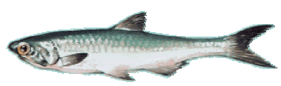
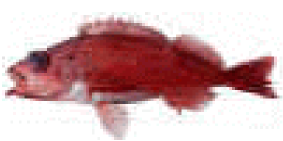
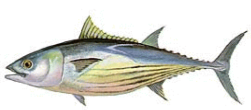
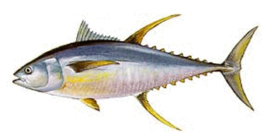
FISHERIES RESOURES DIVISION PROGRAM REVIEW

La Jolla Laboratory
Southwest Fisheries Science Center
National Marine Fisheries Services

			
Albacore	Anchovy	Bigeye Tuna	Bluefin Tuna
			
Cowcod	Mako Shark	Market Squid	Sardine
			
Skipjack Tuna	Thresher Shark	White Abalone	Yellowfin Tuna

November 1, 2002

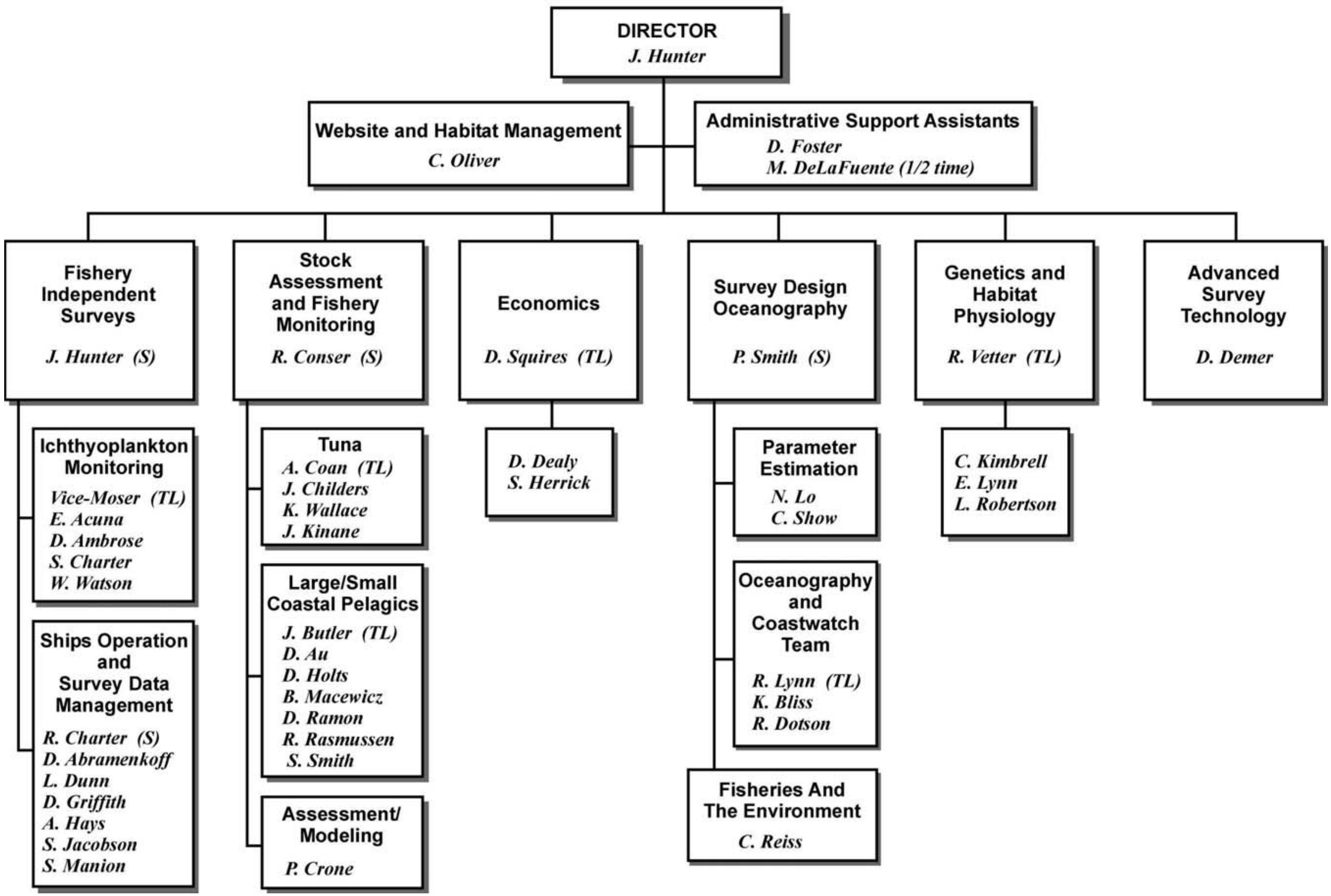
Fisheries Resources Division
Program Review
FY2002

Table of Contents

Agenda
FRD Program Review
November 1, 2002

10:00 - 10:15a	**Introduction**	John Hunter
	Stock Assessment & Fishery Monitoring	
10:15 - 10:40	Squid, cowcod, and white abalone	John Butler
10:40 - 10:55	Pacific tunas, Pacific albacore, and HMS data	Al Coan
10:55 - 11:10	North Pacific albacore and market squid	Paul Crone
11:10 - 11:35	Thresher shark, leopard shark, & FMP	Dave Au
11:35 - 12:00	Sardine assessment & management	Ray Conser
12:00 - 1:00p	**Lunch Break**	
	Economics	
1:00 - 1:15	Biological opinion & bycatch in the drift gillnet fleet	Dale Squires
1:15 - 1:30	Coastal Pelagic Species	Sam Herrick
1:30 - 1:45p	**Ichthyoplankton Monitoring**	John Hunter
1:45 - 2:00p	**Ships Operation & Survey Data Management**	John Hunter
2:00 - 2:30p	**Genetics & Habitat Physiology**	
	Rockfish, mako, and sardine	Russ Vetter
2:30 - 3:00p	**Survey Design Oceanography**	
	Fisheries oceanography	Paul Smith
	Squid escapement and sardine migration	Nancy Lo
	Other Activities	
3:00 - 3:15p	Trinational Sardine Forum, recreational fisheries outreach, UC Davis partnership and FATE	John Hunter
3:15 - 3:30	**Break**	
3:30 - 4:30	**Discussion**	

Southwest Fisheries Science Center
Fisheries Resources Division -- FY02



Essential Spawning Habitat Of Market Squid

John Butler

The spawning habitat of market squid was studied in the two major fishing areas: the Southern California Channel Islands and Monterey Bay. The fishery occurs in winter around the Channel Islands and during spring and summer in Monterey Bay. Spawning habitat in both areas is usually on fine muddy sands in both areas. Squid eggs are found shallower in Monterey Bay (20-35 m) than around the Channel Islands (30-50m). Although eggs are deposited at different depths and during different seasons, the water temperature on the spawning grounds is the same. Squid eggs will survive and hatch at temperatures between 7.5º and 25º C (Issac et al. 2000), however squid eggs were observed in a narrow range of temperatures between 10-12º C in both Southern California and Monterey Bay.

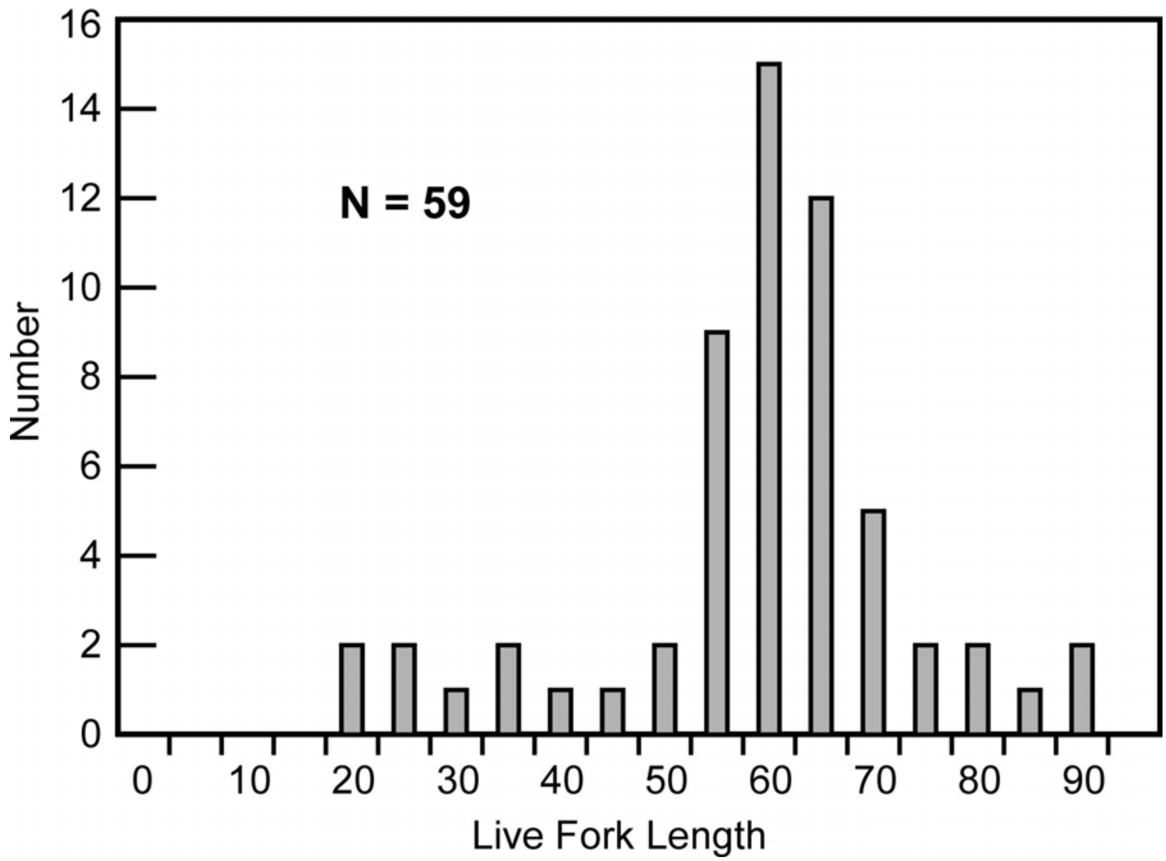
The effect of fishing operations on squid egg beds were studied on a cruise on the *R/V Mako* during June 5-13, 2002 in Monterey Bay. Squid egg beds were observed using Remotely Operated Vehicle (ROV) video transects to identify egg bed damage. Concurrently fishing activity was observed by CDFG wardens and recorded with video. Port samplers also observed bycatch in landings. A total of 15 fishing sets were observed, 8 by drum seine and 7 by purse seine. Squid eggs were observed in 14 of 15 sets. The maximum observed was 417 and the minimum was 8 and the average was 89. The number of eggs observed in drum seine sets were greater than the number in purse seine sets, however the variance was very high for both gear types. Rough seas produced strong surge on the egg beds and it was impossible to determine whether loose egg capsules were the result of fishing activity or wave surge. A second cruise is planned for Southern California during January 2003.

Cowcod

John Butler

The manuscript entitled "Biology and population dynamics of cowcod rockfish (*Sebastes levis*) in the Southern California Bight" by Butler, Jacobson, Moser and Barnes was accepted for publication in the Fishery Bulletin.

Preliminary studies of the Cowcod Conservation Area were conducted using the Remotely Operated Vehicle (ROV) to determine size frequency distribution (see figure) within the CCA and at control sites outside the CCA. At present there is no difference in size distributions between the two areas.

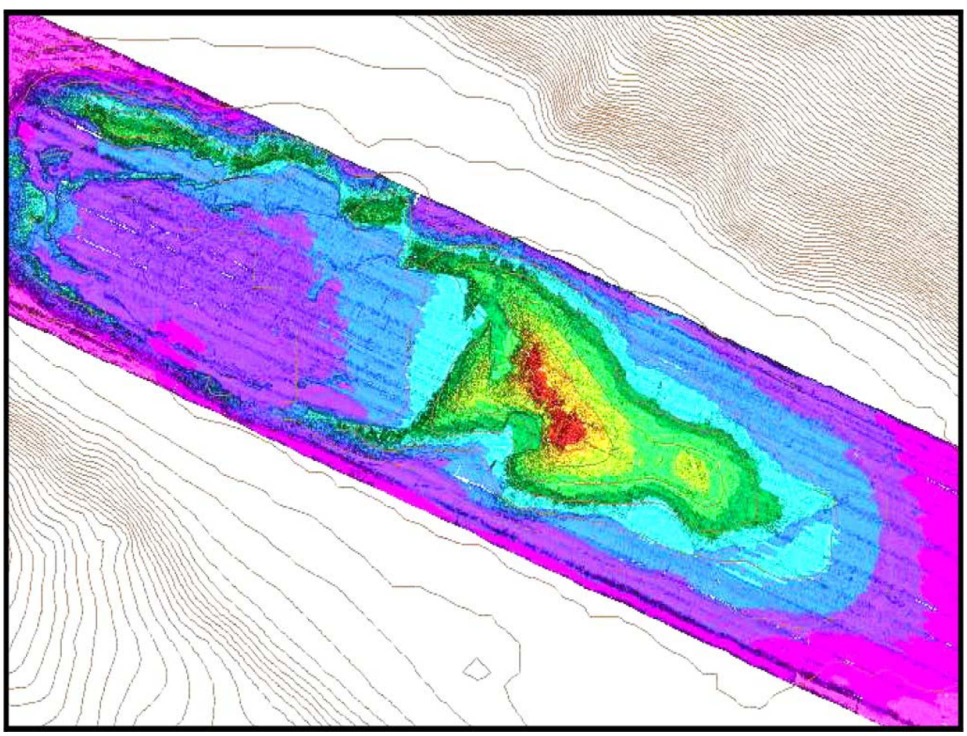


White Abalone Recovery

John Butler

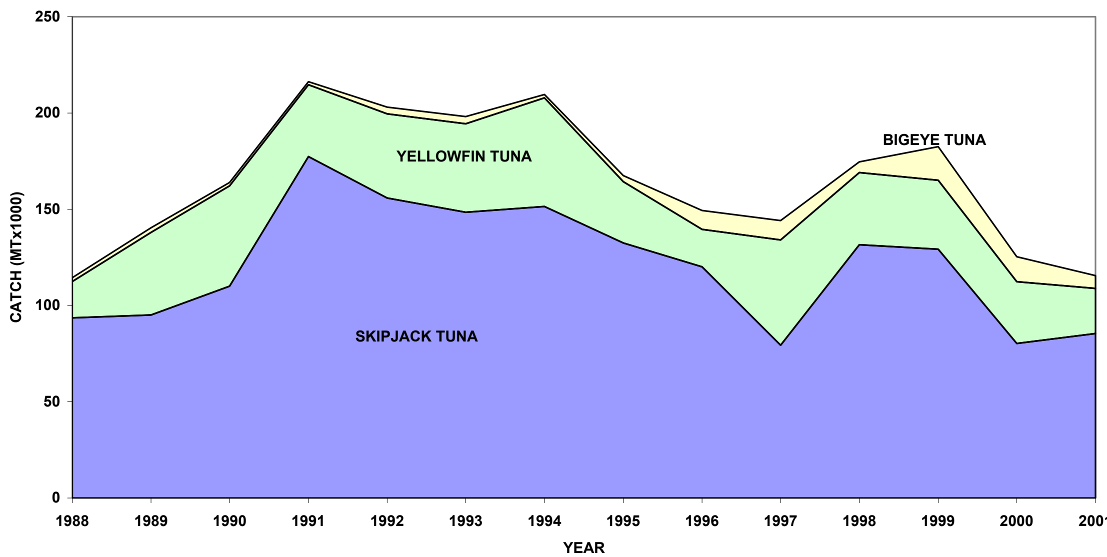
The existing experimental aquarium has been modified to hold white abalone brood stock and culture juveniles for out-planting. Custom brood stock holding tanks have been built and are being installed and plumbed in a secure area of the aquarium. Existing tanks have been retrofitted and plumbed as abalone grow-out tanks. An emergency generator has been purchased and installed to provide life support to the brood stock and grow-out facilities.

Because the permit to collect white abalone was not received prior to the scheduled cruise, activities on a 9-day cruise in July on the R/V David Starr Jordan were changed to population assessment. Essential habitat of white abalone was mapped using both multi-beam and side-scan sonar to compare the utility of both techniques. Video surveys were conducted using a remotely operated vehicle (ROV). High-resolution bathymetry from the multi-beam sonar system was the most useful because it could be used in real time to guide ROV video surveys. An area of 107 km2 was mapped (see figure) and of that 1450 ha was white abalone habitat. Densities were similar to previous surveys, but the amount of white abalone habitat is much larger. The area of white abalone for all of California was estimated at only 752 ha (Hobday and Tegner 2000) or about half of white abalone surveyed on the cruise. Using densities from ROV surveys and habitat area from high-resolution bathymetry, a population estimate was obtained from the area surveyed. Between 5,000 and 30,000 white abalone are on this bank. This greatly changes our understanding of white abalone abundance. Previous estimates of white abalone abundance were much smaller because the estimates of habitat area were underestimated. Further work with multi-beam sonar and ROV surveys is needed to establish present white abalone abundance and distribution. This information is critical to de-listing criteria. Without knowing what the population status is now, it will impossible to monitor rebuilding success.



Monitoring of the South Pacific Tuna Treaty

Al Coan

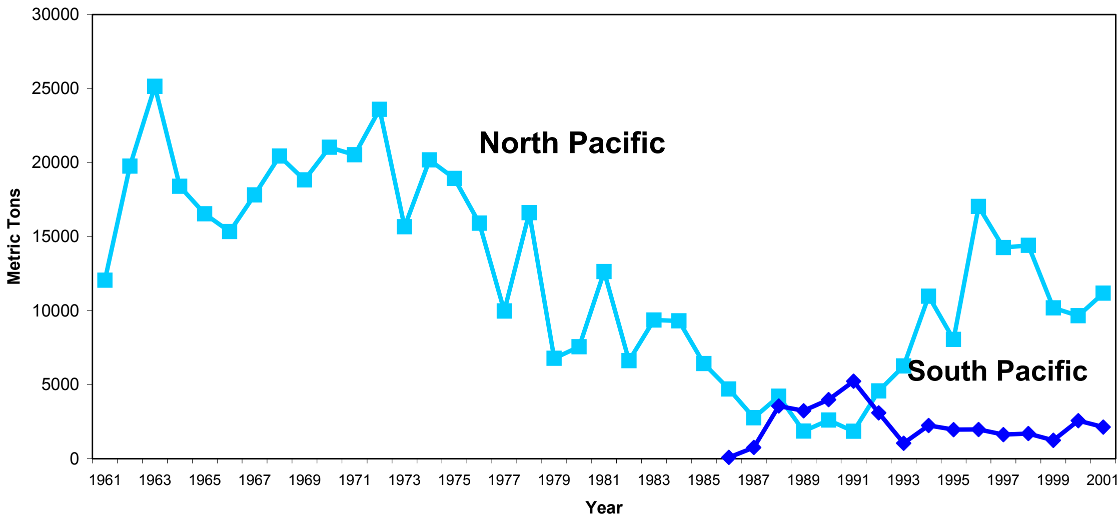


Data collected form the 2001 U.S. purse seine fishery for tropical tunas in the central-western Pacific under the South Pacific Tuna Treaty was processed and made available to scientists who monitor the fishery and assess the condition of the stocks, and was summarized in a report for the Treaty review meeting and the 14th Standing Committee on Tunas and Billfish meeting. Thirty-one U.S. purse seiners fished in the central-western Pacific in 2001, a decrease from the 33 in 2000. Logbooks and landings data were collected from 100% of the fleet and length measurements; species compositions were collected from landings of 62,000 fish. The 2001 U.S. tropical tuna catch (yellowfin, skipjack and bigeye tunas) continued a declining trend that started in 2000 and reached the lowest levels since 1988 (116,000 t). Much of the fleet stopped fishing in December 2000 and continued to remain in port through January 2001 in an effort to decrease supplies of light meat tuna, as cannery prices for small tunas continued at record low levels. After resuming fishing in February 2001, the fleet attempted to catch larger fish that would command higher cannery prices by concentrating on schools of free-swimming tunas (51%) and less on schools associated with Fish Aggregation Devices (FADs, 49%). However, sets on free-swimming schools are half as successful as sets on FADs, which weakened many of the fleet's performance indices; catch rates decreased from 27 t/day fished in 2000 to 25 t/day fished in 2001, and average sets per trip increased 7% from those reported in 2000.

Monitoring of U.S. Pacific Albacore Troll Fisheries and the U.S./Canada Treaty

Al Coan

Seasonal catches of North and South Pacific Albacore by U.S. Troll Vessels

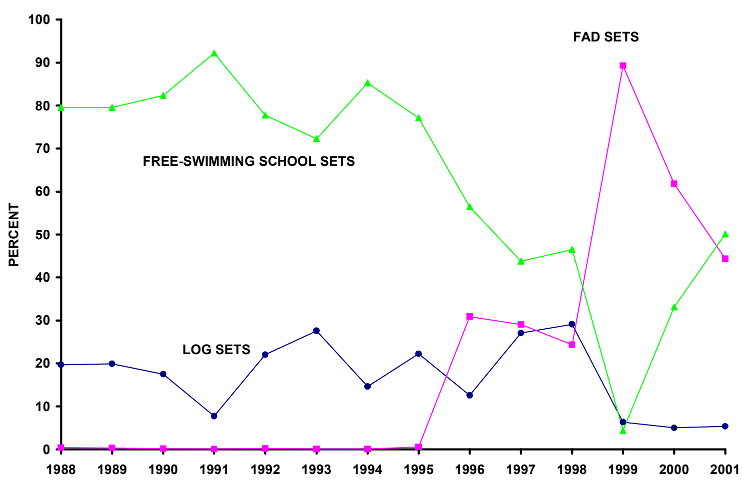


Data for the 2000-2001 South Pacific and 2001 North Pacific fishing seasons were processed, made available to scientists to monitor the fishery and to assess the condition of the stocks, and summarized in a report for distribution to the public. The 2001 U.S. catch of North Pacific albacore was 11,170 metric tons (t), a decrease from the 9,640 t caught in 2000. Areas fished by the North Pacific fleet in 2001 were distributed west of the International Dateline early in the season, off California, Washington and Oregon during mid season and again in offshore areas and off California late in the season. The 2000-2001 U.S. catch of South Pacific albacore was 2,128 t, a decrease from 2,562 t in the 1999-2000 season. While areas fished in 2001 and 2000 were very similar, areas of high catch in 2001 extended further south than in 2000. The catch-per-unit effort, in number of fish per day fished, for the North Pacific increased substantially from 39 fish per day in 2000 to 68 fish per day in 2001. The catch-per-unit effort in the South Pacific decreased substantially from 70 fish per day in the 1999-2000 season to 48 fish per day in the 2000-2001 season. Average size of fish in the North Pacific catch was virtually the same in 2000 and 2001 at approximately 69 cm. In the South Pacific, average size decreased slightly from 73 cm in the 1999-2000 season to 71 cm in the 2000-2001 season.

Sampling Error Associated with Species-Composition Estimates for the U.S. Purse Seine Fishery in the Central-Western Pacific Ocean

Paul Crone/Al Coan

Landing estimates of individual species are critical sources of data for conducting stock assessments and generally considered one of the most important time series for evaluating the status of a fish population. The purpose of this study was to evaluate the current species-composition sampling program for U.S. purse seine landed tunas in the central-western Pacific Ocean and in particular, to determine the quality (i.e., sampling error or precision) of the sample estimates of species composition (1997-2001). The current data collection approach is considered a stratified, multistage sampling design combined with poststratification. Beginning in the mid-1990s, the purse seine fleet began fishing more regularly with FADs (an 'associated' set), which dramatically influenced the biological attributes of the purse seine catches. This dramatic shift from 'unassociated' sets on free-swimming schools to 'associated' (FAD) sets was the motivation for the analysis presented here, i.e., it became evident that sample estimates of species composition could vary substantially across different strata. In general, the mean estimates of species composition (in proportion) for each stratum were relatively precise, particularly, for species encountered more frequently. For example, estimates for species that composed larger proportions (>25%) of the mean estimated compositions had associated coefficients of variation of the mean (CVs) that were generally less than 10%. Whereas, species that composed smaller proportions of the overall compositions had moderately to highly variable landing estimates (i.e., CVs generally >20%). More importantly, the annual-based time series of estimated species compositions (in mt), summed across strata, were very precise, with CVs <6% for skipjack and yellowfin tuna landing estimates and CVs <13% for bigeye tuna landing estimates. To summarize, results presented here indicate that the catch time series for these species are reliable sources of data and thus, are not likely to introduce substantial amounts of variability in assessment models used for these fisheries. Finally, potentially influential non-sampling error associated with the monitoring program is generally discussed.



Stock Assessment of North Pacific Albacore using Statistical Models

Ray Conser/Paul Crone

Recently, members of the North Pacific Albacore Workshop (NPALBW), particularly, scientists from Japan and the USA (SWFSC), committed to undertaking development of more detailed statistical models for understanding the ecological and fishery dynamics associated with the albacore population of the North Pacific Ocean. Recently, classical catch-at-age modeling efforts, such as Virtual Population Analysis (VPA), have been applied to the stock to determine estimates of absolute population abundance and fishing mortality rates. Although VPAs are useful for examining age-specific dynamics of the stock in a statistical framework, they are still considered quite general age-structured tools, given the broad assumptions and spatial/temporal constraints that are inherently associated with such methods. A fairly recent modeling platform that has gained popularity as an assessment tool for tunas in both the South and North Pacific Oceans is MULTIFAN-CL. In general, the MULTIFAN-CL model is a length-based, age-structured modeling approach that provides an integrated method of estimating catch-at-age composition, growth parameters, mortality rates, recruitment, and other fishery-related parameters. Most importantly, MULTIFAN-CL allows the heterogeneous aspects (e.g., selectivity and catchability) of expansive fisheries, such as tuna fisheries, to be 'objectively' examined (parameterized). That is, 'the means to the end' involved in this research are expected to provide useful information concerning 'robust vs. sensitive' areas of stock assessment methods in general, i.e., by contrasting results generated through two, quite different interpretations of available sample data; a general analysis (more reliant on researcher assumptions) and detailed analysis (more reliant on statistical theory).

The research focuses on the following goals, which are presented in chronological order: **first**, to develop a population assessment using MULTIFAN-CL whereby results can be compared, at least in general terms, with results generated by more straightforward VPAs—this goal is not trivial and is likely the most important objective of this overall research effort, given future management-related decisions will likely be based on scientists' ability to sort out potential differences in results generated from simple, general interpretations of sample information and more complex, detailed considerations of these data; **second**, eventually include tag-related information in the MULTIFAN-CL model in efforts to objectively evaluate migratory patterns exhibited by the population; and **third**, following thorough sensitivity analysis concerning important areas of uncertainty (e.g., issues surrounding selectivity, catchability, and movement patterns), develop a flexible, baseline model that utilizes the available sample information in the most realistic and objective manner and ultimately, provides the best description of the dynamics of the albacore population and associated fisheries.

The work has involved reviewing, estimating, and summarizing fishery-related time series from all countries that have exploited the stock over the years. Tasks involved in this work have included rigorous examination of available sample data, consensus regarding important assumptions and construction of important time series used in the models, general and detailed treatment of the data during the modeling stages and finally, summarizations of the substantial amount of results generated from the modeling efforts (e.g., sensitivity runs and profiles of important fishery parameters). Both parties (USA and Japan) agreed that considerable time and effort should be focused on the data files prior to any modeling efforts, given the extent and potential biases associated with the historical data sets. However, sample data applicable to the fisheries of the western and central Pacific Ocean (namely, Japan, Taiwan, and Korea) still need further review. Thus, results from current baseline model runs using MULTIFAN-CL are considered preliminary and useful in meeting the first research objective above, i.e., not for developing sound management advice concerning the stock. Further review of the sample information used as input data in the models will take place in early December, 2002, at the *Eighteenth North Pacific Albacore Workshop*, which will be held at the SWFSC.

NORTH PACIFIC ALBACORE RESEARCH

Population-wide Model Development

FISHERIES TO CONSIDER

(**I**) Eastern Pacific Ocean
- USA troll
- USA longline (HI)
- USA miscellaneous (e.g., pole-and-line, gill net, recreational)
- Canada troll
- Mexico miscellaneous

(**II**) Western Pacific Ocean
- Japan pole-and-line
- Japan longline (inshore and offshore)
- Japan/Taiwan/South Korea gill net
- Taiwan/South Korea longline
- Japan miscellaneous

DATA NEEDS

(**I**) Time series
- Length/age distributions
- Catch-at-age/size matrices
- Catch/effort statistics (e.g., age-aggregated and age-specific)

MODELS

(**I**) VPA

(**II**) MULTIFAN-CL

IMPORTANT ISSUES TO CONSIDER

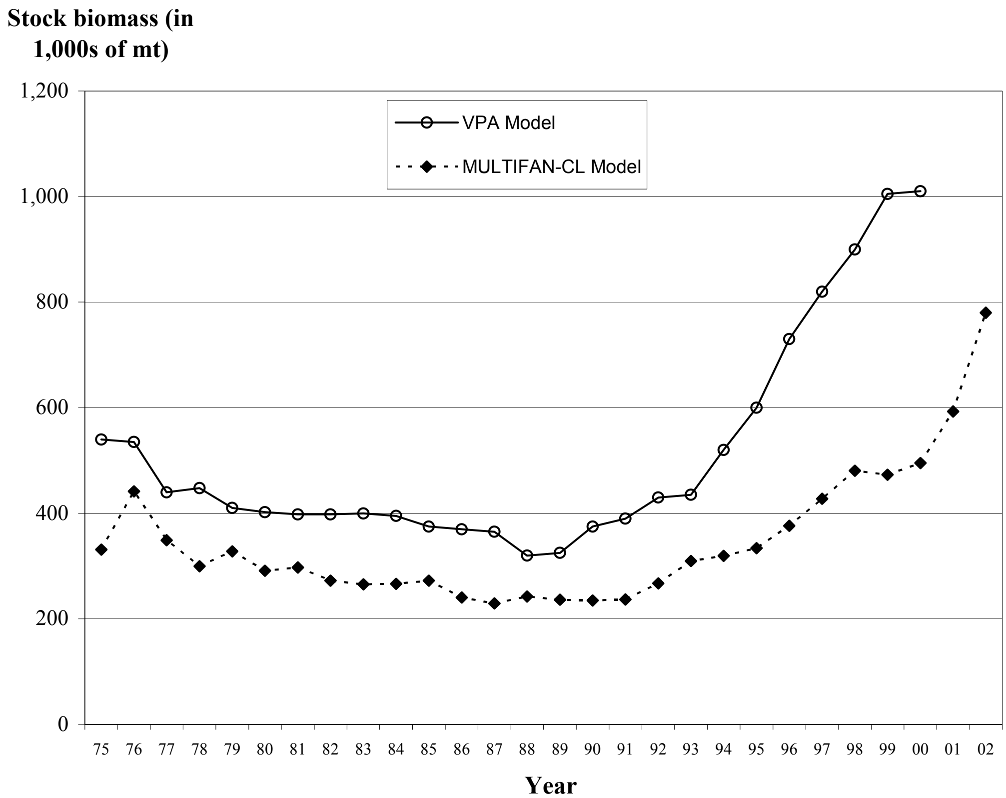
(**I**) Develop baseline MULTIFAN-CL model so results can be compared with current VPA methods

(**II**) Gradually increase complexity of the baseline model

(**A**) Differences in selectivity and catchability associated with the various fisheries

(**B**) Evaluate the stock's movement patterns through inclusion of tag data

NORTH PACIFIC ALBACORE RESEARCH



GENERAL NOTES:

* In sensitity analysis <u>thus far</u>, both models generate similar patterns of selectivity, as well as <u>trends</u> in biomass, spawning stock biomass, and recruitment
* The models appear to be quite sensitive to issues surrounding relative indices of stock abundance
  --How 'tuning' indices of relative abundance (CPUE) are handled in VPA model is very influential
  --How 'catchability' is estimated in MULTIFAN-CL model is moderately influential

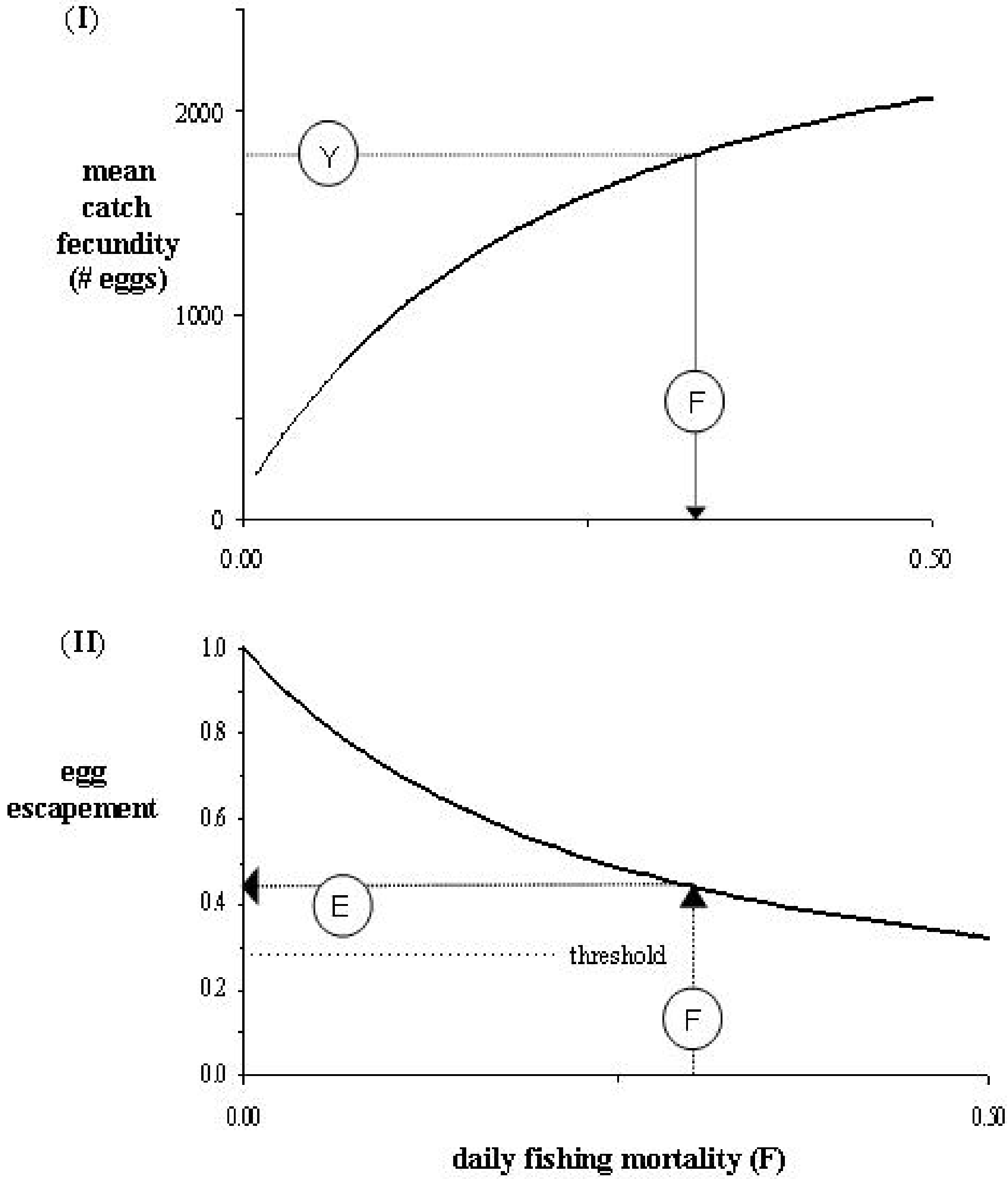
Management/Monitoring of Market Squid Based on Egg Escapement Analysis

Ray Conser/Mike Maxwell/Paul Crone

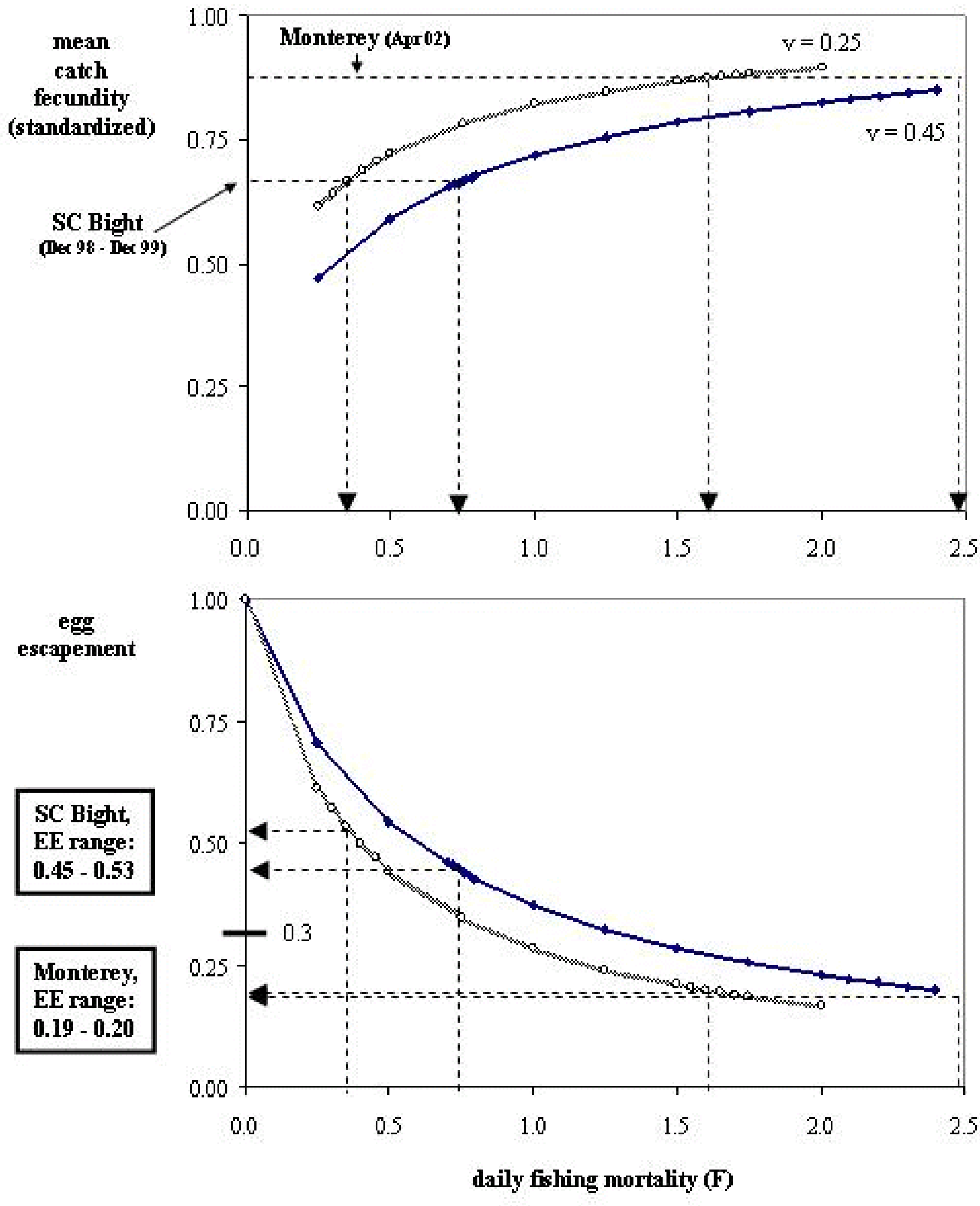
Over the last two years, the SWFSC and California Department of Fish and Game have worked collaboratively in efforts to develop a sound monitoring/management plan for market squid commercially exploited from coastal waters off southern and central California. Developing such as plan was problematic at times, given unique aspects of both squid biology and fishery-related operations. The market squid *(Loligo opalescens)* exhibit characteristics peculiar to many squid: rapid growth and development (i.e., can reach sexual maturity by 4-5 months following hatching); and relatively short lifespans (i.e., less than a year). Because the recruitment of spawning squid in any given year appears to be heavily influenced by environmental conditions and depends strongly on previous spawner escapement, a management strategy based on annual egg escapement (referred to as the Egg Escapement (EE) Method) has been developed for this marine species.

The EE method integrates classical per-recruit theory with recent research on the squid's life history to simulate the mortality and spawning rates of sexually mature females. Histological work has reaffirmed that market squid are 'terminal' spawners, with potential lifetime egg output fixed at sexual maturity. The EE model utilizes the standing stock of eggs in commercially-caught females ('catch fecundity') to estimate fishing mortality on the squid stock, and in turn, egg escapement relative to an unfished condition. That is, to gauge the fishery's impact on the squid population, the estimated reproductive output of the harvested population is compared to the population's output in the absence of fishing. In quantitative terms, the harvested population's egg output with respect to output expected in an unharvested state is the 'egg escapement.'

Crucial to the implementation of the EE method is the selection of a 'threshold' value of escapement. This threshold can be interpreted as a level of egg escapement that is believed to be at a minimum level that is considered necessary to allow the population to maintain viable levels of abundance into the future. From examinations of catch trends off California, as well as similar reference points used in other squid fisheries around the world, the Coastal Pelagic Species Management Team (CPSMT) has recommended a EE threshold value of 30%. It is important to note that an optimal (say 'sustainable') threshold level of egg escapement for market squid is not definitively known at this time and thus, the currently proposed monitoring/management scheme based on the EE method is founded on the assumption that fishing mortality rate(s) that result in EE values above 30% are (currently) the best candidate proxies for a fishing mortality rate that results in MSY (F_{MSY}).



Overview of egg escapement model: (I) mean catch fecundity (Y, in number of eggs), typically estimated from port sampled females, indicates level of directed fishing mortality (F) on the population; and (II) estimated F is then used to determine the population's level of egg escapement (E, in proportion) based on per recruit theory (i.e., life history parameters applicable to the squid population at large).

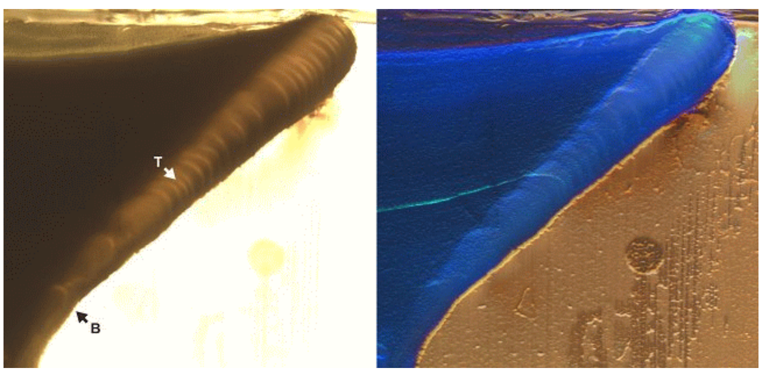


Egg escapement estimates for two scenarios of egg laying rate (v). Data for Southern California Bight: n = 135 females, mean catch fecundity = 2541 (SE = 102), mean potential fecundity = 3897 (SE = 336), mean catch fecundity (standardized) = 2541/3897 = 0.65. Data for Monterey: n = 85 females, mean catch fecundity = 3211 (SE = 110), mean potential fecundity = 3666 (SE = 23), mean catch fecundity (standardized) = 3211/3666 = 0.88.

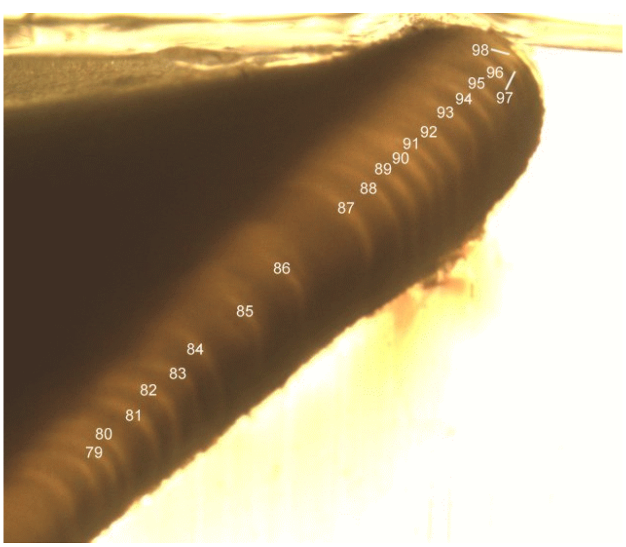
Manuscript Completed on Age-validated Leopard Shark Recaptured After 20 Years

Susan Smith

This paper describes age-validation for a tagged leopard shark at liberty for 20 years, the longest years at liberty for any age-validated shark, and growth for another individual at liberty 21.8 years. Tagging and recapture of fish whose calcified structures have been marked with the flourescent antibiotic oxytetracycline (OTC), provides a conclusive method for establishing the timing of growth zone formation in these structures. With sharks, OTC marking is often preferred over alternate methods of age validation because of their slow and highly variable growth patterns, and because calcified bands in their aging structures (e.g., vertebral centra) are often very difficult to interpret. Additionally, unlike teleosts, timing of band deposition in aging structures has been validated for only a few shark species, and few fish in general have had ages validated over the full range of age classes. This paper documents completion of age validation for this species through all age classes, the first complete age validation for any elasmobranch species. The paper also describes certain findings concerning OTC deposition and sensitivity to light, inter-annual variability in observed vertebral growth, and information on peripheral band deposition, which should prove useful to other researchers conducting fish age, growth and validation studies. Manuscript submitted to journal Dec 2001; accepted for publication September 2002 for issue *Fishery Bulletin* 101(1).



←Transverse section of leopard shark vertebrae under transmitted white (left) and UV (right) light, showing yellow-flourescing time mark. B=Birth year first winter mark, T= tagging year, 1979



←Vertebral section showing corresponding years assigned to annuli distal to the tetracycline mark at year 1979.

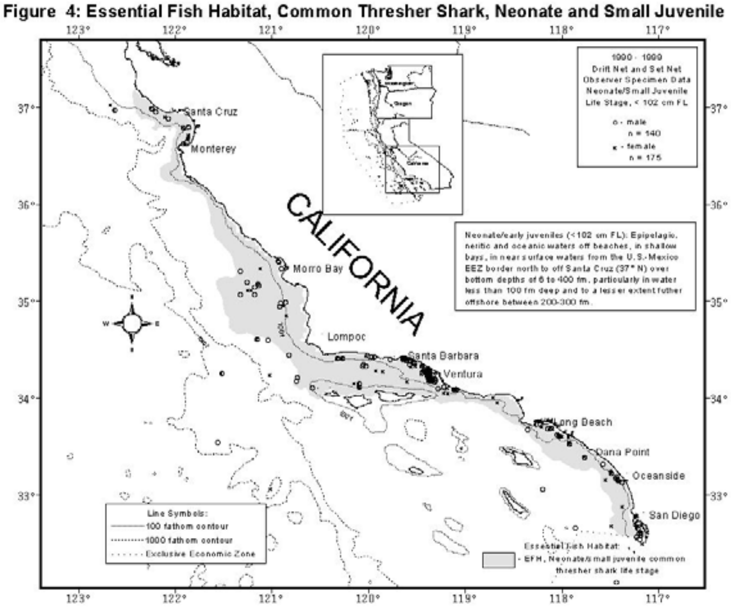
Leopard shark, *Triakis semifasciata*
(Monterey Bay Aquarium photo)

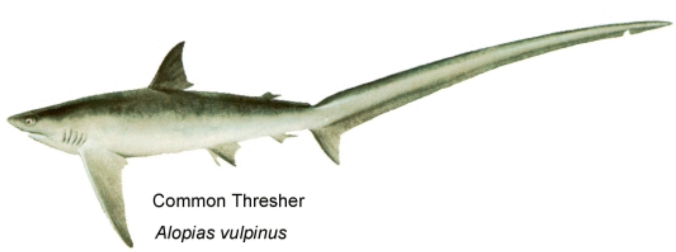
Survey to Begin of Common Thresher Shark Nursery Habitat

Susan Smith and David Holts

Preliminary longline sampling of 0-yr and 1-yr old common thresher sharks will be conducted during the months of June-Sept 2003 between Point Conception and the California-Mexico border to determine presence/absence and catch rate variance of juvenile thresher sharks. Sampling will be conducted in four depth strata along a transect live in four known areas where pups are known to occur–off Coronado, San Diego; San Pedro Bay; Santa Monica Bay and the area between Santa Barbara and Ventura. The purpose is to develop a final sampling regime to 1) delineate core inshore nursery grounds of year 0 pups; 2) determine growth rates during the first year and second of life; to 3) determine physical and biological characteristics associated with thresher shark core nursery grounds, and to 4) determine interannual relative abundance. The inshore and along shore boundaries of this nursery area (or areas) is as yet undefined because existing data are based primarily on catches of stationary nets set non-systematically along the coast and targeting other species. The Division wants to define this habitat using a small laboratory vessel, fishing in inshore waters, and sampling and tagging neonate thresher sharks. This inshore coastal area will be sampled with small lightweight pelagic longlines to catch neonates, and using other sampling devices to record various physical and biological characteristics associated with this habitat. The Division proposes to obtain use of a California Department of Fish and Game vessel to sample these inshore areas.

Figure 4: Essential Fish Habitat, Common Thresher Shark, Neonate and Small Juvenile

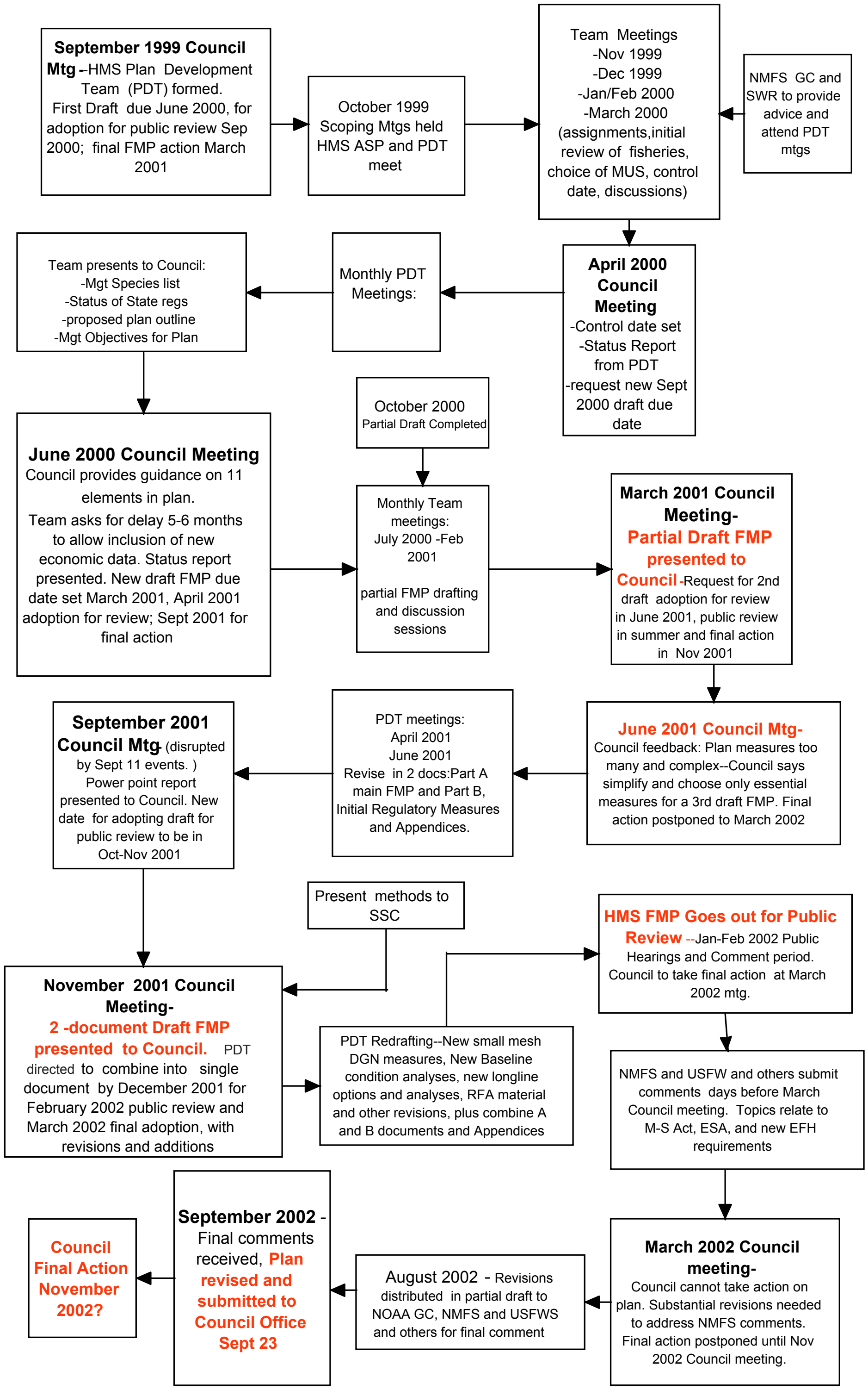




Common Thresher
Alopias vulpinus

Planned Completion Date: Preliminary pilot survey to be conducted June-Sept 2003; subsequent sampling each summer for three years thereafter. Last sampling year to be completed in the summer of 2006, with final results and report in FY 2007. Results of the preliminary pilot survey to be completed 2nd quarter FY 2004.

History of the HMS Fishery Management Plan Development Process



Estimating a Harvest Guideline for Common Thresher Shark

David Au and Christina Show

Introduction. The Magnuson-Stevens Act requires that the Fishery Management Plan (FMP) being developed for the Pacific Council supply MSYs for all managed species, including the common thresher shark. We have estimated local MSY and a harvest guideline for this shark by a non-traditional approach that circumvents the difficulties of estimating mortality on a long-lived slow-growing species and estimating sustainable production from catches reflecting unsustainable, non-equilibrium fishing and changing regulations. These are common problems in assessing low productivity species.

History. Between 1980 and 1990, various State restrictions severely curtailed the drift gillnet fishery for common thresher as CPUE fell and the fishery increasingly targeted swordfish instead. The result is that the catch and effort trajectories for thresher shark reflect more the changing fishery than population production.

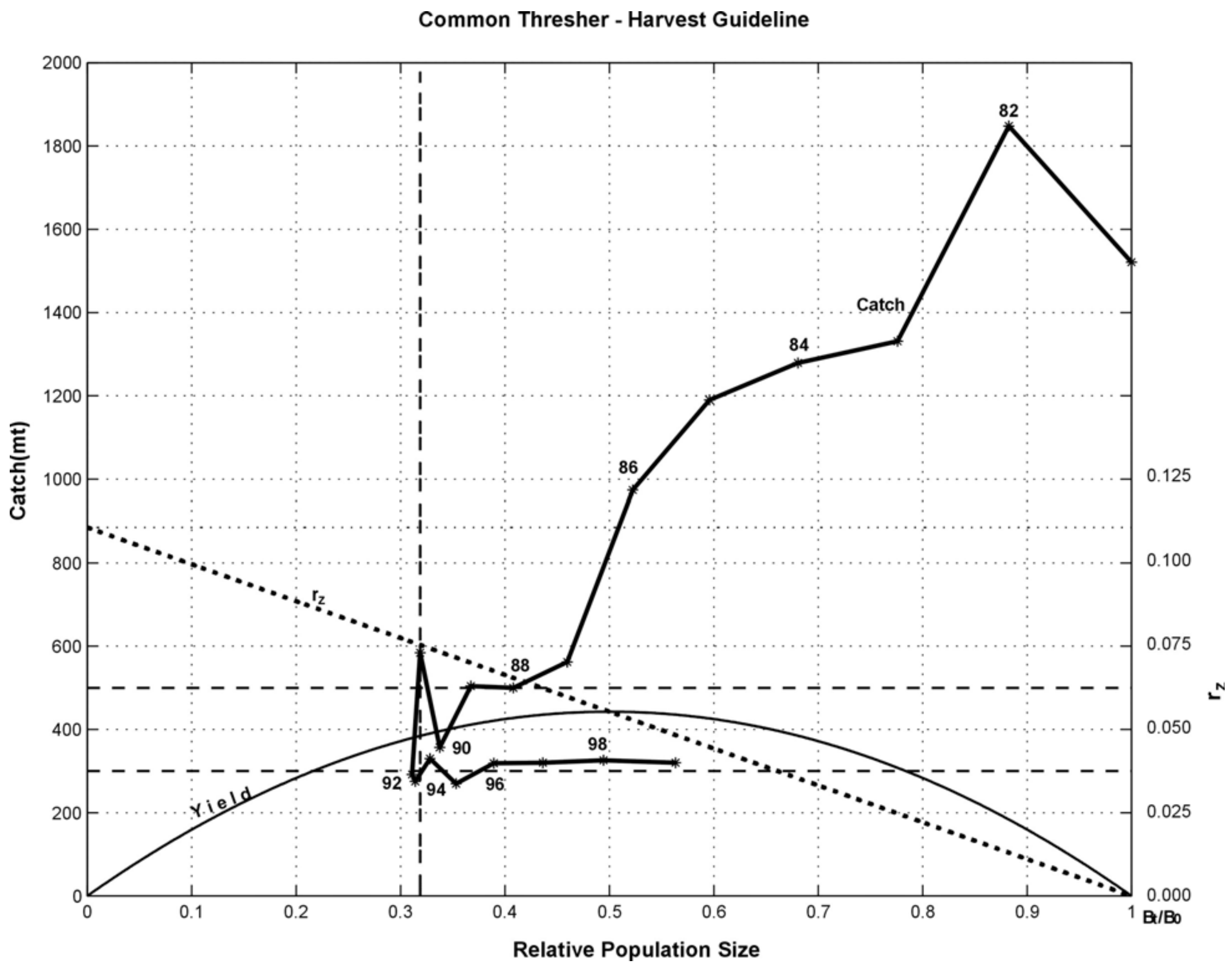
Method. The simple logistic production curve, utilizing estimates of the parameters B_o (initial biomass) and r (intrinsic rate of population increase) was fitted to the 1981-99 gillnet fishery's catch-CPUE relationship to estimate this shark's MSY (and afterwards, the harvest guideline). The intrinsic rate directly estimates sustainable catch rate and was estimated from demographic parameters using a procedure we call "intrinsic rebound potential." Parameter B_o was prorated from B_t (biomass during 1992-3 when the population was temporarily at equilibrium with natural production), which was estimated by dividing the catch of those years by the annual population growth rate then, based on the r-level at that population size (CPUE). CPUE was estimated as the annual weighted average catch (numbers of fish) per net length - hours soaked effort units. Data from approximately 4000 sets per year were utilized.

The production curve applies to the portion of the stock accessed by U.S. fishers. It does not include the unknown production from off Mexico. Thus the MSY given by the curve is actually an estimate of local MSY (LMSY).

The procedure is illustrated in the attached figure showing the catch (y-axis) and relative CPUE (x-axis) fishery history as a time trajectory (1981-99), together with the fitted production curve. The latter, for sustainable production, does not follow the non-equilibrium fishery trajectory. The figure's caption explains the method as illustrated, with horizontal and vertical lines as guides.

Results. The central estimate of LMSY is 450 mt for all gears (see figure). Because the thresher shark is treated as a "vulnerable" species in the FMP, and because the FMP specifies the harvest guideline for such species to be 0.75MSY, the harvest guideline for this shark is 0.75*450mt = 340 mt (rounded).

Comment. The harvest guideline of 340 mt for common thresher shark is to be compared with the Pacific States Marine Fisheries Commission's guideline, presently 578 mt. and also with the 306 mt average catch since 1992, and the maximum 1521 mt catch in 1981.



A proxy estimate of local maximum sustainable yield (LMSY) for the common thresher shark. The 1981-1999 catch vs. relative population size (B_t/B_o) trajectory shows population recovery beginning at 1992-93 (trajectory moves to right) at a relative population size of 0.32 (vertical line) and between sustainable catch levels (horizontal lines) that, along with the productivity at that population size (r_Z at intersection with vertical line), together determine a production function as shown (parabola). In this example, the LMSY proxy estimate is 450 mt.

Stock Assessment of Pacific Sardine with Management Recommendations for 2003

Ramon J. Conser[1], Kevin T. Hill[2], Paul R. Crone[1], Nancy C.H. Lo[1], and Darrin Bergen[2]

A SWFSC/CDF&G collaborative stock assessment was conducted on Pacific sardine (*Sardinops sagax*). The assessment updates the work carried out last year (Conser et al. 2002), and is intended for use by the Pacific Fishery Management Council (PFMC) in developing management goals and setting harvest guidelines for the upcoming fishing season for sardine.

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

Estimated stock biomass ($\geq$1-year old fish on July 1, 2002) from the assessment conducted this year indicated the sardine population has remained at a relatively high abundance level, with a bias-corrected estimate of nearly 1.0 million mt (Figure 1). Estimated recruitment (age-0 fish on July 1) during the past four years has declined considerably from that estimated for the strong 1998 year-class (Figure 2). However, it should be noted that recent recruitment is not estimated precisely, and another 2-3 years of data may be needed to ascertain whether the sardine population biomass has reached a plateau at the 1.0 million mt level.

Estimates of Pacific sardine biomass from the 1930's (Murphy 1966 and MacCall 1979) indicate that the sardine population may have been more than three times its current size prior to the population decline and eventual collapse in the 1960's. Considering the historical perspective, it would appear that the sardine population, under the right conditions, may still have growth potential beyond its present size. However, per capita recruitment estimates show a downward trend in recruits per spawner in recent years that may be indicative of a stock that has reached a plateau under current environmental conditions (Conser et al. 2002).

The stock assessment document is available electronically at:
http://swfsc.nmfs.noaa.gov/frd/Coastal%20Pelagics/Sardine/sardine1.htm

[1] Southwest Fisheries Science Center [2] California Department of Fish and Game

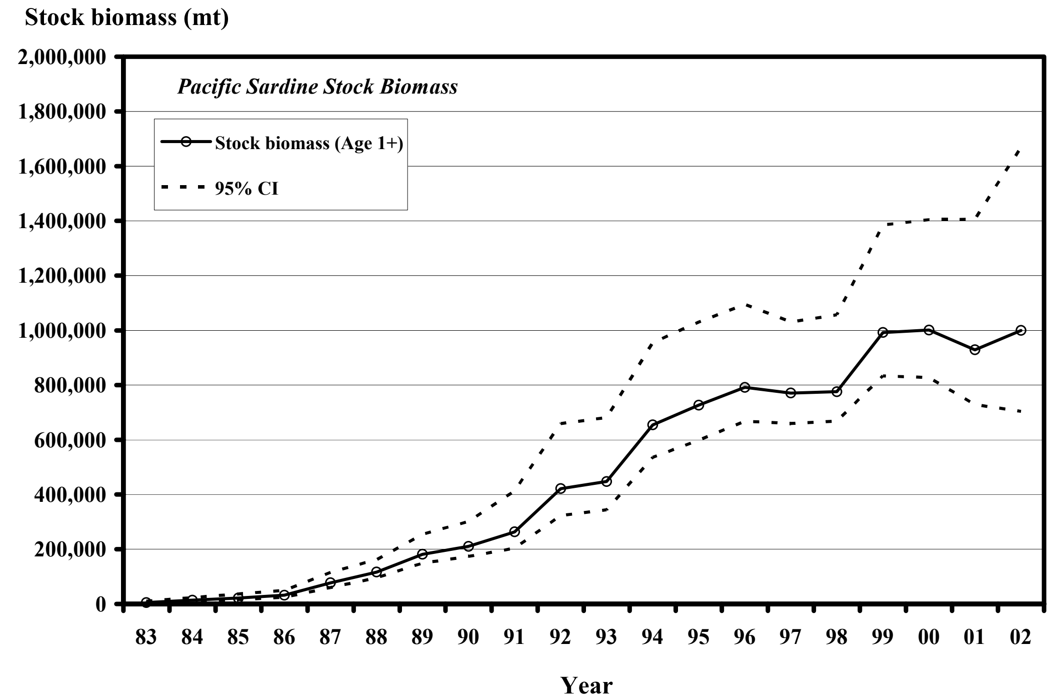


Figure 1. Time series (1983-2002) of Pacific sardine stock biomass (>1-yr old fish on July 1 of each year in mt) estimated from an age-structured stock assessment model.

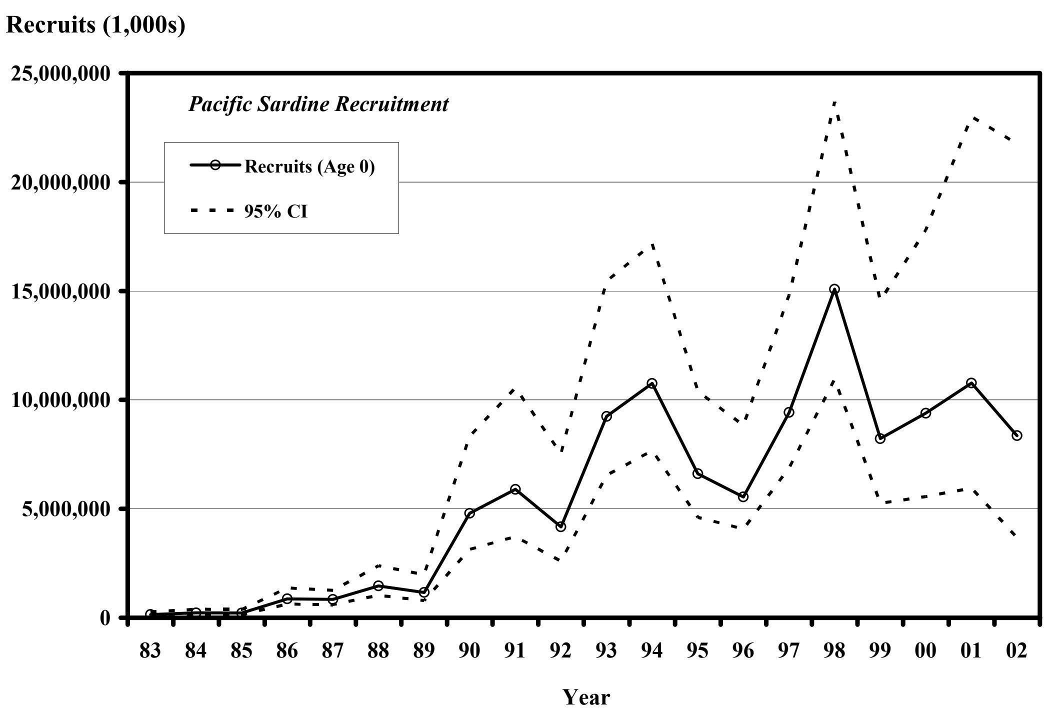


Figure 2. Time series (1983-2002) of Pacific sardine recruitment (0-yr old fish on July 1 of each year in 1,000s) estimated from an age-structured stock assessment model.

Striped Marlin Archival Satellite Tagging

Dave Holts

A satellite tagging experiment was conducted to track the seasonal migratory pattern and post-release survival of striped marlin. Fisheries data indicate striped marlin migrate into southern California from the central Pacific and offshore waters of Mexico where they support a robust recreational fishery during the summer and fall. Little is known concerning the survival of these fish after they move south and back into the central Pacific.

In cooperation with the Marlin Club of San Diego, Center staff and members of the Marlin Club deployed five satellite archival pop-off tags (PSAT) on striped marlin during the second annual Offshore Invitational Tag and Release Tournament (September 2001). The data collected by the PSATs allow an evaluation of the habitat preference, movements and provide a means to estimate survival of animals released during marlin tournament conditions. The PSAT tags store temperature, pressure and light intensity data during deployment which is transmitted to the Argos satellite system. These data are used to determine net movement, time spent at temperature and depth on an hourly basis.

During the tournament, selected marlin were tagged with satellite transmitters. Four of the tagged striped marlin were judged to be in good condition at release and one was in poor condition. Results indicated two of the striped marlin had died shortly after being released. The three surviving marlin all moved south into Mexican waters off Baja California Sur, Mexico (Figure). Recorded light intensity levels, indicating day length, were used to calculate longitude and confirmed south and eastward movement as the fish moved south into warmer water off Mexico.

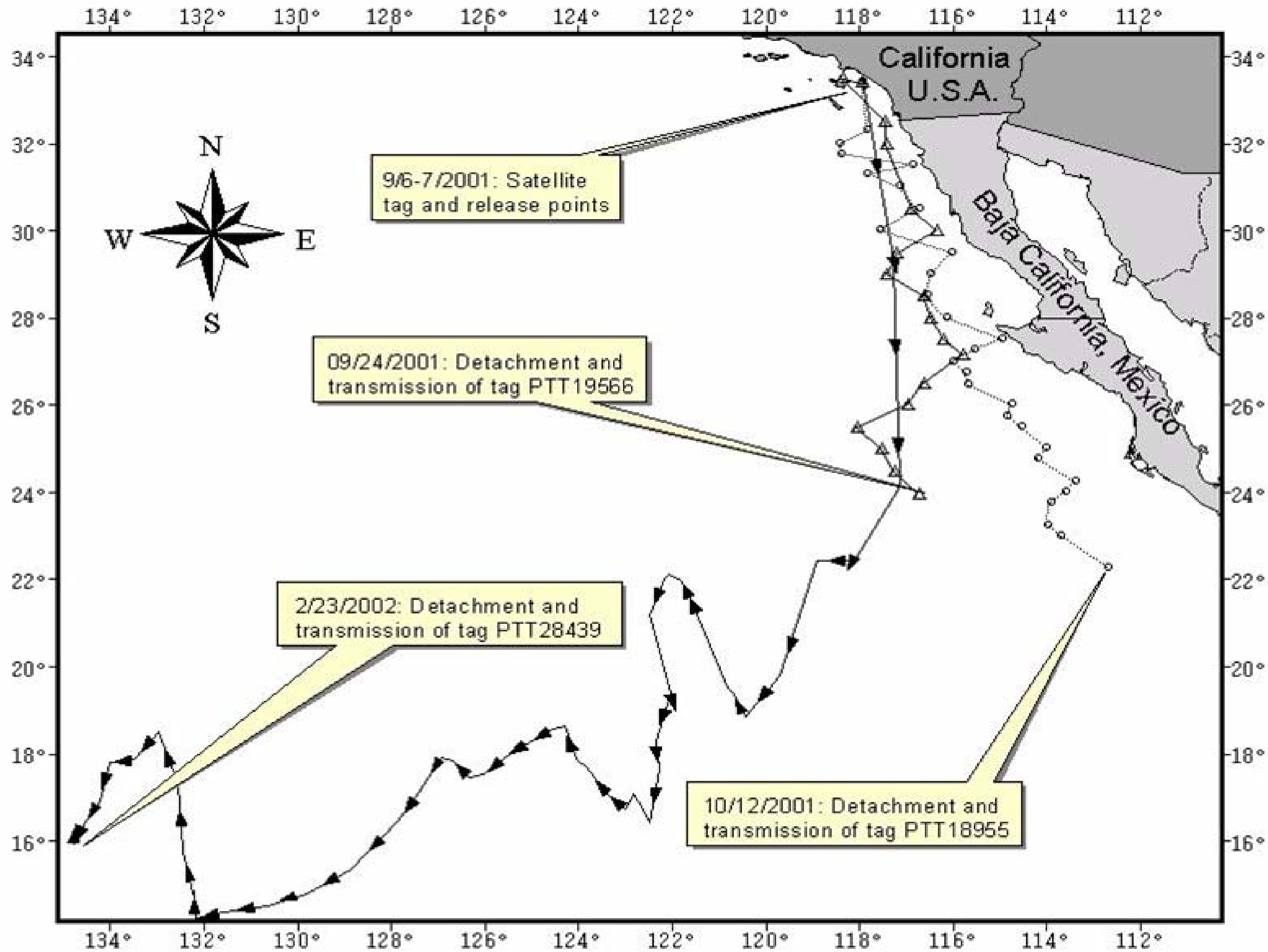
Movement data are:

Marlin 1.	35 days	715 nmi	20.4 nmi/day
Marlin 2.	16 days	559 nmi	34.9 nmi/day
Marlin 3.	180 days	1,400 nmi	7.6 nmi/day

Ambient water temperature ranges and depth of swimming indicated these striped marlin favor the warm surface water above 10 meters, but will occasionally descend to at least 100m. Time at temperature showed 55 %to 90 % of their time above 20°C. Time spent above 10 m depth ranged from 74 % to 86 %.

These results support the theory that striped marlin, after moving into Southern California, return to warmer water off Mexico and the central Pacific by moving south or southeast in the offshore waters along the Baja peninsula. Ambient temperature, depth and light intensity data taken together allow for a fairly accurate estimate of the tracks taken by each of the three marlin.

Striped Marlin Satellite Tagging Tracklines



The International Billfish Survey

Dave Holts

The *International Billfish Angler Survey* began in 1969 and now provides a 33-year time series of recreational catch and fishing effort for billfish in many key Pacific locations. Catch per unit of effort (CPUE) is measured in catch of billfish per angler fishing day. This survey provides the only measure of billfish angler success in the Pacific.

In 2001, 487 billfish anglers reported catching 2,822 billfish during 6,399 fishing days. The annual mean catch-per-effort for all billfish was 0.44 billfish per day in 2001, down from 0.61 in 2000. The current overall mean catch rate of 0.44 is below the prior five-year average of 0.50 (1996 to 2000). The all-time mean high catch rate of 0.57 occurred during the first years of this survey (1969 to 1971). The lowest catch rates averaged 0.33 during the mid-1970s.

Reported catch rates, by area, for blue marlin, striped marlin, Pacific sailfish and black marlin are shown graphically in figure 1.

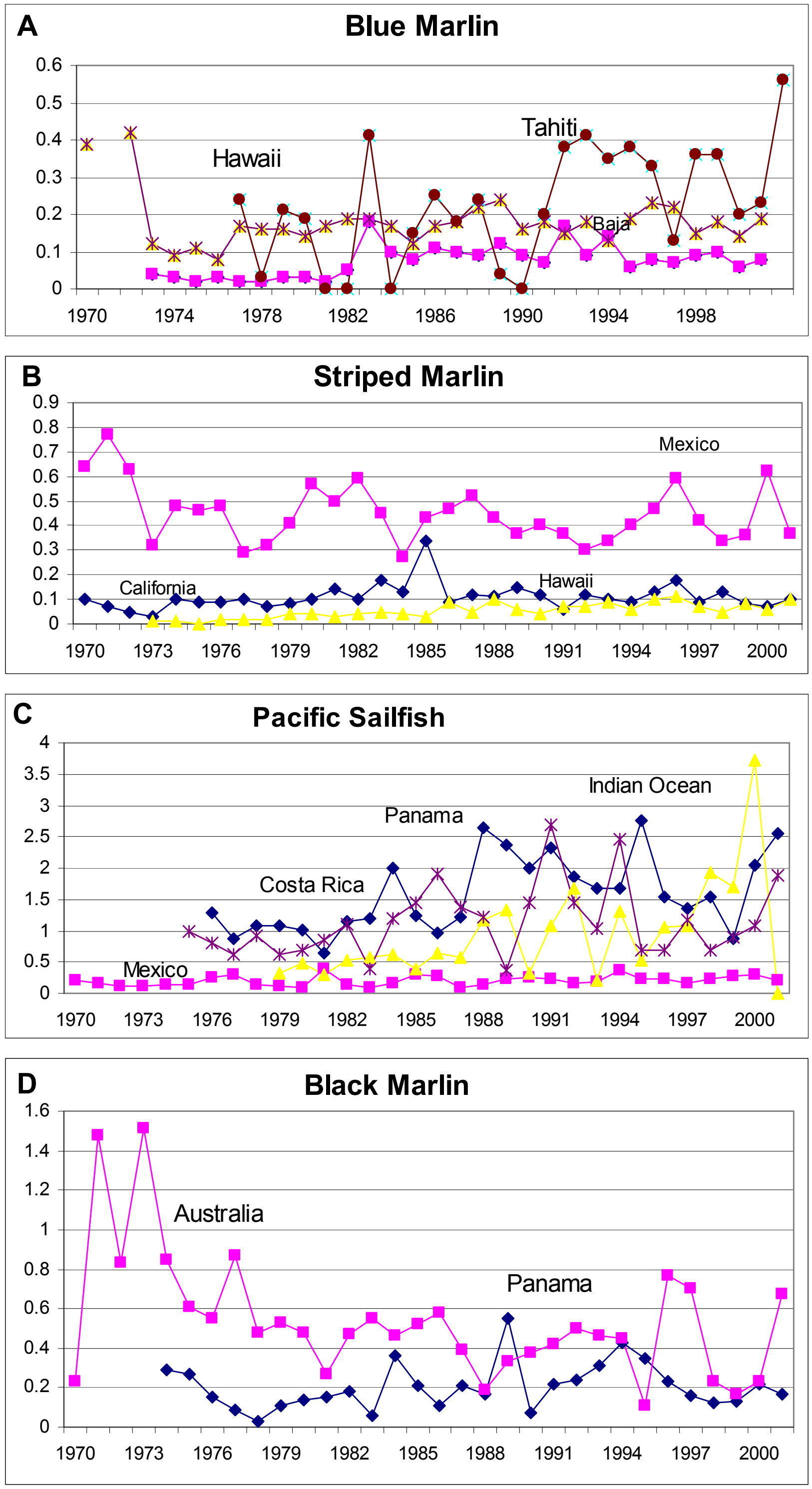


Figure 1. Catch per unit of effort (CPUE) in number of fish per angler day reported by region from 1969 to 2001, for blue marlin (A), striped marlin (B), Pacific sailfish (C), and black marlin (D).

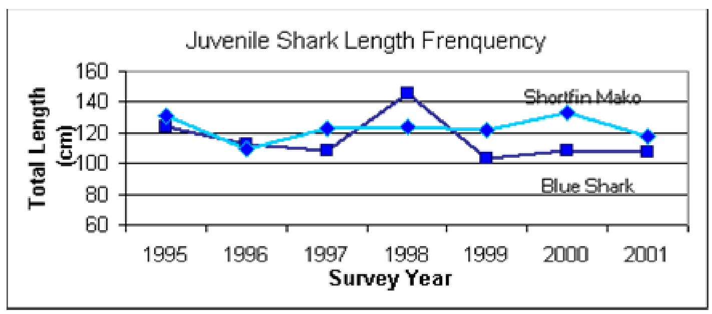
Juvenile Shark Survey

Dave Holts

Fisheries Division staff initiated the juvenile shark abundance survey in 1994 to track changes in relative abundance of juvenile sharks within the southern California bight (SCB). Survey methodology is based on historical records of the longline shark fishery (1988 to 1991). Logbook data provided average densities; spatial distributions and variations in catch which were used to develop the sampling design. A minimum of seven standard stations are sampled four times during each annual survey. The survey is conducted on the Center's research vessel, *R/V David Starr Jordan*. Sampling gear consists of a two-mile longline constructed of stainless steel on which up to 200 leaders and hooks baited with mackerel are attached.

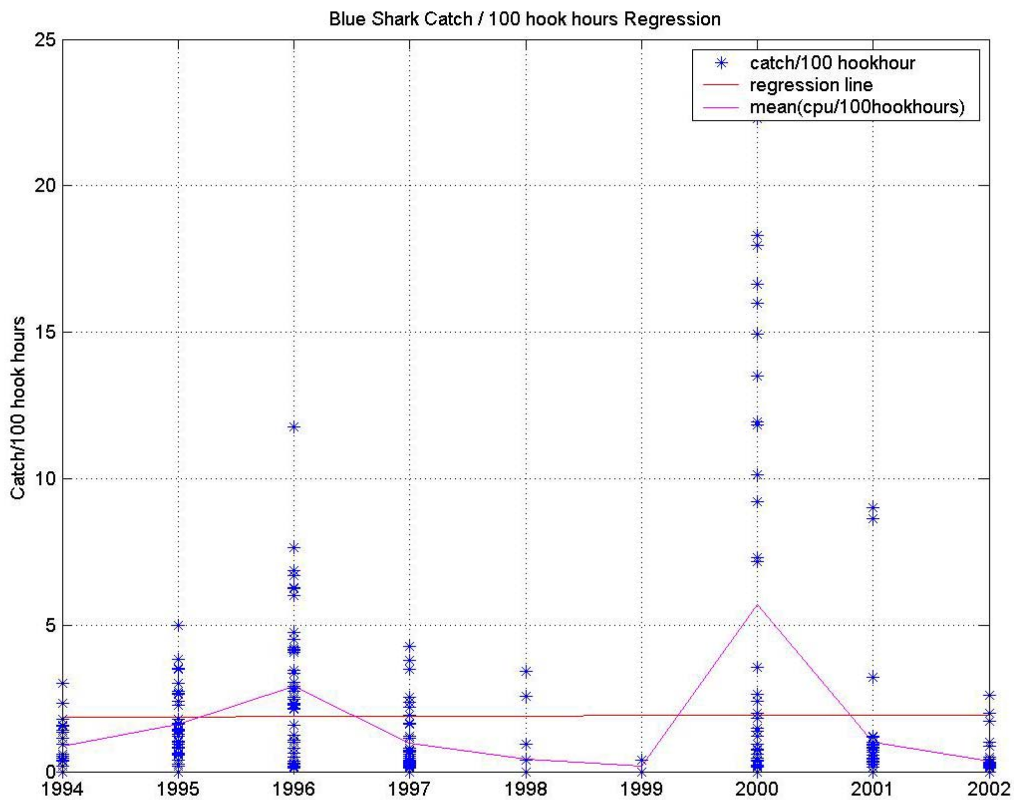
In 2002, 35 logline sampling stations were conducted between June 19 and July 8. In total, 119 mako, 2 thresher and 73 blue sharks were captured and sampled. Catch and catch-per-unit of effort (CPUE) for the shortfin mako declined from 1.01 sharks per 100 hook-hours in 1994 to 0.23 during the 2000 survey but increased in 2001and 2002. The overall decline in mako CPUE is statistically significant (alpha=0.05) over the study period. The catch and CPUE for blue shark ranged between 0.80 and 5.14 from 1994 to 2002, but does not indicate any significant trend. The number of survey sampling sets was limited in 1998 and 1999 in order to conduct acoustic tracking and satellite archival tagging of common thresher sharks.

Mean total lengths for mako changed little over the nine year survey period although considerable variance occurred between years. Mean total lengths of blue shark has decreased.



The declining trends for mako shark CPUE and length frequency of blue shark are a concern. While there are a number of reasons to explain the decline, no obvious cause currently presents itself. It is encouraging that blue shark CPUE and mako length frequencies seem to have stabilized. Continuation of the survey is recommended to ensure a robust time line of mako CPUE and length frequencies of juvenile pelagic sharks in the SCB. Extending the sampling design to include a larger geographic area could provide additional information on mako, and blue shark, populations within their defined essential habitat.

Several ancillary research projects are conducted during the juvenile shark surveys. All sharks are released alive and most are tagged with conventional spaghetti tags to help determine migration patterns, stock boundaries, and age and growth. In 2002, 101 mako and 2 thresher sharks were injected with OTC for ongoing age and growth studies. This brings to 360 and 104 the total number of mako and thresher sharks tagged with OTC since 1995. Total recaptured to date is 3.8%. Blood was drawn from an additional 55 mako and 2 thresher sharks for studies of condition at capture and post release survival. Preliminary assay of blood chemistry indicates extremely high catecholanse and lactate levels at capture and release when compared to resting, captive sharks.


Blue Shark Catch / 100 hook hours Regression
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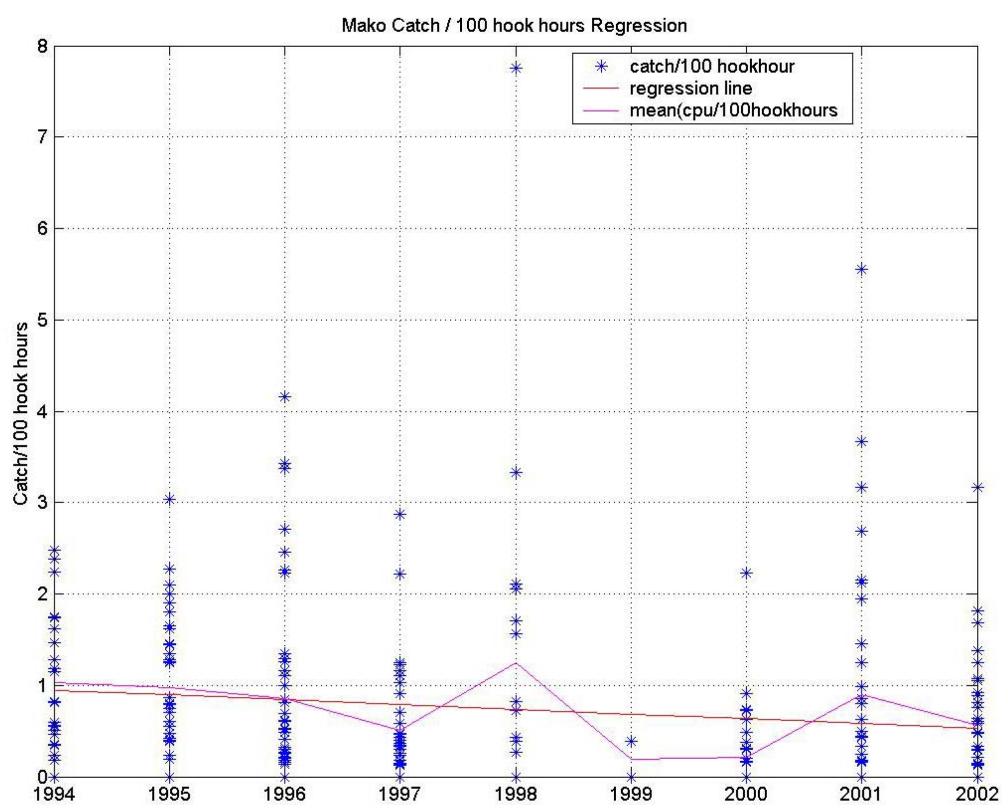
Mako Catch / 100 hook hours Regression
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Marine Ecological Reserves Research Program

John Hunter

The California Marine Resources Protection Act of 1990 required the creation of four coastal marine reserves to conserve biodiversity and to benefit fishery resources by providing protected spawning habitat for species of sport and commercial fishery value, thus providing eggs and larvae to "reseed" fished areas outside the reserves. Subsequently, the California Department of Fish and Game established the Marine Ecological Reserves Research Program (MERRP), administered by the California Sea Grant College Program, to study the new reserves. These new reserves were the Punta Gorda and Big Creek Ecological Reserves in northern and central California, respectively, and Vandenberg and Big Sycamore Canyon Ecological Reserves in southern California. In 1998–1999 the Fisheries Resources Division of Southwest Fisheries Science Center conducted a study at the two southern reserves, to describe and map the benthic habitat at each study site, to describe the fish species at each site, to determine the taxonomic composition and fine-scale distributions of the ichthyoplankton at each site, and to estimate the potential for the eggs and larvae of commercially or recreationally valuable fishes produced in these reserves to "reseed" adjacent fished areas. The study included comparative sampling at two nearby islands (Anacapa and San Miguel Islands) in the Channel Islands National Marine Sanctuary (Figure 1).

Sea surface temperatures generally are cooler at the northwestern study sites (Vandenberg Ecological Reserve and San Miguel Island) than at the southeastern sites (Big Sycamore Canyon Ecological Reserve and Anacapa Island) and cool-water fishes are more common at the northeastern sites, while warm-water fishes are more common at the southeastern sites (AVHRR satellite images of sea surface temperature can be seen at the NOAA Coastwatch web site; a link is available at the Fisheries Resources Division web site http://swfsc.ucsd.edu/frd/). The areas around the two state reserves are mostly sandy bottom with little rocky habitat suitable for rockfishes, abalone, and other species with rocky-bottom habitat affinity. Much more rocky bottom is available at the islands and there is fairly extensive kelp coverage shoreward of about 20m depth at San Miguel Island. Production of eggs and larvae of most shorefishes of fishery value (most have rocky-bottom or kelp forest habitat affinity, for example, rockfishes, California sheephead) is low at both of the state reserve sites, especially at Vandenberg Ecological Reserve. Some soft-bottom fishes including California halibut do spawn in Big Sycamore Canyon Ecological Reserve (Figure 2), but are unlikely to have significant fidelity to that small reserve site surrounded by extensive, similar habitat. Abundances of eggs and larvae of several species of fishery value are high at Anacapa and San Miguel Islands, reflecting the rocky bottom and kelp habitats available there (Figure 3). Results of this study show that there is a relatively close linkage between coastal habitat type and the shorefish component of the ichthyoplankton in those waters, and demonstrate the importance of habitat in sighting of coastal marine reserves.

Results of the MERRP studies at all four state reserves have been published as a cd-rom by California Sea Grant College Program, University of California, La Jolla (http://www-csgc.ucsd.edu/).

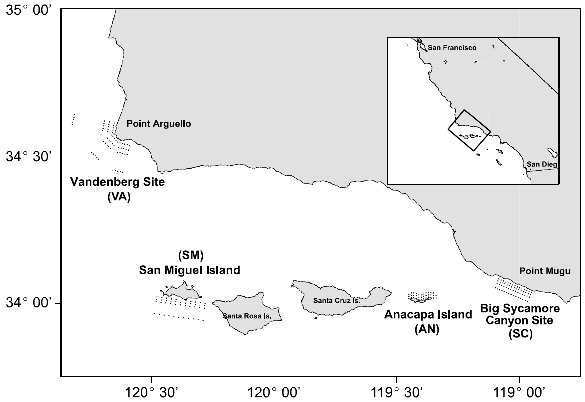


Figure 1

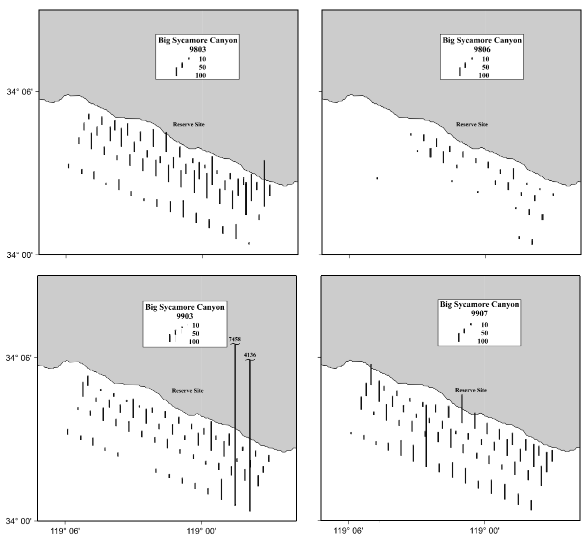


Figure 2

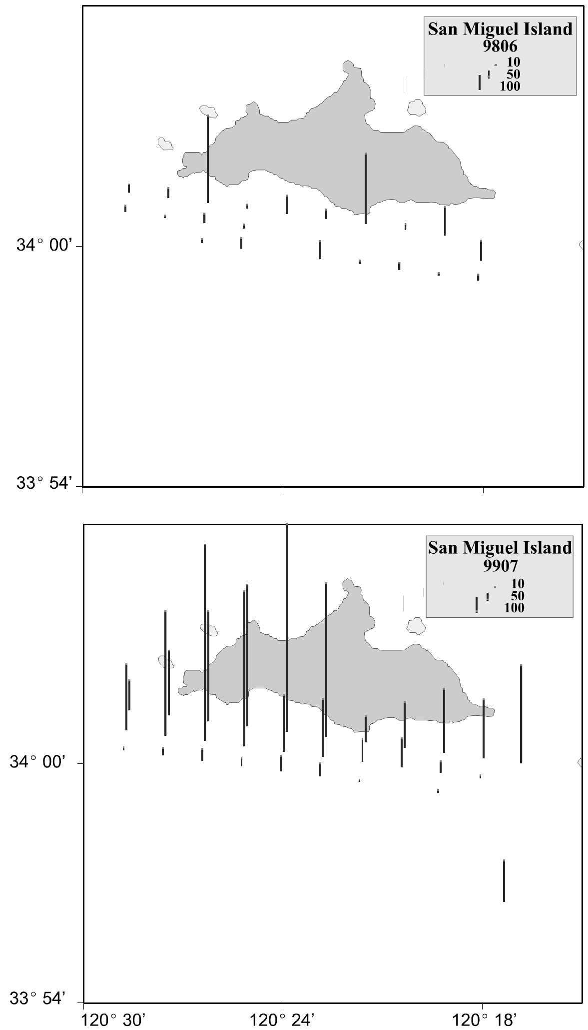


Figure 3

Ichthyoplankton Collected During PRD Dolphin Surveys in the Eastern Tropical Pacific

John Hunter

In response to Public Law 105-42 (1997 International Dolphin Conservation Act) the Protected Resources Division (PRD) conducted annual surveys of the eastern tropical Pacific (ETP) from 1998–2000 to monitor dolphin stocks and make oceanographic and ecological observations related to those stocks, including daily oblique (bongo net) and surface (Manta net) plankton collections. The surface plankton collections are essentially a continuation of a plankton time series based on PRD surveys in the ETP from 1986–1992, and the oblique collections provide a link to the Eastropac Expeditions of 1967–1968. Analysis of the ichthyoplankton fraction of the 1998–2000 plankton samples is complete and this year two NOAA Technical Memoranda documenting the 1998 and 1999 ichthyoplankton and net tow data were published. Preparation of a NOAA Technical Memorandum that documents the 2000 data is nearing completion. In these reports we provide ichthyoplankton, juvenile/adult fish, station and tow data in tabular form, and map the distributions of some of the more abundant ichthyoplankton taxa, such as bullet and frigate mackerels, *Auxis* spp. (Figure 1) and dorado, *Coryphaena hippurus*, in the Manta collections, and Panama lightfish, *Vinciguerria lucetia* (Figure 2) and Diogenes lanternfish, *Diogenichthys laternatus*, in the bongo collections. These data, together with the other biological and oceanographic data collected during the ETP dolphin surveys, are crucial in addressing the question of whether there has been an ecosystem change that may affect the ETP dolphin stocks. In addition, the ichthyoplankton data provide time series information on larval abundances and distributions of valuable fishery species that may be useful in the conservation and management of these resources.

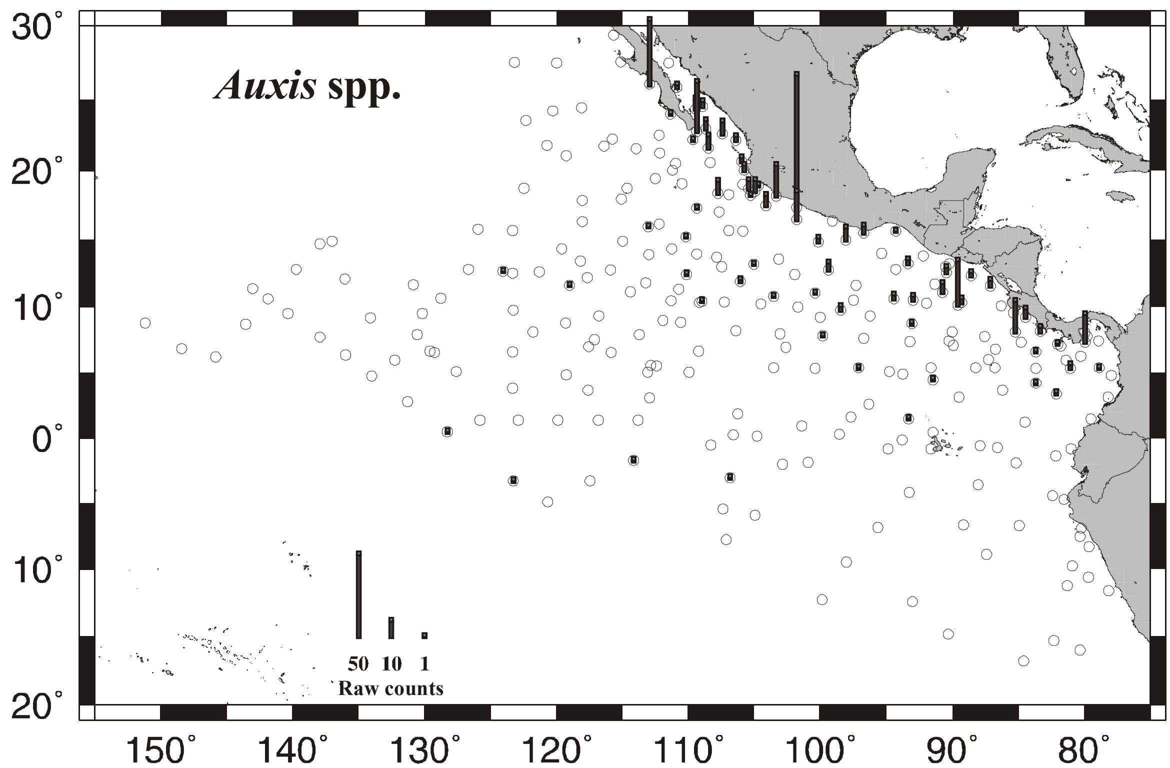


Figure 1a. Distribution of *Auxis* spp. larvae from Manta net tows: 9810EN, 9810JD, and 9810M4.

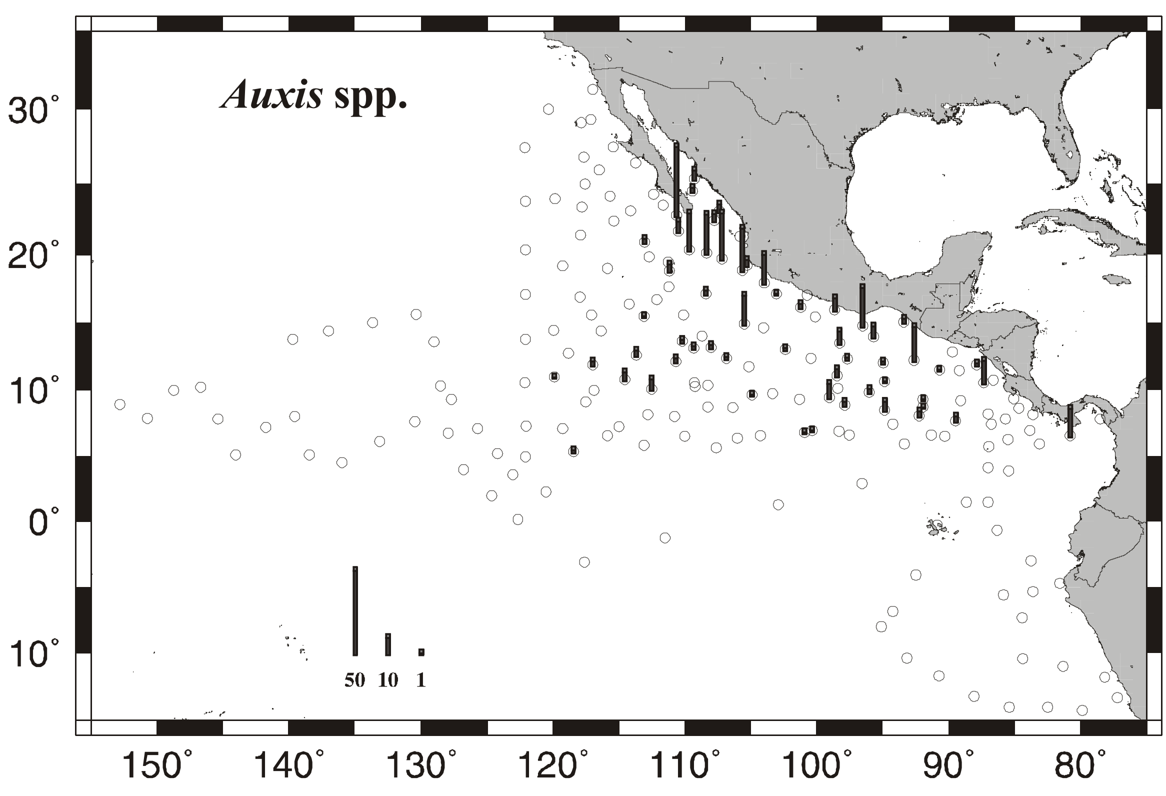


Figure 1b. Distribution of *Auxis* spp. larvae from Manta net tows: 9910JD and 9910M4.

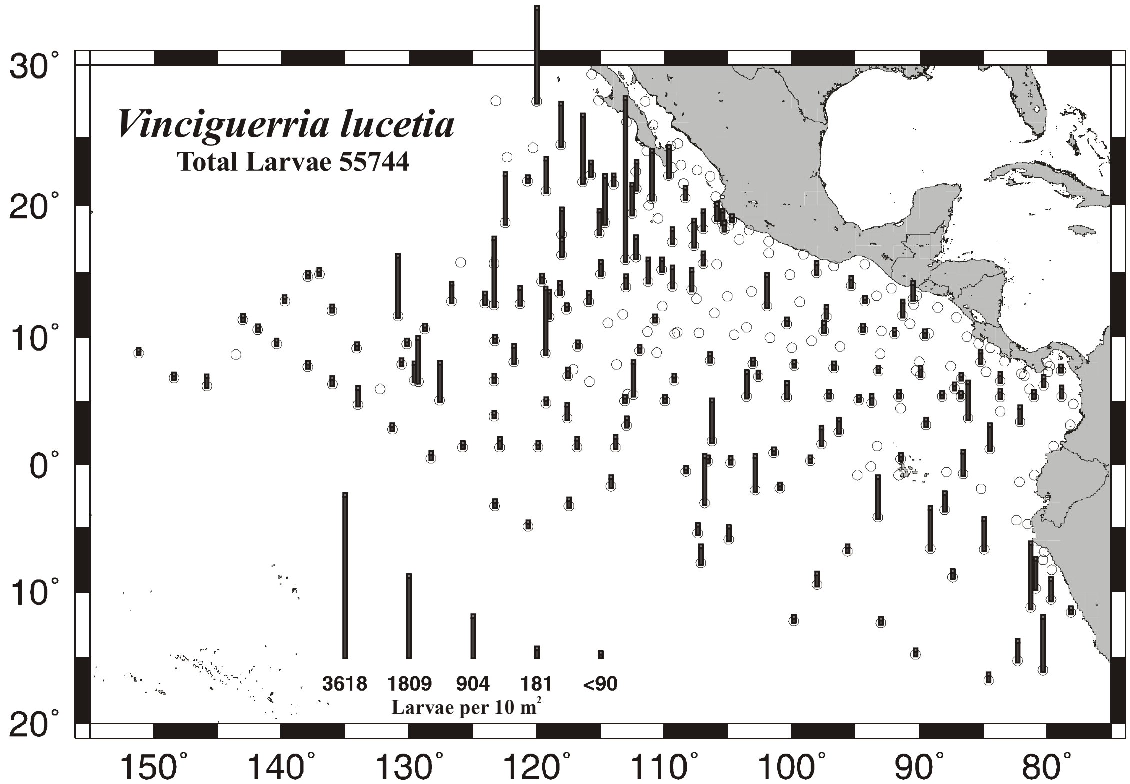


Figure 2a. Distribution of *Vinciguerria lucetia* larvae from bongo net tows: 9810EN, 9810JD, and 9810M4.

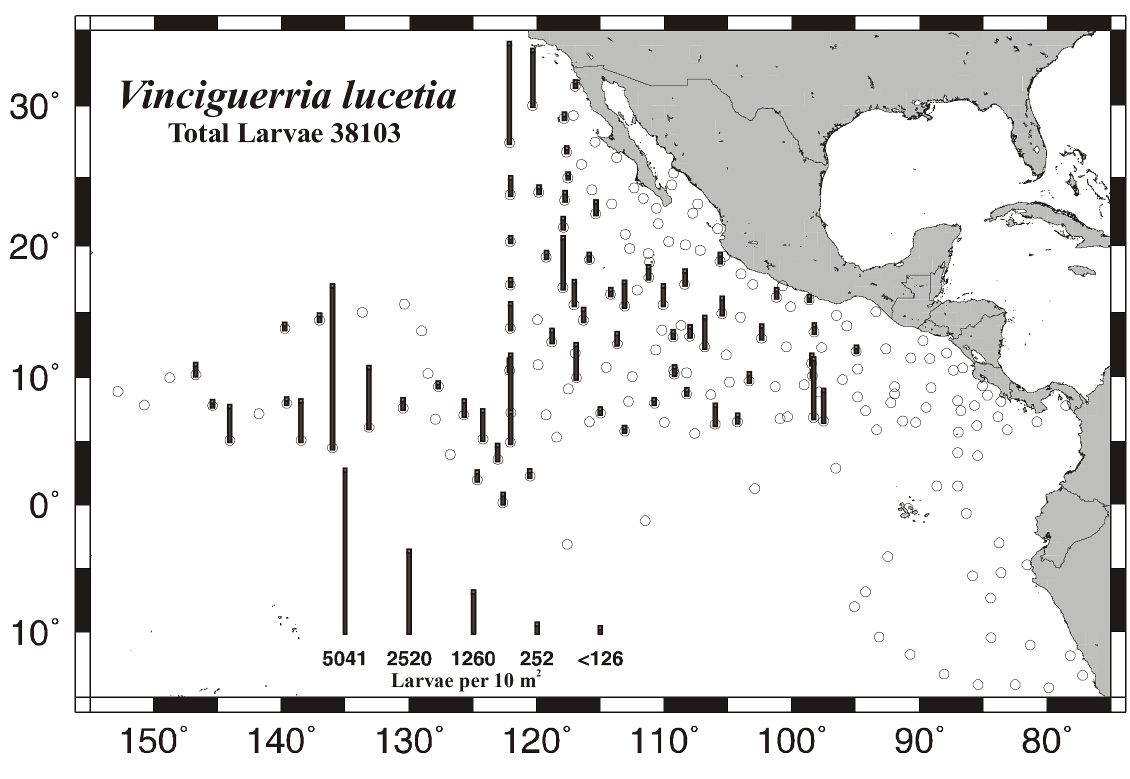


Figure 2b. Distribution of *Vinciguerria lucetia* larvae from bongo net tows: 9910M4.

CalCOFI Atlas 35: Distributional Atlas of Fish Larvae and Eggs from Manta (surface) Samples Collected on CalCOFI Surveys from 1977 to 2000

John Hunter

Surface waters are inhabited by the early life stages of numerous fish species, including many that are found exclusively near the surface and have evolved special adaptations for life in that zone. Beginning late in 1977, quantitative (Manta net) sampling of these near-surface waters was initiated on CalCOFI surveys and it subsequently has become part of the standard station protocol. The data base for the surface ichthyoplankton and net tow data through October 2000 is documented in a series of 19 NOAA Technical Memoranda published in 2001 and 2002. Preparation of a NOAA Technical Memorandum documenting the 2001 data is nearing completion. A distributional atlas, CalCOFI Atlas 35, that summarizes results of this ichthyoneuston sampling, was published in May, 2002. In the atlas we list the rank orders of abundance and occurrence of all 188 ichthyoplankton taxa and categories collected in Manta net tows during the December 1997–October 2000 CalCOFI cruises and show the spatial and temporal distributions of 93 taxa and categories. We also graphically display the relationships of these distributions to El Niño/Southern Oscillation events.

The Manta net time series is particularly important for monitoring larvae that live primarily in surface waters, such as cabezon (Figure 1), lingcod, and sablefish, and the Manta net captures larger larvae than typically are caught with the bongo net, as well as more individuals of especially evasive larvae such as Pacific mackerel and market squid. The CalCOFI Manta net data base, together with the bongo net (oblique tow) data base, is a primary resource for revealing historical trends in fish populations of the California Current region and it is likely to serve a key role in the management and conservation of fishery stocks in the region, as the oblique tow data base already has done. As many of the fish populations decline, the need for these time series increases. The demand for CalCOFI data by scientists preparing stock assessments for the Pacific Fisheries Management Council has increased regularly in recent years.

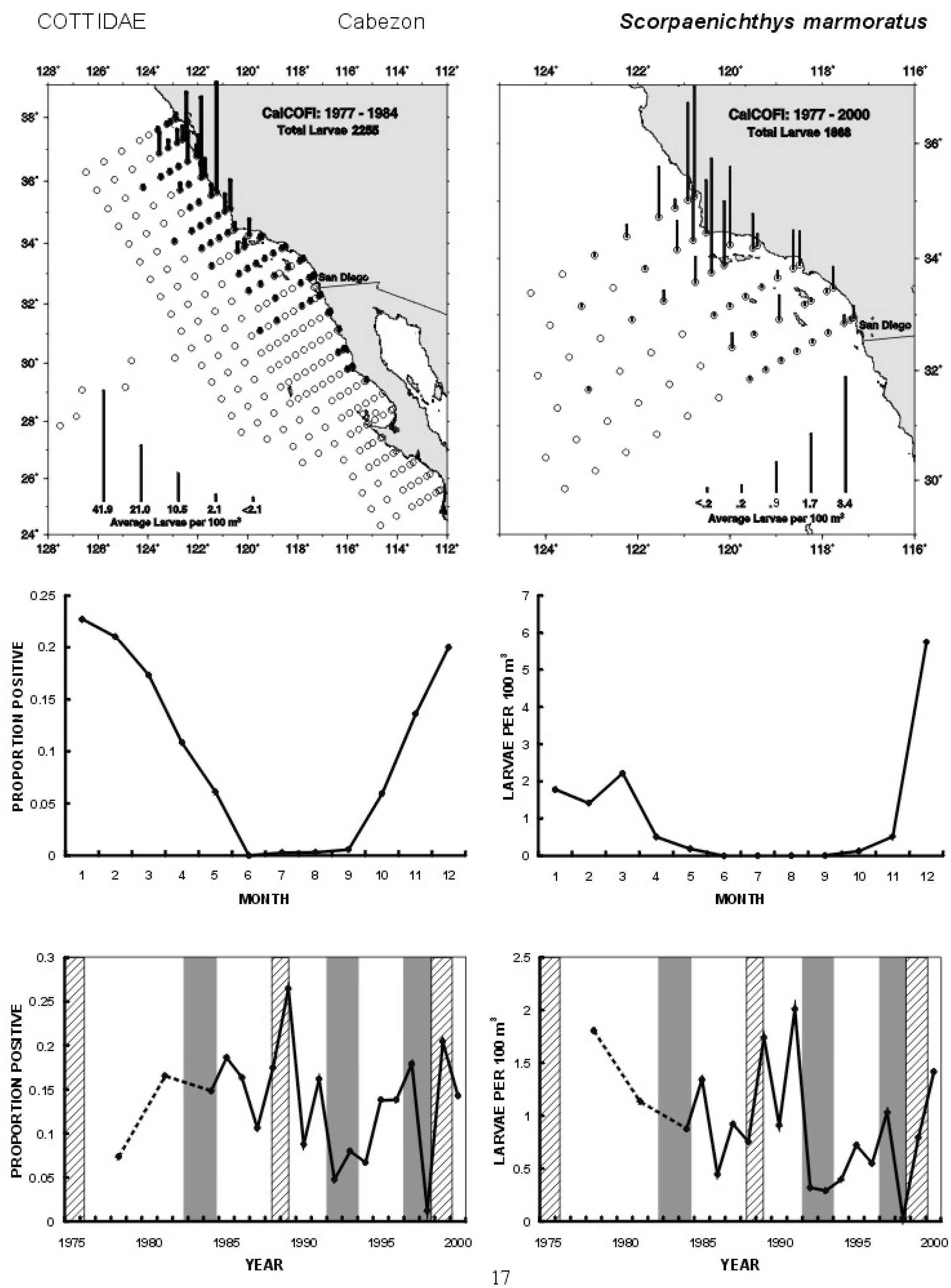


Figure 1. Distribution and abundance (number per 100 m^3) of larval cabezon, *Scorpaenichthys marmoratus*, in surface (Manta net) plankton samples collected during CalCOFI surveys, December 1977–October 2000. The lower two panels are for the current (1985-2002) survey pattern; shaded bars indicate El Niño events, hatched bars are La Niña events.

CalCOFI Ichthyoplankton Survey Data

John Hunter

CalCOFI is a partnership of the Fisheries Resources Division of Southwest Fisheries Science Center, California Department of Fish and Game, and Scripps Institution of Oceanography. CalCOFI has conducted biological-oceanographic surveys in the California Current region since 1949. A primary focus of these surveys has been the monitoring of changing abundances of the eggs and larvae of commercially and ecologically important fishes in the region. Quantitative oblique plankton tows (with a ring net prior to 1977 and a bongo net thereafter) that integrate the upper water column (to 70 m depth prior to 1951, to 140 m from 1951–1969, and to 212 m since then) have been taken since the inception of CalCOFI. The CalCOFI ichthyoplankton data bases are up-to-date, covering all CalCOFI cruises from January, 1951 through April, 2002. The data base for the oblique tows is documented in a series of 40 NOAA Technical Memoranda that list ichthyoplankton and station data for CalCOFI survey cruises for the years 1951 through 2000. Preparation of the NOAA Technical Memorandum that documents the 2001 CalCOFI oblique tow ichthyoplankton data is nearing completion. We are in process of updating the on-line system for accessing the CalCOFI data base and are developing a web site version that will make the data base available through the internet.

The CalCOFI oblique-tow data base is the most extensive and intensive fishery-independent time series for ichthyoplankton in the world. It provides a primary basis for Fisheries Resources Division research on the population biology of the major coastal pelagic fishes – Pacific sardine (Figure 1a), northern anchovy, Pacific mackerel, Pacific hake, and jack mackerel – and important coastal fishes of the California Current region such as bocaccio (Figure 1b) and cowcod. This CalCOFI data base is a primary resource for revealing historical trends in fish populations of the California Current region and it serves a key role in the management and conservation of fishery stocks in the region. As many of these populations decline, the need for the time series increases. The demand for CalCOFI data by scientists preparing stock assessments for the Pacific Fisheries Management Council has increased regularly in recent years. CalCOFI has served, and continues to serve, as a model throughout the world for development of fishery-independent data sources for use in management of marine fisheries.

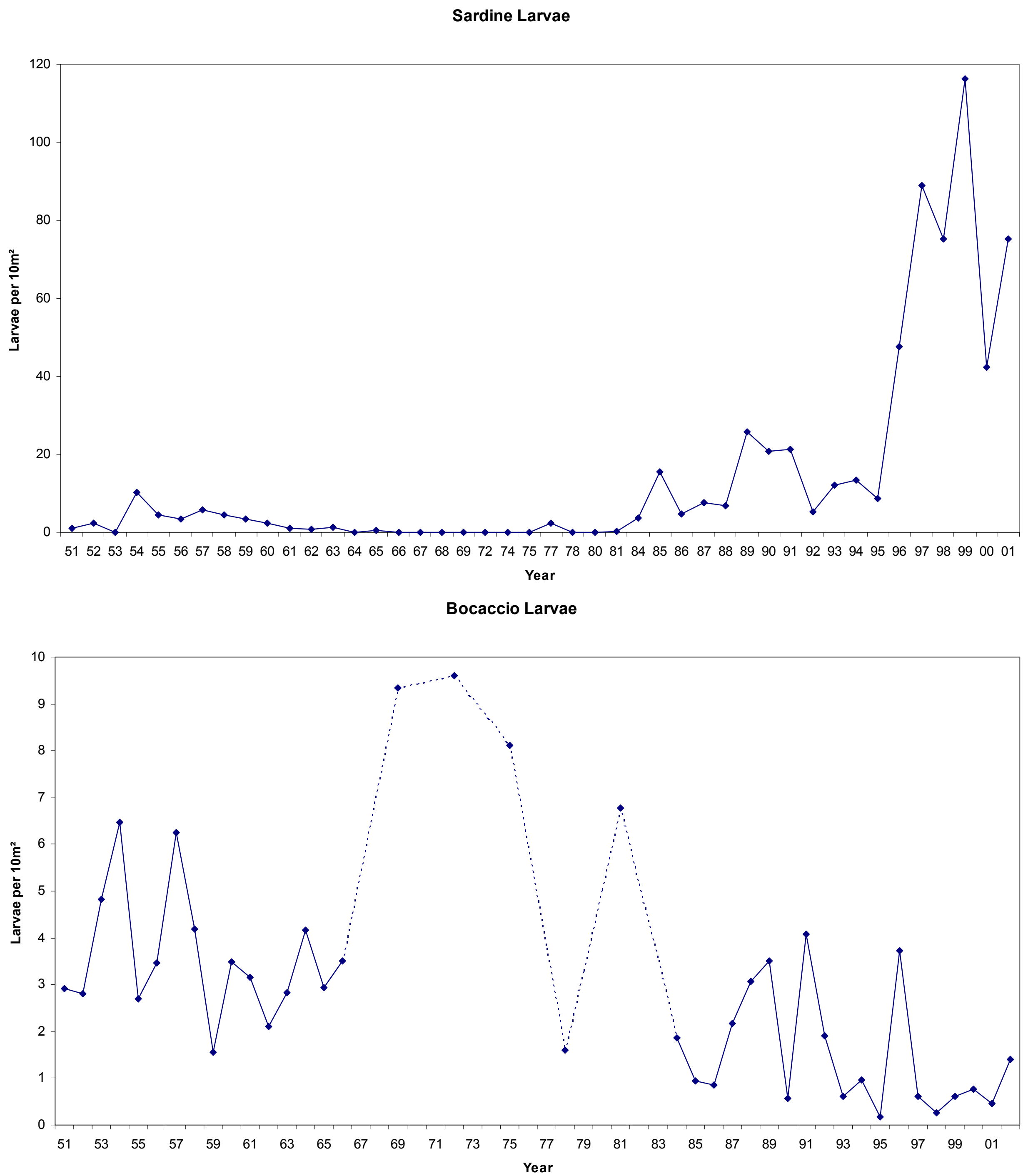


Figure 1. Mean annual larval abundance (number under 10 m^2 of sea surface during the principal spawning season at CalCOFI stations where the taxon consistently occurs) in the current CalCOFI survey area from 1951 to 2002: a) Pacific sardine; b) bocaccio.

Real Time Presentation of April Sardine Egg Surveys on Website

John Hunter

In April we completed a two ship sardine egg survey from San Diego to Monterey Bay. The *David Starr Jordan* completed the regular CalCOFI lines up to line 77 and then did midwater trawling for adult sardine. The *McArthur* completed line at a 10 and 20 miles spacing from San Diego to Monterey. Every day both ships would send the lab the data from that days Continuous Underway Fish Egg Sampler (CUFES). The data was then plotted on a map and posted on a Web page (Figure 1.). Scientist and fishermen interested in the sardine egg distribution could check the Web page daily to see where the sardine spawning was occurring. The Web page also included a map of the distribution of anchovy and mackerel eggs. We noted a significant increase in the number of hit on the Web page during the cruise.

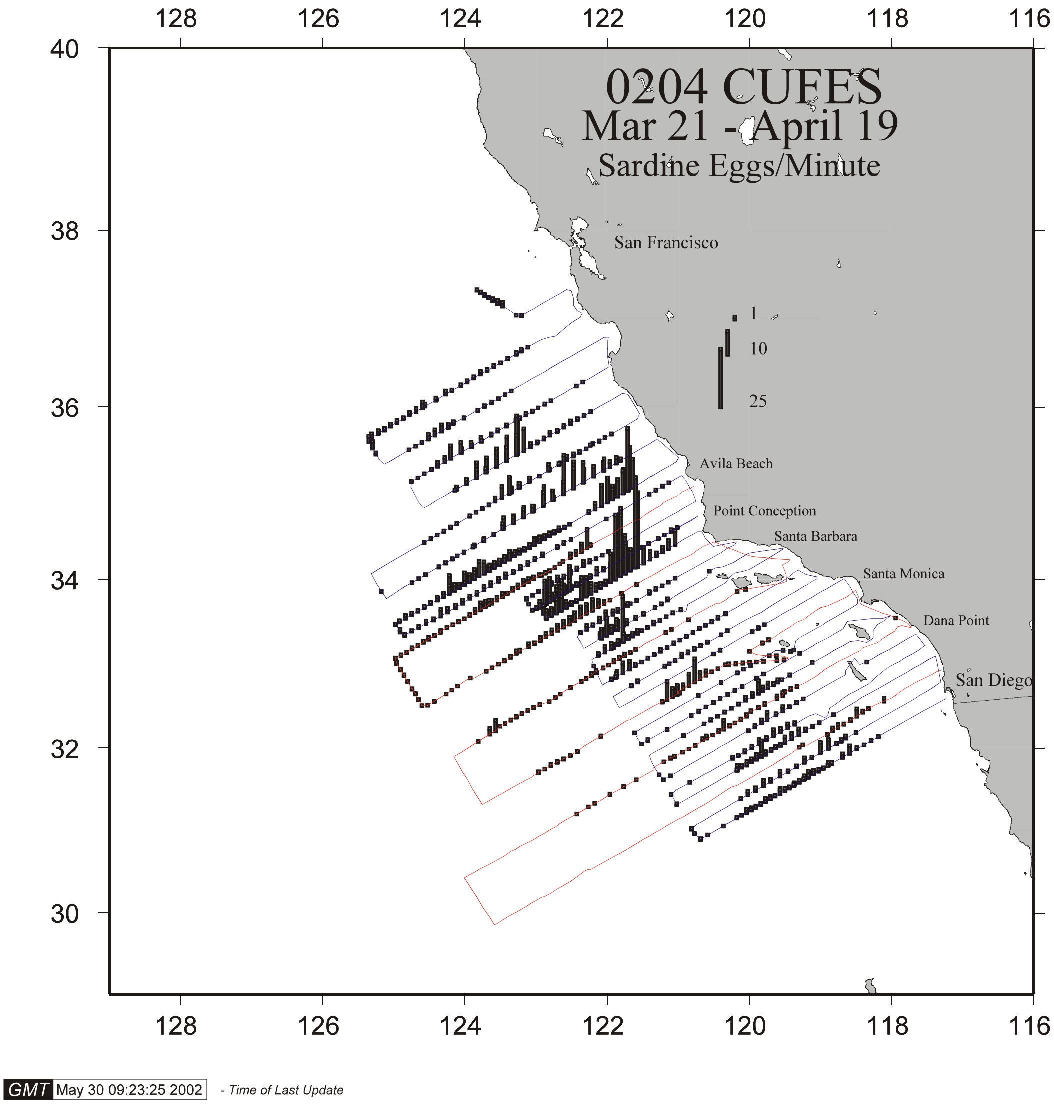


Figure 1. Sardine egg distribution for the April 2002 survey.

Results of the First Ichthyoplankton Baseline Survey of the Cowcod Conservation Area

John Hunter

The 1999 stock assessment for cowcod, *Sebastes levis*, determined that the biomass in the INPFC Conception Area was below 10% of the unfished population, triggering implementation (in 2001) of a rebuilding plan that includes a Cowcod Conservation Area (CCA) of 4300 nm^2, closed to trawling and to fishing below 20 fathoms, in the Southern California Bight. Rebuilding of the stock was estimated to take 98 years provided that removals do not exceed 2.4 mt per annum over the next decade. A 3-year baseline study of the CCA, supported by the Southwest Fisheries Science Center, Northwest Fisheries Science Center, and California Department of Fish and Game, began in February 2002. The project involved high spatial resolution ichthyoplankton surveys to provide an index of abundance for the CCA, measurement of the current flow in the CCA using ADCP at the beginning and end of the survey to evaluate the extent to which the flow regime might facilitate retention of cowcod larvae, and an ROV survey to provide length composition of the juvenile and adult cowcod in the CCA. Ultimately, we intend to develop a CCA larval abundance index calibrated to CalCOFI surveys.

Cowcod larvae were taken at seven (9%) of the 74 stations occupied (Figure 1a), compared to none in the January-February, 2002 CalCOFI survey. Larvae of bocaccio (*S. paucispinis*), a much larger but more depleted stock than cowcod, occurred at 43% of the CCA stations (Figure 1b) but at only 14% of the CalCOFI stations (Table 1). Within the CCA, larval bocaccio and cowcod were concentrated near the offshore banks, with few in open water, suggesting that the larvae may be retained near the spawning habitats of the parents.

At the beginning of the survey surface flow was westward, on the order of 25 $cm.s^{-1}$, along two-thirds of the eastern boundary; this inflow was not balanced by an equal outflow, apparently due to current fluctuations at frequencies greater than the time required to circumnavigate the CCA (Figure 2a). At 200 m depth the pattern was similar, but at much lower velocities (<10 cm.s-1). At the end of the survey a similar result was obtained, but with some balancing outflow to the south (Figure 2c). Within the CCA, the ADCP velocity results gave highly variable vectors in both speed and direction (Figure 2b), suggestive of mini-eddies (20 to 60 km in diameter). These results generally match expectation for winter based on seasonal mean geostrophic currents. A broad trough in mean dynamic height is centered near the study area in winter; flow is poleward to the east, equatorward to the west, and weak or insignificant within the trough. In spring, upwelling winds drive a strong coastal flow to the south and in summer and fall a large, energetic cyclonic flow is centered roughly about San Nicolas Island. The circulation pattern favors retention about bathymetric features, especially in winter (and least so in spring), and thus is most suitable for rockfish and other winter-spawning species that dwell about the banks.

The ROV survey showed that about 90% of the juvenile/adult cowcod in the CCA are older, mature individuals (Figure 3). This distribution is characteristic of a declining population, where most of the individuals are nearing the end of their lives and recent recruitment has not been strong. In contrast, a healthy population is skewed toward smaller, younger animals, and older animals are rare because they have experienced more mortality. These results support the findings of the recent stock assessment.

The central objective of establishing a baseline of larval cowcod abundance in the CCA was accomplished, and twelve of the rare larvae were collected. A valuable byproduct of the first survey was measurement of the abundance of bocaccio larvae over the finely spaced grid used in the survey. The low bocaccio abundance in a recent assessment led PFMC to close nearly the entire shelf region of the Bight to rockfish fishing (excluding the inner 20 fathoms). Fishers may want a sensitive index of bocaccio abundance so that the effects of the closure can be closely monitored. The CCA larval abundance data could be used to determine the precision and estimate the costs of monitoring the abundance of bocaccio in the larger CalCOFI area using ichthyoplankton methods. Survey methods, such as ichthyoplankton surveys, that do not destroy adults are preferred since the stocks are so depleted that added losses resulting from survey catches of adults are undesirable.

Several lines of evidence indicate that the CCA in January and February is a larval retention area. The ADCP records indicate no strong currents during February in the CCA, and historic tracks from surface drifters in winter meander about the CCA with little net direction. Bocaccio larvae apparently were concentrated over the banks in the CCA, where presumably they were born. In normal years, the January-February pattern of slow, meandering flow in the CCA is radically altered during the spring transition in March or April, with its strong northwest winds. Under these conditions, surface larvae would be rapidly transported out of the CCA. The winter spawning of bocaccio, cowcod, and other shelf rockfish of the Bight may be linked to larval retention during the period of reduced flow. Clearly, the offshore banks of the CCA, where large, presumably reproductively active adults are present and larvae are being produced, may be a key element in the rebuilding of these depleted stocks. The concentrations of adults, hence production of young, may be higher in this region because it is farther from shore and spared the level of fishing pressure experienced by more inshore localities. To what extent young produced in the offshore banks may "seed" inshore areas remains an open and interesting question.

In addition to the two target rockfish species, all identifiable fish larvae taken in the CCA are counted and identified, so that high resolution survey data also exist for many other species. These data indicate intensive spawning by Pacific hake around the banks within the CCA, for example.

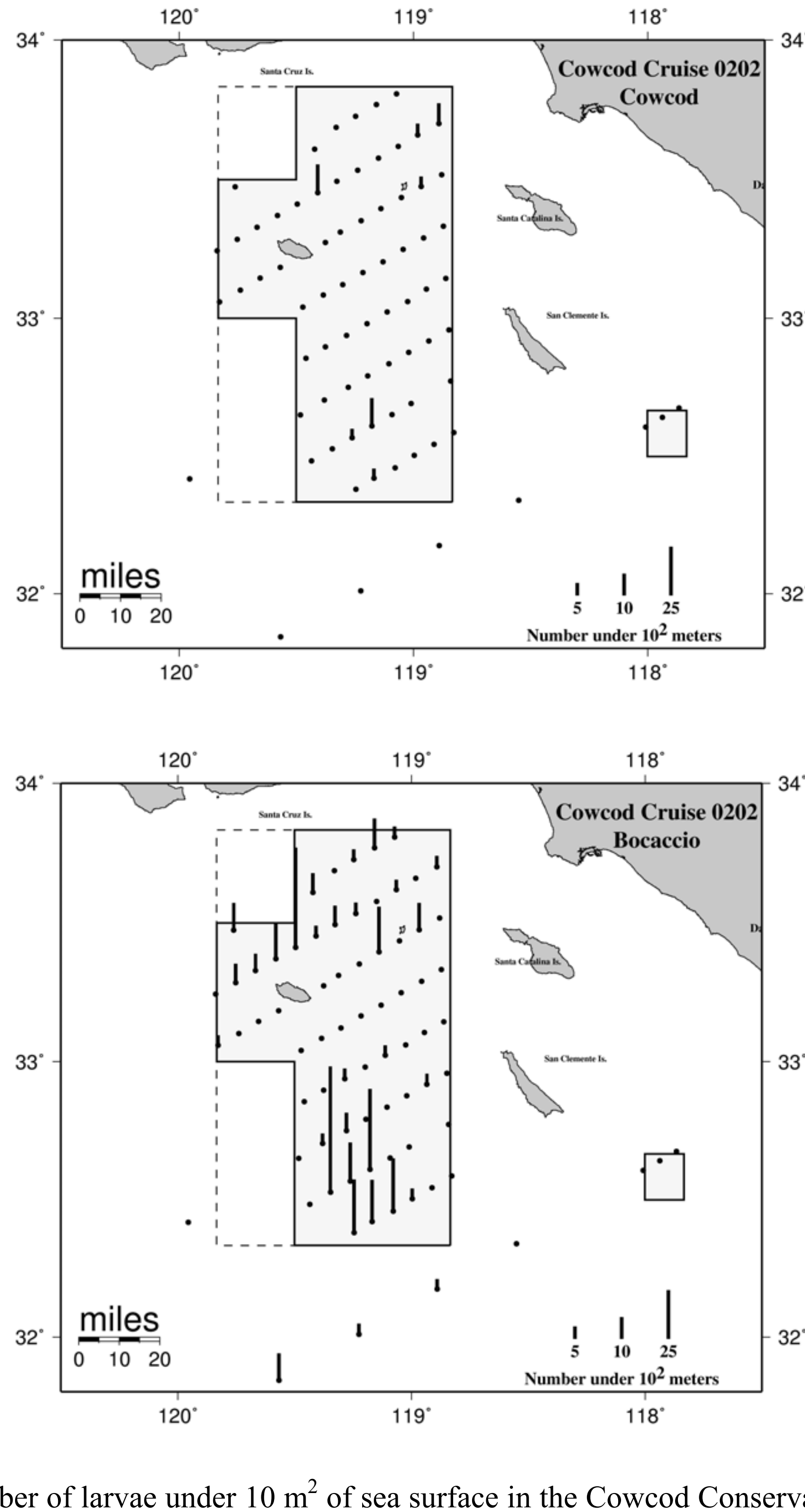


Figure 1. Number of larvae under 10 m^2 of sea surface in the Cowcod Conservation Area during February, 2002: a) cowcod; b) bocaccio.

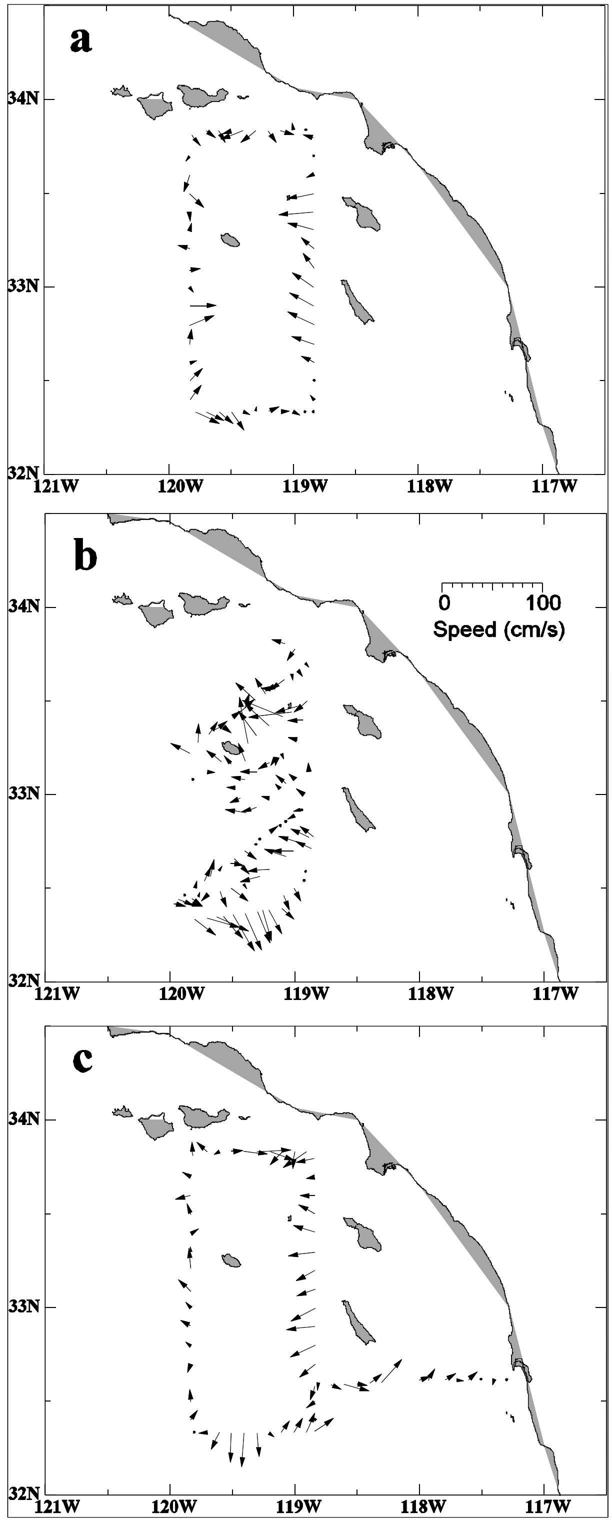


Figure 2. Current vectors in the upper 30 m layer derived from the ADCP: a) initial pass around the CCA perimeter; b) tracks within the CCA; c) final pass around the CCA perimeter.

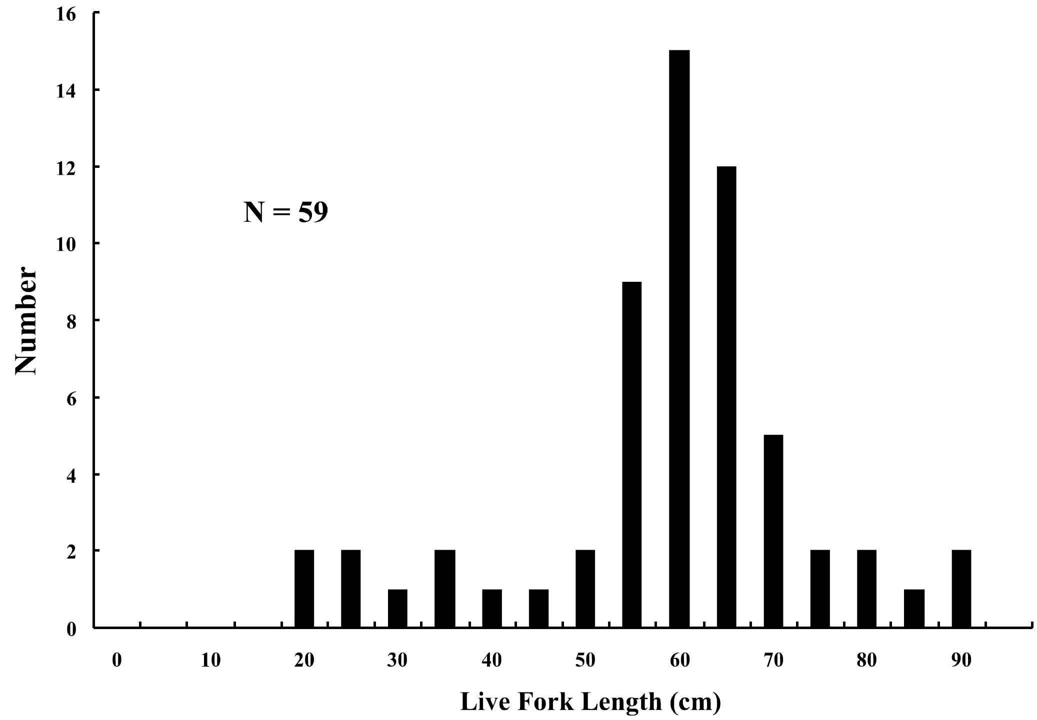


Figure 3. Size composition (fork length, cm) of juvenile and adult cowcod in the CCA, measured live using lasers from an ROV.

Table 1. Comparison of occurrence (proportion positive) and abundance (number under $10m^2$) of larval cowcod and bocaccio collected during the February, 2002 CCA cruise and the January–February, 2002 CalCOFI cruise.

Cruise Type (Year and Month)	Species	Number of Tows	Proportion Positive	Average Number under 10^2 meters
Cowcod Cruise (0202)	Cowcod	74	.09	0.79
CalCOFI Cruise (0201)	Cowcod	65	0	0
Cowcod Cruise (0202)	Bocaccio	74	.43	6.50
CalCOFI Cruise (0201) - all stations	Bocaccio	65	.13	1.74
CalCOFI Cruise (0201) - out to station 80*	Bocaccio	47	.19	2.41

* Larval bocaccio rarely occur seaward of station 80

Population Structure and the Conservation of West Coast Rockfishes

Russ Vetter

This rockfish genetics program addresses multiple goals within and between the SWFSC and the NWFSC: the States of California, Oregon and Washington: and between the US, Canada and Mexico. Specific issues that have led to funding are the proposed listing of Puget Sound stocks of Copper and Brown rockfish as Distinct Population Segments (DPS) worthy of protection under the ESA and the management mandates associated with the new Marine Life Management Act of California. Both of these actions have led to funded projects.

In a recent paper **"Population structure of copper rockfish (*Sebastes caurinus*) reflects postglacial colonization and contemporary patterns of larval dispersal. 2002. Can. J. Fish. Aquat. Sci. 59: 1374-1384",** we demonstrated that copper rockfish colonized the greater Puget Sound Basin (includes St. of Juan de Fuca, San Juan Islands, Canadian Gulf Islands) and Puget Sound proper after the end of the last ice age. Depleted populations within Puget Sound maintain little contact via larval dispersal with populations as near as the Canadian Gulf Islands and even less with more abundant populations on the outer coast. Under the terms of the ESA they are a DPS.

In presentations at the **2002 Western Groundfish Conference, Ocean Shores, WA** and **26th Annual Larval Fish Conference, Bergen, Norway** we showed that similar population structure occurred in brown rockfish *(Sebastes auriculatus)* in and out of Puget Sound. A very interesting antecedent to the brown rockfish study was that populations within Puget Sound showed evidence of introgressive hybridization with copper and quillback rockfish. This was not found between species on the outer coast. If this is occurring because populations within Puget Sound are depleted and mates are hard to find, then this is a serious conservation issue. This work is funded by FPR-Candidate Species.

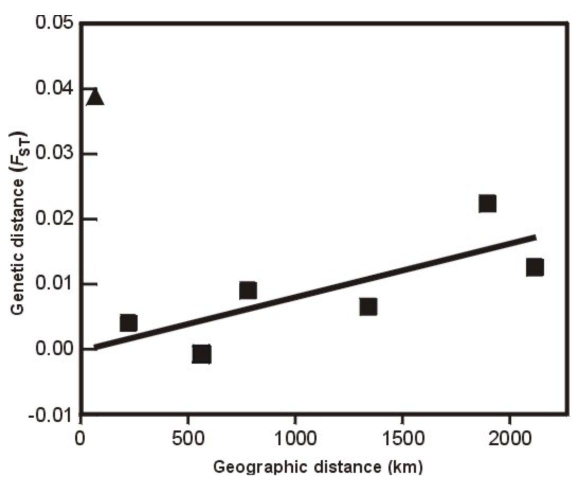
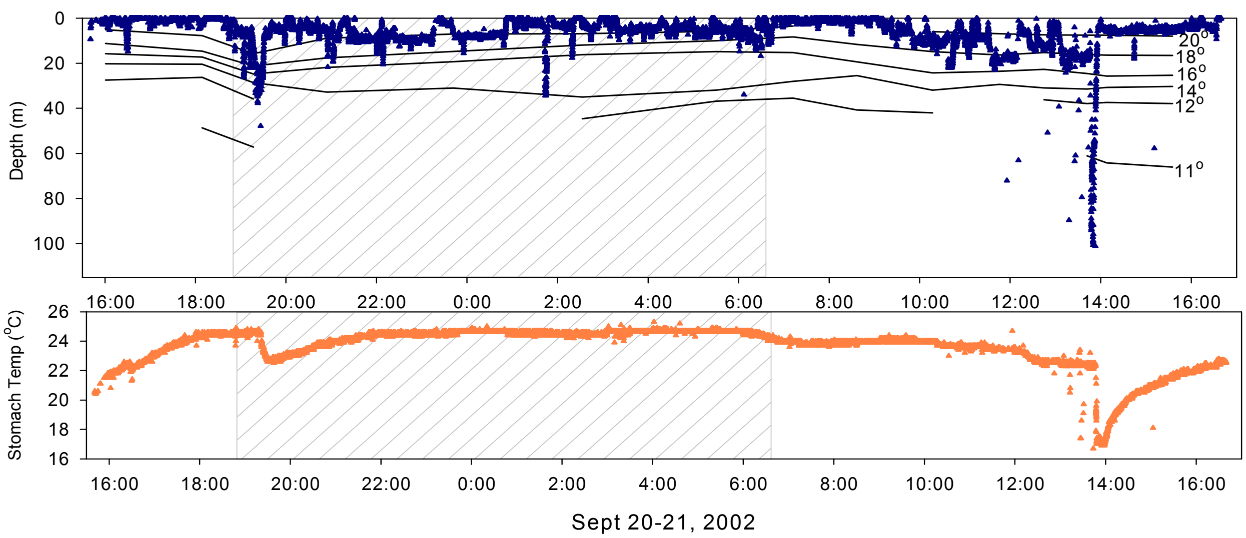


Figure. Genetic vs geographic distance within copper rockfish *Sebastes caurinus*. Genetic distance shown as linearized $F_{st.}$ Squares refer to all possible pairwise comparisons among coastal populations. The triangle refers to the comparison between Puget Sound and the Canadian Gulf Islands. From Buonaccorsi et al. 2002

Shortfin Mako Shark Tracking in the Southern California Bight

Russ Vetter

Postdoctoral Associate Suzanne Kohin in collaboration with Chugey Sepulveda of SIO are collaborating on a short-term habitat use study of shortfin makos in the southern California Bight. The goal of the project is to determine specific areas in southern California waters that may serve as important feeding grounds for shortfin makos, and to determine their depth and temperature preferences. To date, the movements of 5 juvenile makos have been logged for a total of over 100 hours. An ultrasonic pinger transmitted stomach temperature and depth data continuously throughout the tracks. Records from the 3 longest tracks demonstrate that juvenile makos spend most of their time at depths less than 25 meters, however occasional dives below the thermocline were recorded for all sharks. While swimming near the surface, stomach temperature was 2-5° C above sea-surface temperature. Rapid decreases in stomach temperature were observed on several occasions and were likely associated with feeding events. The figure below is the record from a 125 cm female shark followed for 25 hours. On the second afternoon she was observed chasing Pacific Saurys at the surface and then proceeded to make a single dive to close to 100 meters. Stomach temperature fell immediately from about 23 to 17° C, presumably due to ingestion of a cold meal captured below the thermocline. She was followed for about 3 more hours during which time she stayed near the surface and the stomach rewarmed to 22.5° C before she was captured. Dissection of the stomach confirmed the placement of the tag deep within the stomach and the presence of 0.5 kg of Pacific Saurys.



Squid Egg Deposition Model, a Possible Management Tool for Market Squid (*Loligo opalescens*) Population

Nancy Lo, John Hunter and Beverly Macewicz

Introduction

The market squid are taken in a spawning-ground fishery off California, where nearly all of the catch are mature spawning adults. Thirty-three percent of the potential fecundity of *L. oplaescens* was deposited before they were taken by the fishery based on data collected in December 1998-1999. This observation led to the development of a management strategy based on monitoring the escapement of eggs from the fishery.

Methods

To understand the effect of the fishing mortality on the escapement rate of Market squid, we developed models to estimate the mean fraction of the potential fecundity deposited (Q_{sp}) and the proportion of the potential fecundity deposited by a cohort in its life time (t_{max}), which we call the egg escapement rate ($R_{e,t_{max}}$), the ratio of total eggs deposited to the total number of eggs that would have been spawned if no fishery existed.

Under the assumption of exponential decay of both the proportion of eggs deposited and the proportion of squid survived, population quantities related to egg deposition, such as the mean fraction of potential fecundity deposited (Q_{sp}) and egg escapement rate ($R_{e,t_{max}}$)can be expressed simply as functions of three daily instantaneous rates: natural mortality rate (m), fishing mortality rate (f) and the egg deposition rate (v):

$$Q_{sp} = \frac{v}{m+f+v} \qquad (1)$$

and

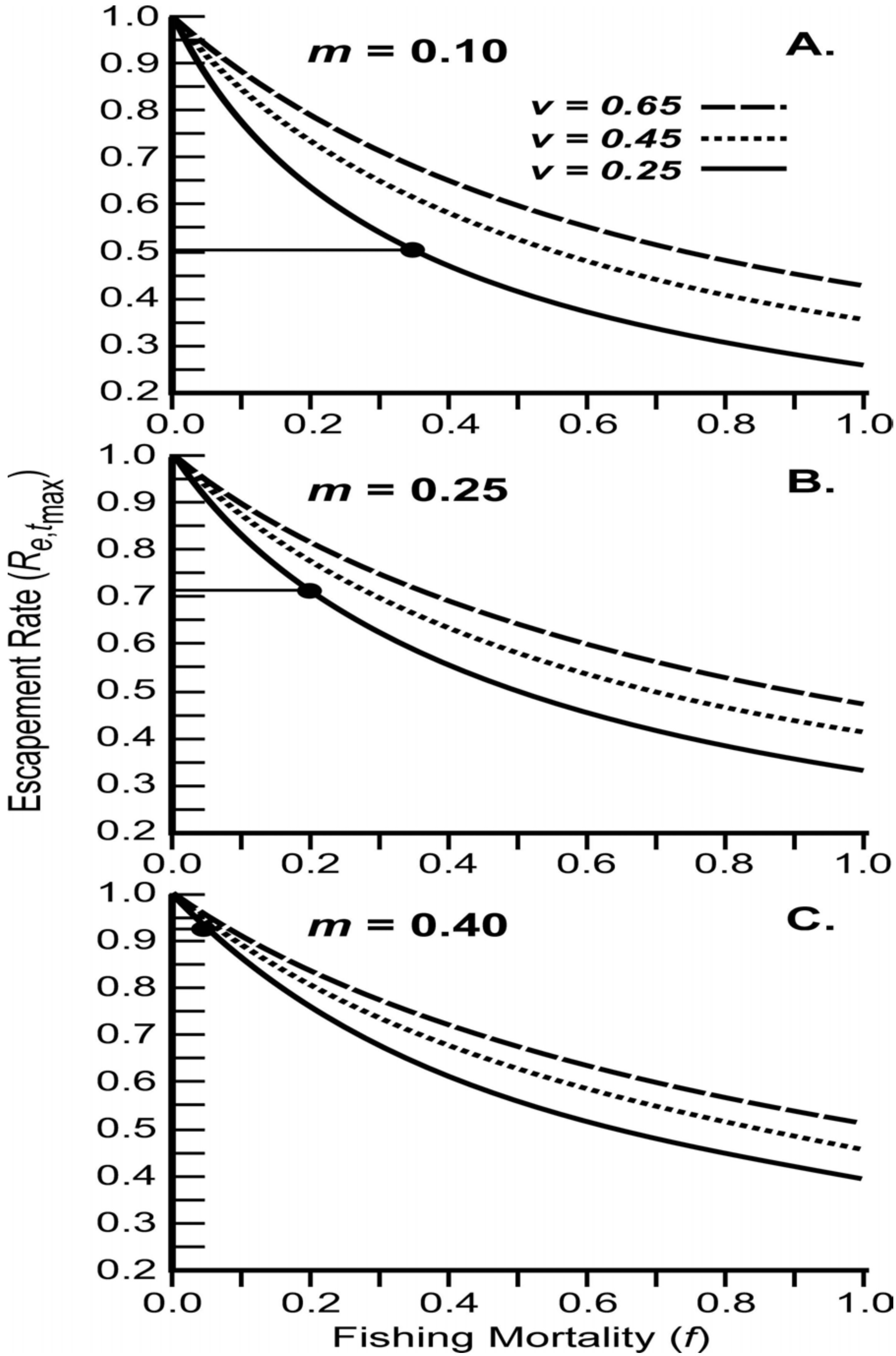
$$R_{e,t_{max}} = \frac{Q_{sp}}{\left(\frac{v}{m+v}\right)} = \frac{m+v}{m+f+v} \qquad (2)$$

Results

We used equation (1) to estimate the total mortality rate (z=m+f=0.45) and egg deposition rate (v=0.25) that produced Q_{sp} of 0.341, closest to the estimated mean fraction of potential fecundity deposited computed from our data: 0.326 (se=0.075). We used equation (2) to examine how natural mortality (m) and fishing mortality (f) might affect egg escapement when natural mortality (m) varies from 0.1 to 0.4 and egg deposition (v) varies from 0.25 to 0.65 (see figure). For a given value of total mortality, say z=0.45, for high m, the escapement is relatively insensitive to changes in daily fishing mortality and the converse is true for low m. The overall effect of v on the egg escapement is less than m and f.

Issues

Field data are needed to verify estimates of length-dependent potential fecundity and standing stock of fecundity estimated from mantle condition index and gonad weight.



m = 0.10
A.
v = 0.65
v = 0.45
v = 0.25
m = 0.25
B.
m = 0.40
C.
Escapement Rate ($R_{e,t_{max}}$)
Fishing Mortality (f)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.0
0.2
0.4
0.6
0.8
1.0

Age-specific Migration and Availability of Pacific Sardine

Nancy Lo

Introduction

Migration rates are important elements of stock assessment models of Pacific sardine off California because it is believed that some sardine migrate from California water to Northwest water in the 'summer' (May - October)and from Northwest to California in the 'winter' (November - April). Northwest (NW) includes Oregon, Washington and British Columbia. The purpose of this project is to obtain estimates of age-specific migration rates of sardine between central California and Northwest (NW) and the age-specific availability coefficient applied to fishing mortality rate of sardine off central California and Northwest. Those estimates can be ultimately incorporated in the stock assessment model, hopefully to improve the quality of stock assessment of Pacific sardine.

Methods

Historical data sets were used in the analysis:

1. Samples from catches collected during 1941-42 season before the collapse of Pacific sardine.
2. Tagging experiment off Central California was conducted from September to November, 1937 in Monterey and San Francisco off Center California.
   and
3. Tagging experiments off NW in August, 1937 and in July and September, 1938

Assuming number of fish of each age group in the samples from catch and from tagging experiments follows multinomial distributions, I obtained maximum likelihood estimates (MLE) of age-specific migration rates: proportion of fish that migrate and availability coefficients: multipliers of fishing mortality rates.

Results

Under the assumption that the recruits off NW are 10% of that off California, estimated northbound migration rates ranged from 0.09 (age 3) to 0.19 (age 11) and southbound migration rates from 0.15 (age 3) to 0.96 (age 11) (Figure 1). That means less than 20% of Pacific sardine move from California to NW in the summer and at least 15% fish and nearly all older fish in NW move to California in the winter. The availability coefficients applied to fishing mortality rates off C. California ranged from 0.51 (age 4) to 0.0048 (age 11) and ranged from 0.84 (age 4) to 0.19 (age 11) off NW. We also obtained estimates of migration rates and availability coefficients assuming that the recruits off NW are 50% of that off California. The results were quite different from the first scenario (Figure 2). We believe that first scenario is closer to the reality.

Issues

Fishery-independent surveys off central California are needed to obtain age composition of sardine outside fishery and CalCOFI survey area in order to verify the availability coefficient to the fishery. A coastal wide snapshot survey is useful to verify the migration of sardine. The current migration model may be expanded to estimate immigration rates between Baja California, southern California and central California.

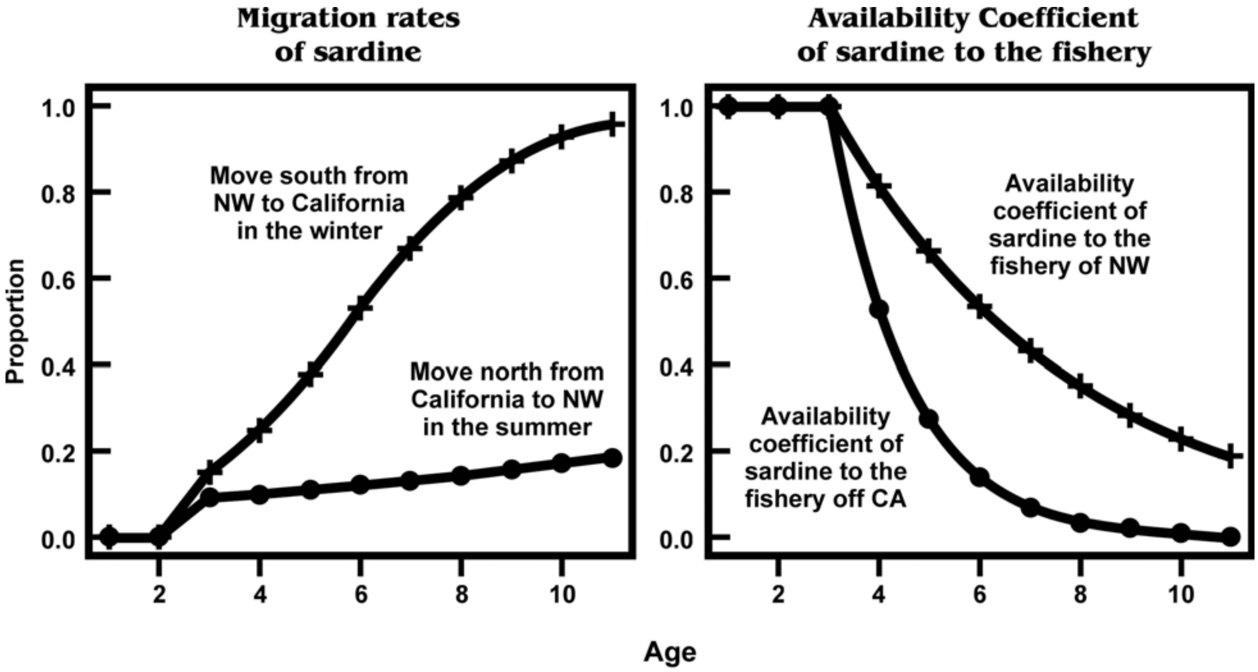


Figure 1. Assuming recruits off NW are 0.1 of California

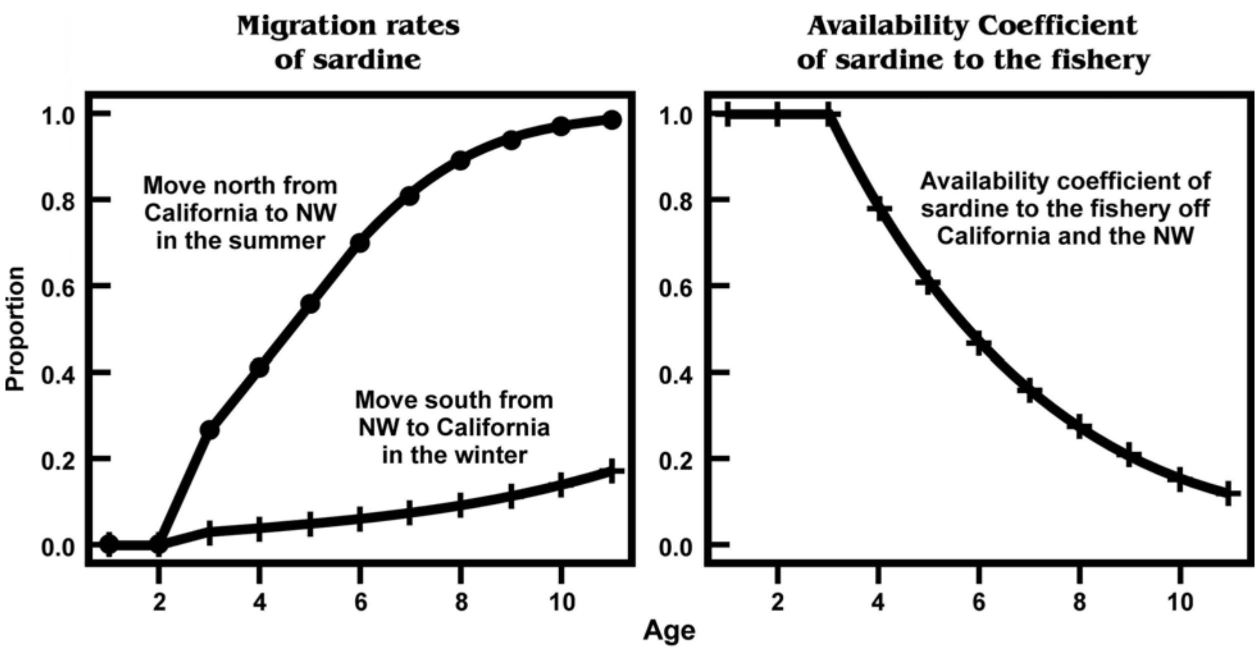


Figure 2. Assuming recruits off NW are 0.5 of California

Characteristics of the Spring Transition off Central and Southern California

R. Lynn, S. Bograd, T. Chereskin, and A. Huyer

(To be submitted November 2002.)

From winter to spring the physical and biological conditions in the coastal ocean off the U. S. west coast undergo relatively large and rapid changes generally termed the 'Spring Transition'. Two surveys, 40-days apart, on the NOAA vessel *McArthur* in early spring 1995 captured this event.

There was a 1.5 to 4 degree decrease in temperatures in coastal surface temperature over 40 days. The April pattern is that of the typical spring coastal upwelling phase. The coastal dynamics changed from a weak, nondescript eddying flow during March to a strong coastal upwelling jet extending the length of the observed coastline by April having velocities of 20 to 30 cm/sec. The development of the coastal upwelling jet is independent of the winter manifestation of the core of the California Current which lies some 300 km offshore. The CC jet is still present in April with only modest changes. Transport within the coastal zone increased by over a factor of 4. These rapid changes were initially confined to within 150 km of the coast. Other observations suggest that this transition can be rather weak or quite strong, and can occur with a variable timeframe that may have a range of two months. The seasonal initiation of upwelling brings changes in turbulence, transport, nutrient enrichment, and plankton blooms. The strong and abrupt nature of the changes and the interannual variation in timing have important implications to seasonal spawning stocks, survival of spawn and the timing of spawning surveys.

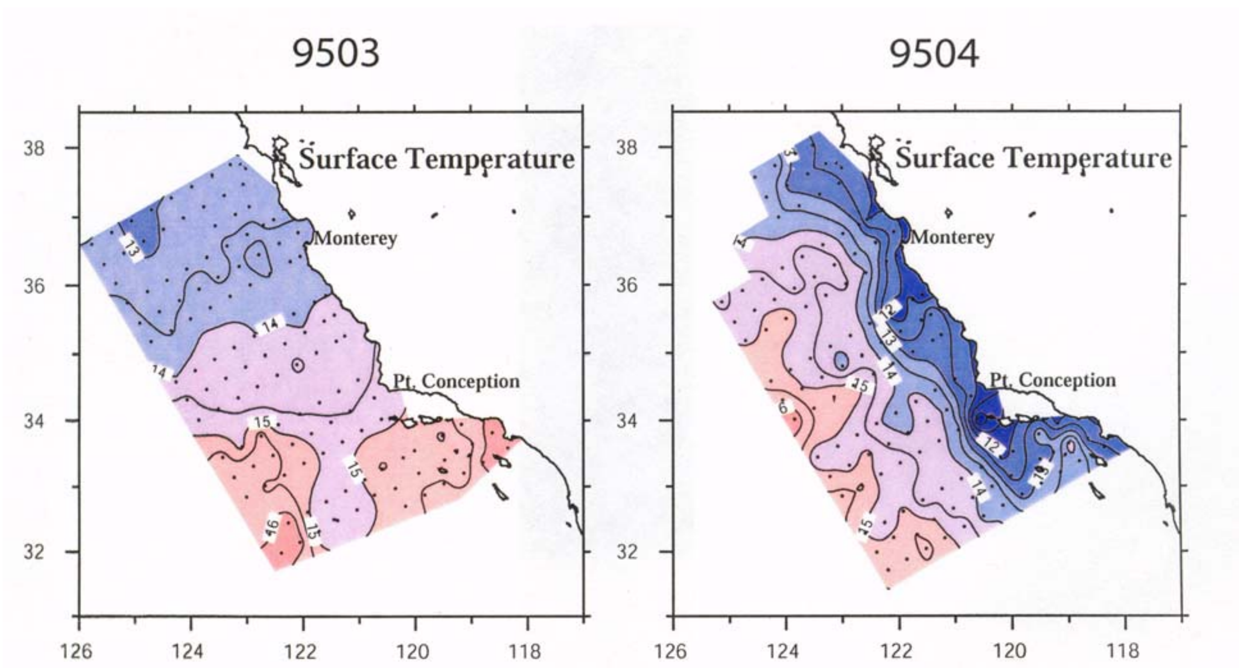


Figure. Surface temperature in March 1995 and (forty days later) April 1995

Long-term Variability in the Southern California Current System

Steven J. Bograd and Ronald J. Lynn

(Manuscript accepted for special volume of Deep Sea Research)

We summarize 50 years of physical oceanographic data in the southern portion of the California Current System (CCS) based on the California Cooperative Oceanic and Fisheries Investigations (CalCOFI) hydrographic record, 1950-1999. The long-term mean water property and circulation patterns are described, and the local signature of the large-scale 1976-77 North Pacific climate regime shift is characterized. Changes associated with the climate shift include (1) significant warming in the upper 200-400 m of the water column, a decrease in salinity in near-surface coastal waters, and an increase in salinity in subsurface offshore waters; (2) deeper density surfaces and increased stratification throughout the region, particularly within the Southern California Bight; (3) a subtle reorganization of the geostrophic flow structure, including an offshore shift of the California Current and increased nearshore poleward flow; and (4) a cross-shore dichotomy, with the nearshore regime changes occurring primarily during the upwelling season and the offshore variability being of lower frequency than nearer the coast. Changes in the vertical structure of the water column are of particular significance, as they have likely rendered upwelling less biologically effective. This is evident in the temperature and salinity changes, which were greatest (warming and freshening) just above the peak stability changes. There is evidence to suggest that another North Pacific-wide regime shift occurred following the 1997-98 El Niño event, and large ecosystem changes are anticipated. The CalCOFI record is ideally suited for revealing the mechanisms of interdecadal physical-biological interactions in the coastal ocean.

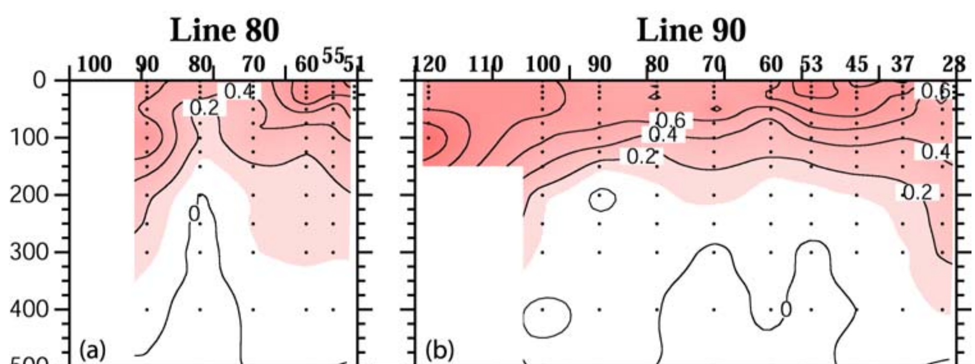


Figure. Regime temperature difference for CalCOFI station line 80 and 90 (1997-99 minus 1950-76).

Dynamic Evolution of the 1997-99 El Niño-La Niña Cycle in the Southern California Current System (Progress in Oceanography 54/1-4: 2002)

Ronald J. Lynn and Steven J. Bograd

Abstract

The development of the strongest El Niño event on record in the equatorial Pacific in 1997-98 and the rapid transition to strong La Niña conditions in 1998-99, had a large impact on the physical and biological environment of the West Coast. We investigate the evolution of the physical structure and circulation dynamics of the southern California Current System (CCS) during this period based on hydrographic data collected on 25 cruises over a 45-month period (February 1996 to October 1999). The El Niño period was characterized by a dramatic increase in dynamic height, extreme water mass characteristics, a strengthening and broadening of the poleward nearshore flow, and a temporary reversal of net alongshore transport. By early 1999, conditions in the CCS had reversed. The data suggest that remotely-driven forcing (propagating oceanic waves) contributed to the anomalies observed during the El Niño period, while the cool-water conditions of 1999 were most likely a result of anomalous local atmospheric forcing.

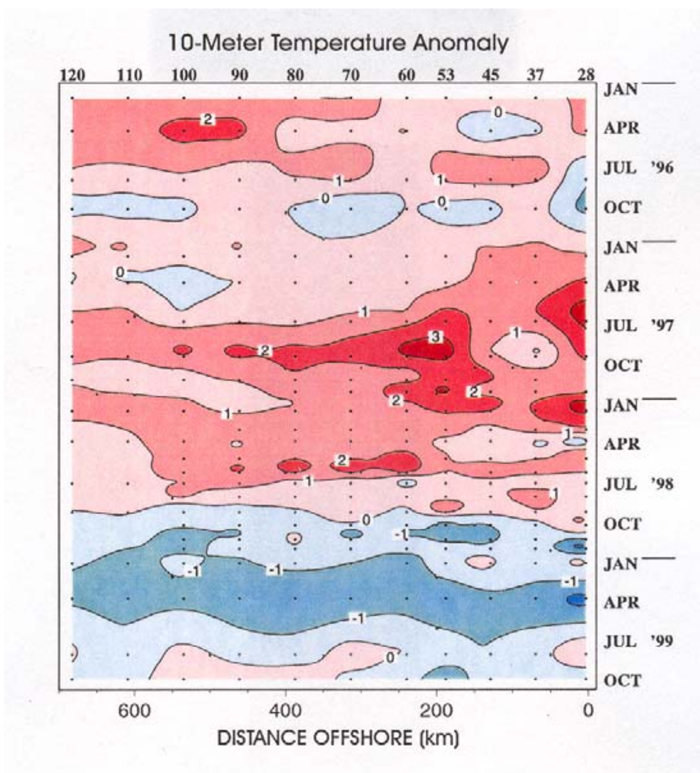


Figure. Time-distance plots (1996-1999) 10-meter temperature anomalies for line 90 stations. Anomalies are based on the 1950-1998 annual biharmonic means.

Variability in the Spawning Habitat of Pacific Sardine (*Sardinops sagax*) off Southern and Central California

Ronald J. Lynn (Fish. Oceanography, in press)

ABSTRACT

The spatial pattern of sardine spawning as revealed by the presence of sardine eggs is examined in relation to sea surface temperature (SST) and mean volume backscatter strength (MVBS) measured by a 150 kHz acoustic Doppler current profiler (ADCP) during four spring surveys off central and southern California in 1996 - 1999. Studies in other regions have shown that MVBS provides an excellent measure of zooplankton distribution and density. Zooplankton biomass as measured by survey net tows correlates well with concurrently measured MVBS. The high along-track resolution of egg counts provided by the Continuous Underway Fish Egg Sampler (CUFES) is a good match to the ADCP-based data. Large interannual differences in the pattern and density of sardine eggs are clearly related to the concurrently observed patterns of surface temperature and MVBS. The strong spatial relationship between sardine eggs and MVBS is particularly evident because of the large contrast in zooplankton biomass between the 1998 El Niño and 1999 La Niña periods. The inshore distribution of sardine spawning appears to be limited by the low temperatures of freshly upwelled waters, although the value of the limiting temperature varies between years. Often there is an abrupt offshore decrease in MVBS that is coincident with the offshore boundary of sardine eggs. Possible reasons for this association of sardine eggs and high zooplankton biomass include an evolved strategy that promotes improved opportunity of an adequate food supply for subsequent larval development, and/or adult nutrient requirements for serial spawning. Hence the distribution of these parameters can be used as an aid for delineating the boundaries of sardine spawning habitat.

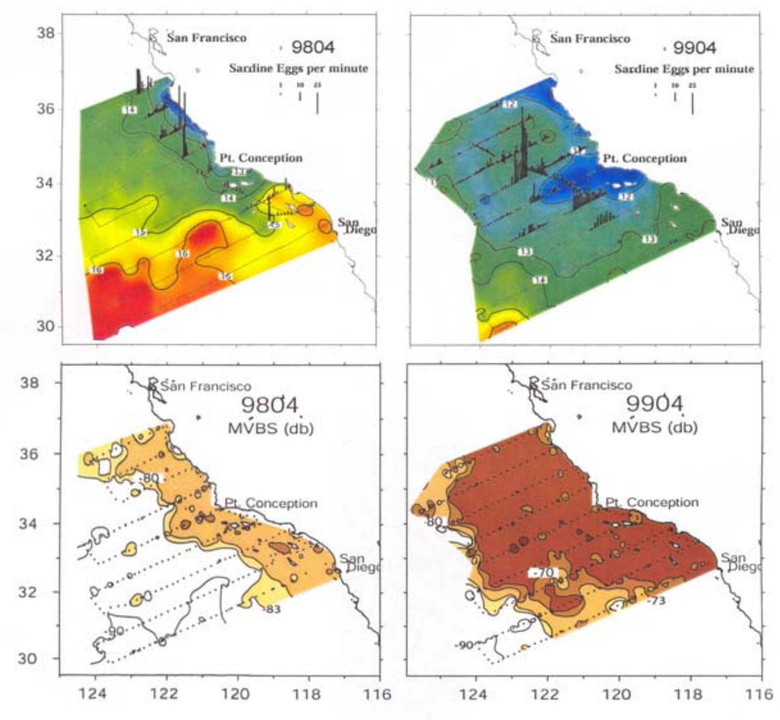


Figure. Sardine eggs and SST for 9804 and 9904. Mean Volume Backscatter (a measure of zooplankton density) for 9804 and 9904.

Wide-bandwidth Acoustical Characterization of Anchovies and Sardines Using a New Technique Based on Reverberation Measurements

Stéphane G. Conti and David A. Demer

Total scattering cross-sections (σ_t) of anchovies (*Engraulis mordax*) and sardines (*Sardinops sagax caerulea*) were acoustically measured over a wide-bandwidth (0.5-202 kHz) from ensembles of reverberation records [J. De Rosny and P. Roux, 2001, *J. Acoust. Soc. Am.* 109(6): 2587:2597]. Measurements were made sequentially from one or more fish swimming in one of two cylindrical galvanized steel tanks containing filtered seawater at a temperature of 21±1ºC. The low frequency measurements were made from two groups of fish (35 anchovies and 10 sardines) in a 1000 *l* tank, and the high frequency measurements (>36 kHz) were made from individual fish in a 100 *l* tank (10 fish for each species). Thus, wide-bandwidth total target strengths ($TTS=10\log(\sigma_t /4\pi)$) were estimated for multiple sizes of these important pelagic species of the California Current. Results show that the *TTS* versus frequency (*TTS*(*f*)) are significantly different for these two species (**Fig. 1**). For sardines, the *TTS*(*f*) increases and then decreases versus increasing frequency, whereas for anchovies, the *TTS*(*f*) increases monotonically with frequency. Moreover, the relationships between *TTS* at 38, 70, 120, and 200 kHz versus fish length and weight were markedly non-linear. The measurement precision was characterized and empirical estimates of *TTS* were statistically compared to theoretical predictions derived using the Kirchhoff ray-mode model (KRM). While the theoretical reduced *TTS*, or *TTS* normalized to a 1 m long fish (TTS_{re}) converged to a single spectrum, the empirical TTS_{re} did not. This discrepancy may result from the fact that the shape and size of the swimbladder are not scalable with the size and shape of the fish body [C.P. O'Connell, 1956, *Fishery Bulletin*, 104(56): 512-523]. These measurements should be useful to improve acoustical identification and delineation of anchovies and sardines, and for estimating their sizes, when surveying with echo-integration methods.

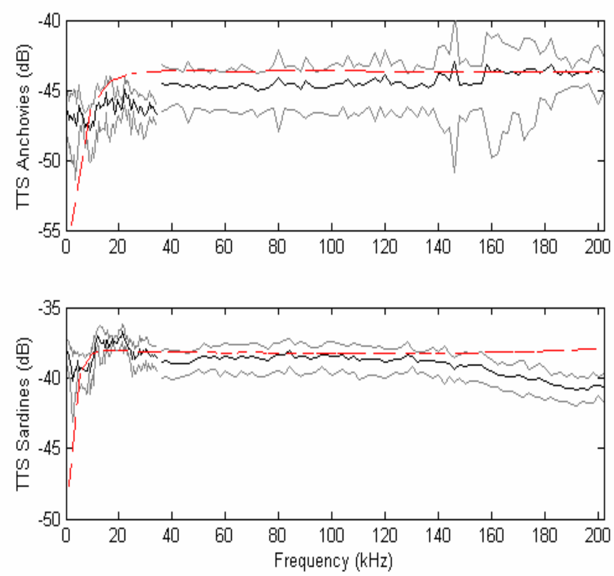


Figure 1: Average *TTS* measurements (dark line) for the anchovies and the sardines, and ± one sd (light lines), for the anchovies and sardines. The red lines correspond to theoretical predictions of the *TTS* for one anchovy and one

Detection and Characterization of Yellowfin and Bluefin Tuna Using Passive Acoustical Techniques

Scott Allen and David Demer

Underwater sounds generated by *Thunnus albacares* and *Thunnus thynnus* were recorded and studied to explore the possibility of passive-acoustical detection. Tuna vocalizations were recorded at the Monterey Bay Aquarium, Monterey, California, and Maricultura del Norte in Ensenada, Baja California, Mexico. At both locations, the most prevalent sounds associated with tuna were low-frequency pulses varying from 20 to 130 Hz, lasting about 0.1 seconds, and usually single and unanswered (**Fig. 1**). A behavior similar to coughing was coincident with these sounds: the animal's mouth opened wide with its jaw bones extended and its abdomen expanded, then contracted abruptly. On one occasion in Mexico, this behavior and associated noise were simultaneously recorded (**Fig. 2**). The center frequencies of these vocalizations may vary as the resonant frequencies of the tuna's swim bladder, suggesting a passive-acoustical proxy for measuring the size of tuna. Matched-filter and phase-difference techniques were explored as means for automating the detection and bearing-estimation processes.

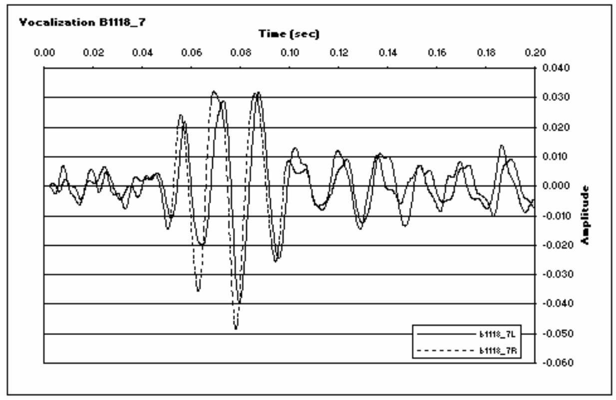


Figure 1. Bluefin vocalization recorded at Maricultura del Norte, 18 November 2000 using two hydrophones (**a**) and their power spectral densities (**b**). Signals were low-pass filtered (Order 4 Butterworth, f_c=600 Hz). Estimated sound pressure level is 105 dB re 1 μP.

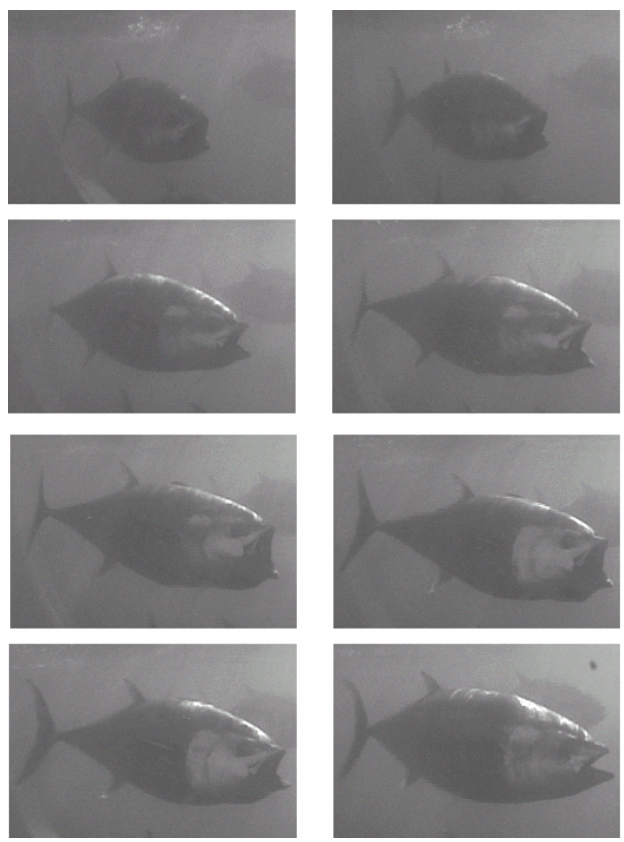


Figure 2. A bluefin tuna vocalizing at Maricultura del Norte Ensenada. During the vocalization, the animal's mouth opened wide with its jaw bones extended and its abdomen expanded, then contracted abruptly.

A Comparison of Lidar and Echo Sounder Measurements of Fish Schools in the Gulf of Mexico

James Churnside, David Demer and Behzad Mahmoudi

In December 2000, the U.S. National Oceanic and Atmospheric Administration's Fish LIght Detection and Ranging (LIDAR) system was used to locate schools of fish from an airplane off the west coast of Florida and measure their volume backscattering coefficients (β_L) at a wavelength of 532 nm. Concurrently, a 208-kHz echo sounder was deployed from a small boat to measure the acoustical volume backscattering coefficients (β_E) of the same schools. Seven schools were characterized with both the lidar and the echo sounder. The correlation between these seven pairs of β_L and β_E measurements was 0.994. A linear regression of β_L versus β_E had a negative y-intercept, which agrees with aerial observations of some degree of avoidance reaction of fish to the passing survey boat (**Fig. 1**). The slope was slightly greater than unity, in agreement with previous calculations that the acoustic backscatter of similar fish is slightly greater than the lidar backscatter. The results of this study indicate that lidar is a suitable tool for rapidly surveying the distributions and abundances of epipelagic fish stocks in the shallow waters off the west coast of Florida, without the biases of fish avoidance reaction potentially affecting acoustical and trawl surveys.

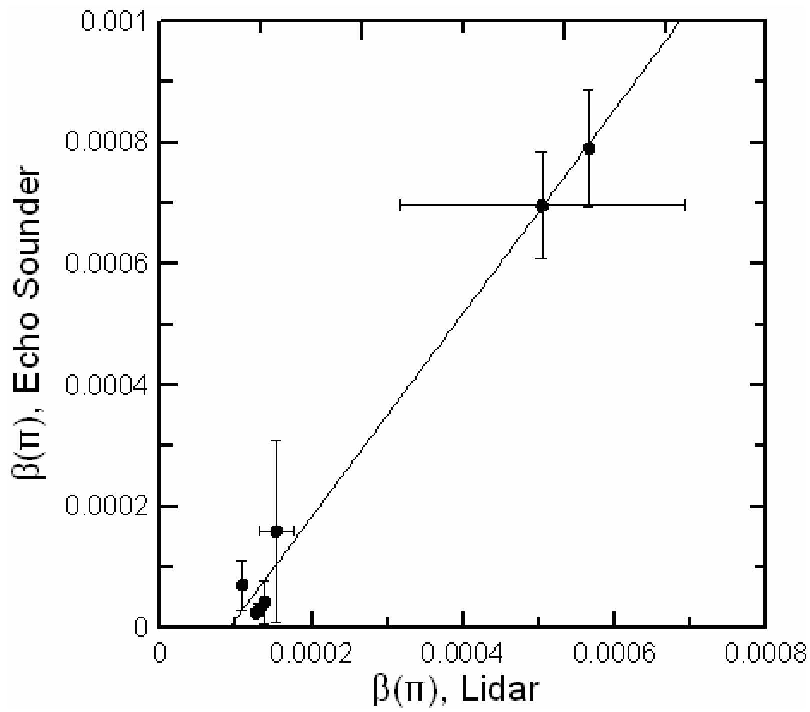


Figure 1. Echo sounder volume backscatter coefficient as a function of lidar volume backscatter coefficient. Points are mean values, error bars represent standard deviation of the measurements, and the solid line is the least-squares regression, with a correlation coefficient of 0.994.

Tuna Industry Cooperative to Reduce By-catch in Fishing on Fish Aggregating Devices

David A. Demer

A research cooperative has been established between the SWFSC and the U.S. Tuna Foundation to minimize by-catch when fishing on fish aggregating devices (FADs). Instrumentation will be developed and deployed to characterize the spatial, temporal, and size distributions of tuna and other fish beneath and surrounding FADs used by the U.S. tuna fishing fleet in the eastern tropical Pacific (ETP). These distributions will be related to concurrent observations of environmental conditions and predator-prey interactions. Ultimately, results from this research could be used to help fishers develop strategies that minimize by-catch of under-size tuna and other undesirable fish species. These actions will help to ensure the long-term sustainability of FAD-based tuna fisheries in the ETP and central and western Pacific. We intend to use multiple-frequency echosounders, *in-situ* target strength measurements, and echo-integration processing methods to quantify the abundance, dispersion, and temporal variability of tuna and other fish beneath and surrounding fish aggregating devices (FADs). Information from beneath FADs will be collected using autonomous and remotely monitored multi-instrumented buoys. The buoys will include a two-frequency (38 and 120 kHz) split-beam scientific echosounder, two passive-acoustical preamplified hydrophones, a data logging and control computer, GPS, multi-port serial adapter, 900 MHz spread-spectrum radio modem with antenna, radar transponder or reflector, strobe light, AGM battery, solar panels, and power control circuitry. The buoy will be a variant of a design that has been successfully deployed in the southern ocean to describe krill abundance and dispersion, environmental conditions, and predator activities in an area around Cape Shirreff, Livingston Island, Antarctica (**Fig. 1**). Volume backscattering strengths and *in-situ* target strengths will be recorded over multiple-hour periods. The spectral characteristics of sound scatter will be used for taxa discrimination and delineation [Demer et al., 1999, *J. Acoust. Soc. Am.* 105(4): 2359-2376]. The position of the buoy will be monitored with GPS. The data set will be stored in its entirety inside the package while a subset is telemetered to the supporting fishing vessel via a VHF modem link. The real-time echograms will be used to direct timing of net sampling and underwater video deployments for validation of acoustical species discrimination algorithms and possibly allow *in-situ* observations of predator-prey interactions. The acoustical analysis will be linked to the concurrently collected biological, oceanographic, and meteorological sampling collected shipboard. Collectively, these observations will allow us to delineate tuna from other co-existent species, estimate tuna sizes, explore associations between biotic and abiotic conditions, and observe tuna behavior and dispersion.

Figure 1. Multi-instrumented, remotely-monitored buoys will be attached to standard FADs.

2001 PUBLICATIONS

Ambrose, D.A., R.L. Charter, and **H.G. Moser**. 2001. Ichthyoplankton and station data for California Cooperative Oceanic Fisheries Investigations survey cruises in 1999. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-311, 69 p.

Bograd, S.J. and **R.J. Lynn**. 2001. Physical-biological coupling in the California Current during the 1997-99 El Niño-La Niña cycle. Geophysical Research Letters 28(2):275-278.

Childers, J. 2001. Summary of the 2000 U.S. North and South Pacific albacore troll fisheries. SWFSC Admin. Rep., La Jolla, LJ-01-05 42p.

Crone, P.R. 2001. Spatial differences in maturity schedules of female Dover sole off Oregon (1989-1991). Fish. Res. 51(2001):393-402.

Durazo, R., T.R. Baumgartner, S.J. Bograd, C.A. Collins, S. de la Campa, J. Garcia, G. Gaxiola-Castro, A. Huyer, K.D. Hyrenbach, D. Loya, **R.J. Lynn**, F.B. Schwing, R.L. Smith, W.J. Sydeman, and P. Wheeler. 2001. The state of the California Current, 2000-2001: a third straight La Niña year. Calif. Coop. Oceanic Fish. Invest. Rep. 42:29-60.

Hunter, J.R. and T. Baumgartner. 2001. Trinational sardine forum proceedings. Interim report on the first meeting. SWFSC Admin. Rep., La Jolla, LJ-01-06, 25 p.

Hyrenbach, K.D. and **R. C. Dotson**. 2001. Post-breeding movements of a male black-footed albatross *Phoebastria nigripes*. Marine Ornithology 29:7-10.

Lo, N.C.H. 2001. Daily egg production and spawning biomass of Pacific sardine *(Sardinops sagax*) off California in 2001. SWFSC Admin. Rep., La Jolla, LJ-01-08 32 p.

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

Logerwell, E.A. 2001. Metabolic rate of California Pacific sardine estimated from energy losses during starvation. Tran. Amer. Fish. Soc. 130:526-530.

Logerwell, E.A. and **P.E. Smith**. 2001a. GIS mapping of survivors' habitat of pelagic fish off California. *In*: Proceedings of the First International Symposium on Geographic Information Systems (GIS) in Fishery Science, T. Nishida, P.J. Kailola, and C.E. Hollingworth (eds.). Seattle, WA, 2-4 March 1999, pp 51-64.

Logerwell, E.A. and **P.E. Smith.** 2001b. Mesoscale eddies and survival of late stage Pacific sardine (*Sardinops sagax*) larvae. Fish. Oceanogr. 10(1):13-25.

Moser, H.G., R.L. Charter, **D.A. Ambrose**, and **E.M. Sandknop**. 2001. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1977 and 1978. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-313, 58 p.

Moser, H.G., **R.L. Charter**, **P.E. Smith**, **D.A. Ambrose**, **W. Watson**, **S.R. Charter**, and **E.M. Sandknop**. 2001. Distributional atlas of fish larvae and eggs in the Southern California Bight region: 1951-1998. CalCOFI Atlas 34, 166 pp.

Moser, H.G., **R.L. Charter**, **W. Watson**, **D.A. Ambrose**, K.T. Hill, **P.E. Smith**, **J.L. Butler**, **E.M. Sandknop**, and **S.R. Charter**. 2001. The CalCOFI ichthyoplankton time series: Potential contributions to the management of rocky shore fishes. Calif. Coop. Oceanic Fish. Invest. Rep. 42:112-128.

Moser, H.G. and **W. Watson**. 2001. Preliminary guide to the identification of the early life history stages of myctophiform fishes of the western central Atlantic. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SEFSC-453, 118 p.

Preti, A., **S.E. Smith** and **D.A. Ramon**. 2001. Feeding habits of the common thresher shark (*Alopias vulpinus*) sampled from the California-based Drift Gill Net Fishery, 1998-99. Calif. Coop. Oceanic Fish. Invest. Rep. 42:145-152.

Smith, P.E, J.K. Horne, and D.C. Schneider. 2001. Spatial dynamics of anchovy, sardine, and hake pre-recruit stages in the California Current. ICES J. Mar. Sci. 58:1063-1071.

Smith, S.E. 2001. Leopard Shark. *In* California's Living Marine Resources: A Status Report. California Department of Fish and Game, University of California Agriculture and Natural Resources, W.S. Leet , C.M. Dewees, R. Klingbiel, and E. J. Larson (eds). Sea Grant Publication SG01-11, pp 252-254.

Smith, S.E. and D. Aseltine-Neilson. 2001. Thresher Shark. *In* California's Living Marine Resources: A Status Report. California Department of Fish and Game, University of California Agriculture and Natural Resources, W.S. Leet , C.M. Dewees, R. Klingbiel, and E. J. Larson (eds). Sea Grant Publication SG01-11, pp 339-341.

Smith, S.E. and S. J. Crooke. 2001. Dolphin. *In* California's Living Marine Resources: A Status Report. California Department of Fish and Game, University of California Agriculture and Natural Resources, W.S. Leet , C.M. Dewees, R. Klingbiel, and E. J. Larson (eds). Sea Grant Publication SG01-11, pp 352-353.

Stout, H.A., B.B. McCain, **R.D. Vetter**, T.L. Builder, W.H. Lenarz, L.L. Johnson, and R.D. Methot. 2001. Status review of copper rockfish (*Sebastes caurinus*), quillback rockfish (*S. malinger*), and brown rockfish (*S. auriculatus*) in Puget Sound, Washington. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-NWFSC-46, 158 p.

Watson, W. 2001. Larvae of *Enchelyurus ater* (Gunther, 1877) and *E. kraussi* (Klunzinger, 1871) (Pisces: Blenniidae: Omobranchini). Records of the Australian Museum 53:57-70.

Watson, W., R.L. Charter, and **H.G. Moser**. 2001. Ichthyoplankton and station data for California Cooperative Oceanic Fisheries Investigations survey cruises in 2000. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-312, 73 p.

Watson, W., H.J. Walker, Jr., D.G. Smith, C. Thacker and G.P. Owen. 2001. Preliminary guide to the identification of the early life history stages of the gobioid fishes of the families Microdesmidae and Ptereleotridae of the western central North Atlantic. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SEFSC-451, 20 p.

2002 PUBLICATIONS

Alam, M.F., I.H. Omar, and **D. Squires**. 2002. Sustainable fisheries development in the tropics: trawlers and licence limitation in Malaysia. Appl. Econ. 2002(34):325-337.

Ambrose, D.A., R.L. Charter, and **H.G. Moser**. 2002a. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1980-81. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-319, 100 p.

Ambrose, D.A., R.L. Charter, and **H.G. Moser**. 2002b. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1985. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-321, 36 p.

Ambrose, D.A., R.L. Charter, and **H.G. Moser**. 2002c. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1989. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-325, 45 p.

Ambrose, D.A., R.L. Charter, and **H.G. Moser**. 2002d. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1993. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-329, 41 p.

Ambrose, D.A., R.L. Charter, and **H.G. Moser**. 2002e. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1997. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-333, 41 p.

Ambrose, D.A., R.L. Charter, and **H.G. Moser**. 2002f. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1998. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-334, 43 p.

Ambrose, D.A., R.L. Charter, and **H.G. Moser**. 2002g. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1999. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-335, 39 p.

Ambrose, D.A., R.L. Charter, H.G. Moser, S.R. Charter and **W. Watson**. 2002. Ichthyoplankton and station data for surface (manta) and oblique (bongo) plankton tows taken during a survey in the Eastern Tropical Pacific Ocean July 30 - December 9, 1998. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-337, 126 p.

Browman, H.I. and **R.D. Vetter**. 2002. Impacts of ultraviolet radiation on crustacean zooplankton and ichthyoplankton: case studies from subarctic marine ecosystems. Ecol. Stud. 153:261-304.

Buonaccorsi, V.P., C.A. Kimbrell, E.A. Lynn, and **R.D. Vetter**. 2002. Population structure of copper rockfish (*Sebastes caurinus*) reflects postglacial colonization and contemporary patterns of larval dispersal. Can. J. Aquat. Sci. 59:1374-1384.

Charter, S.R., R.L. Charter, and **H.G. Moser**. 2002a. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1984. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-320, 84 p.

Charter, S.R., R.L. Charter, and **H.G. Moser**. 2002b. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1986. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-322, 40 p.

Charter, S.R., R.L. Charter, and **H.G. Moser**. 2002c. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1990. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-326, 41 p.

Charter, S.R., R.L. Charter, and **H.G. Moser**. 2002d. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1994. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-330, 40 p.

Childers, J. 2002. Summary of the 2001 U.S. North and South Pacific albacore troll fisheries. SWFSC Admin. Rep., La Jolla, LJ-02-05 43 p.

Cochrane, G.R., **R.D. Vetter**, N. Nasby, **C. Taylor** and R. Cosgrove. 2002. Egg and larval fish production from marine ecological reserves. Part 2, Benthic habitat in four marine reserve locations surrounding the Santa Barbara Basin. California Sea Grant College Program, Marine Ecological Reserves Research Program Research Results, 1996-2001. CD-ROM, CSGCP, University of California, La Jolla, CA, 20 p.

Dutton, P.H., L. Sarti, R. Marquez, and **D. Squires.** 2002. Sea turtle conservation across the shared marine border. *In* Both Sides of the Border, L Fernandez & R.T. Carson (eds.). Kluwer Academic Publishers, Netherlands, pp 429-453.

Grafton, R.Q. and **D. Squires**. 2002. A property-rights perspective of efficiency: privatizing the commons. *In* Efficiency in the Public Sector, K. Fox (ed.). Kluwer Academic Publishers, Netherlands, Chapter 4, pp 83-100.

R.P. Hewitt, J.L. Watkins, M. Naganobu, P. Tshernyshkov, A.S. Brierley, **D.A. Demer**, S. Kasatkina, Y. Takao, C. Goss, A. Malyshko, M.A. Brandon, S. Kawaguchi, V. Siegel, P.N. Trathan, J.H. Emery, I. Everson and D.G.M. Miller. 2002. Setting a precautionary catch limit for Antarctic krill. Oceanography 15(3):26-33.

Lynn, R.J. and S. J. Bograd. 2002. Dynamic evolution of the 1997-1999 El Niño-La Niña cycle in the southern California Current System. Progress in Oceanography 54(2002):59-75.

McFarlane, G.A., **P.E. Smith**, T.R. Baumgartner, and **J.R. Hunter**. 2002. Climate variability and Pacific sardine populations and fisheries. Am. Fish. Soc. Symp. 32:195-214.

Moser, H.G., **R.L. Charter**, **P.E. Smith**, **D.A. Ambrose**, **W. Watson**, **S.R. Charter**, and **E.M. Sandknop**. 2002. Distributional atlas of fish larvae and eggs from Manta (surface) samples collected on CalCOFI surveys from 1977 to 2000. CalCOFI Atlas 35, 97 pp.

Sandknop, E.M., R.L. Charter, and **H.G. Moser**. 2002a. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1987. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-323, 40 p.

Sandknop, E.M., R.L. Charter, and **H.G. Moser**. 2002b. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1991. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-327, 41 p.

Sandknop, E.M., R.L. Charter, and **H.G. Moser**. 2002c. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1995. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-331, 42 p.

Vetter, R.D., H.G. Moser, W. Watson, G.R. Cochrane, N. Nasby, **C. Taylor** and R. Cosgrove. 2002. Egg and larval fish production from marine ecological reserves. Part 1, Overview of Santa Barbara Basin marine reserve study sites and research plan. California Sea Grant College Program, Marine Ecological Reserves Research Program Research Results, 1996-2001. CD-ROM, CSGCP, University of California, La Jolla, CA, 20 p.

Viswanathan, K.K., I.H. Omar, Y. Jeon, J. Kirkley, **D. Squires**, and I. Susilowati. 2002. Fishing skill in developing country fisheries: the Kedah, Malaysia trawl fishery. Mar. Res. Econ. 16:293-314.

Watson, W., R.L. Charter, and **H.G. Moser**. 2002a. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1988. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-324, 44 p.

Watson, W., R.L. Charter, and **H.G. Moser**. 2002b. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1992. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-328, 40 p.

Watson, W., R.L. Charter, and **H.G. Moser**. 2002c. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 1996. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-332, 45 p.

Watson, W., R.L. Charter, and **H.G. Moser**. 2002d. Ichthyoplankton and station data for Manta (surface) tows taken on California Cooperative Oceanic Fisheries Investigations survey cruises in 2000. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-336, 40 p.

Watson, W., R.L. Charter, H.G. Moser, D.A. Ambrose, S.R. Charter, E.M. Sandknop, L.L. Robertson, and **E.A. Lynn**. 2002. Egg and larval fish production from marine ecological reserves. Part 3, Distributions of planktonic fish eggs and larvae. California Sea Grant College Program, Marine Ecological Reserves Research Program Research Results, 1996-2001. CD-ROM, CSGCP, University of California, La Jolla, CA, 67 p.

Watson, W., E.M. Sandknop, S.R. Charter, R.L. Charter, and **H.G. Moser**. 2002. Ichthyoplankton and station data for surface (manta) and oblique (bongo) plankton tows taken during a survey in the Eastern Tropical Pacific Ocean July 28 - December 9, 1999. U.S. Dep. Commer., NOAA Tech. Memo., NOAA-TM-NMFS-SWFSC-338, 96 p.