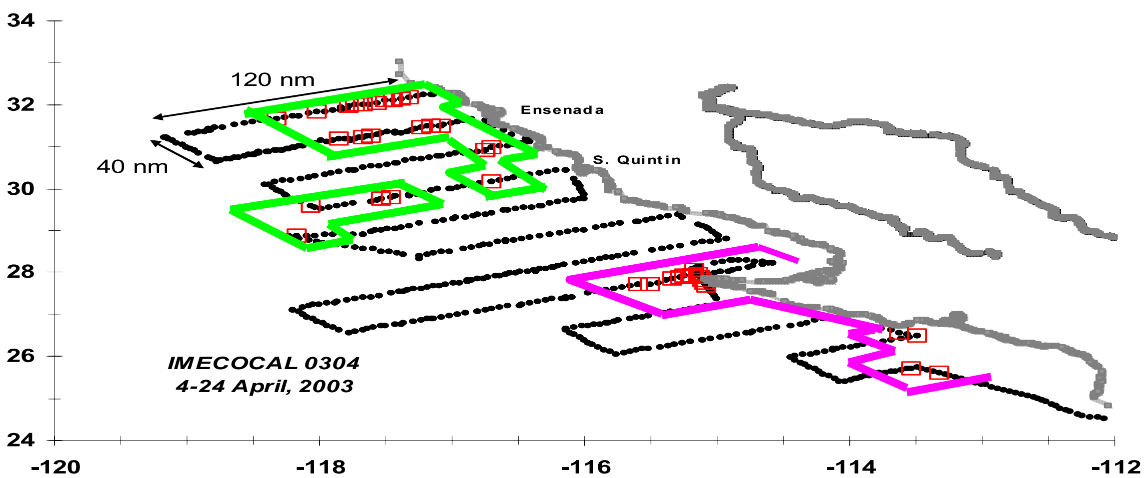


Figure 1. Distribution of positive CUFES samples along IMECOCAL tracklines of April, 2002 and 2003; areas of different sardine spawning groups distinguished by heavy green and magenta boundary lines.

Note that the heavy green and magenta boundaries drawn in Figure 1 divide the region off Baja California into two areas of egg production and are shown here to distinguish the presence of two separate spawning groups during both of the years examined. The importance and ramifications of the two spawning groups are examined in the following section.

2. Distribution and Significance of Two Separate Spawning Stocks off Baja California

The two spawning groups represented in Figure 1 are defined here by their affinity with different water types that comprise separate thermosaline habitats described in Baumgartner et al. (2005). The differences in thermal habitat between these two groups are shown in Figure 2 (% frequency of sardine concentration plotted as green curve; % frequency of temperatures as blue curve) with the groups identified here as a "temperate-subarctic" and a "subtropical" stock using data taken during the four cruises of the year 2000 (January, April, July and October). The areas occupied by the temperate-subarctic stock are shown in Figure 1 for both years by the heavy green borders mentioned above; the areas of the subtropical stock lie within the magenta borders.

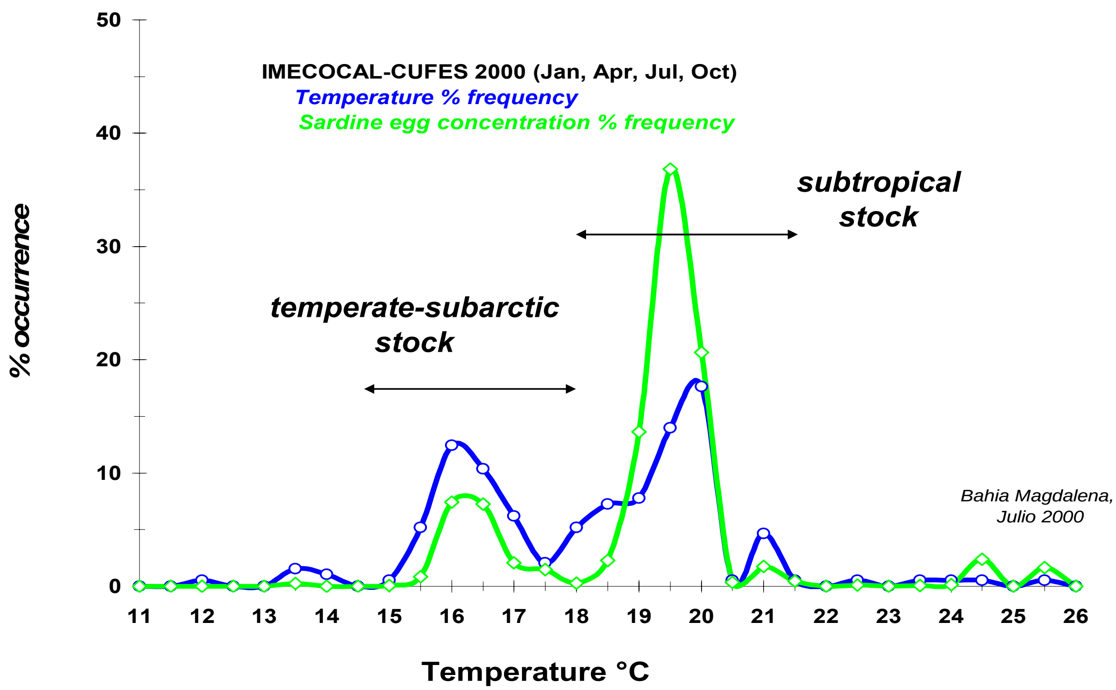


Figure 2. Distribution of frequencies of sardine egg concentrations (green curve) plotted with frequencies of temperatures (blue curve) encountered in the IMECOCAL region during four cruises of 2000. Temperatures are taken from water drawn from ~3 m depth and measured by thermosalinometer in laboratory on main deck of R/V *Francisco de Ulloa*.

Distinguishing the presence of the two spawning stocks is critical for comparison of the biomass estimates in the IMECOCAL region to those of the CalCOFI region. The temperate-subarctic stock (spawning in water between 15.5 and 17.5° C in Fig. 1) can be shown to be the southern extension of the spring spawning stock in the CalCOFI region off southern California. A third stock spawns in 12-14° C water (designated here as "cool-subarctic") and dominates the area from Point Conception north, off central California. Therefore, only the areas of egg production of the temperate-subarctic stock during the successive Aprils are considered in this analysis. Although Figure 2 indicates that the subtropical stock has a greater level of egg production throughout the year, the southern extension of the subarctic stock has dominated egg production during the April IMECOCAL survey periods from 2000 to 2004, corresponding to the season of intensified equator-ward flow of the California Current (Lynn and Sympson, 1987).

The existence of two stocks has an important effect on the fishing activity off Ensenada as can be seen in the monthly landings plotted in Figure 3. From 2001 through 2004, the peak landings occur during the warm season of summer-fall during which the subtropical stock moves northward (and likely close to shore) and is thus accessible to the Ensenada fleet. The period of January through June is a time of relatively low catches when the temporal-subarctic stock extends southward from off Alta California into the waters off northern and central Baja California and the subtropical stock has retreated to the south in the sense that Felix-Uraga et al. (2005) describe. It is also likely that the subarctic stock is less concentrated near the coast (where it would be vulnerable to the Ensenada fleet) particularly during periods of strong coastal upwelling in March and April.

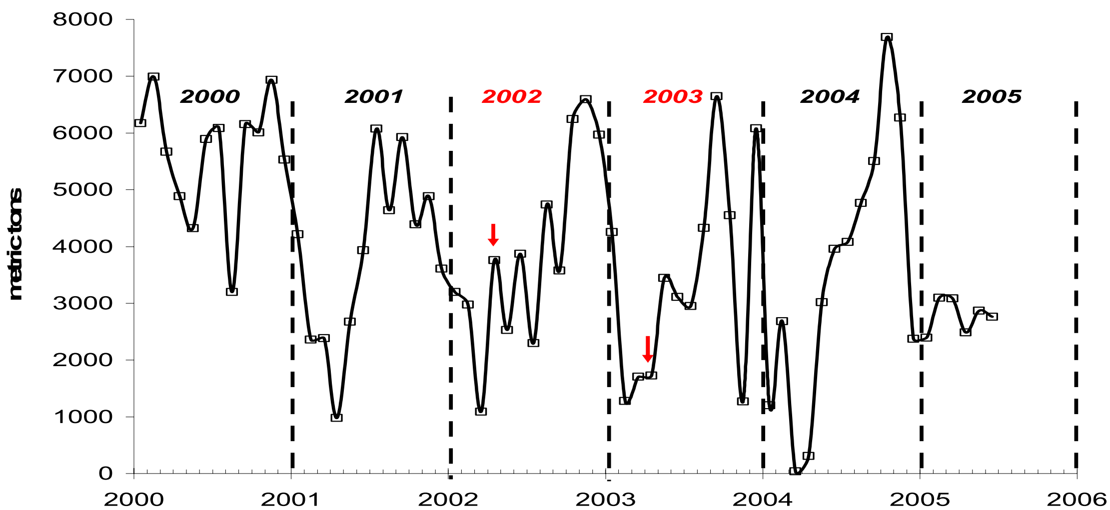


Figure 3. Monthly landings of Pacific sardine in ports of Ensenada and El Sauzal from January, 2000, through June, 2005. The years and months that are the subject of this report are indicated by red arrows and numerals. Note the strong differences in the first semester compared to second semester landings in the years 2001 through 2004.

3. Estimating Daily Egg Production

The total area of spawning distribution of the temperate-subarctic stock, the mean temperature and the mean egg concentration are given in Table 1 along with the total number of CUFES samples, and the number of positive samples, within the area of the temperate-subarctic stock. The spawning area was measured as that enclosed by the green borders shown for the two April survey results in Figure 1. Note that the area is not stratified by egg concentration as is normally done for the CalCOFI area (*e.g.*, Lo and

Macewicz, 2004). The mean temperatures were calculated as the averaged temperatures along the tracklines within the area of egg distribution for each year (Table 1) as measured by the underway thermosalinometer from water pumped aboard ship from approximately 3 m depth. The mean egg concentrations were calculated from the summed sampling periods and egg numbers collected within the boundaries of the temperate-subarctic stock indicated on Figure 1.

Table 1. Data for temperate-subarctic stock taken from IMECOCAL CUFES surveys. Data refer only to the areas within green boundary lines in Figure 1.

year	N spl. num. (CUFES)	N_p (positive CUFES)	Area of Egg Distribution (km^2)	Mean Temperature (°C)	Mean Egg Concentration (eggs/min)
2002	**211**	**77**	**51695**	**15.28**	**0.160**
2003	**100**	**24**	**36200**	**15.94**	**0.034**

We follow the procedure of Lo and Macewicz (2004) who use units of egg density from the standard CalVET net tow (CalCOFI Vertical Egg Tow; Smith et al., 1985) as the basic sampling unit for estimating daily egg production. To do this we convert the values of the near-surface mean egg concentrations measured as eggs/min by the CUFES system to the net tow units (eggs/0.05m^2) using a range of conversion factors that reflect the current uncertainty in the relationship between the collection efficiency of CUFES and CalVET on the IMECOCAL surveys. Table 2 provides the conversions from the 2002 and 2003 CUFES units to a range of seven values in CalVET units using multipliers (equivalent to 1/E as defined by Lo and Macewicz, 2004) in a sequence of 4 through 16. The wide range of conversion factors in Table 2 (and correspondingly wide range of egg densities) is due to the relatively low number of positive comparisons between CUFES samples and CalVET tows per cruise (Figure 4) because of the limited number of CalVET tows in the IMECOCAL station pattern (with 20 nautical mile spacing). Also we only have available the values from the first six cruises in which CUFES was used in the IMECOCAL surveys.

Table 2. Conversion of the near-surface mean egg concentration values from CUFES in **Table 1** to a range of CalVET units of mean egg density (X_{mean} = *eggs/0.05m^2*) based on the specified range of CalVET / CUFES conversion factors [eggs/0.05m^2 : eggs/min = 4 through 16]

	4	**6**	**8**	**10**	**12**	**14**	**16**	***[eggs / 0.05m^2 : eggs / min]***
2002	**0.640**	**0.960**	**1.280**	**1.600**	**1.920**	**2.240**	**2.560**	***X_{mean} (eggs / 0.05 m^2)***
2003	**0.136**	**0.204**	**0.272**	**0.340**	**0.408**	**0.476**	**0.544**	***X_{mean} (eggs / 0.05 m^2)***

The relationships shown in Figure 4 were obtained from comparison of positive CalVET tows and the mean number of eggs/min from five CUFES samples prior to and after the corresponding station with a positive CalVET tow. The conversion factors are the regression coefficients associated with data from each of the four cruises in 2000 and first two cruises of 2001. These conversion factors range from < 1 to > 15. The broad range of regression coefficients probably reflects the differences in stratification and depth of the mixed layer from season to season and year to year (Lo et al., 2005a, p. 108). Although the data are limited, the grouping of January and July coefficients in Figure 4 may be noteworthy and indicate stronger stratification and less vertical mixing than the two April cruises (and for October, 2000) that have significantly higher coefficients suggesting more vertical mixing. The values obtained by adaptive sampling with CalVET tows in the CalCOFI region during the April cruises vary from 2.6 to 6.9. The range of conversion factors from 4 through 16 used in Table 2 reflects the range covering the two April cruises plotted in Figure 4. The higher conversion factors obtained in the CUFES:CalVET regression indicates that the collection efficiency of the CUFES system aboard the R/V *Francisco de Ulloa* may be lower by one-half than the system on the NOAA ship *David Starr Jordan* which has a similar hull mounted intake and was the model for the installation on the *Ulloa*.

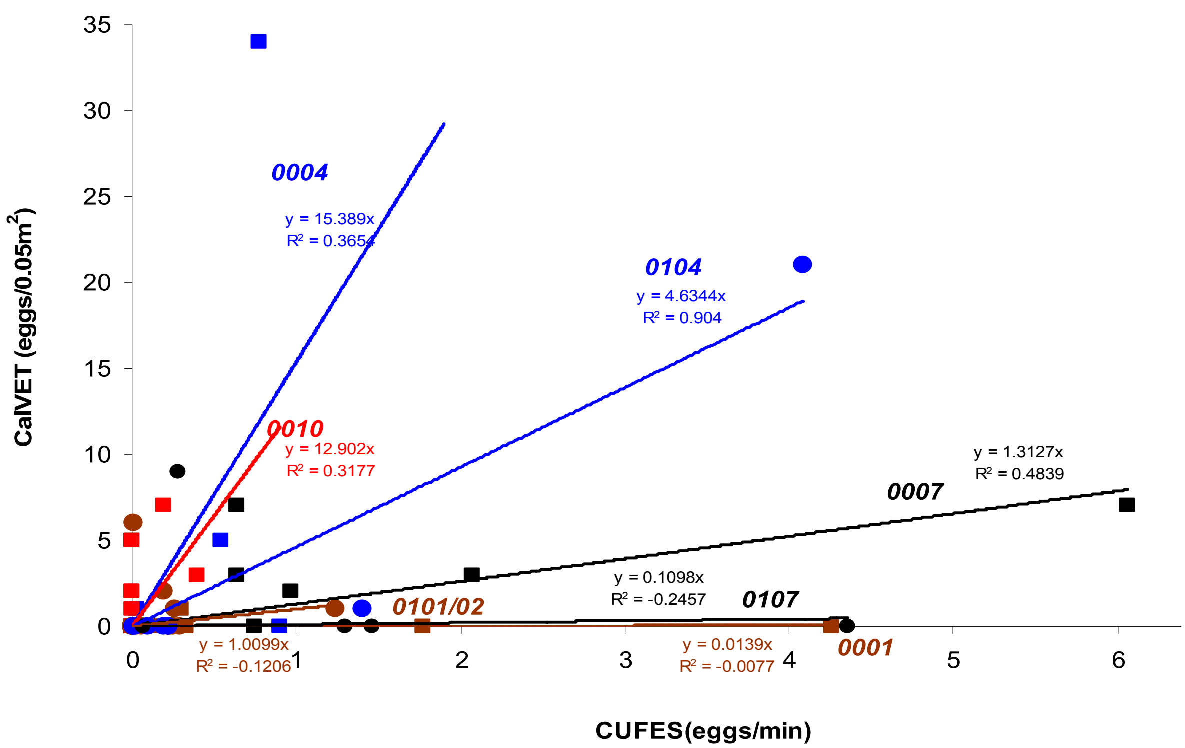


Figure 4. Regression results from CUFES and CalVET data from individual IMECOCAL cruises during 2000 and 2001. CUFES values are averages from five samples prior to and five samples after the stations with positive CalVET tows.

The daily egg production at time *t* follows an exponential decay model of egg mortality (Lo et al., 1996)

eq. 1 $$P_t = P_0 e^{-zt},$$

where P_0 is egg production at time of spawning ($t=0$) expressed in CalVET units of eggs/0.05m^2/day; t is the age of the eggs in days; and z is the instantaneous rate of daily egg mortality. The value of X_{mean} in Table 2 is related to egg production through the integral of P_t over the period from spawning to hatching:

eq. 2
$$\overline{X} = \int_0^{t_h} P_0 e^{-zt} dt \quad .$$

Integrating the expression in eq. 2 yields the value of P_0 as a function of the mean egg density, t_h and z:

eq. 3
$$P_0 = \frac{z \overline{X}}{1 - e^{(-zt_h)}} \quad .$$

A temperature dependent stage-to-age model, modified from Lo et al. (1996), was used to obtain an estimate of the ages of sardine egg hatching at stage 12. This is written as

eq. 4
$$\hat{y}_{i,T} = \alpha e^{(\beta_1 T + \beta_2 i)} (i^{\gamma}) \; ,$$

where $\hat{y}_{i,T}$ is the age in hours of the ith-stage of sardine eggs at temperature T °C, and the coefficients, $\alpha=30.65$, $\beta_1=-0.145$, $\beta_2=-0.037$, and $\gamma=1.41$. The mean ages of hatching for eggs in 2002 and 2003 are given in Table 3 along with temperatures and stages used in the calculation.

Table 3. Calculated age of sardine egg hatching using temperature dependent age-stage model in eq. 4

	Temperature	*stage*	*t (days)*
2002	**15.28**	**12**	**2.97**
2003	**15.94**	**12**	**2.70**

A matrix of values of P_0 are calculated with eq. 3, using the ages of hatching in Table 3, with the range of values of X_{mean} obtained from the conversion factors between CUFES and CalVET given in Table 2, and from three specified values of instantaneous daily egg mortality. The low and middle values for egg mortality reflect those reported by Lo and Macewicz (2004) for the CalCOFI region since 1995 while the high value (0.5) is added as a reasonable limit for the region off Baja California. The resulting values of P_0 are listed in Table 4.

Table 4. Estimated ranges of values for P_0 *[eggs/0.05m^2/day]* from eq. 3 using three values of daily egg mortality and the range of seven conversion factors between CUFES and CalVET in Table 2.

			Calvet/CUFES Conversion (eggs/0.05m^2 : eggs/min)						
			4	**6**	**8**	**10**	**12**	**14**	**16**
2002	Egg Mortality (z)	**0.3**	**0.326**	**0.488**	**0.651**	**0.814**	**0.977**	**1.139**	**1.302**
		0.4	**0.368**	**0.552**	**0.736**	**0.921**	**1.105**	**1.289**	**1.473**
		0.5	**0.414**	**0.621**	**0.827**	**1.034**	**1.241**	**1.448**	**1.655**
2003	Egg Mortality (z)	**0.3**	**0.074**	**0.110**	**0.147**	**0.184**	**0.221**	**0.257**	**0.294**
		0.4	**0.082**	**0.124**	**0.165**	**0.206**	**0.247**	**0.288**	**0.330**
		0.5	**0.092**	**0.138**	**0.184**	**0.230**	**0.275**	**0.321**	**0.367**

4. Estimates of Adult Reproductive Parameters

In the absence of trawl samples of sardines in the spawning areas offshore indicated by Figure 1, we have used data from landings collected by the CICESE to provide an indirect means for estimating adult parameters of the April periods of 2002 and 2003. Note that Figure 1 shows that the general area of operation of the fleet is clearly inshore of the main spawning region during April, 2002. The biological sampling of the landings in April, 2002, and 2003, indicate that the catches were composed almost entirely of juvenile fish (age 0 according to examination of otoliths; specified as < 65 grams, and <170 mm SL). This is evident from the monthly sequence of length-weight plots measured from the 2002 and 2003 landings presented in Figure 5. The larger fish present at the beginning of each year disappear from the catches abruptly by April of 2002 and more gradually by April, 2003. We postulate that the older, larger sardines may have moved offshore to spawn during the spring period of intensified coastal upwelling. Note that the largest fish in the month of January of both years in Figure 5 are still smaller than the smallest fish that were caught by trawling during 2002 (142 grams) in the CalCOFI region (offshore of Point Conception, see Figure 3A and Table 5 of Lo et al., 2005).

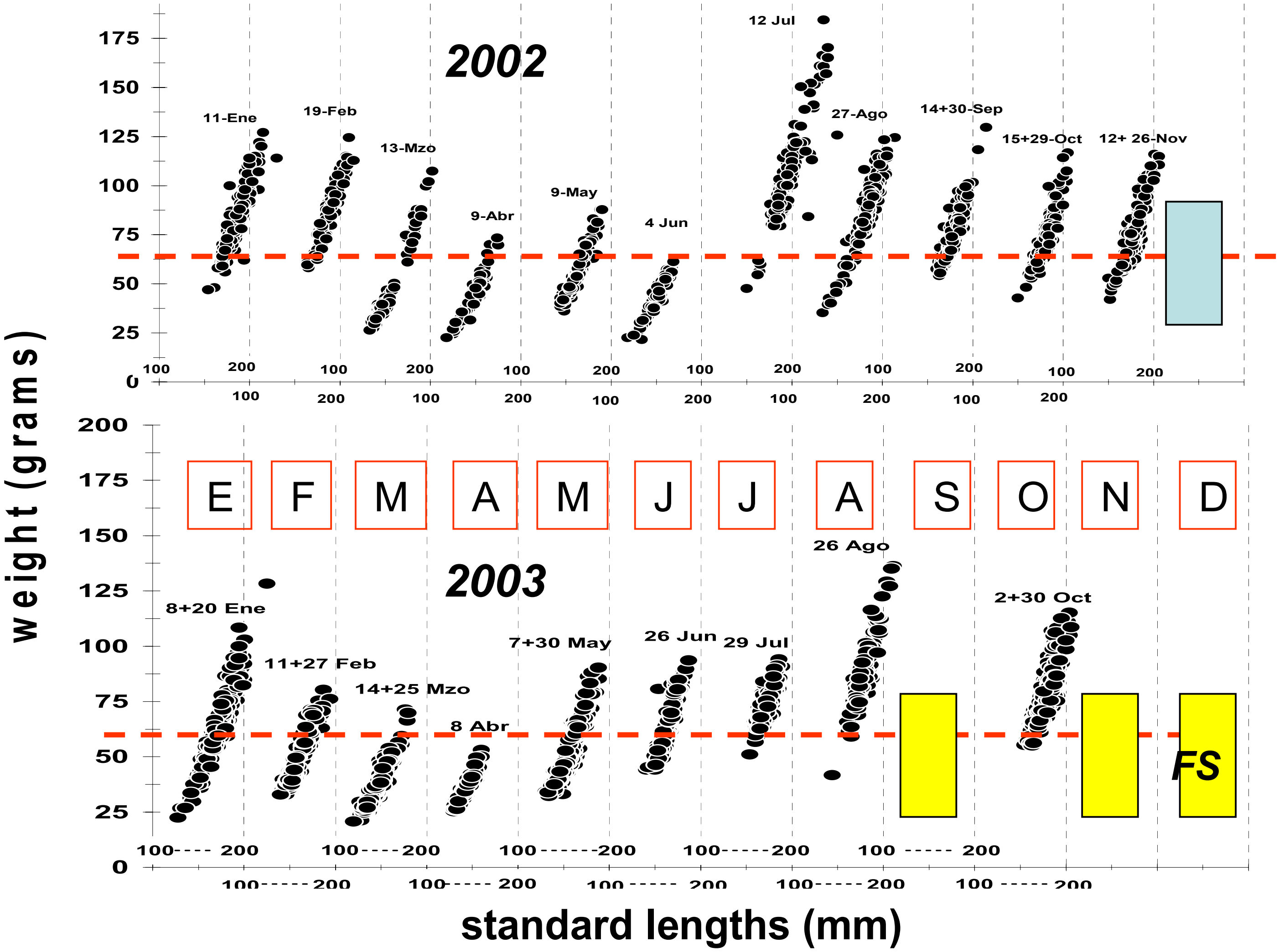
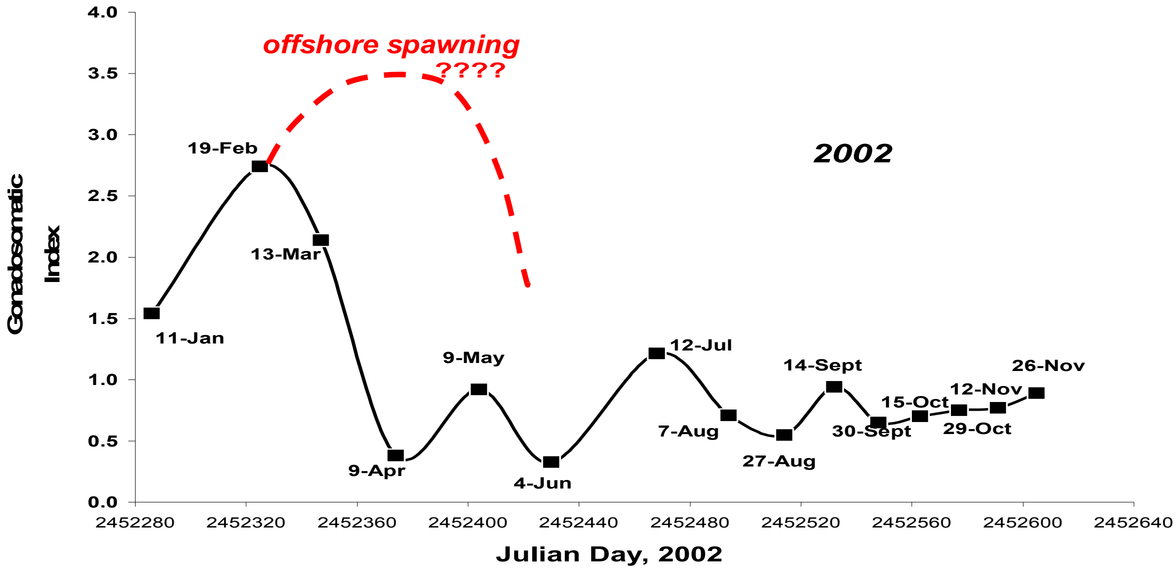


Figure 5. Monthly sequences of length-weight plots for 2002 and 2003 for landings at port El Sauzal. Data are based on 100 individuals per sample. The months with no data containing yellow bars indicate lack of sample due to poor sardine catches; the blue bar in Dec. 2002 indicates lack of sample although sufficient amount of sardines were landed.

Serial plots of gonadosomatic index values for 2002 and 2003 (Fig. 6) show that landings at the beginning of each year contained mature and reproductively active females while both Aprils showed a lack of mature females in the landings. The dashed red curve plotted with data for year 2002 is included in Figure 6 to suggest the values that might have been observed in the offshore females during the peak of spawning that we postulate occurred in March and April. The absence of active, mature spawning females in April, 2003 was confirmed by examination of the ovaries from the biological samples in the histological laboratory at INP-CRIP Ensenada.



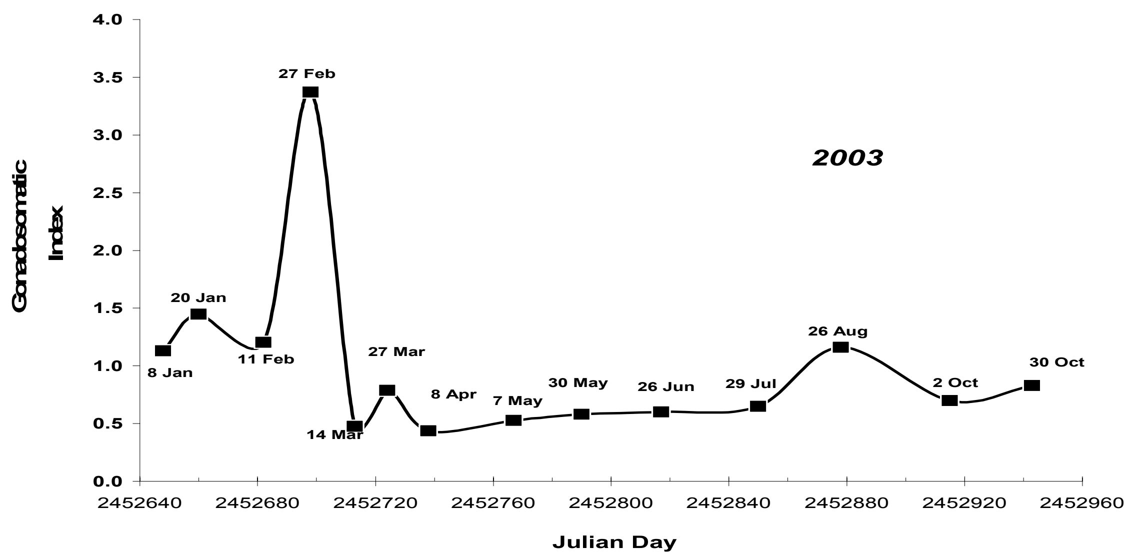


Figure 6. Sequence of simple gonadosomatic index values ([wt. ovary/wt fem.]*100) for El Sauzal landings sampled at El Sauzal for 2002 and 2003. The heavy dashed curve in the plot of 2003 is drawn to suggest offshore movement of mature females in March-April-May presumably drawn to more favorable spawning habitat during that period.

Because the April landings contained only few or no mature females, we resorted to examining the period prior to April for an indirect estimate of adult parameters from the landings data. We assume here that the adult parameters of the older sardines present in the landings near the beginning of the years 2002 and 2003 adequately represent the spawning conditions of the offshore adults during the April periods.

The adult parameters used in calculation of spawning biomass are listed in Table 5 for each of the two years. The female fraction of the sampled adults (R_f) is based on proportion by weight following Macewicz et al. (1996). The average weights of the mature females (W_f) were obtained from the females > 40 grams and > 139mm standard length (ovary-free weights of females are plotted in Fig. 7). We estimated batch fecundity (number of oocytes in the ovary that will be spawned in a single batch) for April, 2002 and April, 2003, from ovary-free body weights of the females ≥ 40 grams (Fig. 7). The values of batch fecundity in Figure 7 were calculated from the regression equation

eq. 5. $$F_b = 439.53(W_{of}) - 10{,}585,$$

which was determined from the relationship between number of oocytes and ovary-free body weights (W_{of}) from trawl and purse-seine samples taken during April-May, 1994 caught in the region of the Southern California Bight down to Punta Eugenia, Baja California. The regression equation was obtained by Macewicz et al. (1996) from determination of the oocyte numbers from ovaries of 51 females (see their Tables 1 and 5) using methods described in Hunter et al. (1985, 1992). We use the means of the calculated batch fecundities in Figure 7 to approximate the 2002 and 2003 values.

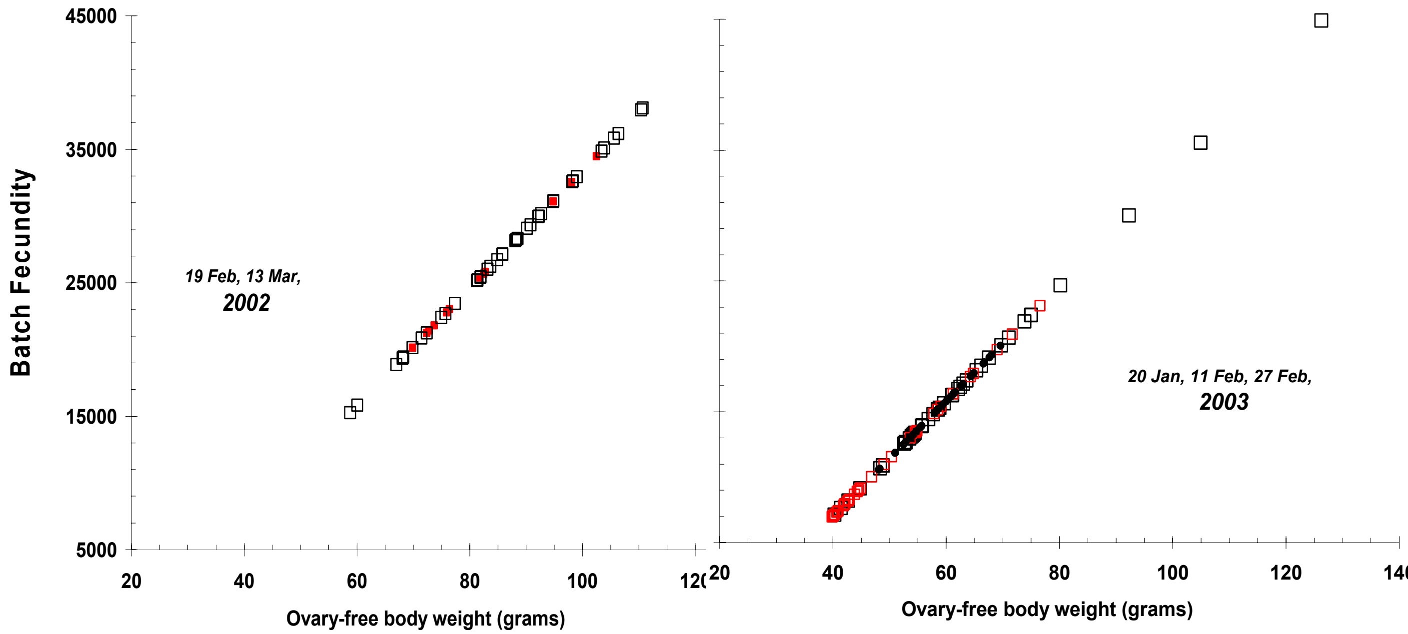


Figure 7. Plots of batch fecundity (num. oocytes in ovary) for samples in landings at El Sauzal for 19 February (black open squares) and 13 March (solid red squares), 2002 (left), and for 20 January (open black squares), 11 February (open red squares) and 27 February, (solid black squares) 2003 (right) calculated from the eq. 5. The mean batch fecundity for 2002 is 26,625; the mean batch fecundity for 2003 is 14,722.

The daily fraction of spawning females (S) could not be estimated from the biological sampling of the landings from which we reconstructed the batch fecundities. We have rather set upper and lower limits based on specific criteria. The limits for both years are set at $S=0.05$ and 0.15 (Table 5) considering the results from adult sampling surveys conducted in 1994, 1997, 2001, 2002 and 2004 (see Lo et al., 2005). The upper limit reflects averaged values in the CalCOFI region obtained from histological examination of ovaries from 1997 ($S=0.131$), 2002 ($S = 0.174$) and 2004 ($S = 0.131$). The rationale for setting the lower limit at $S=0.05$ is given in the following paragraph.

The lower limit of 0.05 provides sufficient range to include the possibility that the peak of spawning had passed off Baja California and encompasses the April-May value obtained for 1994 ($S=0.068$) as an average over three region from Monterey, California, USA, to southern Baja California, México (Macewicz et al., 1996). Female spawning frequencies from the 1994 survey suggest a south to north gradient of diminishing values with $S=0.120$ in the south, from 30° 25′ (San Quintin) to 26° 38′ N (Punta Abreojos); $S=0.074$ from33° 59′ (Santa Monica, California) to 31° 35′ N (Punta Santo Tomas, just south of Ensenada); and $S=0.000$ from 36° 55′ to 36° 35′ N (Monterey Bay) in the north (see Table 7 in Macewicz et al., 1996 and Fig. 3B in Lo et al., 2005a). This pattern indicates that while a peak in 1994 spawning frequencies existed in the southern region, it had not yet occurred in the middle region, and spawning had not yet commenced in the north. The lower limit of spawning frequencies used in this analysis ($S=0.05$), therefore, provides a reasonable intermediate value between no spawning and the off-peak value of 0.07 found in the study by Macewicz (1996).

The lower mean batch fecundity in 2003 reflects the lower minimum weights in the landings sampled for that year. This may also reflect the presence of immature females in the sample of 2003 that could produce an upward bias for the 2003 estimate of spawning biomass (see eq. 6).

Table 5. Adult reproductive parameters estimated from landings at port of El Sauzal (R_f, W_f, *and* F_b) near Ensenada, and with S specified from criteria based on results from adult sampling in literature as described in text.

	R_f	W_f	F_b	S
2002	**0.46**	**84.2**	**26,625**	**0.05 - 0.15**
2003	**0.53**	**65.6**	**14,722**	**0.05 - 0.15**

5. Calculation of Spawning Biomass

The spawning biomasses within the areas enclosed by the green boundaries in the two plots of Figure 1 are calculated using the expression

eq. 6
$$B_S = \frac{P_0 A}{R_f S F_b / W_f},$$

described by Lo et al. (2005a), in which P_0A is the total daily egg production within the boundary of spawning distribution and the denominator is the daily specific fecundity (DSF) which is equivalent to the number of eggs per unit weight of the population per day. The spawning biomass is calculated for the matrix of values of P_0 given in Table 4 and the adult parameters presented in Table 5. The results of the calculations are presented in Tables 6 and 7 and are also plotted in Figures 8 and 9.

Table 6. Calculation of range of spawning biomass estimates for April, 2002, based on specified ranges of CalVET/CUFES conversion factors (4 through 16), daily egg mortality rates (0.3 through 0.5), and upper and lower limits of daily spawning fractions of mature females (0.15and 0.05).

	2002	*S = 0.15*							*S = 0.05*						
		Range of Calvet/CUFES Conversion							**Range of Calvet/CUFES Conversion**						
		4	**6**	**8**	**10**	**12**	**14**	**16**	**4**	**6**	**8**	**10**	**12**	**14**	**16**
Egg Mortality (z = 0.3)	**P_0**	**0.326**	**0.488**	**0.651**	**0.814**	**0.977**	**1.139**	**1.302**	**0.326**	**0.488**	**0.651**	**0.814**	**0.977**	**1.139**	**1.302**
	$P_0(A)$	3.37E+11	5E+11	6.7E+11	8.41E+11	1E+12	1.2E+12	1.35E+12	3.37E+11	5.05E+11	6.73E+11	8.4E+11	1E+12	1.2E+12	1.3E+12
	R_f	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
	W_f	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2
	S	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	F	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625
	$(R/W_f)SF$ [grm]	21.81859	21.8186	21.8186	21.81859	21.8186	21.8186	21.81859	7.272862	7.272862	7.272862	7.27286	7.27286	7.27286	7.27286
	$(P_0\ A / DSF)$ gm	1.54E+10	2.3E+10	3.1E+10	3.86E+10	4.6E+10	5.4E+10	6.17E+10	4.63E+10	6.94E+10	9.26E+10	1.2E+11	1.4E+11	1.6E+11	1.9E+11
	$(P_0\ A / DSF)$ MT	**7713**	**11569**	**15426**	**19282**	**23139**	**26995**	**30851**	**23139**	**34708**	**46277**	**57846**	**69416**	**80985**	**92554**
Egg Mortality (z = 0.4)	**P_0**	**0.368**	**0.552**	**0.736**	**0.921**	**1.105**	**1.289**	**1.473**	**0.368**	**0.552**	**0.736**	**0.921**	**1.105**	**1.289**	**1.473**
	$P_0(A)$	3.81E+11	5.7E+11	7.6E+11	9.52E+11	1.1E+12	1.3E+12	1.52E+12	3.81E+11	5.71E+11	7.61E+11	9.5E+11	1.1E+12	1.3E+12	1.5E+12
	R_f	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
	W_f	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2
	S	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	F	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625
	$(R/W_f)SF$ [grm]	21.81859	21.8186	21.8186	21.81859	21.8186	21.8186	21.81859	7.272862	7.272862	7.272862	7.27286	7.27286	7.27286	7.27286
	$(P_0\ A / DSF)$ gm	1.74E+10	2.6E+10	3.5E+10	4.36E+10	5.2E+10	6.1E+10	6.98E+10	5.23E+10	7.85E+10	1.05E+11	1.3E+11	1.6E+11	1.8E+11	2.1E+11
	$(P_0\ A / DSF)$ MT	**8724**	**13087**	**17449**	**21811**	**26173**	**30536**	**34898**	**26173**	**39260**	**52347**	**65434**	**78520**	**91607**	**104694**
Egg Mortality (z = 0.5)	**P_0**	**0.414**	**0.621**	**0.827**	**1.034**	**1.241**	**1.448**	**1.655**	**0.414**	**0.621**	**0.827**	**1.034**	**1.241**	**1.448**	**1.655**
	$P_0(A)$	4.28E+11	6.4E+11	8.6E+11	1.07E+12	1.3E+12	1.5E+12	1.71E+12	4.28E+11	6.42E+11	8.55E+11	1.1E+12	1.3E+12	1.5E+12	1.7E+12
	R_f	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46
	W_f	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2	84.2
	S	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	F	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625	26625
	$(R/W_f)SF$ [grm]	21.81859	21.8186	21.8186	21.81859	21.8186	21.8186	21.81859	7.272862	7.272862	7.272862	7.27286	7.27286	7.27286	7.27286
	$(P_0\ A / DSF)$ gm	1.96E+10	2.9E+10	3.9E+10	4.9E+10	5.9E+10	6.9E+10	7.84E+10	5.88E+10	8.82E+10	1.18E+11	1.5E+11	1.8E+11	2.1E+11	2.4E+11
	$(P_0\ A / DSF)$ MT	**9801**	**14702**	**19603**	**24503**	**29404**	**34305**	**39206**	**29404**	**44106**	**58808**	**73510**	**88212**	**102915**	**117617**

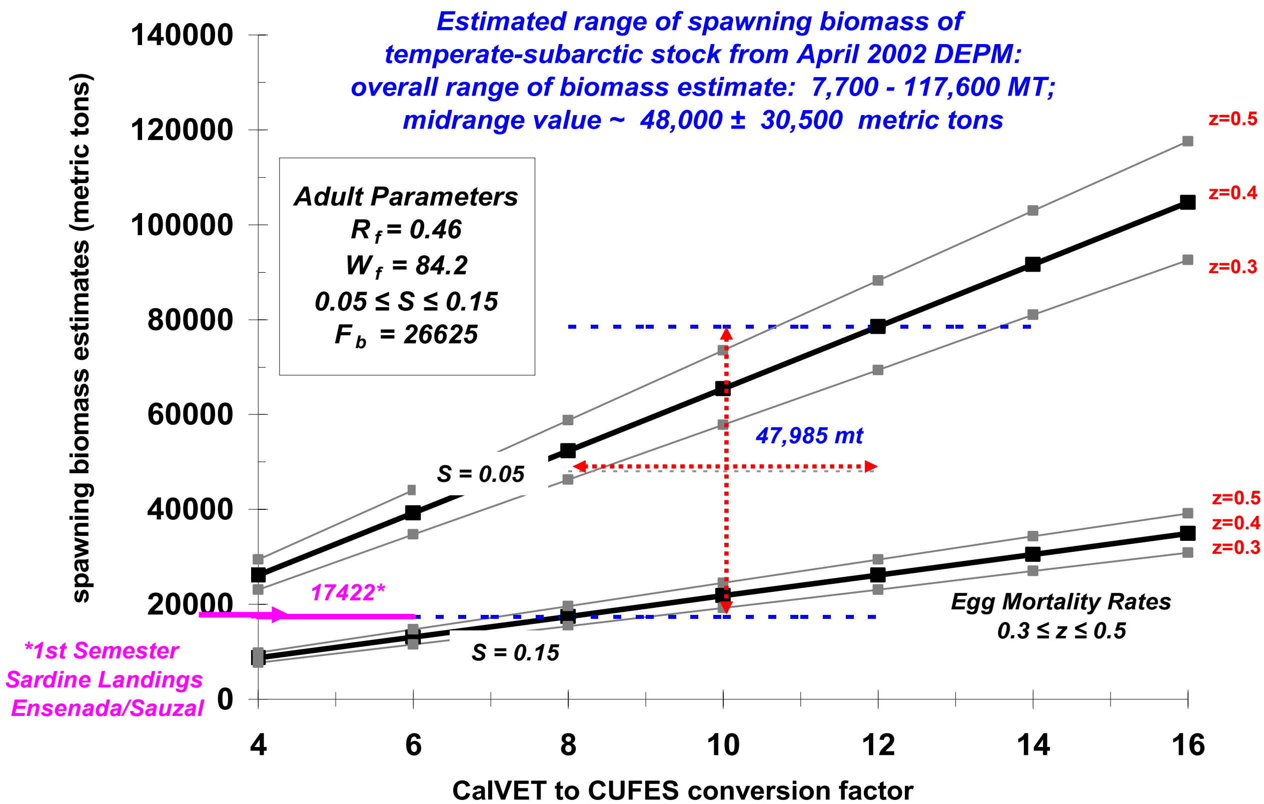


Figure 8. Range of estimates for April, 2002 spawning biomass of the temperate-subarctic sardine stock (see Fig. 1) obtained from matrix of calculations presented in Table 6 using three values for daily egg mortality versus a sequence of seven values of the CalVET-CUFES conversion factor and upper and lower limits of the fraction of spawning females 0.15 and 0.05.

Table 7. Calculation of range of spawning biomass estimates for April, 2003, based on specified ranges of CalVET/CUFES conversion factors (4 through 16), daily egg mortality rates (0.3 through 0.5), and upper and lower limits of daily spawning fractions of mature females (0.15and 0.05).

2003		S = 0.15							S = 0.05						
		Range of Calvet/CUFES Conversion							Range of Calvet/CUFES Conversion						
		4	6	8	10	12	14	16	4	6	8	10	12	14	16
Egg Mortality (z = 0.3)	P_0	0.074	0.110	0.147	0.184	0.221	0.257	0.294	0.074	0.110	0.147	0.184	0.221	0.257	0.294
	$P_0(A)$	5.32E+10	7.98E+10	1.06E+11	1.33E+11	1.6E+11	1.86E+11	2.13E+11	5.32E+10	7.98E+10	1.06E+11	1.33E+11	1.6E+11	1.86E+11	2.13E+11
	R_f	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
	W_f	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6
	S	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	F	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722
	$(R/W_f)SF$ [grm]	17.84145	17.84145	17.84145	17.84145	17.84145	17.84145	17.84145	5.947149	5.947149	5.947149	5.947149	5.947149	5.947149	5.947149
	$(P_0 A / DSF)$ gm	2.98E+09	4.47E+09	5.97E+09	7.46E+09	8.95E+09	1.04E+10	1.19E+10	8.95E+09	1.34E+10	1.79E+10	2.24E+10	2.68E+10	3.13E+10	3.58E+10
	$(P_0 A / DSF)$ MT	1491	2237	2983	3729	4474	5220	5966	4474	6711	8949	11186	13423	15660	17897
Egg Mortality (z = 0.4)	P_0	0.082	0.124	0.165	0.206	0.247	0.288	0.330	0.082	0.124	0.165	0.206	0.247	0.288	0.330
	$P_0(A)$	5.96E+10	8.95E+10	1.19E+11	1.49E+11	1.79E+11	2.09E+11	2.39E+11	5.96E+10	8.95E+10	1.19E+11	1.49E+11	1.79E+11	2.09E+11	2.39E+11
	R_f	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
	W_f	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6
	S	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	F	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722
	$(R/W_f)SF$ [grm]	17.84145	17.84145	17.84145	17.84145	17.84145	17.84145	17.84145	5.947149	5.947149	5.947149	5.947149	5.947149	5.947149	5.947149
	$(P_0 A / DSF)$ gm	3.34E+09	5.01E+09	6.69E+09	8.36E+09	1E+10	1.17E+10	1.34E+10	1E+10	1.5E+10	2.01E+10	2.51E+10	3.01E+10	3.51E+10	4.01E+10
	$(P_0 A / DSF)$ MT	1672	2507	3343	4179	5015	5851	6686	5015	7522	10030	12537	15044	17552	20059
Egg Mortality (z = 0.5)	P_0	0.092	0.138	0.184	0.230	0.275	0.321	0.367	0.092	0.138	0.184	0.230	0.275	0.321	0.367
	$P_0(A)$	6.65E+10	9.97E+10	1.33E+11	1.66E+11	1.99E+11	2.33E+11	2.66E+11	6.65E+10	9.97E+10	1.33E+11	1.66E+11	1.99E+11	2.33E+11	2.66E+11
	R_f	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
	W_f	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6	65.6
	S	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	F	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722	14722
	$(R/W_f)SF$ [grm]	17.84145	17.84145	17.84145	17.84145	17.84145	17.84145	17.84145	5.947149	5.947149	5.947149	5.947149	5.947149	5.947149	5.947149
	$(P_0 A / DSF)$ gm	3.73E+09	5.59E+09	7.45E+09	9.31E+09	1.12E+10	1.3E+10	1.49E+10	1.12E+10	1.68E+10	2.24E+10	2.79E+10	3.35E+10	3.91E+10	4.47E+10
	$(P_0 A / DSF)$ MT	1863	2794	3726	4657	5588	6520	7451	5588	8383	11177	13971	16765	19559	22353

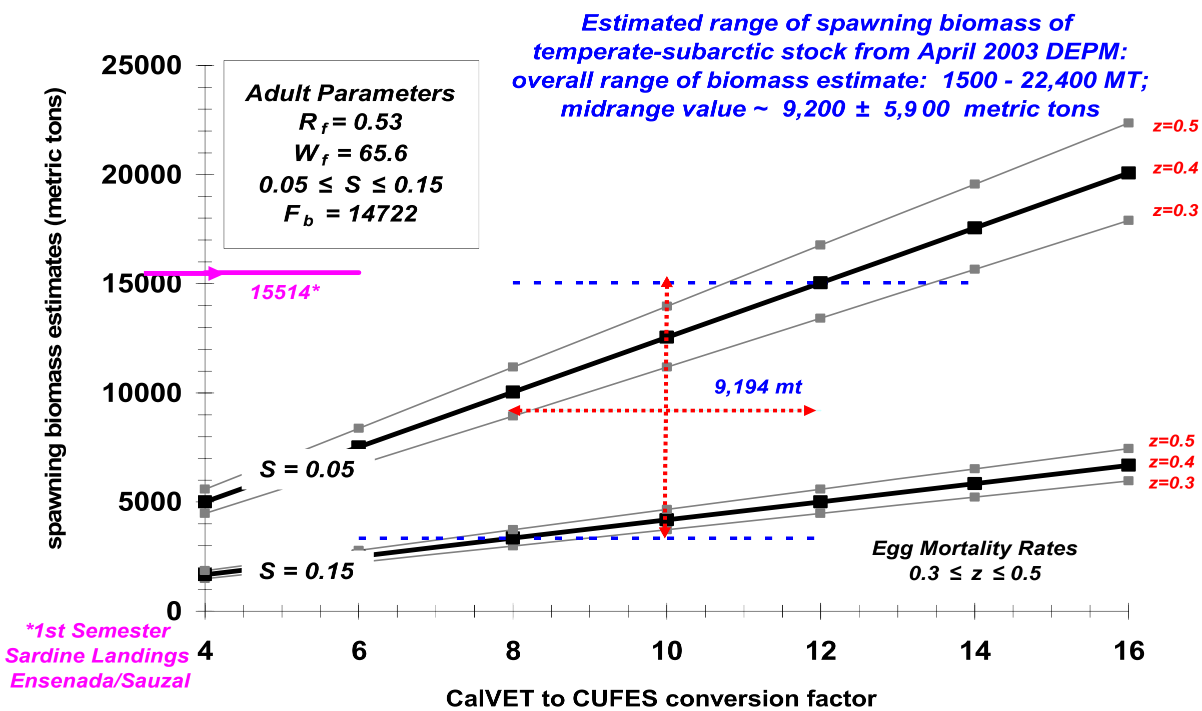


Figure 9. Range of estimates for April, 2003 spawning biomass of the temperate-subarctic sardine stock (see Fig. 1) obtained from matrix of calculations presented in Table 6 using three values for daily egg mortality versus a sequence of seven values of the CalVET-CUFES conversion factor and upper and lower limits of the fraction of spawning females (0.15 and 0.05.)

The results presented in Tables 6 and 7 consist of a range of estimates for the spawning biomasses of the temperate-subarctic sardine stock of the Pacific sardine obtained from the matrices of calculations using three values for daily egg mortality (*0.3* to *0.5*) against a sequence of seven values of the CalVET-CUFES conversion factor (between *4* and *16*) with lower and upper limits of the fraction of spawning females set between *0.05* and *0.15*. According to our analyses, the total range of the spawning biomass estimates for April, 2002, is *7,700* to *117,600* metric tons (Table 6, Fig. 8); the total range of estimates for April, 2003, lie between *1,500* and *22,400* metric tons (Table 7, Fig. 9). The midrange values of 2002 and 2003 are approximately *48,000* ± *30,500* and *9,200* ± *5,900* metric tons, respectively.

The mid-range values of spawning biomass represent conditions for which $z=0.4$, the CalVET-CUFES conversion factor is at 10, yielding $P_0=0.916$ for 2002 and *0.206* for 2003, with the adult parameters, R_f, W_f, and F_b the same as given in Table 5. Given the mid-range values for biomass, we can solve for the daily spawning frequency (eq. 6); the mid-range point is $S = 0.068$ for both 2002 and for 2003 (*cf*. Figs. 8 and 9).

It is instructive to compare the landings in Figure 3 to the estimates of the spawning biomass. Note that the total of first semester landings at Ensenada ports in 2002 (*17,422* mt, see Fig.) is *36.3%* of the *47,985* mt mid-range estimate for April. The April, 2002, landings alone were *3,760* mt, or approximately *7.8 %* of this estimate of the spawning biomass offshore. The total first semester landings of 2003 (15,514) are *169%* of the mid-range estimate of *9,194* mt for the spawning biomass in April. The April 2003 landings were *1,722* mt which is *~11%* of the estimate. The very high proportion of landings to the biomass estimate in 2003 suggests that the mid-range estimate may be low. However, it could also mean that April of that year was a transitory period of low biomass of the subarctic stock off Baja California. This could also be the reason the first semester landings in 2003 (see Fig. 3) show minimal catches during February, March, and April compared to substantially higher catch in January, May, and June, 2003. It is also noteworthy that sampling of the landings (Fig. 5) indicates a much higher proportion of juveniles in the catches of February and March of 2003 than 2002, while the sample from April, 2003, consisted entirely of juveniles weighing less than 55 grams.

6. Comparison of Egg Production and Spawning Biomasses in the IMECOCAL and CalCOFI Regions

The mid-range spawning biomasses (B_S) calculated for the IMECOCAL are compared to the DEPM estimates from the CalCOFI surveys for April, 2002 and 2003 in Table 8, along with the estimates of daily egg production (P_0) associated with the spawning biomasses, the areas of spawning and batch fecundities (F_b) plus the daily specific fecundity (*DSF*). The area of spawning of the subarctic stock in the CalCOFI region is approximately six times that of the IMECOCAL region in 2002 and 10 times greater in 2003. It is important to recognize that while the egg production in the IMECOCAL region is similar to that of the CalCOFI region (the CalCOFI value is the weighted average of areas of both high- and low-density of eggs) during Ápril, 2002, it is almost an order of magnitude lower than the CalCOFI value during April, 2003.

From the above observations, we identify the principal cause of the low biomass estimates in the IMECOCAL region for 2003 as stemming from both the low egg production and the smaller spawning area (parameters that comprise the numerator in eq. 6, the term P_0A). Note however, that the smaller daily specific fecundity (the denominator in eq. 6, R_fSF/W_f) for 2003 in the IMECOCAL region would tend to increase the value of B_s relative to the effect that *DSF* exerts on B_s in 2002.

Table 8. Comparisons between the IMECOCAL and CalCOFI regions for April, 2002 and April, 2003 of estimates of spawning biomasses, mean daily egg production over total areas of both regions, total spawning areas, batch fecundities and daily specific fecundities. CalCOFI data taken from Lo et al. (2005a, their Tables 3 and 6). IMECOCAL data extracted from Tables 6 and 7, with reference to Figs. 8 and 9, above. The 2003 CalCOFI parameters in brackets (*F* and *DSF*) indicate use of 2002 observations of adult parameters for 2003 (Lo et al. 2005a). The values for P_0 for the CalCOFI region are weighted averages from both the high- and low-density areas of egg production.

	P_0		Area		F_b		DSF		B_s	
	IMECOCAL	CalCOFI	IMECOCAL	CalCOFI	IMECOCAL	CalCOFI	IMECOCAL	CalCOFI	IMECOCAL	CalCOFI
2002	0.921	0.728	51695	325082	26625	54403	14.5	22.94	47985	206333
2003	0.206	1.520	36200	365906	14722	[54403]	11.9	[22.94]	9194	485121

The mean batch fecundity used in the CalCOFI region estimates is double that of the IMECOCAL region during 2002 and is more than 3.5 times greater during 2003 (as estimated by eq. 5). This reflects the differences in the ovary-free body weights of the mature females sampled in the CalCOFI region in 2002 (all > 141g; see Table 5 in Lo et al., 2005a) as compared to the weights in the IMECOCAL region plotted in Figure 7. Note, however, that the batch fecundities (and DSFs) from the CalCOFI region are estimated from females sampled only from the high-density area of egg production and may be biased towards high values (Lo et al., 2005a). If the DSF were in fact biased upwards, this could have a significant effect on lowering the biomass estimates from the CalCOFI region.

One of the notable contrasts found in Table 8 is the consistent inverse relationship between the CalCOFI and IMECOCAL regions in the estimated biomasses, values of egg production, and the spawning areas in the two years analyzed. These relationships are depicted graphically in the plots of Fig. 10 a-c. The inverse relationship of lower biomass in the CalCOFI region associated with the relatively higher biomass in the IMECOCAL region in 2002 and vice versa in 2003 is presented in Fig. 10a. Similar plots for daily egg production and spawning areas are presented in Figure 10b and 10c.

If we assume the mid-range estimates in Figures 8 and 9 are reasonable approximations of the spawning biomasses off Baja California, then the DEPM estimate of total biomass of the subarctic stock (from northern California to north-central Baja California) for April, 2002, would be *47,985 + 206,332* (see Lo et al. 2005a) or *254,318* metric tons Thus, the extension of the subarctic stock into the waters off Baja California would have been roughly *19%* of the total spawning biomass from around San Francisco southwards during April, 2002.

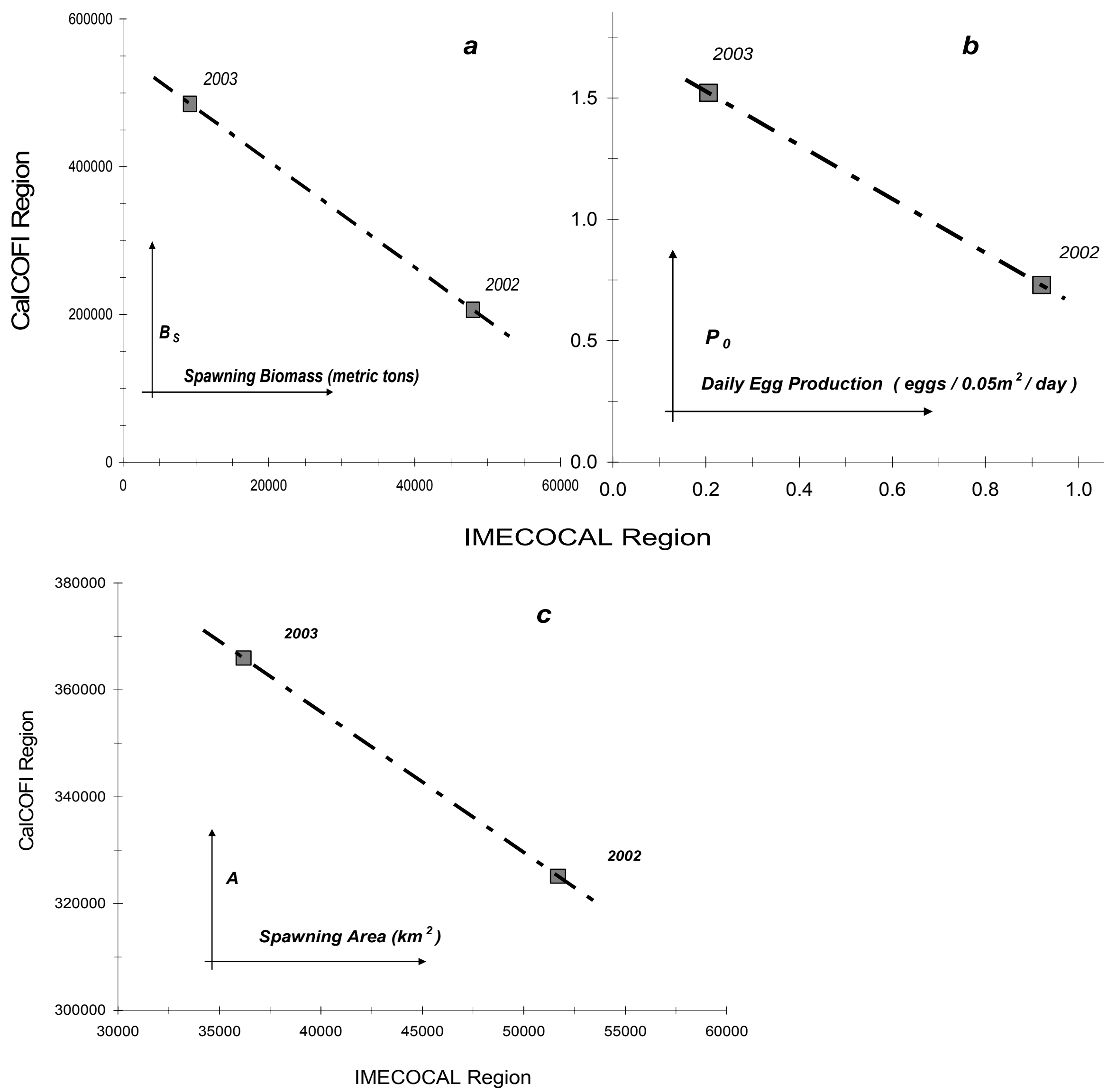


Figure 10. Spawning biomasses (a), daily egg production (b), and spawning areas (c) in the CalCOFI and IMECOCAL regions plotted against one another for the Aprils of 2002 and 2003.

The DEPM estimate for total spawning biomass of the subarctic stock between San Francisco and north-central Baja California during April, 2003, would be *9194 + 485,121* (see Lo et al. 2005a) or *494,315* metric tons. The extension of the subarctic stock into waters off Baja California would then have been only *1.9%* of its total spawning biomass.

It is important to note that these relationships for biomasses and other biological parameters indicate a northward latitudinal shift of the subarctic sardine stock between 2002 and 2003. The change in % total of the biomass values found off Baja California in the two years (19% compared to 2%) suggests an almost total displacement of the stock to the north, across the maritime boundary between the México and the U.S. between April, 2002, and April, 2003. These results indicate that the southward penetration of the subarctic stock into the waters off Baja California can vary considerably from one year to the next.

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