Agenda Item E.1.b
Supplemental NWFSC Report 3
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Pre-Recruit Survey Workshop

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Southwest Fisheries Science Center

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Executive Summary

In 1983 the Southwest Fisheries Science Center (SWFSC) initiated a midwater trawl survey to collect data on, among other things, the abundance and distribution of young-of-the-year (pre-recruit) groundfish, including especially rockfishes of the genus *Sebastes*. Through 2003 this survey was narrowly focused in an area off the coast of central California from lat. 36º30'– 38º20' N. In 2001 a new pre-recruit survey conducted cooperatively by the Northwest Fisheries Science Center (NWFSC) and the Pacific Whiting Conservation Cooperative (PWCC) was initiated, with the primary intent of monitoring young-of-the-year Pacific whiting abundance. The initial coverage of this survey ranged from lat. 35º00' N (just south of Morro Bay CA) to lat. 45º00' N (just north of Newport OR). Beginning in 2004, the geographic extent of both surveys was expanded, so that by 2005, the combined area of both surveys covered the entire U. S. west coast, from the Canadian to Mexican borders (lat. 33 º00'– 48 º00' N).

A workshop focusing on the integration of data from these two pre-recruit surveys in west coast groundfish stock assessments was held September 13-15, 2006 at the SWFSC facility in Santa Cruz, CA. The workshop was organized and moderated by Steve Ralston (SWFSC) and Jim Hastie (NWFSC), with substantial organizational and logistical support from Stacey Miller and Shirley Lee (NWFSC) and Jacki Davis (SWFSC).

Workshop Organization and Objectives

The workshop was attended by over 20 people, including individuals involved in conducting both pre-recruit surveys, stock assessment scientists, and the public. The workshop was structured as an informal series of presentations and discussions focusing on two primary and two secondary questions.

The two primary questions addressed by the workshop were:

1. Can survey data collected by the **R/V David Starr Jordan** (SWFSC) and the **F/V Excalibur** (PWCC/NWFSC) be combined into single coast-wide indices of Pacific whiting and rockfish pre-recruit abundance?

2. Is a power transformation an acceptable way of modeling non-linearity in early life history processes and, if not, what other analytical techniques are more appropriate?

Two questions of secondary importance were:

3. What processes (e.g., density-dependent mortality, measurement error) affect the relationship between survey indices of pre-recruit abundance and model estimates of recruitment?

4. How influential are pre-recruit survey data on: (a) estimated historical times series of stock abundance and (b) projections of near term future abundance? Related to this, how can the informational value of a pre-recruit survey to a stock assessment be evaluated?

Twelve scheduled presentations were organized into three sessions (agenda attached as Appendix 1):

Session 1. Developing a Coast-wide Survey of Groundfish Pre-Recruit Abundance
Session 2: Incorporating Pre-Recruit Indices in Stock Assessments
Session 3: Case Studies

Each session included opportunities for discussion based on individual presentations and for identification of emergent areas of participant agreement relating to the focal questions of the workshop. Additionally, the overall themes of the workshop were discussed by participants in a wrap-up session.

Workshop Areas of General Agreement

Throughout the course of the workshop's discussions, several findings and suggestions for future surveys, research, and/or applications were broadly supported by participants. With respect to question #1 (see above) participants concluded the following:

1. For species that are distributed exclusively or predominantly north of Point Conception, data from the 2001-06 combined surveys provide acceptable spatial coverage for creating a coast-wide index. The combined spatial coverage during 2004-06 is reasonable for all species, including those with substantial catches taken south of Point Conception. However, the spatial coverage of the SWFSC survey during the 1983-2000 period is largely inadequate to index pre-recruit abundance for most species, particularly where coastwide assessment areas are used in population modeling. However, future research may identify oceanographic covariates that may explain the distribution of young-of-the-year groundfish within and outside of the core SWFSC survey area. This may increase the value of this longer time series for assessing a broader array of species. The core SWFSC survey area appears to represent the preponderance of the distribution of a few species reasonably well (e.g., chilipepper), but may also prove useful in region-specific modeling for other stocks that have a more coast-wide distribution (e.g., widow rockfish).

2. Comparison of methods and patterns in catch rates currently indicate that the SWFSC and PWCC/NWFSC surveys are sufficiently similar that data from the two surveys can be combined to form a single pre-recruit index over the area covered. However:
    a. Detailed and more rigorous statistical comparisons of paired trawl observations should continue.
    b. The two surveys should continue to be executed with substantial spatial overlap, though perhaps less than at present, with as many proximate (paired) trawls as feasible in the overlapping region.
    c. To the extent practicable, the number of within-year (time-separated) replicate tows at specific locations should be increased, in order to assess the effect of survey timing (calendar day) on catch rate. Data from monthly trawls conducted by the NWFSC's Newport facility may provide insight regarding the availability of young-of-the-year groundfish to the NWFSC/PWCC survey.

d. Further analysis should be conducted of survey comparability relating to differences in station depth. Ideally, both surveys should use the same site depth/dispersion protocols, but tradeoffs should be better understood before protocols of either survey are changed. Post-stratification of the data by depth and latitudinal bins may be an effective way to accomplish this.

3. In the future, an effort should be made to determine to what extent under-counting of rockfish adhering to large discarded objects (e.g., jellyfish) in PWCC/NWFSC trawls may have contributed to inter-survey differences in catch at proximate tow locations.

4. Existing data from (time-separated) replicate tows in the SWFSC data should be analyzed to assess the potential magnitude of variance and bias effects associated with varying numbers of replicate tows.

5. More effort should be directed towards developing an error budget for the surveys, i.e., inventorying possible sources of variance and what we know about them. This exercise could provide useful guidance when tuning pre-recruit survey indices in assessment models.

6. Alternative General Linear Model (GLM) formulations should be explored for developing pre-recruit abundance indices. In particular, the potential benefits of replacing sampling stations with broader latitudinal and depth zones and introducing interaction terms, should be examined. Additionally, mixed-model (GLMM) forms should also be explored, for example, by treating calendar day as a random effect.

7. As more data become available and the development of regional ROMS (Regional Ocean Model System) or other oceanographic models progresses, their outputs may help in identifying the manner in which meso-scale ocean variability affects the abundance and distribution of young-of-the-year groundfish. A better understanding of these relationships may facilitate improvements in pre-recruit survey design or interpretation of results.

Moreover, with respect to question #2 (see above) participants concluded:

1. It was generally agreed that substantial density-dependent compensatory mortality can occur following measurement of pre-recruit abundance at the ontogenetic stage sampled by the surveys (e.g., 100-d). If compensation is substantial, then non-linearity will be introduced in the relationship between “pre-recruit” and “recruit” abundance.

2. When non-linear transformation of an index is considered, the transformation should be conducted internally within the stock assessment model as an explicit part of the estimation procedure.

3. Recent development of a new SS2 option to include an expectation of density-independent pre-recruit abundance may preclude the need for transformation.

Comparative work to evaluate this issue should be performed, with a good candidate being southern widow rockfish.

4. Implementing a stochastic pre-compensation ontogenetic stage (e.g., 100-d) and a subsequent post-compensation stage in SS2 would be a more direct and biologically realistic way of addressing #3 above. However, it is unclear how to deal with the errors-in-variables problem.

5. It is important to evaluate the degree to which non-linear transformation of pre-recruit survey indices is confounded with tuning to the model's RMSE. Transformation and variance inflation should be conducted jointly.

6. The costs and benefits of using pre-recruit survey information in short-term forecasts are asymmetrical, i.e., the costs of "over-fishing" are likely to be substantially greater than the costs of "under-fishing". This asymmetry should be addressed explicitly by management if pre-recruit indices are used for forecasting. This could be accomplished through the use of decision tables or a "precautionary" control rule.

7. The Pacific whiting case study provided a good example of how to proceed in the next hake stock assessment.

Aside from their use in short-term forecasts of impending recruitment, pre-recruit surveys have the potential to provide significant insights into ecosystem dynamics, including:

- monitoring of epipelagic micronekton species diversity
- sensitivity of sampled taxa to high-frequency environmental variation
- monitoring of "small" forage species for use in trophic models
- potential for early detection of regime shifts (e.g., indicator species)
- may provide information useful in retrospective studies of "what happened?"
- sampling is consistent with the ocean observing system (OOS) concept/framework.

Nonetheless, the workshop was not able to definitively answer the question of the survey's utility in forecasting recruitments. The short duration of the "coastwide" survey (2001-06) was considered inadequate to accomplish that goal. Therefore, the surveys should be continued for another 5 years and their ability to provide useful information to recruitment forecasts should be re-evaluated at a future workshop.

Pre-Recruit Survey Workshop: Presentation Summaries

Session 1. Developing a Coast-wide Survey of Groundfish Pre-Recruit Abundance

Long-term variability in abundance of pelagic juvenile rockfishes in central California based on results from the Tiburon/Santa Cruz midwater trawl survey

Stephen Ralston, of the Southwest Fisheries Science Center (SWFSC) in Santa Cruz, opened the workshop by providing a historical overview of the SWFSC Tiburon/Santa Cruz midwater trawl survey. This discussion covered the evolution of the survey's spatial coverage and design, as well as the composition and historic variability of the catch of YOY rockfish in the core, central California survey area, and the methods used in estimating abundance. Every year since 1986, during late spring, the NOAA R/V *David Starr Jordan* has been used to triple-sample roughly 35 fixed stations along latitudinal transects distributed from Pt. Reyes (38°10' N latitude) south to Monterey (36°35' N latitude). Beginning in 2004, the spatial coverage was expanded from Pt. Delgado (39°50' N latitude) south to San Diego (32°43' N latitude). Within the expanded areas of coverage, stations are generally sampled twice, although triple-sampling has been maintained in the core area. Survey trawls are conducted at night for 15 minutes at a speed of 2 knots. A headrope depth of 30 m is maintained, unless bottom depth is 55 m or less, in which case the headrope depth is set at 7 m. Net performance is monitored using Simrad ITI sensors and TDRs. A 3/8" mesh liner is used in the trawl net's codend.

Given its timing, the survey is best-suited for collecting information about winter-spawning rockfish. Shortbelly rockfish (*S. jordani*) has dominated the catch of these species throughout the survey, accounting for more than two-thirds of the YOY rockfish collected. Other important species that are routinely collected in the survey include (in order of amount): chilipepper (*S. goodei*), widow rockfish (*S. entomelas*), squarespot rockfish (*S. hopkinsi*), blue rockfish (*S. mystinus*), canary rockfish (*S. pinniger*), yellowtail rockfish (*S. flavidus*), bocaccio (*S. paucispinis*), stripetail rockfish (*S. saxicola*), and black rockfish (*S. melanops*). However, none of these species comprise more than 10% of the historical rockfish catch. Though these species represent a limited number of all rockfish species found along the coast, they represent a wide array of life histories, ecological niches, and exploitation patterns.

Typically, catch is comprised of individuals that are roughly 150 days old. By this age, for most cohorts, it is very likely that gross-level year-class strength has been established. Survey abundances of yellowtail rockfish, canary rockfish, widow rockfish, bocaccio, and black rockfish are positively correlated, to varying degrees, with cohort recruitment estimates from existing stock assessments for those species. Survey abundance estimates were developed using a Generalized Linear Model (GLM), incorporating year, station, and calendar date effects. Data were treated as sampled from a delta-lognormal distribution, with a binomial probability of positive catch occurrence, and a lognormal distribution of positive catch amounts. The catch of each species was adjusted to a common age (100 days) to account for substantial inter-annual variability in length composition. Across the ten species identified above, year effects exhibited substantial positive correlations, with most pairwise coefficients falling between 0.65 and 0.85. In particular, major El Niño events were associated with low abundance estimates for most species. In a principal components analysis, over 75% of the variation in survey abundance was accounted for by the first component, which exhibited a strong negative correlation with sea-surface height. Low abundances were generally associated with stronger pole-ward flows in the California current, and high abundances with stronger equator-ward flow. These results provide strong evidence that large-scale spatial and temporal oceanographic phenomena have a major influence on early life-stage rockfish survival and eventual recruitment success.

Bayesian hierarchical methods in estimating the abundance of pelagic juvenile rockfish from survey data

E.J. Dick, of the SWFSC in Santa Cruz, continued the discussion of their survey data and potential methods for modeling abundance. Survey observations for individual species are characterized by a high percentage of zero values, with highly skewed positive distributions. A negative binomial model is not skewed enough to fit these data, and both that approach and other zero-inflated models (e.g., ZIP and ZINB) present challenges in accounting for the adjustment of samples to reflect fish of age 100 days.

The Delta-GLM approach models the age-adjusted data using continuous probability density functions, however, a few issues remain with regard to pre-recruit abundance estimation, and are currently being explored. One of these involves approaches for quantifying uncertainty in the GLM's year effects. A jackknife approach is conceptually simple, but requires the removal of any category containing only 'zero' observations. This is problematic for working with a survey where, for most species, the vast majority of observations are, in fact, zeros. Other approaches might involve estimating indices within assessment models or employing Bayesian methods.

Another issue involves the current modeling assumption that there is no relationship, for a particular species, between the probability of getting a positive tow and the expected amount of catch. For several species, positive correlations are observed between the proportion of positive tows and the mean value of the positive observations. One way of incorporating this relationship would be to allow the information on presence/absence to inform the specification of priors for the positive (e.g. lognormal) portion of the delta-GLM. Since several species of rockfish appear to have highly correlated inter-annual variability and substantial dietary overlap at this life stage, it may also make sense to consider sharing information across species. Linking individual species' GLMs in a Bayesian framework may provide a method for taking better advantage of common patterns among species. Additionally, development of meta-analytic priors using relatively data-rich species may prove particularly beneficial in developing pre-recruit abundance indices for data-poor species.

A comparison of rockfish catches in the SWFSC and PWCC/NWFSC mid-water trawl surveys from 2001-2006

Keith Sakuma, of the SWFSC in Santa Cruz, provided comparisons of both the protocols for implementing the their survey and the newer joint PWCC-NWFSC survey, and survey performance. Temporal and spatial patterns in combined species catch from both surveys were also presented. The annual PWCC-NWFSC survey was initiated in 2001, and has utilized the

F/V *Excalibur* in each year. Both surveys utilize the same gear, sample at the same headrope depth, have similar gear-deployment durations (2.6 vs. 2.8 minutes), and trawl for the same amount of time. Comparison of paired vessel side-by-side trawls conducted from 2002 to 2006 revealed a mean difference in distance trawled between the two vessels of 0.1 km or less in each year. In 2002-03, a substantial difference (121-139 m) in the mean bottom depth associated with the paired trawls was observed. However, this was attributed to the amount of testing done in the vicinity of Monterey Canyon, where small differences in position can result in large changes in bottom depth. From 2004 on, the mean difference in bottom depth ranged from 35-63 m. Comparison of the mean difference in paired trawl vessel positions revealed a downward trend from roughly 1.2 km in 2002, to differences in the 0.3-0.5 km range in 2005-06.

Aggregate length distributions of all YOY rockfish caught in both surveys exhibited similar patterns across years in areas of survey overlap. Within the 'core area' there were between-vessel differences in the mean log-transformed catch for 2001-2002, but no observable differences for 2003-2006. The concentration of PWCC-NWFSC sampling near the continental shelf break in contrast to the high number of SWFSC stations on the continental shelf in shallower waters could have accounted for the differences in catch between the two vessels observed in 2001-2002. Regression analysis of inter-vessel differences in the amounts of rockfish caught in the comparison paired trawls indicated lower catch rates for the F/V *Excalibur*. However, this result was strongly influenced by a small number of trawls from a single year in which the NOAA R/V *David Starr Jordan* had much larger catches. It was noted that more complete inspection of large organisms (e.g. large jelly fish) for YOY rockfish aboard the NOAA R/V *David Starr Jordan* may account for some of the differences. Given the limited number of paired observations, particularly when close proximity of the vessels was used as a filter, the data were not viewed by those in attendance as being sufficient to establish a difference in catchability between the vessels. A comparison of YOY rockfish species richness in the catch of the two vessels showed greater similarity, particularly for paired trawls that were located within 0.3 nm of each other.

Developing a coast-wide survey to estimate inter-annual variation in pre-recruit abundance of Pacific whiting and a comparison of Pacific whiting catches in the SWFSC and PWCC/NWFSC mid-water trawl surveys from 2001-2006

Vidar Wespestad of the PWCC provided an overview of the evolution of the PWCC-NWFSC pre-recruit survey and addressed the development of a coast-wide index for YOY Pacific whiting (*Merluccius productus*). PWCC began conducting limited sampling for YOY Pacific whiting in 1998. The first standardized YOY survey was conducted jointly with the NWFSC in 2001, and has continued on an annual basis since then. In each year, the survey has been conducted aboard the F.V. *Excalibu*r, from Newport, Oregon. The survey utilizes protocols and gear which are similar to those used in the SWFSC survey. There are some differences in station depth between the two surveys, which are largely attributable to the PWCC-NWFSC survey's initial focus on YOY Pacific whiting off the continental shelf and the breadth of the continental shelf throughout much of the northern area. The geographic extent of the survey has expanded over time. From 2001-03, the survey was conducted between roughly 34- 45° N latitude. The survey's range was expanded northward to 47° N latitude in 2004, and to 48° N latitude in 2005.

The trends in mean catch of YOY Pacific whiting from both surveys are very similar. Both exhibit declines from 2001-2003, with increases in 2004, and very low levels in 2005-06. In paired vessel side-by-side trawl comparisons, Pacific whiting catch amounts in the PWCC-NWFSC survey were, on average, 40-50% of amounts caught in the SWFSC survey. However, similar to the YOY rockfish comparison, the difference was attributable to a few large catches from a single year. Annual mean lengths of YOY Pacific whiting caught in both surveys have been within 5-15% of each other since 2001, and both exhibit similar trends in mean length.

Inter-annual variation in the distribution of YOY rockfish on the US west coast and implications for survey utilization

Ian Stewart and Stephen Ralston presented an analysis of the latitudinal distribution of YOY rockfish catch observed by the combined SWFSC and PWCC-NWFSC surveys conducted in 2001-2006. They focused on exploring patterns of coherence among species groups, evaluating the implications of the broader survey area for the longer time-series of ‘core area’ (36-39^{o} N latitude) coverage.

This analysis included 10 rockfish species sampled during the years 2001-2006, when the combined coverage of the SWFSC and PWCC-NWFSC YOY surveys included spatial coverage of at least 35-45^{o} N latitude. Summaries were performed both with catch-weighted and normalized catches for blocks of 1-degree latitude. Three groups of species were identified: a ‘northern’ group including black rockfish, yellowtail rockfish, widow rockfish and canary rockfish for whom more than 70% of the normalized catch occurred north of the core-area, a ‘southern’ group including bocaccio, shortbelly rockfish and squarespot rockfish, for whom more than 50% of the catch occurred south of the core area, and a ‘central’ group, including stripetail rockfish and chilipepper, whose distribution was more or less centered on the core-area.

The distribution of observed catch in 2004-2006, when the combined surveys extended from 33-47^{o} N latitude, suggested that except for the three southern species, sampling in 2001-2003 probably effectively covered the range of most of the YOY present off the U.S. coast. Beginning in 2004, a bifurcation in the mean latitude of the catch of the northern and southern species suggests some directional change in YOY distribution, but this is confounded with changes in survey coverage. When converted to a z-score and compared across species, no clear trend over time is visible in the mean catch-per-unit-effort (CPUE) by species, although catches in 2006 are relatively low for most species. Further, no clear relationship between mean CPUE and mean latitude was observed.

Across all 10 species in 2001-2006 a relatively unimodal distribution of recruitment over latitude was observed. However, bocaccio and chilipepper both had two or more years with apparently bimodal distribution. When smoothed to reduce sampling effects, it appeared that the survey coverage in 2001-2006 likely captured most of the latitudinal distribution of the recruitment events for these 10 species. All years spanned more than 85% of the smoothed distribution. Consistent with other analyses, many of the modes of these events were centered in and around the core-area. Despite this central tendency, there was little evidence for a consistent fraction of the recruitment to occur in the core-area (implying constant catchability for that index); instead a nearly uniform distribution for the fraction in the core area was present across years and species. The coast-wide surveys over 2001-2006 indicate substantial variability in the abundance and spatial distribution of YOY catches.

The authors generally concluded that species within the 'northern' and 'southern' groups show coherent shifts in distribution. 'Meta-analysis' of the 10 rockfish species over 6 years implies that 1983-2000 core-area observations have relatively uniform spatial process error (Q's) and are unlikely to contribute significantly to most assessment results. Covariates to latitudinal distribution could be explored (e.g., sea level anomalies), which might allow better use of the 1983-2000 core-area observations. The 2001-2003 series appears to have captured much, but not all of the YOY distributions. Political boundaries (Canada and Mexico) remain a problem: they do not appear to coincide with breaks in recruitment distribution.

Session 2: Incorporating Pre-Recruit Indices in Stock Assessments

Rockfish early life history – stochasticity and compensation

Steve Ralston of the SWFSC delivered a presentation that was designed to focus attention on some of the biological properties of young-of-the-year marine fishes that are perhaps often unappreciated by stock assessment scientists. He reviewed a paradigm of the early life history of fish developed by Houde (1987) that is based on longstanding research into the "recruitment problem" as originally framed by the critical period hypothesis of Johann Hjort. The vast preponderance of research on marine fishes shows that factors affecting mortality during the early larval phase (e.g., 0-15 d) act in a density-independent manner, and that events in the larval phase are chiefly responsible for inter-annual variation in year-class strength. Another large body of research tends to show that density-dependent compensation in marine fishes occurs post-settlement (e.g., Sissenwine 1984; Fogarty 1993; Myers and Cadigan 1993). As a consequence of this type of early life history (stochasticity early – compensation late), one might predict a non-linear relationship between abundance during the pelagic juvenile stage and abundance at the time of recruitment to the fishery. In particular, non-linearity might be construed to be evidence of compensation, wherein high inter-annual variation in pelagic juvenile abundance is reduced, due to density-dependence by the time a year-class recruits. There is direct evidence of this occurring in west coast rockfish. In particular, Adams and Howard (1996) showed that the daily instantaneous mortality rate of settled YOY blue rockfish (Sebastes mystinus) during the latter half of their first year of life was density dependent, with mortality ranging from 0.001 d^{-1} at low densities to 0.008 d^{-1} at high densities. Others (Hobson et al. 2001; Johnson 2006) have shown similar results and have demonstrated, through both observational and experimental manipulations, that the biological mechanism of the density dependence is predation.

From the review of marine teleost early life history that was presented, Ralston concluded that: (1) small stochastic variation in larval mortality rates can create large differences in recruitment, (2) mortality in the egg/larval stage is largely density-independent, consistent with Hjort's critical period concept, (3) post-settlement density-dependent mortality of young-of-the-year is widespread, and (4) the fundamental process captured by the spawner-recruit relationship is population compensation. Those findings, therefore, imply that: (1) cohorts of pre-settled juvenile fish should show greater variance in numbers than the same cohorts at the age of recruitment, (2) a transformation of pelagic juvenile numbers to account for subsequent density-dependent mortality is appropriate based on biological first principles, and (3) the most logical transformation to use might be the spawner-recruit curve itself.

Temporal and spatial synchrony in recruitment of California Current groundfish based on age-structured stock assessments

John Field, of the Southwest Fisheries Science Center in Santa Cruz, reviewed spatial and temporal synchrony in physics and biological signals in the California Current System (CCS), with a focus on synchrony in recruitment variability for west coast groundfish. This began with a review of literature that describes similarities in physical conditions in the CCS (wind indices, upwelling, sea surface temperature, coastal sea level and transport) over spatial scales of 500 to 1500 kilometers, which have been attributed as key factors in shaping productivity and community structure. Many biological features also reflect such synchrony, for example covariation across similar spatial scales has been described in the literature for coho salmon and Dungeness crab in the California Current (interestingly there was little or no covariation in Chinook salmon survival), with similar patterns observed for salmon and herring in the Gulf of Alaska. Work by Field and Ralston also described similar spatial covariation in rockfish recruitment for chilipepper, widow and yellowtail rockfish, with major geographic boundaries (Cape Mendocino, Cape Blanco, Point Conception), appearing to account for mesoscale differences.

To evaluate temporal synchrony in recruitment, while avoiding confounding from stocks with different exploitation histories, recruitment deviation parameters (essentially, model process error) from assessments conducted in 2005 were evaluated using principal components analysis. Using recruitment deviations for all “reasonably specified” groundfish throughout the CCS, the first PC explained a fairly modest 25% of the variance (with largely positive loadings across a diverse group of taxa), and the second PC appeared to separate flatfish and near-shore roundfish from rockfish and offshore roundfish. By refining the analysis to these clusters, or to solely southern or northern stocks, the leading PC’s explained ~40 to 50% of the variance. One interesting difference is that recruitment deviations were largely negative in the 1990s for most rockfish and offshore roundfish (sablefish, hake), while they were largely positive for flatfish and near-shore roundfish (lingcod, cabezon, scorpionfish). The overall results suggested that temporal synchrony seems to be greatest for several suites of species, however it is also possible that integrating data coast-wide may mask covariation among other species over finer regional scales.

An Archaeological Example of a MSE on the Value of a Pre-Recruit Survey

Although it is widely believed that recruitment estimates would be valuable for stock assessment and management, the question requires examination by a formal Management Strategy Evaluation (MSE). Alec MacCall reviewed results from a MSE conducted by him and others

(Huppert *et al*. 1980) for northern anchovies (a highly recruitment-dependent fishery), which did not support this belief. If there is no explicit management response to a recruitment estimate, the problem becomes identical with that of estimating biomass, and under constant harvest rate management, there is very little benefit to be obtained from increasing precision. The anchovy MSE developed a risk averse harvest adjustment based on a recruitment estimate. The study concluded that a recruitment estimate would not support adjusting the underlying harvest policy unless its precision was better than a CV of 30%, and even then the added value would be small.

Session 3: Case studies

A comparative analysis of SWFSC and PWCC-NWFSC pre-recruit Pacific whiting indices: another look and a simple case study

Tom Helser of the NWFSC presented analysis of Pacific whiting data from both surveys and discussed the development of a coast-wide index of abundance. Differences in the depth and latitude of the two surveys were examined through comparison of median depth and latitude, weighted and un-weighted by catch, for the combined and individual surveys from 2001 to 2006. When weighted by catch, the median survey depth increased substantially from un-weighted median station depth. Since 2003, the surveys displayed opposite trends in median catch-weighted depth, which increased from 200 m to over 600 m with the expansion of the SWFSC survey, but fell by nearly half in the PWCC/NWFSC survey. The catch-weighted median latitude of each individual survey was fairly stable since 2001, though the median latitude of the PWCC/NWFSC survey did shift slightly northward in association with the northerly expansion of the survey beginning in 2004. For the two surveys combined, the catch-weighted median latitude was closer to the SWFSC median latitude in 2001, 2002, and 2004, but closer to the PWCC/NWFSC survey median in the remaining years. This analysis suggested that the PWCC and NWFSC surveys need to make better efforts to standardize the allocation of mid-water tows with regard to depth strata.

Comparison of catch rates in areas of survey overlap determined by the minimum and maximum latitudes conducted by the surveys, using non-parametric permutation tests, revealed significant differences between the two surveys. Using this testing approach, overall catch rates of the surveys were found to be significantly different in four of the six years. These findings highlight the need for continued overlap in survey coverage and consistency in the allocation of tows to depth zones. Differences between the surveys may be less pronounced at larger spatial scales, due to increased chances of sampling dispersed patches of YOY Pacific whiting.

Assessment model estimates of recruitment strength were minimally affected by inclusion of historical data from the SWFSC core survey area, as a result of the wealth of age data included in the model and the survey's limited geographic range. However, 2005 recruitment was estimated to be much lower, with a substantially smaller confidence interval, when the YOY index was included in the model. The variability of the SWFSC YOY index (σ_{YOY} =1.41) for the 1986-2000 period was roughly twice that of the coast-wide index (σ_{YOY} =0.68) for the years 2001-03. The variability of the stock-recruit relationship in the assessment model (σ_R =1.14) fell between these two values. The relative variance among these sources indicates that most recent recruitment deviations are more strongly informed by the coast-wide pre-recruit index than recruitment variation from the stock-recruitment relationship.

Incorporating YOY indices into the assessment and forecast of Pacific whiting abundance.

Steve Martell of the University of British Columbia Fisheries Center, presented the results of simulations designed to test the value of YOY surveys to short-term forecasts of recruitment strength under ranges of YOY survey variability. The simulation was designed to include data gathering, assessment modeling and harvest projection, and management implementation in a closed loop. Four scenarios were evaluated through comparison of deviations between simulated yields and optimal implementation of the 40-10 harvest policy over a 20-year period.

Forecasts of recruitment strength in each of the scenarios were based on different information. These alternatives included: mean recruitment during the preceding five years, the model-estimated stock-recruit relationship, a YOY survey index, and a weighted average of the stock-recruit prediction and the YOY index. For each scenario, the coefficient of variation (CV) of the acoustic survey was set at 0.29 and a range of YOY survey CVs from 0.1 to 1.2 was examined. With the exception of the model relying solely on the YOY survey inform forecasts, all methods performed well in specifying the correct amount of harvest. The model that used only the YOY index performed well for low CVs, but diverged significantly from optimal yields as the CV rose above the CV for the assessment model’s recruitment deviations.

The two major sources of error in specifying annual harvests are inaccurate estimation of management reference points, and inaccurate estimates the stock size, including the magnitude of new recruitment. In cases such as whiting, where there is a large amount of historical age-composition data, YOY surveys have little effect on the estimation of reference points. Furthermore, in this case, (if adult survey q is well understood?) improvements in the accuracy with which reference points are estimated would produce only marginal increases in long-term yields. YOY surveys have the potential to improve forecasts, but it may be costly to CVs to levels where they are adding useful information, rather than noise. They also have considerable value in detecting abrupt changes in stock productivity, or shifts in the geographic distribution of spawning.

Case study for bocaccio

Alec MacCall provided an overview of data used in estimating recruitment in the 2005 bocaccio assessment. There is a remarkably large number of potential bocaccio recruitment indexes, with some extending back into the 1970's. The contrast provided by the high variability in bocaccio recruitment provides a good opportunity to evaluate the performances of these indexes and combinations thereof.

The data sources (summarized in Table 1) are as follows:
Base: Recruitments from bocaccio stock assessment (MacCall 2005).
1. "Core" central California juvenile rockfish mid-water trawl survey (data provided by Steve Ralston, SWFSC).
2. CPUE of bocaccio caught from piers, mostly in central California (RecFIN). Sampling effort has declined progressively since 1980.
3. Impingement rates of bocaccio at power plants in southern California (data provided by Kevin Herbinson, Southern California Edison).
4. Densities of juvenile bocaccio observed from submersibles at southern California oil platforms (data provided by Milton Love, UCSB).
5. Spawning stock biomass (SSB) of bocaccio from the stock assessment (MacCall 2005). Because of low apparent steepness (h near 0.2), parental SSB serves as an index of subsequent recruitment.
6. Average recruitment anomaly from three other fishes: chilipepper rockfish (J. Field, pers. comm.), shortbelly rockfish (Field et al., In press), and Pacific whiting (Helser et al. 2006).
7. Frequency of rockfish juveniles (all spp.) in seabird diets at the Farallon Islands (data provided by Bill Sydeman, PRBO).

Table 1. Summary of bocaccio recruitment information sources.

Case	Source	Period	Locality	Npositive	Nzero	Nmissing	Delay (yr)
0	Assessment	1972-2004	So&Cen Cal	33			3
	Direct Observations						
1	MWT Survey	1983-2004	Cen Cal	19	3		0.5
2	Pier CPUE	1980-2002	~Cen Cal	13	7	3	1
3	Power Plant	1972-2000	So Cal	27	2		1
4	Oil Rigs	1996-2005	So Cal	8		1	1
	Inferred Observations						
5	SSR(=SSB)	1972-2004	n/a	33			0
	Indirect Observations						
6	SSR w avg of	1975-2002	Diffuse	28			3
	devs from 3 spp						
7	Seabird Diet	1975-2004	Cen Cal	30			0.5
	all rockfish						

Each time series of direct observations (#1-4) was analyzed by means of a main effects GLM (i.e., no interactions) of log-transformed observations, with year effect interpreted as the log of the annual index value (Table 2). Data series #1-3 contained zeroes, which were either deleted from the data or were replaced with a constant equal to one-half the minimum observed value. Log recruitment index values were regressed on log estimated recruitment; goodness of fit diagnostics were r-squared and RMSE under log-transformation. The slope of the log-log relationship (i.e., the exponent of a fitted power function) was calculated both as an ordinary least square (OLS) y-on-x regression value and as a GM regression value that may better reflect the functional relationship (Ricker 1973). GM slopes are always steeper, so for the power function exponents in Table 2, GM estimates are larger than corresponding OLS estimates, indicating weaker compensation as estimated by a functional regression.

Table 2. Performance summary of bocaccio recruitment indexes.

		Delete Zeroes				Set Zeroes to 0.5 min value			
Case	**Source**	**r-squared**	**RMSE**	**OLS exp**	**GM exp**	**r-squared**	**RMSE**	**OLS exp**	**GM exp**
	Direct Observations								
1	MWT Survey	0.20	1.16	0.26	0.58	0.23	1.06	0.23	0.49
2	Pier CPUE	0.18	0.97	0.17	0.39	0.47	2.65	0.23	0.33
3	Power Plant	0.37	1.14	0.40	0.65	0.37	1.17	0.34	0.55
4	Oil Rigs	0.28	1.10	0.47	0.88				
	Inferences								
5	SSR(=SSB)	0.24	1.19	0.92	1.89				
alt	slope forced	0.24	1.19	1.00	1.00				
	Indirect Observations								
6	SSR w avg of	0.59	0.87	0.96	1.25				
	devs from 3 spp								
7	Seabird Diet	0.31	1.08	0.67	1.19				
	all rockfish								
	Composites								
8	Avg (1-5)	0.48	1.02			0.50	1.01		
9	Avg (1-4 & 6-7)	0.54	0.95			0.57	0.93		

R-squared values were generally low, and RMSE values tended to be in the vicinity of 1, which was the value of sigma-R in the stock assessment. Thus, no index performed much better than SSB itself in anticipating annual recruitment strengths, and performed far more poorly than the CV=0.3 criterion recommended by Huppert et al. (1980) and described by MacCall in this report. The best performing index was not based on bocaccio at all, but rather was based on inference drawn from three other fish species (#6); however, this index suffers from the longest time delay before it becomes usable (three years, if all assessments are updated annually, otherwise longer yet). For time series #1-3, replacing zero values with a small constant generally did not improve performance.

Conclusion 1: Independent recruitment data support a sigma-r of approximately 1.0.

Conclusion 2: Performance of each index based on direct observation (#1-4) is similar to use of the stock-recruitment relationship (in this case, simply SSB, #5) as a recruitment predictor. Because indexes #1-4 are based on direct observation rather than on an assumed functional relationship on the SRR, if the SRR is used as a likelihood component in the stock assessment, then the direct observations of recruitment merit equal status and may also be used (subject to CV tuning, as usual).

Conclusion 3: Bocaccio recruitment is highly localized in space and time throughout the first year of life, often appearing at only a single location (e.g., the very large 1999 year class was only seen at the San Onofre power plant, and at no other power plant or in any other recruitment index), and may even be missed altogether. Diffusion of the year class over subsequent years as it is recruited to fisheries allows progressively better estimation of its strength through conventional stock assessment modeling. An open question is whether this pattern of localized recruitment is associated with the relatively low current abundance (i.e., it is a result of local depletion), or whether it occurs at all stock sizes.

Conclusion 4: Separate stock assessments of bocaccio in southern California and central California should be routinely conducted in addition to the combined assessment that has been standard. Although overall recruitment patterns (especially the large year classes) and stock abundance is correlated in the two areas, there are also important differences. The southern California segment appears to have been more lightly exploited, and is less depleted than in central California. There also has been a 30 year trend of increasing recruits per spawner in southern California relative to central California.

References

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Use of YOY survey catches: case study for canary rockfish

Ian Stewart presented a preliminary analysis of the use of the YOY index in the canary rockfish stock assessment. There has been some debate in the past about how best to evaluate YOY survey information in stock assessment models. In the case of canary rockfish, the situation is further complicated by the fact that due to delayed entry of recruits to the fishery, there is currently no overlap between the coast-wide YOY survey (2001-2006) and relatively precisely estimated recruitment strengths in the assessment model (~1975-2000).

The 'core-area' (36-39^{o} N latitude) survey index during 1983-2000 for canary rockfish included values that ranged from 0.0-5.8, with standard errors (SE) in log space of 0.27-1.4, based on a jackknife estimator. Five of the 18 observations did not capture any canary rockfish; as has been done in the past, a value equal to one-half of the smallest index recorded was assigned to those years (0.01). The ability of the assessment model to fit these data was evaluated based on four criteria: runs in sign of residuals, linearity in residuals, ~95% confidence interval intersection, and direct comparison of mean input SE vs. root mean-squared error (RMSE) of the model fit. The fit to the standard index had an RMSE of 2.02 and showed inadequate confidence interval intersection, as well as strong evidence of non-linearity (observed vs. expected plot in log space did not follow a 1:1 line for larger observed values). These observations have, in the past, led to the exclusion of these data from the stock assessment model.

To explore the apparent non-linearity and lack of correspondence between input SE and RMSE, a number of alternate model configurations were employed. First, the mean input SE was increased to 1.83; this led to a similar RMSE, but runs in the residual pattern, as well as evidence of non-linearity remained. It was argued that an external transformation of the data via a power function was similar, but not identical to the internal power transformation, does not follow the same paradigm of using the observation sub-model to match expectations with observed data and loses any contribution to the overall model variance from the transformation itself. Therefore it was deemed best to perform this transformation internal to the assessment model. When estimated, the maximum likelihood estimate for the power coefficient on survey catchability was 3.78. Allowing non-linearity through estimation of this parameter appeared to improve the fit, but a substantial mismatch in mean SE (0.83) vs. RMSE (1.39) remained. Inflation of the mean SE to 1.70 resulted in good correspondence with the RMSE, but the estimated value of the power coefficient dropped to 1.95 and the runs in the sign of the residuals returned. From this model behavior, it was concluded that the lack of fit between the expected values in the canary model and the observed index did not appear to be due solely to non-linearity in the relationship or a mismatch in the assumed level of error about the observations, but to additional process error.

An exploration of this phenomenon was performed through the estimation of year-specific catchability parameters. When scaled relative to the maximum value observed, this analysis indicated that in most years only a very small fraction of the recruitment is observed. Estimated catchability was correlated with estimated recruitment strength, which is consistent with the appearance of non-linearity. Simulation of recruitments distributed similarly to those observed in the analysis of Stewart and Ralston (this workshop) for canary rockfish was performed. These simulated recruitments were filtered until the same level of correlation between recruitment strength and the observed index was achieved. This level of process error implied that 30-40% of the largest recruitments would need to be centered on the core-area to realize the pattern of non-linearity and unaccounted-for process error observed for canary rockfish. This was considered a plausible explanation, although the analysis could neither confirm nor reject the true relationship and was intended to be exploratory only.

It was concluded that the variance estimation associated with the YOY survey was an important component to use in assessment models and that alternatives to the jackknife estimator could be explored. Further, zero-observations were influential and current treatment may be inadequate. Estimated variance, non-linearity and zero-observations were confounded, and attempts to address them need to consider all three simultaneously. When spatially induced process error is reduced through the use of a coast-wide index, it is non-clear that non-linearity will remain a substantial problem in these data.

The 1983-2000 core-area YOY index is unlikely to contribute information to the assessment unless covariates to the spatial distribution of recruitment can be developed to inform annual deviations in catchability. Use of the 2001-2006 coast-wide index appears reasonable, based on the ability of spatial processes to account for lack-of-fit in longer time series. Non-linearity, consistency of input variance, and further diagnosis of process error cannot be assessed until there is temporal overlap in the coast-wide YOY index and well-estimated recruitment strengths in the assessment model. At present, it seems appropriate to consider assessment projections in light of YOY data in an alternate 'states-of-nature' manner until the relationship between coast-wide YOY index and subsequent recruitment strength can be directly explored.

Chilipepper and shortbelly rockfish case studies

John Field, of the Southwest Fisheries Science Center in Santa Cruz, presented case studies of shortbelly, chilipepper and southern widow rockfish, each of which was modeled with SS2 and each of which was explored relative to the fit to the historical Santa Cruz lab juvenile index. As shortbelly rockfish have not been the target of commercial fisheries, and are poorly sampled in traditional trawl surveys, less traditional data such as larval production, larval abundance, and food habits data were used in the model. In particular, seabird diet data from 1975-2005 provided an index of age-0 abundance of shortbelly rockfish, while length-frequency data reconstructed from otoliths in scat samples from California sea lions showed clear patterns of strong and weak year classes. The overall results suggest that the population has undergone significant fluctuations in abundance over the last several decades (presumably in response to variable environmental conditions). The recruitment variability signals from the juvenile survey and the seabird food habits data (from the Central California region) were strongly correlated, and both were moderately correlated to the signals from sea lion food habits data (which is from the Channel Islands, south of Point Conception), although there was some evidence of differences in recruitment north and south of Point Conception. However, the use of a power function in modeling recruitment with the juvenile data was discouraged in an earlier review, due to a lack of age data from the adult population to tune the parameter.

The second case study was on chilipepper rockfish, based on an early version of the model (in SS2) being prepared for the 2007-2008 assessment cycle. Chilipepper are a relatively data rich stock, historically the second most abundant commercial Sebastes species in California (with trace landings north of California), and with commercial age and length composition from 1978 through 2005. From 1983-1998, there is a good relationship between model-estimated recruitments and the power-transformed juvenile index, but much less agreement 1983-2003. This is primarily due to the tremendous strength of the 1999 as informed by age and length data (the 1999 year class accounts for over half the landed fish between 2002 and 2006), which was not observed in the juvenile survey. The internal model fit to the juvenile index without a power transform is poor, however the fit with a power transform was somewhat better. The decision of whether to include (or not) the juvenile index has a very significant impact on stock status and productivity.

A final case study was presented for southern widow rockfish, developed in SS2 using landings and age composition data from the "Eureka" fishery in the coast-wide model (covering Eureka, Monterey and Conception areas). This was done to look at regional differences in recruitment that might explain differences in how well the model fits the juvenile survey data. The results were consistent with what was has been noted in the residuals to catch at age fits in the coastwide model by fishery and area, with stronger recruitment inferred in the north in 1980-81, and stronger recruitment inferred in the south in 1984-85, and 1987-88. The external fit between model estimated recruitment and the juvenile index (1983-2001) is considerably better with the southern model than the coast-wide model, (R^2 of 0.20 v. 0.39), and when the juvenile index fit internally, the fit is quite good both with and without a power relationship. However, the juvenile index appears to have an undue influence on estimates of year class strength that should have been better informed by age composition data.

– Appendix 1 –

Agenda

Pre-Recruit Survey Workshop

September 13-15, 2006

Southwest Fisheries Science Center
110 Shaffer Road
Santa Cruz, CA 95060

Wednesday, September 13, 2006

8:00 a.m. Morning Refreshments

8:30 a.m. Welcome and Introductions

8:45 a.m. Review Goals and Objectives of the Workshop

Session 1. Developing a Coast-wide Survey of Groundfish Pre-Recruit Abundance
Moderator: Jim Hastie

9:00 a.m. Steve Ralston: “Long-term variability in abundance of pelagic juvenile rockfishes in central California based on results from the Tiburon/Santa Cruz midwater trawl survey.”

9:40 a.m. EJ Dick: “Bayesian hierarchical methods in estimating the abundance of pelagic juvenile rockfish from survey data.”

10:10 a.m. Break

10:40 a.m. Keith Sakuma: “A comparison of rockfish catches in the SWFSC and PWCC/NWFSC midwater trawl surveys from 2001-2006.”

11:20 a.m. Vidar Wespestad: “Developing a coastwide survey to estimate interannual variation in pre-recruit abundance of Pacific whiting and a comparison of Pacific whiting catches in the SWFSC and PWCC/NWFSC midwater trawl surveys from 2001-2006”

12:00 p.m. Lunch

1:00 p.m. Ian Stewart & Steve Ralston: “Interannual variation in the distribution of YOY rockfish on the US west coast and implications for survey utilization.

1:40 p.m. Discussion: Question #1 - Can data from the R/V David Starr Jordan and the F/V Excalibur be combined into a coast-wide index for young-of-the-year Pacific whiting and rockfish?

3:00 p.m. Break

3:30 p.m. Continue discussion and develop suggestions for further analysis on the question of survey integration and utilization.

Thursday, September 14, 2006

Session 2: Incorporating Pre-Recruit Indices in Stock Assessments
Moderator: Steve Ralston

8:00 a.m. Morning Refreshments

8:30 a.m. Steve Ralston: "Rockfish early life history – stochasticity and compensation."

9:10 a.m. John Field: "Temporal and spatial synchrony in recruitment of California Current groundfish based on age-structured stock assessments."

9:40 a.m. Alec MacCall: "An archeological example of a MSE on the value of a pre-recruit survey."

10:00 a.m. Break

10:30 a.m. Discussion: General Biological/Modeling Issues

12:00 p.m. Lunch

Session 3: Case Studies
Moderator: Steve Ralston

1:00 p.m. Tom Helser & Steve Martell: "Pacific whiting"

1:40 p.m. Alec MacCall: "Bocaccio"

2:20 p.m. Ian Stewart: "Canary rockfish"

3:00 p.m. Break

3:30 p.m. John Field: "Chilipepper and shortbelly rockfish"

4:10 p.m. Xi He: "Widow rockfish"

If time permits, we'll begin discussing Question #2 below before breaking for the day.

Friday, September 15, 2006

8:00 a.m. Morning Refreshments

Session 4. Workshop Discussion
Moderator: Jim Hastie

8:30 a.m. Discuss Questions #2-4:

Question #2 - Is a power transformation (e.g., widow rockfish) an acceptable way of modeling early life history processes and, if not, what other analytical techniques are more appropriate?

Question #3 - What processes (e.g. density-dependent mortality, measurement error) affect the relationship between a survey index of pre-recruit abundance and model estimates of recruitment?

Question #4 - How influential are pre-recruit survey data on: (1) historical estimated times series of stock abundance and (2) projections into the near term? How can the informational value of a pre-recruit survey to a stock assessment be evaluated?

11:00 a.m. Conclusions / Wrap-Up
11:00 a.m. Report Drafting by co-chairs
12:00 p.m. Workshop Adjourns

Appendix 2: List of Participants

Ken Baltz NMFS, SWFSC
E.J. Dick NMFS, SWFSC
Martin Dorn NMFS, AFSC
John Field NMFS, SWFSC
Tom Ghio PFMC, GAP
Jim Hastie NMFS, NWFSC
Tom Helser NMFS, NWFSC
Tom Jagielo WDFW, SSC
Isaac Kaplan NMFS, NWFSC
Shirley Lee NMFS, NWFSC
Alec MacCall NMFS, SWFSC
Steve Martell UBC
Stacey Miller NMFS, NWFSC
Mike O'Farrell SC lab
Christine Peterson NMFS, SWFSC
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Keith Sakuma NMFS, SWFSC
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