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MARCH 2003

MINUTES OF THE 2002
TRINATIONAL SARDINE FORUM
SAN PEDRO, CALIFORNIA, USA
DECEMBER 5-6, 2002

By

J.R. Hunter and D. Pleschner-Steele

ADMINISTRATIVE REPORT LJ-03-05



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MINUTES OF THE 2002 TRINATIONAL SARDINE FORUM
San Pedro California USA
December 5-6 2002¹

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TABLE OF CONTENTS

INTRODUCTION	1
PLENARY SESSION HIGHLIGHTS	1
Landings in Canada and the Pacific Northwest	1
California Landings and US Stock Assessment.....	2
Mexican Landings and Assessments	2
Viral Hemorrhagic Septicemia Virus (VHSV) Disease in the Pacific Sardine	3
Latitudinal Allocation of Sardine Quota in the US.....	4
INDUSTRY PANEL DISCUSSION	5
TRINATIONAL SARDINE FORUM WEB SITE.....	6
NEXT TRINATIONAL MEETING	6
CONCLUDING REMARKS BY THE CHAIRS	6
WORKING GROUP REPORTS	7
Working Group 1: Adult Sampling/Sardine Ageing Workshop.....	7
Working Group 2: Regional Estimates of Biomass in 2002 and Recommendations for Future Activities.....	9
Working Group 3: 2002 Tri-National Sardine Meeting, Working Group Stock Structure and Latitudinal Origins plus VHSV Disease sampling strategies	21
APPENDICIES	
Appendix I: Participant List	29
Appendix II: Meeting Agenda	35
Appendix III: Acronyms	37
Appendix IV: Contributed abstracts and summaries.....	39
Stock Assessment of Pacific Sardine with Management Recommendations for 2003 Executive Summary – Conser et al. (2002)....	41
Biological and Political Implications of the Detection of Viral Hemorrhagic Septicemia Virus (VHSV) in California Sardines – Hedrick et al.	53

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INTRODUCTION

The 2002 Trinational Sardine Forum was held in San Pedro, California, December 5-6, 2002, in a meeting room in the headquarters of the Southern California Commercial Fishing Association, (SCCFA, an association of the southern California purse seine fishing fleet). The meeting was attended by 51 registered participants representing sardine fishing and processing industries, marine resource agencies, and academic scientists from Canada, US and Mexico (Appendix 1). The meeting was supported in part by contributions from SCCFA, southern California processor members of the California Wetfish Producers Association (CWPA), IAI, and NMFS (SWFSC).

The meeting opened with presentations on current year landings in Canada, US and Mexico, and the US sardine stock assessment for 2002 (Appendix II). After these reports, Ron Hedrick, Fish Health Lab at UC Davis, presented background and his latest data on VHS virus disease in Pacific sardine, and outlined present gaps in knowledge. Concluding the Thursday morning session, Kevin Hill (chair of the CPS Management Team) and Sam Herrick (SWFSC economist on the team) reviewed options for geographically-based sardine harvest shares in the US. Herrick outlined examples of the kinds of economic analyses required by law to evaluate such allocation options. In Thursday's afternoon session, representatives from US, Canada and Mexico reported on recent sardine research activities in their respective regions. Concluding the Thursday agenda, Don Pepper (Canada), Orlando Amoroso (SCCFA), and Ricardo Thompson (Mexico) led an open discussion of the scientific issues of importance to the various industry sectors. The day closed with a reception dinner, including grilled and canned California sardines, hosted by SCCFA and CWPA. Cans of California sardines, compliments of Monterey Fish Company, decorated the tables as well as the buffet; many reception attendees happily took them home.

The second day of the meeting began with an early morning optional field trip to the Tri-Marine Fish Company plant on Terminal Island, where 27 participants observed the unloading and processing of sardines. After breakfast and a preview of a DVD compiled by CWPA, highlighting the history of California's sardine industry, the three working groups met to discuss joint projects. The meeting was reconvened in plenary session for working group presentations and plenary discussion.

PLENARY SESSION HIGHLIGHTS

Landings in Canada and the Pacific Northwest

The fisheries in the Pacific northwest and Canada are near shore fisheries (30 NM from the shore or less), generally managed under a policy of gradual expansion of fishing effort with some or all of the fishing observed by marine fishery observers. Lisa Mijacika (DFO) reported that the Pacific sardine in Canada is managed under a plan that allows effort to increase gradually to a harvest ceiling of 15% of the estimated biomass in the US. The fishery has 100% observer coverage which is paid by industry. This year the total allowable catch was set at 5% of the population biomass estimated by the US or 5,040 tons. Landings in 2002 were 703 tons. The Canadian market is primarily large sashimi grade sardines exported to Japan. Jake Schweigert (DFO) pointed out that the sardines taken in the Canadian fishery average about 230mm, although some small fish (175mm) do occur and are caught in traps. The fat content is very high with concentrations ranging from 18% to 37% fat; ages range from 2-8 years with a mode around 4 years. Schweigert also noted that the

volume of the stomach contents has been declining the last few years. This may reflect different environmental conditions but also might be an early indicator of the density dependent changes discussed by Hill in this section.

Michele Robinson (WDFW) reported that the State of Washington manages sardines under a trial fishery, under which the number of participants cannot be limited. Participation in the fishery and overall landings have increased from 4,791 metric tons (mt) in 2000 (by three primary vessels) to 15,212 mt in 2002 (by 19 vessels). About 24% of the trips are observed. More detailed information on the results of the fishery, observed bycatch, and biological sample data are available in the WDFW Summary Report for 2002. Jean McCrae (ODFW) reported that a total catch of 22,000 metric tons was landed by Oregon this year, an increase of 13,000 metric tons from 2001 with 6 trips observed. Nearly all of the sardines from the Oregon fishery are sold in frozen blocks.

California Landings and US Stock Assessment

In California, a total 54,904 mt were landed in 2001, and 54,923 mt have been landed to date in 2002. Kevin Hill (CDFG) presented the latest sardine stock assessment for the Pacific Fishery Management Council. Sardine biomass (age 1+; July 2002) was estimated to be 999,871 mt (Conser et al. 2002; Appendix IV). The harvest guideline for January 2003 was set at 110,908 mt. Sea surface temperatures measured at Scripps Pier have been running below average the last three years, and deep concern existed in industry that the three-year running mean, which regulates the harvestable fraction of the biomass, would drop below the 17.2 degree C threshold. The harvestable fraction would be reduced from the current 15% to 5% when the mean SST reaches 16.8 degrees C. This did not happen in 2002; the mean was 17.3 degrees C and the harvest fraction for US waters for 2003 remained at 15%. The concern remains, however. This is because since the 1998 El Niño, the northeastern Pacific Ocean appears to have entered an ocean climate regime of typically lower than average sea temperatures. At this writing, a weak El Niño is beginning to affect the west coast of the US, which could forestall further decline in the three-year mean SST for a while longer.

One of the most interesting aspects of the analysis of California landings data was preliminary evidence that growth of the sardine population may be slowing due to density dependent processes. The annual biomass estimates 1999-2002 have not shown the annual 30% increase in spawning biomass observed in the preceding years, although the confidence intervals on recent biomass estimates are sufficiently broad to accommodate a 30% increase. Stronger evidence for slowing of population growth were comparisons of life table characteristics between the two periods 1990-1996 vs 1999-2002 provided by Kevin Hill. Using southern California port sample data, he showed a decline in the body weight for all ages, and an increase in the size of first maturity. Similar changes in growth and maturity, were documented by Wada and Kashiwai (1991) for the Japanese sardine population.

Mexican Landings and Assessments

Walterio Garcia (CICIMAR-INP) reported that landings of sardines have declined in Enseñada, Mexico since 2000 when 51,172 metric were landed, with only 22,246 tons landed in 2001 and 16,745 mt through July 2002. Nearly all sardines are taken right off the port of Enseñada or a little south, and very little taken north near the international border. Most of the catch is canned or used for human consumption, and only 5% for meal. There are presently only 11 vessels fishing in the Enseñada area, which is much lower than in the early 1980s, when about 50 vessels were involved in

wetfish fishing, primarily for anchovy. Surprisingly, a large catch is consistently taken from Magdalena Bay, in southern Baja California. Felix Uruga (CICIMAR-INP) reported sardine landings of 40 tons from the Bay only in 2002 and 48 tons from the general vicinity. During El Niños the catch in this small area declines by about half and the fish are believed to shift to the north. He pointed out that landings in Enseñada and Magdalena Bay appear to be inversely related, indicating a coastal migration. In the Gulf of California, Manuel Nevarez (CRIP) reported that currently the Gulf stock of sardines is about 2 million tons, and catches reach 200,000 tons in normal years but drop sharply to less than 75,000 tons in El Niño years. In El Niño years the tropical clupeids (thread herring, big mouth anchovy), invade the Gulf from the south, and they replace the catch of sardine. Where the Gulf sardines move during an El Niño is apparently unknown. Presently the fishery employs a limited entry program, with 32 boats licensed to fish and 27 operating. All of the catch is used domestically, with most of it used for fish meal and a small amount processed by the canning industry.

Viral Hemorrhagic Septicemia Virus (VHSV) disease in Pacific Sardine

The occurrence VHSV in west coast sardines became important to the Pacific sardine fishery when Australian biosecurity officers became concerned that imported frozen sardine from the US might introduce the virus to Australian waters, where the sardines are used as food for pen-cultured bluefin tuna. Concern regarding the introduction of marine diseases increased when substantial die offs of Australian sardines occurred in 1995 and 1998. These massive mortalities were attributed to a herpesvirus, which Australian authorities at one time believed might have been introduced with imported sardines (there has been no evidence to prove or disprove this suspicion). Ron Hedrick, a leading expert on infectious diseases of fish in the US, was asked to participate in the Trinational Sardine Forum and lead a discussion concerning VHSV in eastern Pacific sardines. An abstract of his talk is presented in Appendix III and we provide below a few highlights from his talk and the discussion that followed.

Hedrick reported that the virus was discovered in rainbow trout in Europe in 1931 and later isolated by Jensen et al in 1963. Investigators subsequently found that the origin of the virus may have been Baltic herring fed to trout; the virus subsequently became established in freshwater trout hatcheries throughout Europe.

On the Pacific coast, the virus was first identified in Pacific cod from Alaska in 1988 by Meyers et al. Currently known hosts include cod, hake, pollock, herring, several salmonid species, sand lance, mackerel and sardine. In general, the virus seems to grow faster at low sea temperatures. The disease is rare at temperatures above 15°C. In recent years, documented mass mortalities of sardine trapped in Canadian inlets occur about two times a year, according to Jake Schweighert. Such mass mortalities are often associated with a high prevalence of the VHS virus, although other stressors such as low temperature are believed to play an important role. Recent work by Hedrick and associates (see abstract, Appendix IV) indicated a prevalence of 4-8% among the first populations from which VHSV was isolated, with most detections of the virus occurring at water temperatures between 12° and 15°C. More recent sampling of sardine populations from southern California to Oregon have been found to be free of virus, suggesting that virus prevalence is a seasonal phenomenon most noticeable in spring.

In initial trials, Hedrick and associates found that freezing sardine using procedures employed in commercial processing plants greatly reduces the concentration of the virus, with the range of reduction from 59 to 100 percent. In addition, only a small number of sardines inoculated with live virus for the experiment contracted VHSV, suggesting some fish may have a natural immunity. Participants strongly supported a continuation of VHSV research. Research investigating how processing may affect the virus needs to be continued. In addition, a thorough epidemiological study is needed where the prevalence of the virus or disease can be examined in terms of water temperature, season, age, and geographic origin of the stock. This expanded research is possible by linking the VHS virus tissue sampling to existing sardine sampling programs carried out by members of the Trinational.

Latitudinal Allocation of Sardine Quota in the US

Under the current US fishery management plan, 66% of the sardine harvest is allocated to fisheries south of Pt. Piedras Blancas (south of Monterey) and 33% to the north (including Monterey as well as recently emerging fisheries in Oregon and Washington). After October 1, unused harvest shares are pooled and divided equally between north and south segments of the fishery. Objections to this policy have been raised by the fishers and packers in the newly developing sardine fisheries of Oregon and Washington, which landed 37,000 MT in 2002. The Trinational role, however, is one of science, communication, and international cooperation, and does not involve allocation policy. Nevertheless, we felt an appropriate application of the Trinational's communication role was to hold a discussion of the options, government processes, and economic analyses that will be undertaken by the US Pacific Fishery Management Council to resolve this issue.

Kevin Hill began the discussion by outlining the north-south allocation options identified by the CPS management team, which include preserving the status quo, instituting a coast-wide harvest guideline with no allocations, and moving the north-south allocation boundary north to encompass all of California's limited-entry fishery, and changing the reallocation date to earlier in the year. Hill pointed out that the Council will take into consideration present participation and dependence on sardine, history of the fishery, economics, consistency with the Magnuson Stevens act and FMP, and biological considerations, such as the catch of large spawners in the north and catch of juvenile fish in the south. Generally, it was felt that we do not know enough about subpopulation structure, and migrations to change the allocation policy. Sam Herrick then noted that federal law requires that all allocation options must be accompanied by economic analysis to examine the net economic benefits of different options to the country, and to determine the impact of the regulations on the local community (Regulatory Impact Analysis). For such analyses to be accurate requires extensive data on fishing and processing costs and revenues. Detailed economic data of this kind on the fishery is generally not available, and typically, public sources of information such as vessel landing receipts, and value of exported product from custom districts are used. When questioned how Councils tended to weight criteria based on net benefits to the nation relative to community impact, Herrick responded that, in his opinion, community impact is given a greater weight by Fishery Management Councils in settling allocation issues. It is also very clear that the data currently available for economic analysis of regulatory impacts on a community are very poor for sardine fisheries, and a need exists for fishers, processors and the government to work together to obtain better cost information.

INDUSTRY PANEL DISCUSSION

In free ranging discussion of industry issues chaired by Don Pepper and Orlando Amoroso, industry members stressed the need for better information to support the Trinational sardine fisheries. Of particular value for the industry would be predictive models that would provide a forecast of the availability of fish for future fisheries. In particular, predictions regarding future stability of the resource was viewed as especially valuable by industry representatives. Industry representatives from Canada and the Pacific Northwest were deeply concerned regarding continuance of migration into northern waters, recognizing that changes in the extent of migration might be one of the early responses to changes in ocean climate. The development of better economic information on the fishery, and development of bioeconomic models was stressed as highly important as well. Long range projections of effects of changes in markets was identified as an important issue. Concerns were voiced by US fishermen, regarding losses of fishing grounds to marine reserves in California, and a feeling that they lack representation in meetings that affect their fisheries.

Participants discussed the continuing expansion of the bluefin tuna pen culture on the west coast, and quantities of sardine that may be needed to sustain this developing industry. Five new farms have been authorized in Baja California, and there may be as many as 10 in the near future in Baja California. Bluefin tuna farming is also being discussed as a possibility in US waters. Rough calculations indicated that ten farms, consisting of 15 cages each, would require about 40,000 metric tons of sardines per year. Clearly, as pen farming expands, the ability of sardines and other coastal pelagic species to support that production will need to be examined.

Ricardo Thompson discussed his plans for a new sardine processing facility at Cedros Island (about 600 miles below the international border). The plant on the island has been closed for years, but this new project will bring employment to the area. The plant will consist of a freezer boat moored at Cedros Island with a capacity of processing about 120 metric tons per day. Thompson, identified the need for improved information related to the availability of sardines in the region and sustainability of the supply in the future.

John Royal (San Pedro) perhaps best summed up the situation by pointing out that the need for better information on sardines becomes more urgent every year as sardine fisheries expand, but progress is slow. He went on to say that none of the three governments are paying enough attention to sardines and their transboundary issues, nor are they devoting enough resources to solve the most pressing scientific problems. Royal urged the Trinational Sardine Forum members to recommend to their governments, the development of a MOU establishing a Trinational Sardine Fishery Commission. Patterned after other Fishery Commissions in the world (e.g. the IATTC), the Commission would be funded by contributions from member nations to support key research projects and guide cooperative research projects among members. This concept was endorsed by the participants.

TRINATIONAL SARDINE FORUM WEB SITE

The Southwest Fishery Science Center, Fishery Resources Division agreed to set up a Trinational Sardine Forum Website, (on the SWFSC Site) which shall provide basic information regarding Trinational meetings, working groups and shared information. Those wishing to post information on the web site should contact the web manager, chuck.oliver@noaa.gov. We anticipate the web site will be fully operational by the end of February 2003.

NEXT TRINATIONAL MEETING

The consensus of participants was that the meetings are useful and should be continued. The fourth Trinational meeting shall be held again in San Pedro, during the first week of December 2003. Orlando Amoroso, offered once again to host the meeting, which will be held at the Southern California Commercial Fishing Association Headquarters in San Pedro, as it was in 2002.

CONCLUDING REMARKS

In 2002, our Trinational shows us that the overall picture for the Pacific sardine fisheries is positive and dynamic. The world-wide expansion of bluefin tuna ranching and the opening of Japanese markets, caused by the collapse of the Japanese sardine fishery, are producing new and expanding markets for Pacific sardine. Landings and revenues are increasing because of the development of the new markets and because of the increased availability of the putative northern stock since its recovery. However, there are a few warning signs. Population growth of the northern stock may have slowed in the last few years. The northern stock may grow more slowly in the future, owing to the onset of density dependent processes, and because of a general cooling of the California Current. Of course, a less productive northern stock in a cooler California Current will be protected to some extent by automatic changes in the temperature dependent harvest guidelines in the US Fishery Management Plan. On the other hand, under conditions where the northern stock is stable or growing more slowly, even the maximum harvest rate of 15% might soon be exceeded by the combined catches from the US, Mexico and Canada (see Conser et al. 2002, Fig. 13, Appendix IV).

Fishing organizations and agencies in Canada, the US and Mexico are committed to not repeat the sardine failures of the past, but commitment alone may be insufficient to offset future problems. Ignorance of sardine biology, and particularly, poor understanding of the interdependence of regional stocks, and those that cross international boundaries, may be a fatal flaw. Solving the stock interdependence issue would not only greatly reduce risk of over-fishing, it also presents a great opportunity to increase efficiency of sardine management in all three countries. We of the Trinational Forum have done our best to build cooperative projects and improve joint understanding of sardine dynamics, but a limit exists on how much can be accomplished using the purely informal, and voluntary approach of the Trinational. Participants recommended a binding and official commitment by the three governments to work together and commit resources to that end. In short, a Trinational Sardine Commission is needed to commit funds and resources in the three countries for joint work on sardine dynamics, movements, and stock assessments, as well as to guide the collaborative process.

John Hunter and Tim Baumgartner (December 2002)

WORKING GROUP REPORTS

WORKING GROUP 1: Adult Sampling/Sardine Ageing Workshop - Kevin Hill, Chair

Recommendations from Trinational Sardine Forum (TSF) 2001

Participants of TSF 2001 agreed that coastwide standardization of ageing criteria was essential and that an age determination workshop could make a major contribution to the quality of future stock assessments. Objectives the workshop should include: 1) summarize all existing data on age size composition of Pacific sardine, 2) standardize aging methods and criteria, 3) establish guidelines for cross reading of otoliths between labs, 4) develop a joint publication summarizing coast-wide age data. TSF 2002 participants also recommended standardizing gonad maturity codes for sardine, thereby making it easier to combine data from different areas and countries.

Progress and Plans for 2003

I. Sardine Ageing Workshop

Working Group 1 discussed plans for the upcoming sardine ageing workshop, which will be held in spring of 2003 at the Southwest Fisheries Science Center in La Jolla, California. The workshop was initially planned for late April, but after some discussion it was agreed to move the dates to the 2nd and 3rd of April, 2003. The working group discussed a preliminary agenda (below), and agreed to hold a conference call in January to organize workshop details.

Preliminary Workshop Agenda:

- 1) Discuss and resolve basic sardine ageing methods and issues
 - sampling rate (fishery)
 - resolving first annulus, check marks, outer edge
 - standardizing birth date and year class assignment
- 2) Cross-reads among existing ageing experts
 - full spectrum of samples by region and season
 - representation of all ages
 - excellent, average, and difficult examples
- 3) Validation and verification
 - marginal increment analysis, and review of previous work
- 4) Presentation of regional data
- 5) Joint publication on coastwide age distribution, growth, maturity
- 6) Develop format for sharing summarized age and growth data among agencies

Preliminary List of Workshop Participants:

DFO Sandy McFarlane + 1 other
WDFW Michele Robinson + 1 other
ODFW Jean McCrae + 1 other
CDFG Kevin Hill, Darrin Bergen, Stephen Wertz, Valerie Taylor, Leanne Laughlin, Kelly O'Reilly, + 1 other
CICIMAR Casimiro Quiñonez, Roberto Félix, + 1 other (?)
CISESE Tim Baumgartner, Sarita de la Campa, Yanira Green, Pablo Santos, Christina Sanchez

INP

NMFS John Butler? Paul Crone?

II. Revision of Gonad Maturity Codes

Working Group I recommended that a standard maturity code for sardine be applied throughout the range, making it much easier to combine data from different areas and countries. Beverly Macewicz (SWFSC) drafted a 4-stage maturity code system (abbreviated below) and provided photographs and background information to facilitate coastwide implementation. Participants from each agency agreed to implement the system in early 2003, after Macewicz' finalized guidelines, including photographs, are distributed. The classification codes will also be applied to other small pelagics such as mackerel and anchovy.

Females:

- 1 - Immature
- 2 - Intermediate (not immature, but no oocytes visible)
- 3 - Active (yolked oocytes visible)
- 4 - Hydrated

Males:

- 1 - Immature
- 2 - Intermediate (not immature, but no milt present)
- 3 - Milt present

WORKING GROUP 2: Regional Estimates of Biomass in 2002 and Recommendations for Future Activities – Nancy Lo, Chair

Members: Martin E. Hernandez-Rivas, mrivas@vedipn.ipn.mx; Sandy McFarlane, mcfarlanes@dfo-mpo.gc.ca; Robert Emmett, robert.emmett@noaa.gov; Ray Conser, rconser@ucsd.edu; Yanira Green-Ruiz, motagreen@yahoo.com.mx; Sarita De la Campa, scampa@cicese.mx; Darrell Kapp, dkapp@netos.com; Nancy C.H. Lo, Nancy.Lo@noaa.gov; Lisa Mijackia, mijacikal@pac.dfo-mpo.gc.ca; Rene Torres Villegas, jvillega@ipn.mx

Group e-mail address: sardine.forum

1. IMECOCAL and CalCOFI, April cruises, 2002

Objectives: To estimate spawning biomass of Pacific sardine from Baja California, Mexico to San Francisco, CA, US.

Activities

1.1. CalCOFI

In 2002, a full-scaled survey was conducted to estimate the spawning biomass of Pacific sardine. In this survey, ichthyoplankton samples from CalVET and CUFES were taken aboard R/V *McArthur* (March 21 - April 19) (Figure 1) and R/V *David Starr Jordan* (March 27 - April 14) (Figure 2). The *Jordan* segment was the routine CalCOFI April survey. Adult sardine samples for reproductive output were taken aboard R/V *David Starr Jordan* (April 14-25) after the routine CalCOFI cruise.

The daily egg production of Pacific sardine (*Sardinops sagax*) off California from San Diego to Monterey was estimated to be $0.728/0.05\text{m}^2$ (CV = 0.17). The estimate of daily specific fecundity (number of eggs/population weight (gm)/day) was 22.94 (compared to 23.55 used in the past years). Reproductive parameters of the mature female sardines from the April 2002 survey were as follows: R, the sex ratio, was 0.386 (CV = 0.19); F, mean batch fecundity, was 54403.26 eggs/batch (CV = 0.05); S, spawning fraction was 0.174 per day (CV = 0.28); and W_f , mean female fish weight, was 159.2 grams (CV = 0.04).

The spawning biomass was estimated to be 206,333mt (CV = 0.35) for an area of 325,082 km^2 . The area is similar to 321,386 km^2 in 2001. The estimates of spawning biomass of Pacific sardine in 1994 and 1996 - 2002 are 129,000 mt, 83,000 mt, 440,000 mt, 310,000 mt, 280,000 mt, 1.06 million mt, 791,000 mt, and 206,000 mt respectively. Therefore, the estimates of spawning biomass have been fluctuating since 1994. One possible reason for the fluctuation may be due to the migration.

1.2. IMECOCAL: (See the Research report from Northern Baja California by Tim Baumgartner)

2. NWFSC Biomass off Northern Oregon and Southern Washington

Objectives: To estimate spawning biomass of Pacific sardine off Oregon in 1999 - 2002.

Activities

- 2.1. Egg surveys in 1999-2002. No egg surveys were conducted in 1999-2002.
- 2.2. Adult surveys. Similar to year 2001, no off-shore survey was conducted to capture adults in June because locations and timing of the spawning were unknown. Effort was concentrated on near-shore trawling surveys off Oregon and Washington:
 - a) Bonneville Power Administration (BPA) Columbia River plume study: from northern Washington to Newport in May, June, and September. The study is funded by BPA and NMFS until at least 2005.
 - b) Predator/baitfish study off the Columbia River: night surface trawl surveys off the Columbia River every 10 days from late April through July.
 - c) Lower Columbia River purse seine survey: every 2 weeks from April through September.

This section reports the preliminary estimates of biomass of Pacific sardine based on July samples from night surface survey trawls of predator/baitfish study off the Columbia River from Willapa Bay down to Tillamook Head in 1999-2002 (Figure 3). Night surface trawls were conducted every 10 days from late April through July. During each survey, 12 surface trawls were conducted: 6 on 2 lines (Willapa and the Columbia). The net reached down to 20 meters depth of water. We believe this area has similar hydrographic conditions: dominated by the Columbia River plume, has high Chlorophyll, and evidently higher abundance of sardines than other areas in the region.

The preliminary biomass estimate for each cruise was computed using the logarithm of (number of sardines/m³) for each tow. The initial sardine density for a cruise was obtained by anti-log transformation. The mean density was then multiplied by the total volume of water in the study region to estimate the total abundance of sardines during that cruise. The estimate of total number of sardines was then converted to metric tons using length-weight relationship.

The biomass estimates ranged from 21,000 mt to 102,000 mt during these four years for the area from Willapa Bay down to Tillamook Head (Table 1). This high fluctuation may be due to sampling effort or due to movement. The fork length of 807 sardines collected from Late April to early August was measured and tabulated (Figure 4). The range of fork lengths was from 144 to 289 mm. The fat contents were obtained from commercial catches off Washington in June-October, 2002, ranging from 7% in June to a maximum of 25% in September (Figure 5).

Table 1. Summary of July surface trawl surveys off Oregon and Washington, 1999-2002.

Number of Pacific Sardine off S Wash/N Oregon				
Year	early July	Mid July	Late July	
1999	16,738,383	10,282,076	667,488,503	
2000	644,545,899	766,670,243	no trawls after 22 July 2000	
2001	35,637,249	162,221,196	235,583,259	
2002	544,696,457	48,770,214	none taken	

Average Fork Length of Pacific Sardine (mm)			
Year	early July	Mid July	Late July
1999	246	239	235
2000	237	243	
2001	233	241	242
2002	247	247	

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	

Biomass of Pacific Sardine off S Wash/N Oregon (metric tons)				
Year	early July	Mid July	Late July	mean
1999	2,585	1,471	91,200	31,751.98
2000	90,129	114,467		102,298.2
2001	4,740	23,612	34,904	21,085.55
2002	85,229	7,607		46,417.95

3. Canadian Trawl surveys

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

Activities: The July trawl survey was interrupted due to vessel problems. The survey was conducted for 4 days in early August from August 9-14 and occupied the southern lines off west coast of Vancouver Island. Biological samples of sardine were also collected from salmon surveys in July 21-28 and September 14-19. No other trawl surveys were conducted in 2001-2002 as in previous years. A minimum value of biomass of sardine estimate will be obtained from the partial August survey, 2002 (Figure 6).

4. IMECOCA: January survey in South Baja California and Gulf of California (See Research Report from Southern Baja California by Manuel Otilio Nevarez Martinez).

Objectives: To estimate spawning biomass of Pacific sardine in southern Baja California, Mexico and in the Gulf of California and to investigate the migration of Pacific sardine between the Gulf and west of Baja California.

One survey was conducted in Gulf of California in 2002 (personal communication, Yanira Green-Ruiz).

5. Future plans and Recommendations

Mexico

1. Acquire a 2nd CUFES equipment package for ichthyoplankton surveys off southern Baja California in Pacific Ocean and inside Gulf of California. The surveys will be implemented in January 2005.
2. Improve procedures for adult reproductive parameters. Biologists will be sent aboard commercial vessels to obtain fresh gonad samples and preserve specimens aboard commercial fishing boats during April 2003 in Ensenada and San Carlos Fishery in 2004 to incorporate Cedros Island with laboratory in freezer ship (Bajo Cero).
3. Perform analyses for retrospective estimate of sardine spawning biomass from southern Baja California to San Francisco for 2002. Data files should be edited and ready for analyses by February 1, 2003: staged eggs, and egg counts from CUFES and from CALVET tows of 0204 survey, and histological adult samples collected during April 2002.
4. Organize a workshop in February, 2003 in Ensenada on the procedures of implementation of DEPM for 2002 survey data for estimating sardine biomass off Mexico.
5. Apply for joint funding from CONACYT (National Science and Technology Council) with industry organizations in January 2003. The decision for granting funding will be made in July 2003.

Canada

1. Conduct in-shore surveys for spring/fall 2003 and winter 2004 for biomass estimate and more accurate estimates of annual migration.
2. Obtain a minimum biomass estimate for 2002 offshore area based on incomplete trawl survey in August 2003. Continue annual trawl survey.
3. Propose an ichthyoplankton survey of Nootka Sound in conjunction with Canadian trawl fishing in July some year in the future. The ichthyoplankton survey will depend on the availability of US research vessel equipped with CUFES.
4. Propose scientific workshops to address specific sardine population related issues in the near future. In particular, a predictive economic-oceanographic model for sardine biomass estimates was suggested by Don Pepper, the Canadian industry representative, and therefore we would hope that Canadian scientists will take the lead to organize this workshop and Canadian industry will provide the necessary funding.

US

1. Southwest Fisheries Science Center is initiating NW trawl surveys in July 2003 and January 2004. The surveys can be conducted more efficiently if spotter pilots in Washington and Oregon are able to assist in locating fish schools for trawling. It was also suggested that an ichthyoplankton survey off Oregon and Washington be conducted in July 2003 to collect sardine egg and larval samples for a full scaled Daily Egg Production estimate of spawning biomass in NW.

2. Aerial survey by spotter pilots in Oregon and Washington. Darrell Kapp and Ryan Kapp who fish and pack sardines in Astoria indicated about 5 pilots spotting sardines June-September in Oregon and Washington. In addition to inviting spotter pilots to join the July trawl survey to search for fish schools, John Hunter proposed that spotter pilots off NW join the ongoing aerial survey program off California by submitting their logbooks of their flights off Oregon and Washington. One spotter pilot introduced by Kapps is Jerry Mahoney (phone number is 206 369 7192). They indicated that Mahoney knew all the other pilots and could contact them. It would certainly be useful to have an index of sardine abundance for the area off NW.

Cooperative Sardine Surveys off the Pacific Northwest Coast

New Sardine Survey: Hunter (SWFSC) presented the plans of the SWFSC to conduct sardine acoustic trawl and CUFES surveys off the coast of Oregon and Washington in July 2003 and January-February 2004 (acoustic-trawl only). These surveys were designed to fill major gaps in knowledge of sardine populations, by measuring the age structure and reproductive rates, and assessing the extent the fishery is dependent on migration and on local production of sardine. The objective of the surveys would be to estimate the biomass present at these two times of the year, with the ratio of the two values providing an estimation of the relative proportion and size and age structure of the sardine stock that over-winters off the coast of Oregon and Washington. The study shall also support studies of the epidemiology of VHSV disease in sardine. Hunter stressed that the SWFSC needed the help and local knowledge of those in the Region to make the cruises a success. The working group made the following decisions, and suggestions regarding the cruises.

- ETD for 2003 cruise was set at July 9, 2003 and the 20 day cruise shall be broken into two 10 day legs to facilitate the participation of local volunteer scientific participants.
- Jean McCrae and Michele Robinson and Brian Culver (WDFW) agreed to make an effort to place volunteers on the cruise. Two volunteer positions are needed to fill the scientific crew complement of the July 03 Cruise.
- The window for the January 04 Cruise shall be extended to January-February to increase the number of possible candidate fishing vessels for the two surveys.
- Tissues samples shall be taken which can be used to measure prevalence of VHSV.
- In the past, the NWFSC (Robert Emmett), has carried out an inshore egg survey in July to identify salmon forage. The group recommended that they be encouraged to continue this work in July 03 and to coordinate with the planned sardine survey so that both projects could be enhanced by the combined information. (Bob who usually attends Trinational meetings was unable to attend this year but he will be contacted).

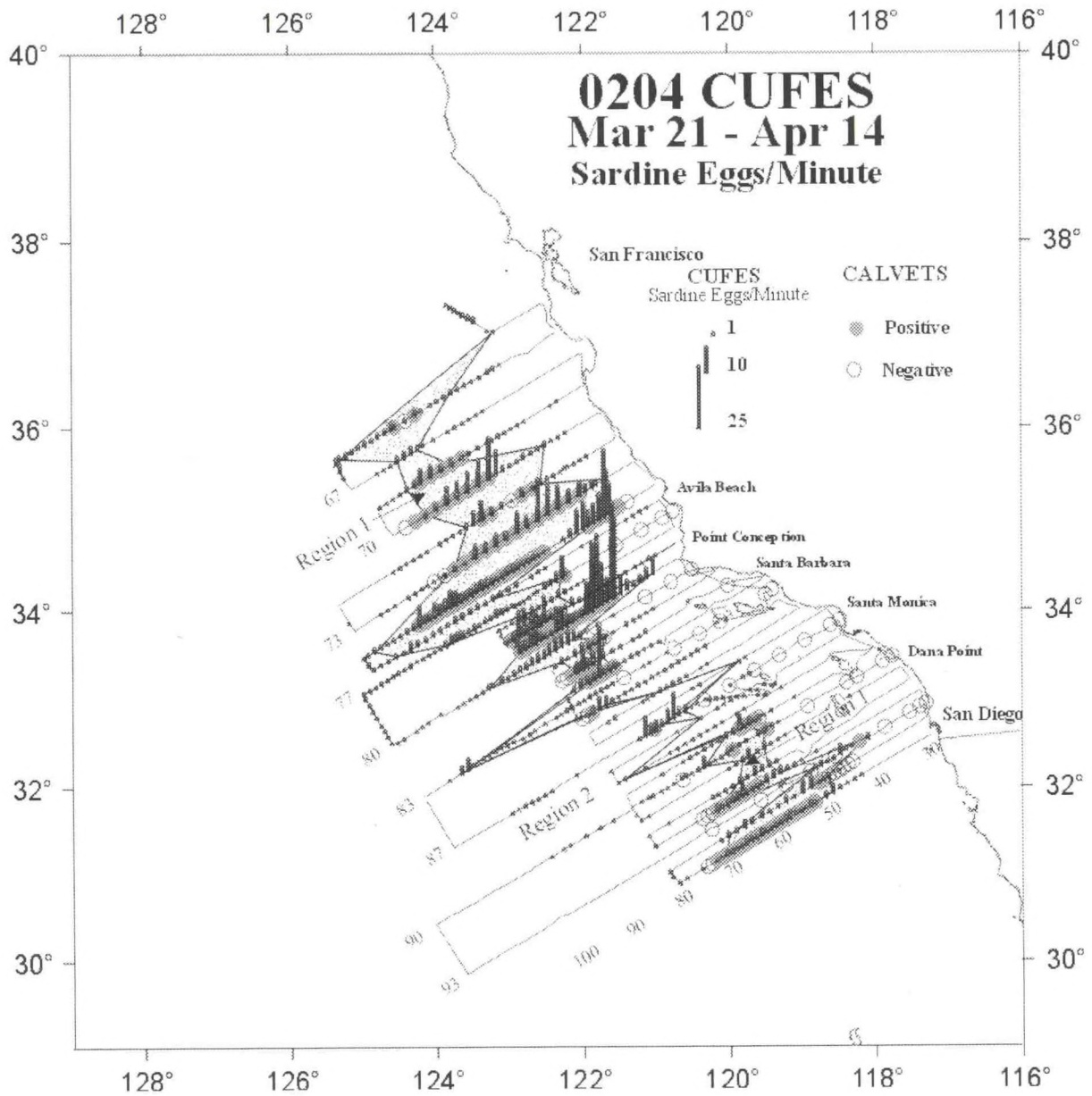


Figure 1. Sardine eggs from CalVET (or Pairovet; solid circle denotes positive catch and open circle denotes zero catch) and from CUFES (stick denotes positive collection in March-April 2002 survey). The number on line 93 are CalCOFI station numbers. Region 1 is stippled area.

- As currently planned, the July 03 Cruise will involve only trawling, counting sonar targets, and mapping egg distributions using the underway fish egg sampler (CUFES). This simple design was selected to keep costs low and conserve deck space. Participants recommended a more complex design where, in addition to the above measurements, vertical net tows are taken to provide a full water column calibration of the CUFES data, and CTD casts are taken to characterize the spawning habitat of sardine. While these additions are desirable, they involve considerable deck-space and costs (including the purchase and installation of a hydrographic winch) which maybe difficult to overcome.

Sardine distribution and condition: Information on geographic distribution of catch, reproductive state, and oil content will be of considerable value in designing the surveys discussed above. The distributions would be of particular value if they could be related to oceanographic conditions such as sea surface temperatures from satellites. This information is also needed for placing the characteristics of the NW catch in the broader context of the stock.

- Jean McCrae and Michele Robinson agreed to process the data from the vessel log book programs in Oregon and Washington and make them available in a common format to the SWFSC. Hunter and Charter (SWFSC) will analyze the data and post summaries, maps and figures of the combined data from Oregon and Washington fishing seasons on a new Trinational website. (Individuals and organizations contributing this information will be identified, and rules of confidentiality will be followed.)
- Darrell Knapp (Astoria Sea Food) maintains systematic records of oil content of the sardine catch processed at his Astoria Sea Food plant. He agreed to make these data available to the SWFSC scientific team and Trinational working groups. These data will be displayed on the Trinational web site.

Aerial Fish Spotter Surveys: The value of aerial information on sardine fish schools detected by fish spotter pilots for assessment work and for enhancement of survey data was discussed. Aerial spotter data from southern California have been routinely used in the past as a sardine recruitment index in the annual US stock assessment. Currently, there are about five pilots who locate sardine schools for fishers in the Pacific NW. The SWFSC has a spotter pilot log book program for the southern California but, currently, none of the pilots flying off Oregon and Washington are participants. The SWFSC will investigate the feasibility of adding pilots from the Pacific NW to the log book program. Locating sardine schools from the air during surveys planned for '03 and '04 would be particularly advantageous since the observations could make important contributions to sampling design.

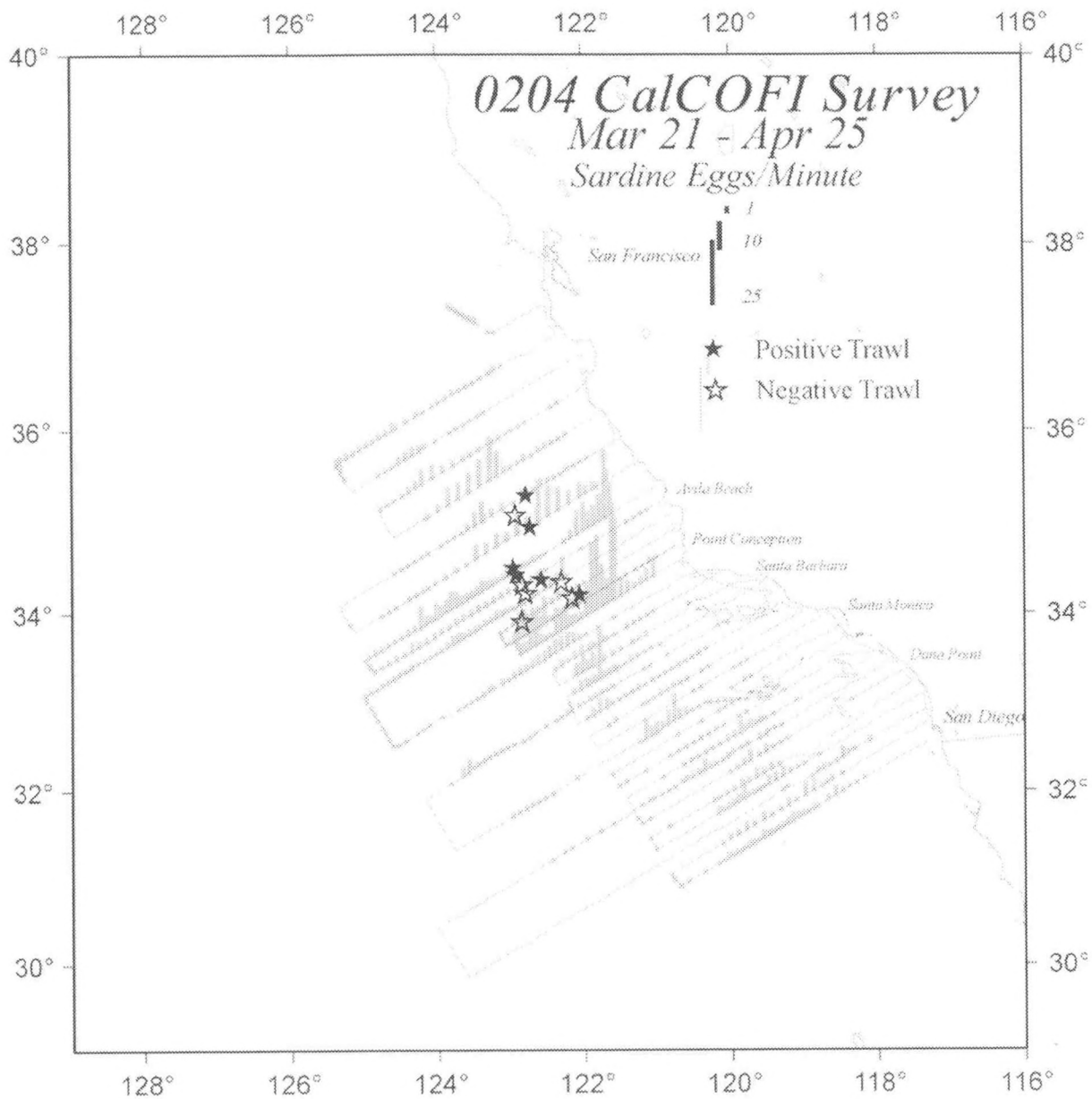


Figure 2. April 2002 trawl start locations. Solid stars are trawls that contained at least one sardine. Background in CUFES track line and sardine egg abundance.

Information:

2 lines (Willapa and Columbia River) were surveyed every 10 days from late April through July, 1999, 2000, and 2001.

Gear - 264 rope trawl - mouth opening of 360 m²

Estimated representative survey area - 20,000 km² (From above Grays Harbor to Cape Falcon - and out ~35 nm).

Total volume (4×10^{11} m³) within the survey area was calculated using 20 m (depth the net fished) x the survey area.

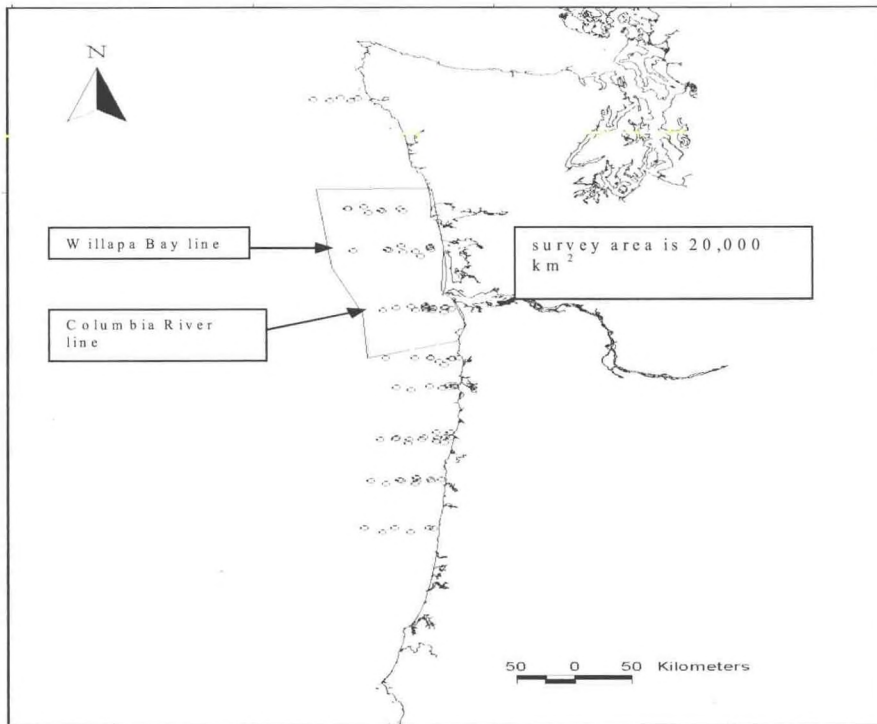


Figure 3. Surface trawl survey off Oregon and Washington from late April – early August, 1999-2002.

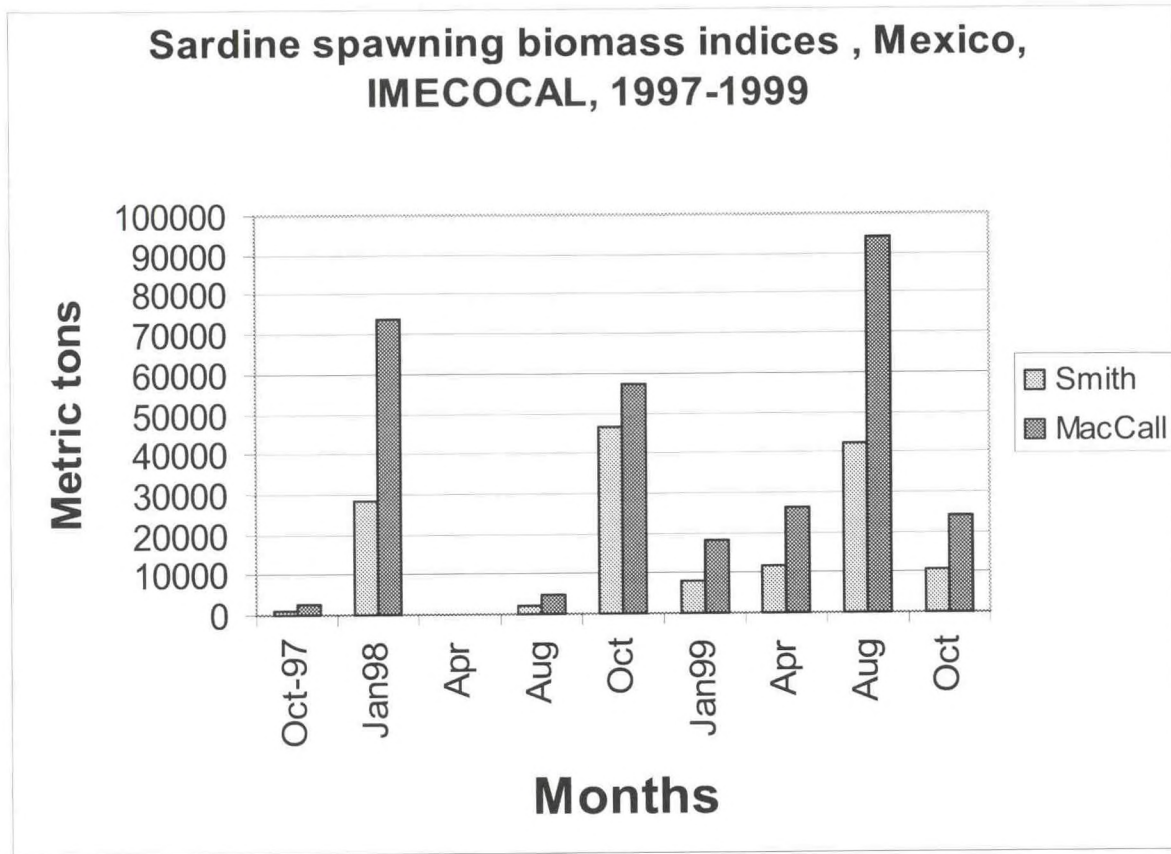


Figure 4. Distribution of fork lengths of sardine from night surface trawl surveys collected from late April to early August, 2002.

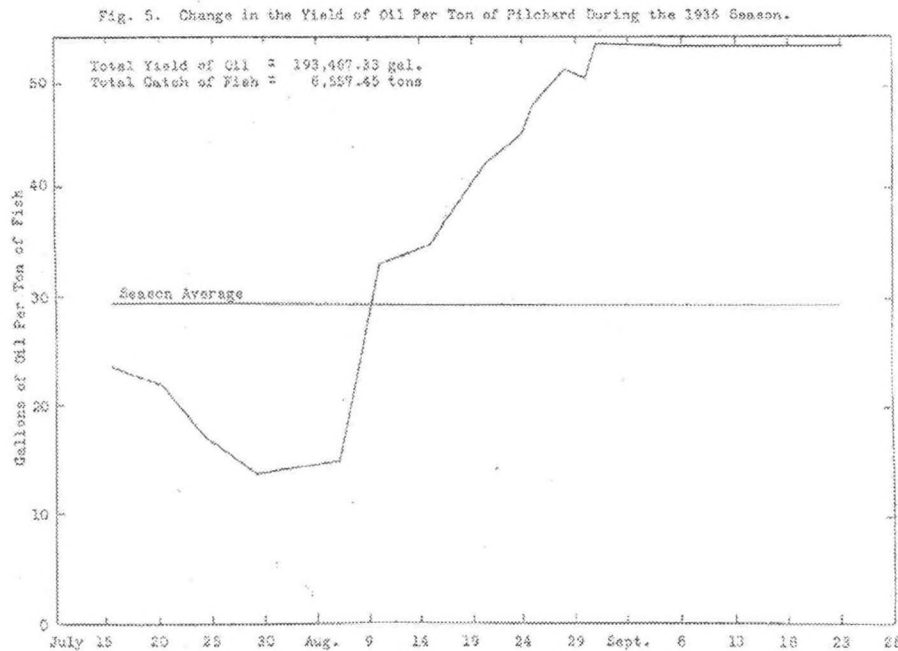
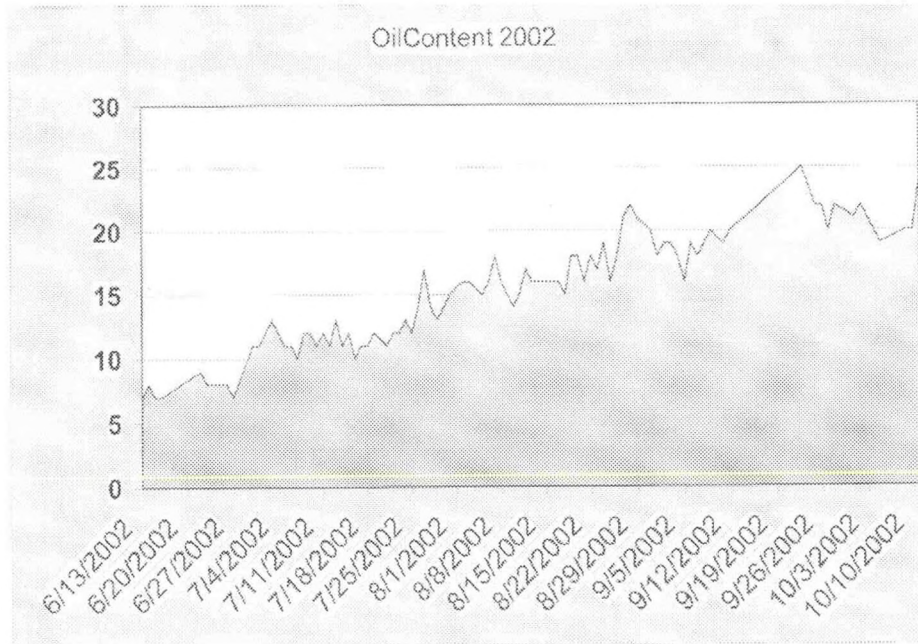


Figure 5. Upper panel reflects fish fat content from commercial catches in June-October off Oregon in 2002 with a comparison to lower panel data on oil yield taken in 1936 by W.M. Chapman, Biological Report No. 36C, State of Washington, Division of Scientific Research, Department of Fisheries.

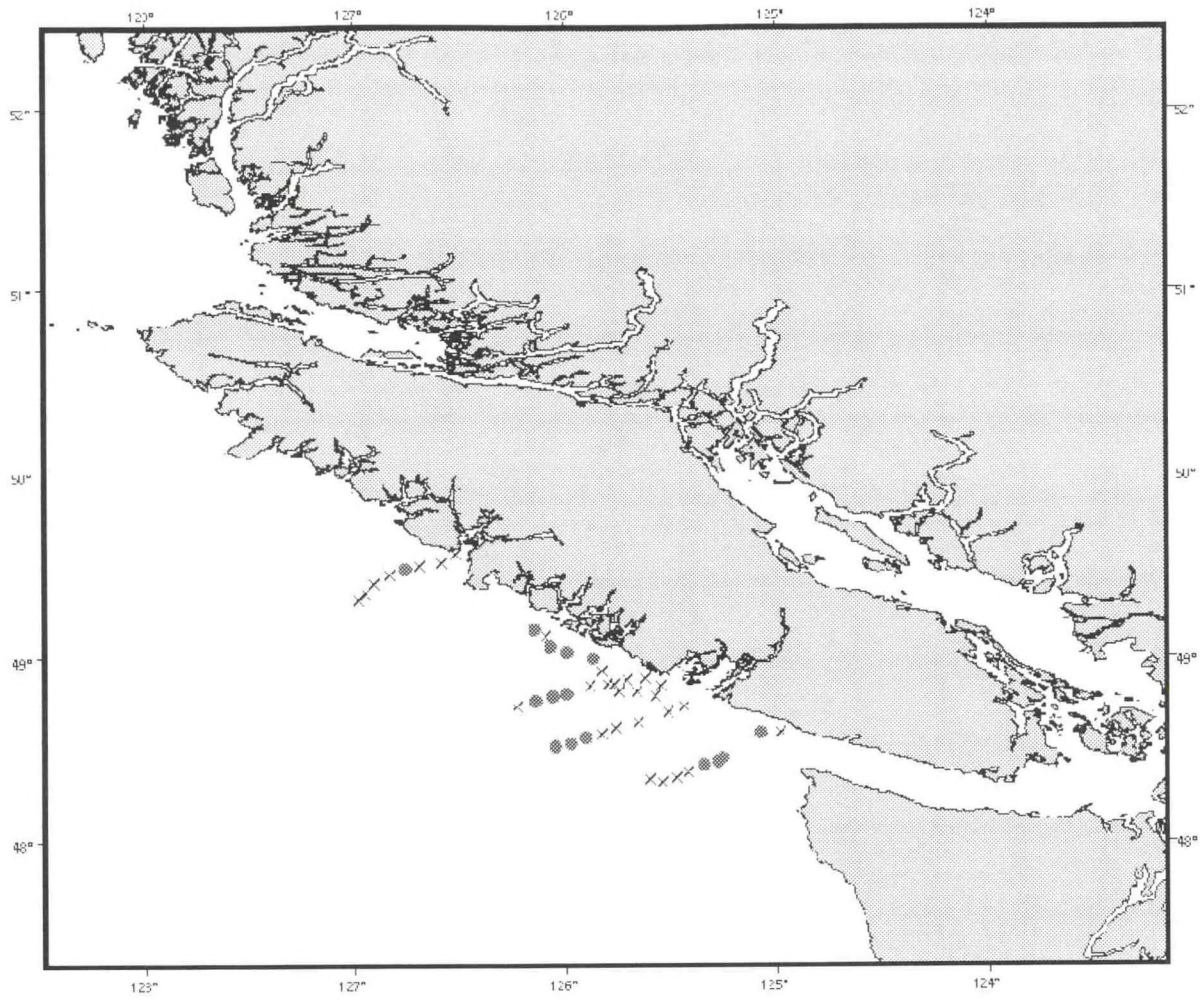


Figure 6. Partial trawl survey August 9-14, 2002 off Vancouver Island, British Columbia, Canada.

WORKING GROUP 3: 2002 Tri-National Sardine Meeting, Working Group Stock Structure and Latitudinal Origins plus VHS Disease sampling strategies – Russ Vetter, Chair

Historical Opinions, and Beliefs about Population Structure

1. Sardine in the Sea of Cortez constitute a stock. This stock undergoes extreme fluctuations in population size but probably has not gone locally extinct in recent times.
2. When populations are low in the Sea of Cortez, sardine retreat to core areas
3. Sardine recovery in the Sea of Cortez may sometimes be aided by migration of sardine from the outer coast of Baja into the Sea of Cortez.
4. The outer coast of southern Baja constitutes a second stock (southern stock). There is movement between the Magdalena Bay region, the Cedros Island region and the Ensenada region. Sardine from this stock may even extend across the border into the southern California inshore landings.
5. The main US stock is a third stock (northern stock). This stock is located offshore in southern California. The spawning center is off the central coast of California and it extends northward to Vancouver, British Columbia during favorable environmental conditions.
6. Information on how the Magdalena Bay landings vary inversely with the Ensenada landings was presented. It was suggested that the core of the southern stock moves north and south during El Niño and La Niña events.
7. Not all Pacific sardine experts believe in the existence of a separate northern stock; Alec McCall's skepticism regarding the existence of a separate northern stock is noted in his review of this document.

Much of the above information has been presented and discussed in the previous Trinational and has been summarized in the paper "Climate Variability and Pacific Sardine Populations and Fisheries" in American Fisheries Society Symposium 32: 195-214, 2002. G. A. McFarlane, P.E. Smith, T.R. Baumgartner and J.R. Hunter.

Hypotheses on Migration Patterns

Sardine populations fluctuate widely. Under certain climate conditions they may shift their centers of distribution and may go locally extinct at the northern and southern portions of their range (off Vancouver and in the Sea of Cortez). When conditions are favorable, sardine recolonize previously unfavorable portions of their range and can reach high biomass in previously empty habitats. Considering just the northern region there are three scenarios:

1. Sardine recolonize the previously empty habitat, grow and reproduce in the new habitat, and locally generate recruits.
2. Sardine migrate northward with a progression of the seasons, or with age, and forage in northern habitats. Either annually, or at some point in the life cycle, they return to their core spawning region and contribute to the larval production of the core population.

3. Sardine migrate northward with age but do not return. The northern animals are a terminal phase that contributes little to the overall fecundity and growth of the core region or the northern extension.

Management Implications

Scenario 1: Fish stocks should be managed separately with the expectation that the northern fishery will eventually collapse if climate conditions change.

Scenario 2: Fish at the northern end of the range should be considered as a valuable part of the core population whose overharvest would decrease the reproductive output of the stock.

Scenario 3: The large northern fish do not contribute in a substantial way to the reproductive output of either the north or the core region and can be harvested either as smaller fish in the core region or as larger fish in the northern region. Here the decision is based on local economic considerations, not biology.

Potential Methods of Examining Population Structure and Latitudinal Origin

1. otolith microchemistry
2. otolith stable isotope composition
3. genetics
4. meristics and morphometrics, vertebral counts
5. magnetic tags
6. parasites
7. immunological differences including susceptibility and evidence of pre-exposures to VHSV

Promising Approaches to Defining Stock Structure

No single method was identified that will easily discern stock structure and migration patterns. Tagging methods have improved. To go beyond what was done previously would require an extensive tagging and recovery program. Involvement of processors in the recovery of tags would be required. Vertebral counts vary with water temperature at the time of metamorphosis. This approach should be pursued as a simple method of examining mixed stock landings. Differences in vertebral counts do not indicate stock differences in a genetic sense but may indicate the natal origin of the individual. Genetic methods involving protein enzyme electrophoresis and mitochondrial DNA have yielded basin-wide information (e.g. Chile vs North America) but have not been useful in discriminating between putative stocks within the northwest Pacific (trinational) region. More variable markers, including microsatellite nuclear DNA and perhaps single nucleotide polymorphisms (SNIPS), might yield results and should be tried. Genetic markers will never be applicable for studying the movements of individual fish over their lifetimes. Changes in external water chemistry, temperature, and diet can result in different chemical signatures in fish otoliths. Study of whole otoliths and individual growth rings can potentially shed light on the natal habitat and subsequent movements of individual sardines. Samples of DNA and otoliths should begin to be collected so that DNA and otolith microchemistry studies can be undertaken when research funds become available.

Sampling Strategy for Studying Stock Structure

It was generally agreed that the primary sampling focus should be on core populations where sardines persist even during unfavorable climate conditions. Sampling should also include areas where two stocks might mix (southern California) and areas at the limits of the range (Vancouver).

These areas would be important to confirm results of stock definition, to examine founder effects, and migration. Possible sampling locations would include:

Sea of Cortez

1. Great Island Tiburon
2. Islas Cerralvo near La Paz

Outer Coast Baja California (southern stock)

1. Magdalena Bay
2. Cedros Island
3. Ensenda (knowing sardines may be a mixture of southern and northern stocks)

Alta California:

1. Monterey (pure northern stock)
2. San Diego (mixed)

Oregon and Washington:

1. Columbia River Plume (might have strong microchemistry signal)
2. Existing otoliths from Emmett studies may be available.

B.C. Vancouver:

1. Ricker survey samples and existing otoliths

Sampling Protocols for otolith microchemistry and DNA analyses

Samples with the most ancillary biological and oceanographic information will be most useful for genetic and microchemistry analyses. Otoliths from existing ageing programs in Mexico, US and Canada would be the easiest place to begin microchemistry studies. Fin clips or other tissue samples from the same individuals used for ageing would provide the best DNA samples. Samples for DNA could be taken when otoliths are being removed. A fin clip or piece of tissue should be placed in ethanol for DNA analyses when otoliths are being removed and other life history characters such as length and weight are being recorded.

Occurrence of VHSV in natural populations

Acute viral hemorrhagic septicemia (VHS) appears to be triggered by cold temperature and or other stressors. The occurrence of VHS in the warmer parts of the sardine's range and the susceptibility of southern stocks to the virus causing VHS (VHSV) are unknown. A priority issue is the survey of southern populations for the presence of VHSV and the characterization of the viral strains if discovered.

Sampling Protocols for VHSV Sampling

Sampling for the presence of VHSV requires more stringent conditions than those for DNA or otoliths. Sampling can be done to detect the presence of virus or to preserve the virus in a viable state so that it can be cultured and studied.

Sampling to detect the presence of virus requires a solution that will prevent enzymatic destruction of the viral genome. In particular an RNAase inhibitor must be added to prevent the cleavage of the single stranded viral RNA. When the proper buffer is provided, along with training in finding viral rich tissues such as spleen and kidney and training in the use of disposable dissecting tools to prevent cross contamination, good results can be expected. Juveniles would be most desirable.

Linking to Stock Demographics

It is critical that sampling for population structure and incidence of VHS disease be closely coupled with that needed to characterize the population demographically (age and size structure, growth, and size and age at first maturity). Clearly, if genetic and or otolith microchemistry studies reveal the existence of separate substocks of Pacific sardine, the demography of each substock must be known to deal with this new information in an assessment. Similarly, the epidemiology of sardine VHSV shall be greatly strengthened, and the possible fishing strategies to avoid the disease broadened, if the demography of the substocks is understood.

Scientists from NOAA Fisheries, La Jolla (Russ Vetter), CICESE, Ensenada (Sharon Herzka), CICIMAR-IPN, (Roberto Feliz Urraga) and CRIP-Guaymas-INP (Manuel Nevarez Martinez) will explore preparation of a proposal for joint US-Mexico education funds that would begin studies of microchemistry and genetic differences between Sea of Cortez and outer coast populations.

1. Russ Vetter will consult with new genetics professors at CICESE and with geneticists who have an interest in the genetics of clupeoid fishes, (e.g. Stew Grant, Dennis Hedgecock and Kristy Miller-Saunders), on the most productive approaches for examining the genetics of sardine.
2. Paul Smith will continue to examine vertebral counts (particularly from Cedros Island fishery and San Diego) to see if fish with different thermal birth temperatures occur in the San Diego landings as a possible look at different natal origins for fish landed in the fishery. This does not address the issue of stocks in a genetic sense.
3. Russ Vetter will discuss integration of sampling and archiving protocols with Age Structure and Validation Working Group (K. Hill).
4. Ron Hedrick will stay in touch with sampling efforts of the group in an effort to obtain samples for both live virus (virus isolation) and / or preserved tissues that can be used to detect the virus by PCR analyses.

Fundamental differences in sardine larval abundance by season and geographic location

Whatever the future work regarding stock structure shows, the egg pump (CUFES) has changed our view of this species. In particular, the extensive surveys in the 20's and 30's showed a high abundance of sardine offshore, but by 1938 (and until 1994), it was believed that the major spawning was in the Southern California Bight. If we isolate sardine stock size from the abundance of spawn, we see that the major spawning concentrations in the 1951-2000 period were offshore of Central California, with reduced spawning nearshore in the SCB and along the coast of Baja California in cool water in spring (Mar Apr May Figure 1). In the summer, this historical view places the major concentrations nearshore off Baja California in the vicinity of Sebastian Vizcaino Bay and Magdalena Bay (Figure 2). If incipient subpopulation changes start with isolation, this isolation at spawning time could be important, since the spawners of the imputed northern stock would be feeding in the Pacific Northwest, while the spawning at headlands, bays, and estuaries continues through the summer in extremely warm habitats.

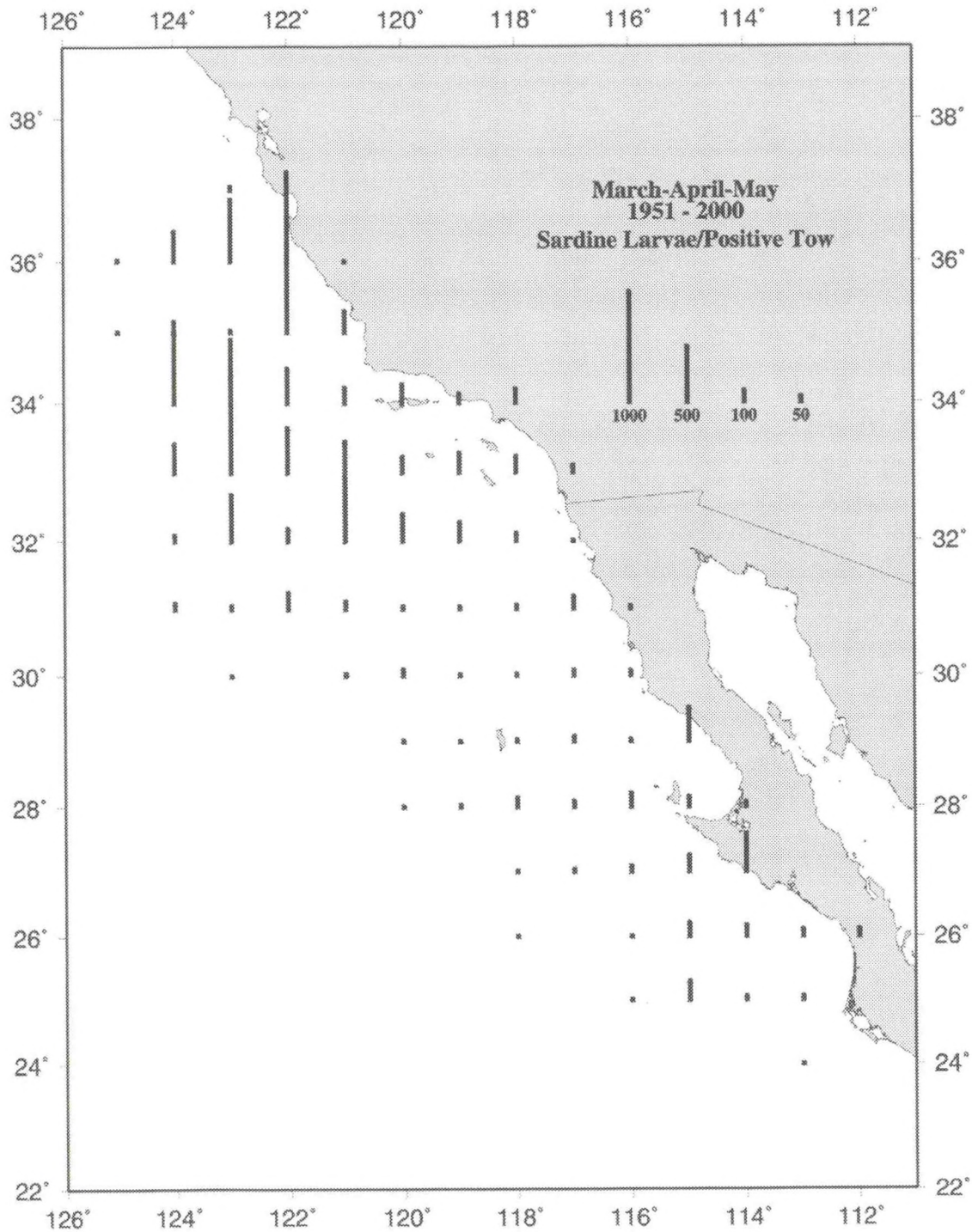


Figure 1. Sardine spawning was detected in 80 one-degree squares in the CalCOFI surveys from March April May of 1951-2000. The height of the bar is proportional to the abundance of sardine larvae of all sizes per positive tow. The presentation is approximately the same as that for the CUFES surveys but represents all depths to 140-200 meters or near the bottom.

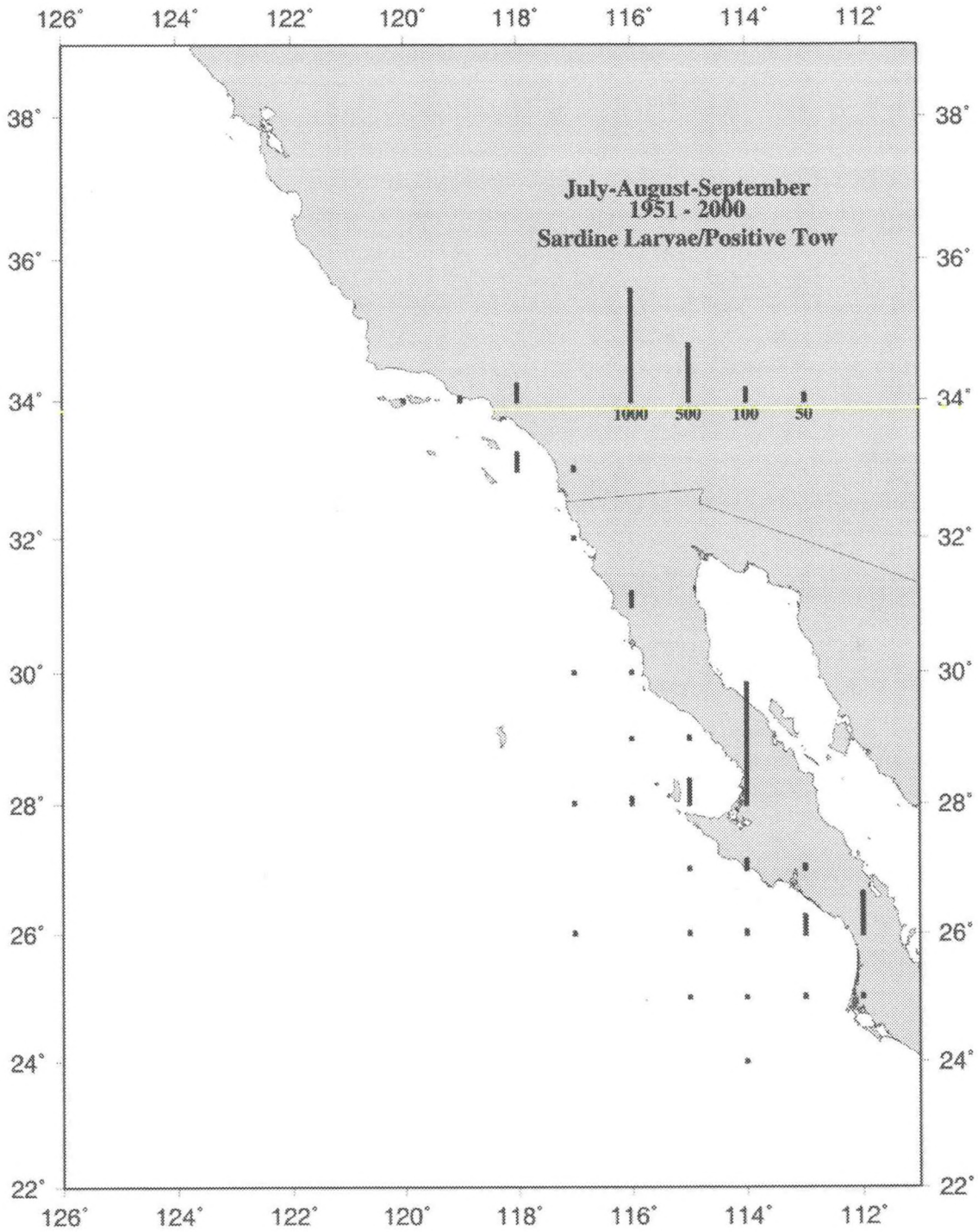


Figure 2. Sardine spawning was detected in 28 one-degree squares in the CalCOFI surveys in July August September of 1951-2000. The height of the bar is proportional to the mean abundance of sardine larvae of all sizes per positive tow. The presentation is approximately the same as that for the CUFES surveys but represents all depths to 140-200 meters or near the bottom.

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APPENDIX I: List of Participants

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San Pedro, CA
December 5-6, 2002

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APPENDIX II: Agenda

2002 TRINATIONAL SARDINE FORUM
Agenda
SOUTHERN CALIFORNIA COMMERCIAL FISHING ASSOCIATION HEADQUARTERS
San Pedro, CA USA
December 5-6, 2002

Thursday, December 5, 2002

8:00 AM	Welcome and Meeting Logistics	Hunter, Baumgartner, Amoroso
REPORTS ON FISHERY STATUS AND LANDINGS		
8:10 AM	Canada	Mijacika
8:25 AM	State of Washington Landings	Robinson/Culver
8:40 AM	State of Oregon Landings	McCrae
8:55 AM	US Sardine Assessment	Hill
9:10 AM	Baja California Landings	Cotero/Garcia
9:25 AM	Gulf of California Landings	Nevarez
9:40 AM	Coffee Break	

FOCUS ISSUE #1: VHS DISEASE

10:00 AM	Review of VHS disease in sardine	Hedrick
10:30 AM	Discussion of VHS disease	Hedrick

FOCUS ISSUE #2: US NORTH/SOUTH SARDINE ALLOCATION

11:15 AM	Options	Herrick
11:30 AM	Discussion	Herrick/Hill
12:00 PM	Lunch Break	

RESEARCH PLANS AND REPORTS

1:30 PM	Review biomass and distribution of sardine NW US	Smith
1:50 PM	US: SWFSC Survey Plans in 2003-2004	Hunter
2:10 PM	Canadian Research Report	McFarlane/Schweigert
2:30 PM	Research Report from Northern Baja California	Baumgartner
2:50 PM	Research Report from Southern Baja California	Felix
3:10 PM	Coffee Break	

FOCUS ISSUE #3: EMERGING ISSUES FOR SARDINE FISHERIES

3:30 PM	Industry Round Table Identifies Issues and Their Priority	Baumgartner (discussion leader)
5:00 PM	Adjourn	

EVENING RECEPTION – IMMEDIATELY FOLLOWING ADJOURNMENT

Hosted by Southern California Commercial Fishing Association & the California Wet Fish Producers Association

2002 TRINATIONAL SARDINE FORUM
Agenda
SOUTHERN CALIFORNIA COMMERCIAL FISHING ASSOCIATION HEADQUARTERS
San Pedro, CA USA
December 5-6, 2002

Friday, December 6, 2002

- 6:00 AM **Optional Field Trip to San Pedro Processing Plant**
- 8:00 AM Light Breakfast provided in meeting room
- 8:30 AM Instructions to Working Groups
- 8:45 AM Working Groups meet
- 10:00 AM **Coffee Break**
- 10:15 AM Working Groups resume meetings
- 12:00 AM **Lunch**
- 1:30 PM Working Groups report back
- 3:30 PM **Coffee Break**
- 3:50 PM Write Key Finds and Recommendations for 2002 Report
- 5:30 PM **Adjourn**

TRINATIONAL WORKING GROUPS

Regional Estimates of Biomass [Lo, Chair]
Stock Structure and Latitudinal Origins (includes genetics and VHS disease) [Vetter, Acting Chair]
Age Structure and Validation [Hill, Chair]

APPENDIX III: Acronyms

BPA	Bonneville Power Administration
CalCOFI	California Cooperative Oceanic Fisheries Investigations
CalVET	CalCOFI vertical egg tow
CANSAR	Catch at age analysis for sardine
CDF&G	California Department of Fish and Game
CICESE	Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, B.C.
CICIMAR-IPN	El Centro de Investigacion Cientifica y de Educacion Superior de Ensenada
CONACYT	National Science and Technology Council
CRIP	Centro Regional de Investigaciones Pesqueras de Quaymas
CTD	Conductivity-Temperature-Density (or depth)
CUFES	Continuous Underway Fish Egg Sampler
DEPM	Daily Egg Production Method
DFO	Department of Fisheries & Oceans, Canada
EPCOR-IAI	Eastern Pacific Consortium of the Inter-American Institute for Global Change Research
IMECOCAL	Investigaciones Mexicanas de la Corriente de California
INP	Instituto Nacional de la Pesca
MOU	Memorandum of Understanding
NMFS	National Marine Fisheries Service
NWFSC	Northwest Fisheries Science Center
ODFW	Oregon Department of Fish and Wildlife
PFMC	Pacific Fishery Management Council
SCCFA	Southern California Commercial Fishing Association
SIO	Scripps Institution of Oceanography
SNIPS	single nucleotide polymorphisms
SWFSC	Southwest Fisheries Science Center
TSF	Trinational Sardine Forum
VHS	viral hemorrhagic septicemia
WDFW	Washington Department of Fish and Wildlife
WG	Working Group

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APPENDIX IV: Contributed Abstracts and Summaries

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Stock Assessment of Pacific Sardine with Management Recommendations for 2003

Executive Summary

by

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Pacific Fishery Management Council
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October 2002

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<http://swfsc.nmfs.noaa.gov/frd/Coastal%20Pelagics/Sardine/sardine1.htm>

Introduction

The following summary presents pertinent results and harvest recommendations from a stock assessment conducted on Pacific sardine (*Sardinops sagax*). It is an update to the stock assessment carried out last year (Conser et al. 2001), and is intended for use by the Pacific Fishery Management Council (PFMC) when developing management goals for the upcoming fishing season for sardine beginning January 2003.

The assessment results presented here are applicable to the sardine population off the North America Pacific coast from Baja California, Mexico to British Columbia, Canada. Research surveys (fishery-independent) have been conducted on an annual basis in the spawning areas off central and southern California. For most of the contemporary time series (1983-98), significant fishing for sardine occurred only off northern Mexico and California (Area 1 or *Inside Area*). As the sardine population rebuilt and expanded its range through the mid-1990's, sardine became more available seasonally off Oregon, Washington, and British Columbia. Subsequently, fisheries in these more northerly areas expanded with significant landings beginning in 2000. As in past assessments, research survey data (fishery-independent) are used to index the size of the sardine spawning biomass; and when coupled in a modelling framework with fishery-dependent data and structural information on sardine biology and migration, provide the stock size estimates and demographics needed by the PFMC to establish harvest guidelines for the USA fisheries.

Methods

An age-structured stock assessment model (CANSAR-TAM, Catch-at-age ANalysis for SARdine - Two Area Model, see Hill et al.1999) was applied to fishery-dependent and fishery-independent data to derive estimates of population abundance and age-specific fishing mortality rates. In 1998, the original CANSAR model (Deriso et al. 1996) was modified to account for the expansion of the population northward to waters off the Pacific northwest. The models are based on a 'forward-simulation' approach, whereby parameters (e.g., population sizes, recruitments, fishing mortality rates, gear selectivities, and catchability coefficients) are estimated after log transformation using the method of nonlinear least squares. The terms in the objective function (to be minimized) included the sum of squared differences in (\log_e) observed and (\log_e) predicted estimates from the catch-at-age and various sources of auxiliary data used for 'tuning' the model, e.g., indices of abundance from research survey data. Bootstrap procedures were used to calculate variance and bias (95% confidence intervals) of sardine biomass and recruitment estimates generated from the assessment model. The CANSAR-TAM model was based on two fisheries (California, U.S. and Ensenada, Mexico) and semesters within a year were used as time steps, with ages being incremented between semesters on July 1 and spawning that was assumed to occur on April 1 (middle of the first semester).

Fishery-dependent data from the California and Ensenada fisheries (1983 to first semester 2002) were used to develop the following time series: (1) catch (in mt)-Table 1 and Figure-1; (2) catch-at-age in numbers of fish; and (3) estimates of weight-at-age. Fishery-independent data (time series) from research surveys included the following indices, which were developed from data collected from Area 1 (*Inside Area*, primarily waters off central and southern California) and used as relative abundance measures (Table 2): (1) index (proportion-positive stations) of sardine egg abundance from California Cooperative Oceanic and Fisheries Investigations (CalCOFI) survey data (*CalCOFI Index*)-Figure 2; (2) index of spawning biomass (mt) based on the Daily Egg Production Method (DEPM) survey data (*DEPM Index*)-Figure 3, see Lo et al. (1996); (3) index of spawning area (Nmi²) from CalCOFI and DEPM survey data (*Spawning Area Index*)-Figure 4, see Barnes et al. (1997); and (4) index of pre-adult biomass (mt) from aerial spotter plane survey data (*Aerial Spotter Index*)-Figure 5, see Lo et al. (1992). Time series of sea-surface temperatures (Figure 6) recorded at Scripps Pier, La Jolla, California were used to determine appropriate harvest guidelines (*Sea-*

surface Temperature Index), see Amendment 8 of the Coastal Pelagic Species Fishery Management Plan, Option J, Table 4.2.5-1, PFMC (1998).

Survey indices of relative abundance were re-estimated using generally similar techniques as was done in previous assessments (Hill et al. 1999; Conser et al. 2000; and Conser et al. 2001). The final model configuration was based on equally 'weighted' indices except for the CalCOFI index, which was downweighted to 0.7 (relative to 1.0 for the other indices). The relative weight used for the CalCOFI index (0.7) was consistent with previous assessments in which the proportion of the total spawning area covered by the CalCOFI surveys (~70%) was used to determine its relative weighting in the model. Further the CalCOFI Index has undergone considerable saturation in recent years due to the higher frequency of positive stations as the sardine stock expanded throughout and beyond the southern California Bight. As in the previous assessment, the CalCOFI index was fit with a non-unity exponent (0.3547) to allow for a nonlinear relationship between the index and sardine spawning biomass. This procedure produced a better fit to these data and a more acceptable residual pattern than assuming the classical linear relationship between the index of abundance and population size. As in the two previous assessments, the Aerial Spotter Index was assumed to primarily track pre-adult fish (ages 0 and 1 plus a portion of age 2 fish). All of the other fishery-independent indices were used as indices of the spawning stock biomass, which can be approximated by the biomass of ages 1+ sardine.

Recognizing that the geographical extent of the sardine population tends to increase as population size increases (inferred largely from tagging data and the expansion of the fishery in the 1930's), the CANSAR-TAM model uses explicit time-varying migration rates to 'move' sardine from the well-sampled Area 1 (roughly Baja California through central California) to the larger, coastwide stock area. Internal consistency checks are done to ensure that reasonable numbers of sardine are present outside Area 1 to account for the catches of the developing fisheries in the Pacific Northwest. In conjunction with this assessment, a sensitivity run was carried out in which (i) the available catch-at-age from Oregon and Washington fisheries (mostly 2000 and 2001) were formally incorporated into the model and (ii) no structural assumptions regarding migration rates were imposed. As the time series of catch-at-age data from the Pacific Northwest fisheries accumulates and fishery-independent data become available from northern areas, the structure of this sensitivity run is likely to become the template for future sardine stock assessments.

Results

Pacific sardine landings for the directed fisheries off California, USA and Ensenada, Mexico decreased from the high levels that were reached during 2000 (109,000 mt), with a total 2002 harvest of roughly 81,000 mt (Table 1, Figure 1); however, note that semester 2 landings in 2002 reflect projected estimates based on landing patterns observed in the fisheries during the mid to late 1990s (Table 1). Both California and Ensenada landings in 2002 are expected to decrease from the 2000 level, with a more notable decrease in the projected Ensenada landings (51,000 mt in 2000, decreasing to 27,000 mt in 2002). Currently, the USA fishery is regulated using a quota (harvest guideline) management scheme and the Mexico fishery (Ensenada landings) is essentially unregulated.

As has been the case in recent years, landings from the USA Pacific sardine fishery (California, Oregon, and Washington) are below the harvest guideline recommended for 2002 (118,000 mt), with roughly 79,000 mt landed through September 2002 and 87,000 mt projected landings for the entire year (the fishing year ends December 31, 2002).

Estimated stock biomass (≥ 1 -year old fish on July 1, 2002) from the assessment conducted this year

indicated the sardine population has remained at a relatively high abundance level, with a bias-corrected estimate of nearly 1.0 million mt (Table 3 and Figure 7). Estimated recruitment (age-0 fish on July 1) during the past four years has declined considerably from that estimated for the strong 1998 year-class (Table 3 and Figure 8). However, it should be noted that recent recruitment (4-22 billion recruits) is not estimated precisely (Figure 8), and another 2-3 years of data may be needed to ascertain whether the sardine population biomass has reached a plateau at the 1.0 million mt level (Figure 7).

Estimates of Pacific sardine biomass from the 1930's (Murphy 1966 and MacCall 1979) indicate that the sardine population may have been more than three times its current size prior to the population decline and eventual collapse in the 1960's (Figure 9). Considering the historical perspective, it would appear that the sardine population, under the right conditions, may still have growth potential beyond its present size. However, per capita recruitment estimates show a downward trend in recruits per spawner in recent years that may be indicative of a stock that has reached a plateau under current environmental conditions (Conser et al. 2001).

The estimate of 2002 stock biomass from the sensitivity run (in which available catch-at-age from Oregon and Washington fisheries were formally incorporated into the model and no structural assumptions regarding migration rates were imposed) was virtually identical to the corresponding estimate from the baseline assessment model, described above (Figure 10). Most annual biomass estimates from the sensitivity run fell within the 95% confidence interval from the baseline assessment (with notable exceptions in 1998 and 1999). However, biomass estimates from the sensitivity run were systematically smaller than those from the baseline during the (recent) years of rapid stock size increase. This may be indicative of a rapidly growing and expanding stock coupled with a lag in the development of fisheries in the northern area to 'sample' the sardine in that area. Overall, confidence intervals on stock biomass from the sensitivity run were much broader than those from the baseline and some parameters were poorly estimated (e.g. selectivity for the northern fishery). It is reasonable to expect the performance of this model configuration to improve as the time series of catch-at-age data from the Pacific Northwest fisheries accumulates and fishery-independent data become available for northern areas.

Harvest Guideline for 2003

The harvest guideline recommended for the U.S. (California, Oregon, and Washington) Pacific sardine fishery for 2003 is 110,908 mt. Statistics used to determine this harvest guideline are discussed below and presented in Table 4. To calculate the proposed harvest guideline for 2003, we used the maximum sustainable yield (MSY) control rule defined in Amendment 8 of the Coastal Pelagic Species-Fishery Management Plan, Option J, Table 4.2.5-1, PFMC (1998). This formula is intended to prevent Pacific sardine from being overfished and maintain relatively high and consistent catch levels over a long-term horizon. The Amendment 8 harvest formula for sardine is:

$$HG_{2003} = (\text{TOTAL STOCK BIOMASS}_{2002} - \text{CUTOFF}) \cdot \text{FRACTION} \cdot \text{U.S. DISTRIBUTION},$$

where HG_{2003} is the total U.S. (California, Oregon, and Washington) harvest guideline recommended for 2003, $\text{TOTAL STOCK BIOMASS}_{2002}$ is the estimated stock biomass (ages 1+) from the current assessment conducted in 2002 (see above), CUTOFF is the lowest level of estimated biomass at which harvest is allowed, FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries (see below), and U.S. DISTRIBUTION is the percentage of $\text{TOTAL STOCK BIOMASS}_{2002}$ in U.S. waters.

The value for FRACTION in the MSY control rule for Pacific sardine is a proxy for F_{msy} (i.e., the fishing mortality rate that achieves equilibrium MSY). Given F_{msy} and the productivity of the sardine stock have been shown to increase when relatively warm-water ocean conditions persist, the following formula has been used to determine an appropriate (sustainable) 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 years. Ultimately, under Option J (PFMC 1998), F_{msy} is constrained and ranges between 5% and 15% (Figure 11).

Based on the T values observed throughout the period covered by this stock assessment (1983-2002), the appropriate F_{msy} exploitation fraction has consistently been 15% (see Figures 6 and 11); and this remains the case under current oceanic conditions ($T_{2002} = 17.3$ °C). However, it should be noted that the decline in sea-surface temperature observed in recent years (1998-2002) may invoke environmentally-based reductions in the exploitation fraction as early as next year (i.e. in setting the harvest guideline for the 2004 fishing season) – see Figure 11.

Although the 2003 USA harvest guideline (110,908 mt) is less than the 2002 level (118,442 mt), recent fishery practices indicate that it may not be constraining with regard to USA fishery landings in 2003 (Figure 12). However, should the recent declining recruitment trend estimated in this assessment be confirmed with future work, and should the sea-surface temperature decline, it is likely that harvest guidelines in the out years will constrain USA fishery practices and removals.

Further when viewed on a stock-wide basis and considering the landings of Mexico and Canada as well as the USA, adherence to an implied 'stock-wide harvest guideline' may constrain fisheries even without sea-surface temperature declines. Figure 13 compares recent international landings with the annual harvest guidelines that would have resulted from applying the PFMC CPS FMP harvest formula (above) absent the "U.S. Distribution" term. Should Oregon and Washington landings continue to increase (at rates comparable to the past few years) and/or Mexican landings return to their 1999-2000 levels, the implied stock-wide harvest guideline may be exceeded as early as next year (2003).

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Table 1. Pacific sardine time series of landings (mt) by semester (1 is January-June and 2 is July-December) in California and Baja California (Ensenada), 1983-2002. Semester 2 (2002) estimates are projections.

Year	CALIFORNIA			ENSENADA			Grand Total
	Semester 1	Semester 2	Total	Semester 1	Semester 2	Total	
83	245	244	489	150	124	274	762
84	188	187	375	<1	<1	0	375
85	330	335	665	3,174	548	3,722	4,388
86	804	483	1,287	99	143	243	1,529
87	1,625	1,296	2,921	975	1,457	2,432	5,352
88	2,516	1,611	4,128	620	1,415	2,035	6,163
89	2,161	1,561	3,722	461	5,763	6,224	9,947
90	2,272	1,033	3,305	5,900	5,475	11,375	14,681
91	5,680	3,354	9,034	9,271	22,121	31,392	40,426
92	8,021	13,216	21,238	3,327	31,242	34,568	55,806
93	12,953	4,889	17,842	18,649	13,396	32,045	49,887
94	9,040	5,010	14,050	5,712	15,165	20,877	34,927
95	29,565	13,925	43,490	18,227	17,169	35,396	78,886
96	17,896	18,161	36,057	15,666	23,399	39,065	75,121
97	11,865	34,331	46,196	13,499	54,941	68,439	114,636
98	21,841	19,215	41,055	20,239	27,573	47,812	88,868
99	31,791	24,956	56,747	34,760	23,810	58,569	115,316
00	35,174	22,761	57,935	25,800	25,373	51,173	109,108
01	30,118	24,785	54,903	9,307	12,939	22,246	77,149
02	28,079	25,624	53,703	14,453	12,969	27,422	81,125

Table 2. Pacific sardine time series of survey indices of relative abundance and sea-surface temperature, 1983-02.

Year	CalCOFI (% positive)	DEPM (mt)	Spawning area (Nmi ²)	Spotter plane (mt)	Sea-surface temperature (C)
83	na	na	40	na	17.25
84	4.9	na	480	na	17.58
85	3.8	na	760	na	17.80
86	1.9	7,659	1,260	22,049	17.87
87	4.0	15,704	2,120	11,498	17.71
88	7.9	13,526	3,120	55,882	17.55
89	7.2	na	3,720	32,929	17.24
90	3.7	na	1,760	21,144	17.19
91	16.7	na	5,550	40,571	17.35
92	8.8	na	9,697	49,065	17.61
93	6.1	na	7,685	84,070	17.84
94	17.8	127,096	24,539	211,293	17.97
95	13.4	na	23,816	188,924	18.04
96	28.0	83,175	25,890	119,731	18.06
97	27.3	409,585	40,591	66,943	18.06
98	24.3	313,985	33,446	118,492	18.44
99	16.7	282,236	55,171	40,506	18.04
00	7.8	1,063,845	32,784	48,373	17.73
01	12.5	790,958	31,663	na	17.24
02	7.1	206,323	61,753	na	17.31

Table 3. Pacific sardine time series of stock biomass (age 1+ fish in mt) and recruitment (age 0 fish in 1,000s) estimated at the beginning of semester 2 of each year. Stock biomass estimates are presented for Area 1 (Inside) and the Total Area of the stock. The 95% CIs for Total Area biomass and recruitment estimates are also presented.

Year	Stock biomass				Recruitment		
	Area 1	Total Area	Lower CI	Upper CI	Total Area	Lower CI	Upper CI
83	5,145	5,145	2,988	10,237	149,689	89,658	270,675
84	13,409	13,473	9,132	23,233	224,302	147,543	392,307
85	21,173	21,675	15,754	36,295	217,919	147,483	370,813
86	29,917	31,546	24,369	49,475	866,710	623,621	1,366,185
87	73,715	77,313	60,204	115,178	839,143	605,890	1,256,424
88	107,013	116,721	95,152	162,348	1,465,991	1,032,887	2,389,804
89	162,381	181,604	148,898	254,547	1,157,082	791,458	1,975,840
90	176,794	210,440	173,500	301,142	4,792,851	3,130,855	8,333,861
91	226,334	263,632	203,648	413,259	5,889,816	3,719,993	10,548,967
92	353,005	421,519	323,045	659,025	4,170,058	2,597,005	7,521,409
93	335,486	447,224	344,253	681,348	9,244,272	6,537,849	15,455,594
94	494,524	654,337	535,996	955,097	10,755,601	7,664,169	17,160,261
95	508,294	726,690	598,227	1,029,945	6,607,815	4,604,385	10,396,623
96	531,651	791,496	667,663	1,094,850	5,550,420	4,069,965	8,823,371
97	482,595	770,613	659,886	1,030,390	9,424,984	6,870,295	14,799,898
98	457,126	775,882	668,011	1,056,753	15,082,296	10,943,898	23,682,041
99	610,828	992,323	833,745	1,384,818	8,217,217	5,254,279	14,563,581
00	586,710	1,000,871	827,203	1,404,431	9,386,310	5,567,436	17,800,084
01	510,877	928,578	728,391	1,405,681	10,773,256	5,945,732	22,997,633
02	570,306	999,871	704,161	1,668,985	8,362,928	3,677,163	21,765,966

Table 4. Proposed harvest guideline for Pacific sardine for the 2003 fishing season. See Harvest Guideline for 2003 section for methods used to derive harvest guideline.

Total stock biomass (mt)	Cutoff (mt)	Fraction (%)	U.S. Distribution (%)	Harvest guideline (mt)
999,871	150,000	15%	87%	110,908

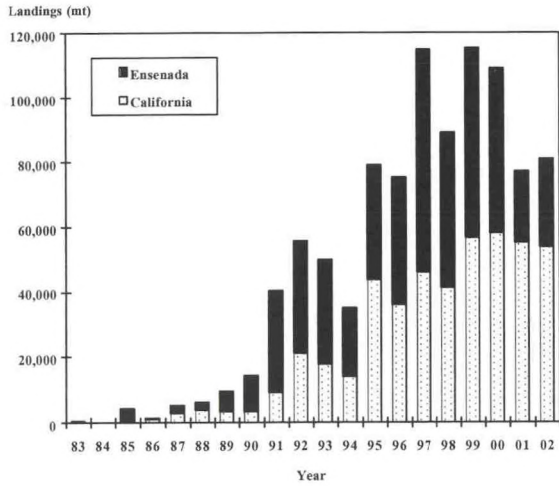


Figure 1. Pacific sardine landings (mt) in California and Baja California (Ensenada), 1983-02.

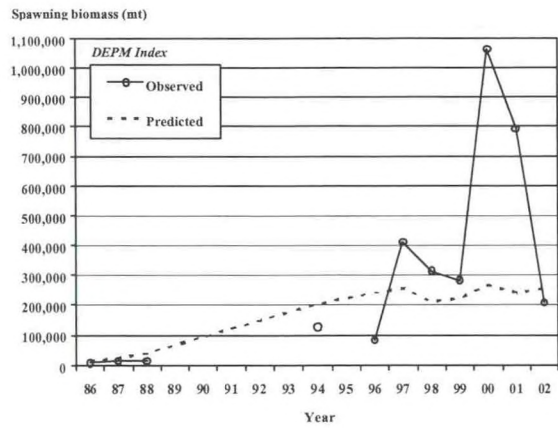


Figure 3. Index of relative abundance of Pacific sardine spawning biomass (mt) off California based on daily egg production method (DEPM) estimates from ichthyoplankton survey data (1986-02). Note that no sample data (Observed estimates) were available for years 1989-93 and 1995.

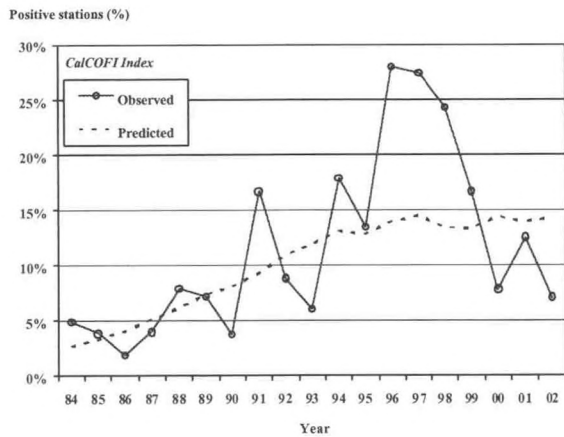


Figure 2. Index of relative abundance of Pacific sardine eggs (proportion-positive stations) off California based on CalCOFI bongo-net survey (1984-02).

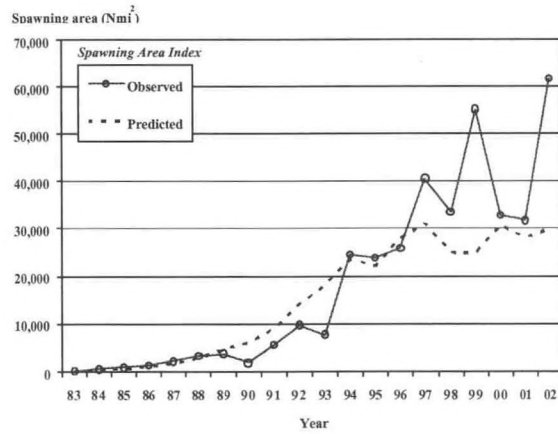


Figure 4. Index of relative abundance of Pacific sardine spawning stock size based on estimates of spawning area (Nmi^2) calculated from CalCOFI and DEPM survey data (1983-02).

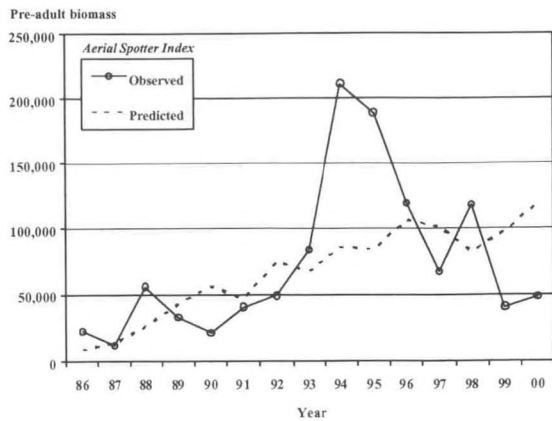


Figure 5. Index of relative abundance of Pacific sardine pre-adult biomass (primarily age 0-2 fish in mt) off California based on aerial spotter plane survey data (1986-00). Note that no sample data were available for 2001-02.

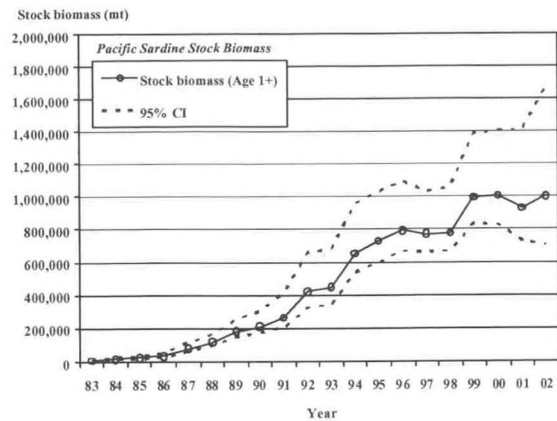


Figure 7. Time series (1983-02) of Pacific sardine stock biomass (age 1+ fish on July 1 of each year in mt) estimated from an age-structured stock assessment model (CANSAR-TAM, see Hill et al. 1999).

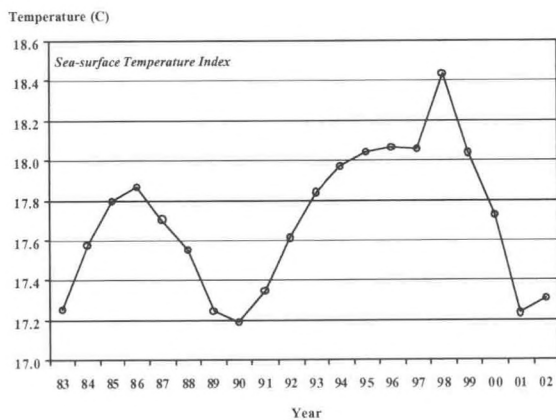


Figure 6. Time series of sea-surface temperature (C) recorded at Scripps Pier, La Jolla, CA (1983-02). Annual estimates reflect 3-year 'running' averages, see Jacobson and MacCall (1995).

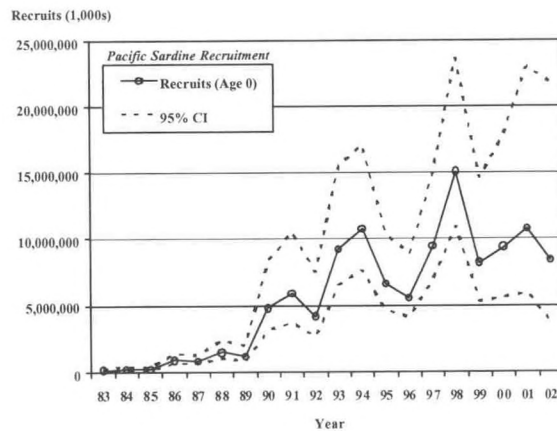


Figure 8. Time series (1983-02) of Pacific sardine recruitment (0-yr old fish on July 1 of each year in 1,000s) estimated from an age-structured stock assessment model (CANSAR-TAM, see Hill et al. 1999).

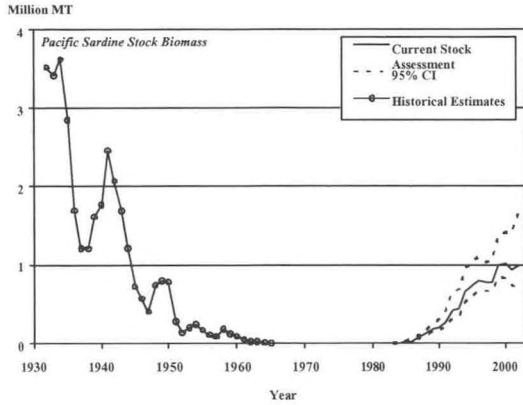


Figure 9. Time series (1983-2002) of Pacific sardine stock biomass (age 1+ fish on July 1 of each year in million mt) and associated 95% confidence intervals estimated in the current stock assessment (cf. Figure 7); and historical stock biomass estimates (1932-65) from Murphy (1966). Confidence intervals or other measures of precision are not available for the historical estimates. No stock assessment-based estimates are available for the period 1966-82. The sardine fishery was closed during much of this period and biomass was at very low levels.

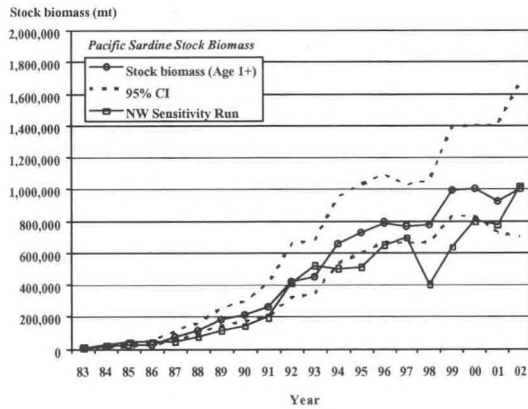


Figure 10. Time series (1983-02) of Pacific sardine stock biomass (age 1+ fish on July 1 of each year in mt) and 95% confidence intervals from this stock assessment (cf. Figure 7); and the stock biomass estimates from a sensitivity run using the NW fisheries data (Oregon and Washington) during 1999-2002. See text for details regarding the sensitivity run.

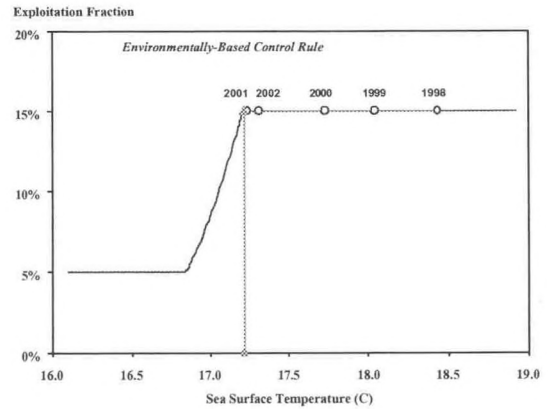


Figure 11. Environmentally-based harvest rate control rule for Pacific sardine as specified in the Coastal Pelagic Species Fishery Management Plan (PFMC 1998). For any given year, sea surface temperature (X-axis) is the running average sea surface temperature at Scripps Pier (La Jolla, CA) during the three preceding years. The exploitation fraction (Y-axis), which can range between 5-15%, is an explicit part of the algorithm used to determine the annual harvest guideline (quota) for the coastwide U.S. fishery – see Table 4. Open circles illustrate the sea surface temperature and exploitation fraction for recent years (1998-2002).

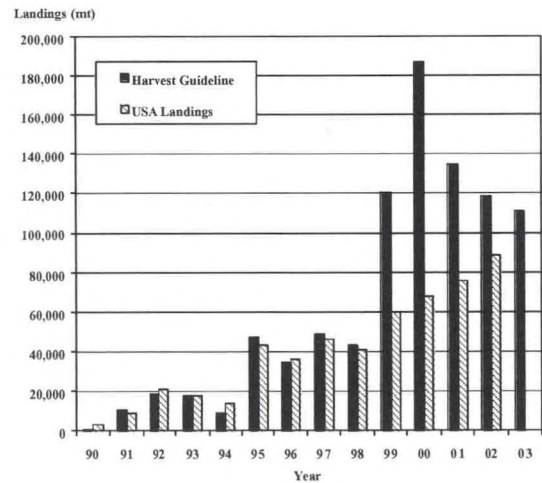


Figure 12. Time series (1990-03) of Pacific sardine harvest guidelines ('quotas') and actual USA landings (mt). State-based (California) regulations were in place for 1990-99, with federal-based (California, Oregon, and Washington) regulations beginning in 2000. Note that landings in 2002 represent an estimate projected through the end of the year. The 2003 harvest guideline is based on the 2002 stock biomass estimated in this assessment (Figure 7).

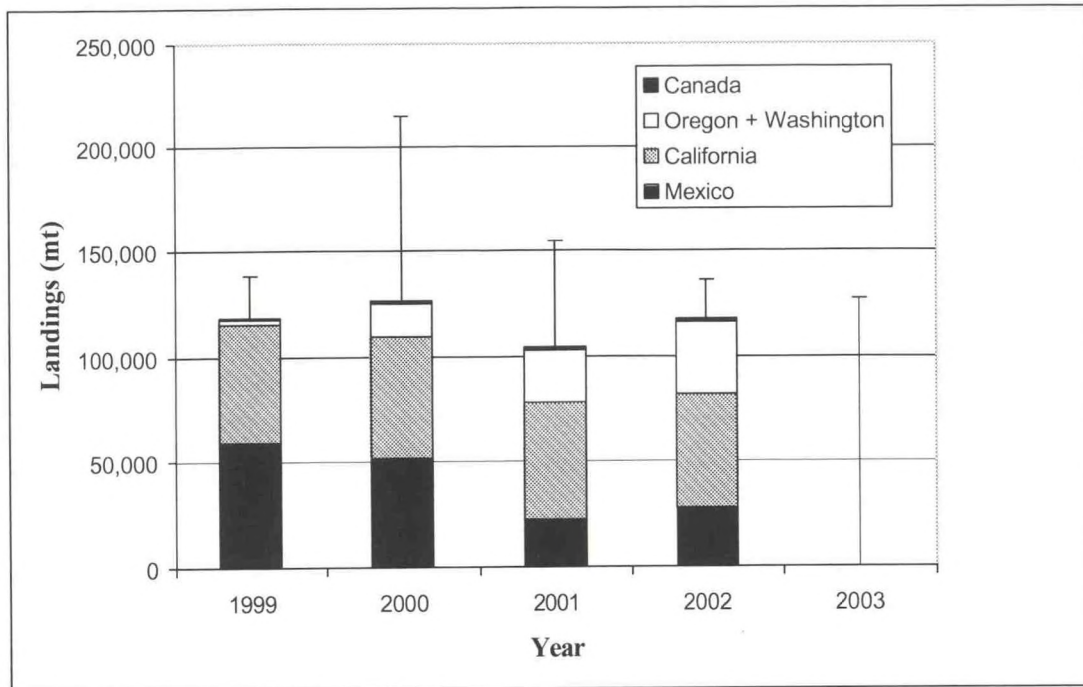


Figure 13. Pacific sardine landings (mt) from Mexico (Ensenada); California; Oregon and Washington; and Canada during 1999-2002. Landings shown for 2002 are estimates projected through the end of the calendar year. The thin bars illustrate the annual harvest guidelines that would have resulted from applying the PFM C CPS FMP harvest formula (see Table 4 and related text) on a stock-wide basis, i.e. applying the harvest guideline formula absent the “U.S. Distribution” term.

Biological and Political Implications of the Detection of Viral Hemorrhagic Septicemia Virus (VHSV) in California Sardines

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Viral hemorrhagic septicemia virus (VHSV) was isolated from populations of Pacific sardines (*Sardinops sagax*) from the coastal waters of Vancouver Island, British Columbia, Canada and most recently from central and southern California, USA. Mortality and evidence of skin lesions typical for viral hemorrhagic septicemia in other marine fish species were observed among sardines in Canada but sardines from California showed no signs of infection. Estimates of the prevalence of infection among apparently healthy sardines ranged from 4–8% at locations where virus was found in California. The prevalence of infection was 58% among sardines in Canada suffering a naturally occurring epidemic in 1998-1999. The greater prevalence and severity of disease due to VHSV among sardines in Canada presumably resulted from water temperatures of 8-9°C that were favorable for virus replication but at the lower range of tolerance for Pacific sardines. The new VHSV isolates were closely related in comparisons of the nucleotide sequence of a 669 nt segment of their glycoprotein (G) gene and all belong to the North American genotype/group of VHSV. The VHSV isolates from sardines in Canada and

California were the most closely related strains of VHSV known in this group of VHSV and differed from isolates obtained from other marine fish species and salmonids found in British Columbia, Canada. Finding isolates with identical nucleotide sequences in sardines from two distant geographic areas may suggest that populations of sardines, most of which originate in the coastal waters of California, carry the virus upon migration to or from more northern waters (e.g. Canada). Two trials were conducted to investigate the role of freezing, either as individual fish or in the commercial process in 40 – 50 lb blocks, on virus stability. Virus concentrations among experimentally infected sardines before and after freezing were determined for individually marked sardines. In the first laboratory freezing trial at -20°C , there was little reduction of virus concentrations in the kidney and spleen of individual fish after freezing and thawing. In the second trial designed to reproduce the commercial freezing process (also at -20°C), more significant reductions occurred among 11 fish with virus concentrations before freezing. Virus concentrations declined from 59 – 100% after a single freeze and thaw cycle. Virus known to be present in 3 fish before freezing could not be recovered after the freezing process. The initial commercial freezing trial demonstrates clearly that virus concentrations are significantly reduced by processing but not entirely eliminated. With healthy appearing sardines that make up the bulk of the bait fishery, the prevalence of infection and virus concentrations are low. In these cases the freezing process should significantly reduce, although not entirely eliminate, the risk of movements of virus with commercially frozen product.