H. Description and Examples of Future Research

Several important categories of future research to improve stock assessments for West Coast groundfish include: (1) refinement of methods for Category 2 and 3 (data-limited) assessments; (2) improvements in generic methods for Category 1 (data-rich) assessments; (3) improvements in methods for analysis and incorporation of stock assessment data inputs; (4) improvements in methods and information regarding ecosystem and environmental effects on assessments; and (5) improvements in tools for evaluating the economic and biological performance of management alternatives. Finally, (6) there are a number of areas of research that could improve understanding of the basic life history of these stocks, which would improve the accuracy of assessments for these stocks.

1. *Data-limited methods*: Data-limited assessment methods are an active research area worldwide. West Coast groundfish assessments could particularly benefit from (a) improved methods for including composition data; (b) improved priors for recent depletion or fishing mortality; (c) faster estimation methods for DB-SRA and SSS; (d) analytical improvements including state-space estimation and flexible production function modelling; and € next-generation improvements, including spatial models and multispecies tools.

2. *Category-1 methods*: Data-rich assessments could be improved through further development of generic data-weighting tools, and best-practices for associated issues such as selectivity. In particular, (a) time-varying selectivity; (b) improvements in internal or external growth estimation; (c) best practices for other time-varying biological parameters; and (d) next-generation tools such as stratified or continuous-space models, and inclusion of survey and/or diet data directly within the model.

3. *Analysis and pre-processing tools*: Increased throughput of assessments will require continued improvements in data pre-processing and standardization tools. Important topics include in particular: (a) ageing-error estimation, where existing tools fail to include realistic estimates of the true proportion at age; (b) improvements in compositional expansion and input sample size estimation; (c) improvements in other data inputs, including fishery CPUE, discard estimation, fishery catch expansion with estimates of imprecision, maturity schedule estimates, etc.

4. *Improved incorporation of ecosystem and environmental components*: Ecosystem effects are increasingly recognized as impacting biological rates for managed populations. In particular, regime shifts in recruitment and changes in natural mortality due to predation are likely to cause changes over time that may impact assessment results. Improved (a) data collection, (b) reposition, (c) pre-processing and (d) assessment modelling tools will be needed to incorporate these effects while continuing to propagate uncertainty and provide model-fit diagnostics which reviewers expect for tactical assessment models. More research is also needed to identify ecosystem drivers of inter-annual changes in recruitment success, individual growth, and stock distribution.

5. *Improvements in economic and management-performance forecasts*: Assessment model suitability is best interpreted in the context of a given management procedure, as evaluated using closed-loop simulation. Fast and rigorous tools for management strategy evaluation using Stock Synthesis are therefore an important topic for continued research. Bioeconomic modelling is likely to provide decision-makers with policy evaluations that address a broader suite of management objectives, and could inform decisions regarding selectivity and fishing mortality rates for data-rich and data-limited assessments.

6. *Basic life history research*: Stock assessments are heavily dependent upon and sensitive to estimates of life-history parameters, whether they are estimated within or outside of assessment models. Continued and increased research is needed into such life history factors as:
   - maturity, fecundity and egg quality, and their relationships to female spawner age and size;
   - Natural mortality, in terms of not only average rates, but how they vary over time and with the age/size of individuals;
   - Predator-prey relationships and effects on growth, survivorship and reproduction;
   - Location of spawning and environmental factors affecting distribution and recruitment success (e.g. for Pacific hake);
   - The relative effect of single-species density-dependence vs. interspecies competition, predation, and environmental effects on recruitment;
   - Species movement and genetic exchange and differentiation along the coast.