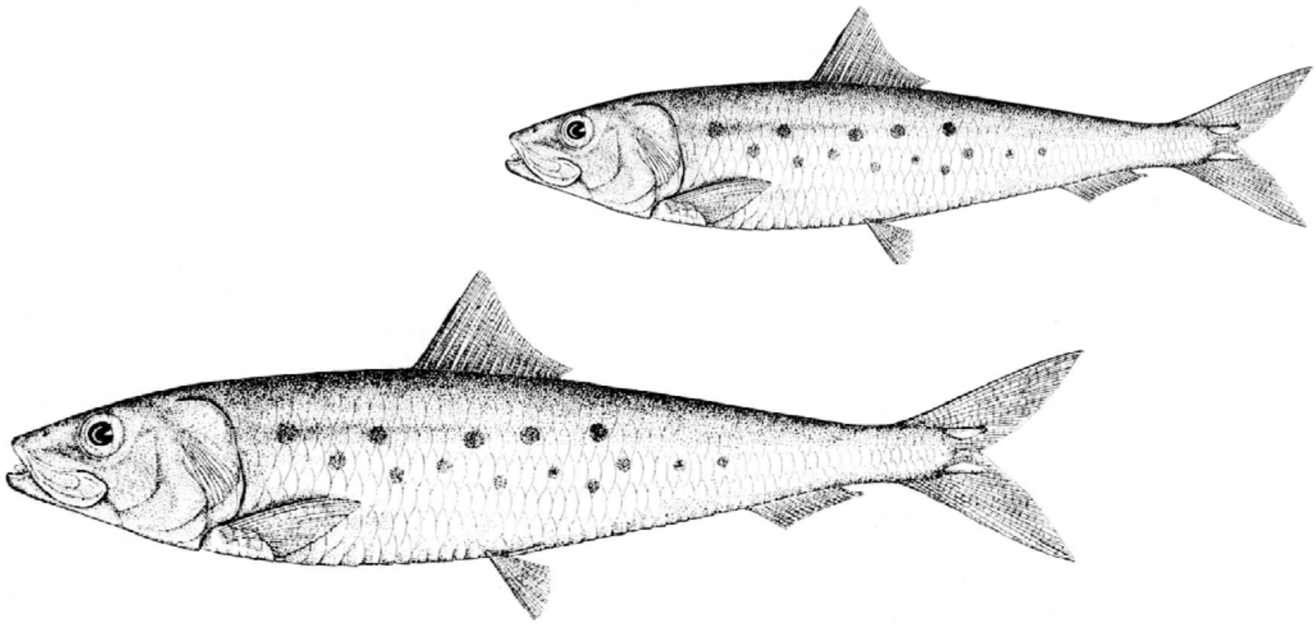

Proceedings of the 2008 Tri-National Sardine Forum

Astoria, Oregon, United States of America
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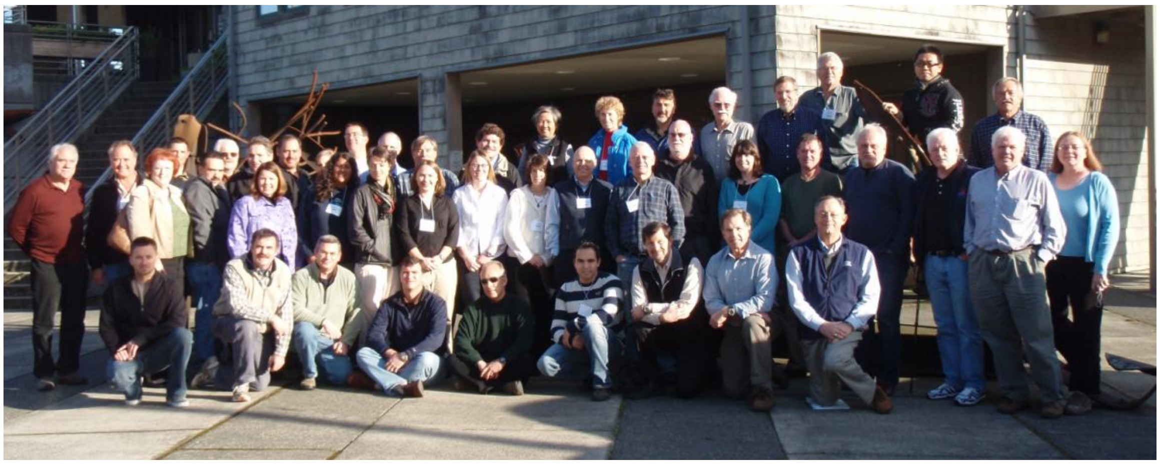

Participants of the 2008 Tri-National Sardine Forum held at the Astoria Seafood Consumer Center, Astoria, Oregon, United States of America

Contents

Introduction

The 9th Annual Trinational Sardine Forum (TSF) was held at the Astoria Consumer Seafood Center, Astoria, OR on December 3 and 4, 2008. Approximately 65 participants attended, representing the fishing industry, scientists, governments, and academia from Canada, México, and the United States (Appendix I). The agenda (in English) is presented in Appendix II. Special thanks to those individuals who helped with local logistics, particularly Jill Smith of Oregon Fish and Wildlife and Mike Okoniewski of Pacific Seafoods who provided support for the banquet.

Dr. John W. Ferguson, Director of the Fish Ecology Division of the Northwest Fisheries Science Center, National Marine Fisheries Service (NMFS) delivered the opening remarks following a welcome statement from Dr. Robert Emmett, Co-Chair of the Forum. Dr. Ferguson noted that it was highly appropriate for the Forum to be meeting in Astoria, Oregon. The fishing industry has a long history in Astoria, and has been an economic backbone for the community. During the 1940's many of Astoria's fishermen and canneries were involved with sardines.

After Dr. Ferguson's remarks, the participants were treated to a very engaging key note address provide by Dr. Alec MacCall, NOAA Fisheries, Santa Cruz, CA. Dr. MacCall has been involved with sardine management/biological issues since the beginning of his career. He was directly involved in the 1978 Northern Anchovy Fishery Management Plan – the first Management Plan for any fishery developed at the Federal level. It is now been updated and called the Coastal Pelagic Species Fishery Management Plan.

Dr. MacCall's lecture was on "Elements to Consider in Sardine Management". He note that the sardine fishery is being managed fairly well in the California Current (CC) ecosystem, given that, of four recent and equivalent sardine fisheries (others are Japan, Peru-Chile, and South Africa), it is the only one that has not collapsed. While there is pressure to re-think sardine management. The CC sardine population has some very some important features to consider. First, is that sardine fisheries are inherently not sustainable, this is clear observed by noting the California paleosedimentary record, which showes that in an unfished condition, the average productive population period is lognormally distributed with a mean length of 72 years. Absences of sardines are exponentially distributed with a 53% chance of recovery per decade. As such, any management strategy must attempt to maintain a "seed stock" to initiate recovery at the end of unfavorable periods.

Dr. MacCall also noted that we are beginning to gain some understanding of mechanisms governing sardine productivity, including CC flow strength, latitude of source water, temperature in the northern feeding area, and curl-driven offshore upwelling. These are large-scale features, and proxy indicators do not need to be measured locally. Maintenance of age structure is vitally important because of probable migrational imprinting behavior, and because older sardines are disproportionately more fecund. Spawning biomass may be a dangerously misleading measure of reproductive potential and should be abandoned in favor of population egg production potential. He also noted that it is possible that sardine reproductive rates may have decreased somewhat in recent years. If the fishery were exploited at high intensities similar to elsewhere in the world, we would most likely be seeing the end of a large sardine biomass about now. However, under the present low exploitation rate, there is still a healthy abundance of fish and good age structure that can be expected to sustain continued productivity unless environmental conditions change in the extreme.

Followed Dr. MacCall's key note presentation, the Forum moved into "Regional Sardine Fisheries Reports" and then to "Research Plans and Reports," which included all contributed papers (Appendix III). Most of the scientific presentations were oriented toward documenting patterns in the regional fisheries and understanding the reproductive capabilities, migratory patterns, stock structure, and the impact of oceanographic and economic conditions on Pacific sardine populations. Following these "Reports" three working groups held consecutive sessions to facilitate the participation of all attendees in each working group. Four posters were also displayed at the meeting hall for the duration of the Forum (Appendix IV).

The TSF Executive Committee represents all three countries: Nancy Lo (United States), Sharon Herzka (Mexico), Robert Emmett (United States) and Jake Schweigert (Canada). The Committee members take turns organizing and hosting the meeting. The 2009 Forum with be the 10th Annual Trinational Sardine Forum and will be hosted by Dr. Rubén Rodriguez-Sanchez, and be held in the Galéon Room, Hotel Marina, La Paz, Baja California Sur, Mexico (November 17-18, 2009). The theme of 2009 Trinational Sardine Forum is "Mechanisms of variation of sardine abundance in the California Current system". Dr. Daniel Lluch-Belda will give the opening speech on "Reexamining an old hypothesis".

A Sardine Workshop entitled "Determining the role of Pacific sardine in the California Current system" will follow the Trinational Sardine Forum (November 19-20, 2009). The Workshop, convened by Jake Schweigert and Sandy McFarlane of the Department of Fisheries and Oceans, Canada, will focus on the development of a tropho-dynamic model to enable the prediction of future changes in abundance and distribution of Pacific sardine in the California Current system. It will be held in the Multimedia Room, Centro Interdisciplinario de Ciencias Marinas (CICIMAR) - Instituto Politécnico Nacional, La Paz, Baja California Sur, Mexico.

Plenary Session Highlights

Regional Sardine Fisheries Reports

Moderator: Robert Emmett

MÉXICO

Gulf of California—Unfortunately no one representing the sardine fishery in the Gulf of California was able to attend.

Bahía Magdelela—Presented by Kevin Hill (NOAA, SWFSC) for Felipe Neri Melo-Barrera, Roberto Félix-Uraga, and Casimiro Quiñonez-Velázquez (Centro Interdisciplinario de Ciencias Marinas,CICIMAR) who were unable to attend.

In 2008, approximately 35,000 MT of Pacific sardine were landed in Bahía Magdelela from about 575 fishing trip. This is down from 50,000 MT landed in 2007 and lowest catch for all years since 2000. In 2007, most catches of sardine and other pelagic fishes occur during summer, from May through September, with sardine composing nearly all the catch (98.7%).   The sardines averaged approximately 155 mm SL in 2007 and were comprised primarily of 1-year-old fishes. However, five age-classes were found (0- to 4-year-olds).   Most sardines caught in 2007 were either immature, post-spawning, or developing. Spawning sardines were observed primarily in January-February, June, and December. From January through October 2008, approximately 34,000 MT of sardines were caught in Bahía Magdelela. This comprised 78% of the pelagic fish catches in the bay. They average about 170 mm SL, much large than in 2007, and were compose of primarily 1- and 2-year-old fishes, equally. Spawning individuals were captured from January through July. A majority of sardine were in spawning condition in March 2008.

***Ensenada (N Baja)*—**Unfortunately no one representing the sardine fishery in Ensenada was able to attend.

UNITED STATES

***California*—**Presented by Dale Sweetnam, Bill Miller, Sonia Torres, Leeanne Laughlin **(**CDFG).

The volume of sardine landed in the early half of the last century in California was unlike any other fishery in North America at that time or since. This was the heyday of Monterey canneries for sardine. When Stienbeck wrote about rivers of silver pouring into Monterey canneries, he was talking about sardine. The peak sardine landings in California occurred in 1936 with 635,000 MT that year, and then declined rapidly in the mid 40s. The decline prompted the formation of a joint venture between state, federal agencies and academia in 1949. The purpose of the joint venture was to study the sardine and identify the potential causes of its collapse. Although it wasn't called that then, this was the beginning of California Cooperative Oceanic Fisheries Investigation. What followed next was a 30-40 year period of virtually non-existent sardine landings, and a correspondingly low sardine biomass.

Beginning in the 90s, sardines landings increased as the population recovered. However, sardine biomass today is not like what it was estimated to be in the 30s. Studies of scale deposits in the Santa Barbara basin suggest that the collapse of the sardine population in the 30s was not unlike events that occurred in the past. Baumgarter et al, reconstructed a history of sardine and anchovy biomass back nearly 2 millennia and found that anchovies and sardines experienced major fluctuations with a period of about 60 years. The authors cautioned that the causes and mechanisms of fluctuations may be different for each event and between species.

Pacific sardines are actively managed by NOAA Fisheries in California. In California waters south of Point Arena it is managed as a Limited Entry (LE) Fishery. In northern California, Oregon,and Washington it is managed as an open access fishery and managed by Oregon and Washington for their state waters. The Coastal Pelagic Species (CPS) LE fleet currently consists of 65 permits and 61 vessels.

In California the fishery can be broken into two parts: the northern fishery consisting mainly of ports around the Monterey area, namely Moss Landing and Monterey. However there are several other ports that sardine are landed, such as Half Moon Bay, San Francisco, and Santa Cruz. There have also been small landings in Eureka in the open access fishery.

The southern fishery is mainly southern California with the major port of San Pedro, Terminal Island, and Port Hueneme. There are also landings in Ventura, Long Beach, San Diego, and Playa del Rey.

The major gear type used in the California sardine fishery is purse seine gear. There was a transition from lampara nets to regular purse seine gear in the 1990s as the fishery took off, and there has been a constant increase in the use of drums for the easier deployment and retrival of the purse gear. In 2008, roughly 40% of the vessels were using drum seines. It also requires fewer deckhands to operate.

In September the Stock Assessment Review (STAR) Panel reviewed the Sardine Stock Assessment and approved the Stock Synthesis 2 (SS2) model. On 11/10/07 the Pacific Fishery Management Council (PFMC) approved the 2008 Harvest Guideline (HG) and 89k MT was allocated coast-wide in three periods with 10% set aside for other CPS fisheries that take sardine once directed allocation is reached and an incidental allowance of 20% once the directed fishery is closed. The 2008 HG of 89,093 mt was a 42% decline from the 2007 HG. For the past 8 years, the total landings from Washington, Oregon and California did not approach the HG. However, in 2008 the fishery appeared to hit the HG fishery will be closed at that time.

In 2006, 46,672 MT of Pacific sardine, with an ex-vessel value of more than $5.0 million, was landed in California. This represented a 26% increase in commercial sardine landings over 2005 (34,479 MT). In California, commercial sardine landings averaged 45,471 MT over the ten-year period from 1996–2006.

California exported a total of 38,543 MT of sardine product to 22 countries in 2006. Most of this product was exported to Australia (21,335 t), Japan (6,023 t), Croatia (3,213 t), and Thailand (2,331 t). These amounts represent over 81% of the total export value of over $21.6 million.

In 2007 the port with the majority of landings in California was Moss Landing with 43%. The Los Angeles ports of San Pedro and Terminal Island accounted for 53% of the landings. Port Heuneme was 4th place at 4%. For the first time, no landings in Monterey.

In 2008, similar to previous years, the majority of California'catch was landed in Los Angeles (26,836.1 MT) and Monterey (17,748.1MT) port areas. Overall highest catches in 2008 were in July (17,475 MT), with most coming from the northern fishery. Highest catches for the southern fishery occurred in March (8,230 MT), which is typically when the southern area catches most of their sardines.

In summary, California sardine landings declined 29% from peak 2007 landings; but increased 20% from 1998-2006 average (47,939 MT). The behavior of fishery changed between allocation periods. The number of landings/day increased between allocation periods, with small significant increase in size of landing. Total incidental landings after the directed fishery was closed on 9/23/08 (as of 12/1/2008) were 7.4 MT. The total catch for live bait (as of 11/1/2008) was 2,734 MT.

Oregon—Presented by Jill Smith (ODFW)

The Oregon fishery is a day fishery only. Fishing boats/processors are primarily based out of the Astoria area. ODFW monitors this fishery very closely – primarily daily. There are eight processors and 26 permit holders. Tides and weather are a major factor. The local Columbia River Bar Pilots assist the fishery by providing information regarding sea conditions and other information.

The Oregon sardine fishery began in 1999 with landings of 775 tons and quickly rose to 45,110 MT in 2005. Harvest remained high in 2006 and 2007, with 35,648 and 42,143 MT landed, respectively. In 2008, landings were only 22,949 MT.

Sardine landing in 2008 occurred only during the 2'nd and 3'rd allocation period (1 July-Dec31). There were 22 boats that fished sardines in 2008. Most sardine landings, 16,165 MT came in during the 2'nd period (1 July-September 14). A typical landing averaged 44 MT.

In 2007, landed sardines in Oregon were 197 mm SL and weighed 111 g, a few sardines >250 mm SL and weighing >250 g. In 2008, sardine average 199 mm SL and 125 g.

From the Oregon Logbook Data, it is appears that most of the sardines landed in 2008 in Oregon came from the area just off the mouth of the Columbia River (directly off and north and south). There were also quite a few relative large sets of sardines made off Grays Harbor, WA.

Washington—Presented by Jill Smith (ODFW) for WDF because they could not send a representative.

There are two primary ports for sardine landings in Washington – Westport in Grays Harbor and Ilwaco at the mouth of the Columbia River. Presently the number of permits is limited and there were 16 eligible permits in 2008.

Total annual catch has fluctuated from a low of 4,363 MT in 2006 to a high of 15,212 MT in 2002 to. In 2008, 6,432 MT of sardines were landed in Washington. Most of this catch came from just three vessels.

Similar to Oregon, sardine landings in Washington in 2008 were highest during the 2'nd period (4,218 MT) and 3'rd periods (2,214 MT). There were no landings during the first period. August continues to be the peak month of landings. Second highest month has gone back and forth between July/Sept. In 2004, landings were made through December, probably because of mild weather. In 2005, landings were made early, in April/May, otherwise there was a late start because of the abundance of small sardines.

There has been a wide variation in the annual average sardine weights through the years. They weighed the most in 2002 when they averaged 182 g and least in 2007 at 107 g. In 2008 sardines average weight was 124 g. Highest individual weights often differ widely per month. Some years 2001, 2003, and 2008 highest weights were observed early in the year (June or July) while in other years it occurs in the fall. This probably depends on the movements and migrations of sardines and the age classes available to fishers.

Sardines landed in Washington are 1-10 years-of-age, with sardines older than 6-years-old, relatively rare. Recently we appear to be seeing a dominate age class move through the fishery. In 2005 the dominate age-class was 2-year-olds. In 2006, landings were dominated by 3-year-olds, and in 2007, 4-year-olds. Unfortunately, age-classes for 2008 landings were not completed in time for the 2008 TSF.

Salmon by-catch in the fishery is very low. In 2008, 45 live Chinook salmon (*Oncorhynchus tshawytscha*) and 27 coho salmon (*O. kisutch*) were captured and released. There were also 149 Chinook and 170 coho salmon that were observed to be dead in the by-catch.

Unfortunately, the 2008 sardine logbook and information about catch location is unavailable for this TSF. However, past data indicate that most of the Washington catch occurs primarily off Grays Harbor. However, it ranges from Cape Flattery, WA to Tillamook Head, OR.

CANADA

British Columbia—Cynthia Johnston and Jake Schweigert (DFO)

Overview of the Canadian Pacific sardine fishery

Cynthia Johnston

The Canadian fishing season runs from June 15 to February 9. It is an opportunistic fishery that is dependent on migration rates of sardines into Canadian waters from the US. Survival and recruitment of juveniles is heavily influenced by oceanic conditions

Background. From 2003-2007 DFO and Industry developed using an incremental approach to establish market development & fishery capacity. This included traditional markets, such as aquaculture feed, bait and onshore food markets (predominantly Asian market in Japan). More recently (2007- currently) DFO and Industry is continuing incremental approach to develop fishery capacity and specifically targeting new markets in Europe and Australia.

Canada has 50 party based sardine licenses (25 commercial and 25 communal commercial licences). The identified total allowable catch (TAC) is evenly split between licenses. In 2007 a process to establish limited entry commercial license eligibilities was initiated. This is a long term management approach to a) develop an on-going eligibility list for commercial licenses, and b) develop an allocation process for the communal commercial licenses. Commercial eligibility list will be finalized for the 2009/2010 season and work on allocation process for communal commercial licenses is ongoing.

Since the 2007/2008 season multiple designation of licenses has been permitted with a maximum of 5 sardine licenses per vessel being allowed. At end of 2008/2009 season this “stacking of licenses” will evaluated. Combined evaluation of two season pilot program will determine if multiple designations (stacking) of licenses will be permanently implemented. Evaluation of stacking will be based on fish harvesters ability to make license allocation changes within 1 business day, the ability of service provider to accurately match catch to licenses, there having no related enforcement issues, and no increase cost to Fisheries and Oceans Canada.

To minimize wastage and reduce mortality, licensed vessels are presently permitted to share individual sets. Vessels may remove fish from the seine gear of another vessel. However, both vessels must record this activity in their logbook, no offloading at sea is permitted, and vessels are not permitted to use packers.

The Industry has funded 3rd party service provider to monitor the sardine fishery. This program includes 4 components:

1) Vessel Hails:Hail out 48 hrs. prior to fishing and Hail in 24 hrs. prior to landing,

2) Logbooks with catch and effort information are maintained,

3) At sea observers: In 2008/2009 they were able to provide 50% coverage in existing areas, and 100% coverage in new fishing areas and during salmon openings on the west coast of Vancouver Island, and

4) 100% dockside validation

The 2008-2009 fishery to date has 50 licenses issued (49 were fished) and 20 unique vessels. The total allowable catch (TAC) in 2009-2009 was 12,491.00 metric tons (Table 1), or 249.82 MT per license. As of the TSF the 2008 catch to date in Canada was 10,435 MT, or 83 % of total TAC. Most of the catch occurred in August and September (Table 2). With the area of highest harvest changing by month (Table 3).

Table 1. Annual sardine catch information from Canadian Waters. Individual Vessel Quota (IVQ) and Total Allowable Catch (TAC) is also shown.

YEAR	LICENSES FISHED	# DAYS FISHED	CATCH (MT)	IVQ (MT)	TAC (MT)	% of TAC
2002	9	93	822	180	9,000	9%
2003	9	70	1,006	180	9,000	11%
2004	23	199	4,259	300	15,000	28%
2005	16	181	3,266	304	15,200	21%
2006	15	65	1,558	270	13,500	15%
2007	10	64	1,524	396	19,800	12%
2008	49	288	10,435	250	12,491	83%

Table 2. Monthly sardine catch from Canadian waters and number of vessels fishing.

	JULY	AUG	SEPT	OCT
APPROXIMATE CATCH (MT)	240	3589	4597	1999
NUMBER OF UNIQUE VESSELS	2	13	17	6

Table 3. Amount of sardine harvest (MT) in Canadian waters by fishing area.

	AREA								Total
Month	8	9	10	12	23	24	26	123	
July	215	0	25	0	0	0	0	0	240
Aug	67	0	198	2,425	0	0	899	0	3,589
Sept	67	532	1,151	37	754	0	1,345	674	4,560
Oct	0	0	0	0	38	301	988	672	1,999
Total	349	532	1,374	2,462	792	301	3,232	1,346	10,388

Report for Working Group I:
Report and Regional Estimates of Biomass of 2008 and Recommendations

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1. Coast-Wide Survey, CalCOFI, and IMECOCAL April Cruises, 2008

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

ACTIVITIES

California Coast Ecosystem (CCE) and Calcofi, APRIL CRUISES, 2008—The CCE surveys were conducted aboard two NOAA research vessels: *David Starr Jordan* (March 24-May 1) to cover the area from San Diego to San Francisco (CalCOFI line of 93.3 to 62.3) and *Miller Freeman* (April 1-30) to cover the area from Port angels, Washington to San Francisco (48.47°N to 36.6°N, down to CalCOFI line 63.3). During the CCE surveys, CalVET tows, Bongo tows and CUFES and trawls were conducted aboard both vessels. Prior to the CCE survey, the routine April CalCOFI survey was carried out aboard David Starr Jordan from March 24-April 9th to cover six lines of 93.3 to 76.6 and only CalVET and Bongo tows were taken. Data from both CCE and CalCOFI suryes were included in estimation of spawning biomass of Pacific sardine.

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

For adult samples, the survey plan was to use the NOAA vessel *David Starr Jordan* and Miller Freeman to conduct 2-3 trawls a night at the predetermined CalCOFI stations for the survey or at random sites on the survey line regardless of the presence of sardine eggs in CUFES collections. The trawl survey was conducted from April 1- May 1, 2008 on both research vessels except the regular CalCOFI survey from March 24-April 9 aboard *David Starr Jordan* and Bad weather reduced the amount of survey time and hence, the number of trawls attempted. Although only ___ trawls were conducted at night near the surface (0-6 fathoms), ___ were positive for Pacific sardines (Fig. 1).

The spawning biomass of Pacific sardine (*Sardinops sagax*) in April - May 2008 was estimated by the daily egg production method (DEPM) to be 134,467 mt (CV = 0.43) for an area of 667,162 km^2 off the west coast of North America from San Diego, U.S.A. to Point Angeles, Washington (30°-48°N), primarily for the area south of 39.5^0N. For the entire survey area, the daily egg production estimate (P_0) was 0.218/.05m^2 (CV = 0.22), although no eggs were collected in the area north of latitude 39.5°N.

Estimates of the spawning biomass of Pacific sardine (*Sardinops sagax*) for the area traditionally occupied by the Daily Egg Production Method (DEPM) survey between CalCOFI lines 63-93, using the DEPM (Lo et al. 1996, Macewicz et al. 1996) was also obtained. The daily specific fecundity was calculated as 21.82 (number of eggs/population weight (g)/day) using the estimates of reproductive parameters from 187 mature female Pacific sardine collected from 12 positive trawls: *F*, mean batch fecundity, 29802 eggs/batch (CV = 0.06); *S*, fraction spawning per day, 0.12 females spawning per day (CV = 0.31); W_f, mean female fish weight, 97.66 g (CV = 0.06); and *R*, sex ratio of females by weight, 0.63 (CV = 0.09). The standard survey area off California, from San Diego to San Francisco (CalCOFI lines 95 to 60), in 2008 was 297,949 km^2. For the standard area, the egg production estimate was 0.43/0.05m^2 (CV = 0.21) and, the spawning biomass was estimated to be 117,426 mt (CV=0.43). Only 1 single sardine was caught north of CalCOFI line of 60.

The spawning biomass north of CalCOFI line 60, near San Francisco, was 17,041 mt. In 2008, trawling was conducted at pre-assigned stations, which resulted in sampling adult sardines in both high (Region 1) and low (Region 2) sardine egg density areas. The estimates of spawning biomass of Pacific sardine in 1994 - 2008 are 127,000 mt, 80,000 mt, 83,000 mt, 410,000 mt, 314,000 mt, 282,000 mt, 1.06 million mt, 791,000 mt, 206,000 mt, and 485,000 mt, 300,000 mt, 600,000 mt, 837,000mt,392,00mt and 117,000mt respectively.

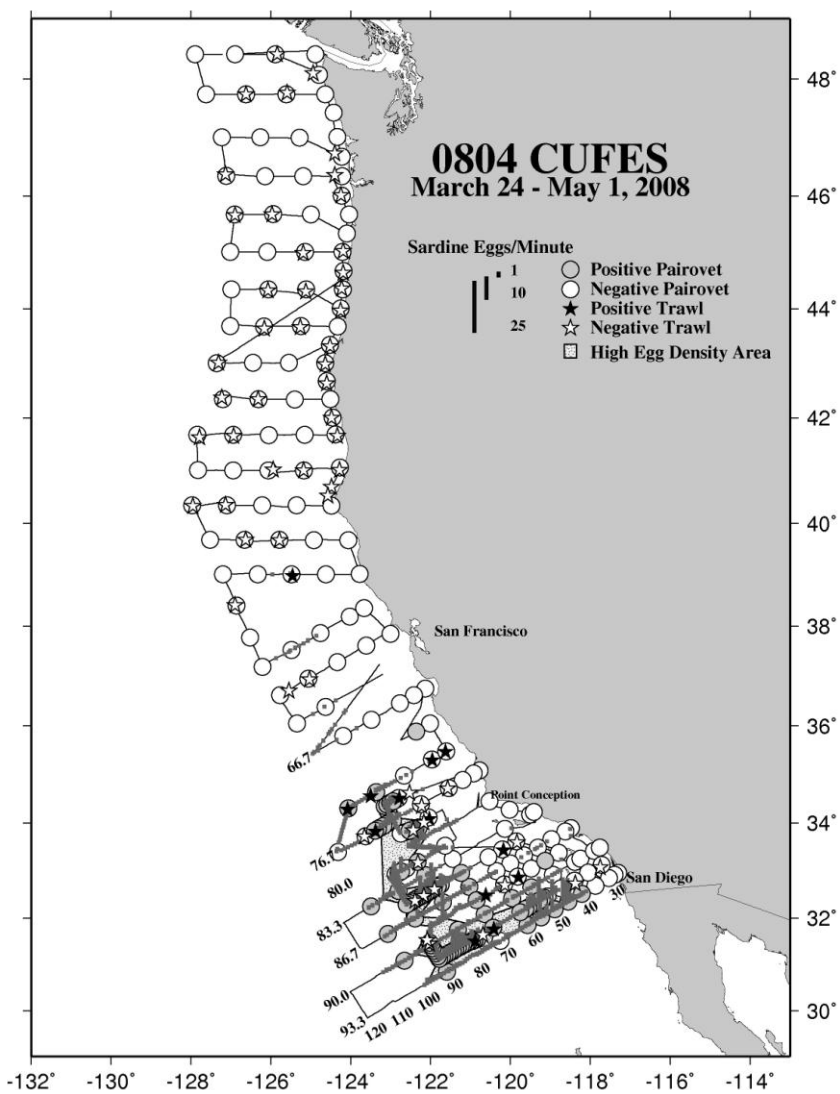

Figure 1. Location of sardine eggs collected from CalVET, a.k.a. Pairovet; (solid circle is a positive catch and open circle is zero catch) and from CUFES (stick denotes positive collection), and trawl locations (solid star is catch with sardine adults and open star is catch without sardines) during the 2008 survey. Region 1 is high density area. Dates of cruises refer to the first and last tow.

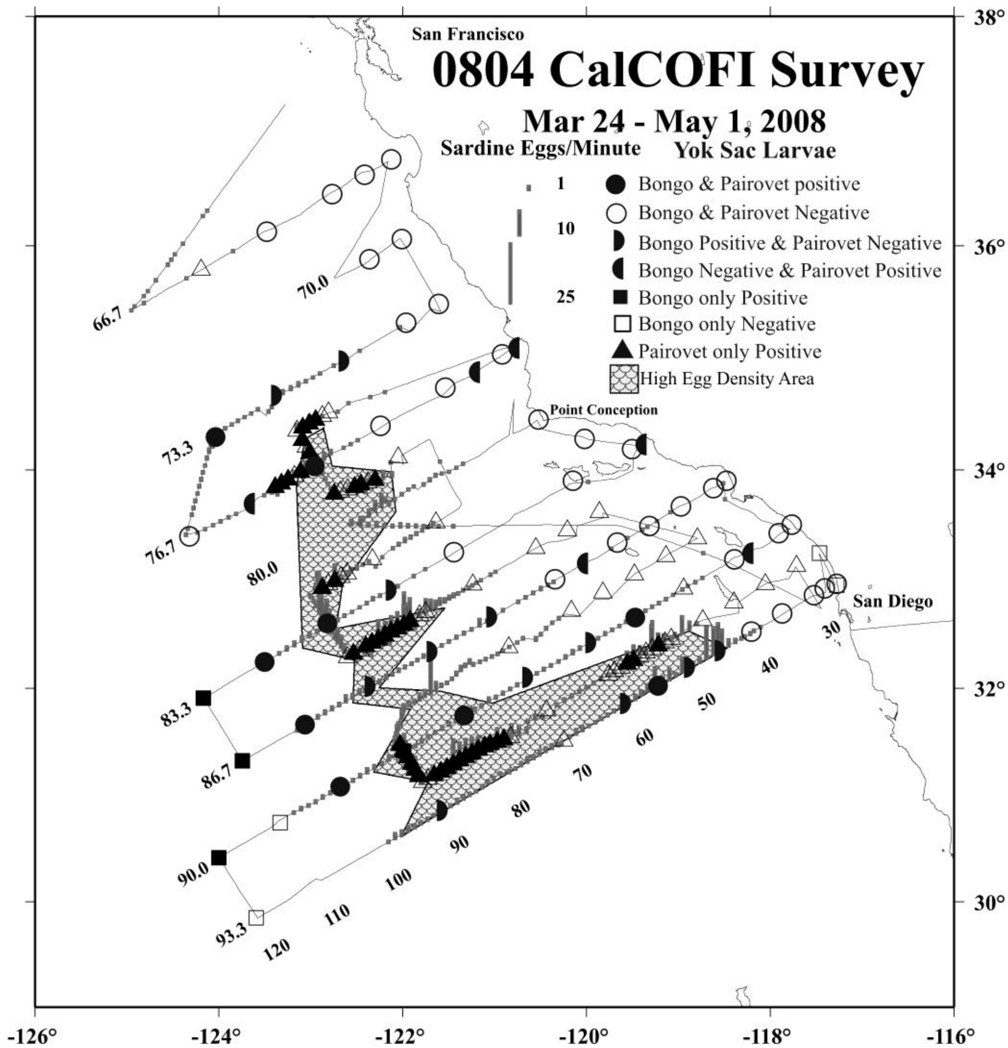

Figure 2. Location of sardine yolk-sac larvae collected from CalVET (or Pairovet; circle and triangle) and from Bongo (circle and square) during the 2008 survey. Solid symbols are positive and open symbols are zero catch. Zero yolk-sac larvae were caught north of CalCOFI line 73.3.

1.2. IMECOCAL in 2008 (no report)

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

2. Pacific Sardine Biomass Estimates and Associated Information off Northern Oregon and Southern Washington in 2008.

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

Two surface trawl surveys collected Pacific sardines (*Sardinops sagax*) off Oregon/Washington in 2008:

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.

Sardine population estimates in the Columbia River region were calculated using the same methodology as past years (volume swept methodology). Sardines captured during the Predator/Forage Fish Survey are usually most abundant in July and August. As such, July or late July/early August information was used to make population estimates. However, in 2008 highest densities were observed in June 2008 so they are also reported here. During each cruise (2 days, 9 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 1.52×10^{11} [area of the study area (7,600 km^2) x 20 m]. Average weight of sardines captured was calculated from mean length.

The sardine biomass estimates off the Columbia River region in late June 2008 was 11,073 MT. In July 2008, sardine biomass off the Columbia River ranged from 938 MT in mid-July to 5,765 MT in late July (Table 1). These estimates are above early July 2007 for similar time periods. Sardine estimates, for early July for 2007 and 2008 were similar between the two years, 2,857 and 2,646, respectively. 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.

The length/frequency data (Fig. 4) indicate that sardines in the Columbia River area in 2008 were composed primarily of one large 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. This is similar to what we observed in 2007. Overall, average sardine lengths in July 2008 were very similar to that of 2007 (Table 1). Oregon/Washington coastal surveys (Fig. 5) also showed essentially one size class in May, June and September 2008 (Fig. 6). For the first time since we started this survey, no 0-age sardines were captured in September (Fig. 7), indicating that spawning did not occur or that recruitment was not successful off the Northwest in 2008.

One-year-old sardines generally range from 125 to 175 mm FL in September. In 2008, this size/age class was also completely absent from our sample collections. This indicates that, as reported in 2007, sardine 0-age recruitment in 2007 was very poor and is now reflected as the absence of one-year-old sardines observe in our samples collections 2008.

Sea surface temperatures were relatively cold in May, June, and July 2008 compared to past years (Fig. 8), with June and July being particularly cold. August sea surface temperatures were about average. Past reports have noted that warm ocean conditions in May/June appear to be conducive for successful spawning and recruitment of Pacific sardine off the Oregon/Washington coast. The observed poor sardine recruitment in 2008 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 probably more abundant off the Columbia River in 2008 than in 2007, but had very low, if any, spawning recruitment success in 2008. These findings suggests that the sardine population in the northern California Current will only have very limited additional sardine biomass originating from Northwest spawning in 2008, similar to what was observed in 2007.

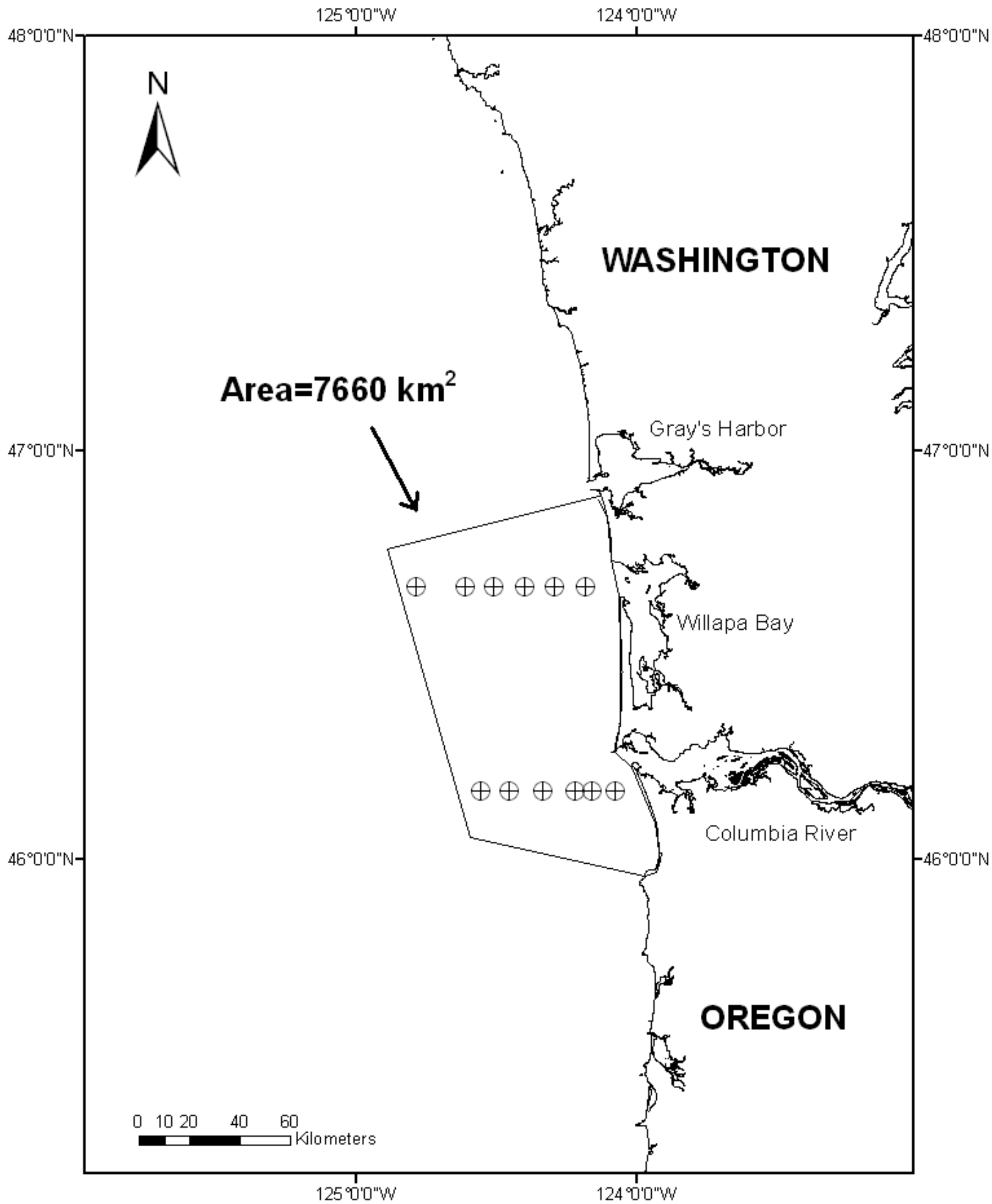

Figure 3. Location of the 12 surface trawl locations sampled at night approximately every 10 days near the Columbia River from late April through early August during the Predator/Forage Fish Surveys.

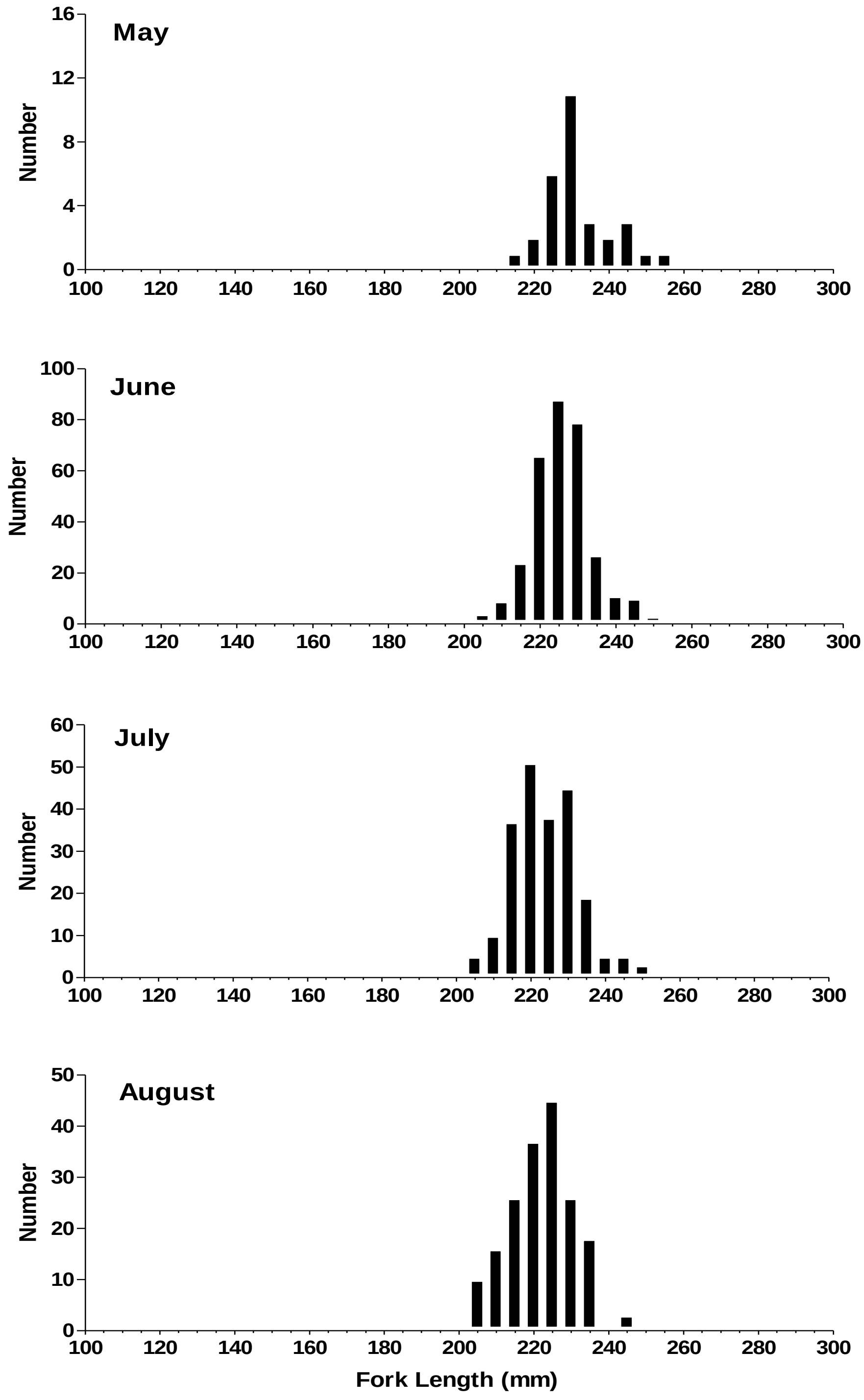

Figure 4. Length frequency of Pacific sardine (*Sardinops sagax*) captured off the Columbia River in 2008 during the Predator/Forage Fish Survey.

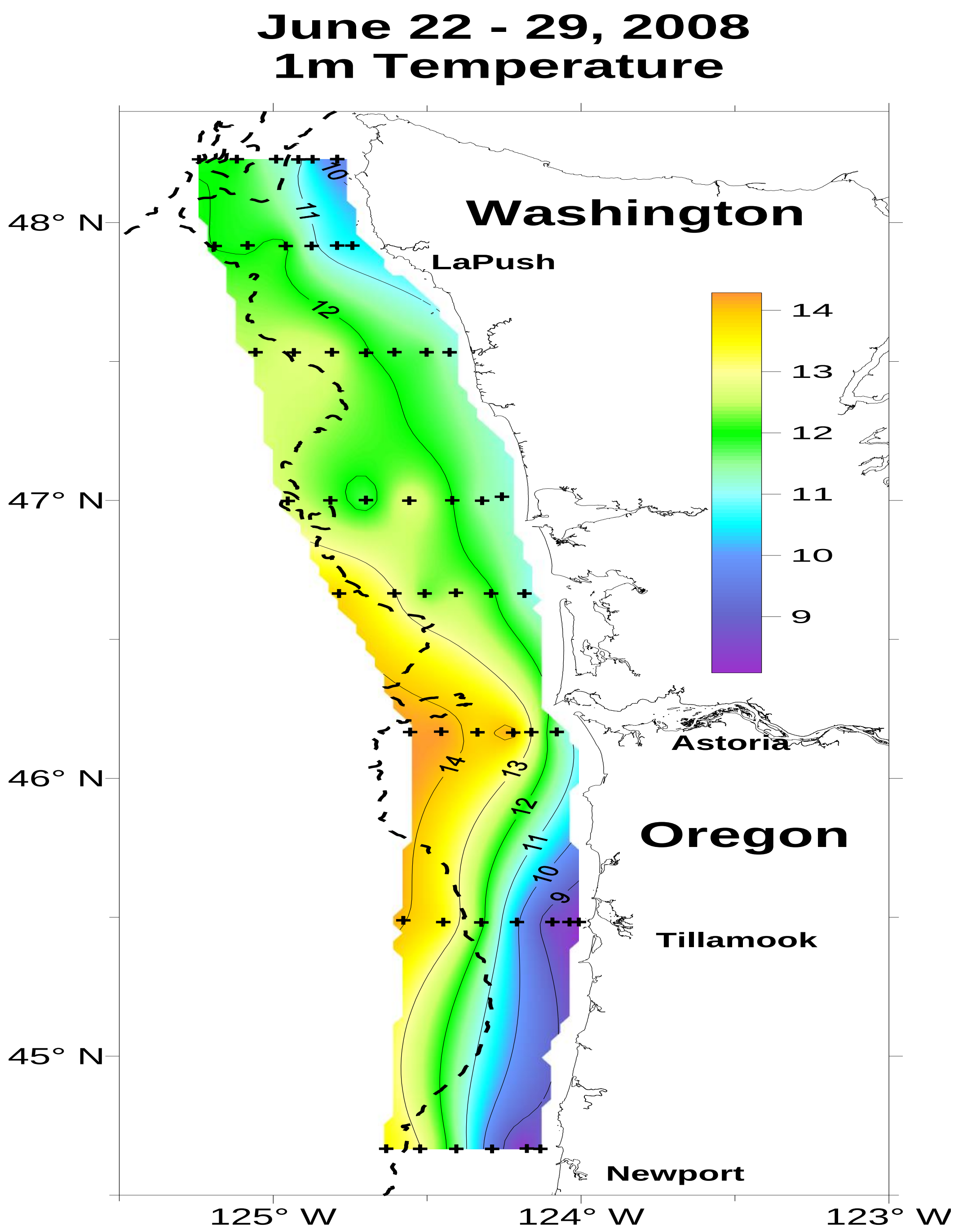

Figure 5. Location of stations sampled annually in May, June and September off Oregon/Washington during the BPA plume study in 2008. Also shown are sea surface temperatures during late June in 2008.

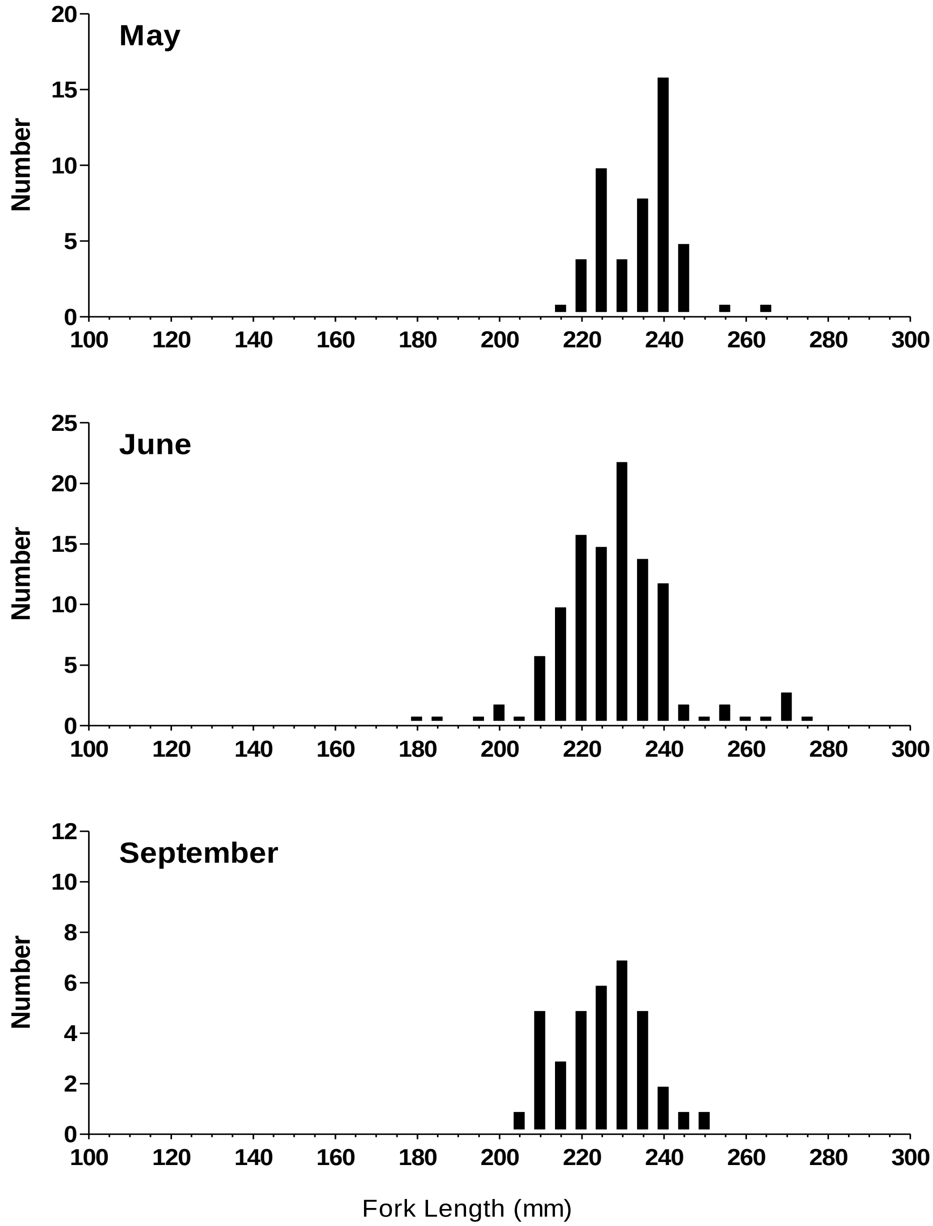

Figure 6. Length frequency of Pacific sardine (*Sardinops sagax*) captured off Oregon/Washington In May, June and September 2008 during BPA plume study.

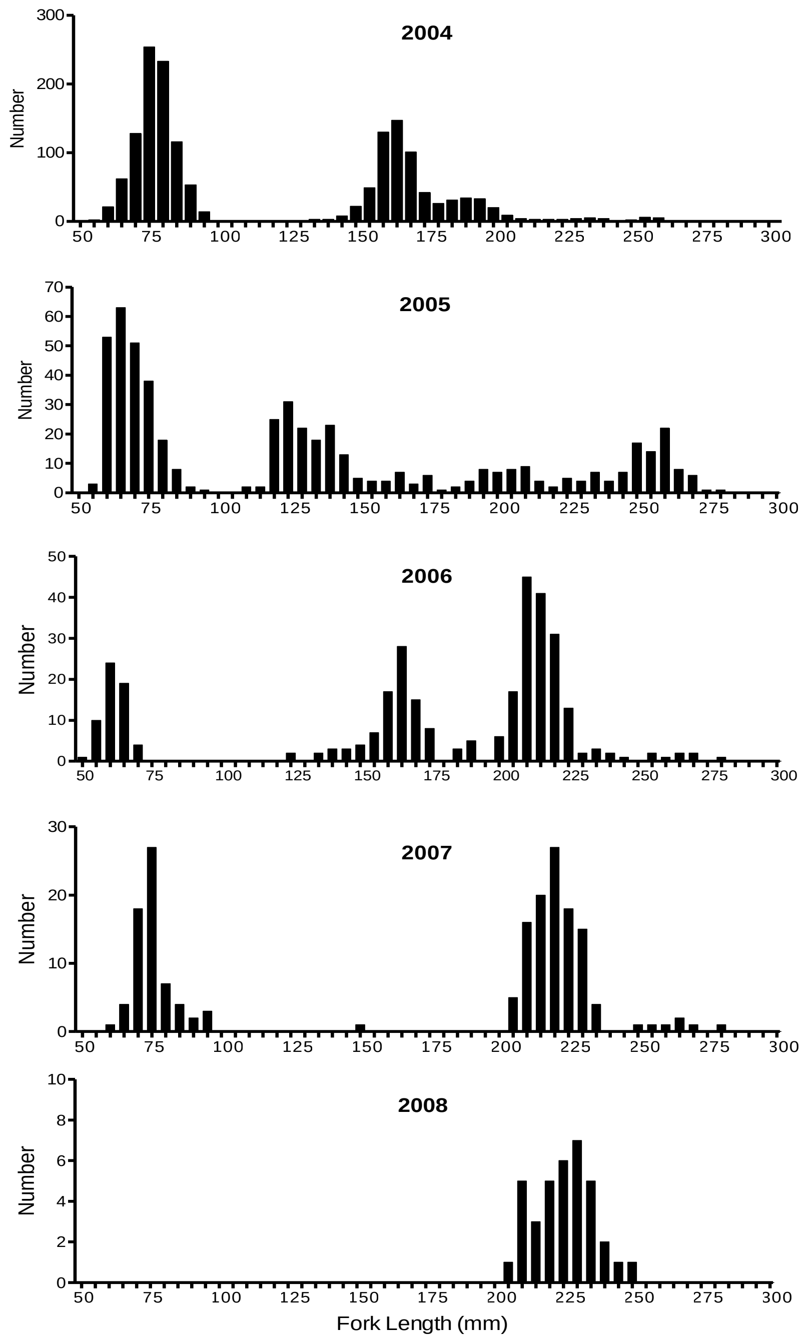

Figure 7. Length Frequency of Pacific sardine captured during September 2004 – 2008 off the Oregon/Washington coast during the BPA plume study.

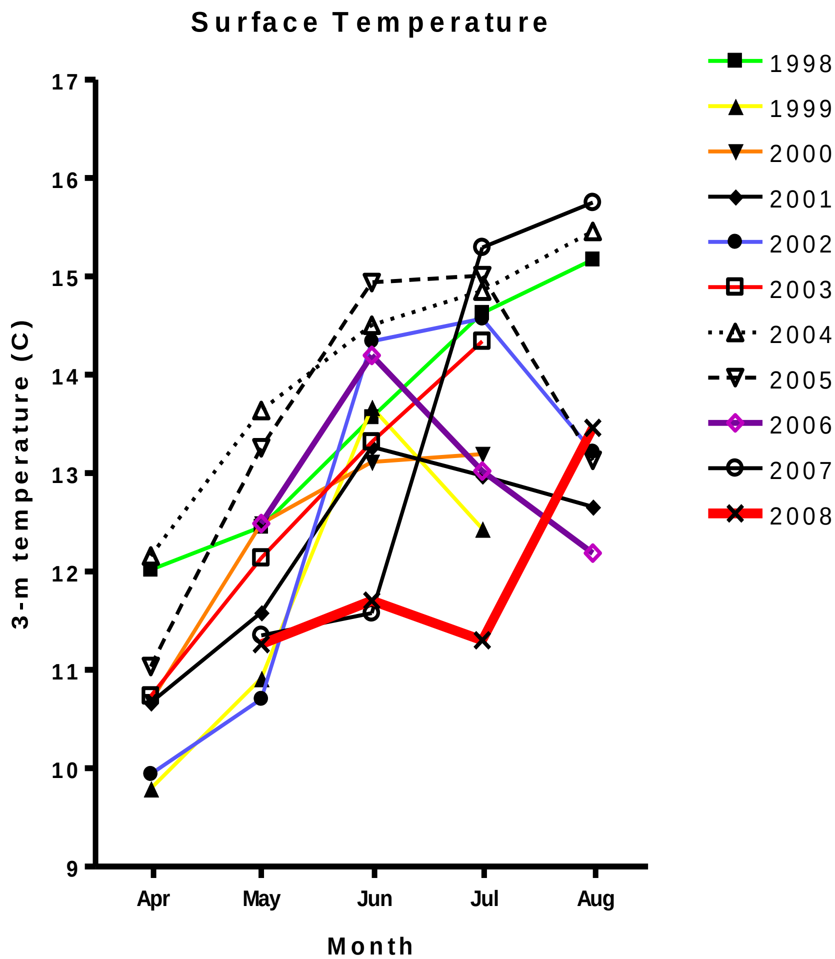

Figure 8. Average monthly surface temperatures (3m depth) off the Columbia River 2008.

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

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

3. Canadian Trawl Survey of Pacific Sardine Abundance in B.C. Waters During 2008

Jake Schweigert
DFO

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

Background. From 1992 to 1996 small numbers of sardines were captured in both commercial and research sets targeting Pacific hake off the southwest coast of Vancouver Island. Since 1997, large numbers of sardines have been captured in surface water research sets targeted on sardine off the west and northeast coasts of Vancouver Island, Queen Charlotte Sound, and in a small commercial fishery for sardines in inlets surrounding Vancouver Island. From 1997 to 1999, sardines were found in the Strait of Juan de Fuca, in the Strait of Georgia, along the west coast of Vancouver Island, Hecate Strait, and off southeast Alaska. Sardine distribution in 2000 was concentrated on the WCVI and ranged as far south as Barkley Sound and as far north as mainland British Columbia, north of Vancouver Island. From 2001 to 2003, sardine distribution became progressively concentrated near shore along the southwest Vancouver Island coast and progressively less prevalent in research cruises. By 2004, sardines were rarely captured offshore or along the research grid; however, large catches of sardines were made in inlets and the shallows along the WCVI, and in 2004 in Queen Charlotte Sound inlets. In 2005, the survey was directed at developing a relationship between day sets and night sets to be used to calibrate future surveys. Sardine distribution in 2006 extended along the entire west coast of Vancouver Island (Fig.9), suggesting a return to distribution patterns seen in the late 1990s. The estimated abundance in 2006 was the highest recorded since the inception of the research surveys.

Activities. Research cruises have obtained sardine samples since 1992. The 2008 survey is the 7 th survey directed at estimating abundance in offshore waters along the WCVI. This report summarizes sardine data collected during a research cruise conducted from July 30 to August 8, 2008. The sardine research cruise was not conducted in 2007, due to unanticipated repairs to the R/V W.E. Ricker.

The 2008 research cruise was carried out aboard the R/V W.E. Ricker, and all fish were captured using a model 250/350/14 mid water rope trawl (Cantrawl Pacific Ltd., Richmond, British Columbia). Fish were measured for fork lengths recorded to the nearest millimeter. Biological samples were also collected for sex, maturity, stomachs and otoliths (Table 2).

From July 30 to August 8, 2008, a total of 71 sets were made in surface waters (<45 m) off the west coast of Vancouver Island (Fig. 10). Of these, 44 sets contained sardines. All sets were made at night.

Similar to most of the previous surveys, the 2008 cruise covered only the five southern areas (due to time constraints). This year, sardines were present in all five areas (Fig.10). Sardine abundance was higher off the Northwest coast of the island (north of Esperanza) compared to Southwest coast. (Fig. 10) The 2008 biomass estimate for area 3 was 67% of the total biomass, the highest abundance seen in that area since the initiation of the surveys.

Biomass estimates were calculated according to the method described in Beamish et al. (2000). The west coast of Vancouver Island was partitioned into major “regions” and total volume was determined to allow biomass estimates to be calculated regionally. Volume swept during each set was determined by multiplying the area of the mid-water trawl net used during the fishing operations by the distance traveled during fishing. Minimum and maximum estimates were determined using the 95% Confidence Interval for the calculated average swept volume within each major area. (Table 3).

Using ratios of sardines in each major area from 1997, 1999 and 2001, biomass estimates were calculated for 2005 (Table 4, Fig. 11). Biomass estimates for 2006 and 2008 were adjusted using the 2005 day/night catch ratios. The adjusted biomass estimate (upper limit) for the 2008 survey is 274,977 mt, slightly lower than the estimated biomass of 2006.

Table 2. Summary of biological samples taken onboard the W.E. Ricker July 30-August 8, 2008.

2008 Pacific Sardine Sample Survey	
Sample Type	# of Sardines
Weight	620
Length/Sex	4390
Maturity	1020
Stomach	617
Otolith	798

As evidenced by the catches during the trawl survey, the general distribution of sardine in 2008 was further to the north than in 2007 and the bulk of the fishery occurred in areas 8-12 and 25 and 26, southern Central coast and northern portions of the west coast of Vancouver Island. No sardines were reported in the Queen Charlotte Islands and none were observed in the juvenile herring survey in the upper Central Coast. However, there were reports of sardine as far north as Gil Island in late September. Along with an abundance of sardine was an improved market for the product, both food and bait, as well as favourable pricing. As a result, the Canadian landings in 2008 to Oct. 12 were 9328 tonnes, the highest level in the recent history of the fishery since 1996. The fishery was comprised primarily of the fish from the 2003 year-class now age 5 and approximately 250 mm in length.

Table 3. Estimates of Pacific sardine biomass from 1997 to 2008.

Area	Total Volume (km3)	Average Swept Vol (km3)	Swept Volume 95% CI	Average # fish per area	Average total mass of fish per area (kg)	Biomass (t) Min (ave (- 95% CI)	Biomass (t) Average	Biomass (t) Max (ave + 95% CI)
				1997				
1	91.0	0.0039	0.0007	57	9.4	184.6	217.2	263.9
2	66.6	0.0042	0.0009	3509	801.0	7499.4	9172.3	11838.4
3	119.7	0.0031	0.0016	645	106.7	2672.8	4069.4	8522.3
4	83.9	0.0032	0.0012	12696	2154.3	39454.3	54852.7	89964.5
5	71.8	0.0028	0.0006	1222	201.6	4234.3	5176.5	6658.0
6	127.7	0.0021	0.0004	1521	239.3	12901.5	15355.1	18961.0
					Total:	66947	88843	136208
				1999				
2	66.6	0.0019	0.0002	1186	194.5	6146.1	6744.4	7471.8
3	119.7	0.0020	0.0001	430	70.8	4126.9	4345.2	4587.9
4	83.9	0.0019	0.0002	559	91.9	3774.0	4159.3	4632.3
5	71.8	0.0017	0.0006	1307	215.7	6487.3	8689.9	13157.2
6	127.7	0.0020	0.0005	5262	877.3	44121.8	55459.3	71123.0
					Total:	64656	79398	100972
				2001				
1	91.0	0.0019	0.0004	0	0	0	0	0
2	66.6	0.0016	0.0002	0	0	0	0	0
3	119.7	0.0015	0.0004	0	0	0	0	0
4	83.9	0.0017	0.0005	4	0.7	12.7	16.2	22.3
5	71.8	0.0017	0.0002	4	0.6	21.6	24.7	28.7
6	127.7	0.0017	0.0005	3616	596.8004	33804.2	43823.7	62284.8
					Total:	33839	43845	62336
				2005				
4	83.85	0.0017	0.00013	1438	216.61	10002.1	10742.7	11601.7
5	71.76	0.0016	0.00006	2585	340.04	14610.4	15157.6	15747.2
6	127.65	0.0016	0.00009	5240	900.33	66058.3	69812.5	74019.0
					Total:	90671	95713	101368
				2006				
2	66.6	0.0019	0.00008	1577.1	228	7864.8	8215.6	8599.1
3	119.7	0.0018	0.00019	1422.0	176	10595.5	11741.3	13165.0
4	83.9	0.0015	0.00033	11035.1	1510	69729.9	85476.6	110409.8
5	71.8	0.0012	0.00018	9192.5	1154	58381.2	66905.2	78343.8
6	127.7	0.0019	0.00026	4327.6	632	36511.7	41464.3	47971.3
					Total:	183083	213803	258489
				2008				
2	66.6	0.0018	0.00019	1476	213.4	7254.0	8028.8	8988.9
3	119.7	0.0013	0.00023	9149	1397.6	108391.0	127569.0	154992.3
4	83.9	0.0015	0.00025	5005	726.0	34002.8	39412.4	46868.8
5	71.8	0.0012	0.00024	24	3.3	166.8	200.8	252.3
6	127.7	0.0016	0.00015	1329	186.3	13389.6	14641.3	16151.1
					Total:	163204.3	189852.3	227253.4

Table 4. Pacific sardine biomass maximum estimates: 200, 2006, 2008 adjusted to provide comparison to 1997- 2008.

Year	Maximum (t)	Adjusted to Day (t)
1997	136208	136208
1999	100972	100972
2001	62336	62336
2005	101368	119614*
2006	258489	312772**
2008	227253	274977**

* adjusted for missing northern areas
** adjusted for night day conversion

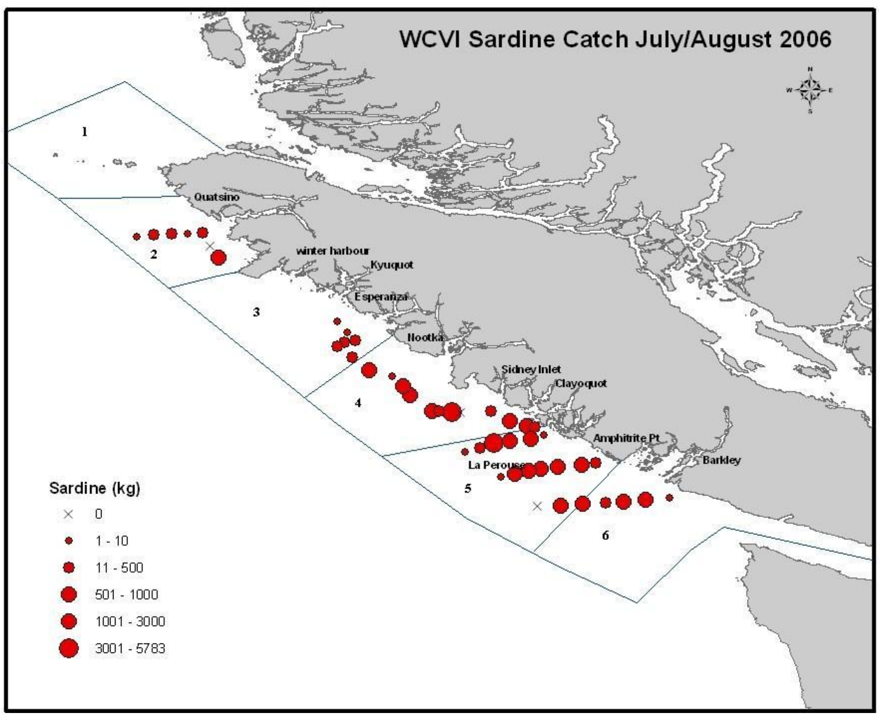

Figure 9. Set locations for the 2006 Pacific sardine cruise off the WCVI, July 31 to August 8, 2006 with region numbers.

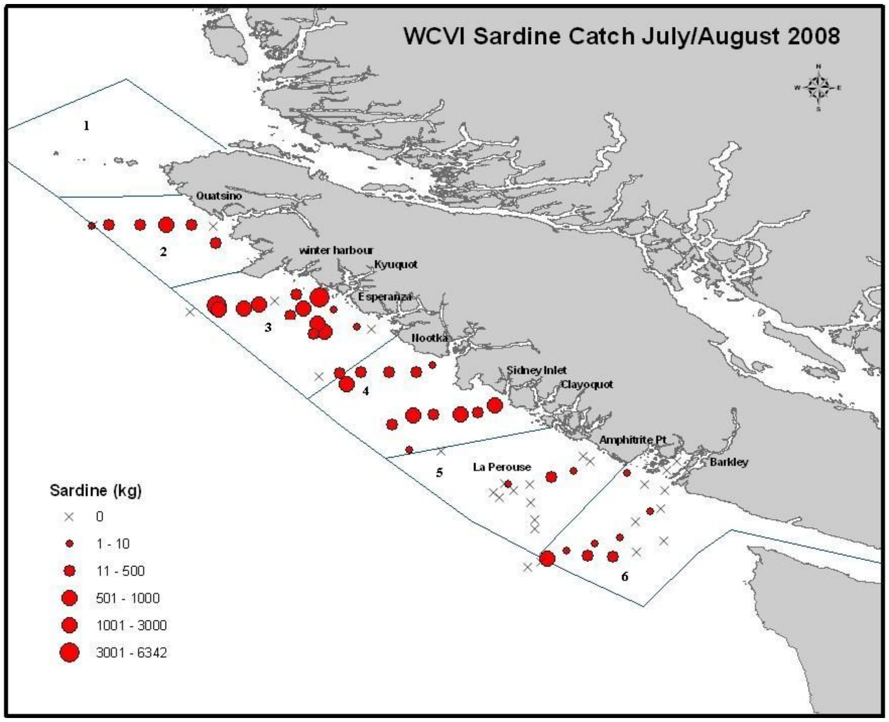

Figure 10. Set locations for the 2008 Pacific sardine cruise off the WCVI, July 30 to August 8, 2008 with region numbers.

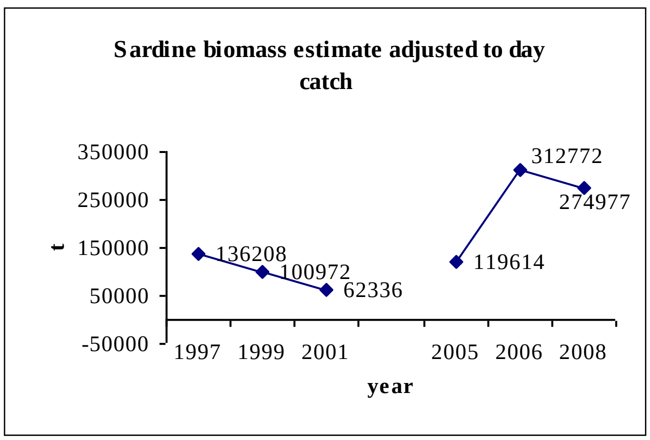

Figure 11. Pacific sardine biomass estimates 1997-2008. Biomass estimate adjusted to day catch for 2005, 2006, 2008.

4. The Feasibility of Using an Aerial Survey to Determine Sardine Abundance Off the Washington-Oregon Coast in Conjunction with Fishing Vessel Observation of Surveyed Schools and Shoals

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Objectives: To estimate the abundance of sardines off Washington/Oregon using aerial surveys and fishing vessels.

A report prepared for: Northwest Sardine Survey, LLC, c/o Astoria Holdings 12 Bellwether Way, Suite 209, Bellingham, WA 98225, October 2, 2008

Introduction

Pacific sardines (*Sardinops sagax*) have been fished in Oregon, Washington and British Columbia since the 1930s (Emmett et. al. 2005). The abundance of sardine appears to have declined in the late 1940s and remained low until the mid 1990s when a series of strong year classes appeared to have greatly increased abundance (Hill 2007). Starting in the mid-1990s, sardine abundance increased in the Northwest, perhaps in response to warm waters brought about by a series of strong el Nino's that caused sardine migration into the region and significant local spawning and recruitment (Emmett et. al. 2005).

Whatever the cause of the increase of sardine in the Northwest, the increased abundance has brought into existence a sardine purse seine fishery off Washington and Oregon that has grown from very small landings in 1999 to over 50,000 t. in 2005 (Hill 2007).

Since the Northwest sardine fishery has redeveloped only very recently, there is little synoptic survey coverage of this area in comparison to the southern California area where sardine have been fished since early in the 20th century. The NMFS Southwest Fisheries Center has conducted sardine egg/larval surveys and acoustic surveys of stock biomass in 2006 and 2008; however, these surveys observed only small amounts of sardine off Oregon and Washington. Fishermen and processors, on the other hand, report large concentrations of sardine off the Oregon and Washington coasts, particularly in the Columbia River area. To support their claim of a larger biomass than estimated in current surveys, the fishing industry funded a project to develop a scientifically valid abundance estimate for this area.

This paper reports the first year results of an effort to develop an aerial-survey-based sardine abundance estimator for the Oregon-Washington coast. An aerial survey, coordinated with fishing activity, was chosen as the primary assessment method because: 1) there was not an opportunity to conduct fishery independent research in the absence of a research catch allocation, and 2) we had the opportunity to make use of fish spotter planes and purse seine vessels operating in the fishery. While this produced some competition between fishing and survey operations for resources, such conflicts were ultimately balanced by fisherman knowledge, which helped to maximize the opportunity to collect observations.

Gunderson (1993) lists aerial surveys as a “direct” survey methodology and outlines the advantages and short comings of the method. He suggests a two stage method utilizing fishing vessels to locate areas of high abundance followed by survey flights over the areas of high abundance. The aerial survey method has been used previously in S. Africa to assess sardine stock abundance (Misund et al. 2003), and Hill et. al. (2007) described how aerial survey indices were developed from spotter pilot logs and a contracted line transect pilot survey conducted in 2004 and 2005 for sardine in Southern California.

We developed our feasibility study following the advice of an expert panel assembled by the Pacific Fisheries Management Council in March 2007. The research plan was designed to evaluate the feasibility of 1) utilizing quantitative aerial photogrammetry collected by a fishery spotter plane to estimate sardine surface area (cover), and 2) using fishing vessels at sea to collect hydroacoustic data and to capture a sample of the schools photographed, to establish the relationship between sardine cover (m^2) and biomass (mt).

Materials and Methods

Biological Sampling

Samples were routinely collected from vessels delivering at fish processing plants. Fishermen kept observed research hauls (point sets) separate from the bulk of landings so total tonnage of observed hauls could be determined. Collections were made from both observed hauls and from general fishery deliveries during the July through August fishing period. During the second (September) open fishing period, biological samples were only collected from point set hauls. During the first period a total of 8 point set hauls were observed, and during the second fishing period in September an additional 3 hauls were observed.

Port sampling was conducted opportunistically throughout the first open fishing period. A total of 60 port samples were collected from unsorted catch while being pumped from the vessel. Fish were generally taken at the start, middle, and end of a delivery as it was pumped. The three samples were then combined and a random subsample of fish was processed. An additional 50 fish sample was collected and sent to NMFS as requested for their examination. Samples were processed for determination of sex, length, weight and maturity.

Sardine weights were taken using an electronic scale accurate to 0.5 gm. Sardine lengths were taken using a millimeter length strip provided attached to a measuring board. Sardine fork length was determined by measuring from sardine snout to inner most fork membrane. Standard length was determined by measuring from sardine snout to the last vertebrae. The standard length measuring method was adopted after discussions with Jill Smith at ODFW. Random otolith samples were taken from point-sets during the September fishing period for aging analysis. Sardine maturity was established by referencing maturity codes (female- 4 point scale, male- 3 point scale) supplied by Beverly Macewicz NMFS, SWFSC (Table 5a). All data were recorded in Excel spreadsheets and were processed using applications contained within the program. Of primary interest were length, weight, and maturity over the course of the season.

Aerial Survey

Survey design—Our survey employed the belt transect method using a systematic sampling design, with each transect a single sampling unit. We chose this design to permit a range of options for data analysis in this pilot study; this configuration can alternatively allow for estimation of density, cover, or biomass (Elzinga et al 2001). From a random starting point, 26 parallel transects were established for the study area off the coast of Washington-Oregon (Table 5b). The established transects had an east-west orientation, in anticipation that this would be generally parallel to the gradient of sardine schools we expected to find distributed along the coast. To fully encompass the expected width of the sardine school distribution transects originated at a distance of 3 miles from shore and extended westward for 35 miles. Transects were spaced 10 miles apart, and were grouped into three separate sub-regions (1-S, 1-C, and 1-N) so as to allow complete aerial coverage of a sub-region in a single day. Our initial focus was area 1-C, which corresponds to the area off the mouth of the Columbia River, where fishing effort has been most concentrated in recent years. Our objectives were, in priority order, to: 1) conduct three replicates of the 10 transects in area 1-C, 2) conduct 1 set of the 6 transects in area 1-N, 3) conduct 1 set of the 10 transects in area 1-S, and 4) conduct replicate transects in areas 1-S and 1-N as time permitted.

Data collection—We used a photogrammetric-aerial digital camera mounting system equipped with a data acquisition system to acquire digital images and to log data along the transects. (Aerial Imaging Solutions, Appendix A). The system recorded altitude, position, and spotter observations, which were directly linked to the time stamped quantitative digital imagery. Our survey was flown with a Piper Super Cub PA18 aircraft at a speed of 80-90 mph. Surveys were typically conducted on days when weather conditions permitted clear visibility of the ocean surface from an altitude of 8000 ft (2438 m). Using standard photogrammetric relationships (see below), the approximate width-swept by the camera with a 24 mm lens is 12,000 ft (3657 m) at that altitude. Digital images were collected with 60% overlap to ensure seamless coverage along the length of the transects. Quantitative aerial photogrammetry was validated by collecting digital imagery of an object of known size (an airplane hangar) at a series of altitudes ranging from 500 ft. to 8000 ft.

Digital images were analyzed to determine the number, size, and shape of sardine schools on each transect. The considerable number of images required for this task (ranging from approximately 700 to 1400 per survey-day) were processed using Adobe Photoshop 2.0 to bring the sardine schools into clear resolution. Measurements of sardine school size (m^2) and shape (perimeter, circularity) were subsequently made using Adobe Photoshop CS3-Extended. Transect width was determined from the digital images using the basic photogrammetric relationship:

$$\frac{I}{F} = \frac{GCS}{A}$$

and solving for *GCS*:

$$GCS = \frac{I}{F}A$$

where *I* = Image width of the camera sensor (e.g. 36 mm), *F* = the focal length of the camera lens (e.g. 24 mm), *A* = altitude, and *GCS* = “ground cover to the side” or width of the field of view of the digital image. Transect width is then obtained by taking the average of *GCS* for all images collected along the transect. Transect length is obtained from the distance between start and stop endpoints using the GPS data logged by the data acquisition system. Transect area is then the product of mean transect *GCS* and transect length.

Purse seine vessels operating during periods of open fishing were opportunistically used to capture fish (i.e. “point sets”) in conjunction with aerial over-flights to attempt to determine the relationship between school surface area (as documented with quantitative aerial photographs) and the biomass of fish schools (Figure 12). For fully captured schools, the total weight of the school was recorded and numbers per unit weight were also determined.

Data analysis

School density—Belt or strip transects represent a special case of quadrat sampling; with the additional consideration that all transects may not be of equal length or area. In our survey, unequal transect areas could result from either 1) variation of transect width (e.g. from a lower visibility causing reduced flight altitude) or 2) variation in transect length (e.g. due to premature transect termination due to fog or other weather conditions). To account for this contingency, we employed an unequal-area transect density estimator computed by dividing the mean number of sardine schools per transect by the mean transect area (Stehman and Salzer 2000). In this formulation

$$\hat{D} = \frac{\bar{y}}{\bar{a}}$$

$$\hat{V}\left(\hat{D}\right) = \frac{1}{\bar{a}^2}\left(\frac{N-n}{N}\right)\frac{s_e^2}{n} \quad \textbf{(Thompson 1992)}$$

Where $\hat{D}$ = the sample-based estimator of density, $\bar{y}$ = sample mean number of schools per transect, and $\bar{a}$ = sample mean transect area. The estimated variance of $\hat{D}$ is derived from standard ratio estimation theory as

$$s_e^2 = \sum_s \left(y_u - \hat{D}a_u\right)^2$$

where N = the total number of transects in the region, n = the number of transects sampled in the region, and $/(n-1)$ where y_u = the number of schools in transect u, and a_u = the area of transect u. Stehman and Salzer (2000) note that, while $\hat{V}\left(\hat{D}\right)$ is an approximation generally valid for a sample size of 30 (Cochran 1977), simulations suggest it may also be valid for smaller sample sizes if the distribution of transect areas is nearly symmetric, or if the correlation between a and y is close to 1.

Total number of schools. Given the estimate of density $\left(\hat{D}\right)$ and the total study area (A), an estimate of the total number of schools $\left(\hat{T}\right)$ is

$$\hat{T} = \hat{D}A$$

and its standard error $\widehat{SE}\left(\hat{Z}\right)$

$$\widehat{SE}\left(\hat{T}\right) = \widehat{SE}\left(\hat{D}\right)A \quad .$$

School cover and biomass— Our measurements of the surface area of individual sardine schools from the digital imagery afforded us the opportunity to estimate total sardine school cover. Cover is defined as the vertical projection of an object from the ground as viewed from above (Elzinga 2001). Let z_u denote the value for sardine school cover (m^2) on transect u. Cover for the entire study area ($Z^{\wedge}$) can then be estimated using the unbiased estimator for a population total, $\hat{Z} = N\bar{z},$ with estimated variance

$$\hat{V}(\hat{Z}) = \frac{N^2 \left(1 - \frac{n}{N}\right) s_e^2}{n}$$

where s_e^2 is the sample variance of z.

To estimate sardine biomass for the study area using school cover data, the relationship between individual school cover and school biomass is required, and the variability of this relationship will determine the feasibility of this approach. An initial examination of this relationship was explored by examining a scatter plot of school cover (m^2) vs. school biomass (mt) using the fishery point set data.

Hydroacoustic Measurement of the Vertical Dimension

In addition to the research point-sets (described above), we utilized echo sounders to measure the depth and height of schools. For this feasibility study two vessels were equipped with Simrad ES 60 recording echo sounders and connected to the ships transducers. Both vessels utilized 50/200 mHz single beam transducers. This configuration allowed recording of the water column under the ship. Echo sign was recorded continually throughout the season, and when possible, opportunistic echo sign and aerial survey comparisons were made. The echo sign data was analyzed in *Echoview* (Myriax Software Pty. Ltd.) to classify schools and to calculate school height statistics.

Results

Biological Sampling

During the July-September sardine fishery, biological data was collected from both routine port samples and point-set research samples. The two sample data types were combined and examined for relationships between sex, length, weight and/or maturity. Over the course of the sardine fishery, length and weight slightly decreased (Figure 13a).

Maturity data collected during the sardine fishery were used to gauge the degree of maturity among fish during the season and to determine if spawning episodes took place within the area and time of the fishery. Early in the fishery, females with flaccid ovaries were observed and some sardines were classified as actively spawning (Figure 13b). The majority of female sardines sampled through the season were classified as stage 2 (fish that had previously spawned); however, from late July on the proportion of newly maturing sardines increased in samples. This change coincides with an observed decrease in length and weight, perhaps indicating migration of smaller fish into the area.

A single sardine sample was collected on August 18th, 2008 from Grand Hale Marine Products Co., Ltd. in British Columbia, Canada. Sex, length, weight, and maturity were taken from this single sample. The mean weight of this sample was 191 g with a mean fork length of 235 mm. Some females observed in the sample had flaccid ovaries indicating that spawning had recently occurred among these fish.

Following power transformation, the length-weight relationship for sardine shows an almost linear relationship (Figure 13c.) The data include both sexes, so part of the variance is due to combining the data. Females generally are larger than males at the same length.

Aerial Survey

Area 1-C—Three replicate aerial surveys of Area 1-C were conducted on 8-22-08 (Figure 14a), 8-23-08 (Figure 14b), and 8-26-08 (Figure 15), respectively. Conditions generally permitted flying at the desired altitude of 8000 ft, however, local conditions (i.e. fog, cloud cover) resulted in some shortened transects on 8-23-08 and 8-26-08 (Tables 6-8). Transect width averaged 3.64 km, 3.68 km, and 3.67 for 8-22-08, 8-23-08, and 8-26-08, respectively. Transect length averaged 61.6 km, 41.6 km, and 54.7 km for 8-22-08, 8-23-08, and 8-26-08, respectively. The resulting area surveyed totaled 223 km2, 152.4 km2, and 200.7 km2 for 8-22-08, 8-23-08, and 8-26-08, respectively.

Plots of the distribution of sardine school cover are shown in Figures 16-18. Schools tended to be aggregated along portions of the transects, confirming that we succeeded in surveying parallel to the gradient of school distribution. Histograms showing the size distribution of individual schools for the three replicate surveys of Area 1-C are shown in Figure 19. Individual schools ranged from 99.3 m^2 to 46,813.2 m^2 on 8-22-08, 87.3 m^2 to 14,802.4 m^2 on 8-23-08, and 29 m^2 to 59,417.2 m^2 on 8-26-08, respectively (Appendix B).

Transect area, school count, and school cover is summarized for the three replicate surveys of Area 1-C in Tables 6-8. Estimates of sardine school density, number, and cover are summarized in Table 9. Density estimates ranged from .3579 schools/m^2 to .6842 schools/m^2 and averaged .5463 schools/m^2, with coefficients of variation (CV's) on the order of .16 to .26. Estimates of the number of schools ranged from 3757.4 to 5564.6 and averaged 4723. Total school cover estimates ranged from 6.1 km^2 to 9.9 km^2 and averaged 7.5 km^2 with CV's on the order of .16 to .29.

The results of 11 point sets made in Area 1-C from 7-27-08 through 9-21-09 are summarized in Figure 20 and Table 10 School cover from aerial photographs ranged from 657.4 m^2 to 9308.4 m^2, biomass from fish tickets ranged from 25.6 mt to 86.4 mt, and school vertical height from vessel soundings ranged from 3.7 m to 14.6 m. In 8 of the 11 cases, observations taken by vessel fishermen agreed with the survey pilot that 80-100% of the school was captured. For these eight point sets, the relationship between biomass and surface area averaged 0.0269 mt/m^2; the CV of these observations was 0.83. Because of this high variability, uncertainty of any biomass estimates computed using these data will be high. Biomass values obtained by multiplying the constant of 0.0269 mt/m^2 by estimates of total cover were 166,976.2 mt, 174,490.4 mt, and 267,441.8 mt for the surveys conducted on 8-22-08, 8-23-08, and 8-26-08, respectively.

Area 1-N—Two replicate surveys of the northernmost sub-region Area 1-N were made on 9-11-08 (Figure 21) and 9-23-08 (Figure 22), respectively. Time did not permit detailed analysis of these surveys as of this writing (9-30-08). It was noted on the survey of 9-11-08, however, that extending the eastern extent of the transects shoreward could potentially better encompass the eastward distribution of sardine schools. Thus, transects on 9-23-11 were extended eastward beyond the originally established eastern waypoints, to the shoreline.

Area 1-S—This southernmost sub-region was surveyed on 9-27-08 and 9-28-08. On 9-27-08, six transects were completed successfully (Figure 23). Additional transects were conducted on 9-28-08, however, a problem with the data acquisition system resulted in no navigational (GIS) data for this survey, thus rendering the survey of limited value for quantitative analysis. Time did not permit detailed analysis of the survey on 9-27-08 as of this writing (9-30-08).

Hydroacoustic Measurement of the Vertical Dimension

The original intent of equipping vessels with recording sounders was to record school vertical dimensions prior to taking a purse seine set, and to run portions of transects with the aerial survey to estimate the portion of sardine schools unobserved from the air. However, the short and intense fishing periods, and poor weather conditions limited our opportunity to fully test the methodology.

We do, however, have recordings of vessels moving about the grounds, and one track in which the spotter pilot was able to observe schools while the vessel was transiting schools. Two of these acoustic and aerial survey observations are shown Figures 24 and 25, respectively.

Figure 24a shows one of the vessels in a cluster of schools photographed from the air. Figure 24b shows the echo sign observed by the vessel as it transited the school. The vessel transited the right side of the school and the echogram shows the portions of the school that the vessel transited. The echogram shows that school was located about 3m below the surface and the bottom of the school was at about 12m, so overall school height was about 9 m , similar to the 8 m average of research point sets.

In Figure 25a the same vessel can be seen getting ready to transit a long narrow school. The corresponding echogram (Figure 25b) shows the school is less dense (green) than the school in the other picture which shows as bright red. Interestingly the school is about the same height as the others, but is not as dense.

School density may be related to shape and other factors (Hara (1986, 1990), Barange and Hampton (1997), Misund et. al. (2003), Castillo and Robotham (2004)). Hara (1986) distinguished between long, or “crescent” shaped schools, versus circular schools. He described the long schools as “migrating” schools and the circular schools as stationary schools. Thus the shape factor may be an important factor to examine along with depth to classify schools. We have several miles of echogram data which we will continue to analyze for school dimensions, shape and other parameters that can be used to quantify schools.

Discussion

We began this project on a “proof of concept” basis: we sought to demonstrate that high quality, quantitative digital aerial imagery could be collected and processed on a scale large enough and rapidly enough for a practical fisheries stock assessment application – namely the in-season enumeration and measurement of sardine schools. We were successful in this endeavor. In approximately one month’s time (from late August through late September), over 2000 images were processed by one scientific technician, who discerned and individually measured the surface area of over 3000 sardine schools. Furthermore, every school selected and measured on the digital images was documented and archived to allow for subsequent examination and review by other observers.

We found that we could sample an area of approximately 200 km^2 in one day of flying, using the belt transect method at a sample size level that generated estimates of sardine cover with CV’s on the order of .16 - .29. Three replicates of one sub-region (Area 1-C) yielded similar results which indicated good repeatability of the method. Our method of direct observation is most likely conservative; we have not yet evaluated the optimal conditions for school detection, and further work should consider the influence of diel vertical movements (Zwolinski et. al. 2007), sea turbidity, and other factors.

While measures of school density, the total number of schools, and school cover can be useful metrics to develop an index of abundance over a period of years for the sardine stock, a direct estimate of biomass is also desired to more quickly characterize the stock status. We found that point sets, coupled with quantitative digital imagery, are a promising method to establish the relationship between sardine cover (m2) and biomass (mt). Sampling limitations during the first season of this project resulted in too few samples to quantify this relationship with good precision. Further work will be useful to expand on this relationship, and to evaluate other techniques as well, such as split-beam sonar quantification of school geometry and biomass.

In conclusion, we have demonstrated that the aerial survey method affords a scientifically valid approach for sardine stock assessment. Alone, aerial surveys can provide a useful method for indexing, and when coupled with adequate sampling “in the third dimension”, biomass estimates may be obtained as well.

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Table 5a. Sardine maturity codes. Source: Beverly Macewicz NMFS, SWFSC.

Female maturity codes	**Male maturity codes**
1. Clearly immature- ovary is very small; no oocytes present	1. Clearly immature- testis is very small thin, knifed-shaped with flat edge
2. Intermediate- individual oocytes not visible but ovary is not clearly immature; includes maturing and regressed ovaries	2. Intermediate- no milt evident and is not a clear immature; includes maturing or regressed testis
3. Active- yolked oocytes visible; any size or amount as long as you can see them with the unaided eye in ovaries	3. Active- milt is present; either oozing from pore, in the duct, or when testis is cut with knife.
4. Hydrated oocytes present; yolked oocytes may be present	

Table 5b. Twenty six aerial transects, pre-selected from a random starting point. Transects are divided into three sub-regions: Area 1-C, Area 1-N, and Area 1-S.

Location	Transect	Transect Latitude		East End			West End			Forward Coverage (miles)			Transect Width -24 mm Lens	
Area 1-C	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Transect	Northward	Overall	5000 ft	8000 ft
Cape Falcon	1	45	48	124	2.50	1	124	52.48	2	35	0	35	7500	12000
	2	45	58	124	2.00	4	124	51.98	3	35	10	45	7500	12000
	3	46	8	124	1.50	5	124	51.48	6	35	10	45	7500	12000
	4	46	18	124	9.00	8	124	58.98	7	35	10	45	7500	12000
	5	46	28	124	8.00	9	124	57.98	10	35	10	45	7500	12000
	6	46	38	124	8.00	12	124	57.98	11	35	10	45	7500	12000
	7	46	48	124	10.00	13	124	59.98	14	35	10	45	7500	12000
	8	46	58	124	15.50	16	125	5.48	15	35	10	45	7500	12000
	9	47	8	124	15.50	17	125	5.48	18	35	10	45	7500	12000
Cape Elizabeth	10	47	18	124	22.00	20	125	11.98	19	35	10	45	7500	12000
Location	Transect	Transect Latitude		East End			West End			Forward Coverage (miles)			Transect Width -24 mm Lens	
Area 1-N	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Transect	Northward	Overall	5000 ft	8000 ft
Cape Elizabeth	1	47	28	124	28.00	1	125	20.50	2	35	0	35	7500	12000
	2	47	38	124	34.00	4	125	26.50	3	35	10	45	7500	12000
	3	47	48	124	36.50	5	125	29.00	6	35	10	45	7500	12000
	4	47	58	124	48.00	8	125	40.50	7	35	10	45	7500	12000
	5	48	8	124	50.00	9	125	42.50	10	35	10	45	7500	12000
Cape Flattery	6	48	18	124	48.00	12	125	40.50	11	35	10	45	7500	12000
Location	Transect	Transect Latitude		East End			West End			Forward Coverage (miles)			Transect Width -24 mm Lens	
Area 1-S	Number	Lat Deg	Lat Min	Long Deg	Long Min	Way Point #	Long Deg	Long Min	Way Point #	Transect	Northward	Overall	5000 ft	8000 ft
Heceta Head	1	44	8	124	12.00	1	125	0.50	2	35	0	35	7500	12000
	2	44	18	124	11.50	4	125	0.00	3	35	10	45	7500	12000
	3	44	28	124	10.50	5	124	59.00	6	35	10	45	7500	12000
	4	44	38	124	9.00	8	124	57.50	7	35	10	45	7500	12000
	5	44	48	124	9.00	9	124	57.50	10	35	10	45	7500	12000
	6	44	58	124	6.00	12	124	54.50	11	35	10	45	7500	12000
	7	45	8	124	3.00	13	124	51.50	14	35	10	45	7500	12000
	8	45	18	124	2.50	16	124	51.00	15	35	10	45	7500	12000
	9	45	28	124	4.50	17	124	53.00	18	35	10	45	7500	12000
Cape Falcon	10	45	38	124	1.50	20	124	50.00	19	35	10	45	7500	12000

Table 6. Transect data for survey of Area 1-C on 8-22-08 (replicate 1).

Transect ID	Start Longitude	End Longitude	Mean Latitude	Length (m)	Mean Width (m)	Area (m^2)	School Count	School Cover (m2)
1	124.0331	124.8673	45.7999	64855.0	3670.0	238014722.7	99	3826.9
2	124.8544	124.0547	45.9695	61980.1	3679.9	228078550.7	109	394286.9
3	124.0553	124.8601	46.1398	62187.8	3662.3	227750339.6	39	38086.9
4	124.9663	124.1357	46.3049	63985.4	3654.5	233835635.0	114	275256.9
5	124.1334	124.9592	46.4635	63427.8	3674.5	233068236.4	178	172263.6
6	124.9620	124.1522	46.6352	62008.1	3715.1	230368318.8	50	47696.9
7	124.1710	124.9972	46.7938	63077.5	3634.4	229249333.2	22	17364.1
8	125.0263	124.2918	46.9707	55889.8	3674.8	205383452.4	84	266416.0
9	124.2644	125.0533	47.1300	59851.1	3521.9	210786602.0	85	71875.1
10	125.1872	124.4062	47.3144	59051.6	3557.0	210045575.4	24	30963.6

Table 7. Transect data for survey of Area 1-C on 8-23-08 (replicate 2).

Transect ID	Start Longitude	End Longitude	Mean Latitude	Length (m)	Mean Width (m)	Area (m^2)	School Count	School Cover (m2)
1	124.0532	124.8634	45.8042	62982.7	3646.9	229688603.5	87	95252.2
2	124.8711	124.0427	45.9653	64207.1	3642.1	233848112.3	0	0.0
3	124.1068	124.8398	46.1394	56636.1	3661.6	207381547.7	191	293787.5
4	124.9559	124.1783	46.3110	59903.7	3623.5	217059887.0	51	101557.6
5	124.1343	124.6445	46.4716	39187.9	3651.1	143080139.2	87	180056.0
6	124.6401	124.1370	46.6418	38517.0	3742.7	144157059.3	161	185599.9
7	124.1679	124.5771	46.8047	31244.2	3666.1	114543209.2	109	106550.5
8	124.5803	124.2590	46.9727	24447.6	3759.9	91919385.2	55	72379.9
9	124.2640	124.5653	47.1347	22855.0	3642.4	83246762.7	146	164676.0
10	124.5640	124.3565	47.3123	15688.8	3790.3	59465547.9	156	207433.8

Table 8. Transect data for survey of Area 1-C on 8-26-08 (replicate 3).

Transect ID	Start Longitude	End Longitude	Mean Latitude	Length (m)	Mean Width (m)	Area (m^2)	School Count	School Cover (m2)
1	124.8726	124.0426	45.7990	64527.2	3655.9	235905197.2	56	116268.8
2	124.8632	124.0458	45.9678	63348.1	3726.3	236055108.0	306	501263.3
3	124.1372	124.8508	46.1326	55141.0	3688.9	203407185.4	264	305126.6
4	124.9554	124.1565	46.3009	61544.6	3627.8	223271533.9	16	16702.6
5	124.1456	124.9640	46.4640	62868.3	3625.5	227929045.0	23	21139.7
6	124.9568	124.1338	46.6342	63016.3	3666.4	231045786.2	215	327910.6
7	124.1761	124.7911	46.8011	46959.2	3719.6	174670545.3	95	216257.0
8	124.4645	124.2585	46.9682	15673.6	3672.3	57558212.3	0	0.0
9	124.4125	125.0864	47.1373	51128.4	3672.4	187765292.1	201	580601.9
10	125.2015	124.3702	47.3031	62854.7	3646.9	229227171.8	22	71690.9

Table 9. Estimates of sardine school density, number, and cover from three replicate surveys of Area 1-C.

	8/22/2008	8/23/2008	8/26/2008
Density (schools/km^2)			
$\hat{D}$	0.3579	0.6842	0.597
$\hat{V}(\hat{D})$	3.48E+15	2.57E+14	2.37E+14
$\hat{SE}(\hat{D})$	5.90E+08	1.60E+07	1.54E+07
CV	0.1649	0.2343	0.2577
Lower CI	0.2422	0.37	0.2954
Upper CI	0.4735	0.9984	0.8985
Total number of schools			
$\hat{T}$	3,757.4	4,848.0	5,564.6
$\hat{SE}(\hat{T})$	619.5	1,135.9	1,434.1
CV	0.1649	0.2343	0.2577
Lower CI	2,543.1	2,621.7	2,753.9
Upper CI	4,971.7	7,074.4	8,375.4
School Cover (m^2)			
$\hat{Z}$	6,194,773.3	6,473,549.3	9,922,022.4
$\hat{V}(\hat{Z})$	3.2524E+12	1.1270E+12	7.1741E+12
$\hat{SE}(\hat{Z})$	1,803,445.7	1,061,662.2	2,678,441.1
CV	0.3	0.2	0.3
Lower CI	2,660,019.7	4,392,691.4	4,672,300.0
Upper CI	9,729,527.0	8,554,407.3	15,171,766.9

Table 10. Summary of eleven point sets conducted from 7-27-08 through 9-21-08 in Area 1-C.

School Cover (m^2)	Biomass (mt)	School Height (m)	Biomass (mt) Pilot	Biomass (mt) Fishermen	Percent Captured Pilot	Percent Captured Fishermen
3763.9	80.5	3.7	40	40	100	100
2543.9	61.9	7.3	20	55	100	100
3763.8	40.3	9.1	50	40	100	100
3262.6	44.2	7.3	20	50	70	100
1121.7	39.2	7.3	45	35	90	100
9308.4	86.4	7.3	60	80	90	100
657.4	50.5	5.5	20	50	90	90
1175.3	35.8	7.3	40	40	30	100
3001.9	25.6	7.3	20	40	100	80
2399.8	71.2	14.6	60	100	80	80
2614.1	73.6	11.0	30	80	75	100

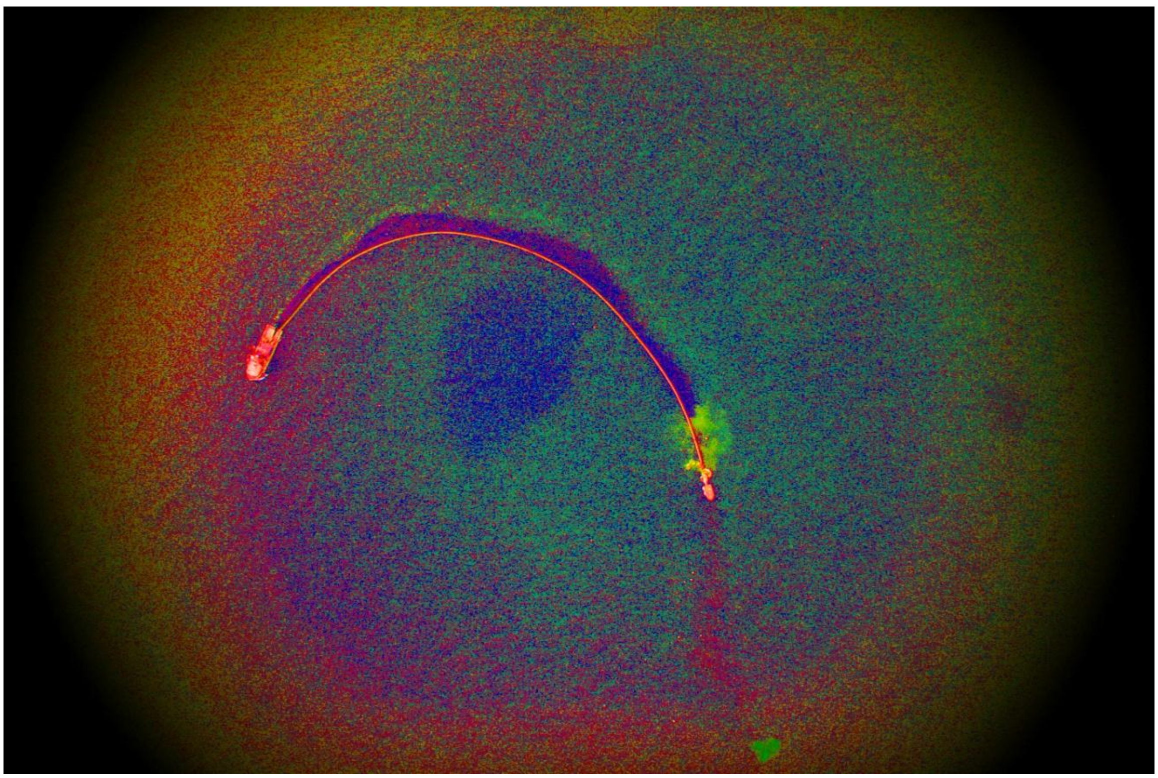

Figure 12. Point set by the purse seine vessel Lauren L. Kapp, 7-27-2008. School size: 3780 m^2. Landed weight, 80.5 mt.

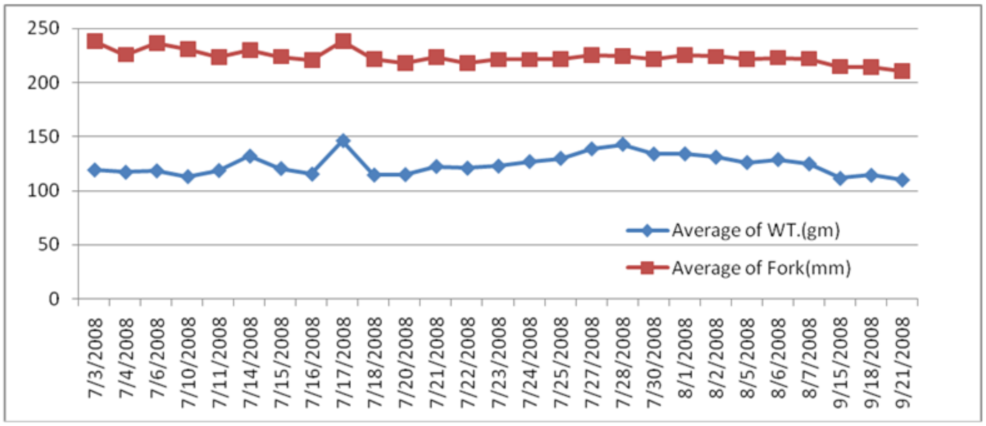

Figure 13a. Relationship between average fork length and average weight by date.

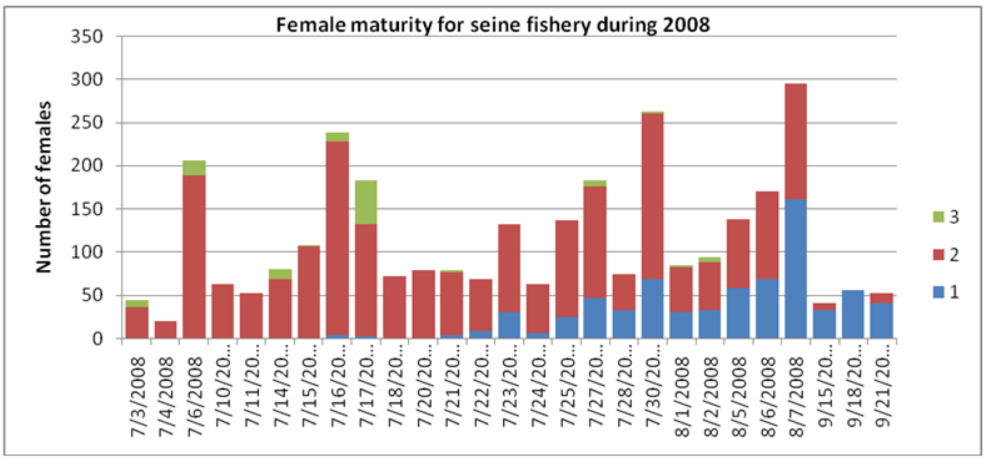

Figure 13b. Maturity of female sardines captured off Washington and Oregon from July through September 2008. Maturity codes: 1 immature 2= developing or recovering and 3 = Active or oocytes visible).

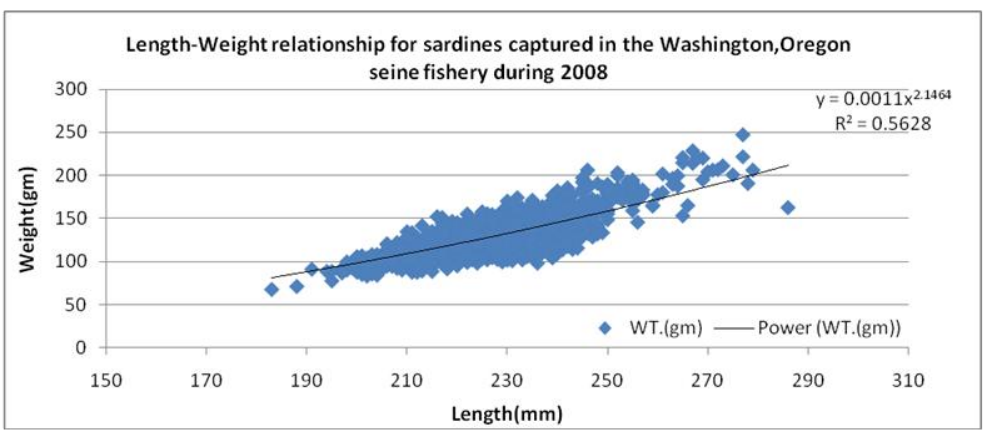

Figure 13c. Relationship between average fork length and average weight.

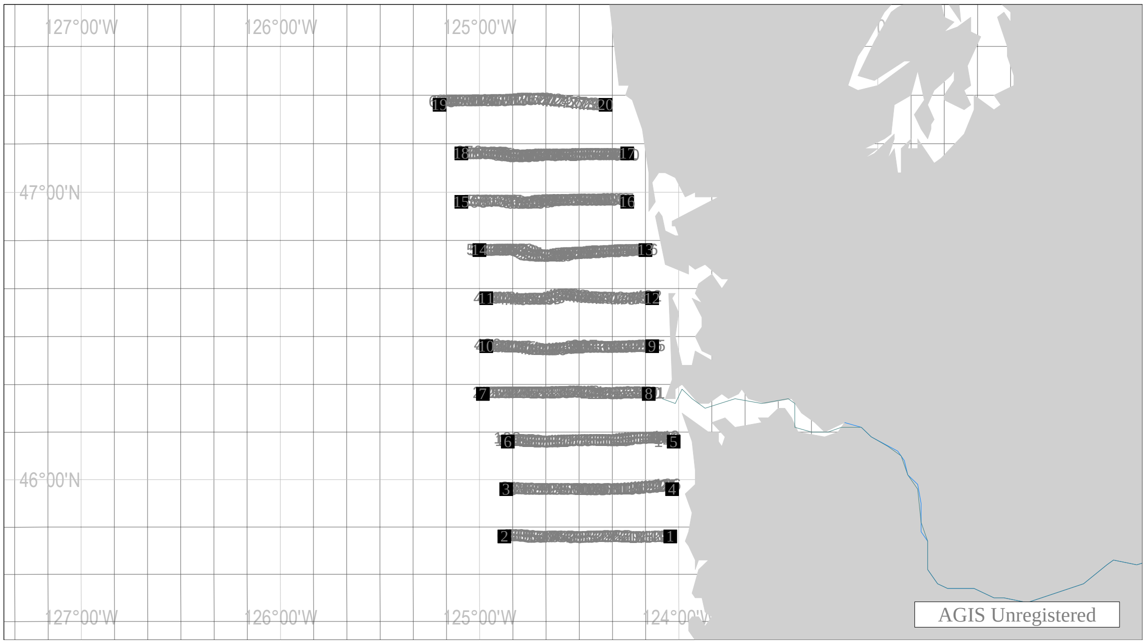

Figure 14a. Transects conducted on 8-22-08 in Area 1-C.

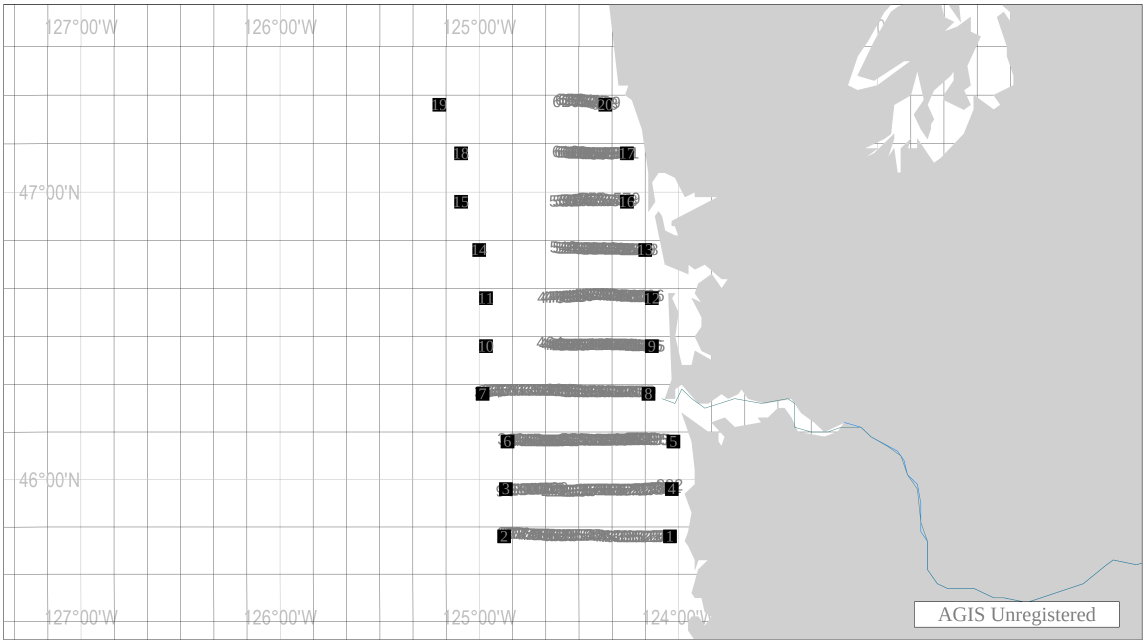

Figure 14b. Transects conducted on 8-23-08 in Area 1-C.

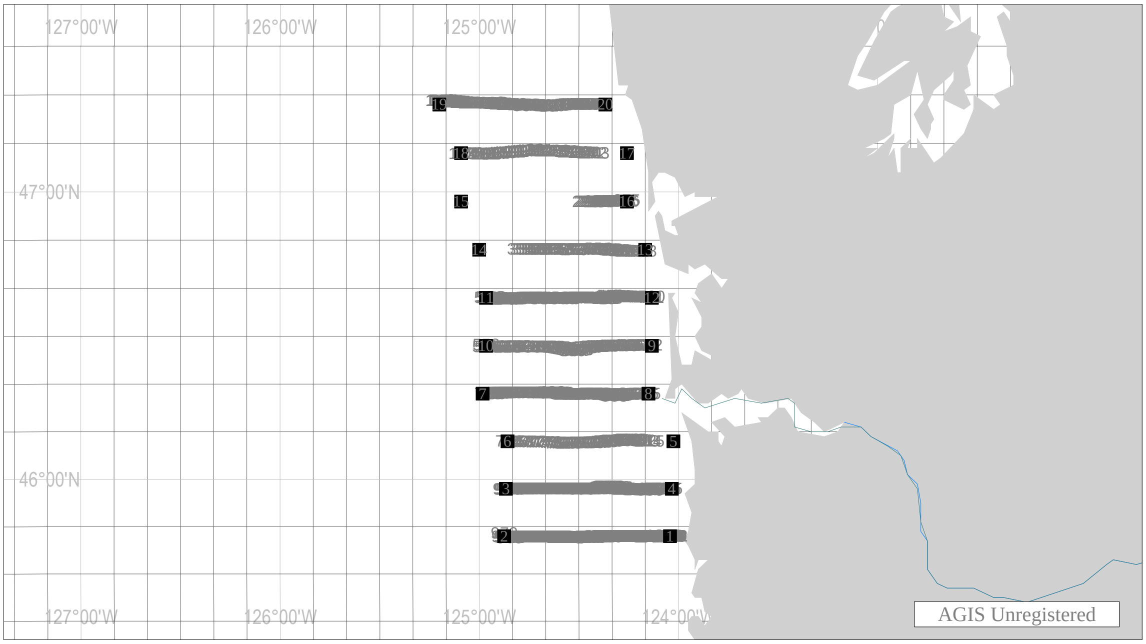

Figure 15. Transects conducted on 8-26-08 in Area 1-C.

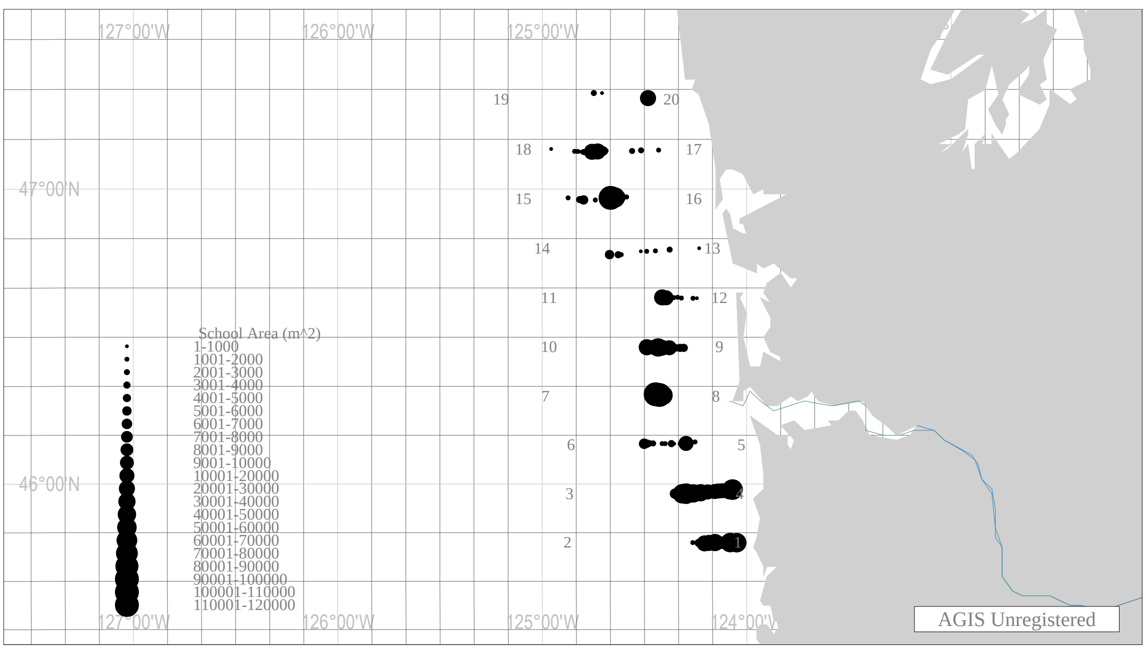

Figure 16. Distribution of sardine schools on 8-22-08 in Area 1-C.

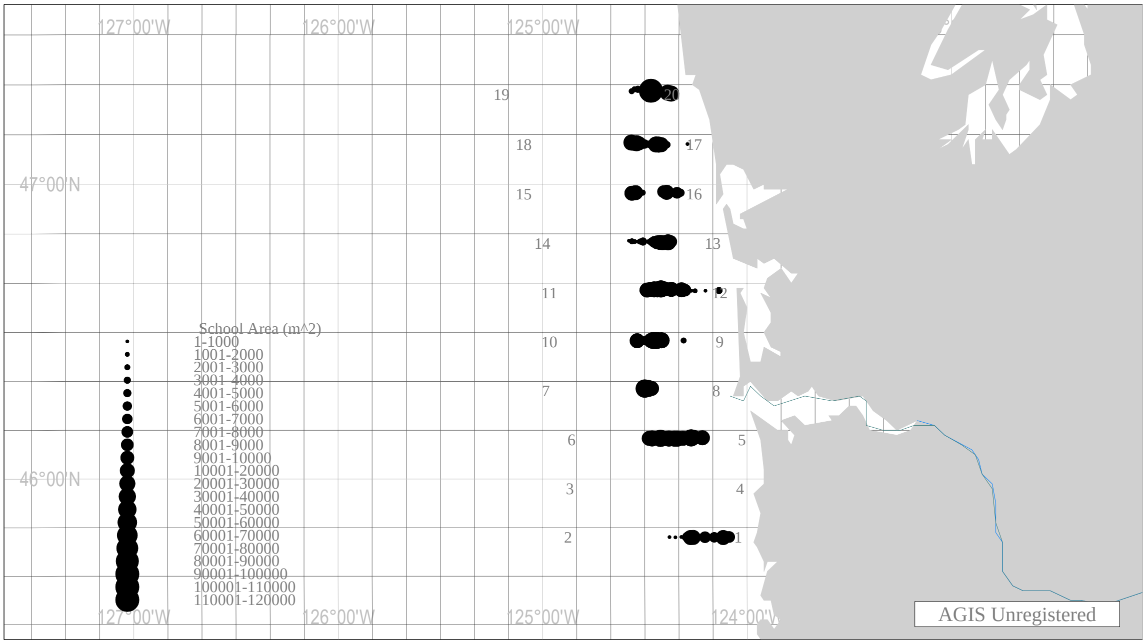

Figure 17. Distribution of sardine schools on 8-23-08 in Area 1-C.

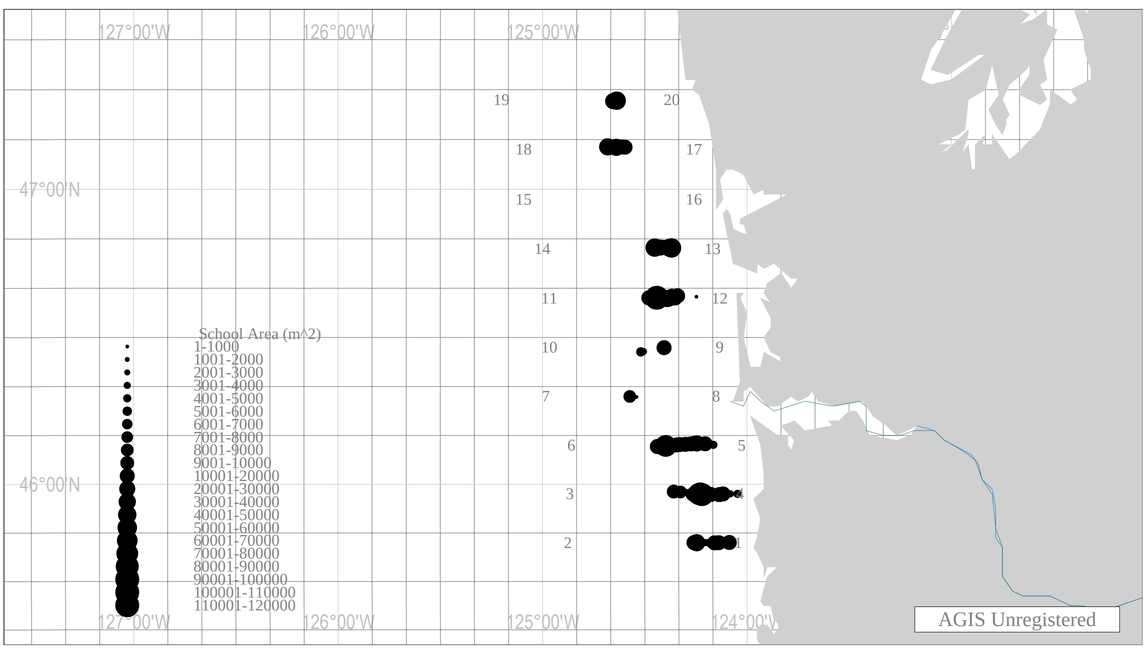

Figure 18. Distribution of sardine schools on 8-26-08 in Area 1-C.

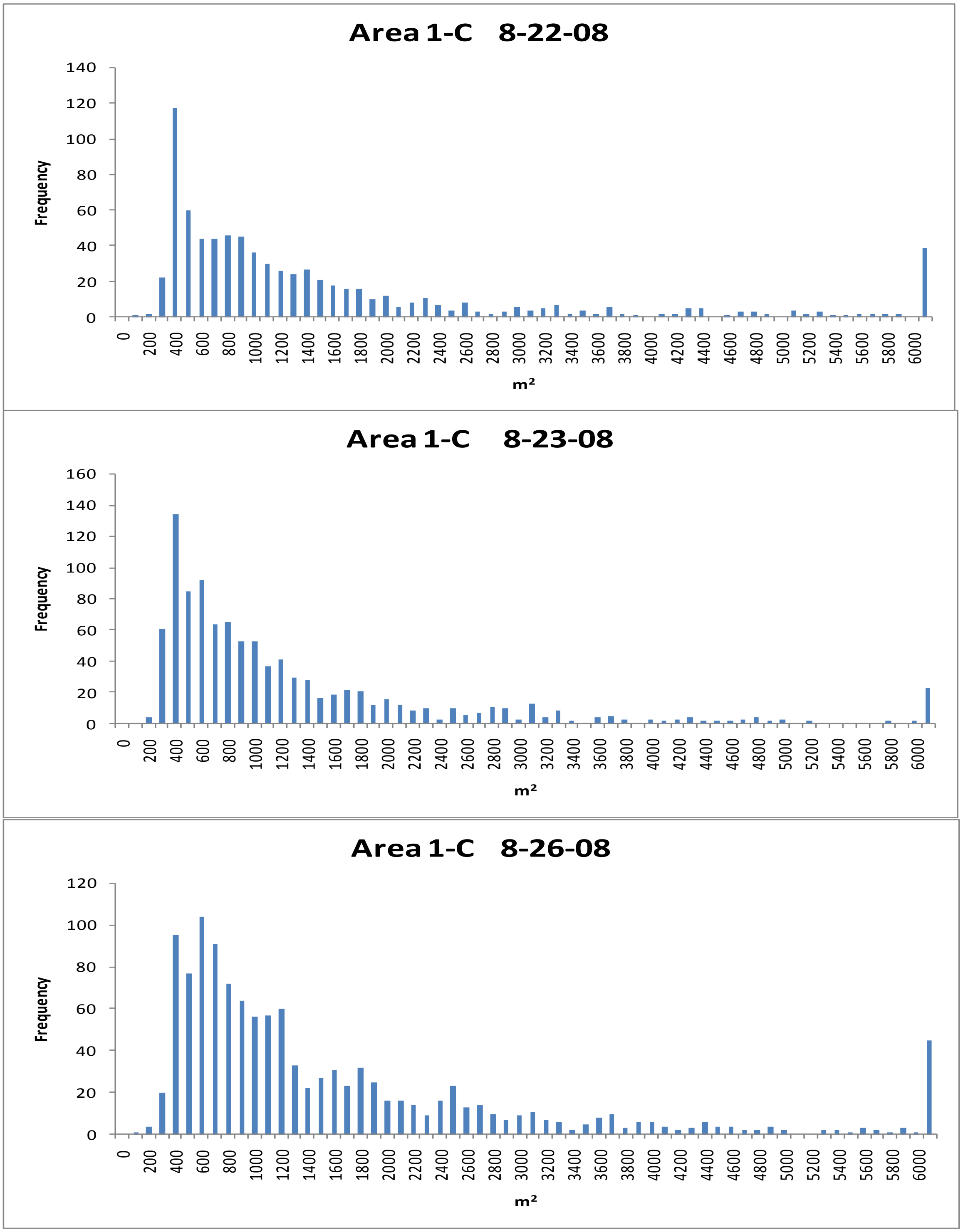

Figure 19. Histograms showing size distribution of individual sardine schools from three replicate surveys of Area 1-C.

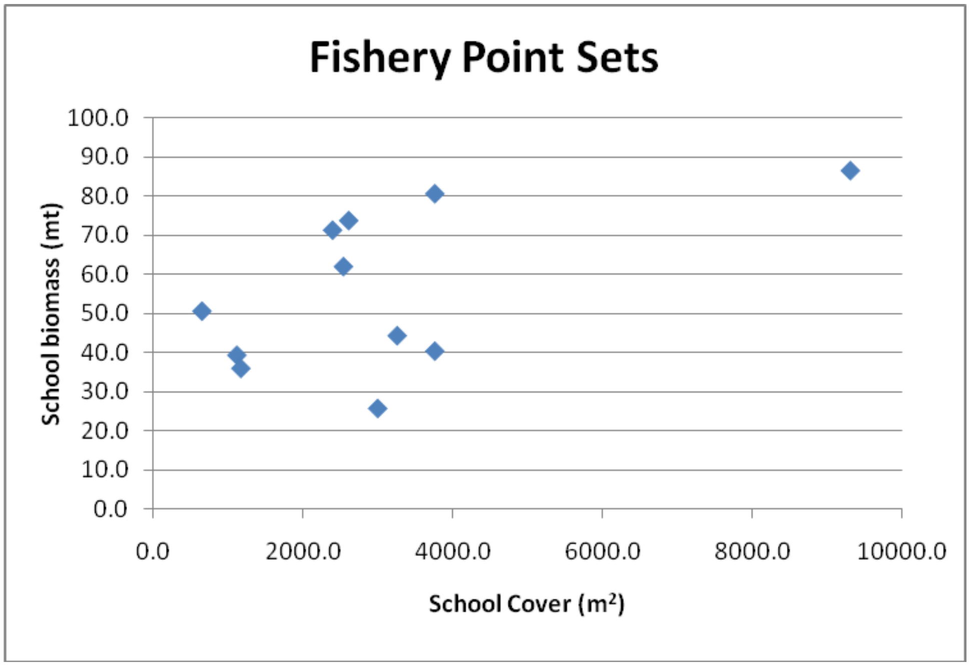

Figure 20. The relationship between school cover (m^2) and school biomass (mt) from 11 fishery point sets made from 7-27-08 through 9-21-08.

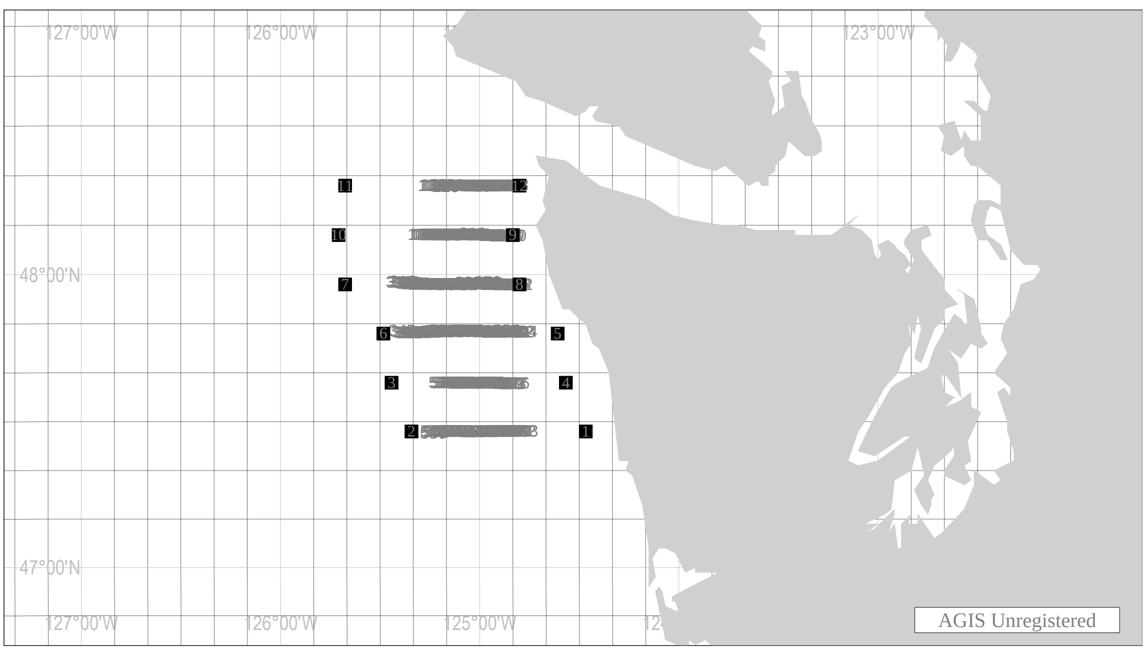

Figure 21. Transects conducted on 9-11-08 in Area 1-N.

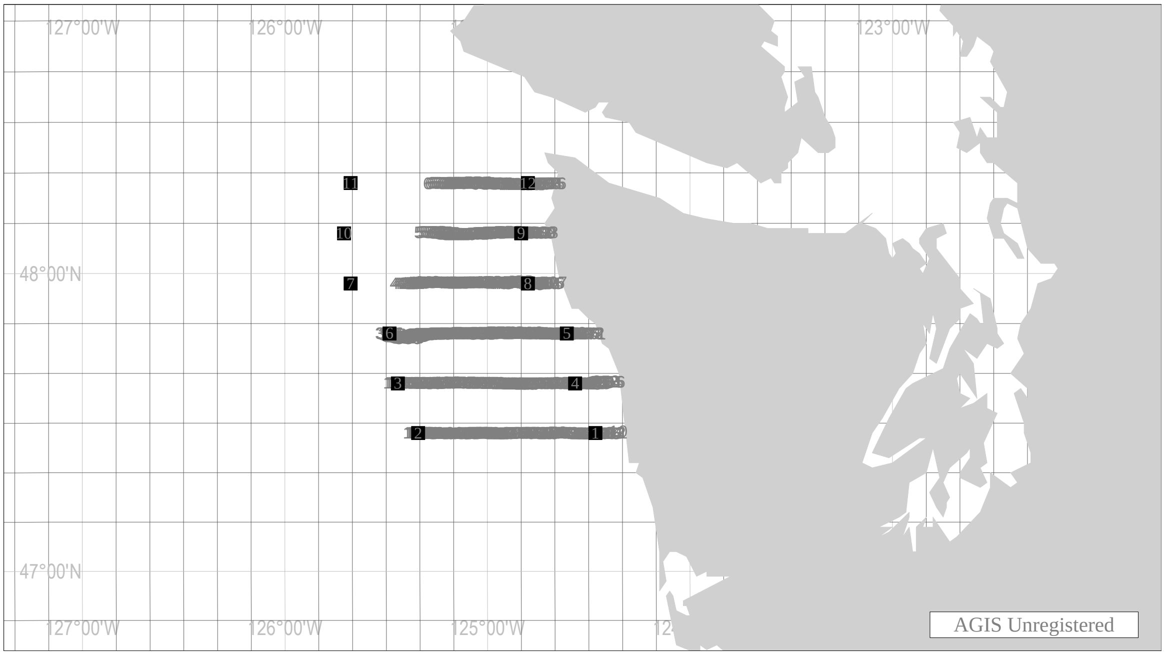

Figure 22. Transects conducted on 9-23-08 in Area 1-N.

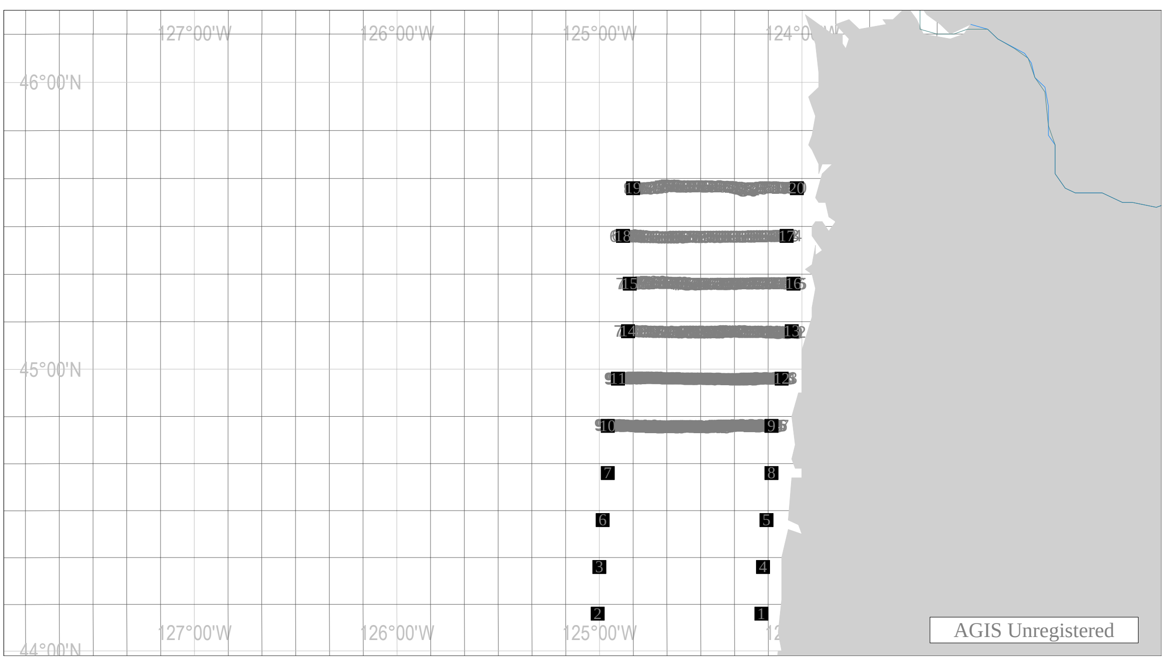

Figure 23. Transects conducted on 9-27-08 in Area 1-S.

Figure 24a. Aerial digital image of vessel collecting ES-60 echo soundings on sardine schools.

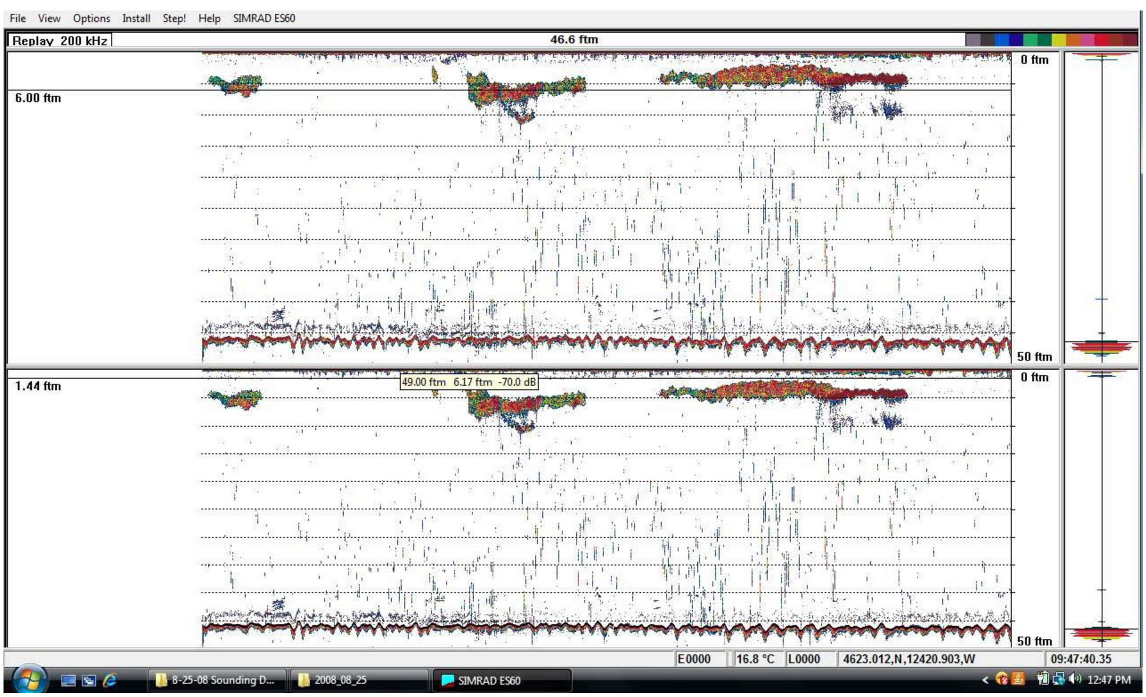

Figure 24b. Corresponding ES-60 echo soundings for photograph above (Figure 24a).

Figure 25a. Aerial digital image of vessel collecting ES-60 echo soundings on sardine schools.

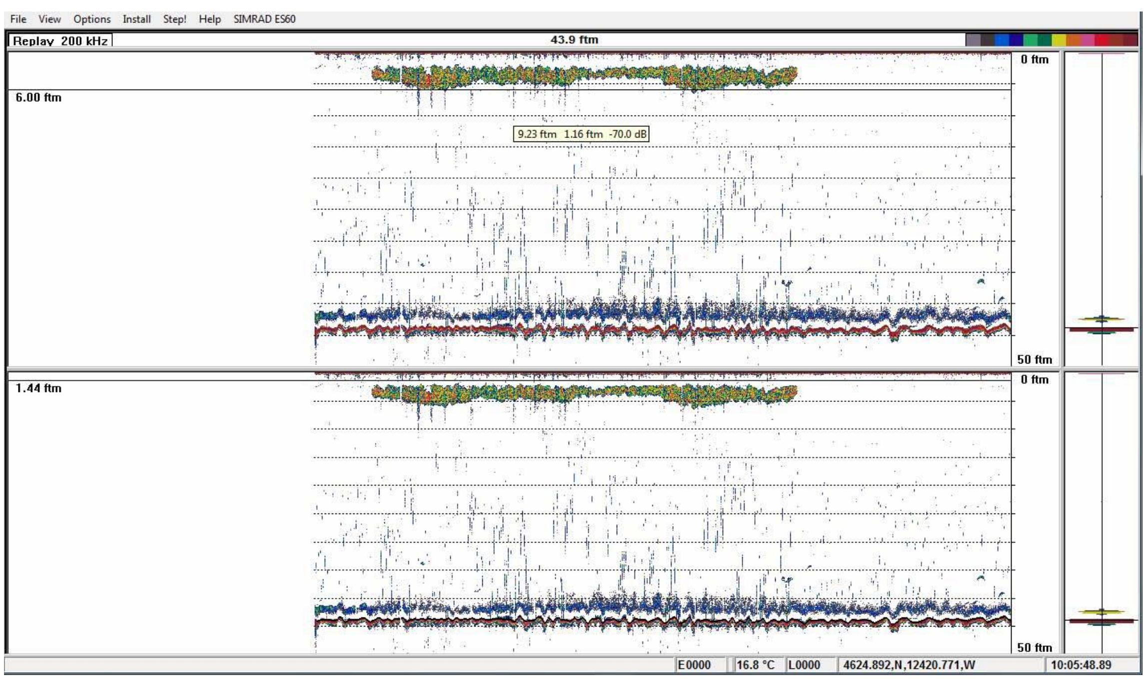

Figure 25b. Corresponding ES-60 echo soundings for photograph above (Figure 25a).

Work Group 1 2008 Recommendations

United States

- 2009 DEPM and CalCOFI surveys in March and April
- Biomass estimates from acoustic data for 2003-2008
- Aerial surveys off NW by the industry
- Possible aerial surveys off California, collaborated with industry
- Possible tagging experiment of sardine using electronic acoustic receivers used for salmon inshore, may need to expand offshore
- Tag sardine from Oregon Coast Aquarium to assess feasibility of tagging and design an experiment (John Ferguson). Bob Emmett will be responsible for feasibility study; post-surgery evaluation, mortality, behavior, etc. Barbara Javor may be able to coordinate similar effort in San Diego.
- Assist T. Baumgartner with counting and staging of sardine eggs
- Think about doing a survey in the NW using a similar net as the Canadians concurrently (end of July, beginning of August). Gear comparison possibly using Aleutian wing
- Ground-truth acoustics with high speed stereo cameras. Use on trawls setting on schools. May be problematic because most trawling occurs at night, but will calibrate acoustics.

Canada

- Regular trawl survey
- Aerial survey during the trawl survey (end of July or beginning of August)
- Compare size and age structure

Mexico

- See above with regard to T. Baumgartner and DEPM surveys.

References

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

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

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

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

Work Group 2: Stock structure, age structure, and adult sampling
Russ Vetter (SWFSC)

SWFSC/Ensenada

- Otolith morphometrics and stable isotopes, as well as genetics in progress
- Not enough genetic markers
- Physiology experiments, temperature preference, aquaculture
- Northern stock of sardines are detrimental above 21 degrees C
- 50 new genetic markers from 3 distinct populations (offshore North, inshore and Magdelana Bay)
- Need to be explicit about where samples are coming from (onshore/offshore, North/South)

2009 Needs

- Rebecca Baldwin will be continuing with her potentially valuable work on sardine parasites.
- We need to know the age structure of the fishery. Unfortunately these data are not often available at the TriNational Meeting. Andrew Claiborne is capable of ageing OR fish. He will age the fish captured by NMFS off Oregon/Washington and have these data available for 2009 meeting.
- Age information is very important: We will organize an inter-agency sardine ageing workshop (during CARE meeting in April), or take photographs of otoliths as a teaching aid for all agencies
- Ageing error matrix for Stock Assessment Model
- Need more adult samples from all areas of the population
- Need to do more sardine diet work.
- E• cosystem modeling in collaboration with John Field would be valuable

Work Group 3: Industry Trends and Issues

Pacific Seafood – Mike Okoniewski

- Fishermen are dedicated, hard workers
- The Pacific sardine fishery has a number of different components: resource, harvest capacity, market, financing, research, accounting
- Research needs to work with industry to fund, inform policy (inter-dependence)
- As an industry, we need to know every step of our operation
- Research priority for industry: biomass estimates along 1600 miles off Pacific coastline don't appear to be accurate
- Aerial survey results seem to be producing real results. These should continue.
- Need to find solutions to reduced sardine quota.
- Collaborate to provide better biomass estimates and to better understand how the resource expands and contracts
- The market is in good shape to handle 200,000 mt/$40 million of sardine (shelf stable, can be provided to Third World)
- Nutritious source of protein

Gold Coast

- Why are we not looking at CPUE? There's fish out there.
- Results will be seen in Canada first
- Be cautious when recruitment is low
- Bioeconomic model should include 5 parties: tribal component in NW, NW (OR and WA), southern US, Canada, Mexico
- User groups on this resource will continue to grow
- Cumbersome as biomass estimates decline
- Don't know if the 2003 year-class is all that is being exploited
- Fleet can avoid younger year classes
- Parallels between sardine and hake fishery
- Big change in markets, processing capacity

Canadian Sardine Association

- We are critical of SS2 model for Pacific sardine.
- Canadians want better science by supporting US Aerial Spotter Index and ground truthing with trawling, and calibrated sonar
- We can develop a benchmark
- Need at least 5 more years of data

Fishery

- Fishery issue: disconnect between fishermen and science
- 2 STAR panels in the upcoming year, 2 quota options and terms of reference
- Need a range in biomass estimates to resolve the huge differences between SS2 biomass estimates and Aerial Spotter Index biomass estimates

Conclusions

- Sardines are colonizers and their expansion process will involve behavior changes because they are so dynamics
- Something with the sardine fishery has changed
- Taiwan, Ukraine and Russia are markets for big fish
- One large year-class can lead to population increases
- There has been poor sardine recruitment over the last 2 years, especially in the Northwest. Although sardine successfully recruit in the NW during some years.
- Seeking Congressional support for additional research resources.
- Industry in poor condition to financially support US Aerial Spotter Index Study
- Need a sustainable volume to support the sardine fishery
- Industry WANTS collaboration with sardine Stock Assessors
- We need to work together so where does the TSF go from here?
- Canadian sardine fishery can be used as an indicator of what is going on throughout the coast
- Cross-national management scheme needed
- Fishery willing to be political

NMFS Response

- Aerial surveys have inefficiencies that need to be addressed
- Acoustics will probably be NMFS major focus for the future to assist with sardine assessment
- Aerial surveys miss SL, fecundity and other important biological information (e.i., recruitment issues)
- Economic outlook is grim for NOAA
- Assessment and review as an International effort rather than a PFMC issue

Work Group 4: Biological and Economical Modeling

Sam Herrick

- Recommended that there be an integrated modeling group (Sam Herrick, NOAA, John Field, NOAA, Sandy McFarlane, DFO, and Don Pepper, CPSA)
- Sardine and ecosystem services
- Critical value for non-commercial predators (recreationally important predators and ecologically important predators or public goods)
- Evaluate the trade-offs between sardines as harvest versus sardine as forage
- Sardine Centric Ecological Economic Model of the CCE
- Value all the uses: consumption for human, bait, aquaculture, recreational, and predators (orcas, whales, birds)
- Trade-off between harvest and forage can provide value of ecosystem services
- Forage is transformed into the annual production of commercial predators and non-commercial predators
- Look at the values of the 2 outputs and the returns on the resource
- Assume a constant net value for harvest and forage
- Maximize net social benefits balancing harvest and forage
- These are going to be used by policymakers
- Requires a great deal of economic (market, non-market values) and ecological data (sardine predators)
- Also interested in a theoretic model developed to examine the interactions between forage fish and aquaculture
- Transboundary Management
- Total Economic Value of sardines in the entire CCE

Comments

- The problem of assigning a monetary value to ecosystem services
- Not engaging in dialogue with the environmental community is dangerous because sardine as forage is a sensitive issue
- Resources are not managed entirely on maximized net benefit to society
- Ecosystem-based fishery management (EBFM) has not fully been realized in this meeting
- How do we manage a highly dynamic species in a highly dynamic ecosystem without the resource crashing because they DO crash
- Maybe we need an integrated ecosystem assessment or an eco-cubed model including the environment (oceanography)
- This will be an inter-disciplinary exercise
- Does managing for optimal yield according to the M-S Act include limiting MSY for ecosystem trade-offs?

CONCLUSIONS

Future of the Trinational Sardine Forum

It was the consensus of the attendees that there might be some benefits for establishing the TSF as an official International Organization. Creating an “official” organization could possiblly leverage funds for research and may lead to better management, benefiting the industry in all countries. However, it was also felt that formalizing the TSF may lead to limitations to agency research personnel and adding a layer of bureaucracy that would hinder the working of the TSF. Any new TSF would probably have to be initiated by Industry. TSF was established as an informal forum by John Hunter in 2000 to talk without restriction

It was also agreed that the Trinational meeting is playing in important role dealing with transboundary management of sardine. The attendees also encouraged the industry to push for coordinated research efforts.

Other issues discussed:

- Develop a TOPP (Tagging of Pacific Predator) like website or a BLOG for TSF
- TSF was established as an informal forum by John Hunter in 2000 to talk without restriction: It has worked very well.
- The two coast-wide sardine surveys are a direct result of the TSF
- Formalizing the TSF may lead to limitations and bureaucracy
- Next year's meeting will be in La Paz, Mexico between November and December
- PICES Sardine Working Group may be an appropriate forum to "officialize" the TSF without getting to bureaucratic

Meeting Adjourned 15:56 December 5, 2008

ACKNOWLEDGEMENTS

Putting on the annual TSF takes a host of people. Special thanks go to the TSF Program Committee and Executive Committee, Drs. Nancy Lo, Sharon Herzka, and Jake Schweigert. Mike Okoniewski and Pacific Seafoods supported the TSF banquet. Jill Smith was instrumental in setting up all meeting logistics in Astoria, OR. Marisa Litz, Andrew Claiborne, and Paul Bentley greatly assisted with registration/meeting logistics. The Northwest Fisheries Science Center also provided some financial support for the meeting. Finally, thanks to the Astoria Seafood Consumer Center for the venue and lunches.

APPENDIX I

LIST OF PARTICIPANTS

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Astoria, Oregon, United States of America
December 4-5, 2008

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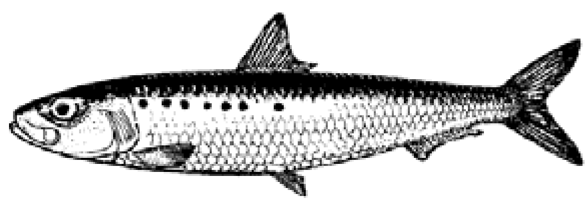
APPENDIX II
English Agenda

9th ANNUAL

TRINATIONAL SARDINE FORUM
FORO TRINACIONAL DE LA SARDINA



2008
PROGRAM

The Seafood Center
2021 Marine Drive, Suite 200
Astoria, OR 97103
(503) 338-4485
December 5-6, 2008

Wednesday, December 3rd
P.M. Arrival in Astoria, OR.
18:00-21:00 Informal welcome gathering – The Wet Dog Café – walking distance from the Holiday Inn Express.

Thursday, December 4th

8:00 **Registration**

9:00 **Meeting Logistics** – Robert Emmett, NMFS, Jill Smith ODFW

9:05 **Welcome and opening remarks** – John Ferguson, Director, Fishery Ecology Program, Northwest Fisheries Science Center

9:15 **Key Note Address:** Elements to consider in sardine management: Alec MacCall – Southwest Fisheries Science Center

10:00 *Break*

Regional Sardine Fisheries Reports

Gulf of California, *Unavailable.*

10:15 Baháa Magdelena, Kevin Hill, SWFSC

Ensenada (N. Baja), *Unavailable*

10:35 California, Dale Sweetnam (CDFG)

10:55 Oregon, Jill Smith (ODFW)

11:15 Washington, Jill Smith (ODFW)

11:35 Overvew of the Pacific sardine fishery off British Columbia in 2008 - Cynthia Johnston and Jake Schweigert (DFO)

11:55 *LUNCH – CATERED BY THE SEAFOOD CENTER*

Regional Sardine Fisheries Reports (Continued)
Research Plans and Reports Stock structure (genetics, microchemistry, traditional approaches, others)

13:30: Biomass estimates - Nancy Lo (SWFSC)

13:50 Stock assessment – Kevin Hill (SWFSC)

14:10 Pacific sardine research off the west coast of British Columbia – Jake Schweigert and Linnea Flostrand. (DFO)

14:30 The Feasibility Of Using An Aerial Survey To Determine Sardine Abundance Off The Washington-Oregon Coast In Conjunction With Fishing Vessel Observation Of Surveyed Schools And Shoals. Ryan Howe, Tom Jagielo, and Vidar G. Wespestad

14:50 Pacific Sardine Biomass Estimates and Associated Oceanographic Conditions off Northern Oregon and Southern Washington in 2008. Robert Emmett and Paul Bentley (NOAA, NWFSC).

15:10 *BREAK and* POSTER SESSION

15:50 Community and Genetic Analyses of Macroparasites from Pacific sardine (*Sardinops sagax*) caught in the California Current System - Rebecca Baldwin (OSU, CIMRS), Kym C. Jacobson (NOAA, NWFSC), Mattias L. Johansson (OSU, COMES), Michael A. Banks (OSU, CIMRS)

16:10 Physical Attributes of Sardine Otolith as a Tool for Detecting Regional Populations - Barbara Javor and Russ Vetter (NOAA, SWFSC)

16:30 Temporal patterns of forage fish and mesozooplankton in the Columbia River plume. Amanda M. Kaltenberg (OSU), Kelly Benoit-Bird (OSU), Robert Emmett (NOAA, NWFSC)

16:50 Adjourn

18:00-21:00 Dinner at The Bayview Bistro

Friday, December 5th Research Plans, Reports, and Analysis

9:00 Three Complete California Current Ecosystem Surveys Conducted in 2006 and 2008.

B. Macewicz and D. Griffith (NOAA, SWFSC)

9:20 Dynamics of sardine population in 2008: Panel Discussion. Vetter, Emmett, Schweigert

9:40 10:00 Fisheries Management for Adults. Don Pepper (Canadian Pacific Sardine Association)

10:20 *Break*

Working groups PLENARY (led by)

10:30 WG1: Regional biomass/Surveys-Nancy Lo (SWFSC)

11:30 *LUNCH – CATERED BY THE SEAFOOD CENTER*

12:30 WG2: Stock structure, age structure and adult sampling-Russ Vetter (SWFSC)

13:30 WG3: Industry trends and issues- Mike Okoniewski (Pacific Seafoods),

14:30 WG4: Integrated biological, economic and oceanographic modeling – Sam Herrick (SWFSC)

15:30 Closing remarks – Future Plans – Robert Emmett and Nancy Lo

16:00 *Adjourn*

POSTER SESSION

Physiological status of Pacific sardines (*Sardinops sagax*) to different thermal regime assessed using blood parameters.
M Martínez-Porchas, M.Hernández-Rodríguez and L.F.Bückle-Ramírez (CICESE)

Analysis of Pacific sardine stocks derived from number of vertebrae.
Andrew Claiborne (NOAA, NWFSC), Robert Emmett (NOAA, NWFSC) and Rebecca Baldwin (OSU)

The effects of variable oceanographic conditions on forage fish lipid content and fatty acid composition in the northern California Current
Marisa N. C. Litz (OSU, CIMRS), Richard D. Brodeur (NOAA, NWFSC), Robert L. Emmett (NOAA, NWFSC), Selina S. Heppell (OSU), Rosalee S. Rasmussen (OSU), Linda O'Higgins (OSU, CIMRS), and Matthew S. Morris (NOAA, NWFSC)

Contrasts and similarities of three complete California Current ecosystem surveys conducted in 2006 and 2008.
B. Macewicz and D. Griffith (NOAA, SWFSC)

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 – Mike Okoniewski (Pacific Seafoods), Don Pepper (Canadian Pacific Sardine Association), Diane Pleschner-Steele (CWPA).
WG4: Biological and Economical Modeling - Sam Herrick (SWFSC)

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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
CIMRS	Cooperative Institute for Marine Resource Studies
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
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

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

COMMUNITY AND GENETIC ANALYSES OF MACROPARASITES FROM PACIFIC SARDINE (*SARDINOPS SAGAX*) CAUGHT IN THE CALIFORNIA CURRENT SYSTEM

Rebecca E. Baldwin[1], Kym C. Jacobson[2], Mattias L. Johansson[3], Michael A. Banks[3]

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In 2005, we started a research project using the macroparasites acquired through infected prey to assess the population structure of Pacific sardine (*Sardinops sagax*) within the California Current System (CCS). Approximately 2200 sardines were collected from 2005 through 2007 between 50^{o} to 32^{o} North latitude, and 120^{o} to 125^{o} West longitude. To date, eleven parasite species have been recovered from approximately 1000 sardines, with five parasite species identified as potential biological tags. The trematodes *Lecithaster gibbosus* and *Pseudopentagramma petrovi* were common only off of Vancouver Island, while the nematode *Anisakis* spp. was common from Vancouver Island to northern California. The trematodes *Parahemiurus merus* and *Myosaccium ecaude* were found throughout the study area but were most prevalent off of southern California. Recently a population genetic analysis of the mitochondrial gene *COX2* in Anisakis spp. was initiated as a complementary approach to the macroparasite community analysis. Fifty-five unique haplotypes were observed in 66 individual nematodes. All DNA sequences were alignable at 74% similarity, and the overall nucleotide diversity was 4.7%. Identical nematode haplotypes were observed off of the Columbia River (n=4), the Columbia River and Willapa Bay, Washington (n=2), Newport, Oregon (n=2), and off of California at Point Delgada and Oceanside (n=2). More individual nematodes will be examined from off of Vancouver Island and southern California to assess if the genetic structure of *Anisakis* spp. can provide insight into the population structure of sardines. Throughout the CCS the parasite community of Pacific sardines varies in prevalence and intensity, suggesting at least four sardine populations may exist between Vancouver Island, British Columbia to Camp Pendleton, California.

PACIFIC SARDINE BIOMASS ESTIMATES AND ASSOCIATED OCEANOGRAPHIC CONDITIONS OFF NORTHERN OREGON AND SOUTHERN WASHINGTON IN 2008.

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

Two fishery oceanographic surveys, which collect juvenile and adult sardines and measure environmental conditions off Washington/Oregon, were conducted in 2008. These surveys have been conducted annually since 1998. Preliminary information from the Predator Survey (nighttime surface trawls) indicates that July and August 2008 sardine biomass estimates (using an area swept methodology) were slightly higher than in 2007. However, highest sardine catches, and thus biomass estimates, occurred in June 2008. This is similar to what occurred in 2007. The September 2008 Plume surface trawl survey from Newport, OR to Cape Flattery, WA caught no 0-age sardines. This is the first time this has been observed since we began this survey in 2008. This indicates that sardines may have not had any recruitment, or that they did not spawn off the Northwest in 2008. Ocean temperatures were anomalously cold in 2008 compared to past years. 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.

INTEGRATED MODELING REPORT TO THE 2008 TRINATIONAL SARDINE FORUM

Sam Herrick
Southwest Fisheries Science Center
8604 La Jolla Shores Dr., La Jolla CA 92037, U.S.A.

Value of sardine as forage:

In work that was reported on at last year's Trinational, we consider economic and ecological issues associated with the Pacific sardine as a commercially harvested species, relative to its importance as prey for species of commercial, recreational and ecological significance. Using economic theory and ecosystem modeling results for the California Current we investigated whether sardines might be more valuable as forage than as commercial landings. Our analysis considers various conditions under which this would be justified. For example, ex-vessel prices of commercially important sardine predators near the high end of their respective ranges in recent years, and the ex-vessel price of sardine at the low end of its respective range would favor leaving more sardine as forage fish. 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 indicate that consideration of the tradeoffs is a key element of ecosystem-based fishery management.

Tradeoffs

In the case of the Pacific sardine resource, the tradeoff of interest is between benefits from sardines as a directed harvest and sardines as forage. The proposal presented here builds on ongoing work to develop a modeling framework for evaluating the forage services provided by Pacific sardine in the California Current Ecosystem (CCE). Under a comprehensive, environmental-ecological-economic-based conservation and management approach (E^3BCM), the impacts of harvesting sardines will extend beyond directed commercial fisheries to consideration of the corresponding effects on sardine predators that constitute higher trophic level commercial and recreational fisheries, as well as non-harvested but ecologically important predators (e.g. marine mammals, seabirds) (Figure 1).

In this context, information about the tradeoffs the public is willing to make across alternative ecological services sardines provide is critical in evaluating the desirability of alternative E^3BCM policy options. To make these evaluations, the tradeoffs associated with different policies need to be expressed in terms of a common denominator that measures the range of benefits under each policy option; From the public's view this translates into the value that the Pacific sardine resource provides in terms of satisfying human needs and wants through its extractive use as directed commercial harvests, as well as to the indirect benefits it provides through its non-extractive use by humans, as forage (see for example Constanza et al. 1997). From an economic standpoint, harvesting sardines is justified if the expected net benefits from harvesting sardines exceed the loss in net benefits from not leaving them in the ocean as food for higher trophic level commercial predators, recreational important predators and non-harvested but ecologically important predators. So at the margin, the socially optimum level of harvest is where the incremental net benefits from harvesting equal the incremental net benefits of forage. This is the level of harvest that maximizes the total social value of the sardine resource.

Pacific sardine: California Current ecosystem servicies
Harvested for human consumption, bait, aquafeeds, aquarium feeds
Forage: direct consumption by commercial, non-commercial/recreational predators; indirect food web effects
Value added from higher trophic level comercial fisheries
Value added from higher trophic level recreational fisheries
Value added from food for ecologically important species

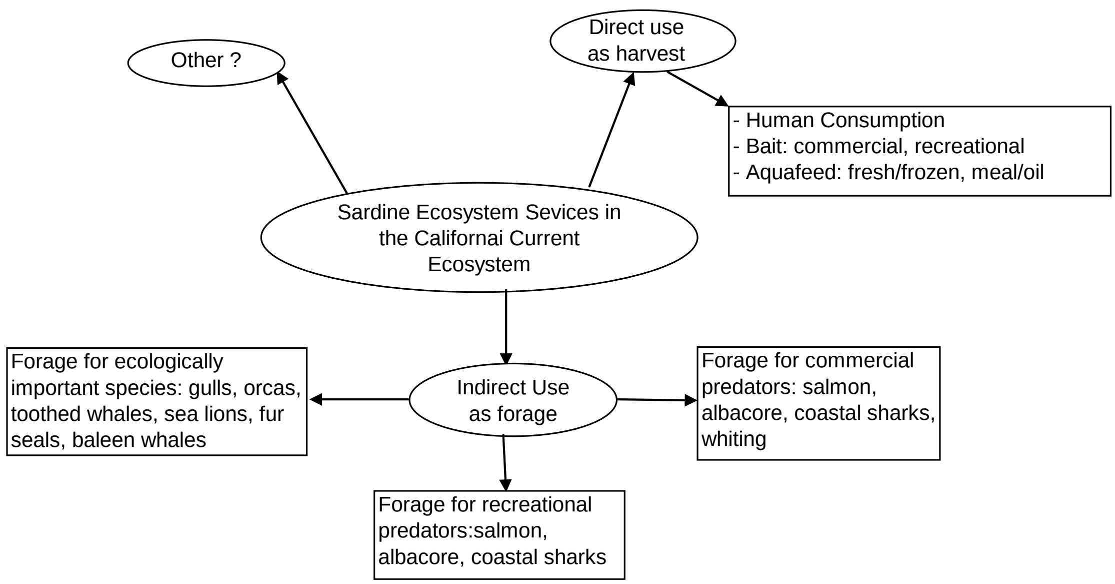

Figure 1. Pacific sardine California Current Ecosystem services.

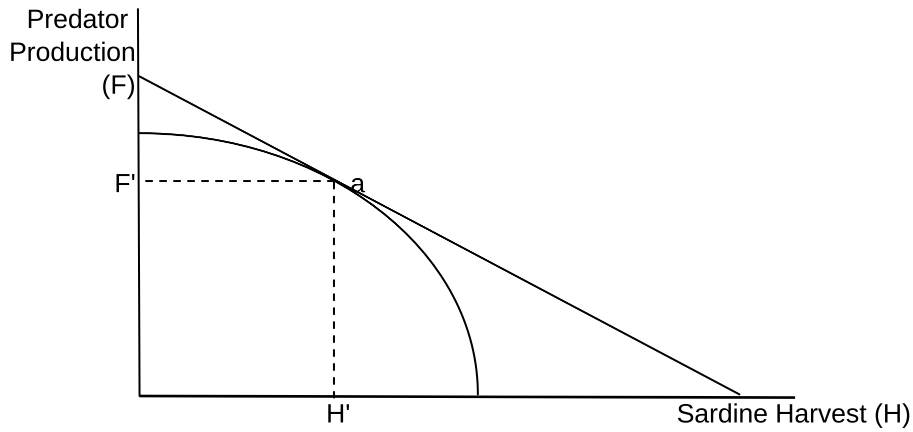

Figure 2. The Pacific sardine resource transformation frontier.

Diagrammatically this problem can be illustrated in terms of an output transformation frontier and the values of the ecosystem services that the Pacific sardine resource provides. The stylized transformation frontier in Figure 2 represents the combination of ecosystem services in terms of forage -- where forage is transformed into the annual production of commercial predators and non-commercial predators -- and harvests of sardines that the existing resource stock is capable of providing. The frontier will move inward or outward as the sardine biomass changes. Being on the frontier represents full utilization of the sardine stock, and movement along the frontier shows the combinations of aggregate production from forage (*F*) and directed sardine harvest (*H*) from full utilization of the resource stock. Theoretically, the frontier represents a specified quantity of inputs in the production of various quantities of *F* and *H*, it follows that all points on the curve reflect the same total cost of producing the aggregate output, but different quantities, of the two outputs. It can then be shown that the slope of the frontier is equal to the ratio of the marginal costs (MC_H/MC_F) of the two ecosystem services. Then, for a particular transformation frontier, the objective would be to select the combination of forage and harvest that maximizes total social value from the sardine stock. If per unit monetary values for harvest (P_H) and forage (P_F) are available, a total revenue (*TR*) curve can be constructed (represented as a straight line, $TR = HP_H + FP_F$ if per unit values are constant). The socially optimum combination of sardine harvest and sardine for forage occurs at the point of tangency of the total revenue curve with the transformation frontier (point a in Figure 2); i.e., where the slopes of total revenue curve and frontier are equal: $MC_H/MC_F = P_H/P_F$. The socially optimum levels of sardine predator production and sardine harvest are F′ and H′ respectively.

To quantitatively model this situation will require a great deal of detailed economic and ecological data. An indication of the data requirements can be seen from the economic and ecological interactions shown in Figure 3. On the economic side, the net benefits of harvesting sardines and their commercial predators can be derived from the market revenues and costs associated with their harvest. The non-commercial predators are not subject to market exchange: recreational catches are not sold;

ecologically important species are public goods. Therefore, evaluating the tradeoffs between harvesting sardines and leaving them in the ocean as food for non-commercial predators will require the use of non-market valuation techniques to enumerate the related benefits and costs of the ecosystem services sardine provide in this role. The net per unit values of the non-market predators can than be used to derive shadow prices for sardines as forage for the recreational and ecologically important predators. The sardine shadow prices will then be incorporated into the existing modeling framework enabling it to evaluate various tradeoffs and determine the socially optimum allocation of the sardine resource as illustrated in Figure 2.

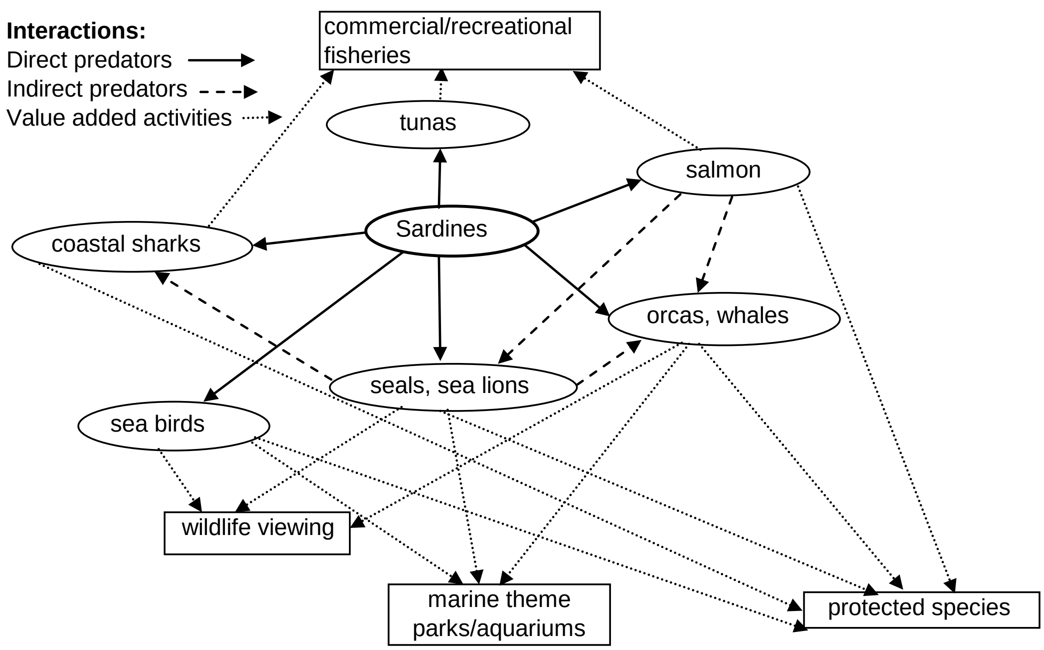

Figure 3. Sardine centric ecological and economic interactions.

On the ecological side, current work in this area has relied on the ecosystem model of Field et al. (2006). This model was developed for dynamic simulations of the Northern CCE, starting in the 1960s but based on food habits data over a broader time period. At that time, sardines were at very low levels of abundance. As a result, the predation and food conversion parameters in the Field et al. model are not likely to be representative for periods with greater sardine abundance or for predators and prey in the southern part of the CCE. The current work takes predation and food conversion parameters as being fixed at the 1960s levels. However, major changes in sardine stock levels and catches and in predator stock levels that have occurred since then are likely to affect these parameters.

Moreover, major changes in sardine stock levels and the spatial distribution of the sardine stock have been shown to be strongly influenced by climate induced environmental changes (Norton and Mason 2003, 2004, 2005; Herrick et al. 2007). These changes are propagated into the ecosystem which reacts by reorganizing trophic relationships and relative species composition. By incorporating the relevant environmental factors into the modeling framework we expect to enhance its predictive and dynamic capabilities, particularly with regard to different climate change scenarios. Therefore to confidently predict and evaluate the effects of a drastic change in sardine stock levels, like the return of the sardine fishery, we would need a more complete model; one that will take into account dynamic relationships between environmental, ecological and economic variables.

While the data requirements for an E^3BCM model may be monumental they are not insurmountable, and are expected to be realized in gradual manner. Nevertheless, incremental results from modeling efforts such as this will be useful for indicating the direction of changes and to illustrate that strategic consideration of the tradeoffs could be an important element of the decision-making and management process. From a comprehensive fishery conservation and management standpoint, the insights and information provided by this modeling effort will contribute greatly to the development of an ecosystem-based fishery management framework.

Related Projects

Aquaculture

As aquaculture has become more widespread, the demand for small pelagic fish species as feed for the cultured species has increased. This has raised concerns that the potential demand for small pelagics as feed in aquaculture is to the detriment of the production of wild fish, and marine life in general. In terms of cultured species that are also targeted by commercial fisheries, economists are interested in the most efficient use of small pelagics, whether as food in aquaculture or as forage for the corresponding wild stocks and other predators, or for direct human consumption as in the case of sardines.

This project will build on a theoretic model developed to examine the interrelations between aquaculture and fisheries in the context of an abstract system consisting of a forage fish, which is also harvested for human consumption, and as an aquafeed, and a predator which is subject to commercial harvesting, recreational harvesting and capture-based aquaculture. This project will apply the theoretic model to empirically evaluate the tradeoffs, opportunity costs and global benefits related to competing uses of the Pacific sardine resource. Besides considering the use of sardines as forage for bluefin and other predators in the wild this application would also consider the use of sardines as food for pen-reared bluefin tuna, as well as the use of sardines themselves as an edible fish. This will entail quite a lot of ecological research about inter-species relationships. Based upon past work, this information has been reasonably available for the California Current Ecosystem off the U.S. West Coast. The investigation would rely on ecological and economic data from secondary sources, and would use sensible first approximations in instances where there are data gaps.

Transboundary Management

This project is exploring the optimal fishing strategy of three economic agents (Canada, U.S. and Mexico) when they face uncertainty under a time-variant and asymmetric sharing of Pacific sardine induced by climate regime shifts. Results to date (reported at this year's, 2008, Trinational) are from simulation techniques to estimate the economic and biological consequences of transboundary Pacific sardine fishing under different coalition game conditions and climate change scenarios.

Total Economic Value

This project will estimate the total economic value of the CCE not just the market value associated with extractive use of living marine resources but the non-market values: existence value, option value, bequest value reflecting the public good nature of CCE resources.

Assessment of the Pacific sardine resource in 2008 for U.S. management in 2009
Executive Summary

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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 separating the catches in Ensenada and San Pedro into the respective northern and southern stocks based on some objective criteria.

Data and assessment

This assessment, conducted using the 'Stock Synthesis 2' model (version 2.00i), uses fishery and survey data collected from mid-1981 to mid-2008. Fishery data include catch and biological samples for the fisheries off Ensenada, California, and the Pacific Northwest (1981-2008). Two indices of relative abundance are included: Daily Egg Production Method and Total Egg Production estimates of spawning stock biomass (1985-2008) based on annual surveys conducted off California. The model was constructed using an annual time step ('Season'), based on the July-June biological year, with four quarters per season (Jul-Sep, Oct-Nov, Dec-Mar, and Apr-Jun).

Model Season	Ensenada (mt)	California (mt)	Pacific Northwest (mt)	Total (mt)
1998	62,333	51,005	563	113,901
1999	57,743	60,361	1,155	119,258
2000	50,457	52,916	17,923	121,295
2001	46,948	52,981	25,683	125,612
2002	44,938	60,714	36,123	141,775
2003	37,040	29,650	39,861	106,551
2004	47,379	45,858	47,747	140,985
2005	56,798	41,849	54,254	152,901
2006	50,762	67,389	41,221	159,372
2007	35,654	80,380	48,237	164,271

Unresolved problems and major uncertainties

The present assessment revealed considerable model sensitivity to one new quarter of composition data from the Pacific Northwest fishery in 2007. The new data caused a shift in selectivity resulting in a significant downward scaling of recruitment and biomass estimates. The shift was driven by the 2003 cohort which has comprised a large portion of the NW catch for several years. In an earlier draft presented at the assessment update review (Oct 7, 2008), the STAT proposed a model in which the effective sample size (ESS) for the NW-07 data was down-weighted to the next largest ESS in for this fishery and time period. The STAT's treatment of the NW-07 ESS deviated from the TOR for assessment updates, so the SSC's CPS Subcommittee rejected this approach. Moreover, since results from the strict 'update' model were inconsistent with results from the final 2007 model, the SSC's CPS Subcommittee recommended rejecting the update and instead basing 2009 management on a 'projection' model in which the final 2007 model is updated with 2007-08 landings only (Agenda Item G.2.c, SSC CPS Subcommittee Report). Since the STAT, CPSMT, and SSC CPS Subcommittee are not in full agreement as to which model the 2009 management season should be based on, results from both the 'update' and 'projection' models are presented in this report.

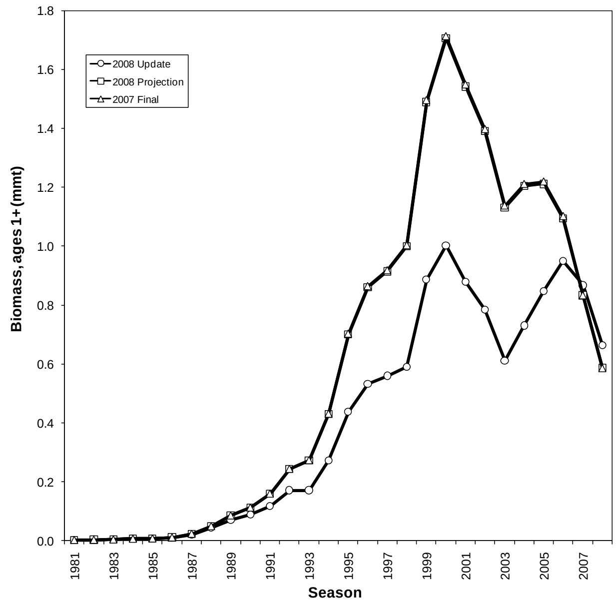
The assessment includes indices of spawning biomass based on annual ichthyoplankton and trawl surveys conducted each spring between San Diego and San Francisco (‘standard’ sampling area). The assessment relies on the assumption that indices of abundance for the ‘standard’ area are linearly proportional 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 (in particular, southern California's Fall fishery) used in the assessment include fish from the southern subpopulation, which presumably has different life history parameters (e.g. growth, maturity, and natural mortality rates). Moreover, timely access to recent Mexican catches (monthly resolution) and biological data remains an ongoing concern. The assessment does not include biological data for Ensenada after 2002.

Stock biomass

Stock biomass, used for management purposes, is defined as the sum of the biomass for sardine aged 1 and older. Stock biomass increased rapidly through the 1980s and 1990s, peaking in 2000 at 1.002 million mt in the update model, or 1.706 million mt in the projection model. Stock biomass has subsequently trended downward to the present (July 1, 2008) level of 662,886 mt in the update model, and 586,369 mt in the projection model.

	Stock Biomass (mt)	
Season	Update	Projection
1998	589,564	999,175
1999	887,809	1,490,210
2000	1,002,330	1,706,520
2001	878,841	1,542,430
2002	785,200	1,391,310
2003	610,683	1,132,110
2004	730,489	1,204,150
2005	847,585	1,211,420
2006	949,717	1,093,800
2007	867,100	832,546
2008	662,886	586,369



Recruitment

Recruitment was modeled using the Ricker stock-recruitment relationship. The estimate of steepness was high for both the update (h=2.708) and projection models (h=2.593). Virgin recruitment (R_0) was estimated at 3.41 billion age-0 fish for the update model and 4.99 billion for the projection model. Recruitment increased rapidly through the mid-1990s, peaking in 1998 at 16.4 billion fish in the update model and 24.5 billion fish in the projection model. Recruitments have been relatively low since the late 1990s, with the exception of the 2003 year class, which was the second largest in the series.

Exploitation status

Exploitation rate for the U.S. and coast-wide sardine fisheries is defined as calendar year catch/total mid-year biomass (ages 0+). Total exploitation rate was relatively high during the early recovery period (mid-1980s), but declined and stabilized as the stock underwent the most rapid recovery phase. Exploitation rate differs for the update and projection models, but the exploitation rate since 1990 has been relatively low under either scenario. For the update model, U.S. exploitation has averaged 7.9% since 1990 and 11.4% since 2003; coast-wide exploitation has been 15.8% since 1990 and 16% since 2003. Based on the projection model, U.S. exploitation has averaged 5.8% since 1990, with an average of 10.1% since 2003; coast-wide exploitation was 10.9% since 1990 and 12.6% since 2003. Coast-wide exploitation has gradually increased until 2007, at just over 19% for both models.

	EXPLOITATION RATE			
	Update Model		Projection Model	
Season	U.S.	Total	U.S.	Total
1998	4.9%	10.7%	3.0%	6.5%
1999	6.1%	12.4%	3.7%	7.5%
2000	6.6%	13.3%	3.9%	7.9%
2001	7.7%	12.5%	4.5%	7.3%
2002	12.1%	18.1%	6.8%	10.2%
2003	8.5%	13.6%	5.1%	8.1%
2004	11.1%	16.9%	7.2%	11.0%
2005	9.0%	15.0%	7.0%	11.6%
2006	9.2%	15.2%	8.2%	13.5%
2007	15.0%	19.1%	15.3%	19.5%
2008	12.5%	---	12.7%	---

Management performance

Based on results from the update model, the harvest guideline for the U.S. fishery in calendar year 2009 would be 66,932 mt. Using the projection model, the harvest guideline for the U.S. fishery would be 56,946 mt. The HG (=ABC) is based on the control rule defined in the CPS-FMP:

$$HG_{2009} = (BIOMASS_{2008} - CUTOFF) \bullet FRACTION \bullet DISTRIBUTION;$$

where HG_{2009} is the total USA (California, Oregon, and Washington) harvest guideline in 2009, $BIOMASS_{2008}$ is the estimated July 1, 2008 stock biomass (ages 1+) from the assessment (update model = 662,886 mt; projection model = 586,369 mt), CUTOFF is the lowest level of estimated biomass at which harvest is allowed (150,000 mt), FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries (see below), and DISTRIBUTION (87%) is the average portion of $BIOMASS_{2008}$ 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_{2008}) SST estimate of 17.83 °C, the F_{msy} exploitation fraction should remain at 15%.

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	99,578
2002	118,442	96,876	136,140	141,369
2003	110,908	69,917	127,480	101,411
2004	122,747	92,723	141,089	141,388
2005	136,179	90,016	156,528	149,939
2006	118,937	91,039	136,709	149,667
2007	152,564	135,946	175,361	173,120
2008	89,093	86,608	102,406	---

TEMPORAL PATTERNS OF FORAGE FISH AND MESOZOOPLANKTON IN THE COLUMBIA RIVER PLUME

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Small pelagic forage fish, including sardines and anchovies, represent a crucial trophic link between plankton and upper trophic levels in coastal upwelling ecosystems. They serve an important ecological role through interactions with other fish groups, particularly juvenile salmon, through a dilution effect that reduces predation by mutual predators. Populations on the Oregon and Washington coast are highly variable from year to year and seasonally, which has a significant effect on the survival and recruitment of salmon. The seasonal timing of the presence of schooling fish on the Oregon and Washington coast is therefore an important variable to determine the success that juvenile salmon will have when they enter the ocean. The objective of this study was to determine the seasonal timing of forage fish presence near the Columbia River estuary, to determine how variable their abundance is throughout the season, and to determine which oceanographic conditions are linked with their presence in order to better understand and predict the timing of their presence. Relative abundance of fish schools and mesozooplankton were acoustically sampled at two stations from April through June, 2008 using 200-kHz Water Column Profilers sampling at high vertical and temporal resolution. Oceanographic and meteorological measurements collected at an NDCB oceanographic buoy were used to characterize upwelling winds, sea surface temperature, and sea surface salinity. Results showed that both fish school abundance and mesozooplankton volume scattering were highly variable in time with peaks often lasting a few days. Multiple linear regressions between biological and oceanographic variables indicate that there may be different variables determining school abundance between the two stations and that river and upwelling conditions may be useful predictors for these conditions in future applications concerning ecosystem-based management of forage fish and salmon.

ELEMENTS TO CONSIDER IN SARDINE MANAGEMENT

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The sardine fishery is being managed fairly well in the California Current (CC) ecosystem, given that, of four recent and equivalent sardine fisheries (others are Japan, Peru-Chile, and South Africa), it is the only one that has not collapsed. Yet there is pressure to re-think sardine management. If so, I offer some important features to consider. Sardine fisheries are not sustainable, but the California paleosedimentary record show that in an unfished condition, the average productive period is lognormally distributed with a mean length of 72 years. Absences of sardines are exponentially distributed with a 53% chance of recovery per decade. Any management strategy must attempt to maintain a "seed stock" to initiate recovery at the end of unfavorable periods.

We are beginning to gain some understanding of mechanisms governing sardine productivity, including CC flow strength, latitude of source water, temperature in the northern feeding area, and curl-driven offshore upwelling. These are large-scale features, and proxy indicators do not need to be measured locally. Maintenance of age structure is vitally important because of probable migrational imprinting behavior, and because older sardines are disproportionately more fecund. Spawning biomass is a dangerously misleading measure of reproductive potential and should be abandoned in favor of population egg production potential.

Sardine reproductive rates may have decreased somewhat in recent years. If the fishery were exploited at high intensities similar to elsewhere, we would most likely be seeing the end about now. However, under the present low exploitation rate, there is still a healthy abundance of fish and good age structure that can be expected to sustain continued productivity unless environmental conditions change in the extreme.

CONTRASTS AND SIMILARITIES OF THREE COMPLETE CALIFORNIA CURRENT ECOSYSTEM SURVEYS CONDUCTED IN 2006 AND 2008.

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During the 2004 Tri-national Sardine Symposium held at the Southwest Fisheries Science Center (SWFSC) in La Jolla, CA, the SWFSC proposed to complete a Coast-wide survey off of the west coast of North America (in coordination with scientists from Mexico, Canada and groups from Oregon and Washington) from Baja California to British Columbia in order to obtain estimates of total biomass for the Pacific sardine (*Sardinops sagax*). Since the completion of the first Coast-wide survey in the spring of 2006, two additional Coast-wide surveys, now called the California Current Ecosystem Survey (CCES), have been completed during the spring and summer of 2008. By conducting the CCESs in the spring and summer of 2008, calculations of migration rates as well as total biomass could be calculated. This talk/poster will attempt to present most of the general trends and highlight the differences as well as the similarities discovered between these three surveys as well as looking at recent results from previous Northwest surveys.

FISHERIES MANAGEMENT FOR ADULTS

Don Pepper. PH.D.
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Fisheries management is like Bach's piano exercises: too easy for amateurs and too difficult for professionals. The mixture of biology, economics and the common-property aspects are a toxic brew for any regulatory agency. The progression of the fisheries sector from a subsistence back-water to the current legal and political cock-fight has been a slow but inexorable process. The Pacific sardine fishery provides a suitable case for analysis to demonstrate many of the obvious problems but also a demonstration of what should be done for a management regime that cuts the Gordian Knot of piecemeal management.

Fisheries management entails addressing three subjects: biology and population dynamics, economic issues, and finally the political milieu in which fisheries take place. Each has its issues and problems. This paper argues that a new approach must be made in each area and an integrated approach can provide benefits to actors in the drama and to society as a whole. The major conclusion of this paper is that methods for estimation the sardine biomass must be changed to incorporate deficiencies in the current models and examine the realities in the ocean. Second, the fragmentation of the industry (processors and fishermen) needs a new approach in maximizing the value of the resource to the industry and society. Third, regulatory agencies must provide better inputs into management from a commitment to flexibility and the development of a strategic plan.

Finally, is it time to give the Trilateral Forum a more formal status?

APPENDIX IV

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

ANALYSIS OF PACIFIC SARDINE STOCKS DERIVED FROM NUMBER OF VERTEBRAE

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Abstract

It is critical to successful management of the Oregon and Washington Pacific sardine fisheries to know if fish caught in the Pacific Northwest are a discrete population. Previous research has hypothesized that the Pacific sardine has three subpopulations based off California. One method used for defining Pacific sardine populations is vertebral counts. It is accepted that many species of fish from warmer waters have lower average number of vertebrae than fish of the same species from colder waters. This study uses this assumption to examine vertebral counts of Pacific sardine captured from San Pedro California to Willapa Bay Washington. We found no significant difference in vertebral counts between any of the samples ($P>0.01$).

THE EFFECTS OF VARIABLE OCEANOGRAPHIC CONDITIONS ON FORAGE FISH LIPID CONTENT AND FATTY ACID COMPOSITION IN THE NORTHERN CALIFORNIA CURRENT

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Abstract

We evaluated the benefit of lipid and fatty acid content in four species of forage fish (northern anchovy, Pacific sardine, Pacific herring and whitebait smelt) to serve as biological markers of ocean conditions in the California Current large marine ecosystem (CCLME) during the contrasting oceanographic years of 2005 and 2006. Upwelling was severely curtailed in the CCLME in 2005, leading to delayed biological productivity, whereas upwelling was more normal in 2006, beginning during the spring period. Total lipid content range was lower for all forage fish species in 2005 (0.37-23.52% wet mass) than measured in 2006 (1.31-26.37% wet mass). Principal components analysis (PCA) described 59% of the variance within the multivariate lipid and fatty acid data set using just two PC axes and PC2 was sufficient to explain lipid and fatty acid variations by sampling season ($r2=0.22$, $p<0.01$). Using ratios of fatty acid biomarkers docosahexaeonic acid (DHA) and eicosapentaeonic acid (EPA) we detected a transition from a diet composed primarily of dinoflagellate origin in early 2005 to a diet of diatom based productivity by late summer 2005, a shift due to prey availability which was corroborated through phytoplankton sampling. Moreover, we found higher levels of macrozooplankton carnivory, substantiated by the accumulation of monounsaturated eicosenoic and erucic fatty acids in Pacific herring and northern anchovy in 2006 relative to 2005. Lipid levels were negatively correlated ($r2=0.26$, $p=0.04$) with DHA concentrations, and positively correlated ($r2=0.40$, $p=0.01$) with EPA values. Accumulation of different lipid and fatty acid profiles in the forage fish community demonstrates how ocean conditions and productivity in the CCLME can affect food web structure. The implication of this variation to the health and success of the forage fish community and to subsequent user groups (e.g. salmon, important groundfish species) has yet to be determined.

PHYSIOLOGICAL STATUS OF PACIFIC SARDINES (*SARDINOPS SAGAX*) TO DIFFERENT THERMAL REGIME ASSESSED USING BLOOD PARAMETERS

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Abstract

Little is known regarding the effect of temperature on the physiology of *Sardinops sagax*. We evaluated the effect of different thermal regimes on select blood parameters previously shown to reflect physiological condition. Sardines were captured off Ensenada during the fall of 2008 and exposed to three acclimation regimes: summer cycle (SC), winter cycle (WC) and constant optimal temperature (OT:18°C). SC and WC treatments were maintained at a low and high temperature for 7h (18 and 23°C for SC and 13 and 18°C for WC); changes in temperature occurred over 5h. Cortisol, glucose, alanine and aspartate aminotransferase (ALAT and ASAT) levels and erythrocyte counts were measured at 18 °C for all thermal regimes, and also at 13 and 23°C for WC and SC, respectively. Cortisol levels were not significantly different at 18°C independent of acclimation treatment. However, they were 48% lower at 13°C and 55% higher at 23°C compared to mean values at 18°C. Glucose levels were significantly higher at 23°C for SC (158mg·dl^{-1}) than other treatments, which did not differ significantly (87mg·dl^{-1}). While there were no differences among treatments in ALAT levels, ASAT levels tended to increase as a function of temperature. Significant differences were only found between SC 23°C and both OT 18°C and WC 13°C. Erythrocyte concentrations were 234, 151 and 282x10^{7} cells·ml^{-1} for the OT, WC and SC acclimation regimes, respectively. Thermal acclimation had an effect on survival (90, 84 and 68% for OT, WC and SC, respectively). We conclude that *S. sagax* thrive at lower temperatures, whereas high temperatures (23°C) negatively influence physiological status. The physiological response obtained for the SC regime evaluated at 23°C indicates this temperature may be considered a detrimental sublethal temperature, particularly in long exposure periods. This work is part of a project financed by Mexico´s CONACYT (P46060-Z).