Exhibit H.1
Situation Summary
November 2001

NATIONAL MARINE FISHERIES SERVICE REPORT

Situation: National Marine Fisheries Service will briefly report on recent developments in the coastal pelagic species fishery and other issues of relevance to the Council.

Council Task: Discussion.

Reference Materials: None.

PFMC
10/10/01

Recommendations for Market Squid Management and Research

Coastal Pelagic Species Management Team

Preface

The Coastal Pelagic Species Management Team (CPSMT) convened from August 14-15, 2001 to address management and research issues associated with the market squid (*Loligo opalescens*) resource off the California coast. The overall goal of this CPSMT meeting was to review information generated from the recently conducted Stock Assessment Review (STAR) session for squid held in May 2001. Specifically, the CPSMT focused on the following objectives during the two-day meeting: (1) develop consensus regarding important points concluded in the STAR Panel's Report; (2) determine if the suite of model configurations based on the *Egg Escapement* (EE) method could be further reduced into a tractable subset (Maxwell 2001); (3) further evaluate important parameters of the EE approach (e.g., population 'threshold' levels) in efforts to establish maximum sustainable yield (MSY)-based management schemes; and (4) develop sampling, laboratory, and analysis schedules that support the EE approach in particular, and also discuss the merits of gathering auxiliary data that would improve understanding of squid population dynamics. The following synopsis presents the CPSMT's recommendations.

Summary

First and foremost, the CPSMT generally supports the findings of the STAR Panel and in particular, its conclusion that the EE method can provide an effective framework for monitoring/managing the squid population in the future (see objective (1) in Preface). That is, the current port sampling program implemented by the California Department of Fish and Game (CDFG), along with newly developed laboratory and analysis procedures conducted by the National Marine Fisheries Service (Southwest Fisheries Science Center, SWFSC), will provide an objective method for establishing Maximum Sustainable Yield (MSY)-based management goals for the squid resource, e.g., for developing biological reference points. In practical terms, the EE approach can be used to evaluate the effects of fishing mortality (F) on the spawning potential of the stock and in particular, to examine the relation between the stock's reproductive output and candidate proxies for the fishing mortality that results in MSY (F_{MSY}). However, it is important to note that this approach does not provide estimates of historical or current total biomass and thus, a definitive yield (i.e., quota or Acceptable Biological Catch) cannot be determined at this time. Ultimately, the EE approach can be used to assess whether the fleet is fishing above or below an a priori-determined sustainable level of exploitation and in this context, can be used as an effective management tool. Reasons for adopting the EE method for monitoring/managing the squid population, rather than other analytical approaches (e.g., surplus production and depletion models), are presented in STAR (2001).

A critical underpinning of this recommendation is that the fishery continues to concentrate strictly on squid spawning grounds–the fishing fleet attracts mature squid using lights deployed during the evening hours. This *spawning-grounds* squid fishery appears to have the following characteristics: (1) historically, harvests have consisted almost entirely of mature animals that have had an opportunity to spawn, i.e., lay some or all of their eggs before capture; (2) recruitment and future catches in each fishing season largely depend on successful and adequate spawning in the preceding season; (3) the squid are determinate spawners, with potential lifetime fecundity fixed at maturity; (4) the squid die soon after laying their full complement of eggs, i.e., semelparous reproduction; and (5) interpretable, anatomical evidence of spawning must be able to be estimated from commercial harvest data, which can be routinely collected through an ongoing port sampling program. The fact that evidence of spawning can be derived from commercially landed specimens offers a unique opportunity to implement an EE method for fishery monitoring/management. Ultimately, estimates of past spawning, coupled with per-recruit analysis theory, can provide the necessary statistics for determining the relationships between important equilibrium-based fishery descriptors, e.g., for determining how fishing mortality (F) influences residual eggs at time of capture, eggs per recruit, and EE.

Although the CPSMT is supportive of such an approach for this fishery and recommends beginning efforts for its implementation, there still exist areas of uncertainty that would greatly benefit from further evaluation. In this regard, the following areas of squid biology are only generally understood at this time and thus, were treated through 'sensitivity' analysis at the modeling stage: (1) maturation rate; (2) duration of spawning; (3) egg-laying rate; and (4) natural mortality rate.

The CPSMT recommends that the squid resource be formally reviewed again in 2004. Thus, a research/management sequence should be started for completion by early 2004. Important areas of work include: (1) rigorous monitoring of the landed catch for the occurrence of immature squid; (2) collection of fishermen logbook data that will allow changes in fishing techniques and success to be accurately measured; and (3) initiating studies that shed light on areas of squid biology still unresolved (see above). An extensive research/management list is presented in Maxwell (2001) and summarized in STAR (2001).

Finally, the following discussion (see Additional Notes) addresses pertinent decisions made by the CPSMT to develop a workable monitoring/management plan for the squid fishery based on the EE method, i.e., the STAR Panel (STAR 2001) provided general recommendations regarding analytical methods and left determination of specific model configurations and other management-related parameters to the CPSMT.

Additional Notes

The following discussion briefly describes technical decisions made by the CPSMT regarding the squid stock assessment conducted in 2001 in general and the EE method in particular (see Maxwell 2001). The discussion is partitioned into four general areas: (1) selection of a 'preferred' model scenario; (2) selection of a 'threshold' level of egg escapement (EE value) that can be considered a warning flag when tracking the status of the population; (3) fishery operations in (and after) El Nino/Southern Oscillation (ENSO) events; and finally, (4) necessary management-related constraints.

Preferred Model Scenario

The CPSMT largely relied on researchers familiar with squid biology to identify a 'preferred' (most plausible) model scenario from the suite proposed in the overall analysis. First, given that *model version 1* was the more general of the two proposed versions and adequately captured what is known (at this time) regarding the maturation schedule of this species, the CPSMT recommended that this version be focused on when deriving final estimates. Further, two important areas of squid biology that were treated in sensitivity analysis during modeling exercises included hypothesized rates of natural mortality (M) and egg laying (v). The CPSMT recommended that the preferred model scenario be based on $M = 0.15$ and $v = 0.45$ (both are daily rates), given: (1) data on the energetics of egg production and longevity of sexually mature adults indicate higher values of M are more likely than lower values; and (2) anatomical examinations of reproductive organs of young spawning females support egg-laying rates that are roughly equivalent to $v = 0.45$. It is important to note that rates of natural mortality (M), as well as fishing mortality (F), are generally believed to be much higher for this marine animal than that estimated for species of fish; however, mortality associated with squid should be interpreted in the context of this species' life history strategy, namely, it's relatively short life span and associated high productivity.

Threshold Level of Egg Escapement

A 'threshold' level of egg escapement can be practically interpreted as a level of 'reproductive' (egg) escapement (EE) that is believed to be at or near a minimum level that is considered necessary to allow the population to maintain it's level of abundance into the future (i.e., allow for 'sustainable' reproduction year after year). It is important to note that a threshold level of egg escapement applicable to this species is not known in strict terms at this time (and likely not a fixed value on an annual basis), but rather, determined from evaluating general patterns of harvest observed in the squid fishery off California, as well as examining similar reference points relied upon in other squid fisheries as approximate guidelines. The CPSMT recommended that a threshold value of 0.3 (30%) be used initially, given: (1) a reproductive escapement threshold of roughly 0.4 (40%) has been used effectively in other squid fisheries (e.g., Falkland Islands fishery)–keeping in mind that the Falkland Island fishery harvests primarily juveniles; (2) not all of the squid spawning grounds off the California coast are subject to fishing pressure; (3) an existing weekend closure allows two days per week for spawning in the absence of fishing; and (4) the daily mortality of females during spawning is likely quite high.

Given the reasons above, it is certainly possible that a more appropriate threshold level is even lower than 0.3; however, the CPSMT does not recommend a lower level of egg escapement, given: (1) this is a new approach that should be monitored for some time before adopting a lower threshold; (2) there are some uncertainties about the retention of eggs in the females after capture; (3) there may be unevaluated fishery-dependent sources of mortality after spawning, such as fishing gear destruction of egg beds; (4) squid are members of a lower animal trophic level of the marine ecosystem and thus, play an important role as a forage species utilized by animals at higher trophic levels; and (5) sample data indicate that it is not likely that the recommended threshold will hamper the operations of the fishery as observed since the mid 1990s.

ENSO Events

The CPSMT deferred consideration of the effects of ENSO conditions on the squid population and ultimately, the fishery itself, until studies that focus on the influence of such oceanographic phenomena on squid abundance and distribution generate useful management advice. A consistent observation during such events is a temporary cessation of availability to the fishery. Although researchers generally believe this 'disappearance' is due to both reduced reproduction by the population and movement out of the established spawning grounds and into favorable habitat, the extent and magnitude of each response are not clearly defined at this time. Most importantly, there is no indication from the post-ENSO landings of long-term detrimental damage to the population's ability to sustain itself, i.e., the population has recovered relatively quickly following El Nino events. Although catches by the fleet dramatically decline during such periods and in effect, 'self-regulate' the fishery, the CPSMT cautioned that further restrictions on catch may be warranted in the future, given the broad impact that these oceanographic conditions have on many marine animal populations distributed along the U.S. Pacific coast.

Monitoring and Management Issues

Most importantly, the CPSMT concurred with the STAR Panel that the current squid fishery should remain under the immediate jurisdiction of the state of California (i.e., CDFG)–keeping in mind the federal-based policies inherently in place for all U.S.-based fisheries. The newly adopted EE method should be considered a joint effort between the CDFG and NMFS (see Summary above). Additionally, sample data (e.g., catch-related statistics) are currently being collected by the Oregon Department of Fish and Wildlife (ODFW) and the Washington Department of Fish and Wildlife (WDFW), with the possibility that in the future, ODFW and WDFW, along with CDFG, may assist in collection of information directly related to the EE method.

The CPSMT recognized that the management measures already in place by the CDFG for the squid fishery are effective tools for controlling the amount of fishing pressure exerted on the population, e.g., weekend closures and protected (no fishing) areas along the coast. In this regard, the CPSMT recommended that management-related exercises that may be needed in the future (via the EE method, e.g., falling below a threshold of 0.3) be implemented by the CDFG using similar, but somewhat more rigorous, regulations as those in place currently. Finally, the CPSMT strongly recommended that the recent CDFG-proposed annual landings cap on the total harvest of squid be supported. This management measure should not be considered a trivial constraint, given many of the conclusions drawn from the overall squid assessment were based on past fishing practices of the fleet and the dynamics of the population may indeed change if subjected to uncharacteristically high catches (also, see *spawning grounds* squid fishery in Summary above for related point).

References

Maxwell, M. R. 2001. Reproductive (egg) escapement model and management recommendations for the market squid fishery. Summary Paper from *Stock Assessment Review (STAR)* Meeting, NOAA/NMFS/SWFSC, May 14-17, 2001. 27 p.

Stock Assessment Review (STAR) Panel. 2001. Report of the Stock Assessment Review (STAR) panel for market squid. Panel Report from *Stock Assessment Review (STAR)* Meeting, NOAA/NMFS/SWFSC, May 14-17, 2001. 18 p.

Exhibit H.2.b
Final Workshop Report
November 2001

Report of the Stock Assessment Review (STAR) Panel for Market Squid

May 14-17, 2001

Southwest Fisheries Science Center
La Jolla, California

1. Introduction

In 1999, the Department of Commerce rejected portions of Amendment 8 to the Pacific Fishery Management Council's (Council) Coastal Pelagic Species (CPS) Fishery Management Plan (FMP) on the grounds that the amendment did not include an estimate of maximum sustainable yield (MSY) for market squid. In September 2000, the Council's Scientific and Statistical Committee (SSC) reviewed newly derived estimates of MSY for market squid. Because of the uncertainties surrounding these estimates and more generally, ongoing concern regarding the appropriateness of defining MSY for this species, the SSC did not recommend an MSY value.

Fortunately, recent research conducted on market squid life history (including growth, maturity, and fecundity) along with enhanced fishery-dependent data (port sampling and logbooks) have provided significant new information. The SSC recommended (and the Council concurred) that the SSC should work with the National Marine Fisheries Service (NMFS) and the California Department of Fish and Game (CDFG) to organize a stock assessment review (STAR) panel for market squid during 2001.

The STAR Panel met May 14-17, 2001 at the NMFS Southwest Fisheries Science Center, La Jolla, CA. A principal goal of the STAR was to integrate the ongoing market squid research into the Council's CPS FMP. Terms of reference for the STAR panel addressed the MSY issue as well as control rules for practical management of the market squid fishery (Appendix A) . The Panel members were:

Tom Barnes	CDFG & Council's GMT
Ray Conser (co-chair)	NMFS & Council's SSC
Larry Jacobson	NMFS - Woods Hole (outside reviewer)
Tom Jagielo (co-chair)	WDFW & Council's SSC
Heather Munro	Munro Consulting & Council's CPSAS
Paul Smith	NMFS & Council's CPSMT

An agenda and eight working papers (WP) were prepared for the STAR and distributed to Panel members and other interested parties on May 1, 2001 (Appendices B and C, respectively). The WP authors presented their work to the Panel and were available throughout the week to consult with the Panel, provide additional information and data, and to carry out additional analyses, as needed. In addition to the Panel members and WP authors, the STAR discussion and participation was open to all interested parties. In total, approximately 25 participants were involved in the process (Appendix D). Excellent facilities and support were provided by the NMFS and CDFG staff in La Jolla.

Considerable interaction occurred throughout the STAR meeting among STAR Panel members, WP authors, and other participants. In some cases, this 'give and take' resulted in alternative interpretations of data as well as modelling improvements. Additional model runs were carried out during the meeting and the results were tabled for discussion. Consequently, some important aspects of the STAR Panel consensus were based on the modelling work done during the course of the meeting. The Panel requested that WP8 be revised after the meeting to reflect and fully document the analyses carried out during the STAR Panel meeting. The analyses and results contained in WP9 reflect the STAR Panel consensus at the end of its meeting with respect to the most appropriate modelling and management control rules.

2. Biology and Life History Findings

The STAR panel considered new results about the biology of the market squid. Together these findings are crucial for beginning the consideration of rational management techniques for controlling the future direction of the fishery from the standpoint of sustainable yield over time. There are also elements in the biology and life history which represent exotic departures from the usual fishery management principles and approaches and these deserve special attention. Thus it is the task of this report to consider the wide range of biology and life history results, and focus on those which provide the most information for management and supply questions which must eventually be considered. The headings under which these will be considered are age and growth, temperature controlled development rates, genetics, fecundity, and some behavioral aspects of the El Niño phenomenon.

The fundamental distinction in the squid fishery, versus fisheries on long-lived multiple spawning fishes, is that little or no fishing precedes spawning and consequently, substantial population spawning has occurred before any adults are caught. Thus, the management approach can be based directly on the status of spawning from the appearance of past spawning in the squid catch. It is common to both of the squid fisheries in California (Monterey and Southern California) that there are substantial periods in the year in which spawning most likely has occurred for which there is no fishery. Similarly, the height of the fishery within each year is restricted to a few months. If the life cycle is materially less than one year, there will be interspersed reproductive episodes with only natural mortality occurring.

Lastly, the catch records for both Monterey and Southern California show cataclysmic decline of landings during El Niño Southern Oscillation (ENSO) events. Since the fishery is on adults, some degree of reproductive success has already occurred. Subsequent fishing seasons will reflect either deficiencies in reproductive success or changes in the availability of squid. If the subsequent season is low in catch, also, one would tend to think of depletion of that cohort of spawners; if the subsequent season is high in catch, one would have to infer reproductive recovery to that extent or introduction of squids which have not been affected adversely by ENSO.

2.1 Age and Growth

Growth of squid paralarvae is slow. Juvenile growth accelerates as the animal approaches maturity as described with a power function:

$$\mathbf{DML = a\ T^{b}}$$

Where DML is dorsal mantle length and T is age in days. In a single cohort, the reported 'a' was 0.001342 and the exponent 'b' was 2.132. The average age of females sampled in the fishery was 186 days following hatching and feeding. The male average age was essentially the same at 190 days. It is not known whether age rings in the statolith continue after maturation or if continuing rings are visible.

If one assumes that daily rings continue to be formed and can be counted, a display at monthly interval in the 1998-99 fishery shows that squid age composition in the catch ranges from 5 to 9 months with a mode which is at either six or seven months. (WP3, Figure 2). Since statolith rings form in the week between hatching and disappearance of yolk, about 2 months can be added to the period between generations, 8-9 months. The seasonality of catches in both habitats may not reflect the progression of cohorts from short seasons in an annual cycle but may merely reflect the economic factors or availability of shallow spawning aggregations. Cohort formation, if any, may be smeared with temperature, by the depth distribution of hatching, and subsequent variations of rates of growth to maturity.

The key uncertainties with respect to market squid age and growth are:

[i] variations of growth rate following maturity;
[ii] interannual and intra-cohort variations in juvenile growth rate;
[iii] interannual and intra-cohort variations in maturation by age;
[iv] a more complex growth model may be needed to adequately represent growth throughout the full life

history, especially for mature animals; and

[v] accuracy of daily statolith ring counts after the onset of maturity.

2.2 Temperature Dependent Incubation

Temperature controlled incubation time at 7 degrees C exceeded 90 days; at about 12.5 C, squid eggs hatched in 50 days; and at 20 C hatching time was as fast as 24 days. The 25 C temperature was lethal and hatching at 6 C temperature was not lethal but did not complete development. Since all ages are from hatching without knowing the temperature at incubation, the incubation period appears to range from 1 to 3 months with a mean approaching 2 months. The yolk-sac may persist a week. The key uncertainties are: [i] temperature distribution at spawning; [ii} possible change in depth during ENSO; and [iii] possible transport or migration of adjacent stocks after ENSO.

2.3 Genetic Separation of Stocks

The degree of genetic mixing of squid between the Monterey and the Southern California Bight fisheries is not well established but there may be short-term isolation sometimes referred to as 'viscous' dispersal. Coast wide genetic studies are now being conducted to which the local studies reported so far from Monterey and Southern California Bight may be referred. Uncertainties are [i] the local depletion and resupply rates and [ii] the scale and degree of genetic mixing

2.4 Dynamic Fecundity

Potential fecundity may be obtained from oocytes as the gonadal tissue is formed. Maturation begins with the investment of a mode of oocytes with yolk. Ovulation onset is detected by empty follicles in the ovary and the presence of eggs in the oviducts. There appear to be more than one batch of eggs spawned by most females. By far the majority of females sampled in the commercial catch have some evidence of spawning. The dynamics of fecundity are controlled by temperature, size of female, and age of female. Only small numbers of females so far sampled have greater than 3 post-ovulatory follicular stages. Signs of multiple spawning waves in the ovary are accompanied by changes in mantle condition. There are also signs of wide area synchrony in modes of mantle condition which may be more useful in determining actual age than statolith rings after maturity. Uncertainties are: [i] the relationship between potential and residual fecundity at the population scale; [ii] the persistence of detectable post-ovulatory follicles; and [iii] the relationship between mantle condition and environment.

2.5 Aspects of El Niño

Within most decades of fishery management, we can expect one or two ENSO events. Based on previous ENSO's in the modern market squid fishery, we can expect, at least, wide disruption in the availability of squid on the spawning grounds, and perhaps increases in natural mortality as well. To date, the recovery of the fishery following ENSO's has been remarkably fast. The key El Niño issues with respect to squid management are:

[i] Does ENSO change the risk of overfishing?

[ii] Should the first year after recovery from ENSO be managed differently?

[iii] Do management models require additional parameters to account for the environmental effects?

[iv] Are there other organisms in the ecosystem approach which need to be considered in this light?

3. Fishery and Fishery-Independent Data

The STAR panel discussed a number of fishery and fishery independent data sources with potential for use in the assessment of market squid (Table 1). The data sources in the present assessment (WP7, WP8, and WP9) came primarily from fishery and survey information sampled in the S. California Bight. The additional data sources listed in Table 1 were discussed by STAR panel members as potential sources of information for future assessments.

Catch data, summarized by blocks from which the squid were taken, were obtained from CDFG landing receipt information. Samples from CDFG 1998-2000 port sampling were used to characterize mantle length, body mass, and sexual maturity of the landed catch. Age composition of the catch was derived from a sub-sample of 908 port sampled squid. Biological samples from a CDFG midwater trawl cruise in 2000 were used to supplement the port sample data. Presently, port sampling data are also used to estimate the bycatch of immature squid in the fishery; the assumption is that few discards are made at sea because squid are pumped directly from the seine net to the vessel hold without at-sea sorting.

WP7 presented three indices of squid abundance: 1) a CPUE index of abundance, 2) a midwater trawl survey index of abundance, and 3) a sea lion scat index. The CPUE index of abundance utilized catch per block information from fish landing receipts, and a time series of fishing effort which was obtained from analyzing satellite images of the S. California Bight (1992-2000). Light pixels on the satellite images were quantified and used as an index of fishing effort; a positive relationship was apparent when light pixels for each night were compared with catch landed the following morning. A project to ground truth the light pixel – fishing effort relationship with night time flyovers of the S. California Bight (1999-2000) is underway. Because light shields are now required on light boats, satellite data may not be useful for future effort estimation. In the future, it may be possible to use information from fishery logbooks to establish a new index of fishing effort. The midwater trawl survey index of abundance was derived from the Mais surveys (1966-1988). Tows were filtered by depth, duration, and location criteria, and an index for the S. California Bight was prepared. Squid abundance in each survey was described in terms of the proportion of tows that caught one or more squid of mantle length 80 mm or longer (proportion positive). The sea lion scat index was derived from scat samples taken from San Nicolas and San Clemente Islands. The trend in squid abundance was quantified as the proportion of scat samples that contained squid beaks per calendar quarter for each island (proportion positive).

The STAR panel noted that non-linear relationships can exist between stock abundance and both types of indices used for market squid, i.e. catch rate indices and proportion positive indices. Non-linear relationships in catch rates can result from saturation for schooling species, and proportion positive indices may be nonlinear because they are bound between zero and one (see Section 5.2, below). The STAR panel also pointed out that using CPUE as an index of abundance is problematic for a schooling animal such as squid. In the squid fishery, light boats locate spawning aggregations and attract squid to the surface for subsequent capture by the round haul fishing vessels, and unqualified CPUE is not likely to be directly proportional to abundance. A mandatory fishery logbook program was instituted in 2000, and logbook data are now available for both the light boat and fishing boat components of the fishery. Logbook data, if properly standardized, hold potential as a tool to estimate effective fishing effort. It will be important to take into account factors such as search time, changes in catchability, and market factors which could bias the results.

The SSB/R fecundity escapement management, as described in WP1, WP2, WP8, and WP9, approach would require reliable estimates of 1) age composition of the landed catch, 2) egg escapement from harvested and unharvested components of the population, 3) growth and maturation rates, 4) adult vulnerability to the fishery, and 5) fishery effort data. Biological data will be required from both survey and fishery samples to characterize mantle length, mantle condition factor, fecundity, and proportion mature by age. Reliable estimates of total catch and effort will be required to estimate egg take by the fishery.

Finally, the SSB/R approach as described in WP8 and WP9 assumes that the great majority of the stock's adults spawn at sites that are targeted by the fishery. There is a need to quantify the full extent of the squid spawning distribution, to evaluate the escapement of squid eggs from the unfished components of the population. Midwater trawl surveys, ROV surveys, and paralarvae surveys are tools which could potentially be used to characterize the full distribution of the squid resource.

4. Stock Assessment-Related Models and MSY Estimation

4.1 Maximum Sustainable Yield

Working papers with results from several different approaches to estimating MSY were made available to the Panel (WP7 and WP8). Assessment authors presented the data, methods, and results for one of the approaches. Group discussion focused on the technical strengths and weaknesses of their work, and whether the basic MSY concept was appropriate to a species that is very short lived and exhibits wide year-to-year fluctuations in availability and/or abundance.

Results from a surplus production model were presented, using the ASPIC software where the stock was not assumed to be in equilibrium. Input data were catch for the southern California Bight, effort on the primary fishing grounds, and three auxiliary tuning indices. The auxiliary indices were proportion positive for squid in a midwater trawl survey, and proportion positive for squid beaks in California sea lion scats at two separate locations. Assessment authors explained that the auxiliary data were included despite a caveat that the data were suspect and might introduce bias. The CPUE and effort data met a primary assumption for surplus production because CPUE decreased with increasing effort. Also, use of satellite images of lightboats (number of pixels) suggests a good approximation to lightboat effort.

The MSY range for the Southern California Bight was 30,000-60,000 mt. Considerable discussion was given to whether surplus production results from a time series that included obvious habitat response (i.e. El Niño years) was appropriate for estimating MSY. There was a consensus that resulting MSY estimate represented an intermediate or average value across a range of environmental conditions. Such an average MSY estimate would not represent stock conditions in most individual years, and would be impractical for use in year-to-year fisheries management. In response to that concern, the assessment authors informed the Panel that an attempt had been made to estimate MSY with no El Niño years in the data, but the range of results was so wide that they were not useful. There was general agreement that the use of auxiliary indices in the model had the potential benefits, but squid were not rare in some of the auxiliary data and therefore it appeared that the indices might be saturated.

The Panel recommended that the surplus production model be further explored when substantial new data such as a logbook time series become available, with particular attention to: 1) accounting for environmental effects; and 2) transformation of the auxiliary index data. However, the Panel did not request additional surplus production model work by the assessment authors during the meeting because it was thought that their efforts could be better spent investigating more promising harvest control rules in the limited time available.

Some additional approaches to MSY proxies were available from an Environmental Assessment to Amendment 9 of the CPS-FMP (WP5). The data and methods were presented to the Panel with the caveat that these approaches had already been reviewed by the Council's SSC and were not found to provide useable estimates of MSY for market squid. The Panel briefly discussed some of the alternatives in WP5, but did not think that they warranted further investigation at this time. A major concern was that although the approaches were straightforward and easy to understand, they require several tenuous assumptions and do not utilize much of the recently available data on biology, life history, and reproduction.

4.2 Estimation of Mortality Coefficients (Z)

During the Panel meeting, a catch curve was constructed from southern California catch and age data during December 1998 through June 1999. Daily age data were pooled to estimate catch composition by age in months. Log transformed catch at age estimates suggested that full recruitment occurred at age 6 months, and data from age 6-10 months were used to estimate Z. Two approaches for estimating Z resulted in a range of Z = 0.3-0.6 per month. The assessment authors suggested that monthly M is therefore less than 0.6. Considering the atypical life history of market squid, it is unclear if catch curve assumptions about constant recruitment were violated. Further, and perhaps more importantly, market squid ageing via daily ring counts appears to be problematic after the onset of maturity.

4.3 Leslie-DeLury (Modified Depletion) Model

A Leslie-DeLury depletion model was explored by in WP7, but the results were equivocal. The Panel thought that the approach was not appropriate for market squid at this time, in part because of uncertainty surrounding recruitment. In particular, there do not appear to be any viable recruitment indices currently available. The model would also benefit greatly from improved effort data such as a mandatory logbook time series. The Panel suggested that the model be further explored when such data become available.

4.4 Panel Recommendations on MSY for Market Squid

The Panel concluded that current attempts to estimate MSY were not defendable as a basis for managing the fishery, and there was doubt that technical refinements to this approach would change the determination. Major conceptual problems inherent in applying this approach to market squid remain to be addressed, such as: a life span of less than one year duration; strong environmental effects on availability and/or abundance; potentially biased or saturated auxiliary indices of abundance; harvest centered on terminal spawning grounds; and high variability in recruitment. Although correcting problems in the surplus production approach may be worth pursuing, the Panel believes that a more robust and promising prospect for harvest control rules lies in further investigation and development of spawning escapement targets with respect to SSB/R, along the lines of the data and analyses that were presented as an alternative to MSY (see Section 5, below).

5. Control Rules and Other Management Measures

As discussed in Section 4,above, the concept of MSY as a constant level of catch is problematic for most species, including market squid. The potential policy importance of MSY in management of market squid is heightened because stock assessment models, data and biological reference points to guide management actions under the MSFCMA are lacking. If suitable biological reference points and models were available, they could be used qualitatively (e.g. in making decisions about "active" vs. "monitored only" management) or quantitatively as management targets and management thresholds in overfishing definitions, harvest control rules, calculation of ABC or short-term management of fishing effort.

Approaches based on biological reference points are more effective in terms of maintaining high catches and conservation than trying to manage a fishery towards a static MSY catch level. The panel therefore concentrated on developing approaches for calculating biological reference points, evaluating the probability of overfishing in the current fishery for market squid, developing approaches to collecting data from the fishery for comparison to biological reference points, and in developing conceptual approaches to harvest control rules that might be applicable to market squid.

5.1 Biology and Fishery Considerations

The following are key points (not prioritized) concerning the biology and fishery for market squid are important in considering technical and policy aspects of biological reference points and harvest control rules.

a. In the current fishery, market squid are caught almost entirely while aggregated on spawning grounds. This fact has several important implications:
    i. Landings are almost entirely composed of sexually mature market squid.
    ii. There is little or no fishing mortality on immature individuals.
    iii. Maturity and recruitment to the fishery occur at the same time for market squid living in an area where fishing occurs.

b. Market squid appear to live 6-12 months under natural conditions. Thus, natural mortality rates for market squid are uncertain, but the average lifetime natural mortality rate is much higher than for most finfish. These characteristics have several important implications:
    i. Recruitment and future catches in each year or generation depend on successful and

adequate spawning in each preceding year or generation.

ii. The persistence of the fishery depends entirely on new recruits to the spawning population. The catch is composed entirely of new recruits to the spawning population.

iii. The fishery and stock are potentially sensitive to environmental factors or fishing that might reduce spawner abundance or survival of eggs over short periods of time. However, sensitivity to these factors has not been clearly demonstrated.

c. Market squid are determinate spawners whose potential lifetime fecundity appears to be fixed at maturity. This means that individual market squid would not replace oocytes and eggs after they are spawned.

d. According to the best available information and opinion of experts at the STAR Panel meeting, individual market squid probably die shortly after their potential fecundity is exhausted and spawning is completed. The duration of spawning, number of spawning bouts and time to death for individual spawning market squid are uncertain and possibly variable. Duration of spawning and time to death are believed to be on the order of days to weeks. Longer spawning periods seem less likely but cannot be ruled out completely. Thus, market squid appear to be functionally semelparous with natural mortality rates that are high on average (to account for the short life span). Moreover, natural mortality rates may increase substantially when market squid become sexually mature and recruit to the fishery.

e. Relatively high fishing mortality rates are probably necessary to catch market squid in terminal spawning ground fisheries before they die of natural causes. This characteristic is due to high natural mortality rates in general, and is likely reinforced by increases in natural mortality rate around the time of spawning.

f. There are spawning grounds where no fishing currently occurs. The size of these areas is unknown but may be significant.

g. Discard appears to minor for market squid.

h. Fishing activities are currently prohibited on weekends (29% of the fishing season).

i. Market squid are a valuable fishery.

j. Landings data suggest that availability of market squid to California fisheries is affected strongly during El Niño periods. This may be due to reductions in abundance, to displacement of the stock away from the fishery, or both factors. Presently, data are not available to prove or disprove either hypothesis.

k. With the exception of El Niño periods, market squid have consistently supported high levels of catch over the last twenty years while markets were favorable. Thus, the current level of average catch appears sustainable under current environmental conditions with no El Niño.

l. Availability and markets have changed over time making long-term trends in landing data difficult to understand.

m. Relatively smooth short-term, inter-annual trends in landings data suggests that catch in the market squid fishery tends to be relatively consistent from year to year, with the exception of El Niño periods. The relationship between abundance and catch is uncertain, however, and short-term abundance may be more variable than catch.

n. Recent increases in landings correspond to a period of warm water conditions in the California Current and strong markets. Hypotheses about the climate-induced trends in abundance are difficult to evaluate based on landings data due to changes in markets.

o. The market squid fishery is currently regulated by license moratorium. A limited entry system is under consideration. These measures may reduce the probability of dramatic increases in fishing effort over the short term.

p. Market squid paralarvae can be taken in plankton nets throughout the year indicating that spawning occurs throughout the year. Birth dates of recruits to the fishery spanned a range of at least eight months during one season of sampling (1998-1999).

5.2 Approaches to Developing Biological Reference Points

Preliminary attempts to estimate biological reference points (MSY, F_{MSY}, and B_{MSY}) from surplus production models were not fruitful (WP7; Section 4, above). In reviewing modeling efforts, the STAR panel noted that stock assessment models should use all available information to the extent possible and that nonlinear relationships between abundance and indices expressed as commercial catch rates or proportions (e.g. proportion mid-water tows positive for market squid) should be considered.

a. Catch rates are often nonlinear for schooling species due to "saturation". The relationship between abundance and catch rates for schooling species is often, for example, expressed as a nonlinear power function $cpue=qB^x$, where cpue is the catch rate, B is market squid biomass, and q and x are parameters. Values of the exponent parameter around x=0.5 are common for pelagic fish.

b. Proportions are nonlinear because they are confined to the range between zero and one. Depending on the frequency of a positive sample, the number of samples and other factors, indices based on proportion positive data (e.g. proportion tows positive for market squid) are often best modeled based on likelihood calculations for binomial or Poisson variables.

In view of difficulties with surplus production models for market squid, and because new information on reproductive biology was available (WP1), the STAR panel focused attention on reference points based on egg escapement, and related concepts. Egg escapement, for example, is the number (or proportion) of a female squid's potential lifetime fecundity that she is able to spawn, on average, before being taken in the fishery.

At least two traditional escapement approaches are potentially useful for squid. The first is based on depletion models and real-time management. This approach has been used in the Falkland Islands for *Illex argentinus* with some success. It attempts to manage a fishery so that some fraction of abundance or spawning biomass (a proxy for egg production) escapes the fishery. Fishing effort, season length and other management measures are established prior to the fishing season, based on data from the previous years and any additional information that might be available (e.g. results from a preseason trawl survey). Once the fishery is opened, catch rates and other data are monitored closely. The fishery is closed if escapement is likely to fall below the management target. Preliminary attempts to fit depletion models to market squid data were not fruitful (WP7; Section 4, above). The market squid fishery is a terminal spawning ground fishery with high natural mortality rates and continuous recruitment of newly matured individuals so that trends in catch rates would be difficult to evaluate. Real time management is data and analysis intensive, and likely not applicable to the market squid fishery at this time because data and modeling resources are limited. For these reasons, the STAR panel does not consider depletion model approaches to be potentially useful for market squid at this time.

The second traditional reference point approach for egg escapement is based on conventional yield- and spawning biomass "per recruit" models used in many other fisheries. The second approach, or variants described below, is more useful for market squid. The idea was proposed in WP8 where preliminary model runs were carried out. Refinements and extensions are in WP9.

The most typical approach is to use a spawning biomass per recruit model to calculate the lifetime spawning biomass expected from an average female recruit to the fishery, at various levels of fishing mortality. Biological reference points based on fishing mortality rates and expected spawning biomass per recruit from model results are chosen by policy makers. A common biological reference point in squid fisheries is F40%, the fishing mortality rate that reduces a females expected lifetime spawning biomass to 40% of the expected value if no fishing were to occur.

Using new biological information presented for the first time at the STAR Panel meeting, conventional spawning biomass per recruit models for market squid can be parameterized to calculate egg production (egg escapement) over the life of an average female, rather than spawning biomass. Egg production is a better measure of reproductive output than spawning biomass for market squid and most other species.

Information required to fit per recruit models was available from working papers, participants at the STAR panel meeting and published sources. The required information includes estimates of growth (size at age, WP3), natural mortality (WP 3 and 7), maturity and fecundity at age (WP1), and fishery selectivity. The available information was reliable enough for "ballpark" calculations at the STAR Panel meeting. This modelling is documented in WP9.

Market squid biology and the market squid fishery are unique and it was important to configure per recruit models in appropriate ways:

a. Recruitment to the spawning stock (maturity at age) and recruitment to the fishery (fishery selectivity at age) were assumed the same because the fishery operates on spawning aggregations.

b. Mortality rates are extremely high, particularly for spawners, so short time steps (i.e. one day) were used in calculations.

c. Mature individuals (spawners recruited to the fishery) may have a higher natural mortality rate than immature individuals. Therefore, models incorporating potential changes in natural mortality with spawning are required.

d. Average lifetime egg production must be less than the average standing stock of oocytes in newly mature virgin females (WP1).

Two models for calculation of egg escapement per recruit and yield per recruit were used at the STAR panel meeting (see WP9). The models were both based on traditional Thompson and Bell (1934) per recruit calculations. Both per recruit models were run with a range of parameter values to accommodate uncertainty in key parameters. Similar results were obtained using both approaches.

Model 2 had the potential advantage of being more biologically realistic, but the potential disadvantage of greater complexity and the greater cost of requiring estimates for more biological and fishery parameters. Model 1 may be more appropriate given uncertainty about biological and fishery parameters in squid and consequently, this model will be relied upon more heavily in the discussion that follows, However, use of two models allowed the STAR panel to verify calculations and the robustness of conclusions to different model structure.

Based on discussions at the STAR panel meeting, new biological information about fecundity and the possibility of measuring fecundity in port samples, per-recruit models for market squid were modified to calculate standing stock of eggs per female in the catch (SSPF) as a function of fishing mortality (see equations in WP9 and Figure 4 in WP9 for illustration of the concept). There are two novel aspects to this approach: 1) use of fecundity in each age group rather than egg production, and 2) calculations per surviving spawning female rather than per female recruit. In the context of SSPF, "daily fecundity" means the standing stock of eggs and oocytes in the ovary and oviduct at time of capture of spawning female market squid. It is important to distinguish between daily fecundity in the context of SSPF (a measure of the standing stock of eggs and oocytes in female market squid), and daily reproductive output or egg production (a measure of eggs spawned per day) in the context of traditional egg per recruit analysis. SSPF may be more useful than daily egg production for market squid because fecundity can be measured in field samples directly or indirectly using proxies such as mantle condition (WP1).

SSPF is a new concept developed at the STAR meeting, but the idea is analogous to using average size of fish in the catch or population as a measure of fishing mortality (Ricker 1975). For comparison, egg production per recruit was calculated as well. SSPF can be calculated with a few simple modifications to the traditional Thompson and Bell (1934) per-recruit model (WP9 Fig 4). The STAR panel recommends that this approach be explored as the basis of control rules for market squid management.

<u>Status of the Stock Relative to Commonly-Used Reference Points (such as F40%)</u>
F40% has not been established as either a management target or threshold for the market squid fishery. However, it is used as a biological reference point in other fisheries for short-lived squid species and maybe an adequate proxy reference point for a future threshold overfishing definition or management target.

The conclusion, based on sensitivity analysis and other considerations, that current F in the market squid fishery is likely less than F40% (see WP9) is due primarily to high natural mortality rates for spawners and determinate fecundity. Basically, the preliminary sensitivity analysis suggests that natural mortality occurs so quickly that it is difficult for a fishery on the spawning grounds to "keep up" and remove spawners before a substantial fraction of their eggs are spawned. Rapid spawning of a substantial fraction of potential egg production is due, in part, to determinant fecundity in female market squid (eggs are not replaced after spawning). This result is a preliminary and qualitative one, but likely robust given the life history of market squid, current fishing practices, and the results of sensitivity analyses. However, more extensive sensitivity analysis, particularly involving assumptions about daily fecundity, spawning duration and natural mortality rates of mature individuals should be carried out.

It is important to remember that conclusions about the probability that F exceeds F40% in the market squid fishery depend on current fishing practices and, in particular, on the assumptions that almost all fishing occurs on terminal spawning aggregations and that squid are short lived with determinate fecundity. The resilience of the fishery may change significantly if a substantial fishery develops for immature squid.

Finally it should be noted that F40% was used in sensitivity analysis for demonstration purposes only, and is not proposed by the STAR panel as a policy for market squid. The STAR panel did not evaluate the potential suitability of F40%.

6. Conclusions and Recommendations

The analyses carried out during the STAR panel and described more fully in WP9 indicate that average fecundity of market squid from port samples could be compared to reference points from per recruit analysis cast in units of fecundity per spawner (SSPF), if assumptions about determinate spawning are valid, if fecundity in fishery samples can be practically measured, and if the fishery continues to operate on terminal spawning aggregations. There appears to be a direct correspondence between equilibrium fecundity per spawner, equilibrium fishing mortality, and equilibrium egg escapement calculated using per recruit models. The utility of equilibrium reference points seems as valid for market squid as for finfish, where they are commonly used, although this is a topic for future research given the unusual life history of squid. Thus, in principle, it should be possible to find a fecundity based reference point that corresponds to a fishing mortality rate goal or egg escapement goal, and that can be compared to data from samples of catch in the market squid fishery.

The practical problems that still need to be answered include: 1) refinement of biological parameters for per recruit modeling; 2) development of port sampling protocols for measurement of fecundity on a routine basis (e.g. mantle condition samples requiring laboratory analysis will likely be required); 3) evaluation of the precision of reference points and fecundity estimates; and 4) recommendation of options for management target and thresholds in the market squid fishery. Additional consideration and review of the concept of using fecundity samples in stock status determinations for market squid is required because the approach is new and untried. For example, the fecundity-based approach may not provide adequate sensitivity to reliably detect significant changes in stock status in a timely enough manner to implement an appropriate management response. Empirical validation of the performance of this method through several El Niño cycles will be necessary to document the viability and responsiveness of this new management approach for market squid.

Once biological reference points for management targets and thresholds are specified, conventional control rule approaches for actively managed fisheries could be readily employed. It should be possible to use threshold reference points in defining overfishing for market squid and defining overfished stock conditions. It may be possible to achieve target egg escapement levels by regulating the number of days fished, even in the hypothetical circumstance of very high fishing mortality rates on all spawning grounds. This approach or one based on seasonal closure could, theoretically, make more complex harvest control approach unnecessary. However, socio-economic factors would have to be considered as well. For example, the simple weekend closure presently in place has the advantage of allowing for escapement throughout the fishing season, regardless of year to year variations in spawning timing, and in theory could afford unimpeded escapement of approximately 28% of the full spawning potential annually. As a topic of future research, it is important to determine if control rules for market squid should be adjusted to allow more or less harvest in the face of unusual environmental events (e.g. El Niño), ecosystem factors (predator requirements), unusual stock conditions (e.g. evidence or recruitment failure), or changes in the operation of the current fishery (e.g. fishing on immature market squid). As described above, the most important potential change would be the development of substantial fishing pressure on immature squid.

Operationally, there are a number of approaches to changing fishing mortality in the context of achieving management targets in routine management of an actively managed stock with a control rule (e.g. see WP9, Figure 5). The STAR panel cannot recommend specific measures to increase or decrease fishing mortality. However, the list of candidate measures includes changes to trip limits, changes to the number of boats fishing, changes to the days per week when fishing occurs, changes in the fishing season, or changes in areas where fishing occurs, etc. Many of these examples appear practical and likely to be effective.

In principle, fecundity estimates from port samples might be used to indirectly determine the status of the market squid fishery with respect to F-based biological reference points used as management targets and thresholds in the market squid fishery. However, it would be more desirable to use a modern stock assessment model that incorporated all available data (including catch, fecundity, abundance index trends, etc.) to calculate fishing mortality rates directly for comparison to F-based biological reference points. This will become increasingly important as additional data sources (e.g. logbooks) and new research surveys come online. This type of modelling could also be instrumental in assessing the overall performance of the fecundity-based per recruit management approach, discussed above.

7. Research and Data Needs

A number of questions were raised at the STAR panel meeting as to data requirements for management of the market squid fishery and, in particular, if it is necessary to continue collecting age samples and other data from port samples and logbooks. These important practical questions are closely related to choice of reference points and control rules. However, given uncertainties about the nature of the eventual management approach and likely rapid development of new modeling approaches, it was impossible to provide definite advice. The STAR panel therefore recommends that current fishery data collection procedures be maintained in the near term as appropriate, until management approaches and data requirements become more clearly established or until data needs can be prioritized. Issues related to fishery sampling should be discussed with the full range of stakeholders.

As described above, there are a number of biological parameters with imprecise and uncertain estimates. Many of these parameter estimates are important and could be improved with additional fishery independent surveys, enhanced sampling, and analyses. The most important areas requiring additional work include questions about reproductive biology (a key area of uncertainty) that include potential fecundity of newly mature virgin females, duration of spawning, egg output per spawning bout, temporal pattern of spawning bouts, growth of relatively large immature squid, and growth of mature market squid. Important questions about growth might be addressed through SEM studies of statoliths.

The potential use of target egg escapement levels is partly predicated on the assumption that the spawning which takes place prior to capture is not affected by the fishery and contributes to future recruitment. However, since the fishery takes place directly over shallow spawning beds, it is possible that incubating eggs are disturbed by the fishing gear, resulting in unaccounted egg mortality. It is also possible that the process of capturing ripe squid by purse seine might induce eggs to be aborted, which could also affect escapement assumptions. A comparatively small-scale program to obtain at-sea observations could provide information on the degree to which these concerns are a factor in the fishery.

The CalCOFI ichthyoplankton collections contain approximately 20 years of unsorted market squid specimens that span at least two major El Niños. This untapped resource might be useful in addressing questions about population response to El Niño conditions.

Table 1. Fishery independent and fishery dependent data sources for market squid stock assessment and management.

Fishery Independent Data			
Data Type	**Data Source**	**Coverage**	**Notes**
Midwater trawl survey	Kenny Mais CDFG	Central CA - S. Baja up to 8 times annually 1966-1988	In 2000, CDFG conducted a survey with similar methods Examined by Maxwell (Doc#7) as auxilliary index of abundance for surplus production modeling Summarized by population positive tows
Midwater trawl survey	NMFS-Tiburon	Farralons to Monterey Bay 1987 - present	
Midwater trawl survey	Oregon predator and Salmonid surve	Mouth of Columbia River 1997-1999 to present?	
Midwater trawl survey	NMFS-AFSC Whiting survey		
Sea lion scat data	Lowry and Carretta 1999	San Clemente and San Nicholas Islands 1981 - present	Proportion of scat samples containing squid beaks per calander quarter Examined by Maxwell (Doc# 7) as auxilliary index of abundance for surplus production modellin
ROV transects	CDFG	Fishing grounds in S. CA and Monterey Bay 1999 - present	Sampled known spawning grounds to observe egg case attachment and distribution.
ROV transects	NMFS-SWFSC	Fishing grounds in S. CA, 2000?	Sampled at depths beyond fishing grounds
Paralarval survey	CalCOFI Bill Hamner, UCLA	S. California Bight 1999 - present	Bongo net tows
Bottom Trawl survey	NMFS-AFSC Triennial shelf survey	BC, WA, OR, CA to Point Conception 1977 - present	
Bottom Trawl survey	CDFG Halibut survey		
Power plant impingement			Samples from power plant water intakes
Sanitary district otter trawls			Samples from areas around sewer outfalls
Areal spotter survey	CDFG	Fishing grounds in S. CA	

Fishery Dependent Data			
Data Type	**Data Source**	**Coverage**	**Notes**
Commercial fishery port samples	CDFG	Fishing grounds in CA November 1998 - present	Sexual maturity, age-at-length, species composition, observed bycatch, landings, fecundity
Fishery logbook	CDFG, CA commercial fishery	Fishing grounds in CA November 1998 - present	Effort data, fishing location, bycatch information
Fishery landing receipts	CDFG, CA commercial fishery	Fishing grounds in CA 1929-1980 by port; 1981-present by block	tonnage, price, location, and gear type (1981-present); tonnage by port only (1929-1980)
Satellite imagery	NOAA, CDFG	Fishing grounds in S. CA	Effort data (1992-2000); problematic going forward due to light boat shielding requirements Used in surplus production and Leslie-DeLury modelling.

Appendix A. Terms of Reference

The following terms of reference for the Market Squid STAR Panel were approved by the Pacific Fisheries Management Council at its April 2001 meeting:

[1] Review recent findings on the biology and life history of market squid, including the assessment-related aspects of age and growth, maturity, fecundity, spawning behavior, longevity, habitat, and environment.

[2] Review newly developed fisheries-related data, including catch history, effort data, and port sampling protocols as they relate to estimation of key biological, population parameters.

[3] Review all aspects of MSY estimation, as required by the Magnuson-Stevens Fishery Conservation and Management Act for all FMPs, and address the concept of MSY as it relates to a species that is short-lived and whose abundance/availability is largely environmentally determined.

[4] Consider management measures for market squid, including operationally-practical control rules, long-term monitoring programs, and in-season adjustment mechanisms.

[5] Prepare a report for the SSC detailing the findings of the review, practical management recommendations, and the key research & data needs.

Appendix B. Agenda for the Market Squid Stock Assessment Review (STAR)

Southwest Fisheries Science Center
8604 La Jolla Shores Drive
La Jolla, CA 92038
May 14-17, 2001

Monday, May 14th

08:00	Welcome, introductions, and logistics
08:15	Review terms of reference and agenda. Assignment of rapporteurs.
08:30	Presentation of working papers
12:00	Lunch
13:00	Presentation of working papers -- continued
14:30	Discussion of recent biological findings as they relate to stock assessment & management (Section 2 of the STAR Panel Report). Requests for additional information and/or data from working paper authors (as necessary).

Tuesday, May 15th

08:00	Discussion of newly developed fisheries-related data as they relate to stock assessment & management (Section 3 of the STAR Panel Report). Requests for additional information and/or data from working paper authors (as necessary).
10:00	Discussion of MSY estimation for squid and the SFA requirements (Section 4). Requests for additional analysis and/or data from authors (as necessary).
12:00	Lunch
13:00	Discussion of management measures including operationally-practical control rules, long-term monitoring programs, and in-season adjustment mechanisms (Section 5). Requests for additional analysis and/or data from authors (as necessary).
15:00	Review additional data and analyses, as requested from working paper authors.

Wednesday, May 16th

08:00	Review additional data and analyses, as requested from working paper authors.
10:00	Review draft rapporteur's report on biology and life history findings (Section 2).
11:00	Review draft rapporteur's report on fisheries-related data (Section 3).
13:00	Continue review of additional data and analyses, as requested from working paper authors, as necessary.
14:00	Review draft rapporteur's report on MSY estimation (Section 4).
15:00	Review draft of rapporteur's report on control rules & other management measures (Section 5).
16:00	Drafting session for full STAR Panel draft report.

Thursday, May 17th

08:00	Drafting session for full STAR Panel draft report -- continued
10:00	Discussion of research and data needs (Section 6 of the STAR Panel Report).
10:30	Review full STAR Panel draft report.
12:30	Discuss procedures for completion of the final STAR Panel report.
13:00	Adjournment

Appendix C. Working Papers Presented to the Market Squid STAR Panel

WP1 Macewicz, B. J., J. R. Hunter, N. C. H. Lo, and E. L. LaCasella. 2001. Lifetime fecundity of the market squid, *Loligo opalescens. Working Paper 1.*

WP2 Macewicz, B. J., J. R. Hunter, and N. C. H. Lo. 2001. Validation and monitoring of the escapement fecundity of market squid. *Working Paper 2.*

WP3 Butler, J., J. Wagner, and A. Henry. 2001. Age and growth of *Loligo opalescens. Working Paper 3.*

WP4 California Department of Fish and Game (CDFG). 2001. Status of the market squid fishery with recommendations for a conservation and management plan. M. Yaremko (editor). *Working Paper 4.*

WP5 Coastal Pelagic Species Management Team (CPSMT). 2001. Coastal pelagic species fishery management team working review: market squid optimum yield and maximum sustainable yield working plan. *Working Paper 5.*

WP6 Isaac, G., N. Neumeister, and W. F. Gilly. 2001. The effects of temperature on early life stages of the California squid (*Loligo opalescens*). *Working Paper 6.*

WP7 Maxwell, M. R. 2001. Stock assessment models for the market squid, *Loligo opalescens. Working Paper 7.*

WP8 Maxwell, M. R., and P. R. Crone. 2001. Management recommendations for the market squid fishery. *Working Paper 8.*

WP9* Maxwell, M. R. 2001. Reproductive (egg) escapement model and management recommendations for the market squid fishery. *Review Summary Paper.*

* WP9 is a revision of WP8 requested by the STAR Panel to document the analyses carried out during the STAR Panel meeting. The analyses and results contained therein reflect the STAR Panel consensus at the end of its meeting with respect to the most appropriate modelling and management control rules

Appendix D. Participants

Last Name	First Name	Affiliation	
Amoroso	Orlando	San Pedro Purse Seine Vessel Owners	May 17 only
Barnes	Tom	CDFG, La Jolla	
Butler	John	SWFSC, NMFS	
Conser	Ray	SWFSC, NMFS	
Crone	Paul	SWFSC, NMFS	
Garrison	Karen	NRDC, San Francisco	May 15 only
Henry	Annette	CDFG, La Jolla	
Herrick	Sam	SWFSC, NMFS	
Hill	Kevin	CDFG, La Jolla	
Hunter	John	SWFSC, NMFS	
Jacobson	Larry	NEFSC, NMFS – Woods Hole, MA	
Jagielo	Tom	WDFW, Olympia, WA	
Klingbeil	Rick	CDFG, Los Alamitos	May 15 & 17
Lo	Nancy	SWFSC, NMFS	
Lutz	Steven	USC	
Maxwell	Mike	UCSD, Scripps Institution of Oceanography	
Munro	Heather	Munro Consulting	
Oliver	Chuck	SWFSC, NMFS	May 14-15
Smith	Paul	SWFSC, NMFS	
Vetter	Russ	SWFSC, NMFS	May 14 only
Wagner	John	UCSD, Scripps Institution of Oceanography	May 14 only
Wertz	Steve	CDFG, Los Alamitos	May 14 only
Yaremko	Marci	CDFG, La Jolla	

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL REPORT ON AMENDMENT 10 TO THE COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN

The Coastal Pelagic Species Advisory Subpanel (CPSAS) met Wednesday to discuss portions of Amendment 10 to the Coastal Pelagic Species (CPS) Fishery Management Plan (FMP). There were two issues to consider: 1) options for a market squid maximum sustainable yield (MSY) proxy, and 2) options for limited entry permit transfer and issuance. The CPSAS support the following:

1. Market Squid MSY Proxy

The CPSAS voted unanimously that the suite of four options presented by the CPS Management Team (CPSMT) to determine an MSY proxy for market squid is sufficient to proceed for public review.

The majority of the CPSAS (7 of 8) voted to accept and support the Egg Escapement Approach presented by the CPSMT in its entirety as the CPSAS's preferred option. A minority of the CPSAS supports all aspects of the Egg Escapement Approach, but is concerned that the 30% threshold identified by the CPSMT may not be appropriate and should be higher.

2. Limited Entry Permit Transfer and Issuance

The CPSAS heard a presentation from the CPSMT on the options being considered for limited entry permit transfers. The CPSMT agreed to consider two additional options for permit transfer presented by the CPSAS. The CPSAS voted unanimously to support the suite of options moving forward for public review.

The CPSAS also heard options for issuing new permits in the limited entry fishery if the situation becomes necessary in the future. The CPSAS voted unanimously to support the suite of all three options moving forward for public review. The CPSAS voted to support Alternative 2 as their preferred option.

PFMC
11/01/01

Market Squid MSY Alternatives in Draft Amendment 10

- Alternative 1 (status quo - no action). Set no MSY.

- Alternative 2 (set MSY proxy based on evaluation of historical landings, see *draft Amendment 9*, section 5.2.1).

- Alternative 3 (set MSY proxy based on spawning area expansion method, see *draft Amendment 9*, section 5.2.2).

- Alternative 4 - CPSMT Preferred. (set F_{MSY} proxy based on Egg Escapement method, see *Recommendations for Market Squid Management and Research, CPSMT Report, Exhibit H.2.b)*.

CPS LIMITED ENTRY ISSUES IN DRAFT AMENDMENT 10

- **Issue 1* - Establishes capacity goal for CPS limited entry fleet.**
- **Issue 2* - Establishes conditions for transfer of existing permits.**
- **Subissue 2a - Establishes a process for adjusting permit transferability to maintain the capacity goal.**
- **Subissue 2b - Establishes procedures for issuing new permits.**

*** Reviewed and adopted by Council in April 2001**

Issue 1 – Capacity Goal for the CPS Limited Entry Fleet

- Alternative 1 – Adopted. Maintain a larger, diverse CPS finfish fleet, with normal harvesting capacity equal to the long-term potential yield and with physical capacity to harvest peak period amounts. (current 65 vessels with total GRT = 5,642 mt)

- Alternative 2. Work the fleet down to a smaller number of 'CPS specialists' with normal harvesting capacity equal to average total finfish landings over the 1981-2000 period. (28-33 vessels)

- Alternative 3. Base the fleet size on our expectations of long-term potential yield of CPS finfish and the number of vessels physically capable of harvesting that yield without an excess capacity reserve. (12 vessels)

- Alternative 4 (status quo - no action). Maintain a fixed fleet of 65 vessels with no capacity goal or limits on fleet GRT.

Issue 2 – Conditions for Transfer of Existing Permits

- Alternative 1 (status quo - no action). No transferability of permits except 1) if the permitted vessel totally lost, stolen or scrapped, or 2) the permit is placed on a replacement vessel of the same or less harvesting capacity.

- Alternative 2. Allow CPS finfish limited entry permits to be transferred without constraints.

- Alternative 3 – Adopted. Allow permits to be transferred with restrictions on the capacity of the vessel to which it would be transferred to: 1) full transferability of permits to vessels of comparable capacity (vessel GRT +10% allowance), and 2) allow permits to be combined up in cases where the vessel to be transferred to is of greater capacity. Each permit would retain the original GRT endorsement.

Subissue 2a – Process for Adjusting Permit Transferability to Maintain the Capacity Goal

- Alternative 1 (status quo). No provisions for adjusting transferability. A CPS limited entry permit would be transferable per conditions under *Issue 2, Adopted Alternative 3*.

- Alternative 2. Restore fleet capacity to target fleet GRT (5,642 mt) by restricting conditions for permit transfer when the upper threshold of fleet GRT(fleet GRT plus 5%, or 5,924 mt) is reached. Once the trigger point is met or exceeded, permits could only be transferred by combining-up on a 2 for 1 basis. Transfer restrictions could be repealed once fleet GRT is reduced back down to the 5,642 mt target.

- Alternative 3 *(CPSMT Preferred).* Same trigger point as Alt. 2, but once it is met or exceeded, permits could only be transferred to vessels with equal or smaller GRT and the 10% vessel allowance would be removed. The 10% allowance could be reconsidered once total fleet GRT is reduced to 5,642 mt target.

Subissue 2b – Procedures for Issuing New Limited Entry Permits

- Alternative 1. No qualifying criteria in the FMP. Permits would be issued on a first come first served basis (e.g. by lottery or auction).

- Alternative 2 *(CPSMT Preferred).* Use qualifying criteria originally established in Amendment 8 for issuance of new CPS finfish limited entry permits. This would entail continuing down the list of 640 vessels having landings during the 1993-97 window period in order of decreasing window period landings.

- Alternative 3. Establish new qualifying criteria (i.e. new window period, minimum landings). This would probably be desirable if there were reasons to extend the window period further back in time to qualify vessels whose history in the fishery pre-dated the original window period. This option would probably require an amendment to the FMP.

COASTAL PELAGIC SPECIES MANAGEMENT TEAM RECOMMENDATION
SQUID RESEARCH AND MANAGEMENT OFF CALIFORNIA

Statement to the Pacific Fishery Management Council

November 1, 2001
Clarion Hotel - San Francisco Airport
Millbrae, CA

The Coastal Pelagic Species Management Team (Management Team) convened from August 14-15, 2001 to address management and research issues associated with the market squid (*Loligo opalescens*) resource off the California coast. The overall goal of this Management Team meeting was to review information generated from the recently conducted Stock Assessment Review (STAR) session for squid held in May 2001. Specifically, the Management Team focused on the following objectives during the two-day meeting: (1) develop consensus regarding important points concluded in the STAR Panel's Report; (2) determine if the suite of model configurations based on the *Egg Escapement* (EE) method could be further reduced into a tractable subset; (3) further evaluate important parameters of the Egg Escapement approach in efforts to establish maximum sustainable yield (MSY)-based management schemes; and (4) develop sampling, laboratory, and analysis schedules that support the Egg Escapement approach in particular, and also discuss the merits of gathering auxiliary data that would improve understanding of squid population dynamics. The following synopsis presents the Management Team's recommendations (for further details see *Recommendations for Market Squid Management and Research - Exhibit H.2.b, CPSMT Report, November 2001*).

First and foremost, the Management Team generally supports the findings of the STAR Panel and in particular, its conclusion that the Egg Escapement method can provide an effective framework for monitoring/managing the squid population in the future. That is, the current port sampling program implemented by the California Department of Fish and Game, along with newly developed laboratory and analysis procedures conducted by the National Marine Fisheries Service (Southwest Fisheries Science Center), will provide an objective method for establishing Maximum Sustainable Yield (MSY)-based management goals for the squid resource. In practical terms, the Egg Escapement approach can be used to evaluate the effects of fishing mortality on the spawning potential of the stock and in particular, to examine the relation between the stock's reproductive output and candidate proxies for the fishing mortality that results in Maximum Sustainable Yields. However, it is important to note that this approach does not provide estimates of historical or current total biomass and thus, a definitive yield (i.e., a quota or Acceptable Biological Catch) cannot be determined at this time. Ultimately, the Egg Escapement approach can be used to assess whether the fleet is fishing above or below an a priori-determined sustainable level of exploitation and in this context, can be used as an effective management tool.

The Management Team recommends that the squid resource be formally reviewed again in 2004. Thus, a research/management sequence should be started for completion by early 2004. Important areas of work include: (1) rigorous monitoring of the landed catch for the occurrence of immature squid; (2) collection of fishermen logbook data that will allow changes in fishing techniques and success to be accurately measured; and (3) initiating studies that shed light on areas of squid biology still unresolved.

Finally, the following discussion addresses pertinent decisions made by the Management Team to develop a workable monitoring/management plan for the squid fishery based on the Egg Escapement method, i.e., the STAR Panel provided general recommendations regarding analytical methods and left determination of specific model configurations and other management-related parameters to the Management Team. This discussion is partitioned into four general areas (see Additional Notes in *Exhibit H.2.b*): (1) selection of a 'preferred' model scenario; (2) selection of a 'threshold' level of egg escapement that can be considered a warning flag when tracking the status of the population; (3) fishery operations in (and after) ENSO events; and (4) necessary management-related constraints.

Preferred Model Scenario

The Management Team largely relied on researchers familiar with squid biology to identify a preferred model scenario from the suite proposed in the overall analysis. The Management Team recommends that *model version 1* (based on a scenario with natural mortality rate = 0.15 and egg laying rate = 0.45) be used to assess the status of the squid population.

Threshold Level of Egg Escapement

A ‘threshold’ level of egg escapement can be practically interpreted as a level of reproductive escapement that is believed to be at or near a minimum level that is considered necessary to allow the population to maintain it’s level of abundance into the future. The Management Team recommends that a threshold value of 0.3 (30%) be used to assess the status of the squid population.

ENSO Events

The Management Team deferred consideration of the effects of ENSO conditions on the squid population and ultimately, the fishery itself, until studies that focus on the influence of such oceanographic phenomena on squid abundance and distribution generate useful management advice.

Monitoring and Management Issues

The Management Team concurs with the STAR Panel that the present squid fishery needs to be closely monitored using the state-coordinated port sampling programs. Fishery monitoring should be especially attentive to the possible future development of a juvenile fishery. Further, it is recommended that regulatory-related issues applicable to the current squid fishery off California remain under the jurisdiction of the California Department of Fish and Game through consultation with the Management Team itself – keeping in mind the federal-based policies inherently in place for all U.S.-based fisheries. Finally, the newly adopted Egg Escapement method should be considered a joint effort between the California Department of Fish and Game and the National Marine Fisheries Service, with future involvement by the Oregon Department of Fish and Wildlife and the Washington Department of Fish and Wildlife if the fishery or monitoring programs observe northern expansion of the population.

PFMC
11/01/01

COASTAL PELAGIC SPECIES MANAGEMENT TEAM HANDOUT ON AMENDMENT 10 TO THE COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN - DRAFT SUMMARY OF ALTERNATIVES -

Issue 1 – Capacity Goal for the CPS Limited Entry Fleet

Alternative 1 - Adopted. Maintain a larger, diverse CPS finfish fleet, which also relies on other fishing opportunities such as squid and tuna, with normal harvesting capacity equal to the long-term expected aggregate fin.fish target harvest level, approximately 110,000 mt, and with physical capacity available to harvest peak period amounts of finfish, 275,000 mt. The current fleet of 65 vessels would satisfy this goal. Estimated normal harvesting capacity for the current fleet ranged from 60,000 mt to 111,000 mt per year; physical harvesting capacity ranged from 361,000 to 539,000 mt per year. Total calculated Gross Registered Tonnage (GRT) for the current fleet is 5,642 mt.

Alternative 2. Work the fleet down to a smaller number of vessels with certain characteristics (e.g., smaller number of larger, 'efficient' vessels; or smaller number composed of CPS finfish 'specialists'), with normal harvesting capacity equal to average total finfish landings over the 1981-2000 period, approximately 57,676 mt.

Alternative 3. Base the fleet size on our expectations of long-term expected yields from the combined CPS finfish species and the number of vessels physically capable of harvesting that yield, 110,000 mt annually, without an excess capacity reserve.

Alternative 4. (status quo - no action). Maintain a fixed fleet of 65 vessels, with no capacity goal or limits on fleet GRT.

Issue 2 – Conditions for Transfer of Existing Permits

Alternative 1. (status quo - no action). No transferability of permits except 1) if the permitted vessel totally lost, stolen or scrapped, such that it cannot be used in a federally regulated commercial fishery, provided application for the permit originates from the vessel owner who must place it on a replacement vessel of the same or less harvesting capacity within one year of disability of the permitted vessel, or 2) the permit is placed on a replacement vessel of the same or less harvesting capacity provided the previously permitted vessel is permanently retired from all federally managed commercial fisheries for which a permit is required.

Alternative 2. Allow CPS finfish limited entry permits to be transferred without constraints.

Alternative 3 - Adopted. Allow CPS finfish limited entry permits to be transferred with restrictions on the harvesting capacity of the vessel to which it would be transferred to: 1) full transferability of permits to vessels of comparable capacity (vessel GRT +10% allowance), and 2) allow permits to be combined up to a greater level of capacity in cases where the vessel to be transferred to is of greater harvesting capacity than the one from which the permit will be transferred.

Subissue 2a – Adjusting Permit Transferability to Maintain the Capacity Goal

Alternative 1. (status quo per ***Issue 2, Adopted Alternative 3***). A CPS limited entry permit would be transferable on a 1 for 1 basis to a vessel with a harvesting capacity not in excess of 110% of that of the transferring vessel; if in excess of 110%, additional permits would have to be combined with the original permit to match the harvesting capacity of the vessel to which the permits will be transferred. There would be no provisions for adjusting transferability.

Alternative 2. Restore fleet capacity to target fleet GRT (5,642 mt) by restricting conditions for permit transfer when the upper threshold of fleet GRT(fleet GRT plus 5%, or 5,924 mt) is reached. Under Alternative 2, once the trigger point is met or exceeded, permits could only be transferred by combining-up on a 2 for 1 basis. Transfer restrictions could be repealed once fleet GRT is reduced back down to the 5,642 mt target.

Alternative 3. *(CPSMT Preferred)* Restore fleet capacity to target fleet GRT (5,642 mt) by restricting conditions for permit transfer when the upper threshold of fleet GRT(fleet GRT plus 5%, or 5,924 mt) is reached. Under Alternative 3, once the trigger point is met or exceeded, permits could only be transferred to vessels with equal or smaller GRT and the 10% vessel allowance would be removed. The 10% allowance could be reconsidered once total fleet GRT is reduced to 5,642 mt target.

Subissue 2b – Procedures for Issuing New Limited Entry Permits

Alternative 1. No qualifying criteria in the FMP. Under this option permits could be issued on a first come first served basis (e.g. through lottery or auction). Each vessel applying for a permit would have to have its harvest capacity evaluated so that in aggregate the new CPS finfish harvesting capacity target was not exceeded. This option is probably not doable unless none of the vessels applying have a history in the fishery.

Alternative 2. *(CPSMT Preferred)* Use qualifying criteria originally established in Amendment 8 for issuance of new CPS finfish limited entry permits. This would probably entail continuing down the list of vessels having landings during the 1993-97 window period in order of decreasing window period landings. In this case, the next permit awarded would go to the 71st of the 640 vessels with window period finfish landings if this vessel were to apply. Each vessel on the list would have to have its harvest capacity evaluated so that in aggregate the new capacity target was not exceeded.

Alternative 3. Establish new qualifying criteria. This would involve establishing a new window period, minimum landings, etc. This would probably be desirable if there were reasons to extend the window period further back in time to qualify vessels whose history in the fishery pre-dated the original window period. Each vessel applying for a permit would have to have its harvest capacity evaluated so that in aggregate the new CPS finfish harvesting capacity target was not exceeded. This option might require an amendment to the FMP.

Issue 3 – Market Squid MSY

Alternative 1 (status quo - no action). Set no MSY.

Alternative 2. Set MSY proxy based on evaluation of historical landings, see *draft Amendment 9*, section 5.2.1). The CPSMT reviewed existing data (including fishery and biological) for the California market squid fishery to recommend an MSY value. There are not adequate data to make a mathematical MSY determination; therefore, guidance was taken from the NMFS publication: *Technical Guidelines on the Use of Precautionary Approaches to Implementing National Standard 1 of the Magnuson-Stevens Fishery Conservation and Management Act (Restrepo et. al., 1998).* Those guidelines suggest that in data poor situations such as the California market squid fishery, a proxy may be used for MSY, and that it is reasonable to use recent average catches from time periods when there is no qualitative or quantitative evidence of declining abundance. See *draft Amendment 9* for candidate average-catch calculations. This Alternative was not supported by the Science and Statistical Committee (SSC).

Alternative 3. Set MSY proxy based on spawning area expansion method, see *draft Amendment 9*, section 5.2.2). Commercial catch information from CDFG is available by location for the time period 1981 through 1999. Location information is recorded by fishing block, which encompasses a 10 by 10 nautical mile area. Over that time period, 262 unique blocks have been recorded on landing receipts. This number may be used to represent the total available fishing area in the range of the California fishery. In keeping with expansion of the fishery over this time period, the number of blocks fished has generally increased since 1981. By scaling the catch in any given season to account for what might have been caught in that season were all the blocks utilized, a proxy MSY for that year may be determined. See *draft Amendment 9* for candidate average-catch calculations. This Alternative was not supported by the Science and Statistical Committee (SSC).

Alternative 4 *(CPSMT Preferred).* Set F_{MSY} proxy based on egg escapement method, see *Recommendations for Market Squid Management and Research, CPSMT Report, Exhibit H.2.b, November 2001).* The current port sampling program implemented by the California Department of Fish and Game (CDFG), along with newly developed laboratory and analysis procedures conducted by the National Marine Fisheries Service (Southwest Fisheries Science Center, SWFSC), can provide an objective method for establishing Maximum Sustainable Yield (MSY)-based management goals for the squid resource, e.g., for developing biological reference points. In practical terms, the Egg Escapement (EE) approach can be used to evaluate the effects of fishing mortality (F) on the spawning potential of the stock and in particular, to examine the relation between the stock's reproductive output and candidate proxies for the fishing mortality that results in MSY (F_{MSY}). However, it is important to note that this approach does not provide estimates of historical or current total biomass and thus, a definitive yield (i.e., quota or Acceptable Biological Catch) cannot be determined at this time. Ultimately, the EE approach can be used to assess whether the fleet is fishing above or below an a priori-determined sustainable level of exploitation and in this context, can be used as an effective management tool. Further technical details needed to implement the EE method are presented under four broad headings in the *CPSMT Report* cited above: (1) selection of a 'preferred' model scenario; (2) selection of a 'threshold' level of egg escapement (EE value) that can be considered a warning flag when tracking the status of the population; (3) fishery operations in (and after) El Niño/Southern Oscillation (ENSO) events; and finally, (4) necessary management-related constraints. This Alternative was supported by the Science and Statistical Committee (SSC) and is the preferred Alternative of the CPSMT. Reasons for adopting the EE method for monitoring/managing the squid population, rather than other analytical approaches (e.g., surplus production and depletion models, as well as Alternatives 1-3 above), are presented in *Report of the Stock Assessment Review (STAR) Panel for Market Squid, Final Workshop Report, November 2001.*

Report of the
Stock Assessment Review (STAR) Panel
for Market Squid

May 14-17, 2001

Southwest Fisheries Science Center
La Jolla, California

Market Squid Stock Assessment Review (STAR) BACKGROUND

- Department of Commerce rejected portions of Amendment 8 to the CPS FMP (1999)

- Draft Amendment 8 did not include an estimate of maximum sustainable yield (MSY) for market squid

- SSC reviewed newly derived estimates of MSY for market squid (Sept 2000)

- The SSC did not recommend an MSY value due to:
  - (1) great uncertainties surrounding the MSY estimates
  - (2) general, ongoing concerns regarding the appropriateness of defining MSY-based reference points for this species

- Significant new biological findings & fishery data are now available (CDF&G and SWFSC research efforts)

- SSC recommended (and the Council concurred) that:
  - (1) SSC, NMFS, AND CDF&G should organize a stock assessment review (STAR) panel
  - (2) Squid STAR Panel should meet during 2001

Market Squid Stock Assessment Review (STAR) Terms of Reference (Appendix A)

[1] Review recent findings on the biology and life history of market squid, including the assessment-related aspects of age and growth, maturity, fecundity, spawning behavior, longevity, habitat, and environment.

[2] Review newly developed fisheries-related data, including catch history, effort data, and port sampling protocols as they relate to estimation of key biological, population parameters.

[3] Review all aspects of MSY estimation, as required by the Magnuson-Stevens Fishery Conservation and Management Act for all FMPs, and address the concept of MSY as it relates to a species that is short-lived and whose abundance/availability is largely environmentally determined.

[4] Consider management measures for market squid, including operationally-practical control rules, long-term monitoring programs, and in-season adjustment mechanisms.

[5] Prepare a report for the SSC detailing the findings of the review, practical management recommendations, and the key research & data needs.

Market Squid Stock Assessment Review (STAR)

Panel Members

Tom Barnes	CDFG & Council's GMT
Ray Conser (co-chair)	NMFS & Council's SSC
Larry Jacobson	NMFS-Woods Hole, outside reviewer
Tom Jagielo (co-chair)	WDFW & Council's SSC
Heather Munro	Munro Consulting & Council's CPSAS
Paul Smith	NMFS & Council's CPSMT

Market Squid Stock Assessment Review Working Papers (Appendix C)

WP1	Macewicz, B. J., J. R. Hunter, N. C. H. Lo, and E. L. LaCasella. 2001. Lifetime fecundity of the market squid, *Loligo opalescens*.
WP2	Macewicz, B. J., J. R. Hunter, and N. C. H. Lo. 2001. Validation and monitoring of the escapement fecundity of market squid.
WP3	Butler, J., J. Wagner, and A. Henry. 2001. Age and growth of *Loligo opalescens*.
WP4	California Department of Fish and Game (CDFG). 2001. Status of the market squid fishery with recommendations for a conservation and management plan. M. Yaremko (editor).
WP5	Coastal Pelagic Species Management Team (CPSMT). 2001. Coastal pelagic species fishery management team working review: market squid optimum yield and maximum sustainable yield working plan.

Market Squid Stock Assessment Review (STAR) Working Papers - continued (Appendix C)

WP7 Maxwell, M. R. 2001. Stock assessment models for the market squid, *Loligo opalescens*.

WP8 Maxwell, M. R., and P. R. Crone. 2001. Management recommendations for the market squid fishery.

WP9* Maxwell, M. R. 2001. Reproductive (egg) escapement model and management recommendations for the market squid fishery.

* WP9 is a revision of WP8 requested by the STAR Panel to document the analyses carried out during the STAR Panel meeting. The analyses and results contained therein reflect the STAR Panel consensus at the end of its meeting with respect to the most appropriate modelling and management control rules

Market Squid Stock Assessment Review (STAR) Participants (Appendix D)

Last Name	First Name	Affiliation
Amoroso	Orlando	San Pedro Purse Seine Owners
Barnes	Tom	CDFG, La Jolla
Butler	John	SWFSC, NMFS
Conser	Ray	SWFSC, NMFS
Crone	Paul	SWFSC, NMFS
Garrison	Karen	NRDC, San Francisco
Henry	Annette	CDFG, La Jolla
Herrick	Sam	SWFSC, NMFS
Hill	Kevin	CDFG, La Jolla
Hunter	John	SWFSC, NMFS
Jacobson	Larry	NEFSC, NMFS – Woods Hole, MA
Jagielo	Tom	WDFW, Olympia, WA
Klingbeil	Rick	CDFG, Los Alamitos
Lo	Nancy	SWFSC, NMFS
Lutz	Steven	USC
Maxwell	Mike	UCSD, SIO
Munro	Heather	Munro Consulting
Oliver	Chuck	SWFSC, NMFS
Smith	Paul	SWFSC, NMFS
Vetter	Russ	SWFSC, NMFS
Wagner	John	UCSD, SIO
Wertz	Steve	CDFG, Los Alamitos
Yaremko	Marci	CDFG, La Jolla

Market Squid Stock Assessment Review (STAR)
Maximum Sustainable Yield

C Focused on MSY as a basis for practical management reference points

C Reviewed earlier work on MSY estimation for market squid (WP 5)

C Reviewed new work on MSY estimation (WP 7 & WP 8)

C Explored other possible means for estimating MSY with available data

C **STAR Panel Conclusions on MSY:**

(1) Currently available MSY-based reference points do not provide a practical basis for year-to-year management of market squid

(2) It will be more fruitful to explore MSY proxies as a basis for market squid management than to continue efforts on MSY-based reference points

(3) Egg escapement reference points may provide viable MSY proxies for market squid

Market Squid Stock Assessment Review (STAR)
Practical Control Rules for Management

- Market squid life history strategy and the current operational practices of the fishery upon them present unique management challenges and opportunities

- Traditional management approaches, such as those used for the Council's groundfish and salmon FMP's, may not be appropriate for market squid management

- An egg escapement approach to market squid management, which captures these unique aspects, was presented to the STAR Panel and refined during the meeting.

- **STAR Panel Conclusions on Egg Escapement Approach:**

  (1) Although further refinement and sensitivity analysis are desirable, the egg escapement approach is technically sound

  (2) Current port sampling protocols and laboratory procedures appear to provide the key data elements needed to implement the approach

  (3) The STAR Panel recommends that this approach be explored as the basis of control rules for market squid management

Market Squid Stock Assessment Review (STAR)
Status of the Market Squid Stock

C The fishing mortality rate (F) on market squid in recent years is likely less than the F associated with commonly used reference points, e.g. F40%

C This conclusion follows from the current fishery & life history characteristics. In particular that:
(1) fishing occurs almost entirely on terminal spawning aggregations
(2) market squid are short-lived with determinate fecundity and extremely high natural mortality after reaching maturity

C The resilience of the market squid stock may change significantly if a substantial fishery develops for immature squid

C Additional research and data collection are needed to confirm these preliminary conclusions (see Sections 6 & 7 of the STAR Panel Report)

Market Squid Stock Assessment Review (STAR)

Acknowledgments

C CDF&G (and the California legislature) for financial support of much of the new biological research on market squid

C The authors of the working papers presented to the STAR Panel – both for their work and preparations prior to the Panel meeting, and for the additional efforts extended during the meeting to support the STAR Panel requests

C The superb support provided by the CDF&G and NMFS staff in La Jolla.

C The excellent meeting and computing facilities provided by the NMFS Southwest Fisheries Science Center

Stock Assessment of Pacific Sardine with Management Recommendations for 2002

Ray Conser[1] Kevin Hill[2] Paul Crone[1]
Nancy Lo[1] Darrin Bergen[2]

NMFS Southwest Fisheries Science Center[1]
California Department of Fish and Game[2]
8604 La Jolla Shores Drive
La Jolla, CA 92038 USA

Dedication

This paper is dedicated to the late
Dr. Garth Murphy
who passed away during 2001

- Dr. Murphy was a world-renowned population biologist and a genuine pioneer in the study of Pacific sardine. Without his diligent, conscientious, and truly innovative efforts, this work would not have been possible.

Sardine Stock Assessment Overview

Available Data

Modelling

Stock Structure

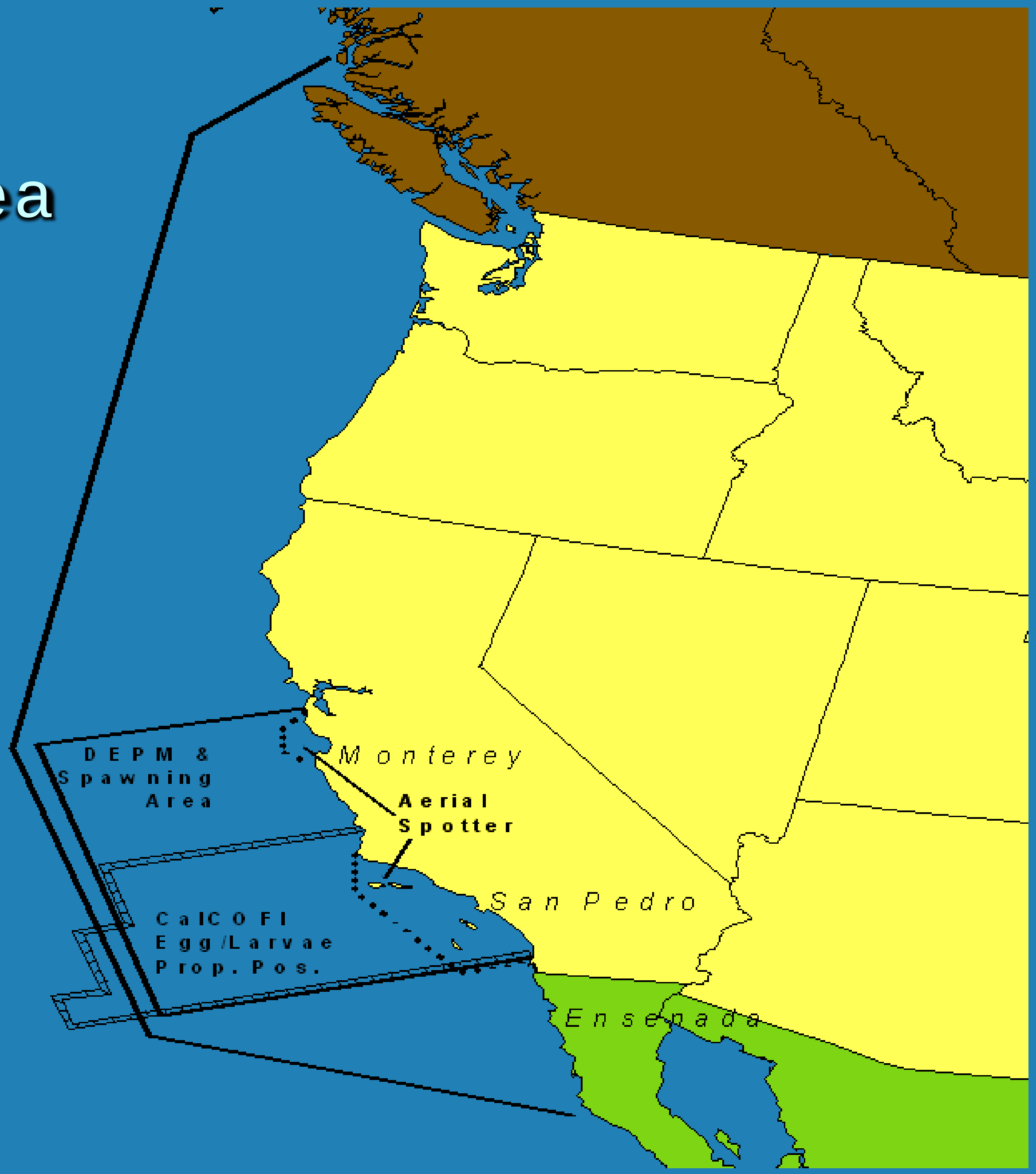
Data Sources for Stock Assessment

- Fishery-dependent data
  - Landings
  - Catch-at-age
  - Biological information
- Fishery-independent data
  - Research survey indices of abundance
  - Spotter pilot index abundance
  - Environmental data (SST)

Stock Assessment Modelling

- Age-structured model (CANSAR—TAM)
  - Flexible catch-at-age analysis
  - Incorporates fishery-independent data
  - Integrates a simple migration model
  - Parameter estimates via NL least squares
  - Uncertainty estimated via bootstrapping

Stock Area



DEPM &
Spawning
Area
Monterey
Aerial
Spotter
CalCOFI
Egg/Larvae
Prop. Pos.
San Pedro
Ensenada

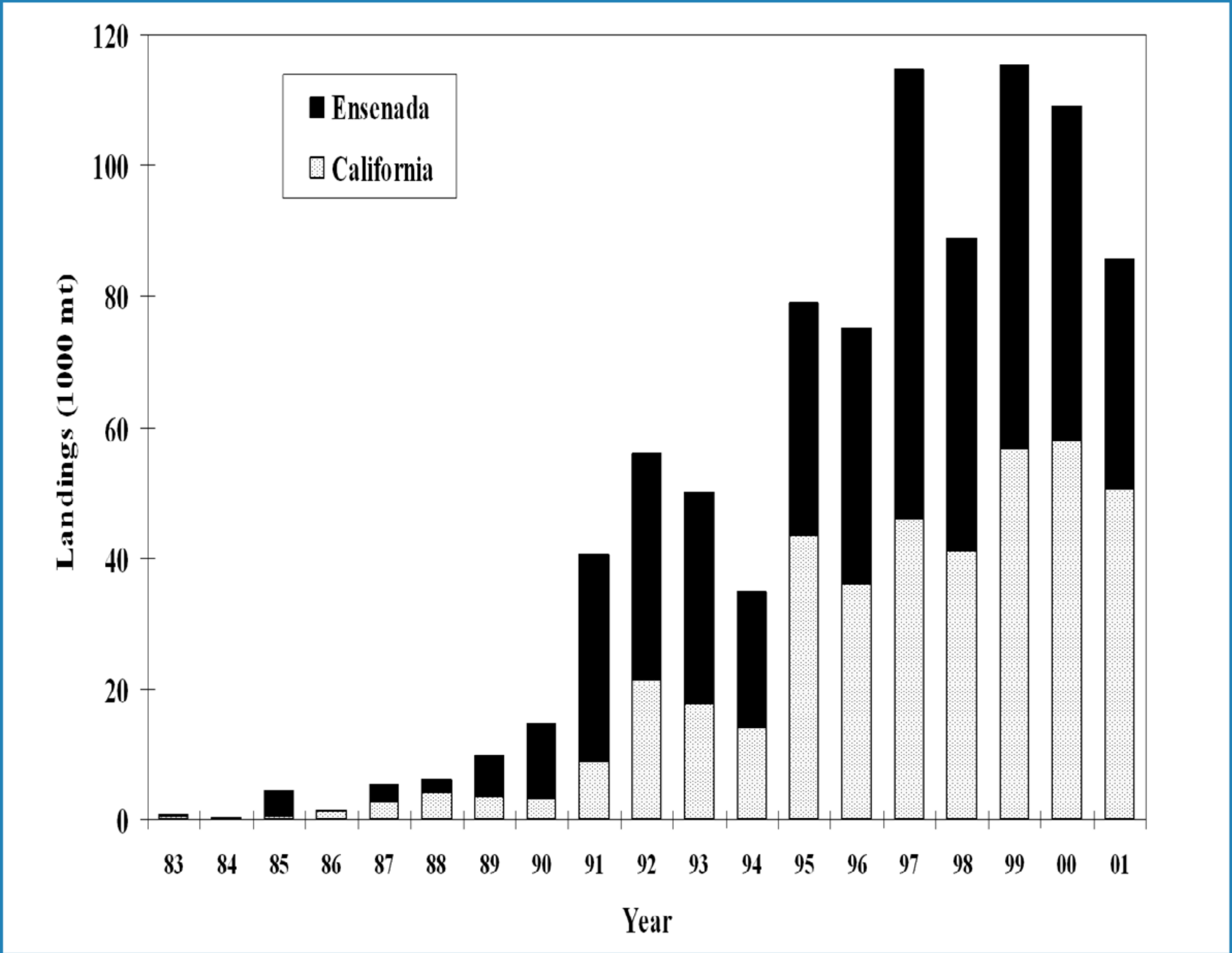
“Inside Area”


DEPM &
Spawning
Area
Monterey
Aerial
Spotter
San Pedro
CalCOFI
Egg/Larvae
Prop. Pos.
Ensenada

Data Sources from "Inside Area"

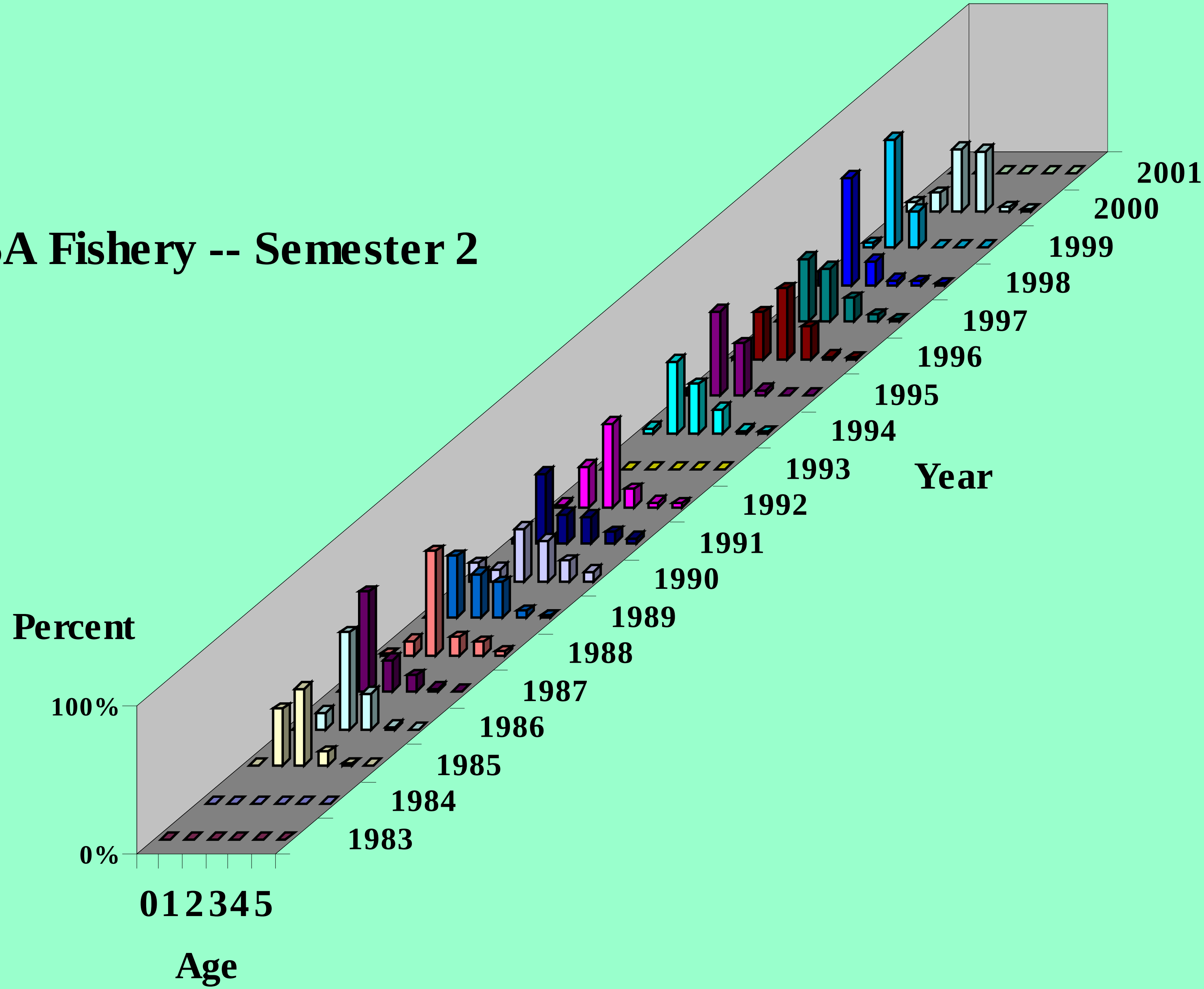
- Fisheries Data
  - USA (California) + Mexico (Ensenada)
- Indices of Abundance (California)
  - Research surveys (egg & larval)
  - Spotter pilot index
- Environmental Data (California)
  - Sea surface temperature at Scripps Pier (La Jolla)

Sardine Landings, 1983-2001



Sardine Catch-at-age, 1983-2000

USA Fishery -- Semester 2



Indices of Sardine Abundance

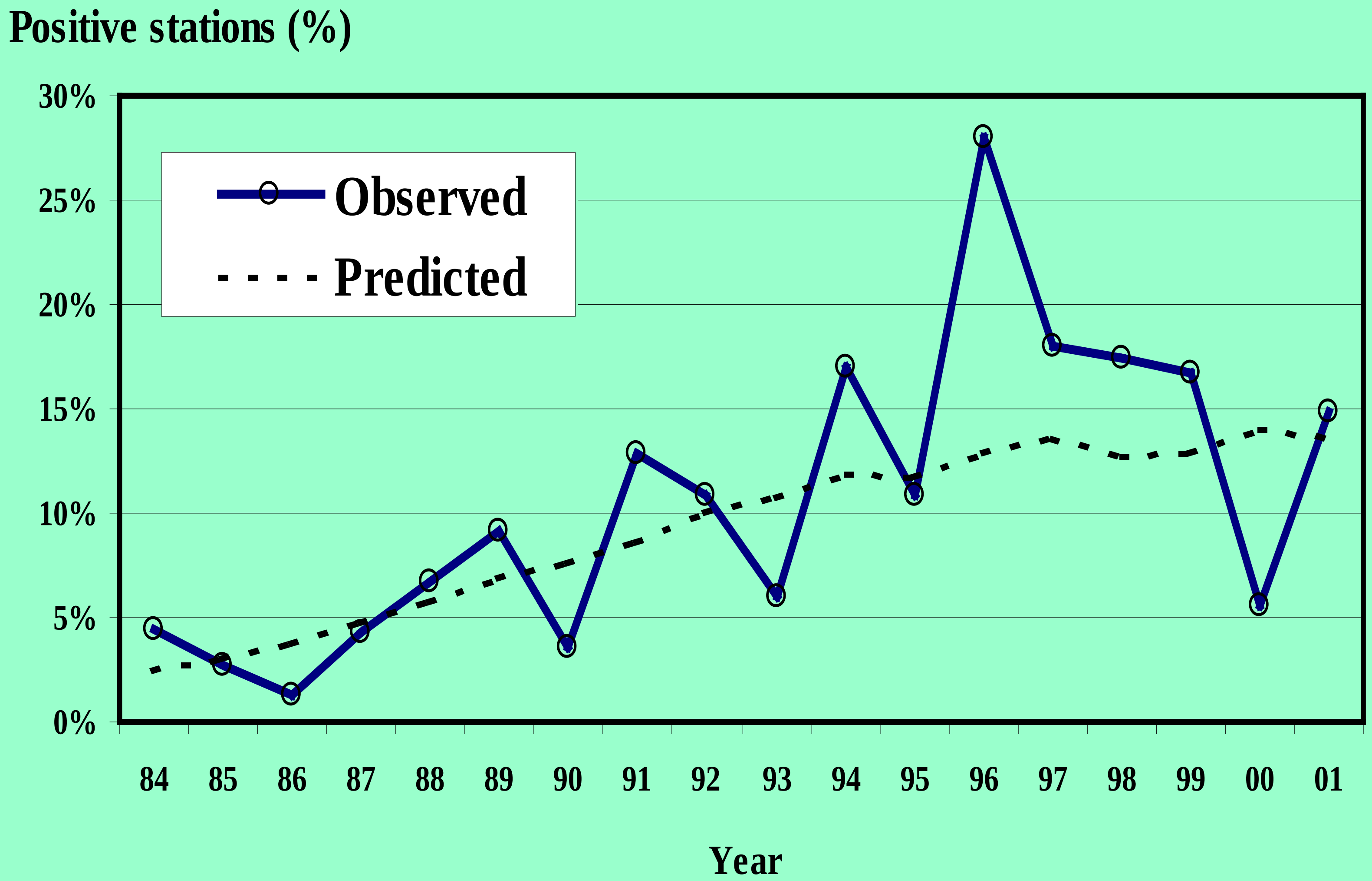
- Indices of Spawning Stock Biomass
  - CalCOFI egg index (proportion positive)
  - Spawning area index (nm^2)
  - Daily egg production method index (mt)
- Index of Pre-Adults
  - Aerial spotter plane pilot index (mt)

3-Year Moving Average SST (°C)

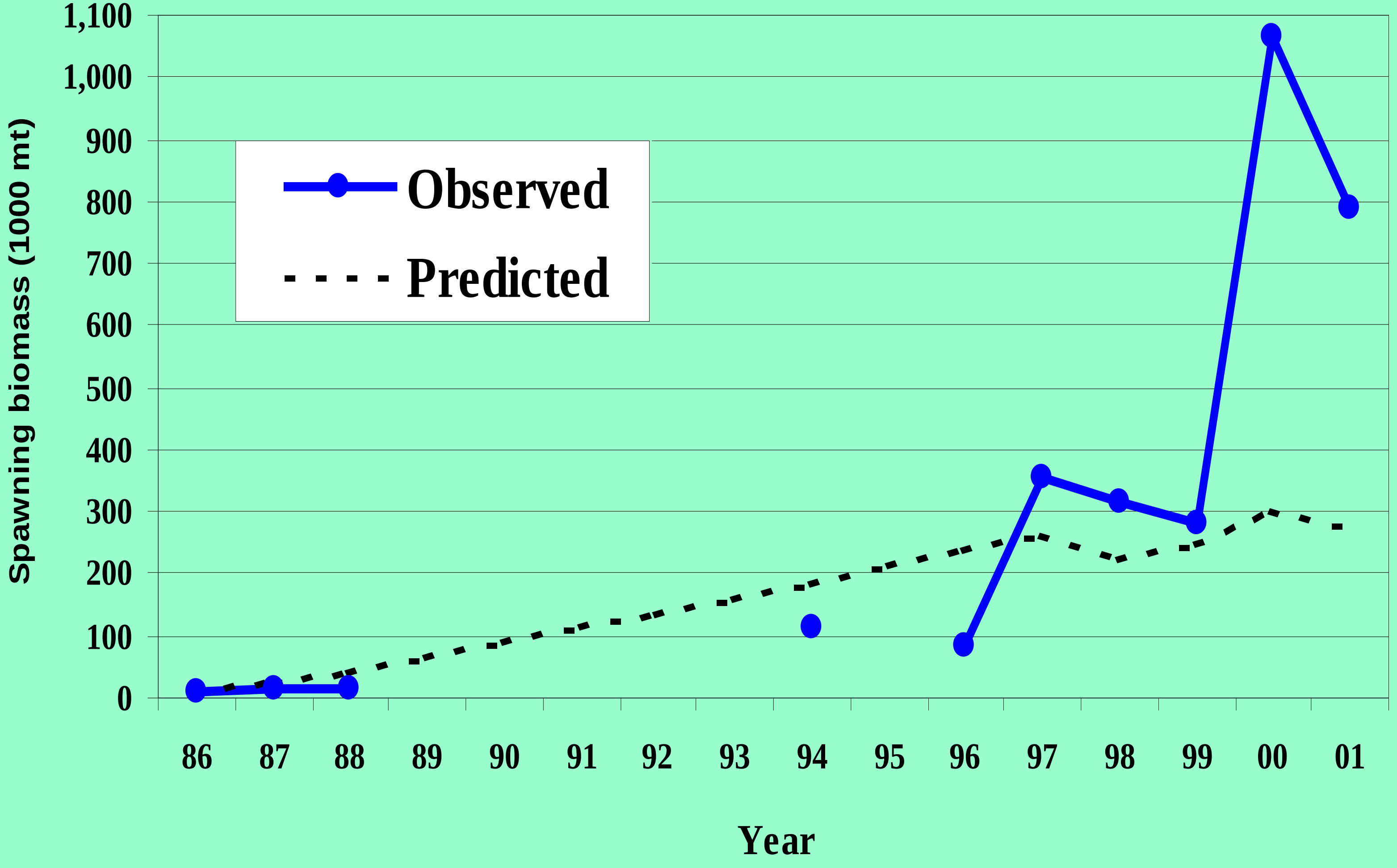
Sardine Stock Assessment Results

Model Calibration with Indices of Abundance

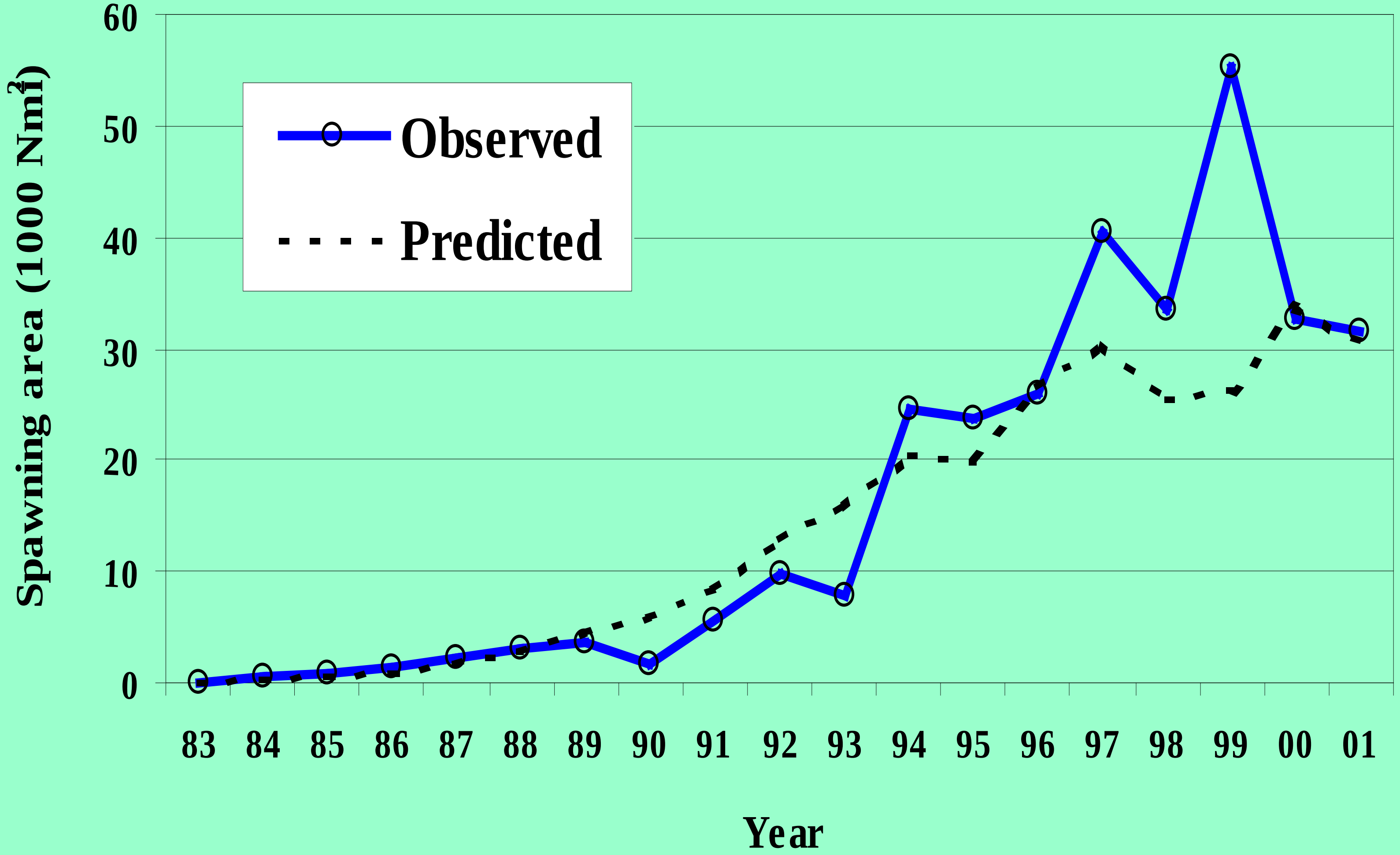
CalCOFI Index of SSB



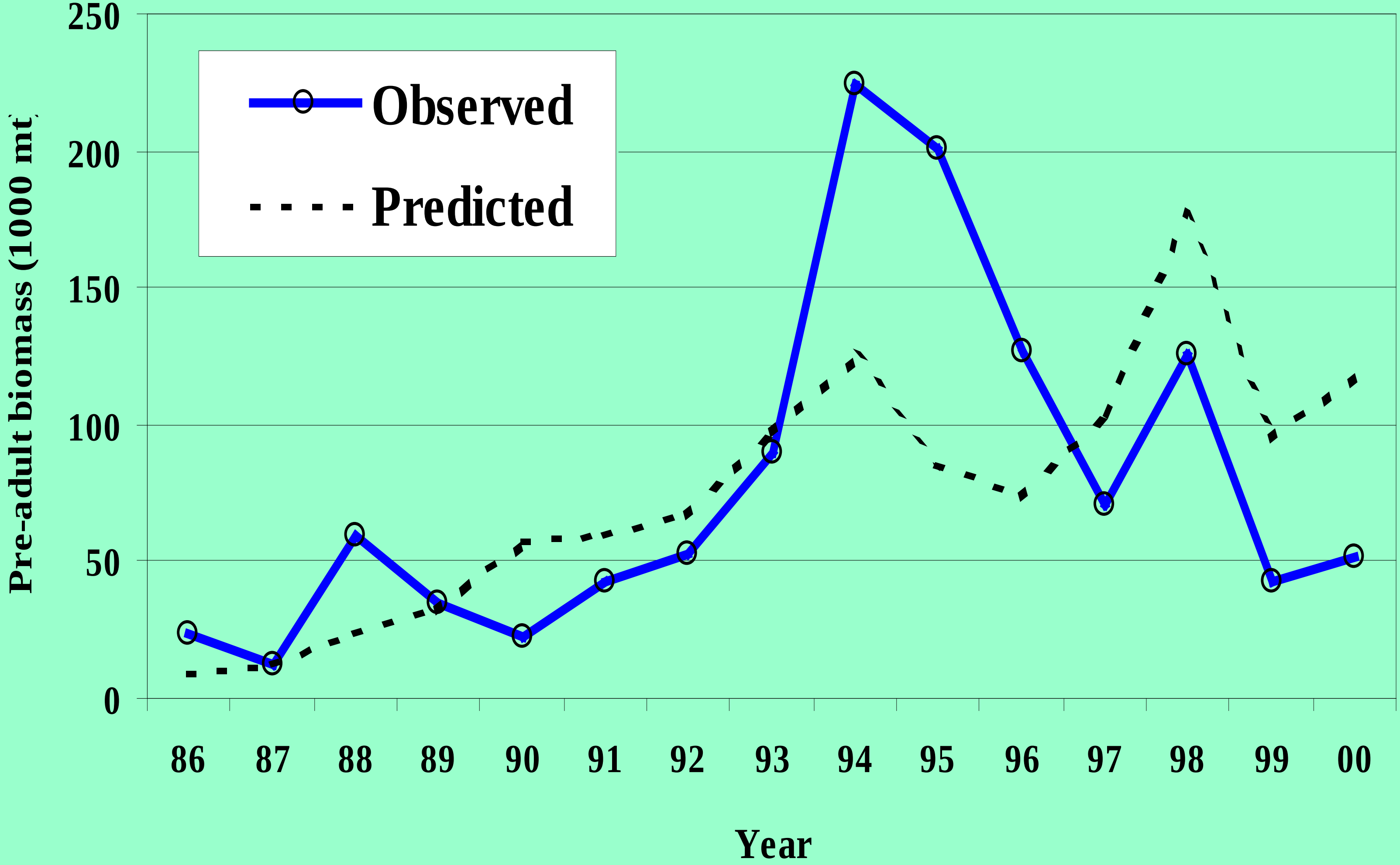
Daily Egg Production Method (DEPM) Index of SSB



Spawning Area Index of SSB



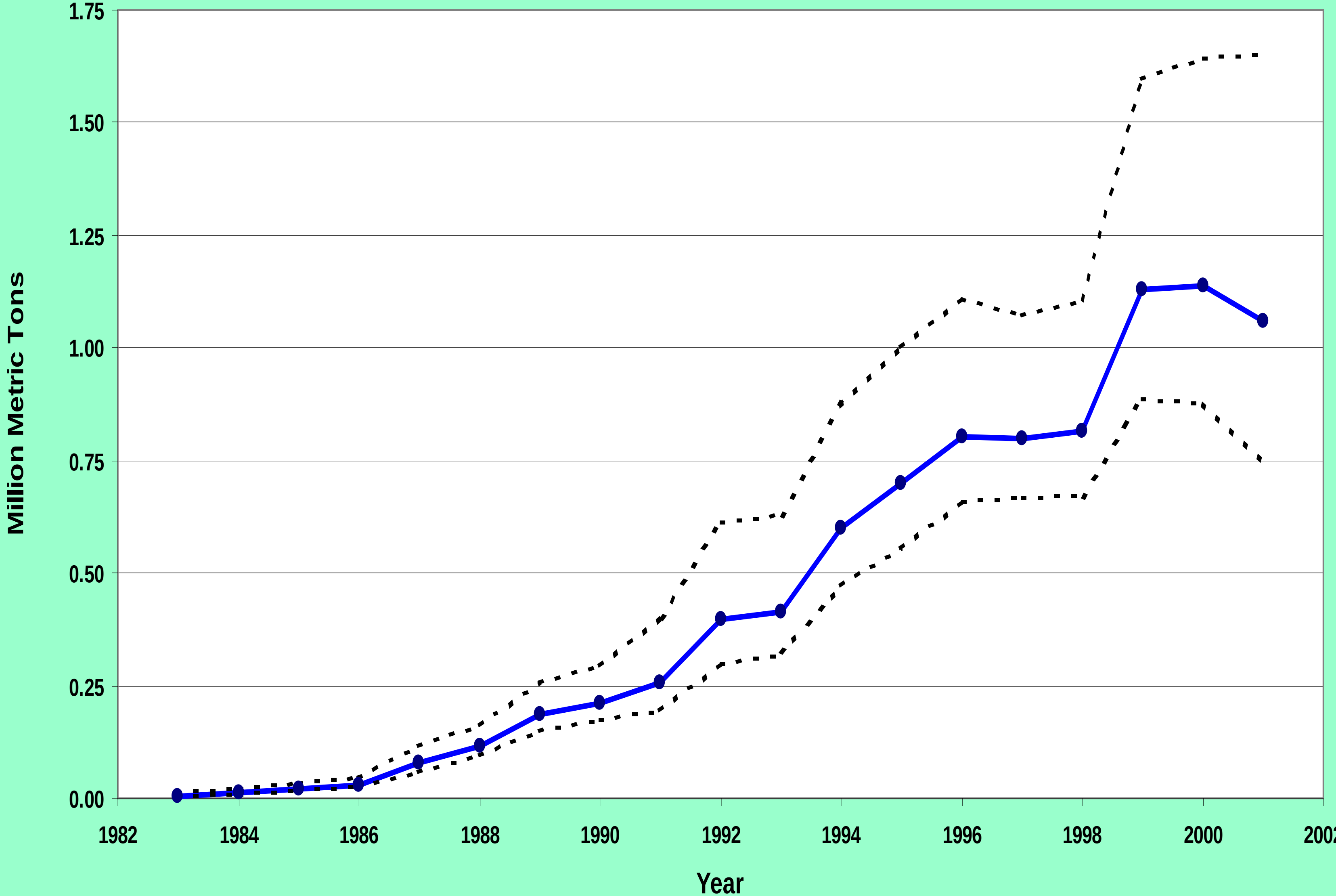
Spotter Pilot Index of Pre-Adults



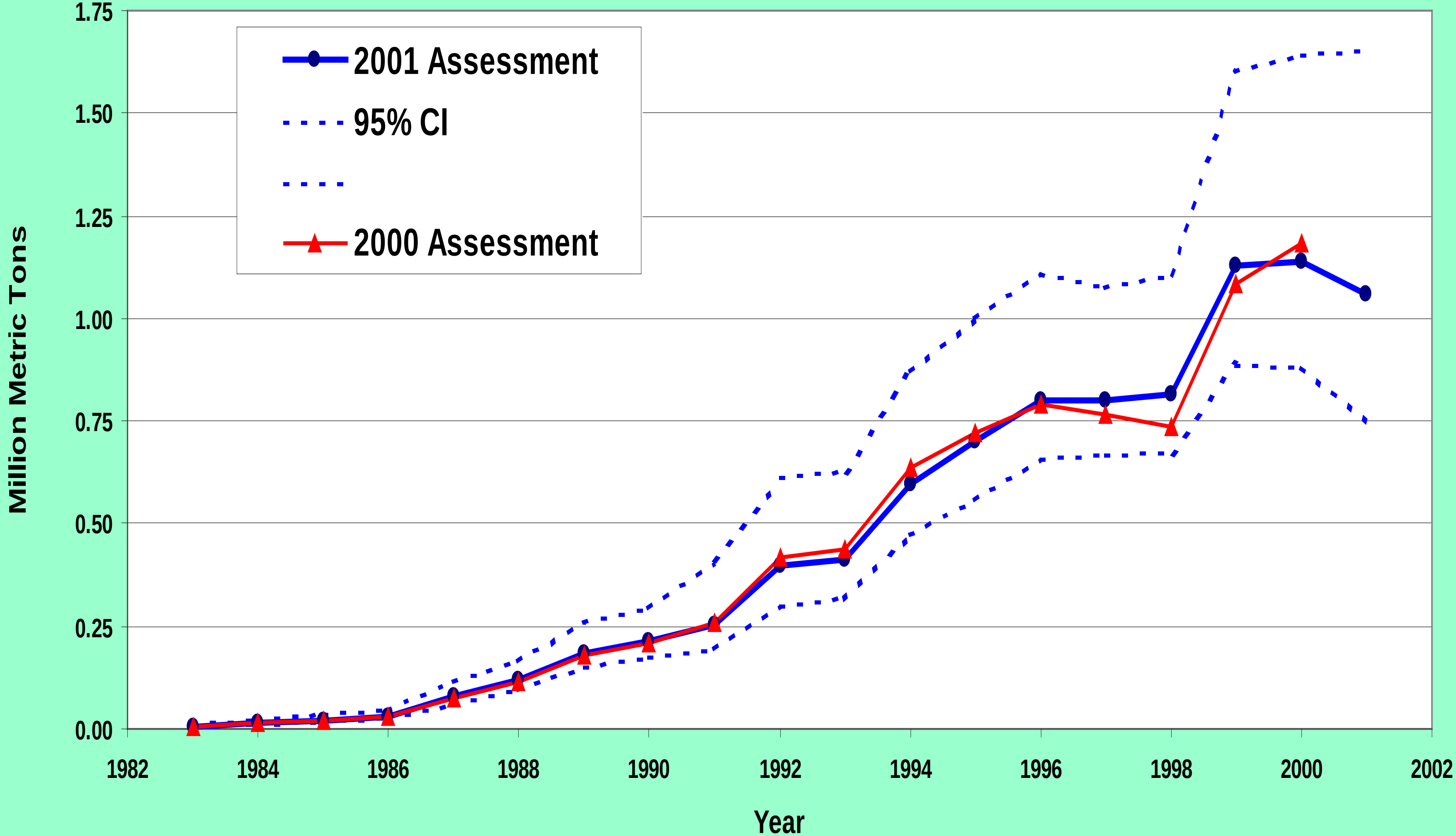
Sardine Stock Assessment Results

Estimates of Stock Biomass and Recruitment

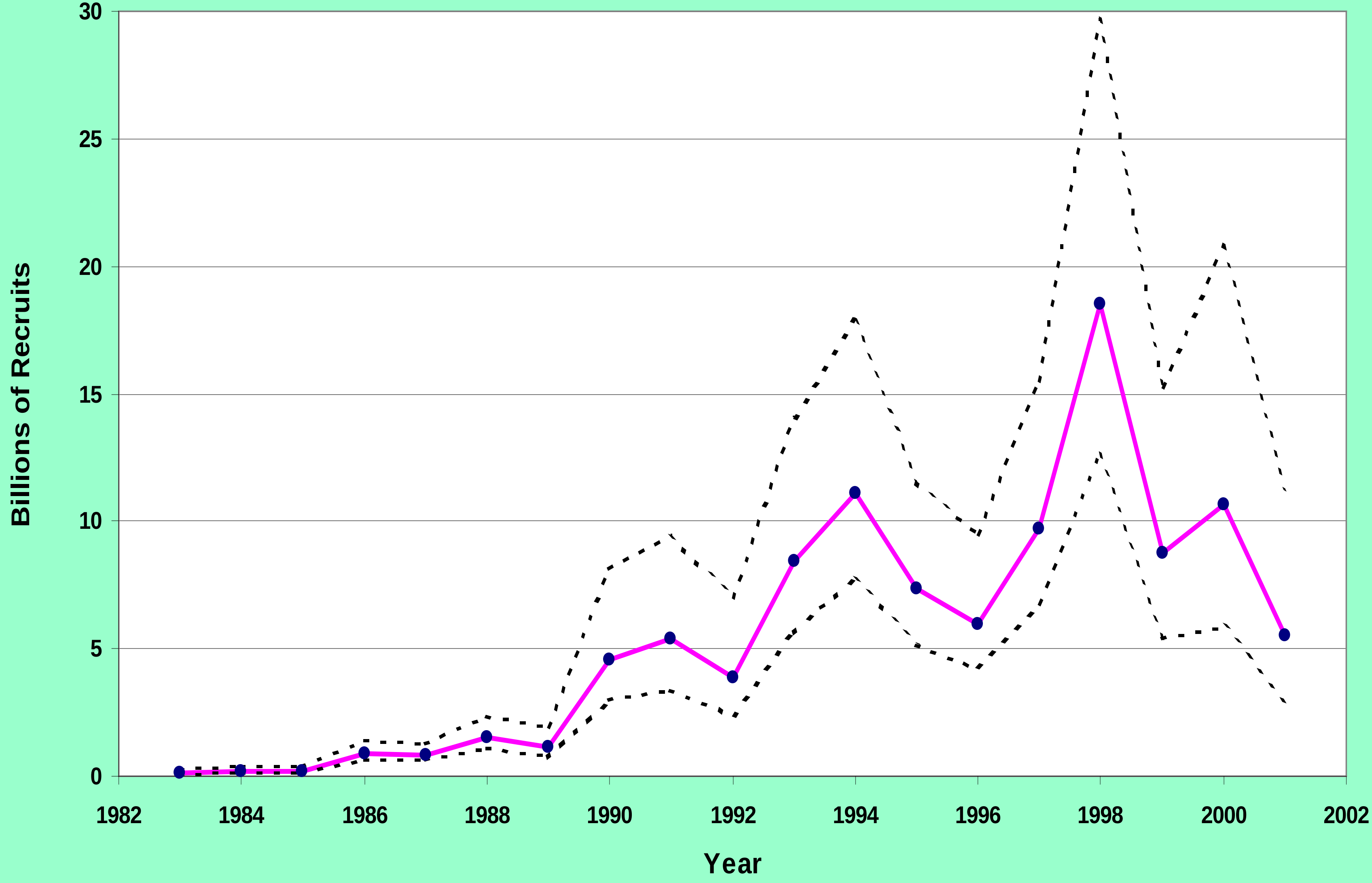
Pacific Sardine Biomass, Ages 1+ with 95% Confidence Intervals



Pacific Sardine Biomass, Ages 1+
Comparison with 2000 Assessment

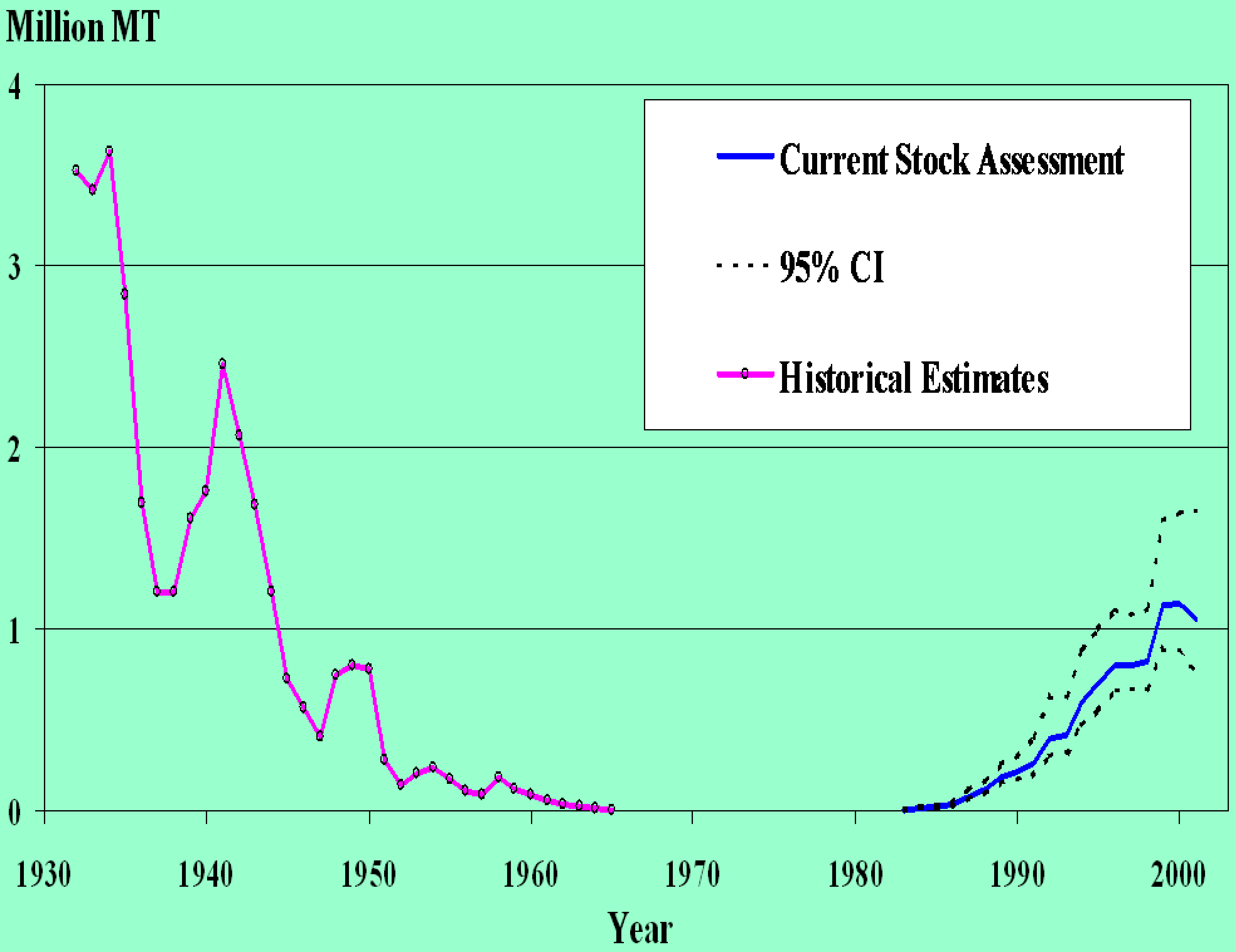


Pacific Sardine Recruitment, Age 0 with 95% Confidence Intervals



Per Capita Recruitment

Long-Term Stock Biomass



Sardine Stock Assessment Results

Harvest Guidelines for USA Fisheries in 2002

and

Future Management Considerations

Proposed Harvest Guideline for 2002

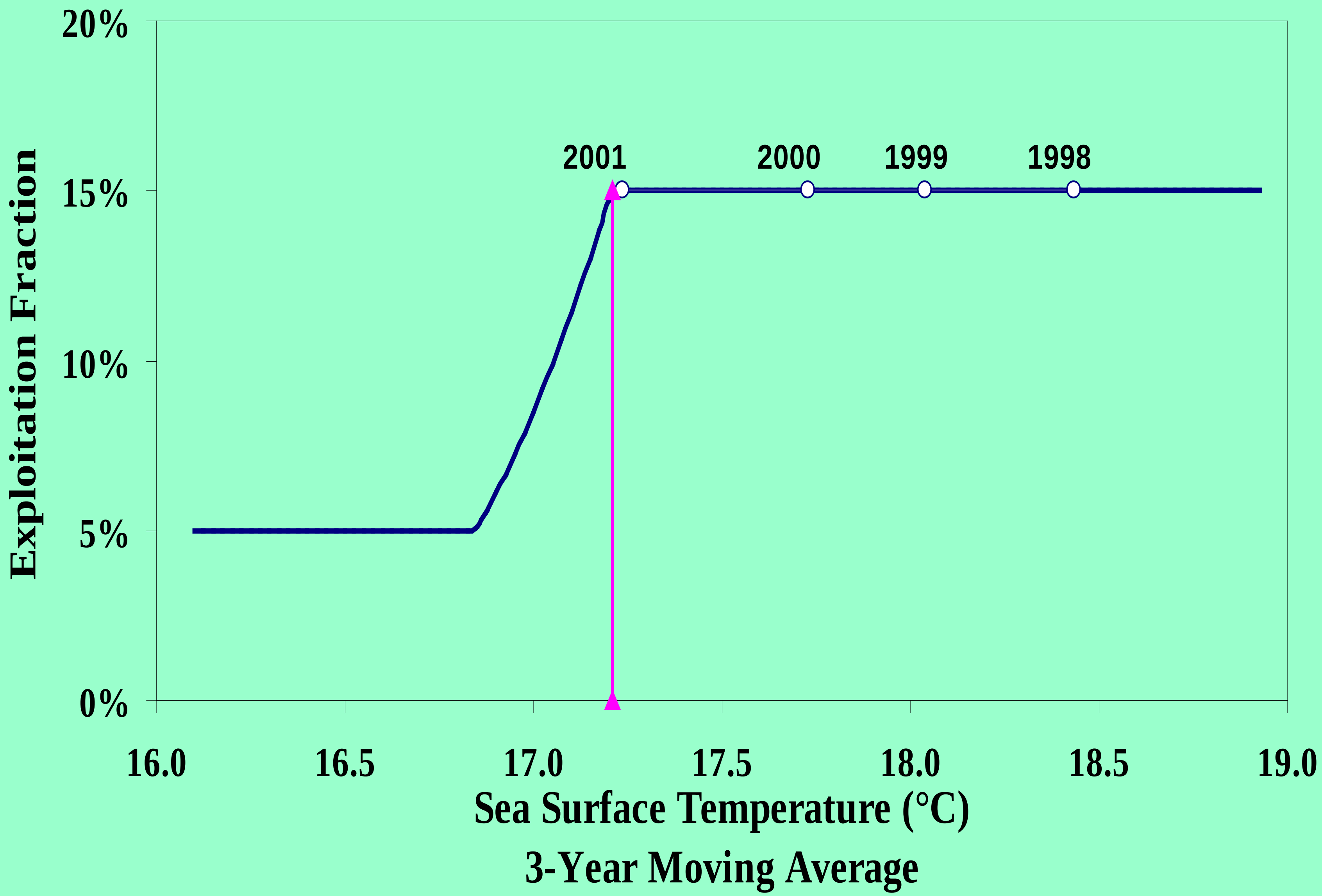
$HG_{2002} = (Biomass_{2001} - Cutoff) \cdot Fraction \cdot USA$

$HG_{2002} = (1,057,599 - 150,000) \cdot 15\% \cdot 87\%$

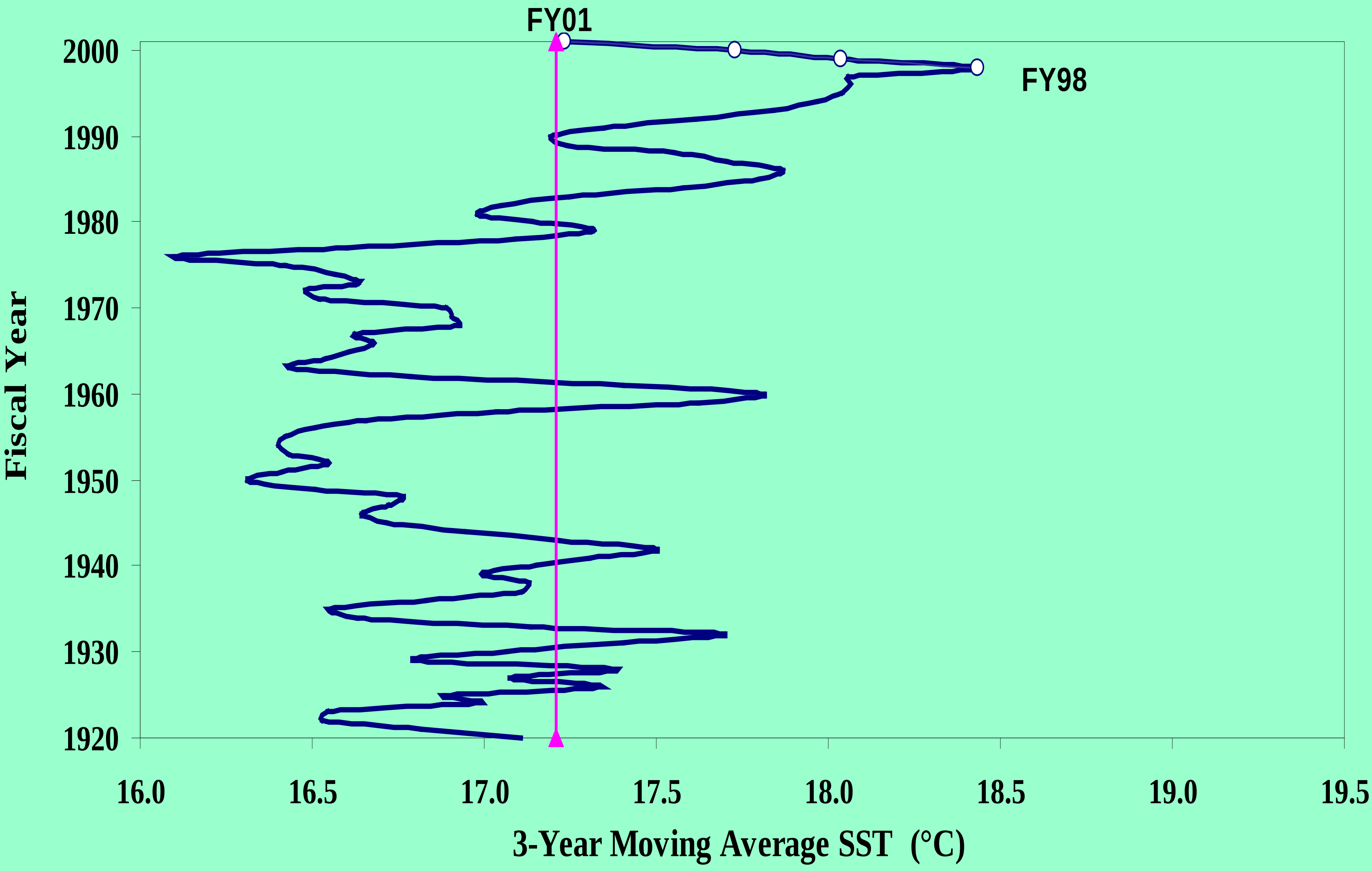
$HG_{2002} = (\quad 907,599 \text{ MT} \quad) \cdot 15\% \cdot 87\%$

$HG_{2002} = 118,442 \text{ MT}$

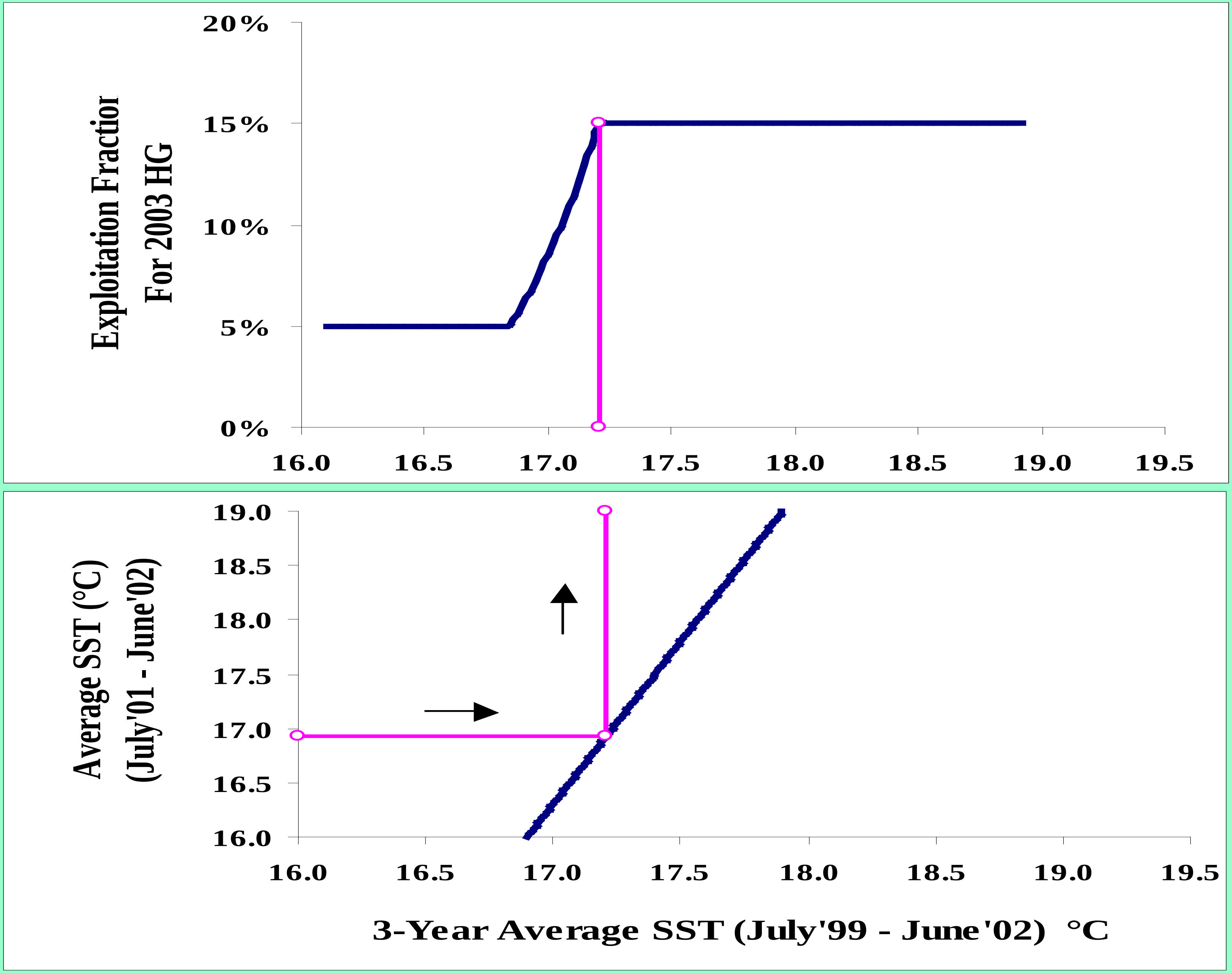
Environmentally-Based Control Rule



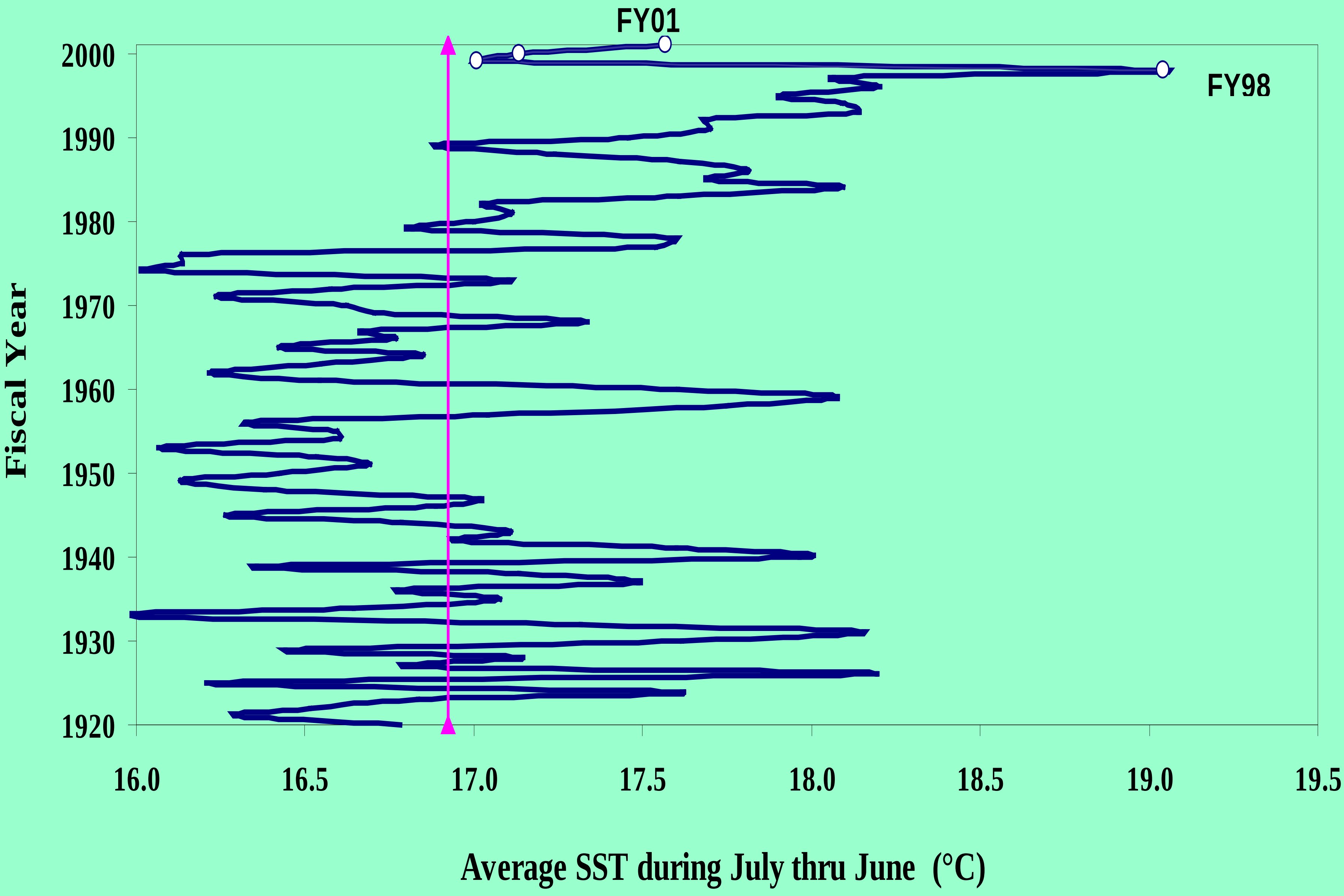
Long-Term SST (3-Year Moving Average)



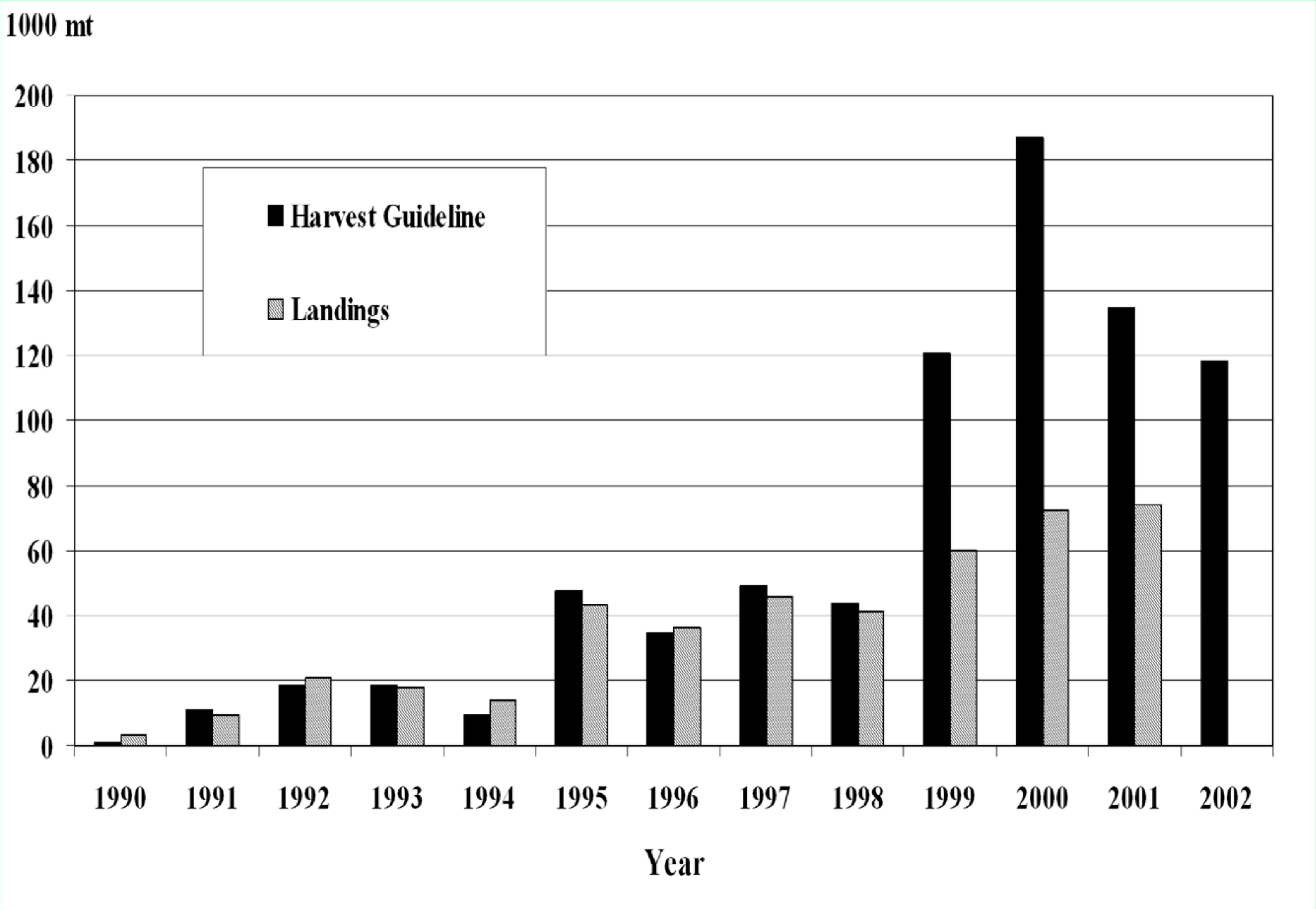
Control Rule for 2003 Harvest Guideline

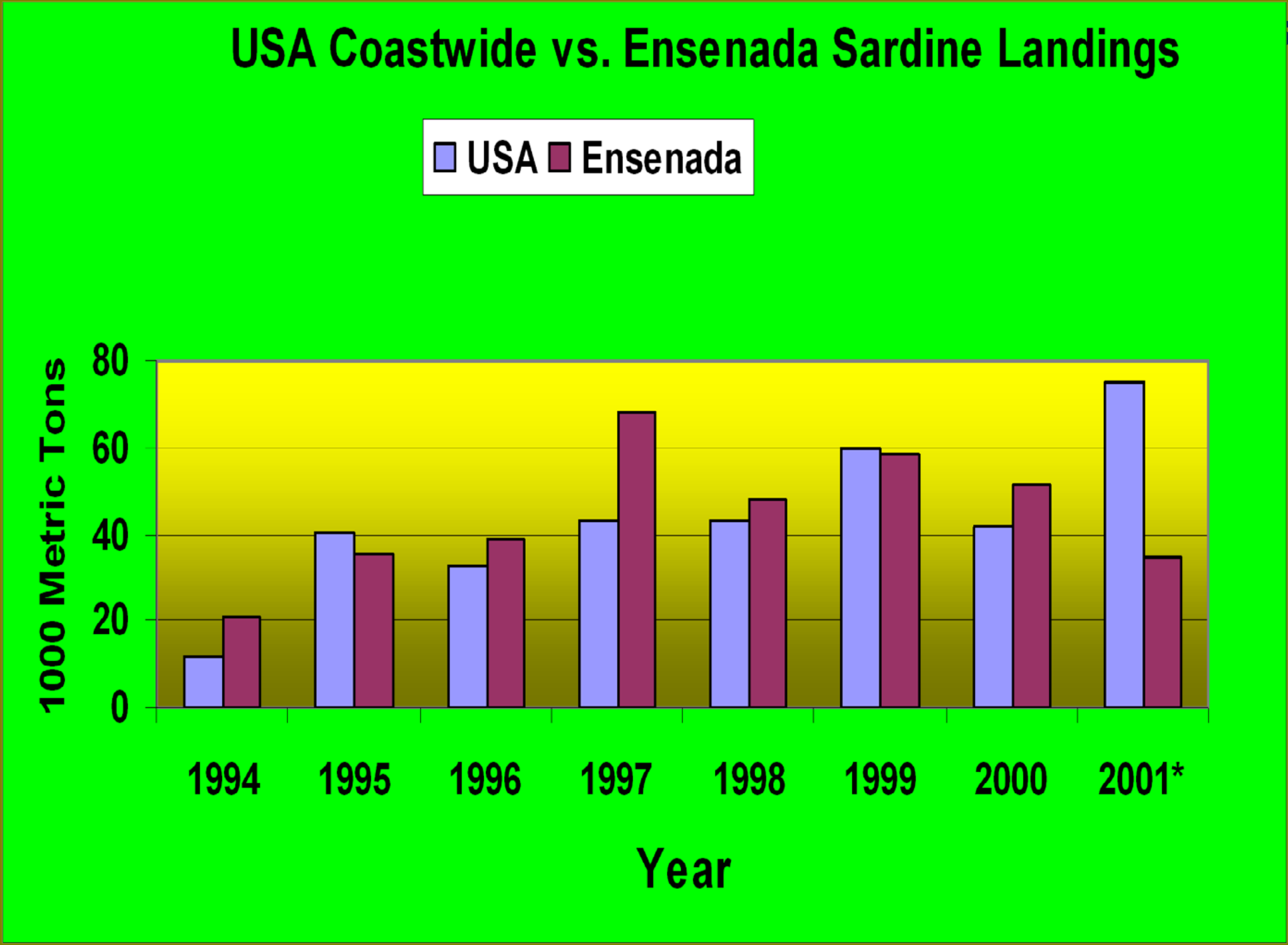


Long-Term SST (Annual Average)



USA Coastwide Harvest Guidelines and Subsequent Annual Landings




USA Coastwide vs. Ensenada Sardine Landings
USA
Ensenada
1000 Metric Tons
0
20
40
60
80
1994
1995
1996
1997
1998
1999
2000
2001*
Year

Principal Assessment Limitations

- Both fishery-dependent and fishery-independent data were essentially limited to southern California + Ensenada (Inside Area)
- Biological data were sparse for Mexican & Canadian fisheries, and for the USA northern fisheries
- Survey data were unavailable for Mexican & Canadian fisheries, and for USA northern fisheries
- Sample data were insufficient to critically examine migration modelling & assumptions

Improving Coastwide Data Availability and Stock Assessment Modelling

2nd Trinational Sardine Forum
(USA, Mexico, and Canada)

San Diego (Old Town)
November 29-30, 2001

Sardine Stock Assessment and Harvest Guidelines -- Conclusions

- Status of the stock
  - Spawning biomass at high level
  - Rate of population increase may have slowed
  - Recent recruitment may be at lower level

- Harvest Guidelines
  - 2002 HG not likely to constrain USA fishery
  - Future HG's may become constraining if:
    - Recruitment declines are confirmed in subsequent assessments
    - SST continues to decline, invoking environmentally-based precautionary management

Figure Template

Major Section Template xxxxx

Major Section Template

Bullet List Template

- Fishery-dependent data
  - Landings
  - Catch-at-age
  - Biological information
- Fishery-independent data
  - Research survey indices of abundance
  - Spotter pilot index abundance
  - Environmental data (SST)

Exhibit H.3.b
Supplemental SSC Report
November 2001

SCIENTIFIC AND STATISTICAL COMMITTEE STATEMENT ON PACIFIC SARDINE HARVEST GUIDELINE FOR 2002

Dr. Ray Conser briefed the Scientific and Statistical Committee (SSC) on the stock assessment results for Pacific sardine and the 2002 U.S. harvest guideline. The assessment model and data analysis are identical to those used in previous years. The analysis incorporates the most recent fishery and survey data.

The data shortcomings identified last year have not been rectified. The First Trinational Sardine Forum (U.S.A., Mexico, and Canada), which was convened in 2000, was not successful in building the coastwide database (British Columbia through Baja, California) needed for sardine stock assessment. Thus the only option available to the Coastal Pelagic Species Management Team (CPSMT) for 2002 was to update the previous assessment model, which is based on that portion of the sardine population off the southern half of California, and extrapolate the results to include Mexico and the northern areas. The Second Trinational Sardine Forum will be convened in San Diego during November 29-30, 2001. If successful, the data thus obtained will provide a basis for developing a new coastwide assessment in 2003. The SSC views the Forum as the most promising venue for the Trinational collaboration needed to improve the assessment, and encourages the U.S. state agencies (Washington, Oregon, and California), federal agencies, and the Council family (CPSMT, Coastal Pelagic Species Advisory Subpanel (CPSAS), SSC, and Council staff) to fully participate in the Forum. For now, the SSC recommends the current assessment be accepted, as it is based on the best available information.

A year ago the SSC recommended that a peer review (similar to the groundfish Stock Assessment Review (STAR) process) be scheduled for Pacific mackerel and Pacific sardine in early 2002. The CPSMT is optimistic that the upcoming Second Trinational Sardine Forum will be more successful than the 2000 Forum in assembling a coastwide data base. If progress is made, the SSC recommends the peer review that we requested last year be rescheduled for spring of 2003, so the new coastwide sardine assessment can be reviewed, in addition to the Pacific mackerel assessment.

The SSC notes that Pacific sardine is now, along with Pacific whiting, the most abundant fish resource off the West Coast; at one time sardine was the largest single-species fishery in the world. Yet the research program for supporting sardine assessment is seriously underfunded. The current fishery independent surveys are restricted to the southern half of California and only provide indices of sardine egg abundance and daily egg production. The aerial fish spotter index only covers the nearshore areas of the southern California Bight. The adult parameters used in recent biomass estimates are computed on the basis of biological data collected in 1994, at a time when the population was one-tenth of the 2002 biomass. The SSC strongly urges the National Marine Fisheries Service at both the regional and national levels to develop and fund a resource survey plan and budget with a specific time line, including ship time that will sample the sardine population over its range, with the objective of estimating spawning biomass and age composition of the sardine population.

PFMC
11/01/01

AMENDMENT 10 TO THE COASTAL PELAGIC SPECIES FISHERY MANAGEMENT PLAN

Situation: There are two items related to Amendment 10 that will be presented to the Council. The first is the results of the market squid maximum sustainable yield (MSY) workshop. The second is consideration of subissues related to capacity and permit transferability in the coastal pelagic species (CPS) fishery. It is anticipated the Council will take preliminary action on Amendment 10 in March 2002 and final action in June 2002.

Market Squid MSY

A workshop to review market squid stock assessment methods was held in May 2001. The workshop sought to address disapproved provisions in the CPS fishery management plan (FMP); specifically, MSY for market squid. A principal workshop goal was to investigate ways to integrate squid research into the FMP. Council review of this workshop is carried over from the September 2001 meeting as world events prevented the Coastal Pelagic Species Advisory Subpanel (CPSAS) from meeting to review the workshop report.

A final workshop report will be presented to the Council. The Scientific and Statistical Committee (SSC) will report on their review of the workshop. The CPS Management Team (CPSMT) and CPSAS will provide their recommendations for incorporating workshop findings into the CPS FMP.

Limited Entry Issues

As noted above, Amendment 10 also addresses capacity issues and permit transferability in the CPS limited entry fishery. The CPSMT and CPSAS will report on two subissues requiring Council input: (1) the process for adjusting permit transferability to maintain the capacity goal, and (2) the process for issuing new limited entry permits if fleet capacity falls below the capacity goal.

Council Task: Guidance on the contents of and process for developing Amendment 10.

Reference Materials:

1. Exhibit H.2.b, Final Workshop Report.
2. Exhibit H.2.b, CPSMT Report.
3. Exhibit H.2.b, Supplemental SSC Report.
4. Exhibit H.2.b, Supplemental CPSAS Report.

PFMC
10/15/01

COASTAL PELAGIC SPECIES ADVISORY SUBPANEL STATEMENT ON PACIFIC SARDINE HARVEST GUIDELINE FOR 2002

The Coastal Pelagic Species Advisory Subpanel (CPSAS) met in Los Alamitos, California, on October 10 to review the latest stock assessment for pacific sardine and the proposed harvest guideline of 118, 442 metric tons for the 2002 season.

The CPSAS appreciates the work done by the Coastal Pelagic Species Management Team (CPSMT) and supports the proposed 2002 harvest guideline. However, the CPSAS still continues to voice concerns about the scope of the stock assessment; for example, the fishery-dependent data collected in the Washington and Oregon fisheries are not currently incorporated into the assessment. The CPSMT and stock assessment authors assure the CPSAS that these efforts will be considered in future efforts as the current model is refined to include coastwide information. The CPSAS will continue to support any of these efforts as we feel it is imperative to achieve an accurate coast-wide biomass estimate.

Lastly, the CPSAS would like to encourage the state agencies to send representatives to the Tri-National Sardine Forum in San Diego beginning November 29th. This is an important meeting that includes needed input from both Mexico and Canada. It is critical representatives from the northern states are able to participate in the meeting, so they are able to contribute vital regional information.

PFMC
11/01/01

COASTAL PELAGIC SPECIES MANAGEMENT TEAM STATEMENT ON PACIFIC SARDINE HARVEST GUIDELINE FOR 2002

The Coastal Pelagic Species Management Team (CPSMT) and Coastal Pelagic Species Advisory Subpanel (CPSAS) recently met to review results from the latest Pacific sardine stock assessment which will be used to set a harvest guideline (HG) for the 2002 season. The CPSMT concurs with the stock assessment team's analyses and recommends that the Council adopt a harvest guideline of 118,442 metric tons (mt) for the upcoming season.

The CPSMT discussed questions related to the temperature component of the harvest control rule and identified a need to reevaluate research areas related to this issue. The CPSMT will discuss this issue at their next scheduled meeting, will develop a work schedule, and can provide the Council with an update at the March meeting.

As communicated by the Scientific and Statistical Committee (SSC), it is critical that both industry and management bodies actively pursue additional research funds, which will be necessary to improve future assessments of the sardine population off North America.

Finally, the CPSMT concurs with the SSC regarding a revised stock assessment review schedule for sardine and Pacific mackerel for spring 2003.

PFMC
11/01/01

Exhibit H.3.b
Supplemental SSC Report
November 2001

SCIENTIFIC AND STATISTICAL COMMITTEE STATEMENT ON PACIFIC SARDINE HARVEST GUIDELINE FOR 2002

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PFMC
11/01/01

Stock Assessment of Pacific Sardine with Management Recommendations for 2002

Executive Summary

by

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October 2001

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

Dedication

This paper is dedicated to the late Dr. Garth Murphy, who passed away during 2001. Dr. Murphy was a world-renowned population biologist and a genuine pioneer in the study of Pacific sardine. Without his diligent, conscientious, and truly innovative efforts, this work would not have been possible.

Introduction

The following summary presents pertinent results and harvest recommendations from a stock assessment conducted on Pacific sardine (*Sardinops sagax*). It is an update to the stock assessment carried out last year (Conser et al. 2001), and is intended for use by the Pacific Fishery Management Council (PFMC) when developing management goals for the upcoming fishing season for sardine beginning January 2002.

The assessment results presented here are applicable to the sardine population off the North America Pacific coast from Baja California, Mexico to British Columbia, Canada. The majority of the fishery-independent and fishery-dependent data were collected off northern Mexico and southern California only (Area 1 or *Inside* Area); however, as was done in past assessments, assumptions regarding sample coverage (e.g., representativeness of survey trends to areas outside Area 1) and sardine biology (e.g., recruit emigration out of Area 1) were used to make scientific inferences about the entire population, e.g., to provide fishery managers coastwide estimates of stock biomass, mortality rates, and harvest guidelines.

Methods

An age-structured stock assessment model (CANSAR-TAM, **C**atch-at-age **AN**alysis for **SAR**dine - **T**wo **A**rea **M**odel, see Hill et al. (1999) was applied to fishery-dependent and fishery-independent data to derive estimates of population abundance and age-specific fishing mortality rates. In 1998, the original CANSAR model (Deriso et al. 1996) was modified to account for the expansion of the population northward to waters off the Pacific northwest (see above). The models are based on a 'forward-simulation' approach (see Megrey (1989) for a description of the general modeling approach), whereby parameters (e.g., population sizes, recruitments, fishing mortality rates, gear selectivities, and catchability coefficients) are estimated after log transformation using the method of nonlinear least squares. The terms in the objective function (to be minimized) included the sum of squared differences in ($\log_e$) observed and ($\log_e$) predicted estimates from the catch-at-age and various sources of auxiliary data used for 'tuning' the model, e.g., indices of abundance from survey (fishery-independent) data. Bootstrap procedures were used to calculate variance and bias (95% confidence intervals) of sardine biomass and recruitment estimates generated from the assessment model. The CANSAR-TAM model was based on two fisheries (California, U.S. and Ensenada, Mexico) and semesters within a year were used as time steps, with ages being incremented between semesters on July 1 and spawning that was assumed to occur on April 1 (middle of the first semester).

Fishery-dependent data from the California and Ensenada fisheries (1983 to first semester 2001) were used to develop the following time series: (1) catch (in mt)-Table 1 and Figure-1; (2) catch-at-age in numbers of fish; and (3) estimates of weight-at-age. Fishery-independent data (time series) from research surveys included the following indices, which were developed from data collected from Area 1 (*Inside Area*, primarily waters off southern California) and used as relative abundance measures (Table 2): (1) index (proportion-positive stations) of sardine egg abundance from California Cooperative Oceanic and Fisheries Investigations (CalCOFI) survey data (*CalCOFI Index*)-Figure 2; (2) index of spawning biomass (mt) based on the Daily Egg Production Method (DEPM) survey data (*DEPM Index*)-Figure 3, see Lo et al. (1996); (3) index of spawning area (Nmi^2) from CalCOFI and DEPM survey data (*Spawning Area Index*)-Figure 4, see Barnes et al. (1997); and (4) index of pre-adult biomass (mt) from aerial spotter plane survey data (*Aerial Spotter Index*)-Figure 5, see Lo et al. (1992). Time series of sea-surface temperatures (Figure 6) recorded at Scripps Pier, La Jolla, California were used to determine appropriate harvest guidelines (*Sea-surface Temperature Index*), see Amendment 8 of the Coastal Pelagic Species Fishery Management Plan, Option J, Table 4.2.5-1, PFMC (1998).

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

It is important to note that survey indices used in fishery assessments are often based on variable and biased data; however, we assumed that biases were generally consistent from year to year, which in effect, allows the trend indicated in an index to be interpreted in relative terms and ultimately, useful in statistical modeling.

Results

Pacific sardine landings for the directed fisheries off California, U.S. and Ensenada, Mexico decreased from the high levels that were reached during 2000 (109,000 mt), with a total 2001 harvest of roughly 86,000 mt (Table 1, Figure 1); however, note that semester 2 landings in 2001 reflect projected estimates based on landing patterns observed in the fisheries during the mid to late 1990s (Table 1). Both California and Ensenada landings in 2001 are expected to decrease from the 2000 level, with a more notable decrease in the projected Ensenada landings (51,000 mt in 2000, decreasing to 35,000 mt in 2001). Currently, the U.S. fishery (California landings) is regulated using a quota (harvest guideline) management scheme and the Mexico fishery (Ensenada landings) is essentially unregulated. Since the mid 1990s, actual landings from the California fishery have been less than the recommended quotas.

As was the case in recent years, landings from the U.S. Pacific sardine fishery (California, Oregon, and

Washington) are well below the harvest guideline recommended for 2001 (135,000 mt), with roughly 62,000 mt (46% of harvest guideline) landed through September 2001 and over 72,000 mt of the quota remaining (the fishing year ends on December 31, 2001).

Estimated stock biomass ($\geq$1-year old fish on July 1, 2001) 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 1.1 million mt (Table 3 and Figure 7). Estimated recruitment (age-0 fish on July 1) during the past three years has declined considerably from that estimated for the strong 1998 year-class (Table 3 and Figure 8). However, it should be noted that recent recruitment (6-11 billion recruits) is not estimated precisely (Figure 8), and another 2-3 years of data may be needed to ascertain whether the sardine population biomass has reached a plateau at the 1.1 million mt level (Figure 7).

Estimates of Pacific sardine biomass from the 1930's (Murphy 1966 and MacCall 1979) indicate that the sardine population may have been more than three times its current size prior to the population decline and eventual collapse in the 1960's (Figure 9). Considering the historical perspective, it would appear that the sardine population, under the right conditions, may still have growth potential beyond its present size. However, per capita recruitment estimates derived from the current assessment (Figure 10) show a downward trend in recruits per spawner that may be indicative of a stock that has reached a plateau under current environmental conditions.

Harvest Guideline for 2002

The harvest guideline recommended for the U.S. (California, Oregon, and Washington) Pacific sardine fishery for 2002 is 118,442 mt. Statistics used to determine this harvest guideline are discussed below and presented in Table 4. To calculate the proposed harvest guideline for 2002, we used the maximum sustainable yield (MSY) control rule defined in Amendment 8 of the Coastal Pelagic Species-Fishery Management Plan, Option J, Table 4.2.5-1, PFMC (1998). This formula is intended to prevent Pacific sardine from being overfished and maintain relatively high and consistent catch levels over a long-term horizon. The Amendment 8 harvest formula for sardine is:

$$HG_{2002} = (\text{TOTAL STOCK BIOMASS}_{2001} - \text{CUTOFF}) \bullet \text{FRACTION} \bullet \text{U.S. DISTRIBUTION},$$

where HG_{2002} is the total U.S. (California, Oregon, and Washington) harvest guideline recommended for 2002, TOTAL STOCK BIOMASS_{2001} is the estimated stock biomass (ages 1+) from the current assessment conducted in 2001 (see above), CUTOFF is the lowest level of estimated biomass at which harvest is allowed, FRACTION is an environment-based percentage of biomass above the CUTOFF that can be harvested by the fisheries (see below), and U.S. DISTRIBUTION is the percentage of TOTAL STOCK BIOMASS_{2001} in U.S. waters.

The value for FRACTION in the MSY control rule for Pacific sardine is a proxy for F_{msy} (i.e., the fishing mortality rate that achieves equilibrium MSY). Given F_{msy} and the productivity of the sardine stock have been shown to increase when relatively warm-water ocean conditions persist, the following formula has been used to determine an appropriate (sustainable) FRACTION value:

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

where T is the running average sea-surface temperature at Scripps Pier, La Jolla, California during the three preceding years. Ultimately, under Option J (PFMC 1998), F_{msy} is constrained and ranges between 5% and 15% (Figure 11).

Based on the T values observed throughout the period covered by this stock assessment (1983-2001), the appropriate F_{msy} exploitation fraction has consistently been 15% (see Figures 6 and 11); and this remains the case under current oceanic conditions (T_{2001} = 17.24 °C). However, it should be noted that the decline in sea-surface temperature observed in recent years (1998-2001) may invoke environmentally-based reductions in the exploitation fraction as early as next year (i.e. in setting the harvest guideline for the 2003 fishing season) – see Figure 11.

Finally, although the 2002 harvest guideline (118,442 mt) is less than the 2001 level (134,737 mt), recent fishery practices indicate that it may not be constraining with regard to fishery landings (Figure 12). However, should the recent declining recruitment trend estimated in this assessment be confirmed with future work, and should the sea-surface temperature continue to decline, it is likely that harvest guidelines in the out years will constrain fishery practices and removals.

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Table 1. Pacific sardine time series of landings (mt) by semester (1 is January-June and 2 is July-December) in California and Baja California (Ensenada), 1983-2001. Semester 2 (2001) estimates are projections.

	CALIFORNIA			ENSENADA			
Year	Semester 1	Semester 2	Total	Semester 1	Semester 2	Total	Grand Total
83	245	244	489	150	124	274	762
84	188	187	375	<1	<1	0	375
85	330	335	665	3,174	548	3,722	4,388
86	804	483	1,287	99	143	243	1,529
87	1,625	1,296	2,921	975	1,457	2,432	5,352
88	2,516	1,611	4,128	620	1,415	2,035	6,163
89	2,161	1,561	3,722	461	5,763	6,224	9,947
90	2,272	1,033	3,305	5,900	5,475	11,375	14,681
91	5,680	3,354	9,034	9,271	22,121	31,392	40,426
92	8,021	13,216	21,238	3,327	31,242	34,568	55,806
93	12,953	4,889	17,842	18,649	13,396	32,045	49,887
94	9,040	5,010	14,050	5,712	15,165	20,877	34,927
95	29,565	13,925	43,490	18,227	17,169	35,396	78,886
96	17,896	18,161	36,057	15,666	23,399	39,065	75,121
97	11,865	34,331	46,196	13,499	54,941	68,439	114,636
98	21,841	19,215	41,055	20,239	27,573	47,812	88,868
99	31,791	24,956	56,747	34,760	23,810	58,569	115,316
00	35,174	22,761	57,935	25,800	25,373	51,173	109,108
01	29,491	21,131	50,622	9,327	25,645	34,973	85,594

Table 2. Pacific sardine time series of survey indices of relative abundance and sea-surface temperature, 1983-2001.

Year	CalCOFI (% positive)	DEPM (mt)	Spawning area (Nmi^2)	Spotter plane (mt)	Sea-surface temperature (C)
83	na	na	40	na	17.25
84	4.4	na	480	na	17.58
85	2.7	na	760	na	17.80
86	1.3	7,659	1,260	23,393	17.87
87	4.3	15,705	2,120	12,294	17.71
88	6.7	13,526	3,120	59,455	17.55
89	9.1	na	3,720	34,915	17.24
90	3.6	na	1,760	22,543	17.19
91	12.8	na	5,550	43,147	17.35
92	10.8	na	9,697	52,149	17.61
93	6.1	na	7,685	89,462	17.84
94	17.0	111,493	24,539	224,109	17.97
95	10.8	na	23,816	200,266	18.04
96	28.0	83,176	25,889	127,108	18.06
97	17.9	356,300	40,592	70,995	18.06
98	17.4	313,986	33,447	125,500	18.44
99	16.7	282,248	55,173	42,827	18.04
00	5.6	1,063,837	32,785	51,157	17.73
01	14.8	790,925	31,663	na	17.24

Table 3. Pacific sardine time series of stock biomass (>age-1 fish in mt) and recruitment (age-0 fish in 1,000s) Area 1 (Inside) and the Total Area of the stock. The 95% CIs for Total Area biomass and recruitment estimates are also presented.

	Stock biomass				Recruitment		
Year	**Area 1**	**Total Area**	**Lower CI**	**Upper CI**	**Total Area**	**Lower CI**	**Upper CI**
83	5,160	5,160	2,838	10,593	136,715	81,424	247,317
84	12,631	12,697	8,633	21,818	219,570	140,150	380,174
85	20,229	20,700	14,833	33,546	214,612	144,140	355,474
86	29,015	30,549	23,149	47,123	881,452	626,663	1,376,263
87	73,890	77,335	59,908	114,700	848,884	606,457	1,272,934
88	107,881	117,451	94,475	161,783	1,514,815	1,068,053	2,360,016
89	165,712	184,806	150,033	257,873	1,137,582	774,913	1,922,349
90	178,364	212,005	172,399	294,998	4,557,052	2,967,789	8,105,133
91	218,867	255,720	192,889	400,869	5,419,305	3,386,492	9,434,244
92	331,042	396,653	296,490	613,863	3,853,609	2,423,474	6,997,714
93	310,159	414,063	316,699	627,553	8,438,703	5,672,733	14,107,041
94	452,187	597,933	469,907	871,270	11,079,031	7,774,557	17,875,746
95	498,620	699,738	555,514	1,001,197	7,349,791	5,138,966	11,552,173
96	551,579	801,400	655,898	1,109,174	5,967,108	4,188,319	9,481,244
97	512,049	799,611	667,520	1,071,563	9,702,305	6,703,749	15,457,928
98	489,991	814,152	670,965	1,106,158	18,533,895	12,607,022	29,697,885
99	717,496	1,128,472	887,194	1,598,895	8,735,328	5,417,935	15,248,587
00	681,209	1,136,424	878,663	1,640,441	10,645,970	5,819,861	20,781,050
01	595,901	1,057,599	750,750	1,648,778	5,537,943	2,937,915	11,255,609

Table 4. Proposed harvest guideline for Pacific sardine for the 2002 fishing season. See ***Harvest Guideline for 2002*** section for methods used to derive the harvest guideline.

Total stock biomass (mt)	Cutoff (mt)	Fraction (%)	U.S. Distribution (%)	Harvest guideline (mt)
1,057,599	150,000	15%	87%	**118,442**

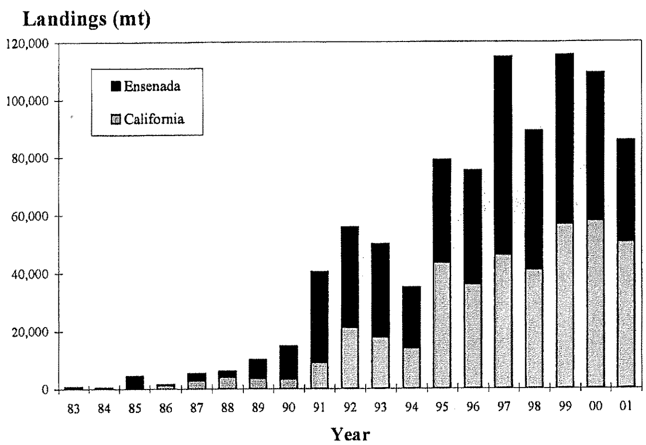


Figure 1. Pacific sardine landings (mt) in California and Baja California (Ensenada), 1983-01.

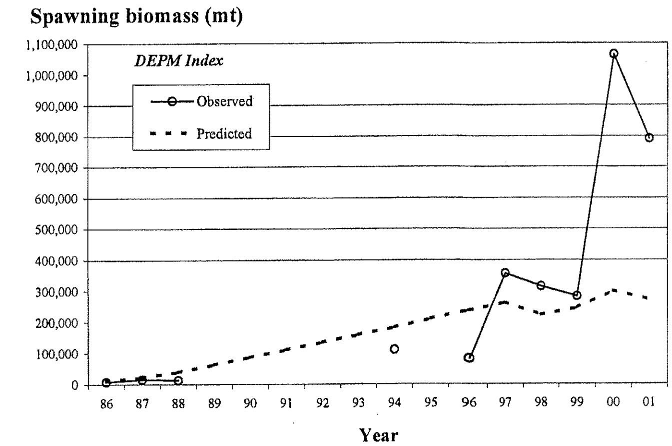


Figure 3. Index of relative abundance of Pacific sardine spawning biomass (mt) off California based on daily egg production method (DEPM) estimates from ichthyoplankton survey data (1986-01). Note no sample data (Observed estimates) were available for years 1989-93 and 1995.

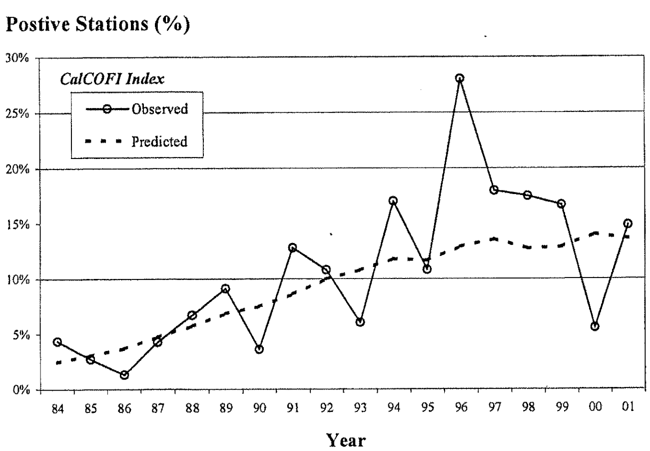


Figure 2. Index of relative abundance of Pacific sardine eggs (proportion-positive stations) off southern California based on CalCOFI bongo-net survey (1984-01).

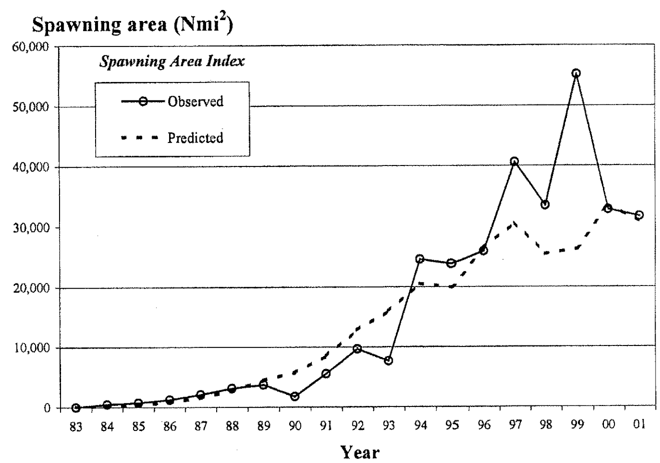


Figure 4. Index of relative abundance of Pacific sardine spawning stock size based on estimates of spawning area (Nmi^2) calculated from CalCOFI and DEPM survey data (1983-01).

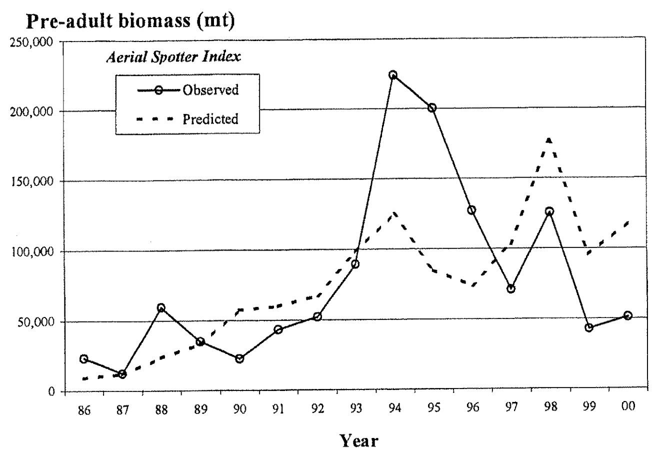


Figure 5. Index of relative abundance of Pacific sardine pre-adult biomass (primarily age 0-2 fish in mt) off California based on aerial spotter plane survey data (1986-01). Note that no sample data were available for 2001.

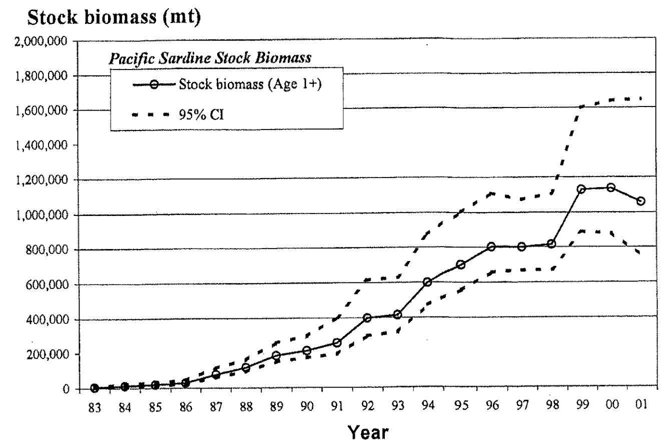


Figure 7. Time series (1983-01) of Pacific sardine stock biomass (≥1-yr old fish on July 1 of each year in mt) estimated from an age-structured stock assessment model (CANSAR-TAM, see Hill et al. 1999).

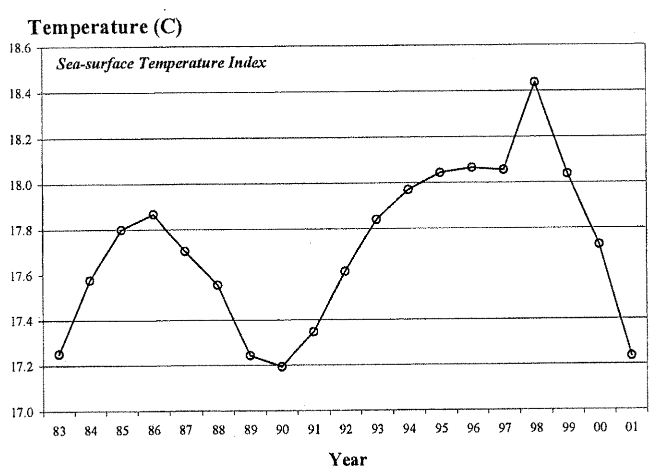


Figure 6. Time series of sea-surface temperature (C) recorded at Scripps Pier, La Jolla (1983-01). Annual estimates reflect 3-year 'running' averages, see Jacobson and MacCall (1995).

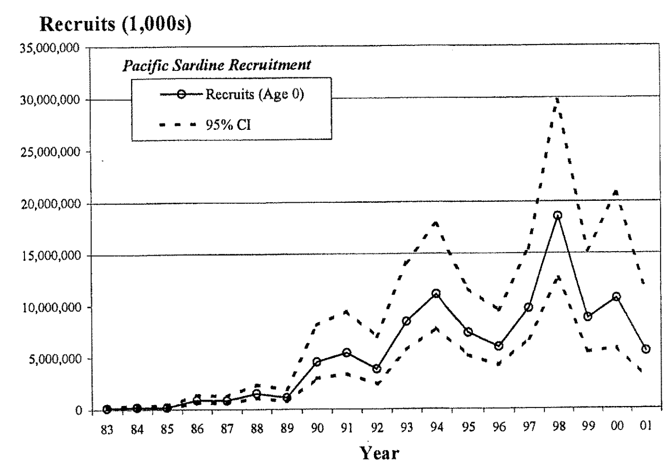
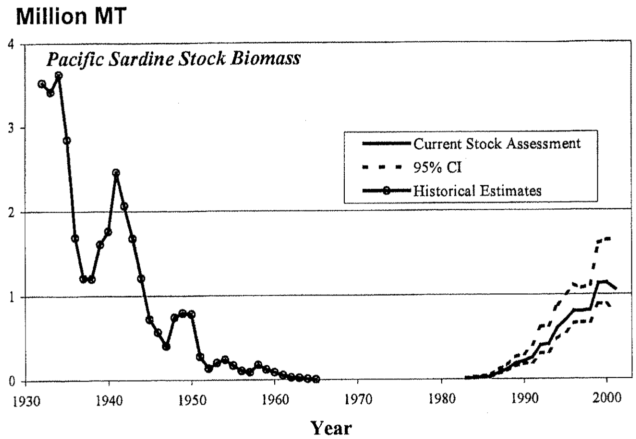


Figure 8. Time series (1983-01) of Pacific sardine recruitment (0-yr old fish on July 1 of each year in 1,000s) estimated from an age-structured stock assessment model (CANSAR-TAM, see Hill et al. 1999).



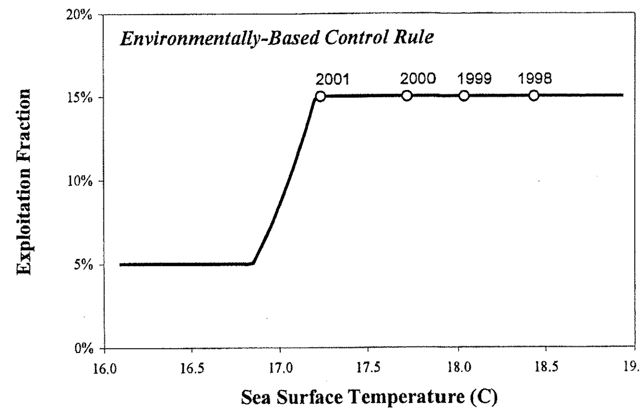
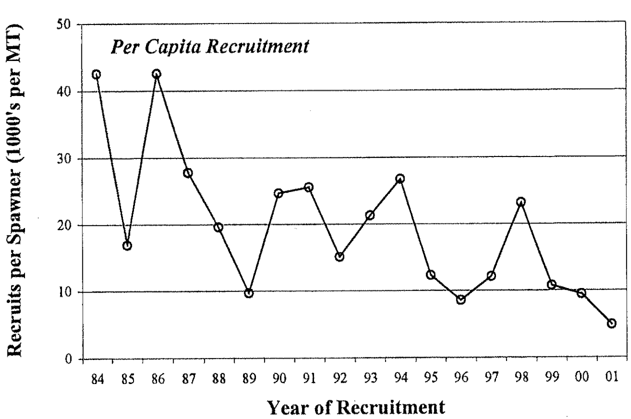


Figure 9. Time series (1983-2001) of Pacific sardine stock biomass (>1-yr old fish on July 1 of each year in million mt) and associated 95% confidence intervals estimated in the current stock assessment (cf. Figure 7); and historical stock biomass estimates (1932-65) from Murphy (1966). Confidence intervals or other measures of precision are not available for the historical estimates. No stock assessment-based estimates are available for the period 1966-82. The sardine fishery was closed much of this period and biomass was at very low levels.

Figure 11. Environmentally-based harvest rate control rule for Pacific sardine as specified in the Coastal Pelagic Species Fishery Management Plan (PFMC 1998). For any given year, sea surface temperature (X-axis) is the running average sea surface temperature at Scripps Pier (La Jolla, CA) during the three preceding years. The exploitation fraction (Y-axis), which can range between 5-15%, is an explicit part of the algorithm used to determine the annual harvest guideline (quota) for the coastwide U.S. fishery – see Table 4. Open circles illustrate the sea surface temperature and exploitation fraction for recent years (1998-2001).



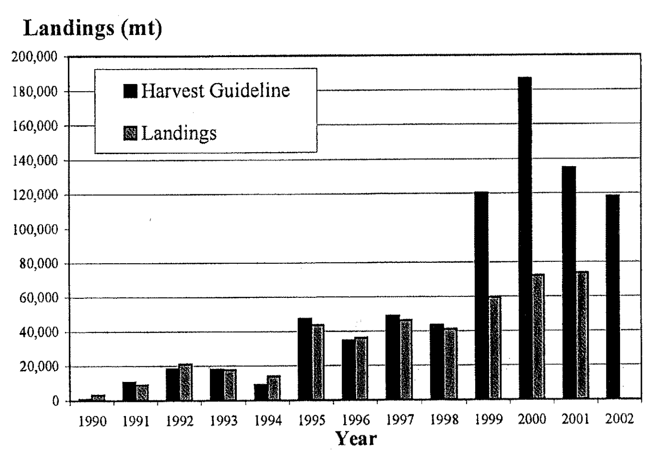


Figure 10. Ratio of Pacific sardine recruitment (1000's of 0-yr old fish) to stock biomass (Age 1+ in MT) during the previous year. Estimates of recruitment and Age 1+ biomass are taken from the stock assessment model (see Figures 7 and 8). Age 1+ biomass is used as a proxy for the spawning stock biomass of Pacific sardine.

Figure 12. Time series (1990-02) of Pacific sardine harvest guidelines ('quotas') and actual landings (mt). State-based (California) regulations were in place for 1990-99, with federal-based (California, Oregon, and Washington) regulations beginning in 2000. Note that landings in 2001 represent an estimate projected through the end of the year. The 2002 harvest guideline is based on the 2001 stock biomass estimated in this assessment (Figure 7).

Exhibit H.3
Situation Summary
November 2001

PACIFIC SARDINE HARVEST GUIDELINE FOR 2002

Situation: Per the coastal pelagic species (CPS) fishery management plan (FMP) annual cycle, the Council is scheduled to review the Pacific sardine stock assessment and adopt a recommendation to the U.S. Secretary of Commerce for a harvest guideline for the 2002 Pacific sardine fishing season. The current harvest guideline (which expires December 31, 2001) is 134,737 mt (based on a biomass estimate of 1,182,465 mt). The current stock assessment and harvest guideline recommendation are summarized in Exhibit H.3, Attachment 1.

Annually, the harvest guideline is divided between northern and southern sub-areas. For 2001, the north and south allocations were 44,912 mt and 89,825 mt, respectively. The location dividing the northern and southern sub-areas is Point Piedras Blancas, on the central California coast.

The CPS Management Team (CPSMT) and the CPS Advisory Subpanel (CPSAS) have reviewed the assessment and the recommended harvest guideline. They will present their respective advice to the Council. The advisors will also present an update on the review of CPS stock assessment methods.

Council Action:

1. **Adopt Pacific sardine harvest guideline and sub-area allocation for 2002.**
2. **Guidance about how to proceed with review of CPS stock assessment methods.**

Reference Materials:

1. Exhibit H.3, Attachment 1, *Status of the Pacific Sardine Resource and Fishery in 2001 With Management Recommendations for 2002.*
2. Exhibit H.3.b, Supplemental SSC Report. received 11-1-01
2. Exhibit H.3.b, Supplemental CPSMT Report. received 11-1-01
3. Exhibit H.3.b, Supplemental CPSAS Report. received 11-1-01

PFMC
10/11/01