Theme Session J
What's the catch? Designing and implementing statistically sound fishery sampling schemes in the real world

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Sampling schemes for estimating the species composition and size/age structure of fishery landings and discards are often the main source of data for reconstructing historical stock trends and fishing mortality rates for use by fisheries managers. Reliable estimation of landings and discards not only lies at the core of modern fisheries management but also forms the basis for future advances in the application of ecosystem-based approaches. The sampling and experimental designs under which data are collected circumscribe future uses, yet there are major challenges in implementing statistically sound sampling designs for commercial fisheries because of the practical difficulties faced in taking representative samples from the target population. These constraints need to be understood to prevent weak and occasionally unwarranted inferences from fisheries and stock assessment data. Such understanding is essential to meet the demands of managers and society which hope to improve the economic performance of fishery resources and to infer ecosystem principles. Moreover, current data collection systems must be robust to allow future scientists to answer as yet unknown questions with rigor and with proper estimation of uncertainty.

As part of its Quality Assurance Framework, ICES runs planning groups, study groups, and workshops aimed at supporting the development of statistically sound catch sampling schemes, taking into account practical issues in designing and implementing such schemes, and evaluating the quality of the data in a way that will be helpful to end users. The 2013 Annual Science Conference provided a timely and essential opportunity to review the development of such schemes in Europe and worldwide, and review the accumulated knowledge and experience to help improve and enhance them. In this session we sought to bring together case studies from many different types of large-scale and small-scale fisheries to illustrate the state-of-the-art in the design and implementation of fishery sampling schemes and associated analytical methods. A total of 19 papers and three posters were presented in this Theme Session with a focus on the practical aspects of sampling design programs for landings and discard estimation. Many of the papers addressed issues in the ICES area, and a suite of papers described fishery sampling schemes in Alaska, but the theoretical aspects of the papers had worldwide application.

Several important programmatic conclusions could be drawn from the papers:

- Broad scale collection programs require support of institutions and senior management to implement and maintain data collection systems.
- Sampling designs must be well documented at every stage of sampling. This includes not only the basic sampling design, but also every stage of execution. Such documentation is essential if data are post stratified or used in domain estimation. Thorough documentation is also necessary for tailoring of estimators to the realized sampling design. In the real world, not all designs can be fully realized due to weather conditions, logistical constraints of staff or practical aspects of budgets. Hence there is a need

for scientific flexibility resting on a foundation of theory supplemented by the details of implementation.

- The need for documentation extends to the formulation of sound databases. Several papers demonstrated the need for complex data structures to support modern sampling programmes. In one instance daily estimation of total landings and discards was required to support quota monitoring.
- A review of existing schemes for electronic monitoring suggested that such programmes must be evaluated in the context of overall fisheries governance. Current systems are not able to reliably estimate discards by species over all fisheries and fishing conditions. Moreover, biological attributes of landings and discards are difficult to measure. Electronic monitoring systems require significant post processing and will likely benefit from new technologies that automate or semi-automate the processing of video images. Discard information from EM cannot be used for real-time discard estimation without significant improvements in the processing time for quantitative measures. EM may have greater utility as a tool for compliance with regulations, such as a ban on discards, however such use must be incorporated into a programme of enforcement that penalizes harvesters that violate the regulation.

A number of important statistical conclusions were also drawn. Several studies demonstrated the importance of the primary sampling unit as the most important factor for proper estimation of uncertainty. Within-sample replication, for example oversampling of length or age samples within a tow or trip, was shown to add relatively little information because of the inherent intra-cluster correlation of observations. A general reduction of within-haul or within-trip sampling was shown to have little effect on the precision of fundamental quantities such as catch at age due to cluster sampling effects. Precision is affected more by the number of independent primary units sampled. This principle was also demonstrated at the level of the stock assessment, wherein the assessments based on more sparsely sub-sampled primary units performed nearly as well as those based on much larger sub-samples. The importance of precision in catch vs survey information was nicely demonstrated in one paper that revealed that poor catch estimation interacted with survey information to produce highly biased results. In some cases, poor catch estimation completely compromised the ability to achieve acceptable levels of precision in the stock assessment irrespective of gains in survey precision.

Such findings have important implications for allocation of overall sampling effort. In particular, efforts to increase the number of primary sampling units would improve precision. Under a fixed cost scenario, an increase in primary sampling units could improve the ability to answer future questions. Similarly, cost savings might allow for improved sampling of currently neglected species. World fisheries are replete with examples of new fisheries on underexploited species that quickly become overfished owing to lack of basic information.

An important debate on the utility of métiers as sampling strata occurred. Métiers can also be used to define domain estimation after the sampling is conducted. It was noted that métiers constitute “soft strata” that can overlap and make it difficult both to define a sampling frame and to raise to total catch. These negative aspects were offset to some extent by the degree to which such definitions facilitated communications with fishermen. Several papers emphasized the importance of full engagement

with the fishing industry as a precursor for improving data quality, increasing compliance with regulations, and decreasing the rejection rate for at-sea observer trips.

Statistical theory, that suggests information from a single tow is often equivalent to the information of a single random sample, must in turn confront the difficulties of actually obtaining a representative sample from a deck load of fish. Practical on-deck experiments once again emphasized the need to properly document the conditions under which a sample is taken.

The interplay between model-based and design-based information was emphasized in several papers. Model-based inference is often more costly in terms of computations, but it can show where design-based inference falls short, and can in some cases reduce bias and improve precision in key estimates such as catch-at-age as compared to standard design-based estimators. Model-based inference can be used to extract information from previous years and also improve imputation schemes for within-year estimation.

Comparison of estimators revealed that ratio estimators performed best when the correlation between the measured variable and covariate was high. Similarly, a number of papers reinforced the notion that over-stratification can lead to biased estimation. In particular, ratio-estimators can result in highly biased estimates of catch-at-age in cases with high number of strata and small samples sizes (of primary sampling units) within strata. This should also give pause to managers and industry that continually press for increased precision of estimates at ever finer temporal and spatial scales. Examples in the ICES area include the requirements for high precision of estimates at fine-scale métier definitions, which can prove impossible within existing resources, and the impending EU discard ban may result in requests for high-resolution data to monitor its effect. One statement that resonated with the participants was the notion that not all objectives can be obtained simultaneously. It was succinctly stated as: “Cheap, fast or accurate -pick two.”

In summary, the papers collectively demonstrated remarkable advances in the application of statistical theory, development of scientific and computing infrastructure to support catch estimation, practical experience with implementing advanced catch monitoring programs, and evaluating the effect of data quality on fishery management advice. The rapid advances in Europe in these areas show the increasing impact of ICES initiatives since the late 2000s on development of statistically-sound, cost-effective catch sampling schemes, and reinforce the need for future ICES expert groups on these topics to progress the development and uptake of such schemes and to improve the awareness of data quality issues in assessments and advice.