

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
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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:

$$DML = a T^b$$

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 defensible 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 pre-season 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 $F_{40\%}$, 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.

Status of the Stock Relative to Commonly-Used Reference Points (such as F40%)

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 determinate 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 of 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 auxiliary index of abundance for surplus production modelling Summarized by population positive tows
Midwater trawl survey	NMFS-Tiburon	Farrallons to Monterey Bay 1987 - present	
Midwater trawl survey	Oregon predator and Salmonid surv	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 auxiliary 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 Hammer, 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	
Jagiello	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	

Recommendations for Market Squid Management and Research
Coastal Pelagic Species Management Team Supplemental Report

Pacific Fishery Management Council Meeting
DoubleTree Hotel-Columbia River
Portland, OR 97217

September 10-14, 2001

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 Niño/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 (ν). The CPSMT recommended that the preferred model scenario be based on $M = 0.15$ and $\nu = 0.45$ (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 $\nu = 0.45$. 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 Niño 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.

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON
FINAL REPORT ON MARKET SQUID MAXIMUM SUSTAINABLE YIELD
METHODOLOGY WORKSHOP

At the Council's request, the Scientific and Statistical Committee (SSC), in conjunction with the California Department of Fish and Game (CDFG) and the National Marine Fisheries Service (NMFS), held a market squid maximum sustainable yield (MSY) methodology workshop in May of 2001. Dr. Paul Crone of the Coastal Pelagic Species Management Team (CPSMT) presented an overview of the various modeling approaches, and provided considerable detail on the egg escapement approach to assessing the market squid resource. SSC member Dr. Raymond Conser, co-chair of the squid Stock Assessment Review (STAR) Panel, briefed the SSC on the panel's report.

The squid MSY workshop was a highly successful collaboration among CDFG, NMFS, and the SSC. This collaboration was essential to the assembly and analysis of all available biological and fishery data. The panel provided a thorough review of the data and alternative approaches to the squid MSY problem. All of these efforts resulted in productive and timely completion of the review.

The STAT Team and STAR Panel worked together in refining a yield-per-recruit approach based on egg escapement, and both groups recommend this policy for monitoring status of the squid stocks. There are two parts to the egg escapement approach, 1) eggs produced per female in the catch, and 2) recruitment to the spawning grounds. Squid recruitment is highly variable and probably environmentally driven. The egg escapement approach requires an estimate of remaining eggs per female at the time of capture by the fishery. CDFG port samplers are collecting the specimens needed to make this estimate on a seasonal basis. It will be important to provide continuing support for this sampling and for the laboratory work needed to count the eggs.

The egg escapement approach developed by the STAT Team and further refined during the STAR Panel process provides a sound basis for developing a harvest control rule that is based on biological principles. However, there is a continuing need to address uncertainties in the science that were identified during the workshop. To this end, the SSC supports the idea of a STAR Panel review in 2004. It will also be important that the CPSMT develop precautionary management options that reflect uncertainties in the science. The SSC looks forward to reviewing this work as it is incorporated into Amendment 10 of the CPS Fishery Management Plan.

PFMC
09/13/01

FINAL REPORT ON
MARKET SQUID MAXIMUM SUSTAINABLE YIELD METHODOLOGY WORKSHOP

Situation: In May 2001, a workshop was held to review market squid stock assessment methods. The workshop was, in part, to address disapproved provisions in the Pacific Fishery Management Council's (Council) coastal pelagic species (CPS) fishery management plan (FMP); specifically, maximum sustainable yield (MSY) for market squid. A principal workshop goal was to investigate ways to integrate squid research into the Council's CPS FMP.

The workshop chairs will present a final report to the Council. The Scientific and Statistical Committee reviewed the workshop report and will provide their recommendations to the Council.

In addition, the CPS Management Team and Advisory Subpanel will provide reports to the Council discussing how best to incorporate the workshop findings into the CPS FMP.

Council Task: Discussion and guidance regarding market squid maximum sustainable yield and its relevance to the CPS FMP amendment.

Reference Materials:

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

PPMC
08/15/01



Washington
Department of
**FISH and
WILDLIFE**

Preliminary Report of the 2001 Trial Purse Seine Fishery for Pacific Sardine (*Sardinops sagax*)

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September 2001

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**WASHINGTON DEPARTMENT OF FISH AND WILDLIFE
PRELIMINARY REPORT OF THE 2001 TRIAL PURSE SEINE FISHERY
FOR PACIFIC SARDINE (*Sardinops sagax*)**

Background

In Washington, sardines are managed under the Emerging Commercial Fishery provisions as a trial commercial fishery. A trial commercial fishery allows the harvest of a newly classified species, or harvest of a previously classified species in a new area or by new means (WAC 220-88-010). In February 2001, in response to a request from Washington-based fishers and processors, the Washington Fish and Wildlife Commission approved a trial ocean purse seine sardine fishery for 2001.

The target of the trial fishery was sardines; however, anchovy, mackerel, and squid could also be landed. These coastal pelagic species (CPS) are managed by the Secretary of Commerce through the Pacific Fishery Management Council (PFMC) under a federal fishery management plan (FMP). By definition, a Washington trial commercial fishery cannot limit participation, and under current law, an experimental fishery (which allows participation to be limited) cannot be established for any fishery under the jurisdiction of the Secretary of Commerce (i.e., a federally managed fishery) (WAC 220-88-020).

Current limited entry provisions and direct harvest controls have been developed in the FMP for waters south of 39° N latitude which encompasses most of the distribution of the CPS stocks and fisheries. This leaves specific management measures north of 39° N latitude (Oregon and Washington) up to the state management agencies, as long as those management measures conform to the overall guidelines of the FMP. PFMC develops and adopts separate annual harvest guidelines for the two areas which take into account the biological and ecological impacts of harvesting forage fish. State fishery management measures must be developed to ensure that the harvest guidelines are not exceeded.

Goals and Objectives

The goals for this trial fishery were to provide fishing opportunity consistent with the Pacific Fishery Management Council's CPS FMP and Washington Department of Fish and Wildlife (WDFW) policy, collect information on sardines off Washington to improve the coastwide stock assessment, and document the extent of bycatch occurring in the fishery.

Objectives include:

- Collect length, weight, age, sex, and maturity data from the catch landed into Washington.
- Document bycatch, in terms of species, amount, and condition. Recommend management measures to reduce bycatch, as necessary.
- Document harvest methods, distribution of harvest, and catch per unit of effort.

Fishery Regulations

The trial fishery began on May 15 and is scheduled to continue through October 31, 2001. The fishery is being managed to a harvest guideline of 15,000 mt. Purse seine fishers were regulated by a set of permit conditions (see Appendix A).

Fishery Description

The fishery opened on May 15, 2001; however, the first landing into Washington occurred on June 19. To date, the Department has issued a total of 32 permits and 12 permit holders have participated in the fishery.

As of August 31, a total of 9,037 mt of sardines were landed into Washington which leaves 5,963 mt remaining in the Washington harvest guideline. A total of 242 landings were made and 127 occurred within the month of July. The majority of the landings (75%) were made into Ilwaco, and 56% of the catch occurred in waters south of the Columbia River. A comparison between the 2000 and 2001 seasons is contained in Table 1.

Table 1. Catch comparisons between 2000 and 2001 trial sardine fisheries.

	2000	2001
Sardine Harvest	4,791.4 mt	9,037 mt
# of Landings	153	242
# Vessels Participating	3 (88%)	12

Observer Coverage/Logbooks

The purpose of requiring observer coverage is to document total catch and bycatch in the purse seine fishery. Bycatch has been recorded in terms of species, amount, and condition; observers noted whether the fish were released or landed, and whether the fish were alive, dead, or in poor condition. The Department has been aiming for 30% coverage and averaged about 24% overall.

So far, all of the vessels participating in the fishery have chosen to utilize Department observers, rather than contract with private observer companies. A "sardine hotline" was established for fishers to notify the Department of their planned fishing activities so observer coverage could be scheduled accordingly. Observers have been in daily contact with the vessels to schedule onboard trips directly.

Fishers have been cooperative in allowing observers on board and in scheduling departure times and locations. In general, logbooks have been completed and submitted as requested.

Bycatch

Based on observer data, the bycatch of non-targeted species has been fairly low. Bycatch has included chinook and coho salmon, spiny dogfish, blue shark, and other species. Salmon and shark were the primary bycatch species of concern. To date, salmon and shark species have accounted for 1.8% of the overall bycatch, and there have been 23 observed chinook mortalities.

The preliminary expanded total bycatch of these species (in numbers of individuals) for the fishery, based on observer data, is contained in Table 2.

Table 2. Preliminary expanded observed bycatch data (in numbers of individuals) for the 2001 trial fishery and comparison to the 2000 trial fishery.

	Chinook (live)	Chinook (dead)	Coho (live)	Coho (dead)	Unident. salmon (live)	Shark (live)	Shark (dead)
2001	449	170	571	504	80	150	50
2000	38	3	276	116	7	169	31

Biological Samples

Department staff have collected 53 biological samples of 25 sardines each (1,325 sardines total)—of these, 31 samples have been processed to date. Otoliths were extracted which measured about 1.5-3 mm in length; these otoliths were sent to the California Department of Fish and Game (CDFG) laboratory in LaJolla for age-reading.

Data sheets accompanied the otoliths which included the catch date, vessel name, standard lengths of the sardines, individual weights, sex, and maturity.

Sex and maturity were determined by using the CDFG Standard Maturity Guide for Wetfish which was based on Hjort, J. (1914) State of Sexual Organs. Sexual maturity codes 1-4 were used for the sardine samples:

<u>Code</u>	<u>Description</u>
-------------	--------------------

- | | |
|-----|--|
| (1) | Virgin individuals. |
| (2) | Maturing virgins or recovering spent. |
| (3) | Sexual organs becoming swollen. |
| (4) | Ovaries and testis nearly filling 2/3 of ventral cavity. |

The majority of the samples analyzed were males (53%), with most of them having a sexual maturity of 1 or 2. The highest subcategory overall were females with a sexual maturity of 2. There was one male and one female with a sexual maturity of 4.

Standard lengths of sardine samples were taken and ranged between 116 mm and 250 mm. In general, the average lengths of the samples decreased slightly over time. Average length overall was 211 mm.

Individual weights of sardine samples (n=50) were also taken and ranged between 27.1 g and 242 g. The average weight was 154.4 g.

Summary of WDFW Activities

Coastal Marine Fish staff developed the processes to implement the trial fishery and administered the observer program, notification process, port sampling, data recording, and biological analyses. Two additional full-time observers were hired and existing staff were utilized to augment our observer program and conduct dockside sampling. The observers worked onboard commercial fishing trips to document bycatch, determine catch composition, and collect market samples.

Samplers monitored unloading at processing plants for incidental catch data, weighed sub-samples of the sardine catch, and collected logbooks to determine harvest distribution, CPUE, and unobserved bycatch information. Additional staff time has been spent extracting otoliths, measuring, weighing, and determining sex and maturity of samples, and summarizing observer and logbook information.

**2001 TRIAL PURSE SEINE FISHERY FOR PACIFIC SARDINES
DEPARTMENT STAFF RECOMMENDED PERMIT CONDITIONS**

As adopted by the Fish and Wildlife Commission on February 9, 2001

Permits

- Participants are required to have an Emerging Commercial Fisheries License (\$185 for residents; \$295 for non-residents) and a trial commercial fishery permit issued by the Director.
- Permits are non-transferable and must be carried on the fishing vessel during harvest and sale of catch.
- The permit is subject to revocation by the Director for failure to abide by the conditions of the permit, violation of other fishing regulations, or other valid reason.
- Permits will not be issued to (and may be revoked from) those who: 1) have an outstanding balance of fees owed to the Department for greater than 30 days; or 2) did not comply with the permit conditions of the previous years' fisheries. This decision will be at the discretion of the Director and may be waived if special circumstances warrant.

Season

- Permits would be valid during the time period of May 15, 2001 to October 31, 2001.

Harvest Guideline

- The fishery would be managed to a harvest guideline of 15,000 mt landed into Washington. If the fishery is projected to exceed the guideline, the Director may adjust the harvest guideline or close the fishery.

Observer Coverage

- WDFW retains the right to require certified observers to be on-board for the duration of any trip harvesting sardines and the Director has the discretion to recover costs for observer coverage.
- Options for observer coverage are:
 1. Use a Department-provided observer - The Department will have observers available; fishers electing this option would need to reimburse the Department at a rate of \$100 per landing (even if the trip was not observed) and payment must be received by the 10th day of each month for the previous month's landings; OR
 2. Hire a NMFS-certified observer - Fishers may contract with an independent observer company to hire NMFS-certified observers; these observers would need to complete a training session with the Department prior to observing a trip. Fishers electing this option are required to have a minimum of 50% of their trips observed and their first fishing trip observed.

- Fishers must notify the Department which option they are electing for observer coverage at least 48 hours prior to their first fishing trip of the season; this option cannot be changed during the season without approval by the Director.

Notification

- Each fisher participating in the trial fishery must contact the Department's fishing hotline during official business hours (Monday-Friday; 8:00 a.m.-5:00 p.m.) at least 48 hours prior to departing for their first fishing trip, and at least 24 hours prior to departing for their subsequent fishing trips. On the message hotline, fishers are required to provide the following information:
 - Name
 - Phone number to contact fisher
 - Time and location of departure
 - Estimated time of return

NOTE: This notification requirement may be waived if other arrangements are made with individual fishers and/or processors.

Data Collection

- Participants must identify the vessel to be used in the fishery and agree to carry WDFW employees on board the fishing vessel whenever fishing under the permit. Agency employees will be granted full access to the catch and be allowed to gather biological data as needed. Up to 500 sardine per day may be retained by WDFW for biological information.
- Logbooks are required and will be provided by WDFW. Logbooks must be returned to WDFW by November 15, 2001.

Gear

- The trial fishery is open to purse seine gear only, and gear specifications will be detailed to ensure that the net meets a purse seine definition.
- Legal purse seine gear must be onboard the vessel making the landing.

Species

- Participants may retain and sell sardine and incidental catches of mackerel, squid, and anchovy. All other species must be released immediately and care taken to minimize damage to prohibited species.
- No salmon may be landed on the boat's deck but must be released or dip netted directly from the net before the completion of each set.
- Consistent with standards in the offshore whiting fishery, a mortality greater than 1 chinook per 20 mt of Pacific sardine would be sufficient to rescind a permit or close the trial commercial fishery.

Fishing Area

- The fishery would be restricted from the area inside 3 miles to minimize bycatch, conserve forage fish, and reduce conflicts with the existing baitfish fishery.

Landings

- All landings made under the authority of this permit into Washington must comply with existing state and federal regulations and requirements including observers.
- The transfer of catch from one vessel to another vessel is prohibited.

Part of CDFG Report
 9-14-01 Supplemental CDFG Report
 Exhibit H.3.b.iii

U.S. West Coast Sardine Landings (Metric Tons), Jan-Aug 2001

	So. Calif.	No. Calif.	Oregon	Washington
Jan	8,932	668	0	0
Feb	6,753	8	0	0
Mar	6,759	0	0	0
Apr	1,989	97	0	0
May	3,543	0	0	0
Jun	1,121	0	2,273	49
Jul	1,542	1	4,449	4,906
Aug	3,790	1	4,021	4,083
Total	34,430	776	10,743	9,038

	Season Summary Jan-Aug, 2001		
	South	North	U.S. Total
Harvest Guideline (HG)	89,825	44,912	134,737
Landings	34,430	20,557	54,987
Remaining HG	55,395	24,355	79,750

COASTAL PELAGIC SPECIES MANAGEMENT TEAM REPORT ON
PACIFIC SARDINE FISHERY UPDATE

At the August 14-15 meeting of the Coastal Pelagic Species Management Team (CPSMT), the CPSMT held a discussion on the status of the 2001 Pacific sardine fishing season. State representatives provided brief overviews of landings to date, along with projections for the remainder of the year. Landings and remaining harvest guidelines for northern and southern allocation areas were discussed with respect to the October 1 reallocation authorized by the fishery management plan (FMP). The Oregon and Washington fisheries have had relatively high landings to date, but the Monterey, California fishery has had negligible landings due to poor resource availability. The Monterey fishery is anticipated to increase in the fall if a more typical season resumes. Given the possibility that the Oregon and Washington fisheries could preempt the Monterey fishery from the northern harvest guideline, the CPSMT recommends that the October 1 reallocation schedule, as specified in the FMP, be executed. This will ensure the harvest guideline is achieved, and the Monterey, California fishery is provided opportunity to harvest a reasonable share of the harvest guideline.

PPMC
09/11/01

PACIFIC SARDINE FISHERY UPDATE

Situation: The Pacific sardine fishing season began January 1, 2001 with a harvest guideline (HG) of 134,737 mt. The harvest guideline is allocated for Subarea A, north of 35° 40' N latitude (Pt. Piedras Blancas) to the Canadian border, and Subarea B, south of 35° 40' N latitude to the Mexican border. The northern allocation is 33% of the HG (44,912 mt); the southern allocation is 66% of the HG (89,825 mt). The HG is in effect until December 31, 2001, or until it is reached and the fishery closed.

Per the fishery management plan (FMP), nine months after the start of the fishing season (in this case, October 1, 2001) any uncaught portion of the harvest guideline will be totaled and reallocated with 50% of the total allocated to the northern area and 50% of the total allocated to the southern fishery area. The FMP authorizes National Marine Fisheries Service (NMFS) to reallocate the HG as an "automatic measure," which is an action that could be initiated by NMFS without prior public notice, opportunity to comment, or a Council meeting.

Landings information for the 2001 fishery will be reported to the Council. Fisheries occur in waters off California, Oregon, and Washington; and each state monitors their respective fisheries. The states may also report to the Council about specific aspects unique to their fisheries.

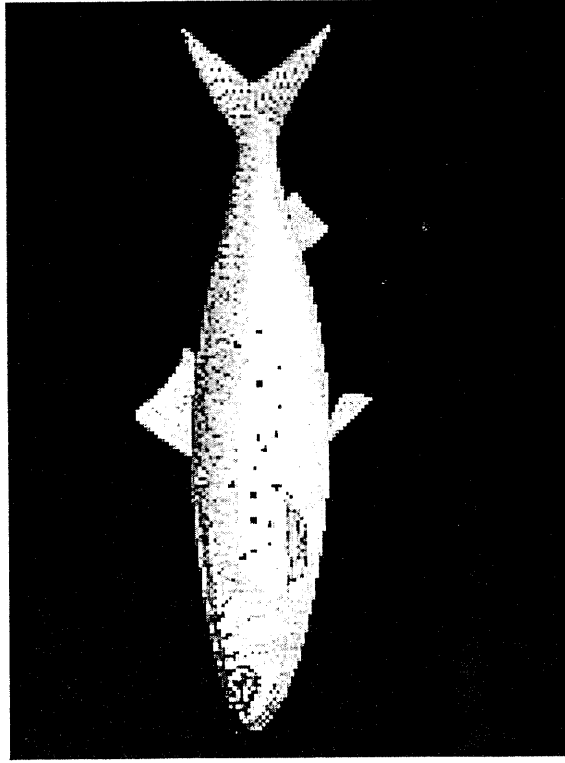
Council Action: Consider inseason management measures.

Reference Materials:

1. Exhibit H.3.b, Supplemental Reports from Coastal States
2. Exhibit H.3.c, Supplemental CPSMT Report.
3. Exhibit H.3.c, Supplemental CPSAS Report.

PPMC
08/23/01

Preliminary Report of the Oregon and Washington



Developmental and Trial Sardine Purse Seine Fisheries

Sardine Landings (mt)

1999 – August 31, 2001

	Oregon	<u>Washington</u>
2001	10,743	9,038
2000	9,516	4,791
1999	771	0

2001 Fishery Description

	<u>Oregon</u>	<u>Washington</u>
# Landings	390	242
# Permits	20	32
# Vessels	11	12
# Processors	5	4-5
% Catch off	82% OR	56% OR
OR/WA	18% WA	44% WA

Monitoring/Reporting

Oregon

Logbook coverage: 81%

Observed trips: 20

Washington

Logbook coverage: 100%

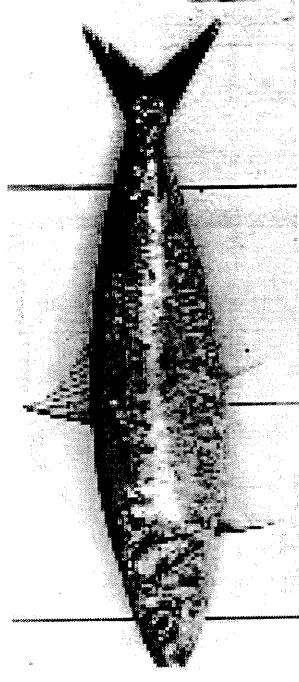
Observed trips: 60



Observed Bycatch (#s of individuals)

	<u>Oregon</u>	<u>Washington</u>
Chinook (live)	2	24
Chinook (dead)	2	23
Coho (live)	9	49
Coho (dead)	6	82
Unid. salmon (live)	2	18
Spiny dogfish	29	18
Thresher shark	1	0
Blue shark	1	9
Other shark	1	1

Biological Samples



	<u>Oregon</u>	<u>Washington</u>
# Samples	32	31
Avg Weight (g)	151.5	154.4
Avg Length (mm)	210	211

U.S. West Coast Sardine Landings (Metric Tons), Jan-Aug 2001

	So. Calif.	No. Calif.	Oregon	Washington
Jan	8,932	668	0	0
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