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OCTOBER 2008

PROCEEDINGS OF THE 2007 TRINATIONAL SARDINE FORUM

by

Nancy C. H. Lo and Anne C. Allen

ADMINISTRATIVE REPORT LJ-08-02

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San Diego, California, United States of America
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2007 Trinational Sardine Forum participants at the Hubbs-SeaWorld Research Institute, 2595 Ingraham St., San Diego, CA, 92109, United States of America

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IN MEMORIAM
Orlando Amoroso

The Trinational Sardine Forum (TSF) family was saddened to learn of the death of Orlando Amoroso, who passed away unexpectedly from natural causes on February 15, 2008.

Orlando, President of the National Alliance for Sustainable Fisheries at the time of his death, long-standing representative of California's wetfish industry, as well as purse seine vessel owner, was an active member of the Trinational Sardine Forum since its first meeting in 2000, held in Ensenada, Mexico. Orlando hosted two forums as the TSF tradition grew, in 2002 and 2003 in San Pedro, California. He was a key member of the planning committee and financial supporter of the TSF. He was also the inspiration behind a new working group on "Industry Trends and Issues," which was introduced in 2004 by Orlando and Martín Gutiérrez (Asociación de Armadores de Pelágicos Menores de Ensenada). The industry trends discussion was co-chaired in ensuing years by Orlando and Don Pepper, Pacific Sardine Association in B.C. Canada, resulting in lively debate on how sardine science can better serve industry needs.

The 2003 TSF organizers in San Pedro, California: Tim Baumgartner (left), Kevin Hill (middle), and Orlando Amoroso (right).

Tim Baumgartner of CICESE, Ensenada, another pioneering member of the TSF, remembers Orlando's dedication to the group: "I met Orlando during the first meeting of the TSF in Ensenada in November, 2000. I remember him standing at the rear of the group in plenary session watching, listening, absorbing, and keeping up the momentum when necessary with encouraging comments.

By the end of our second TSF meeting in San Diego in 2001, I realized I had gained a good friend and colleague in Orlando, a fellow traveler, a friend and supporter of the goals of the TSF that coincided with his support for the sardine fishery in southern California. He clearly appreciated the benefits and potential of the TSF for the sustainability and joint prosperity it offers for the national industries of our three countries—an appreciation that led to his enthusiastic support of the TSF from the beginning. Thus Orlando became one of the major participants in our fledgling efforts and contributed significantly to the early success and long-term effectiveness of the TSF, contributions which included major logistical support and a venue and facilities in San Pedro for our third and fourth annual meetings. His appreciation and advocacy for the importance of the cross-border collaborations that are the underlying strength of the TSF were constant. This was critical in the early years of the TSF, since the organizers were never sure whether this group would become a sustained effort, or would be ending after the next meeting, and Orlando's support helped assure the continuation of the TSF."

Orlando Amoroso (left) led a discussion on "Emerging Issues for the Sardine Industry: Identify Issues and Their Priority" at the 2003 TSF in San Pedro, California, with Mike Okoniewski (middle) and Don Pepper (right).

The Trinational Sardine Forum family extends condolences and best wishes to Orlando's family. Orlando's presence will be missed in Astoria in 2009.

Diane Pleschner-Steele, Tim Baumgartner and Nancy Lo

INTRODUCTION

The 8th Trinational Sardine Forum (TSF) was held at the Hubbs-SeaWorld Research Institute, San Diego, CA on November 29 and 30, 2007. Close to 90 participants attended, 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 Anne Allen and Dr. Roger Hewitt of the Southwest Fisheries Science Center, and Diane Pleschner-Steele of the California Wetfish Producers Association. We also thank Mr. Donald B. Kent, Director of the Hubbs-SeaWorld Research Institute for providing the meeting place, and Mr. Vince Torre, President of the California Wetfish Association for providing the financial aid to make this Forum possible.

Dr. William W. Fox, Jr., then Director of the Southwest Fisheries Science Center, National Marine Fisheries Service, delivered the opening remarks following a welcome statement from Dr. Nancy Lo, the co-chair of the Forum. Dr. Lo gave a brief historical overview of the TSF, and the progress made by the TSF in the past years. Dr. Fox emphasized that although the natural decadal fluctuations of a population is normal, the early collapse of the sardine population in the late 1950s was primarily due to the mismanagement of the fishery. The current coastal pelagic Fishery Management Plan stemmed from the 1976 Fishery Management Act, and was the first fishery plan at the Federal level. In the last two decades the sardine population has recovered and expanded to support a large fishery. For the 2008 fishing year, the U.S. allowable quota may be reached prior to the end of the fishing season (Note: The 2008 harvest guideline was set to be 89,093 mt, page 8 and Hill et al. Appendix III). However, scientific research on Pacific sardines on a large spatial scale has been limited. For example, the original CalCOFI grid spanned from southern tip of Baja California to the California-Oregon border. The grid has been reduced to just the southern California Bight since 1985 and extended to San Francisco during winter/spring cruise since 1997. The first coast-wide California Current ecosystem survey from Baja California to British Columbia (B.C. to B.C.) occurred in 2006, but due to lack of funding was not repeated in 2007. The TSF allows us to hear from knowledgeable scientists and industry representatives to address these kinds of problems constructively.

Two sessions followed the opening statements: “Regional Sardine Fisheries Reports” and “Research Plans and Reports.” The latter included all contributed papers (Appendix III). Most of the scientific papers presented were oriented toward documenting patterns in the regional fisheries and understanding the reproductive capability, migratory patterns, stock structure, and the impact of oceanographic and economic conditions on the Pacific sardine population. Seven posters were also on display around the meeting hall for the duration of the Forum (Appendix IV).

The highlight of second day of the meeting was the focus issue: management of sardine populations. The keynote lecture was “Use of the Daily Egg Production Method to assess and manage a new fishery: A case study of the sardine fishery off South Australia,” by Dr. Tim Ward, Southern Australian Research and Development Institute (SARDI). After the focus issue presentation, the three working groups held sessions consecutively during the plenary per the recommendation of the Program Committee, to facilitate the participation of all attendees in each working group. The working group session was followed by an enlightened panel discussion on “Future sardine surveys” moderated by Dr. Fox, with panel members from each TSF country

representing government, academia and industry. Finally, the Forum drew to an end with the promise of reconvening in the fall of 2008.

The TSF Executive Committee represents all three countries: Nancy Lo (United States), Sharon Herzka (México), Robert Emmett (United States), and Jake Schweigert (Canada). The committee members take turns organizing and hosting the meeting. Next year's Forum will be held in Astoria, Oregon, and will be hosted by Robert Emmett.

PLENARY SESSION HIGHLIGHTS

Regional Sardine Fisheries Reports

Moderator: Jake Schweigert

México

Gulf of California - Manuel Nevárez-Martínez (CRIP – Guaymas)

No report as Manuel Nevárez-Martínez was unable to attend the Forum this year.

Bahía Magdalena - Casimiro Quiñonez-Velázquez (CICIMAR)

In Bahía Magdalena the sardine fishery operates mainly inside the bay. In 2007, seven ships conducted 583 trips. Through September 2007, the annual small pelagic catch was 45,624 tons, and should reach 50,000 tons by the end of the year. The catch was largely dominated by Pacific sardine. In some years, thread herring and anchoveta are also regularly caught. The catch effort mirrors the total catch, in that more effort leads to greater catch. In 2005, the catch was high when the water temperature was 19°C. Lower catches are recorded when the water temperature is 24-26°C, resulting in monthly catch variations. Low values of SST in 2004-2005 corresponded with low CPUE. From 2004-2007, monthly length distributions of Pacific sardine showed that the percentage of fish smaller than 150 mm has decreased to 34%. In 2007, larger fish dominated the catch. In Bahía Magdalena landings, females are much more common than males (chi-squared, $p<0.001$). Spawning occurs in spring, with young maturing in summer and fall. A discriminant analysis was used to compare the morphometry of otoliths caught from Bahía Magdalena and Ensenada from 1994-2002. Results showed that three Pacific sardine stocks exist along the west coast of Baja California and California: a cold, temperate, and warm stock. A discriminant analysis was also used to compare body morphometry between Pacific sardines from Ensenada, Bahía Magdalena, and Guaymas in the Gulf of California. Sardines caught in Bahía Magdalena in autumn are very similar in morphometry to those from Guaymas. However, fish caught in Ensenada are very different in morphometry from those from Guaymas. The results show that in Bahía Magdalena, the landed sardines come from two stocks; one temperate and the other warm (Gulf of California). These results should be considered in the stock assessment, in order to reduce errors in the biomass estimates of Pacific sardine.

Ensenada (N. Baja) - Alfredo Cota Villavicencio (CRIP Ensenada, INP)

Alfredo Cota Villavicencio was unable to attend to Forum; however he did submit the following abstract:

During the 2006 fishing season 61,109 metric tons were caught: 93.39% were sardine, 0.38% Pacific mackerel and 2.56% anchovy. The summer months had the most important landings. The size of the fleet was nine vessels which operated around Ensenada Bay. The size composition of both sexes shows individuals larger than 150 mm (legal size) during the summer months; and smaller during the fall and winter months. Females had the largest size.

United States

California - Sonia Torres, Leeanne Laughlin, and **Dale Sweetnam** (CDFG)

The fishery in California is unique in that it is has a combination of federal and state management. The majority of California is in limited entry, and northern California from Point Arena north, Oregon, and Washington are an open access fishery. The limited entry fleet has 63 permits and 61 active vessels. The Pacific sardine harvest guideline (HG) for each calendar year is determined from the previous year's stock biomass estimate (≥ 1-year-old fish on 1 July) in U.S. and Mexican waters. The 2006 harvest guideline was 118,937 t, determined from 2005 biomass of 1.1 million t. A new allocation scheme was instated in 2006. It began with a coast-wide allocation of 35% of the harvest guideline, or 41,628 t for January-June. On July 1st there was a reallocation of 40% plus the unharvested remainder for a total of 67,782 t. On September 15th there was a further reallocation of 25% plus the unharvested remainder, or 80,562 t. By 31 December 2006, 69% (82,323 t) of the HG had been caught coast-wide.

A total of 46,672 mt of Pacific sardines, with an ex-vessel value of more than $5.0 million, was landed in California in 2006. This represents a 26% increase in commercial sardine landings over 2005 (34,479 t). Approximately two-thirds of the total catch was landed in southern California and one-third landed in northern California.

By port, the landings were highest in Los Angeles and Monterey; however landings in Santa Barbara/Ventura are increasing. The landings by month showed the same pattern as the last few years, with a peak in southern California early in the year, and an additional peak at the end of the year. The landings in northern California peaked at the end of year. Nearly all of the sardine catch in California is taken by round haul gear. Purse seining accounted for 82% of the landings, while 17% were caught by drum seine. Other gear types include lampara nets, and very small amounts of brail, hook and line, and trawl.

The 2007 harvest guideline of 152,562 t was based on the 2006 biomass estimate of 1,319,072 t. The 2007 landings through November 7th was 69,045 t and are projected to reach 85,000 t by the end of the year. The total U.S. sardine landings are projected to be 115,000 t, the highest since the reinstatement of the fishery. The 2007 landings thus far represent a 48% increase over the 2006 total landings.

The California landings from January through September 2007 showed a different pattern from previous years. In the spring, northern California fishermen are usually catching market squid.

However this year the sardine catches in southern California were unexpectedly high in spring and summer, and market squid weren't being caught in northern California until mid-November. Northern fishermen have only been switching from sardine to squid in the last few weeks.

In September 2007, the Stock Assessment Review (STAR) panel reviewed the Pacific sardine stock assessment and approved the SS2 model, and on November 10, 2007, the Pacific Fishery Management Council approved an 89,093 t harvest guideline, allocated coast-wide in three time periods. Ten percent of the harvest guideline was set aside for other CPS fisheries that take sardine once directed allocation is reached, and incidental take is set at 20% once the directed fishery is closed.

A comparison of the U.S. harvest guideline with the actual U.S. landings from 2000-2008 shows that the total landings from Washington, Oregon and California have not approached the harvest guideline in any of the last eight years. However, the 2008 harvest guideline is 42% lower than 2007, and if landings in 2008 are similar to those in 2007 it's possible that the total landings may reach the harvest guideline for the first time, leading to a closure of the fishery.

Oregon - Brett Wiedoff (ODFW)

The developmental fishery in Oregon began in 1999 with 20 permits and was changed to a state limited-entry fishery in 2006 (26 permits). The ex-vessel value was 4.4 million dollars in 2007, slightly less than 2006. The fishing areas were mostly north and south of the Columbia River mouth. Oregon fishery landings this year were about 42,000 mt with 22 vessels participating in the fishery. Due to inclement weather and decreasing fish availability there will be fewer catches for the remainder of the year. Fishermen need to meet a minimum requirement of ten landings of 5 mt a piece in order to renew their permit. Thus, under this new rule, fishermen must own or operate their vessel for renewal of their permits for the next year. This rule should encourage the landings to go with the vessel, not just the permit, prevent the transfer of permits, and encourage the continuous participation in the fishery.

The landing trends have changed, with a general increase in landings in Oregon, and a general decrease in landings in Washington. The California fishery is usually strongest in January-May while the Oregon and Washington fishery starts typically in June or July. In Oregon, sardines caught in August and September have the highest oil content. The California fishery starts again September-December. Based on the 2008 U.S. West Coast fishery allocation, Oregon expects to have to close their fishery in the second period.

In Oregon, the quality of fish is an issue, so fishermen want to bring them in cold. Consequently, there are not many large landings. In 2007, the average weight of fish was between 105-115 g, slightly higher than 2006 with a few fish being 220 g, which Japanese longliners like. Out of 1,465 fish measured for length frequency, the average standard length in 2006 was 193-203 mm.

Washington - Carol Henry (WDFW)

Washington's experimental sardine fishery is in its second year under that designation. Only 17

permits were issued in 2007 in an effort to limit the number of participants, down from 20 permits issued in 2006. The catch in 2007 was 4,663 mt from 112 landings by 6 vessels, down from a peak of 15,212 mt in 2002. The two primary ports are Westport and Ilwaco. The annual landings over last eight years have decreased, however peak landings months continue to be August and September. It's very difficult to find markets for sardines, as processors work primarily on whiting. However, some canneries have reconfigured to improve procedures of offloading, processing, and shipping of sardines, so the catch is likely to go up next year. This year, fishing started late in July and stopped in mid-October. The average weight of fish caught was approximately 100 g for all three months. For port sampling, 25 fish were sampled from each landing. Most of the fish ranged between 2 and 4 years old with few fish older than 5 year old.

Canada- Lisa Wilson and Jake Schweigert (DFO)

The opportunistic fishery in Canada is dependent on migration rates of sardines and is heavily influenced by oceanic conditions. There has been limited participation to date, but a high level of interest in access to the fishery remains. The main markets are tuna aquaculture feed, longline bait, and the onshore Asian food market.

Current management practices allow for fifty licenses (25 communal commercial for First Nations and 25 commercial). Allowable gear types are purse seine or trap net gear with no offloading at sea or use of packers. Multiple designations of licenses are permitted on a pilot basis. A certified, third party service provider is used to conduct a catch monitoring program, which requires 50% random at-sea observers, 100% dockside validation and at-sea observers in new areas, and mandatory logbooks. An advisory process provides stakeholders with an opportunity to give recommendations for annual management to the Department of Fisheries and Oceans (DFO). Currently licenses are a privilege and are issued annually at the Minister's discretion. However, DFO is considering a longer term management approach with a limited entry license regime to create annually renewable licenses.

The 2007/2008 sardine fishery season opened June 1, 2007 and will close February 9, 2008. Thus far, 1,524 mt have been caught of mixed sizes, low fat content, and low quality. Out of 46 license holders (25 commercial and 21 communal), only 12 fished. Bycatch was less than 0.2% of the total catch and comprised mainly pink and other salmon and chub mackerel. The total allowable catch was 19,786 mt based on a 15% harvest rate and a 10% migration rate of the estimated abundance for 2007. This resulted in individual vessel quotas of 396 mt per license. However, catch occurs mainly in July-September with the highest catch in August. The season is commencing slowly due to the small fish size. Sardine weights have been on a steady decline since 2004.

Some challenges identified by fishery participants include the: 1) high cost of co-management - $1,000 per license for science and management, and $2,000 per license for monitoring; 2) lack of infrastructure, such as poorly equipped processing plants, little dedicated freezer space, and poor transportation; 3) lack of scientific information on stock assessment, migration patterns, fish size, etc.; and 4) lack of marketing and low fish price.

The annual Canadian trawl survey on the west coast of Vancouver Island with the R/V *W.E. Ricker* was canceled due to mechanical problems. Sardine distribution was estimated from bycatch data collected during high seas salmon surveys. The survey tracklines were concentrated along the west coast of Vancouver Island but extended to the Alaska border. Sardines were found primarily along the west coast of Vancouver Island during June in the nearshore as well as in the inlets in recent years. In 2007, sardines were also found along the west side of Queen Charlotte Island in July. Juvenile herring surveys conducted in the central coast north of Vancouver Island using a small purse seiner setting at night also caught sardines in nearly every set.

The majority of the 2007 fishery landings occurred in August and September near the northeastern tip of Vancouver Island with minor landings along the west coast of Vancouver Island and in southern Hecate Strait. The bulk of the catch was taken near Port Hardy and landed there to minimize transportation costs. Total bycatch was 0.23% by weight with most being rockfish (63%) and herring (25%). The majority of the fish landed exceeded 200 mm in length with the largest fish caught in Area 12 at the northeast tip of Vancouver Island.

FOCUS ISSUE

Use of the Daily Egg Production Method to assess and manage a new fishery: A case study of the sardine fishery off South Australia – Dr. Tim Ward, SARDI Australia

The Daily Egg Production Method (DEPM) has been used to estimate the spawning biomass of sardine (pilchard), *Sardinops sagax*, in South Australian (SA) waters since 1995. The best estimate of spawning biomass in 1995 was 165,000 t, but this fell by over 70% to 37,000 t in 1996, following an unprecedented mass mortality event. Estimates of spawning biomass increased to reach 146,000 in 1998, but fell by over 70% to be approximately 36,000 t in early 1999, following a second mass mortality event. Spawning biomass increased steadily from 2000 onwards to reach ~201,000 t in 2004. Difficulties associated with the estimation of egg mortality and egg production introduced additional uncertainty into the estimate of spawning biomass for 2005, which was approximately 130,000 to 175,000 t. The estimate of spawning biomass for 2006 was 226,000 t.

The management of sardine was primarily based on the estimates of spawning biomass and not based on the age-structure model. This is due to the difficulties in sample age structure, estimating natural mortality and recruitment, increased uncertainty in biomass estimation and limited predictive capability. However the age structured model was used as a tool but not to manage the sardine stock.

In the early years of the SA Sardine Fishery, the Total Allowable Catch (TAC) for the following calendar year was set as a proportion of the spawning biomass (i.e. 10.0% to 17.5%, depending on the size of the spawning biomass). More recently, a baseline TAC was set at 30,000 t which will be maintained as the effective TAC while the estimates of spawning biomass remains between 150,000 and 300,000 t, which correspond to exploitation rates of 10% and 20%, respectively. Decisions rules were put in place for determining TAC for years when the spawning biomass is above 300,000 t with exploitation rates <10% or below 150,000 t with exploitation rates >20%.

The application of the DEPM has facilitated the rapid and sustainable development of the South Australian Sardine Fishery. This growth would not have occurred in the absence of this methodology. The primary limitation of the DEPM, which is the relative imprecision of individual estimates of spawning biomass, has been mitigated in the SA Sardine Fishery by developing a harvest strategy which has performance indicators and reference points that are designed to reflect a key management objective for this industry, i.e. to maximize stability in catches.

WORKING GROUP REPORTS

Working Group 1: Regional Estimates of Biomass - Nancy Lo (SWFSC)

1. CalCOFI and IMECOCAL April cruises, 2007

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

CalCOFI, April cruises, 2007

Nancy Lo, Beverly Macewicz and Richard Charter, SWFSC

The 2007 survey consisted of three legs aboard the NOAA Ship *David Starr Jordan*: Leg 1 was the regular CalCOFI survey and Legs 2 and 3, the DEPM survey. Leg 1 was scheduled to run from March 27-April 12 and to occupy six CalCOFI lines (93.3 - 76.7). Leg 2 was scheduled for April 13-20 and was to occupy six lines northward from line 91.7 and offshore to station 70. Leg 3 was scheduled to occupy four CalCOFI lines (73.3 - 63.3). Due to equipment problems and weather conditions, Leg 1 ended on April 19th after covering five CalCOFI lines from 93.3 to 80.0. Leg 2 ran from April 19-23, and covered three lines from line 91.7 out to station 70, ending at Port San Luis. Leg 3 ran from April 23-May 1 and due to weather conditions covered three lines: 76.7, 66.7 and 63.3. Thus the 2007 survey cruise began on March 27, ended on May 1, and occupied 11 lines (93.3- 63.3) out of the 17 planned lines, spaced 20 or 40 nm apart (Fig. 1). Bongo samples were taken at CalCOFI stations except those on line 63.3. For Leg 1, CalVET tows were taken only at regular CalCOFI survey stations. For Legs 2 and 3, 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. The 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 (Lo et al. 2007). This adaptive allocation sampling was similar to the 1997 survey (Lo et al. 2001).

In addition to sardine eggs and yolk-sac larvae collected with the CalVET net, yolk-sac larvae collected with the Bongo net have been included to model the sardine embryonic mortality curve since 2000 (Fig. 2). Beginning in 2001 (Lo 2001), the CUFES data from the ichthyoplankton surveys have been used only to map the spatial distribution of the sardine spawning population

with the survey area post-stratified into high density and low density areas according to the egg density from CUFES collections. Staged eggs from CalVET tows and yolk-sac larvae from CalVET and Bongo tows in the high density area have been used to model an embryonic mortality curve to estimate P_0 and embryonic mortality rate. P_0 in the high density area was later converted to the daily egg production, P_0, for the whole survey area.

For adult samples, the survey plan was to use the NOAA Ship *David Starr Jordan* to conduct 3-4 trawls a night at the regular CalCOFI stations at random sites on the survey line regardless of the presence of sardine eggs in CUFES collections. The trawl survey was conducted from April 19-30, 2007. Bad weather reduced the amount of survey time and hence, the number of trawls attempted. Although only 18 trawls were conducted at night near the surface (0-6 fathoms), 15 were positive for Pacific sardines (Fig. 1).

The estimate of the daily egg production for the entire survey area was 0.864/0.05 m^2 (CV = 0.25) for a total area of 356,159 km^2 (104,940 nm^2) from San Diego to San Francisco. The daily specific fecundity was 15.68 eggs/gm/day and the average interval between spawning (spawning frequency) was about 9 days (inverse of spawning fraction or 1/0.114). The estimates of the mature female Pacific sardine reproductive parameters in the standard sampling area from 14 positive trawls and 203 mature females were: F, mean batch fecundity, 21,760 eggs/batch (CV = 0.084); S, fraction spawning per day, 0.114 females spawning per day (CV = 0.34); W_f, mean female fish weight, 81.62 g (CV = 0.085); and R, sex ratio of females by weight, 0.51 (CV = 0.09). The final estimate of spawning biomass of sardine in 2007 was 392,492 mt (CV=0.45) or 431,741 short tons (st) (=392,492 x 1.1) for an area of 356,159 km^2 (104,940 nm^2) from San Diego to San Francisco. The point estimates of spawning biomass of Pacific sardine from 1994-2007 are respectively: 127,102; 79,997; 83,176; 409,579; 313,986; 282,248; 1,063,837; 790,925; 206,333; 485,121; 281,639; 621,657; 836,501; and 392,492 mt (Lo et al. 2005).

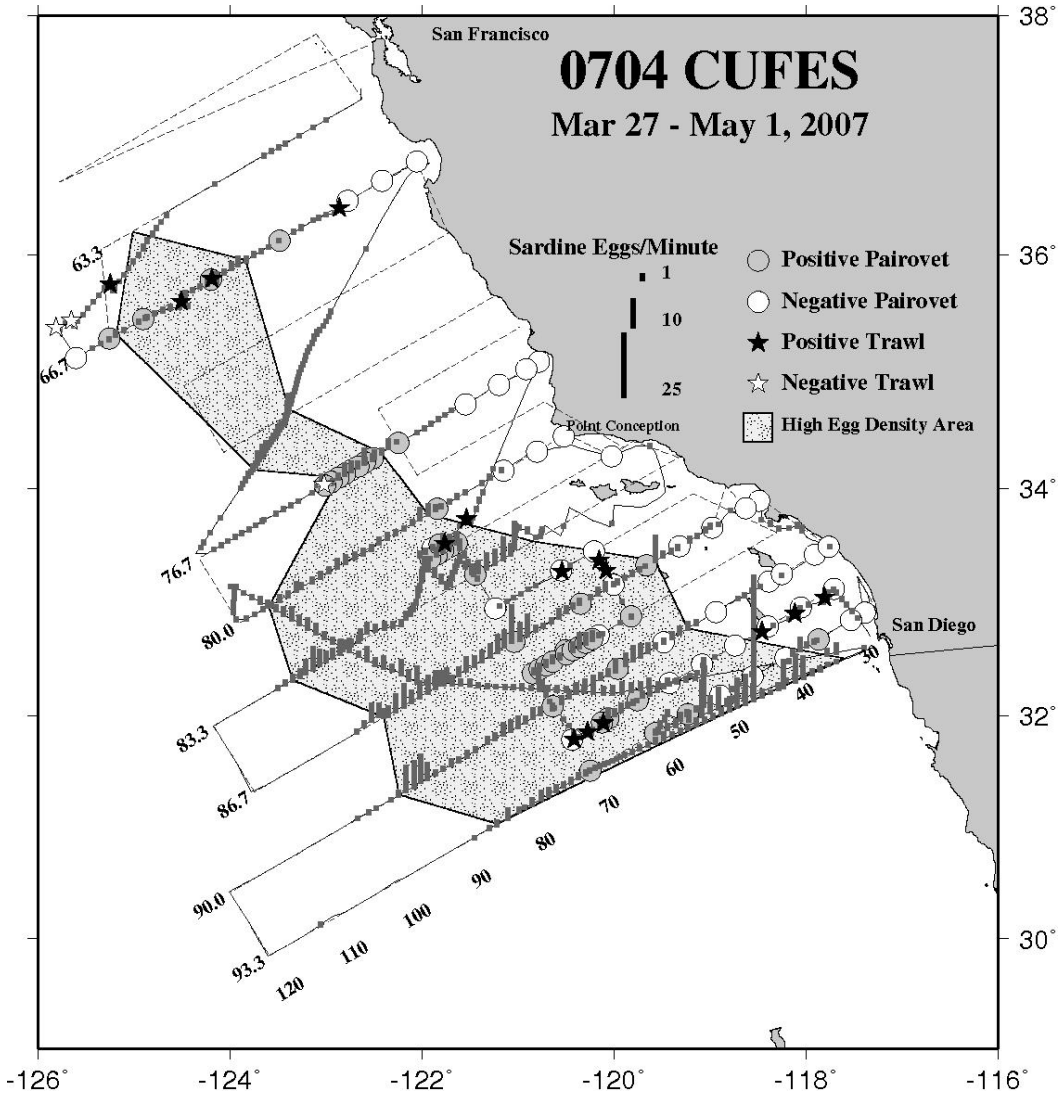

Figure 1. Sardine eggs collected from CalVET (or Pairovet; circles), CUFES (stick denotes positive collection) and trawl samples (stars) during the March-May 2007 survey. Region 1 is dotted area. The solid symbols are positive collections and the open symbols are zero catches.

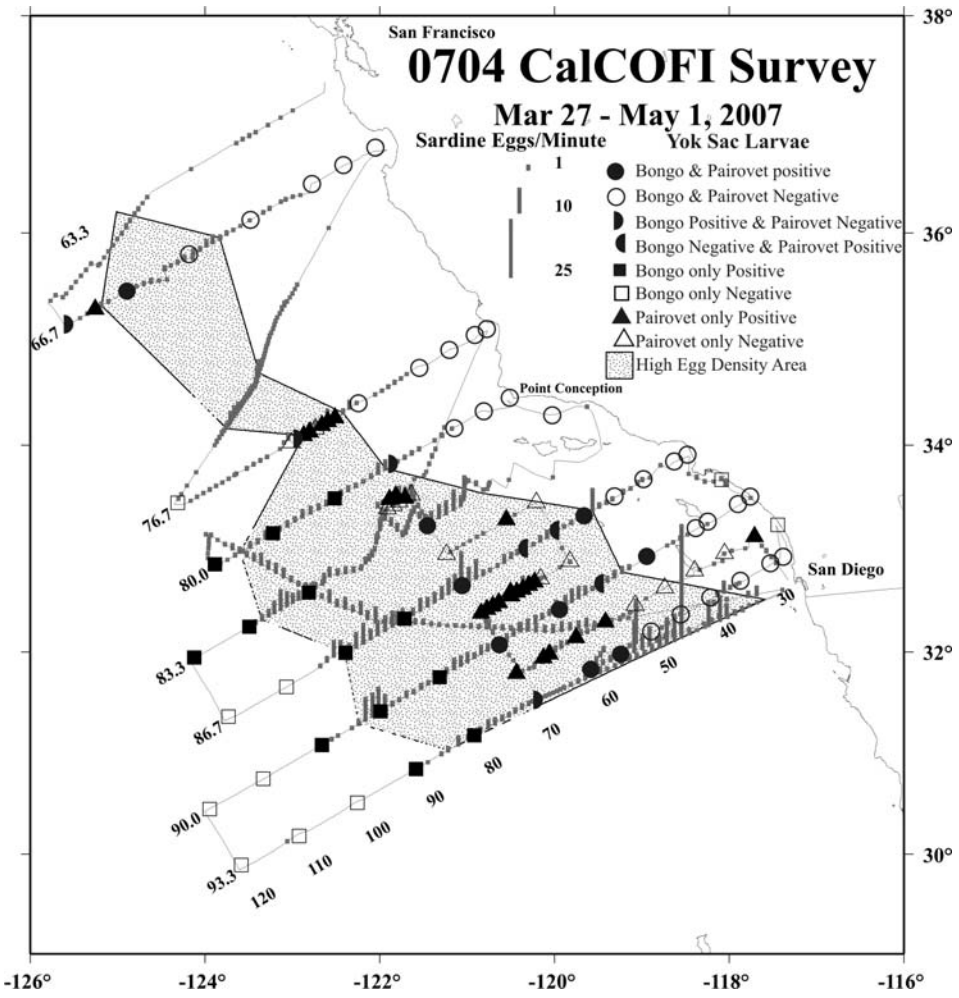

Figure 2. Sardine yolk-sac larvae collected from CalVET (or Pairovet; circle and triangle) and from Bongo (circle and square) tows during the March-May 2007 survey. Solid symbols are positive and open symbols are zero catch.

IMECOCAL in 2007 (no updated report)

Spawning biomass was estimated for the years: 1997-1999, 2002 and 2003 as 2,662, 59,000, 94,000, 48,000 and 9,200 mt. The first three estimates were computed from sardine larval data and the 2002 and 2003 spawning biomasses were estimated from CUFES egg samples from IMECOCAL surveys (Lo et al. 2006).

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

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

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

Two surface trawl surveys collected Pacific sardines (*Sardinops sagax*) off Oregon and Washington in 2007:

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

Population estimates and size of Pacific sardines off Columbia River region

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

The sardine biomass estimates off the Columbia River region in July 2007 ranged from 3,727 mt of sardines in early July to 2,857 mt in late July (Table 1). These estimates are below late July 2006 estimates (11,285 mt). However, wide fluctuations in population estimates can be expected because sardines have very patchy distributions, and they show large movements both within and outside the study area.

During most years, the highest estimated biomass of sardines occurred in July/August. In 2007 however, highest estimated sardine biomass was observed in June (7,424 mt; Fig. 4). The only other year when estimated sardine biomass was highest in June was 2001.

The length/frequency data (Fig. 5) indicate that sardines in the Columbia River area in 2007 were composed primarily of one size class. However, the average size decreased each month. We suspect the change in size was due either to an influx of smaller sardines into the study area, or the movement of larger sardines out of the area. Overall, average sardine lengths in July 2007 were very similar to that of 2006 (Table 1). Oregon/Washington coastal surveys (Fig. 6) showed two size classes in June and three in September (Fig. 7). Similar to 2006, relatively few 0-age sardines were captured in September 2007 (Fig. 8), indicating that recruitment from 2007 Northwest spawning was not as successful as in 2004 and 2005, when many 0-age sardine were caught (Fig. 8). One-year-old sardines generally range from 125 to 175 mm FL in September. In 2007, this size/age class was completely absent except for one individual. This indicates that, as reported in 2006, sardine 0-age recruitment in 2006 was very poor and is now reflected in very low numbers of one-year-old sardines in 2007. If 2006 and 2007 sardine recruitment is low, as our data indicates, this may be reflected in fewer sardines available to the commercial sardine fishery operating off the Columbia River in 2008.

The ocean was relatively cold in May and June 2007 compared to past years (Fig. 9), but 2007 had the warmest SST's ever observed in July and August. Past reports have reported that warm ocean conditions in May/June appear to be conducive for successful spawning and recruitment of

Pacific sardine off the Oregon/Washington coast. The observed poor sardine recruitment again supports the hypothesis that warm ocean conditions in May/June are important for sardine to successfully spawn and recruit off the Pacific Northwest.

Sardine catch and length/frequency data indicate that sardines were more abundant off the Columbia River in 2007 than in 2006, but had very low spawning recruitment in 2007. This suggests that the sardine population in the California Current will only have limited additional sardine biomass originating from Northwest spawning in 2007, similar to what was observed in 2006.

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

Estimated Number of Pacific Sardine off S Wash/N Oregon			
Year	Early July	Mid July	Late July/early August
1999	6,361,531	4,298,041	110,264,191
2000	246,539,570	293,661,085	no trawls after 22 July 2000
2001	13,547,385	61,691,990	89,693,132
2002	207,891,576	18,538,962	non taken
2003	10,259,428	847,269,268	73,626,122
2004	11,672,862	79,086,033	173,551,785
2005	156,052,620	No Trawls	103,173,678
2006	5,948,632	3,829,993	106,931,506
2007	32,381,019	No Trawls	26,078,994
Average Length of Pacific Sardine			
Year	Early July	Mid July	Late July/early August
1999	246	239	235
2000	237	243	
2001	233	241	242
2002	247	247	
2003	251	249	237
2004	108 and 256	135 and 251	143 and 245
2005	189	No Trawls	190
2006	207	210	215
2007	222	No Trawls	218
Average weight of Pacific Sardine (g) Calculated from average length			
Year	Early July	Mid July	Late July
1999	154	143	137
2000	140	149	
2001	133	146	148
2002	156	156	
2003	165	160	140
2004	22 and 248	41 and 236	48 and 220
2005	73	No Trawls	74
2006	95	99	106
2007	115	No Trawls	110
Biomass of Pacific Sardine off S Wash/N Oregon (metric tons)			
Year	Early July	Mid July	Late July/early August
1999	985	613	14,984
2000	34,475	43,845	No Trawls
2001	1,802	8,980	13,289
2002	32,529	2,892	No Trawls
2003	1,690	211,098	10,290
2004	2,705	5,533	36,574
2005	11,399	No Trawls	7,621
2006	564	378	11,285
2007	3,727	No Trawls	2,857

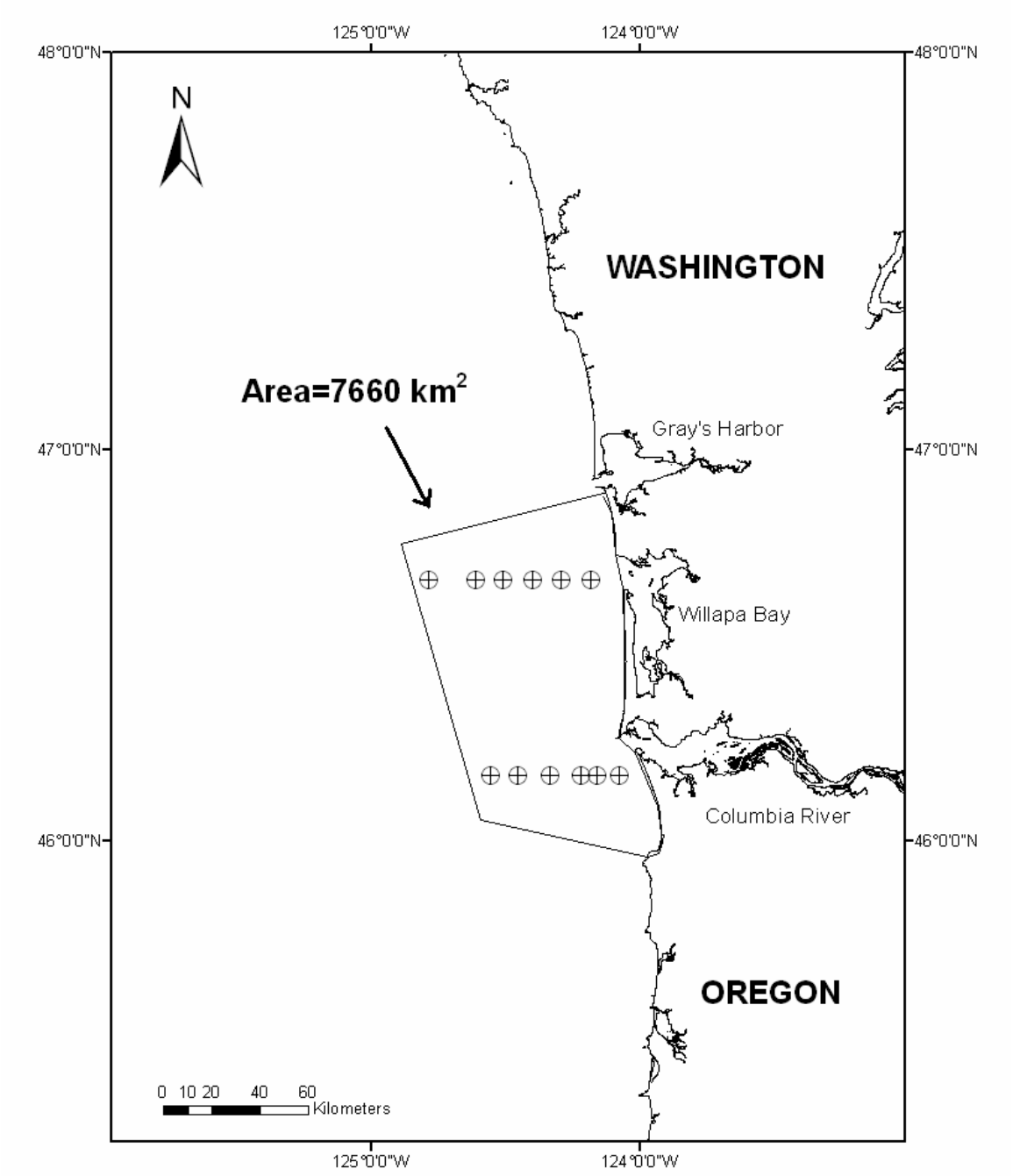

Figure 3. Location of the 12 surface trawl locations sampled at night approximately every 10 days near the Columbia River from late April through early August during the Predator/Forage Fish Survey.

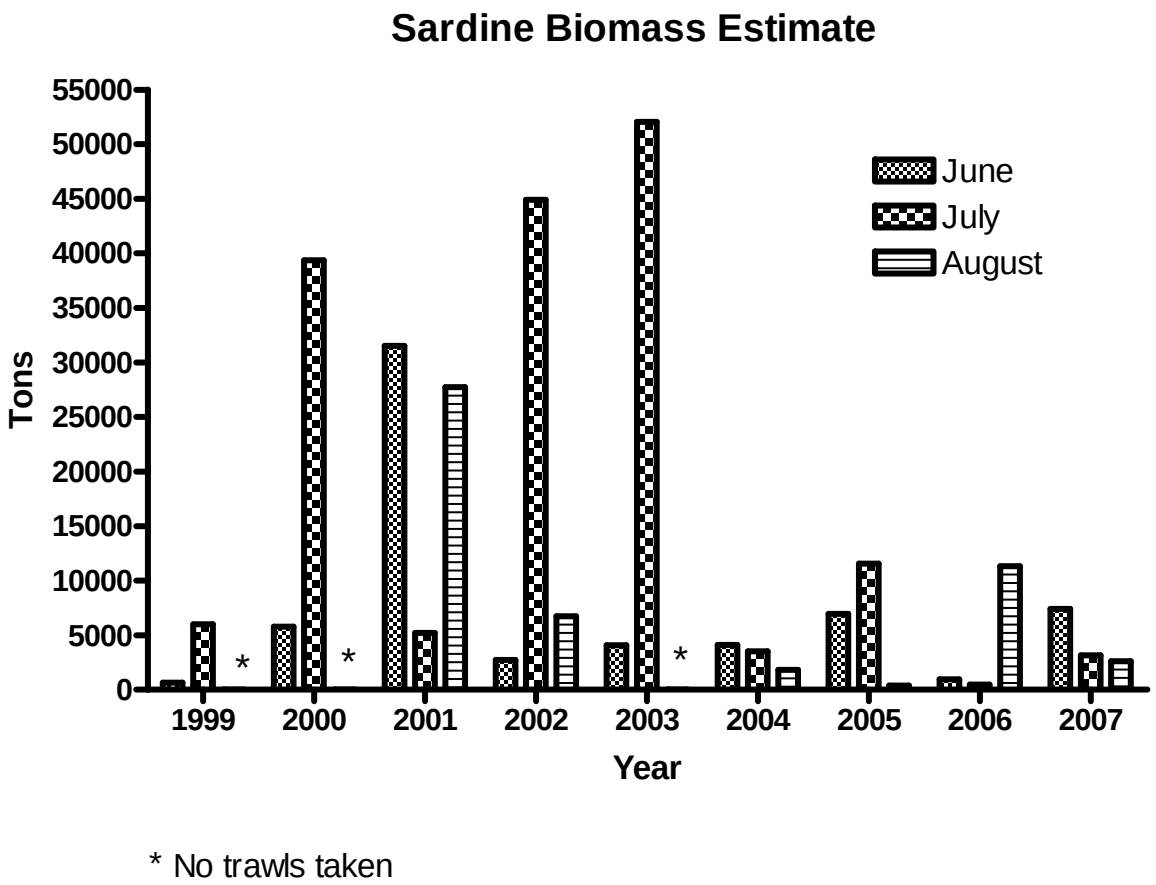

Figure 4. Monthly biomass estimates of Pacific sardine (*Sardinops sagax*) captured off the Columbia River 1999-2007 during the Predator/Forage Fish Survey.

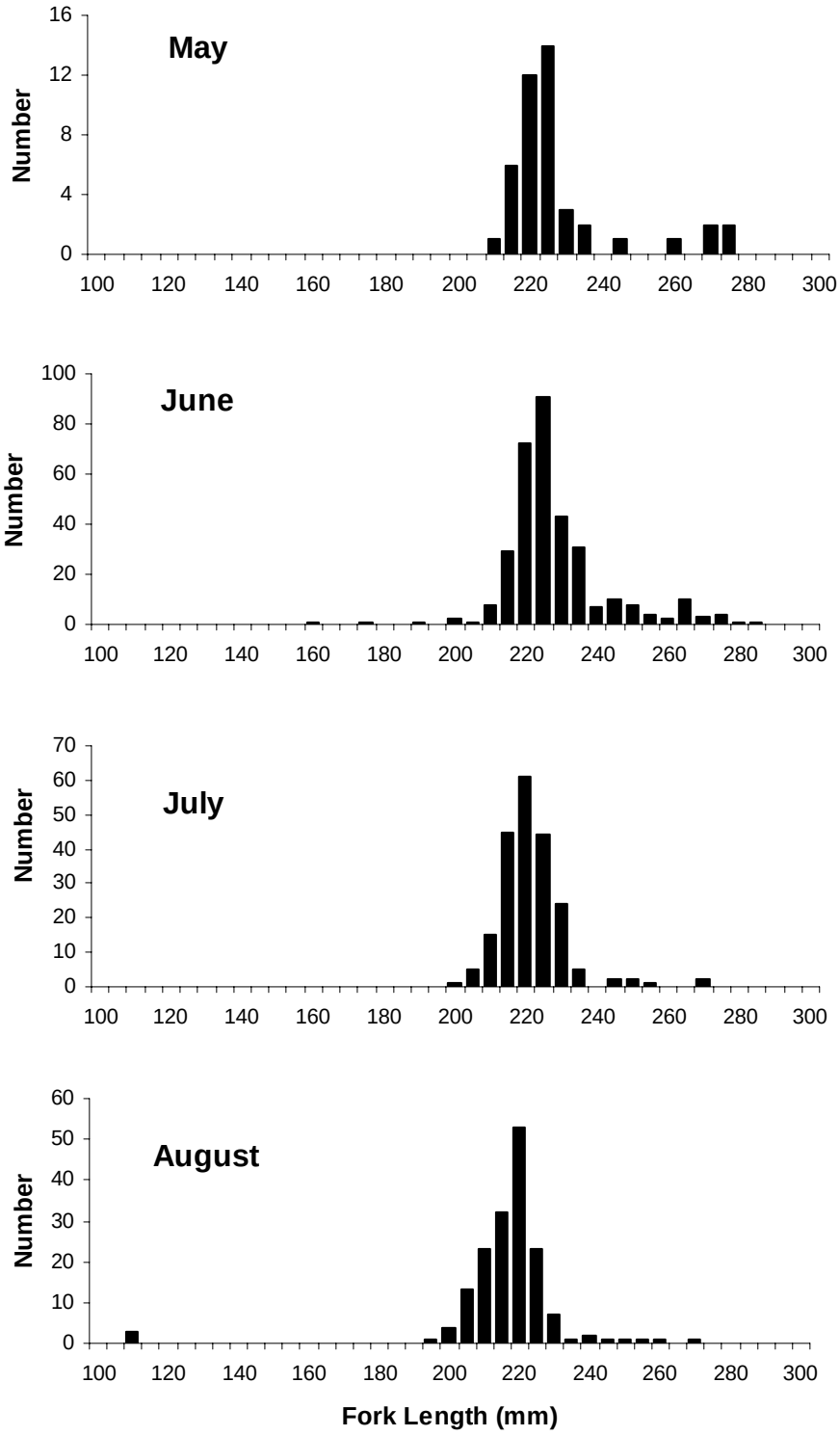

Figure 5. Length frequency of Pacific sardine (*Sardinops sagax*) captured off the Columbia River in 2007 during the Predator/Forage Fish Survey.

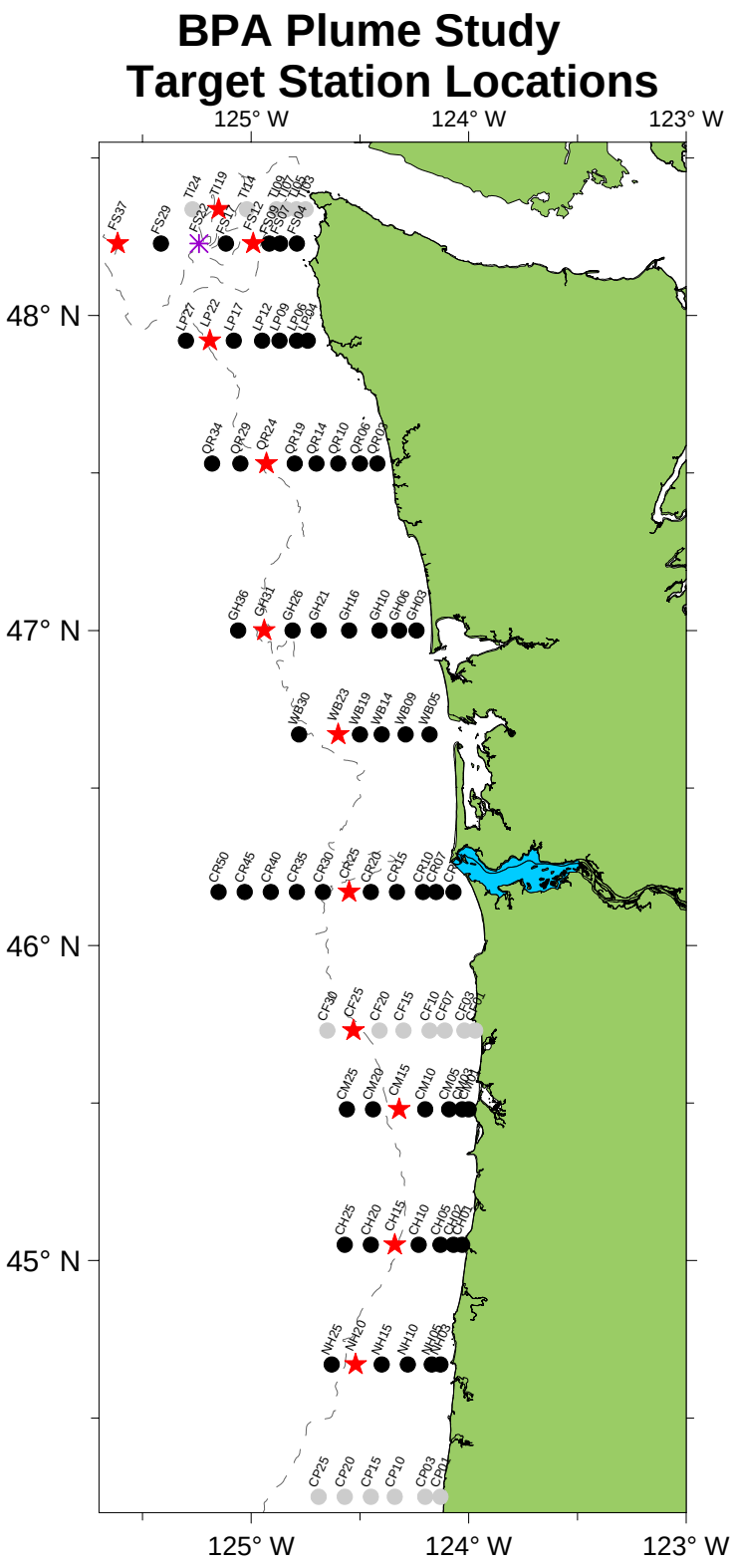

Figure 6. Location of stations sampled annually in June and September off Oregon/Washington during the BPA plume study.

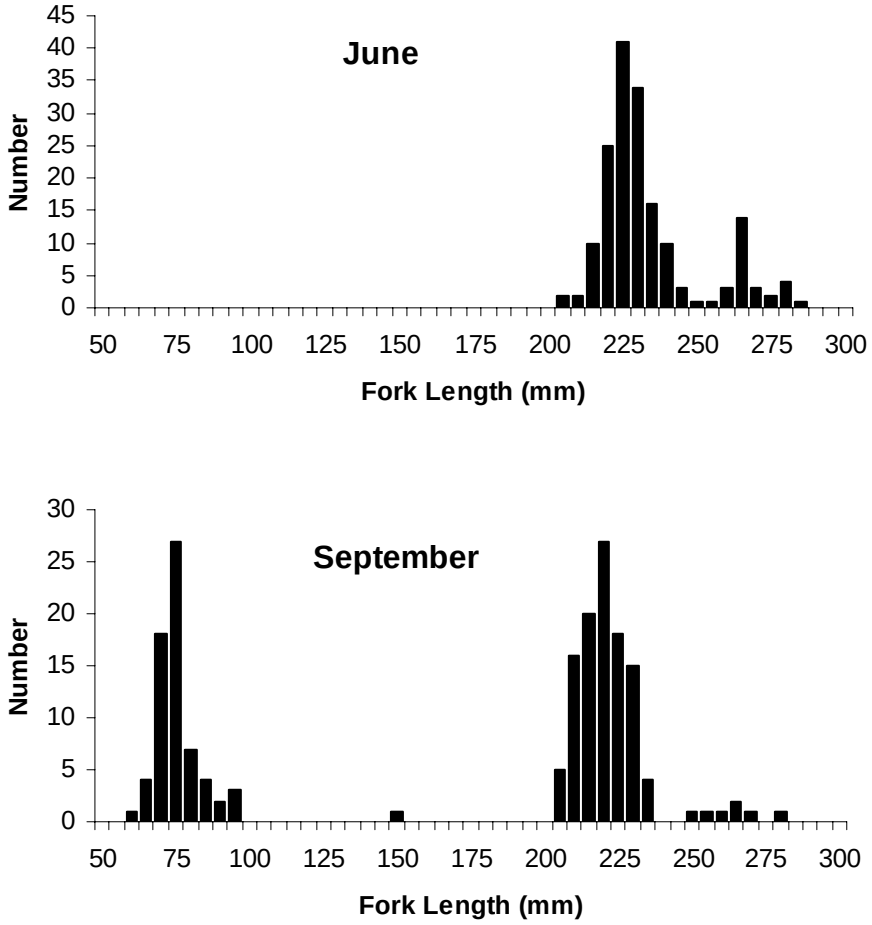

Figure 7. Length frequency of Pacific sardine (*Sardinops sagax*) captured off Oregon/Washington in June and September 2007 during BPA plume study.

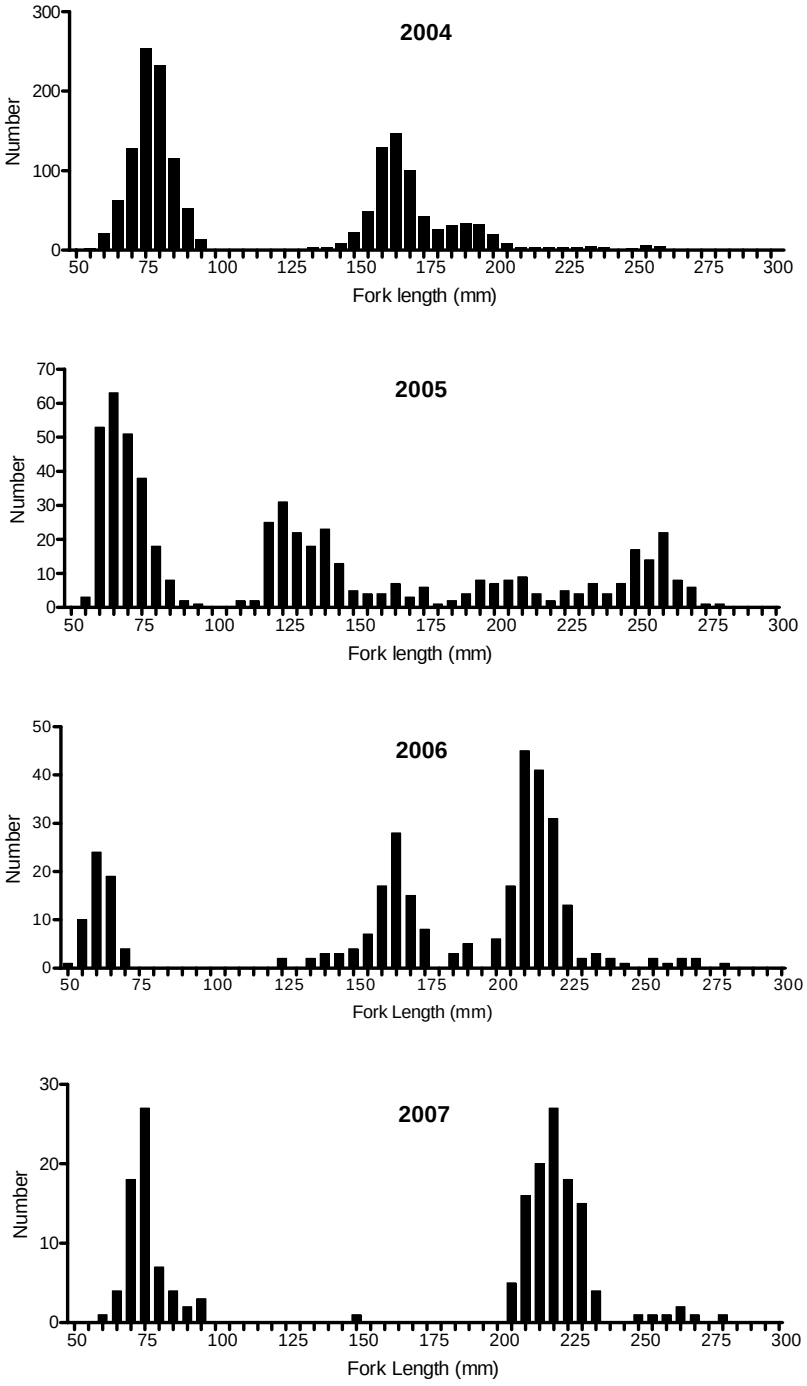

Figure 8. Length frequency of Pacific sardine captured during September 2004 – 2007 off the Oregon/Washington coast during the BPA plume study.

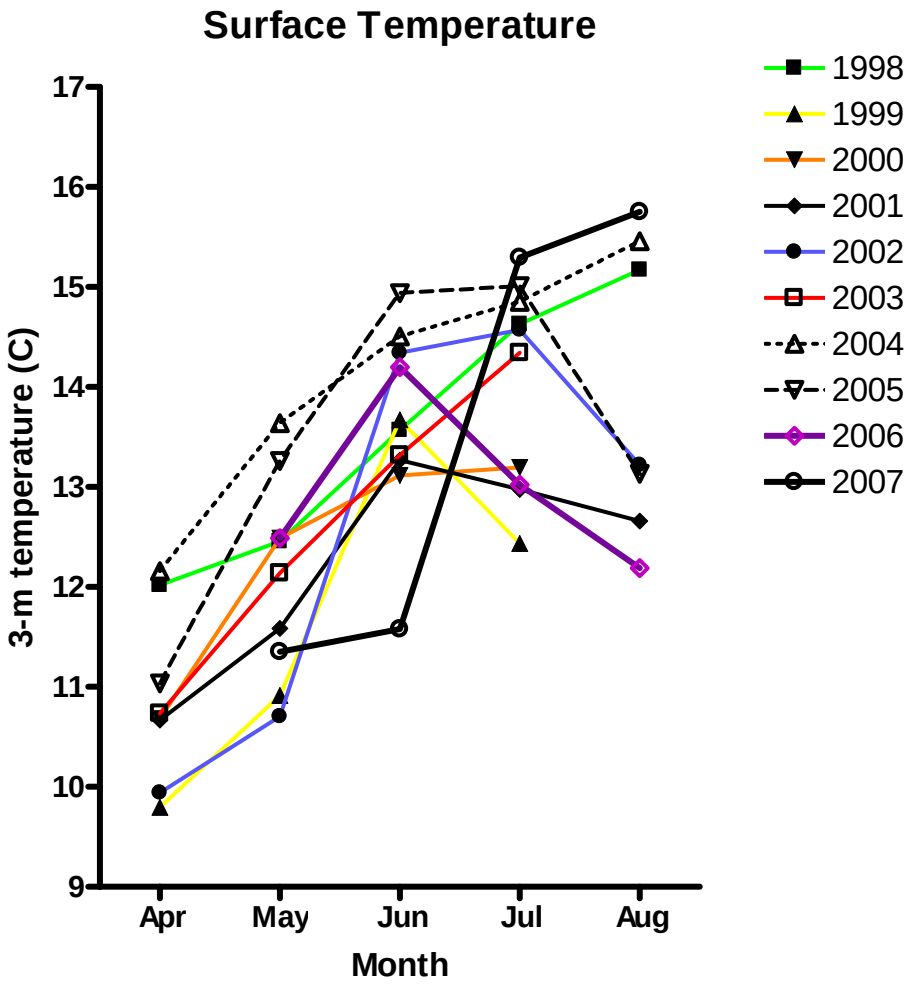

Figure 9. Average monthly surface temperatures (3 m depth) off the Columbia River 1998-2007.

3. Canadian Trawl Surveys of Pacific Sardine Abundance in B.C. Waters during 2007

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

Background

From 1992 to 1996 small numbers of sardines were captured in both commercial and research sets targeting Pacific hake off the southwest coast of Vancouver Island. Since 1997, large numbers of sardines have been captured in surface water research sets targeted on sardine off the west and northeast coasts of Vancouver Island, Queen Charlotte Sound, and in a small commercial fishery for sardines in inlets surrounding Vancouver Island. From 1997 to 1999, sardines were found in the Strait of Juan de Fuca, in the Strait of Georgia, along the west coast of Vancouver Island, Hecate Strait, and off southeast Alaska (McFarlane and Beamish, 2001; McFarlane and MacDougall, 2001). Sardine distribution in 2000 was concentrated on the west coast of Vancouver Island and ranged as far south as Barkley Sound and as far north as mainland British Columbia, north of Vancouver Island. From 2001 to 2003, sardines became progressively concentrated near shore along the southwest Vancouver Island coast and progressively less prevalent in research cruises. By 2004, sardines were rarely captured offshore or along the research grid; however, large catches of sardines were made in inlets and the shallows along the west coast of Vancouver Island, and in 2004 in Queen Charlotte Sound inlets. In 2006, sardines were again widely distributed off the west coast of Vancouver Island, both inshore and offshore, likely due to the presence of the abundant 2003 year-class.

Activities

Unfortunately, due to the breakdown of the *W.E. Ricker* in mid-2007 the trawl survey could not be completed on the west coast of Vancouver Island as in previous years. Anecdotal reports of sardine in Canadian waters indicated that fish were widely distributed into Hecate Strait reaching almost as far north as the Alaska border. However, there were fewer reports of sardines in the inlets of the west coast of Vancouver Island than in recent years. A limited amount of information on sardine size composition was collected as part of a juvenile herring survey that was conducted in the Central Coast area of British Columbia. The survey is conducted using a small purse seiner fishing at night. The sampling locations are shown in Figure 10.

Sardines were captured at virtually all sampling sites and there was little difference in the length frequency of sardines at each sampling location. The combined length frequency data for the sardines taken in this survey are shown in Figure 11. It is evident that all the sardines captured are greater than 20 cm suggesting that they are probably ages 4 and older. In fact, the bulk of the fish are most likely from the very strong 2003 year-class.

A significant die-off of sardines also occurred during the summer of 2007 off the eastern end of Kwakshua Channel and northwards. The fish were widely distributed in this area making it difficult to estimate the tonnage involved. Although samples were collected, no proximate cause of the mortalities was determined.

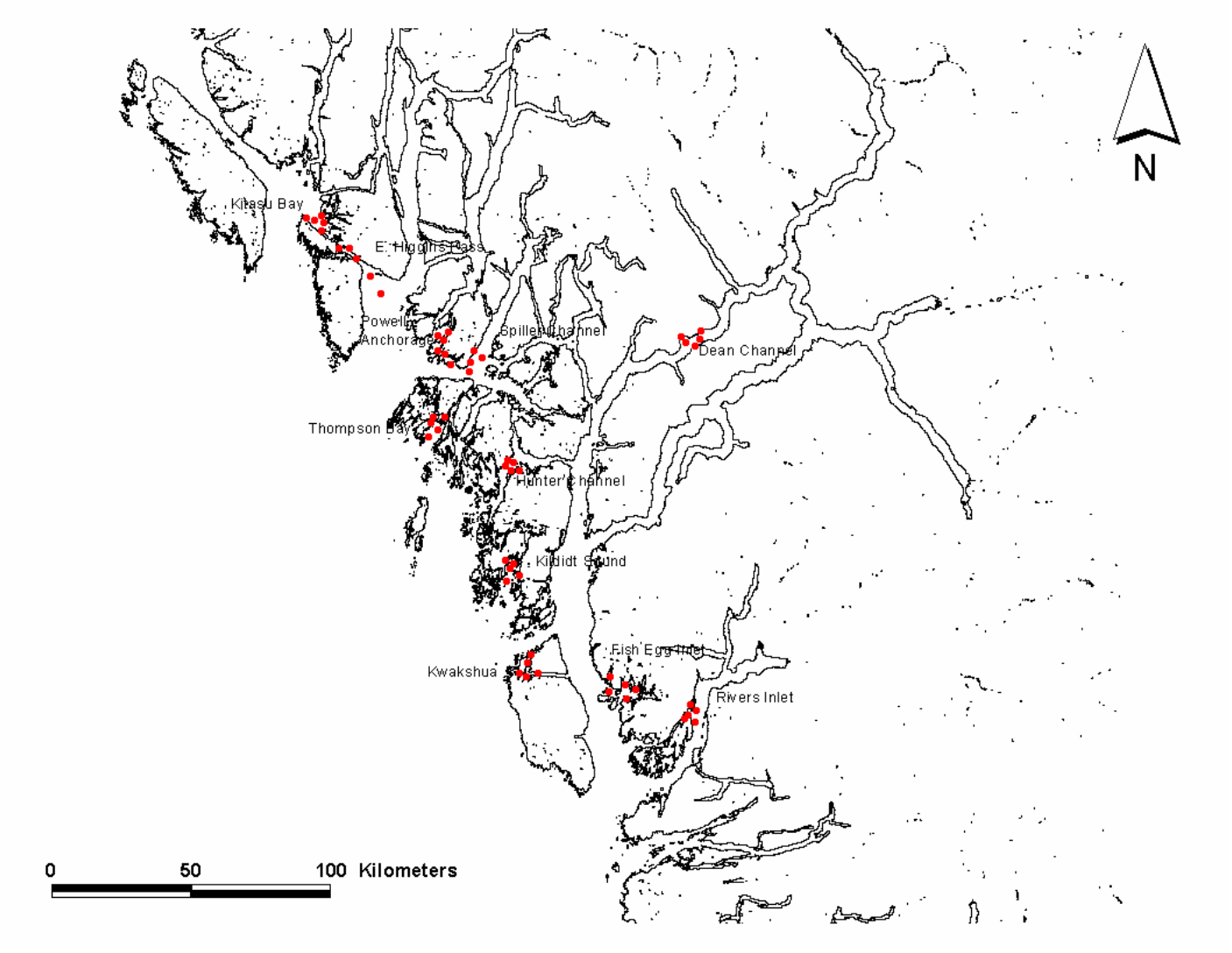

Figure 10. Juvenile herring survey seine sampling sites in the Central Coast, August 2007 with a total of 53 sampling sites occupied.

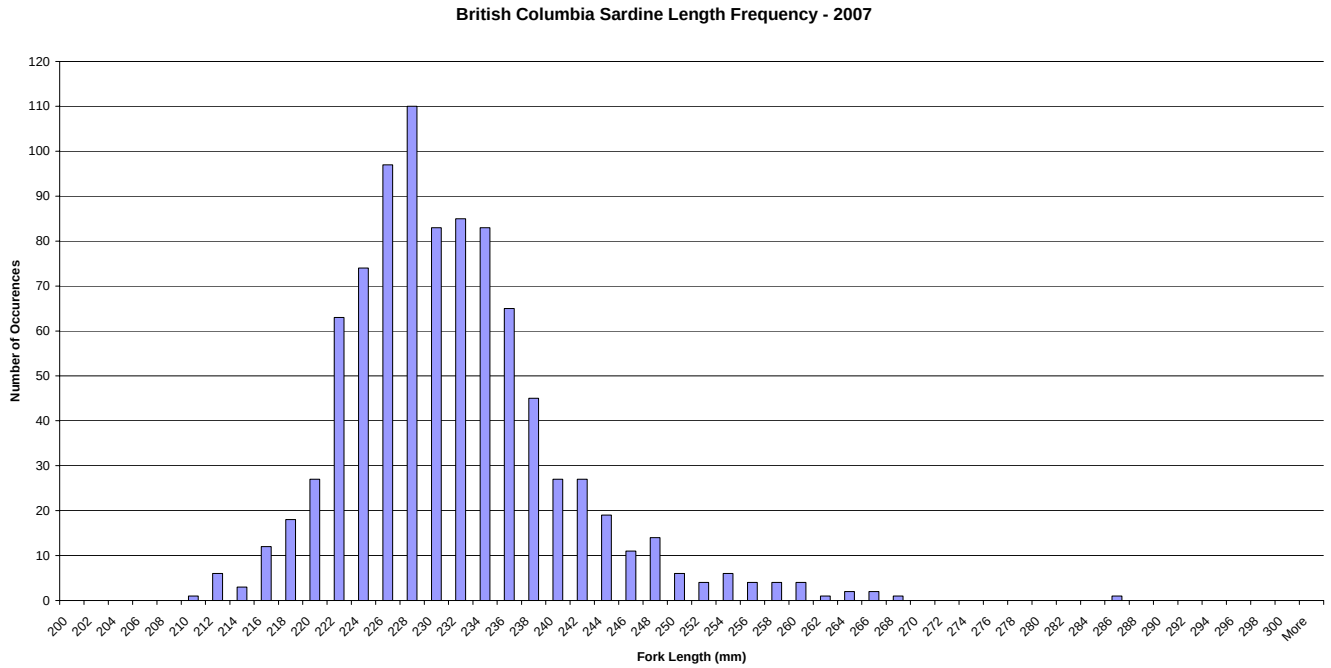

Figure 11. Length frequency distribution (n=906) of sardines collected in seine net sets during the juvenile herring survey in the Central Coast, August 2007.

Working Group1: Future Plans and Recommendations

During the plenary session, the 2007 future plans and recommendation from the 2006 TSF by each country's representatives were reviewed and discussed (Hrabok et al. 2007). Representatives from each of the three countries provided the 2008 future plans and recommendations for regional biomass estimation. Mexican scientists from INP unfortunately were unable to attend and Mexican scientists from academia were able to provide some information to the best of their knowledge. The feasibility of conducting an aerial survey off the Northwest coast in 2008 was also discussed. This aerial survey was suggested to provide sightings of sardine schools to ascertain the status of the biomass of sardine due to the concerns raised from industry as result of the reduction of catch quota for 2008.

Status of the Future Plans and Recommendations from the 2006 TSF

México

In 2007, no adult sardine surveys were conducted; however IMECOCAL surveys were conducted in January, April, and July. The October cruise was canceled in order to fund 2008 cruises. In 2008, the cruise time will be reduced from the usual 21 days to 20 days in January, 17 days in April, 17 days in July, and 15 days in October. Tim Baumgartner has 2007 CUFES samples. INP will not conduct an ichthyoplankton survey in January 2008, as planned. Few eggs were collected by the Pairovet aboard the *Puma* in 2006.

Mexican scientists suggested at the 2006 TSF that biological data on sardines should be compiled from the coast-wide survey to determine the distribution of various characteristics of adult fish, like the age distribution, microchemistry traits, and so forth. For adult sardine samples

collected from 2006 surveys, Kevin Hill, Beverly Macewicz and Barbara Javor did read some otoliths to check the variability among the readers, which turned out to be high. Therefore, a future workshop on ageing techniques is needed. The 2006 otolith samples were given to Dale Sweetnam of the CDFG, and they are continuing analysis. It is also important to update the growth curve of adult sardine.

Canada

Canadian scientists were unable to collect sardine samples as either a part of their regular sardine trawl survey or as a part of hake survey (Hrabok et al. 2006). The long-mentioned biological, economic and oceanographic model is not yet complete. However, Sam Herrick of the SWFSC is working on a similar economic conceptual model, which might be expanded to include biological information with collaboration from John Field. Sandy McFarlane suggested that a working group headed by Sam Herrick be formed, with Sandy, John Field, and Don Pepper as suggested participants. The purse seine and acoustic general abundance survey beginning in 2005 is not likely to continue due to lack of funding by the industry. The original survey was for one year only to investigate the distribution of sardines inshore and in the inlets.

U.S.

A six-day survey of the Northwest coast was conducted in June 2007, and the preliminary cruise results were presented in a poster (Griffith and Macewicz, Appendix IV). Beverly Macewicz was able to obtain 300 sardines from six purse-seine sets under the coastal pelagic species (CPS) observer program to be included in spawning biomass estimation. One problem is taking materials from the preserved fish because the gonads could not be processed onboard. We hope the program will continue and a better preservation method needs to be investigated. Otoliths should be also collected for ageing, estimating maturity, and for microchemistry. The CPS observer program through the CDFG will continue in California in 2008; however, according to Mike Burner there will not be a program in the Northwest. In 2008, adult samples will be collected during the two coast-wide surveys, pending authorization from the Region.

2007 Future Plans and Recommendations

México

IMECOCAL's four scheduled cruises were approved by the Ministry of Resources and Environment but funding has not yet been provided. CICESE will provide loans to allow the cruise to start by January. Sharon Herzka and Tim Baumgartner, CICESE, are requesting an exploratory fishing permit for a Mexican-flagged Norwegian mid-water trawler from Ensenada to trawl offshore to collect adult samples during the IMECOCAL surveys. Because the trawler does not have a permit, nothing is guaranteed. Nancy Lo will contact Manuel Névarez-Martínez (CRIP-Guaymas) and Miguel Cisneros-Mata (Director, INP) to inform them about the coast-wide survey, and stress the importance of collecting adult samples during the IMECOCAL surveys.

Canada

Canadian representatives voiced the willingness to participate in the July coast-wide survey to extend the survey area to Canada. Sandy MacFarlane indicated that Fisheries and Oceans, Canada plans to conduct trawl surveys from the border to the northern tip of Vancouver Island from mid-July to mid-August to occupy the regular 12 transects off the island. They will need to borrow

ichthyoplankton tow nets and CUFES to collect ichthyoplankton samples. Details of loaning the equipment have to be worked out by Richard Charter, as two portable systems will be needed: one for the R/V *New Horizon* and one for the *W. E. Ricker*. The *W. E. Ricker* is supposed to be operational starting in March.

U.S.

SWFSC plans to conduct two coast-wide surveys to cover the area from San Diego to the Washington border: one in April and one in July 2008. The April coast-wide survey will be conducted aboard two research vessels: the NOAA Ship *David Starr Jordan* (DSJ) for 17 days, which will conduct the regular April CalCOFI cruise and cover the area from San Diego to Point Conception. For the next 18 days, the DSJ will cover the area from San Diego to San Francisco for the coast-wide survey. Concurrently, the NOAA Ship *Miller Freeman* will cover the area from the Washington border to San Francisco in 22 days.

The July coast-wide survey will be conducted aboard the DSJ to cover the whole area from San Diego to the Washington border for 50 days while the R/V *New Horizon*, SIO, will conduct the routine July CalCOFI survey. Because the CalCOFI protocol involves bongo tows, etc., and no trawls, the question was raised regarding the possibility of taking extra CalVET tows when high densities of eggs occur in the CUFES during the regular CalCOFI cruise, to increase the sample size of sardine eggs. The constraint on the CalCOFI cruise is ship time, and extra ship time requires more funding. This may not be a problem for the July cruise as the egg density would be lower. Roger Hewitt and Tony Koslow will meet to decide how to prioritize the sample collections.

Roger Hewitt noted that we need to understand that at this stage, we are discussing how to carry out the July survey and the impacts it might have on the other projects that were planned aboard the *David Starr Jordan* in July, finding staffing for 45 days, and the overall practicality of a July coast-wide survey. For 2008, only the April coast-wide survey using two ships is fixed, but the number of days is not decided yet. The NOAA Ship *Miller Freeman* will survey in the north, the *David Starr Jordan* in the south, and we'll also conduct the regular DEPM survey in that time period. Other issues discussed were the possibility of sampling juveniles, occupation of line 97 close to the Coronado Islands, and using down-looking acoustics and side-looking sonar. The NWFSC may provide personnel for the April coast-wide survey. Bob Emmett will check with his staff and the university and will let Dave Griffith know as soon as possible.

2008 Aerial spotter surveys off the Northwest

Much of the WG1 discussion time was devoted to the possibility of planning 2008 aerial surveys off the Northwest to ascertain if the population of sardine in that region is higher than what was concluded by the 2007 stock assessment. (Note: there was no biomass estimate specifically made for the Northwest area. Instead, an overall biomass estimate is obtained each year for the sardines off the west coast of the U.S.). The harvest guideline for 2008 was 89,000 mt, down from 122,000 mt set for 2007. Mike Okoniewski in particular was concerned about the future of the sardine industry. He indicated that if the sardine stock assessment model is correct, then industry will need to plan for the future. However, if the model is in doubt, an additional survey tool is needed to provide further information about the sardine population off the Northwest, and an aerial survey is desirable as the planes can cover a large area. It was also suggested that seining vessels with acoustics should accompany the aerial survey to help calibrate it, and agreed that regardless

of the design, the survey methods must be repeatable, credible, and pass scrutiny from independent reviewers.

All parties agree that a working group needs to be formed, which consists of industry representatives and scientists, to meet to determine the objectives, to plan the aerial surveys, and to discuss the related issues, e.g. Nancy Lo for her survey design experience, Kevin Hill for stock assessment, and Mike Okoniewski and other representatives from industry in the Northwest. A further possibility is to put LIDAR equipment on the airplanes, but this gear only detects to 50 m and works best at night when the fish schools are closer to the surface.

Working Group 2: Stock Structure, Age Structure and Adult Sampling - Russ Vetter (SWFSC)

1. What do we know about recruitment? We have knowledge of:
   - Where the eggs are using CUFES sampling
   - Instantaneous mortality rates and stage duration for *S. sagax*
   - Where the adults are
   - Cycles of sardines and anchovies over time

What's generally missing is nearly a year's worth of data between the larval stage and the large juvenile (or small adult) stage caught in the fishery. If larvae don't get enough to eat, or a surge of predators impacts the larvae or juveniles, then it will be a bad recruitment year even if the CUFES counts were high. We lack data to make statements across four coastal zones of sardine distribution. We should include a focus on measurements of the age-zero class to estimate recruitment using measurements that are simple, cheap, and that can be done before you get off the boat and over very large geographic scales.

2. Tracking sardines through otolith microchemistry and molecular genetics.
   - Significant progress has been made in the last year using stable isotopes and trace metals as a function of temperature and geography. We need to think about linking interpretations of the microchemistry with classical biological oceanography (e.g., recent and long-term CalCOFI and satellite data).
   - Genetics can go very far in the next few years if we fine-tune our approach by searching for adaptive and expressed genes in addition to our current approach of assessing DNA patterns in repeating sequences of unknown genes. We see hints that thermal adaptations exist - they may be genetically encoded and under selective pressure.

Discussion

How do we know where to find the adaptive genes? We need to survey lots of genes. We are getting faster and better at this, but it's a relatively expensive technology overall. Once we know which genes to address, it will be simpler.

Coast-wide sampling: Paul Smith reiterated the need for full coast-wide sampling of spawning that would answer a lot of questions. One of the chief limits in genetics is that statistical power

requires large sample sizes, temporal replicates, over a broad geographic scale. We'd like to have funding and sustain it beyond a year.

Are we looking for structure in a stock that might not have any? And if it does, does it matter? Local and international politics require the search, because with sardines, migration is everything. We need to know if only one trinational stock exists. If we harvest out of one area, how long does it take to fill in again from another area? It's likely they are mixing, but not mixing completely. How much exchange is there between populations? The four oceanographic coastal zones sardines inhabit have different productivity and oceanographic drivers. There are multiple places where young are spawned and presumably survive. Will genetics tell us about migration in and between these zones?

Oceanographic methods: Sam McClatchie feels acoustics are a powerful tool for tracking fish. Do we know enough for new acoustics methods to be used, such as moorings or autonomous vehicles? Maybe this would allow us to resolve important but episodic events over a wide spatial scale, although it would not provide species information.

Juvenile sardines: Barbara Javor reiterated the "missing link" role of juveniles in stock assessment, and offered to be the point person to coordinate otolith and tissue sampling by different groups. If we get incremental samples throughout the year, maybe we can follow where sardines move using genetics and microchemistry. Kevin Hill feels juveniles are interesting to study for local recruitment, but they give only a small picture ─ they likely occur in the area where they were spawned. This is where the understanding of regional oceanography could play a big role in predicting the source and destination of larvae and juveniles.

Ageing sardines: The group agreed there's a need for another otolith ageing workshop since the one in 2004. The workshop could include exchanged samples as a cross-check of methods and lab-specific ageing errors. Jill Smith suggested that all measurement methods (weight, standard length, and maturity) be cross-checked so everyone's data from different regions can be compared. Dale Sweetnam and Kevin Hill agreed to take the lead in finding a time and location for the workshop.

Regional sardines:

Pacific Northwest: Because Oregon sardines are growing well and spawning, there may be now a native-born Oregon core signature (microchemical and genetic).

Baja California: Stable isotopes of C and O in sardine otoliths show high variability among individuals of similar ages and sizes that might result from mixing, even as young fish. Counting otolith daily increments to back-calculate birth dates and growth rates (from increment widths) would complement the microchemical studies for further understanding the Baja California stocks. Counting daily growth increments of sardines will show whether the "winners" that survive the first year come from the time periods of the most spawning.

Working Group 3: Industry trends and issues

Orlando Amoroso (National Alliance for Sustainable Fisheries)
Ragnar Gutiérrez Abarca (Productos Marinos ABC)
Don Pepper (Pacific Sardine Association)
Diane Pleschner-Steele (CWPA)

Don Pepper's presentation focused on the Pacific Northwest fishery and had input from Diane Pleschner-Steele and other industry representatives. A primary theme of the presentation was the dichotomy between scientists and fishermen. Industry members feel that scientists believe too strongly in the stock assessment model, and the fishermen believe that there are more fish than the model indicates. Why are the scientific and fishermen's viewpoints so different? Specific problems include:

- Fat and skinny sardines occur in nature (and don't neatly fit into one model).
- The model works until we have an unusual year. It's unable to predict unpredictable events.

The sardine fishing industry takes issue with the stock assessment presented by Kevin Hill et al. Overall the industry needs:

- Better information from surveys
- More data from the Baja California fishery
- An understanding of the environmental co-variates shared in the sardine's ecosystem

Short-term research needs of the sardine fishery include:

- A focus on the Pacific Northwest
- An aerial spotter index
- Studies of skinny vs. fat fish (e.g., Christa Hrabok's research)

Parameters for the Stock Synthesis Model 2 (SS2) data input include:

- Assumption of one stock
- Weight at length is consistent, age and growth correlate, and maturity index is standardized
- Natural and fishing mortality are set values

Fishermen want background facts on the fish. For example, fat sardines spawn a lot, yet no one seems to be looking at fat content. In addition, Baja California fishermen used to catch 200 g fish all the time yet haven't recently. They feel that fishing is a sampling technique, and catch composition should correlate with age-structure of the biomass. Is there a way to compare what the Pacific Northwest fishermen and Baja California fishermen observe? How do we account for the discrepancies of what the fishermen observe and the mathematical model?

Specific criticisms and questions of the model include:

- DEPM and TEP are down in one surveyed area. What if spawning occurs outside of that area? Many people feel there is a lot of spawning off Oregon, where there's no routine survey.
- SST doesn't seem to correlate with fish abundance. Where are all the fish?
- Is it one stock or several stocks?
- Is the stock moving north?

- It lacks broader field surveys ─ will the spotter index help us?

Fishermen do want to make the model better and bridge the gap between their observations and quantitative stock assessments through short-term and long-term research. Somewhat tongue-in-cheek, Don Pepper offered a phenomenon that might have predictive environmental value ─ sunspots that occur in solar cycles. Don's point was that it doesn't hurt to look around for different and new answers. He suggests the strong 2003 year-class might be a good place to start.

Discussion

The demand for sardines worldwide has increased enormously. Are Pacific sardines still on a long-term increase or are they now in decline? If fishermen need to live with an 89,000 t catch limit, they'll need to retool their business plans.

Unlike sardine fishing in the Pacific Northwest, it's a year-long industry in California. Once we know the biomass, then we need to rethink the allocation. The value of the fish is often in the size of the fish, and the size of the fish is smaller now than it was historically. It's a global market, and all the industry groups are trying to fill the same markets, so there is likely to be healthy competition. Diane Pleschner-Steele feels industry should really get behind the 2008 stock assessment, and offers her support.

How can fishermen participate in the 2008 surveys? Don Pepper says that fishermen can't afford to participate. Industry fishermen use seines and scientific surveys use trawls. It would be very difficult to calibrate the two. John Lenic stated that fishermen can use trawls, but they are selective and only catch slow fish. Seines are more representative because they catch everything, and industry members want scientific methods to be as adaptive as the fish are. Fishing samples would verify what spotter pilots observe.

Specific recommendations from Working Group 3:

- Maintain sustainability and stability in the sardine fishery
- Increase levels of basic research by all governments of sardine population dynamics
- Make an effort at improving data inputs into the SS2 model
- Collect data from spotter planes, hydroacoustic surveys, and fishing vessel samples

Industry does not have much money but wants good science. If scientists have specific recommendations to improve the stock assessment, Don Pepper will take the proposals to the industry to ask for money.

PANEL DISCUSSION: FUTURE SARDINE SURVEYS

Moderator –William Fox (SWFSC)
Panel members - Roger Hewitt (SWFSC), Tony Koslow (SIO) Russ Vetter (SWFSC), Jake Schweigert (DFO), Manuel Nevárez-Martínez (INP), and Don Pepper (CPSA)

The panel discussion session started with opening remarks by Dr. William Fox followed by statements from each panel member with participation of the audience. Note: Manuel Nevárez-Martínez, INP, México, was unable to attend the TSF and Sharon Herzka, CICESE, agreed to serve on the panel in his place.

Opening Remarks

Dr. Fox was impressed with the interesting science presented at the meeting, and was concerned with several issues raised by industry. Are there really more fish than what we are showing in the model, and how can we conduct surveys to answer this question? Do the current population indices reflect the population off the American west coast from Canada to México? The first coast-wide survey in 2006 was primarily aimed to answer these questions. Unfortunately, due to the malfunction of the main winch on one vessel, we had to rely on a single vessel for trawling. This affected the precision of the population estimates that were used as one input to the stock assessment model.

The SWFSC is planning two coast-wide surveys in 2008: one in April and one in July. These will hopefully be coincident with Mexican surveys, and we also welcome the participation of Canadian colleagues. The whole population will be surveyed twice and the precision of the population estimates should be improved. Dr. Fox didn't feel the discussion had occurred yet to know if the management structure will change with regard to stock structure. Currently there are three not well-coordinated management schemes in the U.S., México, and Canada, and thus we are essentially managing the population as three stocks. Dr. Fox emphasized that scientists on future surveys on the west coast should collect data on multiple species at the same time, e.g., hake, sardines, and marine mammals, instead of having separate surveys for individual species. Certainly we should be collecting sardine data in an integrated fashion, for fish length, microchemistry, and other aspects.

Panel Statements

Roger Hewitt – Sampling gear and methods for collecting eggs and adults (nets and acoustics) and environmental variables like water temperature (e.g., CTDs) are essential to estimate the spawning biomass. An ideal set of surveys would include one survey conducted during the spawning season for the spawning biomass and one survey conducted six months later for the recruits. A cost/benefit analysis is important for us to compare the cost of conducting these surveys to the value of the resources. Multi-purpose surveys may be inevitable in the future due to the limited ship time and budget.

The SWFSC did conduct four ichthyoplankton-trawl surveys off the Northwest in July and March, 2003-2005. The biomass estimates varied between the July and March surveys: high in

summer and low in winter, most likely due to migration. Coast-wide surveys that cover offshore areas and span the full North-South range will provide data to verify our hypothesis of migration and help ascertain the stock structure. In addition to or in conjunction with sea surveys, an aerial survey can be implemented through collaboration. Multiple replicates of survey areas are necessary to reduce the variance and to obtain unbiased estimates. We need to figure out how to record the survey in order to reconstruct the populations after they've left the areas.

Tony Koslow – Coast-wide surveys would provide incredible opportunities to collect samples of the whole community, not just sardine, under the broad goals of ecosystem-based management. However, they are very expensive and resources are limited. Maximal collaboration with México, Canada, and industry will benefit all. We need proper nets to catch juveniles, because they are an indicator of the incoming year class. As to issues raised by industry, it is important that industry members believe scientific results are credible. There are potential biases in the methods currently being used: downward-looking acoustics is the only really calibrated method, but it misses fish on the surface. If aerial surveys are conducted, they need to be carried out over a period of years in order to be credible and to provide relative abundances as to the trends, because it is not possible to obtain absolute biomass. One aerial survey won't provide the answer and we must be patient.

Jake Schweigert – Jake would like to see effort put into the July survey off the Northwest, because that is when the fish are there and spawning, not in April. During the last April survey no eggs were collected in the north. In July, however, many fish are in the inlets, and large vessels can't get in to collect samples, which prevents the estimation of fish stock there. Canada's management structure is tied closely to the U.S. stock assessment, with the assumption of a 10% migration rate into Canadian waters and the adoption of the U.S. harvest rate. According to Nancy Lo, based on the 2003-2005 Northwest surveys, the migration rate is 6% of the California biomass. Obviously, the migration rate is an important element. A spotter survey would not help verify the estimate, and increasing funds to improve the precision of the DEPM is more desirable. Adding another index into the stock assessment may be more confusing.

William Fox – Regarding the reason for conducting the coast-wide survey in April—The time series used in the stock assessment of Pacific sardine was based on data collected in April when the peak spawning period occurs for sardine off California. The coast-wide survey data have to be consistent with the past survey to continue the long-term time series. The survey in July will provide estimates for comparison purposes and increase the precision of biomass estimates. In addition, both April and July surveys will provide the assessment of residential populations.

Russ Vetter – These coast-wide ecosystem-based surveys, if conducted well, could be an innovative change for the SWFSC, and will hopefully be repeated. Much energy on the west coast has been devoted to ecosystem issues. For example, if sardines decline, will they be replaced by anchovy or did the whole ecosystem retract? We may believe that there is stasis, but there are many indicators of climate change. Because there was no spawning stock off of Oregon previously doesn't mean there isn't one now or won't be one in the future. Timing is another issue – landings seem to peak in August and September, which may be the optimal time to assess a stock. In Baja California there is a temperate system, with a season of production and a season of rest. Maybe we need to conduct surveys during the rest period. The assessment should include practical management links to higher trophic levels. The albacore fishery doesn't start until August or

September, and we may need to discuss both fisheries as a group.

Sharon Herzka – An early spring coast-wide survey is needed as the systematic sampling is suggested every year during the TSF. There has not been much research conducted on fine temporal and spatial scales, thus while much effort is devoted to the big surveys, the small scale surveys which can provide important information such as larval behavior, transport, and survival have been neglected. As a result, we have little knowledge of physiology compared to other fish species. If sardines are panmictic, this begs the question of why they are so different throughout their range, and how can they inhabit such a different range of conditions? What allows this broad adaptation? In parallel to these surveys we should try to address these other studies. Small-scale surveys would not produce information directly for the stock assessment, but could greatly increase our understanding of the stock. Moreover, the coast-wide survey only covers the northern stock and we need to keep in mind the entire species.

Don Pepper - Whether there is one stock or two is a central issue, and a spotter pilot aerial survey is a tool to determine this. Fishermen feel a need to have a new way to produce a long-term spotter index and to possibly find more fish, or they risk going out of business. He feels the resistance to conducting the spotter pilot survey is the distrust of the scientists toward the fishermen, as fishermen very much believe that there are more sardines out there than the model indicates. Sardine is a straddling stock. Canada has a joint commission to manage salmon, halibut, and hake, and this could be an example for sardine to be managed by a trilateral commission.

Discussion

William Fox - Whether there is a separate stock is interesting to debate but that does not imply that there are more fish to catch. The stocks could be managed separately, which is a management policy issue. It would be worthwhile to find out if there is enough separation in the fish behavior and genetics to parse them along the Pacific coast. Maybe it's better and easier for each country to manage the fish in their area. It would be interesting to have a simulation model to test whether there is an overlap of fish population between the U.S. and México and between the U.S. and Canada.

Russ Vetter - The SWFSC has used data from aerial spotter surveys for anchovy and sardine populations in the past. Aerial surveys can clearly cover more area for less money. The SWFSC marine mammal group conducts aerial surveys with surplus military equipment using photogrammetry techniques to assess marine mammal populations. NOAA does have an air force, and maybe using it we could capture the essence of an aerial survey in a way more palatable to scientists.

Nancy Lo - The SWFSC has used aerial survey data for anchovy for a long time because of its long time-series, with an average of 600 flights a year until the early 2000s. The large sample size compensates for the bias. It's not that we don't like aerial surveys, but it's how one treats the data. Sardines behave differently from anchovy and have expanded far offshore recently. The spotter pilots working for fishermen are looking for fish, and from the catch data, the fish are younger ones. As a result, we have used estimates of fish abundance as an index for recruits. Recently, the numbers of flights have reduced because pilots are going south to work for tuna vessels. We still

value aerial survey data, but we feel a long time-series is useful only for relative abundance.

William Fox - We can probably use the data collected by aerial spotters to improve estimates from our ship surveys. The aerial surveys with tracklines are useful as there are areas where the ship cannot reach, like the inlets off Canada. A well-designed spotter survey could provide data of density of schools over a broader area, which can be used to improve observations from the ship surveys. However the data from the aerial survey need photogrammetry as support. It's not a question of not trusting the fishermen, but it's the scientists' role to be critical and be able to substantiate and defend the information we produce, for example to a Stock Assessment Review (STAR) panel. There are far more users of the sardine population in the U.S. than just the fishermen.

Augie Felando - Can the data from the 2008 survey provide reliable information on the westward shift of populations and cover the entire population? Nancy Lo believes so based on four previous Northwest surveys conducted during July 2003-March 2005, which did go far offshore and caught no sardines at the far western part of survey area.

Mike Okoniewski – Regarding subpopulations, even though sardines are mixing between the U.S. and Canada, research on a much broader scale may be needed to see if there are separate stocks to ensure the safety of the harvest guideline. The idea that there might be separate stocks of sardine is a motivating factor for fishermen and warrants further investigation. The science that is available now compared to the last sardine fishery cycle in the 1930s is incredible, and the discussions during this TSF are encouraging.

Jake Schweigert – In PICES, there are a lot of people interested in sardines. Japanese researchers are looking at relative environmental variables and where the sardines are, and we could put more effort into checking environmental variables versus the fish distribution.

CONCLUSIONS

This two full-day Forum was well attended. In addition to the regular sessions on regional Pacific sardine fisheries, research plans and reports (including many contributed papers), and working group discussions, we had a panel discussion on future sardine surveys led by Dr. William Fox, then Director of SWFSC. Since our first Forum in 2000, substantial progress has been made in identifying age structure, monitoring shifts in maturity, conducting coast-wide biomass surveys and regional surveys to fill gaps, and investigating stock structure (Hrabok et al. 2007; Hunter and Pleschner-Steele 2003; Lo et al. 2006). In particular, the panel discussion focused on how the surveys can best be conducted to provide sound data to verify whether the model projects a reasonable population assessment. The discussion focused on the two upcoming 2008 coast-wide surveys as well as possible aerial surveys off of the Northwest. The focus issue talk was "Use of the Daily Egg Production Method to assess and manage a new fishery: A case study of the Sardine Fishery off South Australia," by Tim Ward, Southern Australian Research and Development Institute (SARDI). This talk provided a different perspective of using the DEPM spawning biomass in managing the fisheries off Southern Australia. The sardine centric ecosystem working group was canceled due to lack of participants.

Instead of breakout sessions for each working group, all three working group sessions were conducted consecutively in one room to facilitate the participation of all attendees. The panel discussion, primarily on the sardine population surveys, was stimulating. Various surveys were suggested for different purposes, ranging from large-scale surveys for population assessment to small-scale surveys for biological characteristics such as larval behavior, transport, and survival, from ship surveys to aerial surveys. It is indeed the common goal of all of us to find ways to enhance the current surveys to improve estimates of biomass coast-wide, and thus improve management strategies.

The Pacific sardine stock assessment indicates 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 1 and 5.2 million fish in recent years, and the biomass has been declining from 1.5 million mt in early 2000 to less than 1 million mt in the 2007 season. The commercial landings off Ensenada and the U.S. were similar to previous years, around 150,000 mt. However, the catch in the Gulf of California is decreasing, and in Bahía Magdalena, the fishing effort has declined during 2003-2006. The total catch of small pelagic fish was 45,624 tons, dominated by sardine. The commercial catch off Canada for 2007-2008 was 1,524 mt as of this meeting, with fish exhibiting low fat content. The harvest guideline (HG) proposed for 2008 (89,093 mt) is substantially lower than the 2007 HG (152,564 mt), but only ~2,000 mt lower than the recent average yield realized by the U.S. fishery. To date, the U.S. fishery has yet to catch all of the HG issued under federal management.

To follow the coast-wide survey conducted in April-May, 2006, the Fisheries Resources Division of the SWFSC is planning to conduct two coast-wide surveys in 2008, one in April and one in July, using two NOAA research vessels. The surveys will cover the area from San Diego to the Washington border. Canadian representatives promised to participate in the July coast-wide survey to extend the survey area into Canada while in April, with the possible participation of México, the survey will be extended into Mexican waters. The NWFSC was asked to assist with personnel to staff both the April and July coast-wide surveys. The results of these surveys will shed much light on Pacific sardine off the west coast of North America in terms of their spatial distribution, biomass, size and age structure, and may elucidate 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 2008 Forum will be held in Astoria, Oregon in early December. Please visit http://swfsc.noaa.gov/tsf.aspx or http://swfsc.noaa.gov for more information.

ACKNOWLEDGMENTS

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APPENDIX I

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San Diego, California, United States of America
November 29-30, 2007

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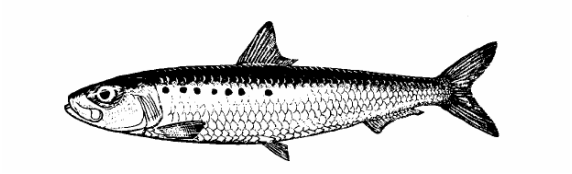
APPENDIX II
English Agenda

8th Annual

TRINATIONAL SARDINE FORUM
FORO TRINACIONAL DE LA SARDINA





2007 PROGRAM

Hubbs-SeaWorld Research Institute
San Diego, California, U.S.A.
November 29th and 30th, 2007
http://swfsc.noaa.gov/tsf.aspx

WEDNESDAY, NOVEMBER 28TH
The Dana Hotel

Arrival in San Diego. The Dana Hotel provides free shuttle transportation to and from the San Diego Airport. Call the hotel direct at 619-222-6440 from the baggage claim area to arrange a pickup.

18:00-21:00 Informal welcome gathering at the Firefly Lounge, inside the Dana Hotel

THURSDAY, NOVEMBER 29TH
Hubbs-SeaWorld Research Institute – Shedd Auditorium

8:00	Registration
9:00	***Opening of the Conference*** Welcome - Nancy Lo, SWFSC
9:10	Opening remarks - Dr. William Fox, Director, SWFSC
9:20	Meeting Logistics - Anne Allen, SWFSC
9:25	***Regional Sardine Fisheries Reports (20 minutes each)*** Gulf of California, Manuel Nevárez-Martínez (CRIP – Guaymas)*
9:45	Bahía Magdalena, Casimiro Quiñonez-Velázquez (CICIMAR)
10:05	***Break***
10:20	***Regional Sardine Fisheries Reports (continued)*** Ensenada (N. Baja), Alfredo Cota Villavicencio (CRIP Ensenada, INP)*
10:40	California, Dale Sweetnam (CDFG)
11:00	Oregon, Brett Wiedoff (ODFW)
11:20	Washington, Carol Henry (WDFW)
11:40	Canada, Jake Schweigert (DFO)
12:00	***Catered Lunch***

* Unable to attend the Forum

13:30 ***Research Plans and Reports***
Biomass estimates – Nancy Lo (SWFSC)

13:50 Stock assessment – Kevin Hill (SWFSC)

14:10 Re-evaluating environmental input for Pacific sardine assessment and harvest control- Tim Baumgartner (CICESE) and Kevin Hill (SWFSC)

14:30 Ecological and economic considerations in the conservation and management of the California sardine- Rognvaldur Hannesson (Norwegian School of Economics and Business Administration, Norway), Sam Herrick and John Field (SWFSC)

14:50 Selected faunal associates of the recovering north temperate Pacific sardine (*Sardinops sagax*) and the south temperate sardine - Paul Smith (SWFSC)

15:10 ***Break***

15:30 Changes in the spawning habitat of sardine (*Sardinops sagax*) off California between 1951 and 2005 - Sam McClatchie, Nancy Lo, Steven Bograd, Richard Charter (SWFSC)

15:50 The genetics of the Pacific Sardine: A review - Axayácatl Rocha-Olivares (CICESE)

16:10 Larval abundances of *Sardinops sagax* in the California Current: An overview of stocks - Martín E. Hernández Rivas[1], William Watson[2], Richard L. Charter[2], Alejandro Hinojosa-Medina[1], Sylvia Patricia Jiménez-Rosenberg[1], and René Funes-Rodríguez[1] ([1]CICIMAR and [2]SWFSC)

16:30 Reproductive patterns of the Pacific sardine (*Sardinops sagax*) in the fishery grounds - Félix-Uraga, R., M. E. Hernández-Rivas, E. Álvarez-Trasviña, F. N. Melo-Barrera and C. Quiñonez-Velázquez (CICIMAR)

16:50 Reproduction of Monterrey sardine *(Sardinops caeruleus)* in the west coast of Baja California - Celia Eva Cotero-Altamirano and Héctor Valles-Ríos (CRIP Ensenada-INP)*

17:10 ***Adjourn, gather in the courtyard for transportation to dinner***

18:00 Dinner at The Fish Market, sponsored by the California Wetfish Producers Association

* Unable to attend the Forum

FRIDAY, NOVEMBER 30TH

Hubbs-SeaWorld Research Institute – Shedd Auditorium

8:00 ***Research Plans and Reports (continued)***
Influence of interannual variability of oceanic fronts in the latitudinal distribution of Pacific sardine's recruitment along the California Current system - Rubén Rodríguez-Sánchez[1], Marlene Manzano[2], Héctor Villalobos[1], Mati Kahru[3], Daniel Lluch-Belda[1] and Sofía Ortega-García[1,](1CICIMAR, 2CIBNOR, 3SIO)

8:20 Growth and survival of Pacific sardine *Sardinops sagax* in 2004 and 2006 in the California Current region - Motomitsu Takahashi and David M. Checkley, Jr. (SIO-UCSD)

8:40 Pacific sardine biomass estimates and associated oceanographic conditions off northern Oregon and southern Washington in 2007 - Robert Emmett and Paul Bentley (NWFSC)

9:00 Condition of Pacific sardine, *Sardinops sagax*, as a function of prey type in British Columbian coastal waters - Christa Hrabok (Ministry of Environment, Province of B.C.)

9:20 Thermal preference and resistance of the Pacific sardine, *Sardinops sagax caeruleus* (Jenyns, 1842) - Mónica Hernández-Rodríguez and L. Fernando Bückle-Ramírez (CICESE)

9:40 ***Break***

10:00 Oxygen stable isotopes in Pacific sardine otoliths: a potential tool to identify regional origins of fish stocks – Barbara Javor and Russ Vetter (SWFSC)

10:20 Oxygen stable isotopic composition [$\delta^{18}O$] as model for stock residency and dynamics of Pacific sardines in the Southern California Bight - Emmanis Dorval, Kevin Piner, Barbara Javor, Larry Robertson, Christian Reiss, and Russ Vetter (SWFSC)

10:40 Elemental analysis of the otoliths of Pacific sardines from Mexican waters using LA-ICPMS - Sonia R. Valle and Sharon Z. Herzka (CICESE)

11:00 ***Focus Issue: Management of sardine populations***
Use of the Daily Egg Production Method to assess and manage a new fishery - a case study of the Sardine Fishery off South Australia - Tim Ward (SARDI)

11:40	***Catered Lunch***
13:00	***Working group (WG) sessions*** WG1) Regional biomass - Nancy Lo (SWFSC)
14:00	WG2) Stock structure, age structure and adult sampling - Russ Vetter (SWFSC)
15:00	WG3) Industry trends and issues - Orlando Amoroso (National Alliance for Sustainable Fisheries), Ragnar Gutiérrez Abarca (Productos Marinos ABC), Don Pepper (Pacific Sardine Association), and Diane Pleschner-Steele (CWPA)
16:00	***Break***
16:20	***Panel discussion: Future sardine surveys*** *Moderator* – Dr. William Fox (SWFSC) *Panel members* - Roger Hewitt (SWFSC), Tony Koslow (SIO) Russ Vetter (SWFSC), Jake Schweigert (DFO), Manuel Nevárez-Martínez (INP), and Don Pepper (CPSA)
17:20	Closing remarks - Nancy Lo
17:30	***End of conference***

POSTER SESSION *November 29-30*

Hubbs-SeaWorld Research Institute – Shedd Auditorium

Update of the macroparasite community analyses of the Pacific sardine (Sardinops sagax) populations in the California Current

Rebecca E. Baldwin[1] and Kym C. Jacobson[2]
[1]Cooperative Institute of Marine Resources Studies, Oregon State University, Newport, OR, 97365, U.S.A.
[2]Northwest Fisheries Science Center, NOAA Fisheries, Newport, OR, 97365, U.S.A.

A Summary of the Northwest Survey in June 2007: Sardines Revisited

David Griffith and Beverly Macewicz
Southwest Fisheries Science Center, NOAA Fisheries, 8604 La Jolla Shores Dr., La Jolla CA 92037, U.S.A.

Microsatellite identification for the Pacific sardine Sardinops sagax caeruleus

Ismael Guzmán Valdivieso[1], John Carlos Garza[2], Alicia Abadia Cardoso[2,3], Axayácatl Rocha Olivares[1]
[1] Molecular Ecology Laboratory, Biological Oceanography Dept., CICESE, Ensenada BC, México 22860
[2] Molecular Ecology Team, SWFSC-NOAA, Santa Cruz, California 95060, U.S.A.
[3] Institute of Marine Sciences, University of California, Santa Cruz, California 95060, U.S.A.

Oregon and Washington Coast Sardine Fishery

Carole Henry[1] and Jill Smith[2]
[1]Washington Department of Fish and Wildlife
[2]Oregon Department of Fish and Wildlife, Astoria, Oregon 97103, U.S.A.

Morphological measurements of Pacific sardine otoliths show regional characteristics

Barbara J Javor, Yuhong Huang, and Russ Vetter
Southwest Fisheries Science Center, NOAA Fisheries, 8604 La Jolla Shores Dr., La Jolla CA 92037, U.S.A.

Genetic assessment of Pacific sardine larvae from different spawning habitats

Osiris Yuriko Ríos Vargas[1], Carol Kimbrell[2], Eric Lynn[2], Russell D. Vetter[2], Axayácatl Rocha Olivares[1]
[1] Molecular Ecology Laboratory, Biological Oceanography Dept., CICESE, Ensenada BC, México 22860
[2] Molecular Genetics Laboratory, SWFSC-NOAA, 8604 La Jolla Shores Dr., La Jolla, CA, 92037, U.S.A.

Sardine otolith weight as a proxy for aging age-0 Pacific sardines

Motomitsu Takahashi[1], Barbara Javor[2], and Russ Vetter[2]
[1]Scripps Institution of Oceanography, University of California San Diego
[2] Southwest Fisheries Science Center, NOAA Fisheries, 8604 La Jolla Shores Dr., La Jolla CA 92037, U.S.A.

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

WORKING GROUPS / CONTRIBUTORS / COMMITTEES

WORKING GROUPS:

WG1: Regional biomass – Nancy Lo (SWFSC)
WG2: Stock structure, age structure and adult sampling - Russ Vetter (SWFSC)
WG3: Industry trends and issues - Orlando Amoroso (National Alliance for Sustainable Fisheries), Ragnar Gutiérrez Abarca (Productos Marinos ABC), Don Pepper (Pacific Sardine Association), and Diane Pleschner-Steele (CWPA)

CONTRIBUTORS:

California Wetfish Producers Association
Hubbs-SeaWorld Research Institute
CalCOFI

PROGRAM COMMITTEE:

Dr. Nancy Lo, SWFSC
Dra. Sharon Herzka, CICESE
Dr. Tim Baumgartner, CICESE
Orlando Amoroso, National Alliance for Sustainable Fisheries

LOGISTIC COMMITTEE:

Anne Allen, SWFSC
Dr. Roger Hewitt, SWFSC
Diane Pleschner-Steele, California Wetfish Producers Association

EXECUTIVE COMMITTEE:

Dr. Nancy Lo, SWFSC
Dra. Sharon Herzka, CICESE
Dr. Robert Emmett, NWFSC
Jake Schweigert, DFO

ACRONYMS

CDFG	California Department of Fish and Game
CIBNOR	Centro de Investigaciones Biológicas del Noroeste, S.C.
CICESE	Centro de Investigación Científica y de Educación Superior de Ensenada
CICIMAR	Centro Interdisciplinario de Ciencias Marinas
CONAPESCA	Comisión Nacional de Acuacultura y Pesca
CPSA	Canadian Pacific Sardine Association
CRIP	Centro Regional de Investigación Pesquera,
CWPA	California Wetfish Producers Association
DFO	Department of Fisheries and Oceans, Canada
INP	Instituto Nacional de la Pesca
JIMAR	Joint Institute of Marine and Atmospheric Research
NMFS	National Marine Fisheries Service
NWFSC	Northwest Fisheries Science Center
ODFW	Oregon Department of Fish and Wildlife
SARDI	South Australian Research and Development Institute
SIO	Scripps Institution of Oceanography
SWFSC	Southwest Fisheries Science Center
UCSD	University of California, San Diego
WDFW	Washington Department of Fish and Wildlife

APPENDIX III

CONTRIBUTED ABSTRACTS AND SUMMARIES – ORAL PRESENTATIONS
(In alphabetical order)

RE-EVALUATING ENVIRONMENTAL INPUT FOR PACIFIC SARDINE ASSESSMENT AND HARVEST CONTROL

Tim Baumgartner[1] and Kevin Hill[2]

[1]Departamento de Oceanografía Biológica, Centro de Investigación Científica y Educación Superior de Ensenada (CICESE), Ensenada, Baja California, México
[2]Southwest Fisheries Science Center, National Marine Fisheries Service, NOAA, La Jolla, CA, U.S.A.

Stock size, distribution and resilience of coastal pelagic fisheries are affected not only by harvesting, but are sensitive to environmental forcing over both short-term (seasonal to interannual) and longer-term (decadal to multidecadal) periods. A major concern in the assessment and recommendation of harvest levels for the Pacific sardine stock is, therefore, the integration of appropriate environmental input into this process. The annual harvest guideline $[HG_{(t)}]$ prepared for year t of the sardine fishery in U.S. waters off California, Oregon and Washington (PFMC, 1998) is currently based on an MSY (max. sustainable yield) control rule as:

$$HG_{(t)} = (BIOMASS_{(t-1)} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION,$$

in which *FRACTION* is a temperature-based percentage of the annual estimate of biomass above a specified cutoff value $(BIOMASS_{(t-1)} - CUTOFF)$ that can be harvested from the population; the *FRACTION* value is currently constrained to fall within the range of 5-15%; the cutoff value is currently set at 150,000 mt. The *DISTRIBUTION* parameter is the percentage of population biomass considered to be available to the U.S. fishery (currently set at 87%). The input of temperature to the harvest guideline enters through the association between temperature and recruitment success developed by Jacobson and MacCall (1995) through the application of a family of surplus production curves to estimate the effects of environmental temperatures on the potential yield of the sardine population.

A serious weakness of the MSY control rule is that the environmental input is limited to a single dimension (coastal ocean temperature) that serves as a proxy for multiple factors acting on successive life history stages over the period from pre-spawning conditioning of adults to recruitment of age-1 fish, a period of roughly 24 months. The relationship between temperature and recruitment success was provided by Jacobson and MacCall as a stand-in until a mechanistic understanding of the underlying dynamic processes could be achieved. This association is based on mean temperatures (from Scripps Pier, La Jolla, California) representing the 36 months prior to recruitment, and is heavily weighted on the period between 1935 and 1963.

Application of the sardine productivity curves from Jacobson and MacCall (1985) for representative temperatures over the period 1985-2005 yields a population biomass that is over 3 times that of the peak biomass estimate derived from the stock assessment modeling for that period. This inconsistency suggests that the underlying processes influencing recruitment success that are subsumed in coastal temperature variability in the Jacobson and MacCall analysis are likely to be changing over a time scale that is relevant to fisheries management. We will discuss the principal changes in the processes associated with ocean warming over the 20th century that are expected to influence recruitment success and how they may be causing the breakdown of the relationship between ocean temperature and sardine reproductive success.

Jacobson, L. and A.D. MacCall, 1995. Stock-recruitment models for Pacific sardine (*Sardinops sagax*). *Can. J. Fish. Aquat. Sci.*, v. 52:566-577.

PFMC 1998. Amendment 8 (to the northern anchovy fishery management plan) incorporating a name change to: the coastal pelagic species fishery management plan. Pacific Fishery Management Council, Portland, OR.

THE BEHAVIOR OF THE SMALL PELAGIC FISHERY DURING THE 2006 FISHING SEASON IN BAJA CALIFORNIA, MÉXICO

Alfredo Cota Villavicencio, Ricardo Troncoso and Francisco Javier Sanchez Gaytan

Centro Regional de Investigaciones Pesqueras de Ensenada, I. N. P.

During the 2006 fishing season 61,109 metric tons were caught: 93.39% were sardine; 0.38% Pacific mackerel and 2.56% anchovy. The summer months had the most important landings. The size of the fleet was 9 vessels which operated around Ensenada Bay. The size composition of both sexes shows individuals larger than 150 mm (legal size) during the summer months; and smaller during the fall and winter months. Females had the largest size.

REPRODUCTION OF MONTERREY SARDINE *Sardinops caeruleus* IN THE WEST COAST OF BAJA CALIFORNIA

Celia Eva Cotero Altamirano and Héctor Valles Ríos

SAGARPA – INP – CRIP Ensenada
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In México, small pelagic fisheries (sardines, anchovy, and mackerel) are the most important weight-wise in landings. The fishery management requires knowledge about the reproductive biology of these species. Random samples of sardines were taken from the landings of the commercial fleet in the west coast of Baja California for biometric data. Samples of gonad tissue were processed in the laboratory, and histological criteria were used to estimate the reproductive condition. The size-frequency distribution showed the specimens ranged from 110 to 241 mm SL with a mode of 190 mm SL, and a few fish less than 120 mm SL or greater than 230 mm SL. The reproductive activity was identified in the winter months, decreasing to spring, with little activity in very early summer. The length at maturity was estimated. We show the relationship with temperature and we discuss the values obtained.

OXYGEN STABLE ISOTOPIC COMPOSITION [$\delta^{18}O$] AS MODEL FOR STOCK RESIDENCY AND DYNAMICS OF PACIFIC SARDINES IN THE SOUTHERN CALIFORNIA BIGHT

Emmanis Dorval, Kevin Piner, Barbara Javor, Larry Robertson, Christian Reiss and Russ Vetter

Southwest Fisheries Science Center, La Jolla Shores Drive, La Jolla, CA 92037
Corresponding author: emmanis.dorval@noaa.gov, (858)-546-5619

Various studies have shown that oxygen isotopic composition [$\delta^{18}O$] of otoliths could be used to infer stock residency and movement of fish populations. However, no studies have investigated the interaction between movement, environmental changes, and cohort-specific growth rates on the accuracy of using [$\delta^{18}O$] as a model for fish population dynamics. We conducted both temperature and feeding experiments to test the assumption that sardine otoliths accurately record environmental water temperature when salinity is maintained at a constant level. Results from the laboratory experiments showed that otolith [$\delta^{18}O$] negatively correlated with temperature, and was not significantly affected by fish growth rate. Further, we assayed juvenile sardine otoliths collected by the California Department of Fish and Game (CDFG) in the Southern California Bight (SCB) from 1995 to 2003 in the spring. Salinity varied little in the SCB throughout this period, and was not a factor influencing the temporal variability in $[\delta^{18}O]_{otolith}$. Sardine $[\delta^{18}O]_{otolith}$ was correlated with temperature in most years, but the significance of this correlation varied with assumed birth-date and growth trajectories of the different cohorts. We will discuss the implications of these results for the understanding of sardine stock structure, residency and population dynamics in the SCB.

PACIFIC SARDINE BIOMASS ESTIMATES AND ASSOCIATED OCEANOGRAPHIC CONDITIONS OFF NORTHERN OREGON AND SOUTHERN WASHINGTON IN 2007

Robert Emmett and Paul Bentley

NOAA Fisheries
Northwest Fisheries Science Center
Newport, OR

Two oceanographic surveys to collect juvenile and adult sardines and measure environmental conditions off Washington/Oregon were conducted in 2007. These surveys have been conducted annually since 1998. Preliminary information from the Predator Survey (nighttime surface trawls) indicates that August 2007 sardine biomass estimates (using an area swept methodology) were similar to those in 2005 and 2006 (~12,000 mt). However, highest sardine catches, and thus biomass estimates, occurred in June 2007. This was very unusual, and probably related to warm ocean temperatures and low upwelling ocean conditions. The September 2007 surface trawl survey from Newport, OR to Cape Flattery, WA caught very few 0-age sardines. This indicates that sardines had very low recruitment from spawning off the Northwest in 2007. This is very similar to what was observed in 2006. The limited sardine recruitment success the last couple of years off the Pacific Northwest may influence future adult sardine abundance in this region, but exactly how much is presently uncertain.

REPRODUCTIVE PATTERNS OF THE PACIFIC SARDINE (*Sardinops sagax*) IN THE FISHERY GROUNDS

Félix-Uraga, R.*, M. E. Hernández-Rivas, E. Álvarez-Trasviña, F. N. Melo-Barrera* and C. Quiñonez-Velázquez*

Centro Interdisciplinario de Ciencias Marinas (CICIMAR). Apartado Postal 592. La Paz, Baja California Sur, México
* Becarios COFAA y EDI

We analyzed the maturity cycle of the Pacific sardine during 1981-1989 and 1997–2005 in contrast with the abundance of eggs and larvae in Magdalena Bay, and the maturity cycle during 1992-2002 at Ensenada in contrast with the larval abundance in the CalCOFI sampling area.

The sardine exhibits a bimodal occurrence of matured individuals in one year at the northern part, with peaks in January and April. In Magdalena Bay the reproductive period is from December to August, with the major peak in February-March and a second minor peak from May-August. In the long term, the maturity index, expressed as a percentage, showed concordance with the spawning products index. The abundance in both indices is noteworthy after El Niño periods.

ECOLOGICAL AND ECONOMIC CONSIDERATIONS IN THE CONSERVATION AND MANAGEMENT OF THE CALIFORNIA SARDINE

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In this paper we draw attention to economic and ecological issues associated with ecosystem-based fishery management by evaluating the importance of California sardine as a commercially targeted species, relative to their importance as forage for a number of higher trophic level species which are of commercial, recreational and ecological significance. Using basic economic theory and ecosystem modeling results for the northern California Current during the 1960s, the question we address is whether the California sardine might be more valuable left in the sea as forage fish than as commercial landings. Although a definitive answer is somewhat elusive given the uncertainty in many of the ecological parameter values, our analysis considers the conditions under which this would be justified, and highlights the data required to implement ecosystem-based fishery conservation and management. For example, at exvessel prices of commercially important sardine predators near the high end of their respective ranges in recent years, and the exvessel price of sardine at the low end of its respective range would favor leaving more sardine as forage fish. With market prices of sardine and commercial predators at their averages for recent years, the value of the annual increase in biomass of non-commercial predators (recreationally-caught fish, marine mammals, seabirds) would not have to be more than about $14 per pound to justify leaving more sardines in the sea as forage species. For instance, the value of the recreational shark fishery alone might be sufficient to tip the balance in this direction. Moreover, given the resurgence of the sardine biomass since the 1960s, realistic changes in ecological parameters such as transfer efficiencies and shares of sardines in the diet of predators could also make the sardine more valuable as forage fish than as commercial catches. However, even if it were advisable to reduce the volume of the sardine fishery to leave more forage for other, more valuable species, it does not necessarily imply that the sardine fishery should be shut down altogether. Rather, our results imply that a strategic consideration of the tradeoffs could be an important element of the ecosystem-based fishery management process.

THERMAL PREFERENCE AND RESISTENCE OF THE PACIFIC SARDINE, *Sardinops sagax caeruleus* (Jenyns, 1842)

Mónica Hernández Rodríguez and L. Fernando Bückle Ramirez

Centro de Investigación Científica y de Educación Superior de Ensenada (CICESE). B.C. Km. 107 Carretera Tijuana-Ensenada. Apdo Postal 360. 22860 Ensenada, Baja California. P.O. Box. 434844. San Diego, CA 92143-4844 U.S.A. E-mail: mhernand@cicese.mx

The study of the effect of temperature on different biochemical, physiological and of behavior processes has been widely documented in different fish species. Among sardines, many projects have been focused on the study of the effect of El Niño on their distribution, reproduction and food availability. However, their tolerance and thermal resistance based on the thermoregulatory behavior of the species is unknown, despite its importance to predicting the effects of temperature changes such as those associated with global climate change. For this reason, we characterized the preferred temperature and critical maximum and minimum temperatures of the Pacific sardine following constant acclimation temperatures. Fish were captured in the Bay of Ensenada, Baja California (31' 43" Lat. N., 116' 47" Long. W.) in summer and autumn 2006. A total of 300 sardines were distributed in five 400 L tanks and acclimated for 20 days at 15, 18, 21, 24 and 26 ± 0.5 ºC. The average weight and length of the fish were 36.3 ± 10.2 g and 17.0 ± 1.41 cm, respectively. The preferred temperature was studied in two 220 L acrylic channels, and exposing the sardines a horizontal thermal gradient, as described by Bückle *et al*. (2004). The identification of the critical thermal maximum (CTMax) and minimum (CTMin) were accomplished following the criteria of Nelson and Hooper (1982) and Hernández (1998).

The preferred temperature range for all treatments was 17.9 to 20 °C; there was no effect of the acclimation temperature on this response. When sardines swam toward the lowest and highest temperatures of the thermal gradient, they exhibited an escape response at 12.5 and 28.9 °C.

Rising thermal stress caused the fish to exhibit a distinctive behavior of inclined swimming (60% of the sardines), muscular spasms and loss of equilibrium. None of the organisms returned to their normal state following thermal stress exposure. The muscular spasms that characterized the CTMax response were observed in the range of 26.8 to 32.4 °C. Loss of equilibrium followed by an inability to return to normal behavior commenced at 30 to 33.9 °C for the thermal acclimation range of 15 to 26 °C.

The effect of decreasing temperature caused the sardines to exhibit muscular spasm responses, increased activity and loss of equilibrium. The CTMin response that characterized sardine acclimated from 15 to 26 °C was loss of equilibrium. A returning to their normal position was observed in the range of 8.2 to 17.6 °C. At the lowest temperatures, sardines exhibited loss of equilibrium and were unable to return to their normal position. However, during the experiment, the sardines did not enter coma as a result of the cold, which has been observed in other species. This work is part of a project financed by México's CONACYT entitled Thermoregulatory Behavior of Aquatic Organisms: A Tool for Predicting the Effect of Climatic Change.

LARVAL ABUNDANCES OF *Sardinops sagax* IN THE CALIFORNIA CURRENT: AN OVERVIEW OF STOCKS

Martín E. Hernández Rivas[1], William Watson[2], Richard L. Charter[2], Alejandro Hinojosa-Medina[1], Sylvia Patricia Jiménez-Rosenberg[1], and René Funes-Rodríguez[1]

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To investigate the existence of three different stocks of the Pacific sardine, *Sardinops sagax*, in the southern sector of the California Current System, the annual means of larval abundances obtained by California Cooperative Fisheries Investigations (CalCOFI) and Investigaciones Mexicanas de la Corriente de California (IMECOCAL) programs through 2002 were plotted in space and time by temperature intervals, 10-17°, 18-21°, and 22-27°C. These intervals were used by Félix-Uraga, et al. (2005) to separate stocks from San Pedro, California, U.S.A. to Bahía Magdalena, Baja California Sur, México; the stocks were termed "Cold", "Temperate", and "Warm" according to temperature range in which they were fished.

The areal distributions of the stocks show that the Cold stock spawns along the coast from San Francisco to Cabo San Lucas and that this spawning is more oceanic in the north, off Point Conception (heavy spawning), around Punta Eugenia (intermediate level of spawning), and very coastal near Cabo San Lucas (light spawning). The Temperate stock spawns from Point Conception (light) to Cabo San Lucas (also light), near shore in the north and with a narrow band of intermediate spawning from Bahía Sebastián Vizcaíno to the south of Bahía Magdalena. The Warm stock spawns from Punta Baja to Cabo San Lucas, with heaviest spawning in a very narrow coastal band from Bahía Sebastián Vizcaíno to Golfo de Ulloa (north of Bahía Magdalena).

The temporal abundances show that the Cold stock was very diminished in the early 1950's, with a brief increase in the Temperate stock in the same period, and a big increase in the Warm stock between 1958 and 1984. After that, the Temperate stock increased slightly from 1985 to 1993, and the Cold stock increased substantially from 1994 to 2002.

We found that the recovery of the Cold stock started in 1994, when spring spawning was established again off the California coast during spring months.

ASSESSMENT OF THE PACIFIC SARDINE RESOURCE IN 2007 FOR U.S. MANAGEMENT IN 2008

Kevin T. Hill[1], Emmanis Dorval[1], Nancy C. H. Lo[1], Beverly J. Macewicz[1], Christina Show[1], and Roberto Félix-Uraga[2]

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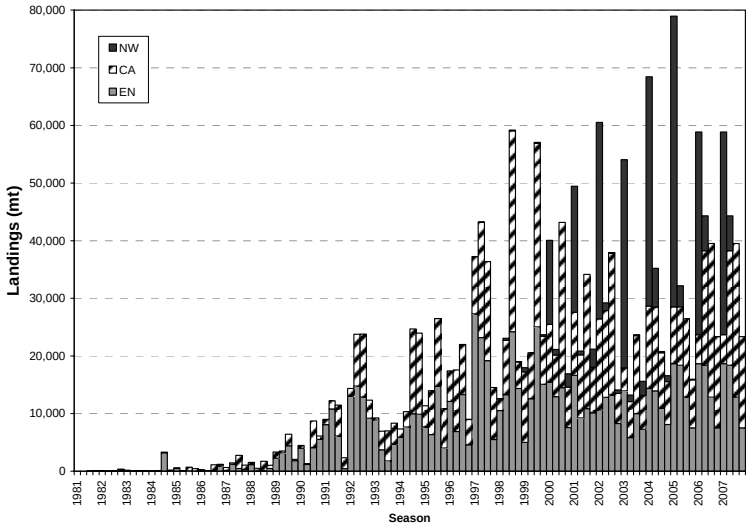
[2] CICIMAR-IPN, Ave. IPN s/n A.P. 592, Col. Playa Palo Sta. Rita C.P. 230096, La Paz, Baja California Sur, México

EXECUTIVE SUMMARY

Stock - Pacific sardine (*Sardinops sagax caerulea*) range from southeastern Alaska to the Gulf of California, México, and is thought to comprise three subpopulations. In this assessment, we model the northern subpopulation which ranges from northern Baja California, México, to British Columbia, Canada, and offshore as far as 300 nm. All U.S., Canada, and Ensenada (México) landings are assumed to be taken from a single northern stock. Future modeling efforts should explore a scenario that separates the catches in Ensenada and San Pedro into the respective northern and southern stocks based on some objective criteria.

Catches - Catches in this assessment include commercial sardine landings from three fisheries: Ensenada (México), California (San Pedro and Monterey), and the Pacific Northwest (Oregon, Washington, and British Columbia), from 1981-82 to 2007-08.

Calendar Year	Ensenada (mt)	California (mt)	Pacific Northwest (mt)	Total (mt)
1997	68,439	46,198	71	114,707
1998	47,812	41,055	489	89,357
1999	58,569	56,747	800	116,116
2000	67,845	58,202	16,016	142,063
2001	46,071	54,903	24,883	125,857
2002	46,845	63,444	38,662	148,951
2003	41,342	37,737	37,839	116,918
2004	41,897	47,702	49,349	138,948
2005	56,684	38,193	55,169	150,046
2006	57,438	51,029	41,323	149,789



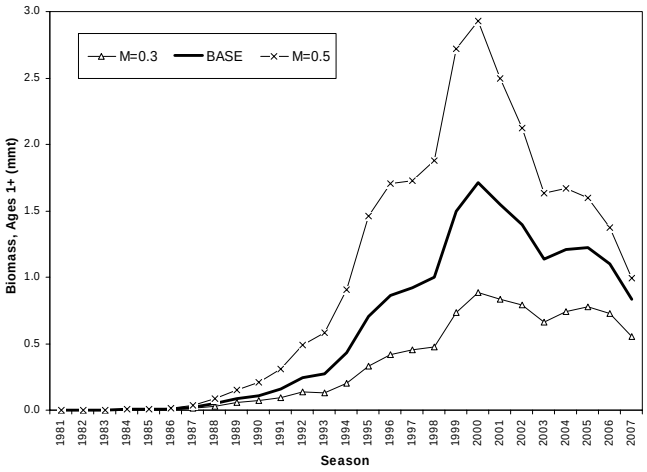
Data and assessment - The last assessment of Pacific sardine was completed in 2006, for U.S. management in calendar year 2007. The current assessment, conducted using 'Stock Synthesis 2' model (version 2.00i), uses fishery and survey data collected from 1981 to 2007. Fishery data include catch and biological samples for the fisheries off Ensenada, California, and the Pacific Northwest (1981-2007). Two indices of relative abundance are included: Daily Egg Production Method and Total Egg Production estimates of spawning stock biomass (1985-2007) based on annual surveys conducted off California. The model was constructed using an annual time step ('Season'), based on the July-June biological year, and four quarters per season (Jul-Sep, Oct-Nov, Dec-Mar, and Apr-Jun).

Unresolved problems and major uncertainties - The assessment includes indices of spawning biomass based on annual ichthyoplankton and trawl surveys conducted each spring between San Diego and San Francisco ('standard' sampling area). The assessment relies on the assumption that indices of abundance for the 'standard' area are linearly proportional to total spawning biomass. While there is no direct evidence for failure of this assumption, there is some evidence that a portion of the stock is spawning outside of this area. This uncertainty can only be improved by broadening the range of the annual survey to include areas north of San Francisco and south of San Diego.

There is uncertainty about sardine stock structure and mixing in the Ensenada and southern California regions. It is possible that some of the catches used in the assessment are from the southern subpopulation, which presumably has different life history parameters (e.g. growth, maturity, natural mortality). Access to recent Mexican catches and biological data remains a concern. Ensenada catches after 2005 are unknown, so are assumed to be equal to recent levels. The assessment does not include biological data for Ensenada after 2002.

Stock biomass - Stock biomass (ages 1+) estimates from the base model begin at very low levels in 1981, rapidly increase to a peak of over 1.7 million metric tons in 2000, and subsequently trend downward to 832,706 metric tons in 2007.

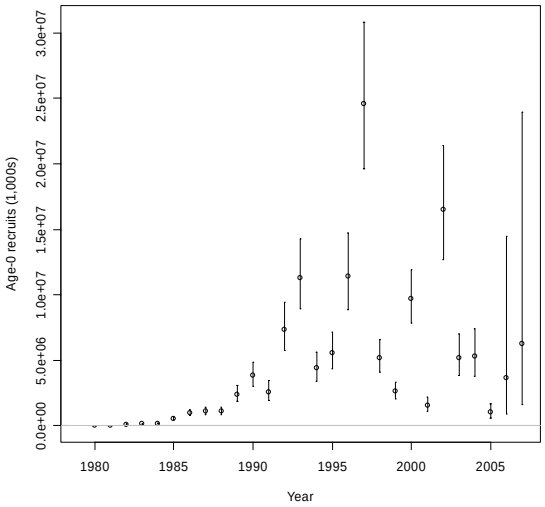
Season	Stock Biomass (mt)
1998	1,002,920
1999	1,495,910
2000	1,713,280
2001	1,548,940
2002	1,397,530
2003	1,137,720
2004	1,211,000
2005	1,219,480
2006	1,101,890
2007	832,706



Recruitment

Recruitment was modeled using the Ricker stock-recruitment relationship. The estimate of steepness was high (h=2.5924). Root mean square error for the S-R fit (0.7634) was well matched to the input σ_R (0.7649). Recruitments begin at very low levels in 1981, peak at 24.6 billion fish in 1998, and subsequently decline with the exception of the 2003 year class which was the second highest (16.5 billion fish) in recent history.

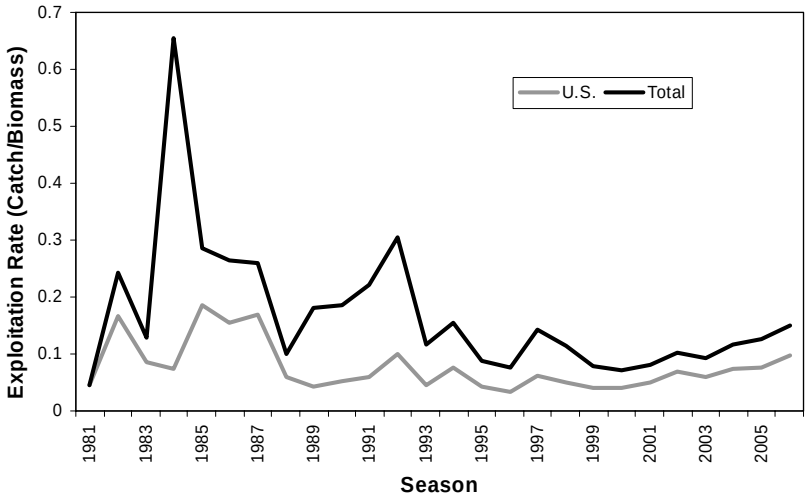
Season	Recruits (age-0, billions)
1998	24.583
1999	5.201
2000	2.603
2001	9.672
2002	1.555
2003	16.469
2004	5.164
2005	5.277
2006	1.010
2007	3.677



Exploitation status

Total exploitation rate (catch/stock biomass) was relatively high during the early period (mid-1980s), but declined as the stock underwent the most rapid period of recovery. Total exploitation was lowest (~7%) in 2000, and has since gradually increased to approximately 15%.

Season	U.S. Exploitation Rate	Total Exploitation Rate
1997	0.0612	0.1431
1998	0.0509	0.1136
1999	0.0410	0.0797
2000	0.0404	0.0708
2001	0.0500	0.0811
2002	0.0688	0.1014
2003	0.0601	0.0937
2004	0.0738	0.1164
2005	0.0762	0.1259
2006	0.0972	0.1507



Management performance

The harvest guideline recommended for the U.S. fishery in calendar year 2008 is 89,093 mt. The HG is based on the control rule defined in the CPS-FMP:

$$HG_{2008} = (BIOMASS_{2007} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2008} is the total U.S.A. (California, Oregon, and Washington) harvest guideline in 2008, $BIOMASS_{2007}$ is the estimated July 1, 2007 stock biomass (ages 1+) from the current assessment (832,706 mt), CUTOFF is the lowest level of estimated biomass at which harvest is allowed (150,000 mt), FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries (see below), and DISTRIBUTION (87%) is the percentage of $BIOMASS_{2007}$ assumed in U.S. waters. The following formula is used to determine the appropriate FRACTION value:

$$\text{FRACTION or } F_{msy} = 0.248649805(T^2) - 8.190043975(T) + 67.4558326,$$

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding seasons (July-June). Based on the current (T_{2007}) SST estimate of 18.14 °C, the F_{msy} exploitation fraction should be 15%.

The HG proposed for 2008 (89,093 mt) is substantially lower than the 2007 HG (152,564 mt), but only ~2,000 mt lower than the recent average yield realized by the U.S. fishery. To date, the U.S. fishery has yet to catch all of the HG issued under the federal management.

Year	U.S. HG	U.S. Landings	Total HG	Total Landings
2000	186,791	67,985	214,702	120,876
2001	134,737	75,732	154,870	99,579
2002	118,442	96,888	136,140	141,369
2003	110,908	69,917	127,480	101,425
2004	122,747	92,747	141,089	141,388
2005	136,179	90,024	156,528	149,939
2006	118,937	91,044	136,709	134,043
2007	152,564	---	175,361	---

Research and data needs

High priority research and data needs for Pacific sardine include:

1) gaining better information about Pacific sardine status through annual coast-wide surveys that include ichthyoplankton, hydroacoustic, and trawl sampling;
2) standardizing fishery-dependent data collection among agencies, and improving exchange of raw data or monthly summaries for stock assessments;
3) obtaining more fishery-dependent and fishery-independent data from northern Baja California, México;
4) further refinement of ageing methods and improved ageing error estimates through a workshop of all production readers from the respective agencies;
5) further developing methods (e.g. otolith microchemistry, genetic, morphometric, temperature-at-catch analyses) to improve our knowledge of sardine stock structure. If

sardine captured in Ensenada and San Pedro represent a mixture of the southern and northern stocks, then objective criteria should be applied to the catch and biological data from these areas;

6) exploring environmental covariates (e.g. SST, wind stress) to inform the assessment model.

CONDITION OF PACIFIC SARDINE, *Sardinops sagax*, AS A FUNCTION OF PREY TYPE IN BRITISH COLUMBIAN COASTAL WATERS

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Condition of a fish is important to the productivity of the population as it directly relates to its abundance of energy reserves, and further to its gonad production for recruitment. Condition factor has been determined to be a simple statistical tool that can be used to determine the wellness, or fatness, of a fish based on abundance of energy reserves. The wellness of a fish directly relates to its diet. In British Columbia coastal waters, Pacific sardines, *Sardinops sagax*, opportunistically eat plankton during the summer months of their migration.

Depending on the climate or oceanic conditions, different food sources are available for sardines to eat. Sampling information from Fisheries and Oceans Canada researchers indicate that from 1997 - 2002, sardine prey item composition and density over the BC continental shelf varied annually due to differing oceanic / climatic conditions. This thesis evaluates whether sardine condition factor varies with respect to prey items. The evaluation was based on matching data for sardine condition factor, plankton data, and primary productivity between 1997 and 2002, and at different coastal sampling locations. Condition factor was found to vary with locations, sampling times, changes in chlorophyll A concentration and prey composition. Some of these differences were not statistically significant, a likely result of the relatively low power of the sampling design. Nonetheless, the observed trends strongly suggest that sardine condition does vary with respect to a combination of factors, including prey item.

OXYGEN STABLE ISOTOPES IN PACIFIC SARDINE OTOLITHS: A POTENTIAL TOOL TO IDENTIFY REGIONAL ORIGINS OF FISH STOCKS

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Calcium carbonate ($CaCO_3$) otoliths in fish contain minute concentrations of the stable isotope of oxygen (^{18}O) whose incorporation is primarily controlled by two environmental factors: the concentration of $H_2{}^{18}O$ in seawater, and $^{16}O/^{18}O$ fractionation biases due to temperature and salinity. The ratio of ^{18}O to ^{16}O ($\delta^{18}O$) in $CaCO_3$ is a well-known measurement to interpret the thermal history of marine organisms. We have applied this method to surveys of juvenile Pacific sardine otoliths from British Columbia to the Gulf of California to determine whether $\delta^{18}O$ "fingerprints" can identify sardines from different oceanographic regions. The overall picture is complex, with a northern trend between Monterey and Vancouver Island, and a southern trend between Monterey and Baja California. Within-region surveys also provide insights into local populations. Juveniles captured near Vancouver Island carried a $\delta^{18}O$ signature distinct from adults, whose $\delta^{18}O$ content resembled that of fish from northern California. Within-year surveys of juveniles in the Southern California Bight showed a trend with fish age that might not follow predictions due to seawater temperature. Bahía Magdalena and central Gulf of California sardines had indistinguishable $\delta^{18}O$ signatures that were similar to fish from San Diego. However, when compared to the expected $\delta^{18}O$ ratios in seawater of these southern regions, the stable isotope concentrations in the $CaCO_3$ structures overall behaved according to predicted temperature-driven fractionations.

CHANGES IN THE SPAWNING HABITAT OF SARDINE (*Sardinops sagax*) OFF CALIFORNIA BETWEEN 1951 AND 2005

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We analyzed a subset of the CalCOFI time series (54 years from 1951 to 2005, 309 cruises) to determine how sardine spawning distributions have changed over the past five decades. We detected 5 significant changes in sardine egg distributions between 1951 and 1969, no significant differences during the prolonged fishery collapse, and 5 significant changes in distribution between 1996 and 2005 during recovery of the fishery. Actual sardine habitat varied by region along the California coast (north and south of Point Conception, 34.5^{o}N, and south of Ensenada, 32^{o}N), and by season (Spring and Fall). We detected significant variability related to ENSO in the Southern California Bight, but not to the north of Point Conception or off Baja California. General Additive Models revealed that sardine egg presence was significantly related to salinity and month to the north of Point Conception from 1951-1972. Models were more complicated in the Southern California Bight, showing differences between the 1951-1972 and 1985-2005 periods, and differences between inshore, Southern California Eddy and offshore regions of the Bight. For the inshore and Southern California Eddy sub-regions, the models suggest a greater influence of nutrient and phytoplankton on the presence of sardine eggs in the lower productivity 1985-2005 period, contrasting with greater influence of zooplankton in the 1951-1972 period. For the offshore, zooplankton was significant as a predictor during both periods. We found that nutrients were significant predictors of sardine egg presence in southern waters off Baja California.

SARDINE FISHERY IN BAHÍA MAGDALENA, B.C.S., DURING 2006

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From January to December 2006, 780 fishing trips were conducted in Bahía Magdalena, B.C.S. and 52,429 t (all species) were caught, of which 97.7% were Pacific sardine *Sardinops sagax*. The rest were represented by the thread herring *Opisthonema* sp. (1.6%), Pacific anchoveta *Cetengraulis mysticetus* (0.32%), round herring *Etrumeus teres* (0.1%) and Pacific mackerel *Scomber japonicus* (0.13%). The Pacific sardine was caught year round; the thread herring and Pacific anchoveta (0.32%) were caught exclusively at the beginning of year, from January to May. The fishing pattern was dominated by the seasonality of the Pacific sardine catch and the activity of the fishery (effort) was in correspondence to this seasonality. From June to October 63.7% of the fishing effort was exercised and corresponded to 63.3% of the annual catch of the Pacific sardine. The standard length (SL) of the Pacific sardine catch during 2006 varied between 114 and 204 mm. The monthly average percentage of sardines less than the minimum legal size (150 mm SL) was 21.5%, and varied between 0% (January) to 56% (July). The length and age structures of the Pacific sardine caught during 2006 showed that the recruitment was detected in May and another pulse from September to November.

THE GENETICS OF THE PACIFIC SARDINE: A REVIEW

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In this presentation I will review the early findings and subsequent research on the genetic variability and differentiation of the Pacific sardine in the light of historical and contemporaneous hypotheses of population structure based on non-genetic findings. Levels of genetic variability of the Pacific sardine have varied widely depending on the genetic marker involved. An early allozyme study published in 1989 set the stage by finding low levels of genetic polymorphism and lack of genetic structure. However, the atypically low variability in these protein coding loci severely limited the power to infer population structure with these data. With the advent of molecular genetic markers, a second study published 15 years later using mitochondrial DNA sequences from the gene coding for the cytochrome *b*, revealed very high levels of genetic diversity in this rapidly evolving genome. However, no genetic differentiation was found among the few localities studied. These results flew in the face of historical and contemporaneous studies of phenotypic and ecological variability that strongly suggested the existence of geographically structured groups of sardines with marked differences in morphological traits and temperature affinities. More recently, genetic studies using another region of the mitochondrial genome (genes coding for subunits 5 and 6 of the NADH enzyme) as well as five polymorphic nuclear microsatellite loci have corroborated the existence of very large levels of genetic diversity in both nuclear and mitochondrial genomes, contradicting the existence of a historical genetic bottleneck. In addition, a widespread genetic survey of adult sardines using these loci did not reveal significant genetic differentiation from the samples based on traditional indices of genetic differentiation (F_{ST}, Φ_{ST}, R_{ST}), in accord with previous genetic findings and with the high dispersal potential of these organisms. On the other hand, genetic analyses of larvae from contrasting spawning grounds (Southern California and central Gulf of California) produced shallow but significant genetic differences between regions. These results suggest that the temperature affinity of spawning groups, evidenced from the egg distribution sampled by CUFES, may be playing a role in shaping the genetic architecture of this highly mobile organism. Additional analyses of these early life stages are required to provide a clearer picture of these processes.

Key words: Pacific sardine, *Sardinops sagax caeruleus*, molecular genetics, population structure, genetic diversity

INFLUENCE OF INTERANNUAL VARIABILITY OF OCEANIC FRONTS IN THE LATITUDINAL DISTRIBUTION OF PACIFIC SARDINE'S RECRUITMENT ALONG THE CALIFORNIA CURRENT SYSTEM

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Given the sensitivity of Pacific sardine to ocean-climate variability, sardine distribution patterns show the role of oceanic fronts in determining their aggregation and influencing their recruitment in the California Current system (CCS), presumably as the forage habitat of young sardines. The latitudinal distribution of young-sardine monthly abundance-indices seems to follow seasonal advection changes of CCS, suggesting recruitment is related to the frontal zone where the California Current (CalC) and inshore California Countercurrent (CcC) converge parallel alongshore. From 1980 to 1997, analysis of interannual changes in sardine seasonal patterns show progressive latitudinal-distribution changes of relative abundances. This suggests poleward changes of favorable conditions for young sardines along the frontal zone between Baja California and California. We made, as a proxy for the interannual variability along the frontal zone, monthly time-series of frequency of SST fronts for four different areas along the California–Baja California coast using the single-image, edge-detection method applied to monthly satellite data from the AVHRR Pathfinder v5. The relation of sardine-abundance and front-frequency indices suggests recruitment increases where optimal front-frequency levels are found and declines where they are suboptimal. Interannual changes in the latitudinal position of population levels along the frontal zone suggest a progressive interannual increase of northward advection of CcC after the 1976–1977 regime shift, whereas CalC southward advection weakened. Our results explain the return of the sardine to the northern part of CCS after the 1980s. Alongshore spatial comparison is a key part of our analysis. The same information (sardine and front indices) analyzed for any single area alone (e.g. interannual changes in the timing of seasonal front-frequency levels and sardine abundance variability off California) is less informative and could lead to different conclusions.

SELECTED FAUNAL ASSOCIATES OF THE RECOVERING NORTH TEMPERATE PACIFIC SARDINE (*Sardinops sagax*) AND THE SOUTH TEMPERATE SARDINE

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The spawning habitats of the North and South Temperate populations are easily separated by selected faunal associates in the CalCOFI surveys. The most difficult separations are in the Southern California Bight region. Here, the usual partitioning in the spawn is in the seasonal, offshore/onshore plane, temperature in the historical record. Even as the North Temperate population thrives overall, it appears that its association with subarctic forms is materially declining in the Southern California Bight. Overall, the South Temperate form has not changed over the course of the surveys but has increased the penetration into the Southern California Bight near the northern extension of this stock. The best way to evaluate the Southern Temperate stock size would be to conduct egg pump surveys and patterned CalVET tows in August of each year accompanied by samples of the spawners. The effect of offshore aquaculture on the sardine stocks should be monitored.

GROWTH AND SURVIVAL OF PACIFIC SARDINE *Sardinops sagax* IN 2004 AND 2006 IN THE CALIFORNIA CURRENT REGION

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We hypothesized that faster growth and development during larval and early juvenile stages results in higher survival in Pacific sardine, *Sardinops sagax*. Growth rates estimated from otolith daily increments were compared among larval, juvenile and pre-recruit *S. sagax* off southern and central California. The larvae, juveniles and pre-recruits of the 2004 and 2006 year-classes were collected in spring, fall and the spring of the subsequent year, respectively. Hatch-date distribution indicated larvae spawned after May had higher probability of survival to the juvenile and pre-recruit stages. In the 2004 year-class, the juveniles and pre-recruits had wider increments than the larvae, and their increment widths are similar up to 80 days old, but thereafter, pre-recruits had wider increments. In the 2006 year-class, the juveniles consisted of the larvae hatched in late spring. These larvae had faster growth and development than those hatched in early spring. This indicates that growth-selective survival works throughout the larval and early juvenile stage in *S. sagax* and is consistent with our hypothesis.

ELEMENTAL ANALYSIS OF THE OTOLITHS OF PACIFIC SARDINES FROM MEXICAN WATERS USING LA-ICPMS

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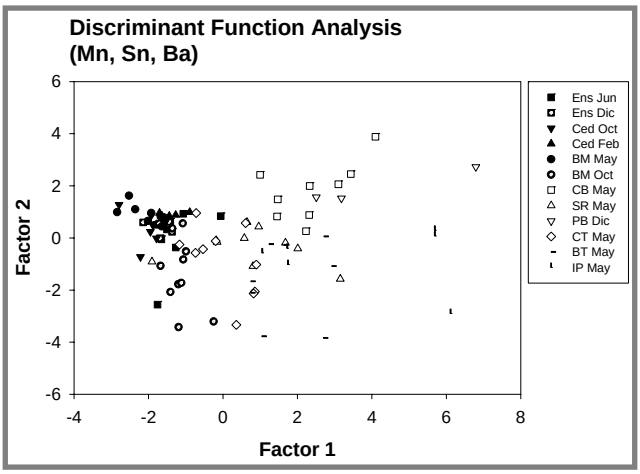
The models of population structure proposed for the Pacific sardine (*Sardinops sagax caeruleus)* along its distribution in the California Current System and within the Gulf of California have not yielded a single, integrated model. Otolith elemental analysis can be used to identify natal origin of adults, infer migration patterns and evaluate the geographic population structure of fish species. Otoliths form part of the inner ear of teleost fishes. Because they grow throughout life and are not subject to metabolic processes, the chemical composition of specific regions of the otolith can be related to particular life stages. While otoliths are comprised mostly of $CaCO_3$, other elements are incorporated in minute concentrations during their formation. Variations in the chemical composition of seawater at different temporal and spatial scales result in location and/or time-specific otolith fingerprints that can be used as natural tracers. For example, the chemical composition of the region of the otolith corresponding to larval period may be used to infer natal origin. However, identifying natal origin first requires evaluating the potential effect of ontogenetic variability in the incorporation of elements into the otoliths.

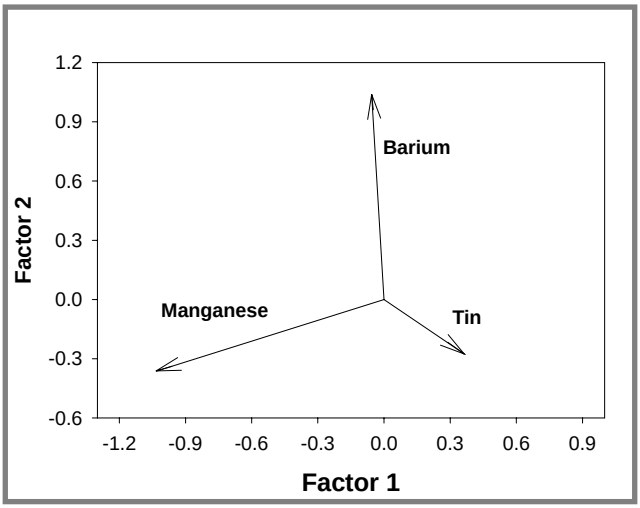
We used Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICPMS) to examine the chemical composition (Mg, Mn, Sr, Sn and Ba) of specific regions of the otoliths of young (ca. 1 yr old) sardines collected throughout their distribution in the Mexican Pacific. Laser ablation was used to obtain subsamples from the otolith nucleus (corresponding to the larval stage) and near the margin (reflecting the capture location). Our objectives were: (1) evaluate whether there was evidence of ontogenetic variability in the elemental composition of Pacific sardines; (2) determine whether this technique can be used to discriminate between sardines collected off the Pacific off Baja California and within the Gulf of California; and (3) evaluate the potential of otolith elemental analysis to identify natal origin and reconstruct migration patterns of Pacific sardines.

Samples were collected off the coast of Baja California (Ensenada, Isla de Cedros and Bahía Magdalena) and in six locations the central Gulf of California between May 2004 and May 2005. There were significant differences in calcium-standardized elemental ratios measured in the otolith nuclei and margins for most elements, except for tin. This suggests an ontogenetic effect associated with the incorporation of elements into the otoliths. Based on discriminant function analysis of the data obtained from the otolith margins (representing the period shortly before capture), samples from the Pacific had clearly distinguishable elemental signatures from those

collected in the central Gulf of California (Figure 1a). The first two discriminant factors accounted for 95% of the variance in elemental ratios. Using jackknife classification analysis, over 90% of the sardines were correctly classified to the region in which they were captured. Some of the samples collected in Bahía Magdalena exhibited a distinct elemental signature, suggesting that residence in the bay may impress a unique chemical fingerprint in the otoliths. Manganese was the most useful element for discriminating between the populations of the Pacific and Gulf of California, while barium was useful for discriminating among locations (Figure 1b). Post-hoc analyses indicated that manganese standardized ratios were significantly higher in the Gulf than in the Pacific locations, which may be due to the extensive hydrothermal activity known to occur in the Gulf of California. The results obtained thus far indicate LA-ICPMS could be used to evaluate whether there is migration among the Pacific, Gulf of California and Bahía Magdalena.

Figure 1. (a) Discriminant function analysis results of the elemental composition of otolith margins of Pacific sardines collected in the Mexican Pacific. Ens: Ensenada; Ced: Isla de Cedros; Mag: Bahía Magdalena; CB: Canal de Ballenas; SR: Santa Rosalía; PB: Punta Borrascosa; CT: Cabo Tepoca; B: Bajos de Tastiota; IP: Isla Pájaros. (b) Discriminant functions standardized by within variances.





APPENDIX IV

CONTRIBUTED ABSTRACTS AND SUMMARIES – POSTER PRESENTATIONS
(In alphabetical order)

UPDATE OF THE MACROPARASITE COMMUNITY ANALYSES OF THE PACIFIC SARDINE (*Sardinops sagax*) POPULATIONS IN THE CALIFORNIA CURRENT

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Macroparasite community analysis is part of an ongoing multidisciplinary program examining Pacific sardine (*Sardinops sagax*) populations from Canada, the United States and México. In 2005 sardines (n=272) were collected from five different locations between March and July. Nine parasite species were recovered, with the trematodes *Parahemiurus* sp. and *Myosaccium ecaude* found in all five locations. Approximately half of the sardines collected between April and September 2006 (n=287 of 610) have been processed from six of fourteen different locations. Six parasite species recovered from sardines caught in 2006 were also the most common species found in 2005. Non-metric multidimensional scaling (ordination) of the parasite communities suggested there are at least three sardine populations within the California Current System: 1) Vancouver Island, British Columbia, 2) Willapa Bay, Washington to Manchester, California and 3) Santa Cruz to Point Arguello, California. Three trematode species, *Lecithaster gibbosus*, *Parahemiurus* sp. and *M. ecaude* show potential as biological tags for Pacific sardine populations in the California Current. Sardines have been collected in 2007 from similar locations to previous years with the addition of new locations in Northern California, and a more intensive temporal sampling from the sardine fishery off of the Columbia River, Oregon. Future work will include genetic analysis of individual worms of the two most widely distributed parasite species within the study area.

A SUMMARY OF THE NORTHWEST SURVEY IN JUNE 2007: SARDINES REVISITED

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During July of 2003, March and July of 2004 and March of 2005, the Southwest Fisheries Science Center, Fisheries Resources Division (FRD), conducted a survey in the region 42° - 48° N latitudes and extending offshore to 128° W. The recent June 2007 survey revisited a sub-region of the original survey three years later in an attempt to understand and compare the annual spawning variability in adult Pacific sardine (*Sardinops sagax*) off of the coast of Oregon and Washington.

The 2007 survey was slightly abbreviated from the previous surveys in that the region examined was 42° to 47° N and only offshore to 126° W. Results from previous surveys indicated that this region encompassed the majority of the spawning population of sardine. All procedures conducted during the 2007 survey followed the same protocol as the previous summer surveys: station activities included CUFES collections, ichthyoplankton tows, CTD casts, weather observations, and a thirty minute surface trawl using a Nordic 264 midwater trawl conducted at night at speeds of three to three and a half knots.

Initial results indicate that both the egg and adult sardine occurrences were more northward and offshore than the 2003 and 2004 summer surveys. With only three surveys being conducted in the summers of 2003, 2004 and 2007 and with environmental factors significantly different in each of the summer years, it is difficult to draw conclusions as to spawning and adult distribution patterns.

MICROSATELLITE IDENTIFICATION FOR THE PACIFIC SARDINE *Sardinops sagax caeruleus*

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The northeast Pacific sardine (*Sardinops sagax caeruleus*) is an important economic resource whose abundance has fluctuated significantly in the past. These large population fluctuations have probably influenced the processes generating and maintaining genetic variability and population structure. Preliminary genetic studies have reported the absence of population differentiation across a wide geographic range. However, to better understand the evolutionary history of Pacific sardines it is necessary to increase the number of polymorphic loci to improve the resolution and power of population structure assessment. Therefore, this study aims to identify new microsatellite loci to use in the study of Pacific sardine population structure. We selected PCR primers from the literature for 48 microsatellite loci developed in other clupeid species and tested all primer sets in Pacific sardines. In order to assess polymorphism and their utility as markers for population genetics, loci were optimized and genotyped in individuals from Oregon and California in the United States, and Magdalena Bay and the Gulf of California in México. Seven of the 48 potential loci were found to represent polymorphic microsatellite loci that could easily be scored in Pacific sardines. The number of alleles per locus ranged from three to 30 and expected heterozygosities ranged from 0.04 to 0.96. The microsatellite loci presented here should prove useful for future fine-scale population genetic analyses. In addition, we have shown that cross-amplification experiments and optimization of homologous loci from other species can significantly reduce the effort and resources needed for the development of new microsatellite markers in Clupeids, a taxon for which there is little genomic information.

Key words: molecular markers, Pacific sardine, cross-amplification, microsatellite DNA

MORPHOLOGICAL MEASUREMENTS OF PACIFIC SARDINE OTOLITHS SHOW REGIONAL CHARACTERISTICS

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Assessment of the population structure of Pacific sardines throughout their range between British Columbia and the Gulf of California has proven to be enigmatic because no criteria have been established to demonstrate unequivocal regional differences in these fish. Our laboratory is developing analytical tools to assess the chemistry and morphology of their otoliths as potential means to identify region-specific characteristics. Morphological and weight measurements of over 2,000 otoliths of all age groups, and a sub-group of age-1 specifically, were compared without regard to the time of year of capture. Correlation analysis shows these features strongly co-vary (average correlation = 0.942). Principal component analysis shows otoliths from México (Ensenada, Bahía Magdalena, and Gulf of California) are similar to each other, and different from otoliths of fish caught in U.S. and Canadian waters. Otoliths of fish from the Southern California Bight are similar to otoliths from Monterey sardines, but both are different from otoliths from Pacific Northwest (Oregon and Washington) and British Columbia sardines. When only age-1 fish were compared, the sample of otoliths from British Columbia was too small to make a valid conclusion. These results support the hypothesis that sardines in Mexican waters represent a sub-population, and sardines that are spawned or maintain a long residence in the Pacific Northwest acquire distinct morphological characteristics in their otoliths.

GENETIC ASSESSMENT OF PACIFIC SARDINE LARVAE FROM DIFFERENT SPAWNING HABITATS

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Sardinops sagax caeruleus is a pelagic species showing morphological variation as well as affinity for specific spawning grounds along its range of distribution from Canada to the Gulf of California. CUFES egg distributions and catch data suggest the existence of spawning groups with marked temperature affinity. This reproductive affinity for different water masses could result in reproductive isolation from each other. However, genetic studies have found no significant differentiation among adult sardines from throughout its range, which is consistent with their large dispersal potential. If reproductive groups of sardines are tuned to spawn at specific temperatures through their lives, their isolation should produce genetic differentiation. Therefore, in this study we determined the genetic variability of sardine larvae as proxies of the adult reproductive groups that spawn in two contrasting habitats: the Southern California Bight (SCB) and the central region of the Gulf of California (GC). We hypothesize genetic divergence between groups due to the use of different spawning habitats. Samples were collected in April 1999 off the SCB and December 2006 in the GC, individuals were surveyed for polymorphisms at nine microsatellite loci. The number of alleles per locus ranged from 19 to 56 and averaged 35. The mean observed (H_O) and expected (H_E) heterozygosities over all loci were, respectively, 0.908±0.070 (SE) and 0.913±0.045 for the SCB and 0.878±0.097 and 0.902±0.074 for the GC. Shallow but significant genetic differentiation (F_{ST} = 0.007-0.009 $p<0.005$) as well as heterogeneity in allele frequencies were detected between regions, but they were not revealed by an Analysis of Molecular Variance. This differentiation could reflect the hypothesized isolation of spawning groups. Alternatively, it could reflect the "Allendorf-Phelps effect", a statistical artifact producing significance under the hypothesis of no genetic isolation. However this would require reciprocal movements between southern California and the central Gulf of California, for which there is no positive evidence. In order to determine the actual causes of this genetic differentiation a closer genetic analysis of both reproductive adults and their progeny is required in these contrasting habitats. Unlike the highly vagile adult stages, the use of recently spawned sardine larvae as proxies for the spawning groups may open a window of opportunity to assess the factors that may be shaping the genetic diversity in this species.

Key words: *Sardinops sagax caeruleus*, larvae, microsatellites, population genetics, Southern California, Gulf of California.

OREGON AND WASHINGTON COAST SARDINE FISHERY

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The poster includes three areas of interest. The first is an overview for 2000-2006 of the combined Oregon and Washington log data, including set locations and set sizes, and a graph of the 1999-2007 Oregon sardine landings by pounds and value. The second is an evaluation of where the sardine industry stands compared to other fisheries in Oregon in the economic hierarchy. The last focus is a pictorial description of what the Oregon processors are doing to increase the value of sardines before export.

SARDINE OTOLITH WEIGHT AS A PROXY FOR AGING AGE-0 PACIFIC SARDINES

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Egg and larval surveys provide a measure for forecasting yearly recruitment to the sardine fishery. It is equally important to determine the survival success of juvenile recruits that also carry a record of their spawn dates in the daily increments of their otoliths. Otolith increment measurement is a time-consuming technique, but otolith weights can be determined very quickly. By comparing increment counts and weights in otoliths of juvenile sardines captured between the Pacific Northwest and Baja California, we demonstrate: 1) monthly accretion rates of otoliths during their first year of growth; 2) curves that predict juvenile fish age based on otolith weight; and 3) a calendar that predicts the spawn dates of juvenile recruits throughout their geographic range. We suggest future surveys target juvenile sardines along with eggs, larvae, and adults, and the use of otolith weights of juveniles for rapid estimation of age and spawning dates.