Selectivity: theory, estimation, and application in fishery stock assessment models

PRELIMINARY WORKSHOP AGENDA

Center for the Advancement of
Population Assessment Methodology (CAPAM)

Southwest Fisheries Science Center (NMFS/NOAA)
3333 North Torrey Pines Court
La Jolla, CA 92037, USA

11-14 March 2013

Date and Time	Topic	Presenter
***11 March* (*Monday*)**		
8:30 am – 5:00 pm	Interactive SS working session	Taylor (IS)
***12 March* (*Tuesday*)**		
8:00 am – 8:30 am	Welcome/Workshop Overview	Methot/Semmens /Crone
8:30 am – 9:30 am	Presentation - A1	Sampson (IS)
9:30 am – 10:00 am	A2	Somerton
10:00 am – 10:30 am	Break	
10:30 am – 11:00 am	A3	Schueller
11:00 am – 11:30 am	A4	Song
11:30 am – 12:00 pm	A5	Hurtado-Ferro
12:00 pm – 1:30 pm	Lunch	
1:30 pm – 2:00 pm	A6	Walter
2:00 pm – 3:00 pm	Group discussion- A	
3:00 pm – 3:30 pm	Break	
3:30 pm – 4:30 pm	B1	Ianelli (IS)
4:30 pm – 5:00 pm	B2	Iwata
5:30 pm – 7:30 pm	Evening social	
***13 March* (*Wednesday*)**		
8:00 am – 9:00 am	C1	Punt (IS)
9:00 am – 9:30 am	C2	Hanselman
9:30 am – 10:00 am	C3	Ichinokawa
10:00 am – 10:30 am	Break	
10:30 am – 11:00 am	C4	Teo
11:00 am – 12:00 pm	Group discussion- C	
12:00 pm – 1:30 pm	Lunch	
1:30 pm – 2:00 pm	B3	Courtney
2:00 pm – 2:30 pm	B4	Crone
2:30 pm – 3:00 pm	B5	Owashi
3:00 pm – 3:30 pm	Break	
3:30 pm – 4:00 pm	B6	da Silva
4:00 pm – 4:30 pm	B7	Lee
4:30 pm – 5:00 pm	B8	Thorson
5:30 pm– 8:30 pm	ADMB Working Session	Martell/ Whitten /Supernaw
***14 March* (Thursday)**		
8:00 am – 8:30 am	B9	Martell
8:30 am – 9:00 am	B10	Kinzey
9:00 am – 10:00 am	Group discussion-B	
10:00 am –10:30 am	Break	
10:30 am – 11:30 am	D1	Butterworth (IS)
11:30 am – 12:00 pm	D2	Wang
12:00 pm – 1:30 pm	Lunch	
1:30 pm – 2:00 pm	D3	Okamura
2:00 pm – 2:30 pm	D4	Sharma
2:30 pm – 3:00 pm	D5	Stewart
3:00 pm – 3:30 pm	Break	
3:30 pm – 4:30 pm	Group discussion - D	
4:30 pm – 5:00 pm	Closing remarks and general discussion	Maunder

Selectivity workshop – General structure

- Chairperson – M. Maunder
- Welcome/Workshop overview – R. Methot, B. Semmens, and P. Crone
- Closing remarks – M. Maunder
- Presentations
  - Presenters will have 30 minutes (25 minutes for presentation and 5 minutes for questions)
  - Invited speakers will have 1 hour (50 minutes for presentation and 10 minutes for questions)
  - Group discussions will be 1-hour per major topic, led by invited speakers and CAPAM staff
- All workshop attendees are invited to participate in an interactive working session to be held on Monday (March 11, 2013) that will include presentations and discussion regarding modeling selectivity using the *Stock Synthesis* model (session led by I. Taylor and CAPAM staff)
  - Additionally, all workshop attendees are invited to participate in an informal evening session to be held on Wednesday (March 13, 2013) that will address ADMB library functions/processes applicable to assessment model development (session led by S. Martell, A. Whitten, M. Supernaw)
- Researchers are encouraged to further develop their presentations into formal manuscripts, i.e., plans are underway for submitting a subset of papers for a special issue in the journal *Fisheries Research* (contact M. Maunder and P. Crone for further details)

Selectivity workshop – Major topics and invited speakers

A. Underlying processes (D. Sampson)
   - Characteristics of the gear (e.g., mesh size)
   - Behavior of the fish (e.g., seasonal movement)
   - Spatial structure of the population (e.g., availability/vulnerability)

B. Specification and estimation (J. Ianelli)
   - Functional forms
   - Interactions with related parameters
   - Estimating smoothness parameters
   - Time varying (time blocks, temporal deviates, VPA-like)
   - Size vs. age

C. Model selection and evaluation (A. Punt)
   - Bootstrap methods (error estimation and data set construction)
   - Hypothesis tests
   - Simulation analysis
   - Convergence issues
   - Diagnostics

D. Impact on management (D. Butterworth)
   - Robustness
   - Management strategy evaluations
   - Biological reference points

CAPAM SELECTIVITY WORKSHOP
PRESENTATION ABSTRACTS

TOPIC: Overview

Title of Presentation: Selectivity: theory, estimation, and application in fishery stock assessment models
Presenter: Paul Crone
Authors: P. Crone, M. Maunder, B. Semmens, and J. Valero
Topic: Overview
Abstract: To date, selectivity issues remain one of the most statistically influential and uncertain parameterizations in overall assessment model development. Selectivity is a critical consideration in most stock assessment models, given its basis provides an objective framework for relating biological compositions obtained from catch or survey samples to the length or age structure of the population at large. Selection processes are inherently linked to estimation of related stock parameters of interest, including fishing and natural mortality, growth, recruitment, and spawning stock-recruitment relationships. Harvest strategies evaluated for optimal exploitation of fish stocks can be strongly influenced by selectivity. Modeling selectivity in stock assessments is not a straightforward exercise, requiring fine-scale investigations to describe appropriately the statistical properties underpinning fish size or cohort time series that typically represent the majority of the overall error in contemporary, multiple data source, fully-integrated fishery models. In this workshop, four core sub-topics of selectivity are reviewed: underlying processes, specification and estimation, model selection and evaluation, and impacts on management. In addition, 21 research presentations provide recent developments and timely case studies for each sub-topic. Further, a suite of manuscripts developed from the workshop presentations will be submitted for consideration as a special issue publication in the journal *Fisheries Research* that addresses *selectivity: theory, estimation, and application in fishery stock assessment models*. There is a need for higher quality, number, and frequency of stock assessments to meet a growing international concern to stem overfishing and provide management advice that supports sustainable fisheries in the future. Ultimately, this workshop provides opportunities for collaboration to produce a meaningful body of work that contributes to fishery research and management.

TOPIC A: Underlying processes

A1. Title of Presentation: Fishery selection and its relevance to stock assessment and fishery management.
Presenter: Dave Sampson (Invited speaker)
Authors: D. Sampson
Topic: A
Abstract: Fishery selection (selectivity for short) is the term often used to describe the phenomenon whereby a fish stock experiences vulnerability to fishing that is size- or age-specific. Selectivity operates both at a local scale, as in the direct interactions of individual fish with the fishing gear (gear-selection), and at a stock-wide scale (population-selection), as evidenced by the differential rates of fishing mortality-at-age that are generally observed in stock assessment results. All age-structured stock assessment models have some form of

fishery selection to modulate the impact of fishing mortality on differing age-classes, but from a stock assessment viewpoint, selection coefficients are nuisance parameters rather than a focus of attention. We begin with an overview of the three main processes that contribute to and influence fishery selection: (1) physical sorting by the fishing gear or differential responses of the fish to the gear produce the phenomenon of gear-selection; (2) differing selection properties of the different types of fishing gear (e.g., trawl versus longline) in turn generate a composite population-level selection curve that is a weighted average of the different kinds of gear-selection; and (3) when the fish are not well mixed spatially, then the spatial distribution of fishing also affects population-selectivity. A fourth special case arises in species that experience gauntlet fishing as they migrate seasonally. Following the review of the processes underlying selection we explore some of the population-selection curves that have been found in a variety of fisheries. The curves exhibit a wide range of shapes and considerable temporal variability. We conclude with a spatial model for fishery age-selectivity and an exploration of some of its properties. A three-region spreadsheet version of the model is used to demonstrate that the common management reference points MSY, B_{MSY}, and F_{MSY} are functions of both gear-selection and the spatial distribution of fishing, which implies that changes in the spatial aspects of fishing are an additional dimension of uncertainty in our fishery management targets.

A2. Title of Presentation: Review of experimental estimation of survey catchability with a focus on yellowfin sole and snow crab in the eastern Bering Sea.
Presenter: David Somerton
Authors: D. Somerton
Topic: A
Abstract: The experimental methods that have been used to estimate the sampling efficiency of bottom trawls can be grouped into those focused on the various components of the trawl capture process and those focused on the use of an alternate sampling device capable of estimating absolute abundance. The efficiency of the 83-112 Eastern trawl for yellowfin sole was estimated by conducting separate field experiments to estimate herding by the bridles and escapement under the footrope then combining the two estimates in a trawl efficiency model. The efficiency of snow crab was estimated by conducting a side-by-side trawling experiment in which a trawl designed to capture all crabs in its path was towed beside survey vessels conducting normal survey tows. Survey catchability was then estimated as a catch-weighted mean over the entire survey area. The results of the experiment indicated that:1) trawl efficiency varied spatially with depth and sediment characteristics and 2) the resulting catchability function was clearly not a logistic function of crab size.

A3. Title of Presentation: Determining relative selectivity of the gulf menhaden commercial fishery and fishery independent gill net data
Presenter: Amy Schueller
Authors: A. Schueller
Topic: A
Abstract: Gulf menhaden are a schooling forage fish that are harvested by one of the largest commercial fisheries by volume in the United States. Purse-seine boats encircle schools, often aided by spotter pilots. High quality, long-term data are available to characterize the reduction fishery over five decades. For past stock assessments, the selectivity of the

reduction fishery has been assumed to be logistic or flat-topped. For the latest assessment, fishery-independent gill net data from Louisiana have been considered for creation of an index of adult abundance. In order to address the difference in selectivity between the two gear types– purse seine versus gill net, length data were compared between the reduction fishery and gill net survey. These data showed that the gill net survey collec range of sizes than the reduction fishery. However, upon further inspection Figure 1 compositions by mesh size, it appears that the "age classes" in the gill net survey are likely relicts of the selectivity of individual mesh sizes in the gill net panels, rather than true age classes. Thus, the length composition data indicate that the selectivity of the reduction fishery should likely be less than the gill net index for larger and smaller sizes. If the gill net index has a dome-shaped selectivity that would mean that the reduction fishery should also have dome-shaped selectivity and should have steeper ascending and descending limbs than the gill net index. The selectivity of each gill net mesh size appears dome-shaped, thus the assumption of dome-shaped selectivity of gill nets overall might be valid in this instance. A potential biological explanation for dome-shaped selectivity for the reduction fishery might be related to the schooling behavior of the gulf menhaden. Gulf menhaden generally school by size. Because of this, the reduction fishery tends to harvest optimum school sizes with respect to time, effort, oil yield, and other harvest factors – the median size of schools harvested in recent years has ranged 18-23 t. Schools of the oldest and presumably the largest gulf menhaden may be smaller than the optimal school size for harvest. On the other hand, schools of small and younger gulf menhaden – usually observed in large schools and during fall as they exit estuarine waters – are generally avoided by the commercial fishery because of their low oil and protein yields and tendency to "gill" in the meshes of the purse seines.

A4. Title of Presentation: The length structure of bigeye tuna and yellowfin tuna catch at different depth layers and temperature ranges: an application to the longline fisheries in the waters near Gibert Islands

Presenter: Liming Song
Authors: L. Song and J. Yang

Topic: A

Abstract: Bigeye tuna (*Thunnus obesus*) and yellowfin tuna (*Thunnus albacores*) are the main catch species of longline tuna fisheries in the world. Although tuna longline CPUEs are often standardized by depth or temperature to adjust for the change in depth of longlines, the selectivity by depth or temperature is not changed in the stock assessment. The aim of this study is to evaluate if the selectivity by depth or temperature needs be considered in the stock assessment. The fishery and environmental data collected in 80 survey sites in waters near Gilbert Islands in 2009 and 2010 were applied to analyze the length structure of bigeye tuna (n=376 individuals) and yellowfin tuna (n=348 individuals) catch at different depth layers (40-200 m, the interval is 40 m, four depth strata) and temperature ranges (25-29 ℃, the interval is 1 ℃, four temperature ranges). A one-way ANOVA was used to test if there was significant difference between the length structure of all samples and the length structure at different depth layers or temperature ranges for bigeye tuna and yellowfin tuna catch, and to test if there was significant difference among the length structures of bigeye tuna and yellowfin tuna catch at different depth layers or temperature ranges. The results showed that: (1) there was no significant difference between the length structure of all samples and the length structure at different depth layers or temperature ranges for bigeye tuna and yellowfin

tuna catch ($p \geq 0.05$); (2) there was no significant difference among the length structures of bigeye tuna and yellowfin tuna catch at different depth layers ($p \geq 0.05$); (3) there was no significant difference among the length structures of yellowfin tuna catch at different temperature ranges ($p \geq 0.05$); (4) there was no significant difference among the length structures of bigeye tuna catch at different temperature ranges ($p \geq 0.05$), except the length structures of bigeye tuna catch between 25-26 ℃ and 27-28 ℃ ($p \leq 0.05$). This study suggested that the selectivity by depth or temperature does not need to be included in the assessment of these stocks.

A5. Title of Presentation: Use of multiple selectivity patterns as a proxy for spatial structure

Presenter: Felipe Hurtado-Ferro

Authors: F. Hurtado-Ferro, A. Punt and K. Hill

Topic: A

Abstract: There is widespread recognition that spatial structure is important for fisheries stock assessments, and several efforts have been made to incorporate spatial structure into assessment models. However, most studies exploring the impact of ignoring spatial structure in stock assessments have developed population models with multiple subpopulations rather than the exploring the impact spatial dynamics may have on estimation performance of non-spatially structured assessment methods. Furthermore, the data available to stock assessments usually do not include tagging or other data to estimate movement rates. One approach around this problem is to use several fleets with different selectivity patterns to represent availability within a spatially-structured assessment method. In this study, the impacts of ignoring spatial structure and the effectiveness of using multiple selectivity patterns as a proxy for spatial structure are evaluated for the northern subpopulation of Pacific sardine (or California sardine; *Sardinops sagax*). A spatially-explicit operating model (OM) is used to explore three spatial factors: the existence of size-dependent seasonal migrations across large geographical areas, the influx of another stock into the area of the assessed stock, and the occurrence of recruitment outside the area where it is assumed to occur. The assessment model is based on the 2010 stock assessment for Pacific sardine, implemented in Stock Synthesis (SS), and includes two seasons per year and six fleets each with a different selectivity pattern. Ignoring spatial structure is found to impact the performance of SS, with seasonal movement having the largest impact on estimation ability. SS compensates for ignoring movement and spatial structure by adjusting the selectivity patterns, but selectivity alone is not able to account for all bias caused by spatial structure.

A6. Title of Presentation: The value of empirical estimates of selectivity in integrated assessments.

Presenter: John Walter

Authors: J. Walter, B. Linton, C. Porch and W. Patterson

Topic: A

Abstract: What is generally termed selectivity within an integrated assessment model is often a product of two processes; the fraction of the animals in the population available to the gear (availability) and the fraction of animals that encounter the gear that are retained (contact selectivity, sensu Millar). While availability is often difficult to empirically determine, contact selectivity can often be empirically determined from experiments and observational studies. Depending upon how well they reflect the modeled fishery or fleet, empirical estimates of contact selectivity can be used as either direct inputs, Bayesian priors

or simply to guide the choice of appropriate functional form for length-based selectivity estimation. Either of the three uses can be exceptionally valuable and influential. We demonstrate the value of empirically derived estimates of hook selectivity for Gulf of Mexico red snapper with a length and age-based SS3 assessment model. By separating selectivity into two component processes, of which contact selectivity is an eminently tractable ground for empirical study, we can greatly reduce one of the key sources of uncertainty within the stock assessment.

TOPIC B: Specification and estimation

B1. Title of Presentation: Evaluating selectivity trade-offs in groundfish assessments

Presenter: Jim Ianelli (Invited speaker)

Authors: J. Ianelli

Topic: B

Abstract: "Selectivity is not a well-defined concept" –Dave Fournier ca. 1991. A fundamental aspect of age structured models is the notion that selectivity (or availability) of living marine resources can vary by age or size. It is easy to imagine that this process might vary over time as well. For example fishing practices which result in targeting abundant spatially-aggregated year-classes over time would cause the relative age-component of fishing mortality to vary over time. For survey data, the age-specific catchability may vary over time if the species characteristics and/or the environment affects the organism's distribution relative to the survey gear. In this paper we evaluate the pros and cons of the myriad alternative approaches to specifying selectivity. An example application in which trade-offs to the non-parametric smoothing approach applied to the Aleutian Islands Atka mackerel stock shows the dimensionality and how the interaction of seemingly different processes can occur. Aspects on estimating time-varying dimensions and age-specific smoothing parameters are presented relative to retrospective patterns and key management parameters.

B2. Title of Presentation: Estimation of selectivity in Stock Synthesis: lessons learned from the tuna stock assessment

Presenter: Shigehide Iwata

Authors: S. Iwata, T. Kitakado, and Y. Takeuchi

Topic: B

Abstract: The estimation of selectivity is one of key issues of stock assessment since it potentially has a large influence on the estimates of management quantities. We here present some lessons learned from the tuna stock assessment about the estimation of selectivity, focusing on the assumption of its functional form and the estimation procedure. Firstly, it has been recognized that some non-parametric functional forms (e.g. cubic spline) are quite attractive in terms of their flexibility. However, we observed in the stock assessment of Pacific bluefin (PBF) tuna that they do not necessarily work to well due to unexpected effects to the model behavior such as non-continuous dynamics of likelihood change by increasing knot numbers, although it was expected to have a better fit than parametric functional form. Secondly, sometimes the balance between likelihood contributions from CPUEs and size compositions is controlled by weighting when they show some incompatibility. To overcome this difficulty, an iterative method for estimating selectivity curves was developed for the 2012 PBF tuna stock assessment. We conducted a small

experiment by applying the method to the dataset for the PBF and it showed that the iteration procedure could have a potential to reach convergence and produce somewhat a reasonable results. The performance of this method should be evaluated further through simulation experiments, but it warrants further investigation.

B3. Title of Presentation: Monte Carlo simulation of selectivity and maturity at age in a length-based-age-structured model
Presenter: Dean Courtney
Authors: D. Courtney
Topic: B
Abstract: A length-based age-structured simulation model was developed to investigate the sustainability of Pacific sleeper shark incidental catch in Alaskan commercial groundfish fisheries. The simulation model is governed by a standard set of age-structured population dynamics equations. The relationship between proportions of sharks at age (age frequency) and proportions of sharks at length (length frequency) is modeled using a von Bertalanffy growth equation and an age-length transition matrix. The Monte Carlo simulation used to verify the expected outcome of including uncertainty in a simulated length at age relationship on the resulting selectivity and maturity at age curves. The expected outcome was less informative (i.e. less steep) selectivity and maturity at age curves than would have been obtained from a length at age relationship simulated without uncertainty. The mean and median values for selectivity and maturity at age from Monte Carlo simulation (n = 10,000) with normally distributed error in the length at age were graphically compared to selectivity and maturity at age obtained from an age-length transition matrix with normally distributed error in length at age. Mean selectivity and maturity at age from Monte Carlo simulation were approximately equal to selectivity and maturity at age obtained from the age-length matrix with normally distributed error in length at age. In contrast, Median selectivity and maturity at age from Monte Carlo simulation were approximately equal to selectivity and maturity at age obtained from an age-length matrix without uncertainty in the length at age relationship. These results were consistent with the literature and provided an intuitive example of the effects of including uncertainty in the simulated length at age relationship on the resulting selectivity and maturity at age curves.

B4. Title of Presentation: Age- vs. length-based selectivity for small pelagic fisheries: outside/inside model considerations and management conclusions
Presenter: Paul Crone
Authors: P. Crone, J. Valero, and K. Hill
Topic: B
Abstract: Pacific mackerel are a productive small pelagic species inhabiting the Northeast Pacific Ocean, characterized by highly variable and infrequent recruitment success and associated stock abundance in any given year based primarily on oceanographic conditions and less so, on direct fishing pressure. In this context, determination of appropriate selectivity assumptions and estimators to use in formal fish stock assessments is not straightforward and demands further scrutiny, given both outside and inside the model, plausible scenarios exist for using age or length data in concert with age- or length-based selectivity. The current stock assessment model was simplified by omitting/pooling particular data sources and fixing parameters to produce two baseline models that included either age-composition or length-composition data. Each baseline model was evaluated in

terms of age and length selectivity parameterization. A parametric bootstrap procedure within the *Stock Synthesis* modeling platform was used to produce four simulated data sets for examining the quality (precision and bias) of derived management statistics of interest (current spawning biomass, MSY, stock depletion, etc.). The benefits of this approach for conducting future sensitivity analysis and diagnostic examinations surrounding the ongoing stock assessment are discussed in this presentation.

B5. Title of Presentation: Characterizing Shape and Interannual Variability in Selection Curves of West Coast Groundfish
Presenter: Brandon Owashi
Authors: B. Owashi and D. Sampson
Topic: B
Abstract: Stock assessments for US West Coast stocks of groundfish are generally conducted using the Stock Synthesis program. In applications of this program one generally configures the model and data set to include a small number of fleets that account for the differences in the age-compositions of the catches from the different segments of the fishery. Often the selection curve for each fleet is assumed to be either constant for the entire modeled period or constant for extensive periods with abrupt changes between periods. However, changes in the relative catches among fleets induce changes in the population-level selection curve, which is a catch-weighted average of the fleet-level selection curves. The population selection curve has a direct relation to management reference points such as MSY and B(MSY). Incorrect assumptions about population selectivity could lead to poor estimates of these reference points. This project develops yearly composite selection curves from existing stock assessments in order to characterize the shape and interannual variability in selection curves of West Coast groundfish.

B6. Title of Presentation: An exploration of alternative methods to deal with time-varying selectivity in the stock assessment of yellowfin tuna in the eastern Pacific Ocean
Presenter: Alexandre Aires-da-Silva
Authors: A. Aires-da-Silva and M. Maunder
Topic: B
Abstract: Selectivity curves in the yellowfin tuna (YFT) assessment are assumed to be constant over time. However, there may be a strong time-varying selectivity process at play. This is the case of the floating-object (OBJ) fisheries which show high variability in the YFT length–compositions, which result from appearance, disappearance, and reappearance of strong cohorts over time. Misspecified selectivity is not desirable in any stock assessment model since it may cause retrospective patterns and biases in recent recruitments and fishing mortalities, which drive management actions. This paper investigates alternative approaches that could be used to model time-varying selectivity in the YFT assessment. The methods vary from ignoring time-varying selectivity to a full time-varying selectivity process through quarterly changes in selectivity, or wider time-blocks which mark changes in selectivity over time. We chose the floating-object fisheries to illustrate the different methods. A balance is required between the amount of selectivity process (numbers of parameters) that is needed to reduce bias in the recent recruitments, and the amount of OBJ length-frequency data to be used in the model fit (full time series of data or a few terminal years only). This work indicates that allowing for time-varying selectivity (quarterly deviates) in the 5 terminal years of the assessment only while fitting to the length-frequency

data available for this period is a reasonable compromise. An "average" stationary selectivity curve is applied to the early period of the assessment with no need to fit to length-frequency data for the early period. This approach seems to greatly minimize retrospective pattern and improve recent recruitment estimates and fishing mortality rates that are influential in population projection work. Improved estimates of other management quantities are also obtained.

B7. Title of Presentation: Evaluation of a practical method to estimate the variance parameter of random effects for time varying selectivity
Presenter: Hui-Hua Lee
Authors: H. Lee, M. Maunder, A. Aires-Da-Silva, and K. Piner
Topic: B
Abstract: Time varying selectivity may be desirable in many fisheries applications, particularly if fisheries with different characteristics are combined together. Virtual Population Analysis (VPA) inherently allows age-specific selectivity to change from year to year, but results in the loss of a lot of information and may not be practical if age composition data is not available for some years. Also, there may be some fisheries that have fairly constant selectivity from year to year and this consistency in conjunction with the age composition data will provide information on several of population and fishing processes. An alternative to VPA is to treat selectivity parameters as random effects, which is a standard approach in contemporary population dynamics model and is equivalent to state-space models. Inference using random effects models involves integrating out the random effect (a high dimensional integral), but this can be too computationally demanding in contemporary integrated fishery stock assessment models. Penalized likelihood approaches have been used in fisheries stock assessment (e.g. for annual recruitment variation), but the maximum likelihood estimate of the variance of the random effect is inconsistent and degenerates to zero. A practical method combines the variance of weakly constrained penalized likelihoods estimates with the variance estimated by iteratively estimation (i.e. use penalized likelihood to estimate the deviates, calculate the variance of the deviates, use the variance in the penalty function and re-estimate the deviates, and repeat until the estimate of the variance converges) to estimate the variance of the random effect. We test the method using simulation analysis roughly based on the stock assessment of bigeye tuna in the eastern Pacific Ocean.

B8. Title of Presentation: A proposal for penalized-likelihood estimation of semi-parametric models in age-structured stock assessment models
Presenter: James Thorson
Authors: J. Thorson
Topic: B
Abstract: Time-varying selectivity is an active and important area of research in stock assessment. One convenient approach is semi-parametric modeling, which incorporates prior information regarding the functional form of selectivity while also allowing systematic deviations away from this form when appropriate. Gaussian process (GP) estimation represents a gold standard for semi-parametric models, and uses mixed-effects to specify a 'prior' on selectivity while allowing available data to update the prior. However, mixed-effects estimation requires numeric integration, and this will be difficult for many existing stock assessment models. We therefore develop an analogous approach for penalized-

likelihood estimation, which uses a penalty on deviations away from the specified form for selectivity. We endeavor to demonstrate that using crossvalidation to tune the penalty allows for identifiability of both the parametric 'prior' and all deviations. We conclude by discussing prospects for incorporating this approach into the existing Stock Synthesis software, i.e., by specifying 20% of compositional data as a 'ghost fleet' (i.e. a fleet that does not enter the objective function) and maximizing a profile of the likelihood of this ghost fleet given different values for the penalty.

B9. Title of Presentation: Best practices for modeling time-varying selectivity
Presenter: Steven Martell
Authors: S. Martell and I. Stewart
Topic: B
Abstract: Changes in the observed size- or age-composition of commercial catch can occur for a variety of reasons including: market demand, availability, temporal changes in growth, time-area closures, regulations, or change in fishing practice, to name but a few. Two common approaches for dealing with time-varying selectivity in assessment models are the use of discrete time-blocks associated with an epoch in the history of the fishery, or the use of penalized random walk models for parametric or non-parametric selectivity curves. Time block periods, or penalty weights associated with time-varying selectivity parameters, are subjective and often developed on an ad hoc basis. A factorial simulation-estimation experiment, with discrete or continuous changes in selectivity, is conducted to determine the best practices for modeling time-varying selectivity in fisheries stock assessments. Both the statistical properties of the assessment model and the policy implications of choosing the wrong model are taken into consideration.

B10. Title of Presentation: Selectivity and two biomass measures in an age-based assessment of Antarctic krill
Presenter: Doug Kinzey
Authors: D. Kinzey
Topic: B
Antarctic krill (*Euphausia superba*) sampled over a 19 year period from four areas in the Antarctic Peninsula by the Antarctic Ecosystem Research Division at the Southwest Fisheries Science Center are believed to be part of a larger population of Antarctic krill that is moving through the sampled areas. Two time series of krill biomass, based on trawl nets and acoustic sampling, respectively, are available from each survey. An age-based assessment model coded in AD Model Builder has been developed. The model framework currently allows either logistic or double-logistic forms of selectivity. The model integrates size composition data collected by the trawl surveys with two potential measures of biomass: trawl densities and acoustic densities. These two potential measures of biomass are uncorrelated through the time series. This study evaluates the ability of the integrated model to reconcile differences in the two sources of krill biomass data by allowing selectivities to be estimated separately for each. Five model configurations with separate selectivities for acoustic and trawl biomass using data that differs only by different weightings on these two data sources, including ignoring one or the other, are compared. The configuration that used acoustic data for biomass and net data for compositions was able to closely fit the biomass data. Configurations that used both sources of biomass data fit those data less well. The configuration using only net data for both biomass and

compositions was unable to fit the net biomass data satisfactorily. Thus separate selectivities for net- and acoustic-based measures of biomass were unable to resolve the differences in the two time series. The net-based measures of krill biomass may not be adequate representations of population-level trends.

TOPIC C: Model selection and evaluation

C1. Title of Presentation: Model selection for selectivity in fisheries stock assessments
Presenter: Andre Punt (Invited speaker)
Authors: A. Punt
Topic: C
Abstract: The choice of how to model selectivity differs among approaches to fisheries stock assessment; VPA tends to make only weak assumptions regarding (age-specific) selectivity (flat selectivity on the oldest ages and temporal stability of selectivity for the most recent years). In contrast, selectivity is more parametric in "integrated" methods and can be age-, length- and age- and length-based. This tends to reduce estimation variation as fewer parameters have to be estimated, but incorrect choices for the functional form for selectivity can lead to bias. This paper illustrates some of the effects of poor choices for selectivity on the outcomes from stock assessments, outlines methods for evaluating whether a particular choice for selectivity is appropriate, and summarizes current ways to how to select among alternative functional forms for selectivity**.**

C2. Title of Presentation: Tradeoffs between bias, model fits, and using common sense about biology and fishing behaviors when choosing selectivity forms.
Presenter: Dana Hanselman
Authors: D. Hanselman and P. Hulson
Topic: C
Abstract: The trawl fishery for Gulf of Alaska Pacific ocean perch (POP) has changed over time from a large-vessel foreign fleet, to a large-vessel domestic fleet, to a generally small catcher-vessel fleet since 1960. Trawl survey catchability was drifting higher over time. We found that instead of fitting logistic selectivity for the fishery throughout the time series, that fitting a combination of logistic and dome-shaped gamma selectivities had a far superior fit to the data and also alleviated the trawl survey catchability drift. We conducted simple simulations using a POP-like population to test when allowing more complicated selectivity functional forms is both estimable and justified. Data were generated with selectivities from the double-normal mode with error, and models were fitted with the logistic, gamma, exponential-logistic models, and double-normal models. Results were examined for differences in model fit and parameter bias. Estimability was evaluated by examining parameter correlations, uncertainty, and model convergence. The results were used to develop "rules-of-thumb" for what level of true complexity of the selectivity curve justifies applying a complex selectivity curve, or if a simpler curve can be more robust.

C3. Title of Presentation: What does each data component tell us about model misspecification in integrated stock assessment models?
Presenter: Momoko Ichinokawa
Authors: M. Ichinokawa, H. Okamura, and Y. Takeuchi
Topic: C

Abstract: The integrated model has the benefit of integrating multiple data sets such as abundance indices and size compositions. However, the relative weighting among different data sets and high correlation between stock size and selectivity parameters can be problematic. In particular, model misspecification or biased samples can easily lead to erroneous evaluation of the stock. An approach to solve this problem is to 'do not let other data stop the model from fitting abundance data well' because 'abundance data should have primacy' (Francis 2011, Can J Fish Aquat Sci 68: 1124-1138). However, size compositions are expected to have specific information on selectivity of fisheries, growth and relative abundance of year-classes, which might eventually affect total stock size estimation. The issue that we want to know is how much model misspecification related to size composition data makes the information contaned in the data unusable. In other words, can size composition data tell anything about stock status under model misspecification? For this purpose, an operating model is established to observe how conflicts occur between abundance indices and size compositions, and between different fisheries targeting different age groups under given scenarios of model misspecification. In the operational model, age-structured population dynamics is simulated to produce observed fishery data (catch, fishery CPUE and catch at length by fishery) for estimating parameters by the integrated stock assessment model, Stock Synthesis fit to length composition data. Various scenarios on model misspecification on selectivity, somatic growth, non-proportionality between abundances and indices, and other important key parameters such as steepness are considered. Then, likelihood profiles of focused likelihood components of SS (e.g. size compositions vs abundance indices) are examined. This analysis shows potential distances from maximum likelihood estimates based on different data sets to the true value, under the condition that model misspecification causes conflicts among different data sets. In addition, the ability or inability to estimate important parameters such as virgin biomass and selectivity parameters simultaneously within the length-based integrated model is discussed.

C4. **Title of Presentation**: Influence of selectivity and size composition misfit on the scaling of population estimates and possible solutions: an example with north Pacific albacore

Presenter: Steve Teo
Authors: S. Teo and K. Piner

Topic: C

Abstract: In the recent stock assessment of north Pacific albacore tuna in 2011, the scale of population estimates and assessment results were highly sensitive to the weighting of size composition data in the model. Therefore, the assessment substantially downweighted the size composition data (lambda=0.01) in order to constrain the population estimates to a biologically reasonable scale. This is a relatively common situation for assessments of highly migratory species, where differences in the selectivity of various fleets are used as proxies for movements to and from different areas where the fleets operate in. In addition, the selectivity processes tend to be modeled as less variable in time and space than the actual movement processes. This may in turn lead to size composition misfit, which can strongly influence the population scaling. Using the north Pacific albacore assessment as an example, we perform a R0 profile with respect to the various data components in the model to understand the influence of size composition misfit on the assessment results. Futhermore, we compare several possible solutions to the problem and discuss the pros and cons of each.

TOPIC D: Impact on management

D1. Title of Presentation:

Presenter: Doug Butterworth (Invited speaker)
Authors: D. Butterworth
Topic: D
Abstract: Assumptions about selectivity can be highly influential on estimates of management quantities from fisheries stock assessment models. Selectivity can influence the optimum yields obtainable from a fish stock as illustrated from traditional yield-per-recruit analysis and are related to the age of fish caught relative to the tradeoff between natural mortality and growth. In addition, selectivity interacts with the stock-recruitment relationship through the proportion of the catch that are spawners. We outline the impact of selectivity assumptions on management quantities and provide several case studies to illustrate the impact. We then discuss how management strategy evaluation can be used to determine what harvest rules, data, and assessment methods are most robust to selectivity misspecification.

D2. Title of Presentation: Selectivity's distortion of the production function and its influence on management advice.

Presenter: Sheng-Ping Wang
Authors: S. Wang, M. Maunder, and A. Aires-Da-Silva
Topic: D
Abstract: Surplus production models (e.g. the Schaefer and Pella-Tomlinson models) aggregated the dynamics of a fish population into a simple function of abundance and do not explicitly represent biological and fishing processes. It has been clearly shown using age-structured models that the symmetrical production function of the Schaefer model is inappropriate for most fish species and the shape of the production function depends on biological parameters such natural mortality, growth, and the stock-recruitment relationship. It also depends on the age-specific selectivity of the fishery. We evaluate the influence of the selectivity curve on the shape of the production function and compare it with the influence of biological parameters. We then compare results of a stock assessment roughly based on bigeye tuna in the eastern Pacific Ocean when the production function does not match the selectivity curve and when the selectivity curve changes over time. Our results provide one more nail in the Schaefer model's coffin.

D3. Title of Presentation: Evaluating the Sensitivity of Biological Reference Points to Variation in Spatial and Temporal Selectivity

Presenter: Hiroshi Okamura
Authors: H. Okamura, M. K. McAllister, M. Ichinokawa, L. Yamanaka, K. Holt
Topic: D
Abstract: We developed a semi-age structured delay-difference model that takes spatial and temporal selectivity change into account. The model can deal with multiple fishing fleets that have different ages at recruitment and different seasonal and depth preferences. Offshore lingcod data in British Columbia were used as an example in this analysis. The commercial trawl fishery of B.C. offshore lingcod occurs in summer and winter seasons and especially since 2003 mostly in deep water (i.e., greater than 50m). Offshore lingcod tend to show seasonal vertical migration which is different by sex: most adult males aggregate in

shallow water and most adult females aggregate in deep water in winter while both distribute equally in deep and shallow water in summer. Male and female juvenile lingcod distribute in only shallow water in both seasons. We examined the sensitivity of biological reference points of B.C. offshore lingcod to assumptions made about migration pattern and effort allocation across seasons and depths. Using the migration pattern which assumes males and females are equally distributed in shallow and deep water in both seasons, estimated MSY and SPR at MSY were robust against change of effort allocation. However, using the migration pattern which assumes 95% adult males distribute in shallow water in winter and 95% adult females distribute in deep water in winter, estimated MSY and SPR at MSY were markedly sensitive to changes in effort allocation. In particular, SPR at MSY could vary considerably depending on the effort allocation to different seasons and depths. Considering that %SPR is widely used as a proxy for MSY reference points, this result suggests that incorporating spatial and temporal selectivity appropriately into stock assessment models could enable improved evaluations of management options for B.C. lingcod and other highly migratory species.

D4. Title of Presentation: The effect of pole and line, and longline selectivity on skipjack and bigeye tuna assessments in the Indian Ocean
Presenter: Rishi Sharma
Authors: R. Sharma, M. Herrera, and A. Langley
Topic: D
Abstract: Skipkjack (*Katsuwonas pelamis*) and bigeye (*Thunnus obesus*) are valuable fisheries in the Indian ocean accounting for 65-75% of the overall tropical tuna catch in the Indian Ocean. Different fleets operate in these waters being primarily purse seine, pole and line and gillnet fisheries for skipjack, and longline and purse seine fleets for bigeye. Issues relating to estimating selectivity and the impacts on management vary substantially by species. For skipjack tuna the effect of pole and line selectivity on the estimates of fishing mortality and optimal yield are examined, and presented. The length composition data suggest a bimodal selectivity shape that is captured by the cubic spline function in SS-III adequately. However, in certain years the length composition is not captured and estimating selectivity by blocks is examined. Some of the residual errors in the fits are consequently removed, but the overall impact on the assessment is marginal at best. In contrast, for bigeye tuna, selectivity is shared across some of the long-line fleets in similar time/area strata, using the cubic spline option as well. This shape was chosen primarily due to the bimodal distribution of the length frequency data. The length composition data shows a sudden increase in size of fish captured after 2003. Time invariant selectivity estimated through cubic splines fails to account for these changes in length compositions, and fitting to these data by blocks creates results that are contrary to the estimates of optimal yield obtained in previous assessments. The consequence of weighting the size-composition data too high to estimate selectivity is discussed as the effective sample size has a huge effect on the overall assessment results. In both cases, however, the impact of selectivity on estimates of fishing mortality and reference points are marginal as compared to the effect of weighting alternative sources of data like the length frequency, and the abundance index data.

D5. Title of Presentation: A retrospective investigation of selectivity for Pacific halibut
Presenter: Ian Stewart
Authors: I. Stewart and S. Martell

Topic: D

Abstract: The Pacific halibut stock assessment represents a particularly challenging selectivity application. Contributing factors include: extremely pronounced temporal changes in size-at age, relatively late (age 6+) appearance of fish in survey and fishery data, a minimum fishery size limit, spatial heterogeneity in demographic parameters, and pronounced spatial trends in population abundance over time. Historical stock assessments have variously modeled selectivity as a function of size or age, and also employed nonparametric forms in attempting to account for these various factors. Despite these efforts, a strong retrospective bias in model results was detected during three separate time periods that ultimately required modification of the selectivity parameterization to ameliorate. A summary of historical and current approaches, along with some of the methods employed to explore the most recent retrospective pattern will be presented.