Embedding Atlantic salmon population dynamics and stock assessment within a hierarchical bayesian integrated life cycle modelling framework

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MOVING BEYOND THE 'BEST ASSESSMENT' PARADIGM – THE INTERNATIONAL PACIFIC HALIBUT COMMISSION EXPERIENCE

It is standard practice to conduct fisheries stock assessments generating a point estimate of stock size, which is then translated into one or more future fishery catch targets and limits. Fisheries managers increasingly require estimates of uncertainty, which are generated through a variety of statistical methods, for explicit or implicit use in decision-making. The general approach often relies on the output of a single stock assessment model, and therefore does not thoroughly account for alternative hypotheses or major sources of uncertainty such as fixed parameter values, model approach (e.g., age-structured, surplus-production), model structure (e.g., treatment of spatial dynamics, delineation of fishing fleets) and data weighting. Assessment scientists following this paradigm can easily fall into the trap of endlessly searching for the 'perfect' model, when the real goal is to describe the dynamics of the stock and pass this information effectively to managers. In 2012, the International Pacific Halibut Commission made the transition from point estimates to risk-assessment, based on a decision table produced for the annual management process. The decision table represents a composite of probability-weighted results from alternative models, allowing a comparison of potential benefits (fishery yields) with the probabilities of various risk metrics, including stock and fishery trends and status. In 2013, the approach was extended to include the use of an 'ensemble' of models, following methods used in climate and hurricane forecasting. These changes have led to increased transparency about perceived risk, the availability of more information for the decision makers, and a clear delineation between scientific and policy considerations. Potential future extensions and improvements to the approach, as well as a brief summary of decisions based on this information will also be discussed.

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EMBEDDING ATLANTIC SALMON POPULATION DYNAMICS AND STOCK ASSESSMENT WITHIN A HIERARCHICAL BAYESIAN INTEGRATED LIFE CYCLE MODELLING FRAMEWORK

Atlantic salmon are assessed and managed at several spatial scales, from river specific stock units (e.g., national assessment, assessment in the Baltic (ICES WGBAST)) to national or broader regional complexes (e.g., management of mixed stock fisheries in the Eastern North Atlantic Ocean (ENAO), ICES WGNAS). Hierarchical Bayesien (HB) integrated life cycle

models are proposed as a template for harmonizing different modelling approaches. Models are written in a state-space form to separate stochastic processes of the population dynamics (age and stage-structured) and of the observations. Ecological processes and various sources of data can be modelled in a probabilistic rationale, with their associated sources of variability in a hierarchy of spatial scales. This provides a framework for harmonizing the models structure and parameterization between different stock units while maintaining the specificities and associated levels of detail in data assimilation. To demonstrate the approach we developed a HB model that improves on the understanding of key drivers for the population dynamics of Atlantic salmon and the stock assessment approach used by ICES WGNAS in the ENAO. The model captures the dynamics of 5 population complexes considered by ICES for stock assessment in the ENAO. It assimilates a 42-year time series of data (1970-2012) compiled by ICES WGNAS. The hierarchical structure provides a tool for (i) assimilating various sources of data at multiple scales; (ii) separating out signals in demographic traits at different temporal (e.g., year, decades) and spatial scales (e.g., specific or common to the 5 complexes). Results show that both survival during the first months at sea and the proportion of salmon returning to freshwater after two years at sea exhibit common decreasing trends in the 5 complexes. Results support the hypothesis of a response of salmon populations to broad scale ecosystem changes.

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INFORMATION USE IN STOCK ASSESSMENTS – A BAYESIAN STATE-SPACE ASSESSMENT MODEL FOR HERRING (*CLUPEA HARENGUS*) IN NORTHERN BALTIC SEA

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Precautionary and efficient fisheries management requires knowledge of fish stock status and fishing impacts, as well as of how likely it is that this status is true. Fish stock assessment models are therefore increasingly accounting for how e.g. observation uncertainties propagate to population estimates. However, traditional stock assessment models commonly rely mainly on fisheries and survey catch time series data. Here we develop a Bayesian state-space assessment model to analyze the effect of accounting for additional information on environmental pressures, here on recruitment, for estimates of a herring stock in the Bothnian Sea (northern Baltic Sea) for over 30 years. The model additionally accounts for prior biological knowledge on important population processes elicited from scientific literature and alternative data sources, and integrates the population dynamic model with different sets of observations data. Results show that including an observation model of population abundance indices from acoustic survey narrows the