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Zonal Snow Crab Workshop / Atelier zonal sur le crabe des neiges

14-18 January, 2002 / le 14-18 janvier, 2002
St. John's, NF

Jake Rice, Chairperson / Président
John Moores, Editor / Éditeur

200 Kent Street / 200, rue Kent
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Canada

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ABSTRACT

The basis for the assessment of status of snow crab stocks in Atlantic Canada was reviewed at this meeting. Each Region presented the major data sources used in their assessments, and the major analyses conducted on each data set. To the extent that it was formalized, the contribution of each type of analyses to final conclusions about stock status were also presented.

Following each Regional contribution, there was a thorough discussion of the assumptions explicit and implicit in how the data were collected and analyzed. Opportunities for alternative analyses, and potential problems with assumptions made by various approaches were highlighted, on a stock by stock basis.

After the Regional, stock-specific discussions, the meeting evaluated the different Regional approaches to assessment of status of snow crab stocks. The intent was to determine if differences among Regions in data collected and uses of the data reflected different assumptions about crab biology and / or fisheries practices, or simply different histories regarding monitoring practices or development of analytical methods. Where different assumptions were identified, the meeting evaluated the scientific basis for making different assumptions. Where inter-regional differences were merely consequences of different histories, opportunities for inter-regional exchange of methods were sought.

Key Conclusions of the meeting were:

- All regions are using a combination of data obtained from research surveys and from the commercial fishery to evaluate the condition of the crab resource in their respective regions. Regional assessments have to take into consideration differences in the biology of species related to local environment, differences in the fisheries and trawl survey (e.g. directed for crab in the Gulf and part of a multispecies survey in Newfoundland).
- The trawl surveys provide a relative index of abundance and should not be considered as an absolute value.

Variation in catchability has been identified depending on bottom type and season. Catchability should be studied in all areas for consideration in future analysis.

RÉSUMÉ

L’objet de la réunion était de passer en revue le fondement des évaluations de l’état des stocks de crabe des neiges du Canada atlantique. Chaque région a présenté les principales sources de données utilisées pour effectuer les évaluations et les principales analyses de chaque ensemble de données. Dans la mesure où on lui a donné un caractère officiel, la contribution de chaque type d’analyses aux conclusions finales sur l’état des stocks a aussi été présentée.

Une discussion approfondie des hypothèses, explicites et implicites, sur les méthodes de collecte et d’analyse des données a suivi la présentation de chaque région, ce qui a permis de faire ressortir, en fonction de chaque stock, les analyses de rechange possibles et les problèmes potentiels des hypothèses issues des diverses approches.

Suite à cette discussion, on a évalué les différentes approches des régions à l’évaluation de l’état des stocks de crabe des neiges, l’objectif étant de déterminer si les différences entre les régions pour ce qui est des données recueillies et des utilisations de celles-ci reflétaient des hypothèses différentes au sujet de la biologie du crabe et/ou des méthodes de pêche, ou simplement un historique différent des méthodes de surveillance ou de l’élaboration des méthodes analytiques. Les hypothèses différentes identifiées ont été évaluées au plan de leur fondement scientifique. Lorsque des différences entre les régions étaient uniquement une conséquence d’historiques différents, on a essayé de trouver des moyens de faire un échange de méthodes entre régions.

Voici les principales conclusions formulées lors de la réunion :

- Toutes les régions utilisent un mélange de données issues de relevés de recherche et de la pêche commerciale pour évaluer la condition de la ressource en crabe dans les eaux qu’elles gèrent. Les évaluations régionales doivent tenir compte des différences dans la biologie de l’espèce par rapport à l’environnement local, ainsi que des différences au niveau de la pêche et des relevés au chalut (p. ex., pêche dirigée du crabe dans le Golfe et élément d’un relevé plurispécifique à Terre-Neuve).
- Les relevés au chalut permettent d’obtenir un indice relatif de l’abondance qui ne devrait pas être considéré comme une valeur absolue.

On a établi que la capturabilité variait selon le type de fond et la saison. Elle devrait être l’objet d’une étude dans toutes les zones de pêche et incluse dans les analyses futures.

1. OPENING REMARKS

The chairperson welcomed the participants to the meeting. Due to weather conditions in the Maritimes, the start of the Workshop was delayed until the afternoon of January 14, 2002. Participants from the Gulf Region were not present until the morning of January 15, 2002.

Snow crab is an important component of the fishery in Atlantic Canada. We need to ensure that the methods employed in each region are scientifically appropriate. Possibly differences in biology and fishing practices may warrant differences in determining stock status. Possibly, regional differences are only superficial and use common assumptions.

2. REVIEW OF AGENDA

With the loss of the Monday morning session, Results of the Strategic Research Projects was deferred until the end of the Workshop. The Regional presentations were to be in two parts: first a formal presentation, then a discussion of the assessment methods employed in that region. The issues of Precautionary Approach and biological reference points were to be addressed as a general item after the area presentations had been completed.

3. DFO QUEBEC REGION

A. Biological basis for the stock assessment. – B. Sainte-Marie

1. Knowledge base for northern Gulf populations

(i) Distribution of fishery

- Coastal populations occupy a narrow (3–100 km) band along Saint Lawrence Estuary and Gulf north shores, Gaspé north shore, northwest coast of Newfoundland, and around Anticosti Island: total coastline in excess of 2400 km.
- Five traditional fishing zones (17 to 13).
- Traditional fishing zones fully developed since the late 1980s.

(ii) Spatial scales

- Populations structured spatially by size and age. In general, bigger-deeper trend.

- Spatial distribution is influenced by environment and population intrinsic factors.
  - All life stages, and in particular juveniles, are sensitive to temperature. Juveniles additionally are strongly selective of sediment type.
  - Annual bathymetric migrations of some population components: juveniles, prepubescent females, adolescent males, and adult males. Pre-recruits concentrate on shallow grounds for moulting in the spring.
  - Distribution patterns of adult males may be influenced by the abundance and location of receptive females, especially during the winter, spring and early summer. Pubescent females form loose aggregations in shallow water, while ripe multiparous females occur in deep water and have a conspicuous mounding behaviour. Abundance fluctuations of the two female types are not synchronous. The adult component of the population is most aggregated in December–June and least aggregated in August–September.
  - The size of aggregates varies from a few metres for mounds to hundreds of metres for moulting crabs (video).

(iii) Growth

- Growth well documented: prerecruits^{-2} are adolescents of 62–78 mm CW and prerecruits^{-1} are adolescents of 78–95 mm CW.

- Delayed (skip)-moulting occurs in juveniles and adolescents and is density-dependent.
- Terminal moult. Life expectancy and change in shell condition with time elapsed after terminal moult is known: males are fully available to the fishery and are of greatest commercial value from about 8 months to 3 years after terminal moult.

(iv) Sex

- Sexual size/age dimorphism in favour of males and expression of male alternative mating tactics suggest strong sexual selection on males. In species with similar features that have been investigated, traits such as body (or weapon) size that procure a competitive advantage are at least in part inherited.
- Reproductive biology is complex: pubescent-primiparous females are polyandrous, dominant (=large, intermediate shell condition) males are sperm economisers and they adjust their guarding/sperm allocation strategy to sociosexual context. There is a strong

potential for interaction between exploitation and female/male reproductive success.

Conceptual model for northern Gulf populations

- Metapopulation exhibiting a productivity gradient, from west ("warm", more productive Estuary) to east (cold, less productive Lower North Shore).
- Recruitment occurs in pulses (cycle with periodicity of 8 to 10 years is hypothesised).
- Temporal lag from west to east in propagation of recruitment pulses.
- Theoretical expectations for population indicators in the context of pulsed recruitment.

B. Data and analytical framework – B. Sainte-Marie

Data sources and limitations

- Data from:
  - logbooks, all fishing zones;
  - at-sea observers and dockside monitoring, all fishing zones;
  - post- or in-season trap surveys, all fishing zones;
  - post- or in-season beam trawl surveys, annually on north shore of zone 17 and BSM (zone 16 centre-west), tentatively every 2 or 3 years at border of zone 15 with zone 14, and of zone 14 with zone 13.
- Main limitations:
  - very incomplete spatial and temporal coverage of populations by beam trawl due to extent of coastline and nature of bottoms (a modified beam trawl is used on the Lower North Shore);
  - trawl selectivity is unknown;
  - assessment of exploitation rate not possible so far (an index of total mortality is calculated for the north shore of zone 17).
- Indicators of stock status are used to determine present status and to project status in future over short (1 year), medium (2–3 years) and long (4–7 years) terms. Note: indicators available across all fishing zones are shaded.

Principal indicators of snow crab stock status

		Time scale for projection		
Stock status indicator	***Data source***	***0–1 yr*** short term	***2–3 yrs*** medium term	***4–7 yrs*** long term
CPUE/Abundance legal males	Logbooks, trap and trawl surveys	✓		
SC legal males	At-sea observers, dockside monitoring, trap and trawl surveys	✓	✓	
CW legal males	At-sea observers, dockside monitoring, trap and trawl surveys	✓	✓	
CPUE/Abundance prerecruits^{-1}	At-sea observers, trap and trawl surveys	✓[a]	✓	
Abundance prerecruits^{-2}	Trawl surveys		✓	
Abundance juveniles and adolescents <62 mm CW	Trawl surveys			✓
CW legal × SC legal	At-sea observers, dockside monitoring, trap and trawl surveys	✓	✓	✓
<u>Sex ratio and primiparous reproductive success</u>	Trawl surveys	✓		
Disease (BCD monitoring and condition indices)	Fishers, trawl surveys	✓	✓	
Environment (CIL and predators)	Fishers and colleagues		✓	✓

[a] prerecruits^{-1} normally are fully available and desirable to spring fisheries only 2 years later; however they may become fully available to autumn fisheries 1 year later.

2. Derivation of outlooks from stock status indicators

Indicators of stock status are interpreted individually and together in a historical perspective of 2 and 3-year trends and by comparison to minimum-maximum values within fishing zones to provide outlooks over the short and medium term:

Stock status indicators

CPUE/Abundance legal: Increasing or high	***CPUE/Abundance legal:*** Decreasing or low
SC legal: high % new and intermediate	*SC legal:* High % intermediate and old
CW legal: small and stable or increasing, or large and stable	*CW legal:* large and decreasing, or small and decreasing
CW legal × SC legal: Small crab – new shell	*CW legal × SC legal:* Small crab – old shell
= Positive Short Term Outlook (PST)	= Negative Short Term Outlook (NST)

CPUE/Abundance pre $^{-1}$: Increasing or high	*CPUE/Abundance pre $^{-1}$:* Decreasing or low
Abundance pre $^{-2}$: Increasing or high	*Abundance pre $^{-2}$:* Decreasing or low
Abundance juv/ado <62 mm: Increasing or high	*Abundance juv/ado <62 mm:* Decreasing or low
= Positive Medium Term Outlook (PMT)	**= Negative Medium Term Outlook (NMT)**

3. Formulation of stock status

- PST: current exploitable biomass is high and stable or increasing; fishing and natural mortality have not exceeded recruitment.
- PMT: recruitment is expected to be good for another 1 or 2 years. The projection may be extended longer if trawl data for smaller male size classes are available.
- NST: current exploitable biomass is low or decreasing, fishing and natural mortality have exceeded recruitment.
- NMT: recruitment is expected to be poor for another 1 or 2 years. The projection may be extended longer if trawl data for smaller male size classes are available.
- PST+PMT: current exploitable biomass is high and will continue to increase if fishing and natural mortality remain constant.
- PST+NMT: current exploitable biomass is high but will start to decline if fishing and natural mortality remain constant.
- NST+PMT: current exploitable biomass is low but will start to increase in 1 or 2 years if fishing and natural mortality remain constant.

- NST+NMT: current exploitable biomass is low and will decline even more if fishing and natural mortality remain constant.

Long-term outlook will vary from negative to positive depending on abundance of juvenile and adolescent male crabs <62 mm CW. Environment and sex ratio considerations are not yet fully integrated in the formulation of stock status. A sustained CIL warming trend would be cause for worry with respect to long-term recruitment; an increase in natural predators (specifically cod) would probably dampen recruitment pulses. Low sex ratios prevailing for a long time would be a cause of concern: further research is planned to evaluate the impact of changes in sex ratio (and specifically of large male partial sex ratios).

Discussion points

- None of the indicators are considered in isolation. Advice is provided based on the overall interpretation of all the indicators. The TAC is basically set by comparison between years. If the indicators are positive, the TAC may be increase may be increased. The scientific analysis does not give precise values.
- In Quebec the crab population is found in a narrow band of suitable habitat while in the Southern Gulf they are dispersed over plateaus.
- Primaparous females are generally found singly in shallow water, while multiparous females are found in aggregations in deeper water. This will affect the distribution of the males. The survey does not consider patchiness.
- The pre-recruit definition is different in different areas. In the Southern Gulf it is the year after terminal moult, while, in Quebec and Newfoundland the long fishing season can result in new shell individuals being harvested late in the season.
- Skip moulting is not a big consideration in Quebec.

C. Estuary and north Gulf of Saint Lawrence snow crab stock assessment: a case example. – Réjean Dufour

1. Overview of fishing zones

Zone 17 (Saint Lawrence Estuary) case study

- Fishery:
  - Landings and CPUE;
  - Distribution of effort;

- Shell condition of legal males;
- Size composition and mean size at sea.

- Beam trawl survey:
  - Survey design;
  - Shell condition;
  - Size composition;
  - Mean size of legal crabs;
  - Kriging;
  - Abundance index for prerecruits and recruited crabs;
  - Total mortality;
  - Projection of recruitment;
  - Projection of fishery CPUE;
  - Sex ratio.

- Trap survey:
  - Survey design;
  - Shell condition and CPUE;
  - Size composition and mean size;
  - Projection of fishery CPUE.

- Stock status summary:
  - 2- and 3-year trends for principal indicators;
  - Analytical sheet and stock status.

Discussion Points

- Should look at separate variograms for the near shore and the offshore stations. The scatter of points raises concerns and takes out the depth affect.
- The small confidence limits associate with the recent points seemed to be inconsistent with the scatter of the data. A cross validation test was recommended.
- The data suggested a strong spatial (east-west) pattern that should be considered in the analysis.
- Only a portion of the Northern Gulf is surveyed annually. The other areas (13 and 14) have little trawlable ground. Information from the detailed surveys is considered for all areas with point checks in the other areas on an opportunistic basis and data from trap surveys. Also have data from the intensive survey of Baie Ste. Marguerite.

- Catchability for the beam trawl has not been determined. It was noted that the trawl opening was relatively small and patchiness could influence catches.
- Highgrading practices are assumed to be consistent from year to year.
- Commercial CPUE was not adjusted for soak time.

SOUTHERN GULF

A. An overview of the Gulf Region survey design, analysis methods and relationships between fishery observations and survey results. - M. Moriyasu

- Fixed Random block design using 10 minute by 10 minute sampling units.
- Approximately 280 sampling stations covering the entire southwestern gulf of St. Lawrence snow crab fishery since 1988. Few samples are taken at depths less than 20 m or greater than 150 m.
- Movement negligible (approx. 10 km);
- Gear type used - Bigouden Nephrops trawl;
- Every crab is observed and measured, other species counted;
- Introduced Scanmar net sensors in early 90's. Changed to Netmind net sensor system in 1999. A side trawler vessel was used from 1988 to 1998. A stern trawler has been used since 1999.
- For eastern Nova Scotia, issues unique to the area need to be addressed in order to provide advice on stock population.
- Large areas deemed non-habitable by snow crab, which needs to be excluded from effective assessment area.
- Bathymetry in Scotian Shelf is much different than the Southern Gulf.
- Long term and seasonal temperature fluctuations also occur in this area.

- Challenges are related to projections of the viability of the stock in light of temperature variations (projections).
- An autocorrelation is often observed within the samples, which is subsequently modelled using a variogram model. This model is then used as the basis of the interpolation technique which is based on a geostatistical approach (kriging).

Discussion Points

- Discussions were related to effect of kriging on interpolation of density given various situations (projections below 0 density for instance). Methods were suggested to incorporate areas of low probability of crab (banks in eastern Nova Scotia) in the analysis.
- It is a relative estimate, but treated as absolute because it fits reasonably well to operational needs.
- There appears to be an inefficiency in the gear for sampling sizes up to 50 mm.

B. MPOGEOS software – E. Wade

A presentation was made showing the software program used in the Gulf Region for estimating global kriging estimate and kriging variance.

- Kriging is a linear interpolation method that minimizes the theoretical estimation error variance while ensuring the estimator is unbiased, i.e., the expectation of the estimation error is null.

- Kriging incorporates the information on spatial structure as summarized by the variogram model. Kriging can be used to estimate density at precise locations (point kriging) or areas (block kriging).

- Co-kriging can be used to incorporate secondary information such as depth, temperature, sediment, other species.
- Initial attempts at using depth with Markov-Bayes approaches, indicator kriging and co-kriging have not provided a reduction in the uncertainty of the biomass estimates because of low correlation between depth information and density.

Discussion Points

- Not clear that having points from four quadrants will protect against bias in establishing distance boundaries.
- There is an apparent lack of depth-abundance relationship.
- The pattern of residuals needs to be examined. There is a history of underestimating uncertainty.

C. Stochastic Simulations – E. Wade

- Stochastic simulations can also be performed to estimate, locally, probabilities of exceeding a given density threshold and its associated conditional variance.
- The idea of simulation is to generate, over a given domain, many possible realizations of the process that faithfully reproduces the characteristics of the global distribution function and of the variogram model.
- In other words, resulting statistics of the simulated values, namely the covariance characteristics and the frequency distribution of the densities, takes precedence over local accuracy.
- In this way we can estimate the probability of having a given level of density of crab in an area.
- Details about simulation methods can be found in Deutsch and Journel (1998).

Discussion Points

- Questions were raised as to why stochastic simulation mapping would be so different from kriging. It was determined that it was an effect of the smoothing effect of kriging.
- How much improvement by introducing the co-variant structure?

D. Gulf snow crab model – E. Wade

Presentation was made on a length based modelling approach applied to the zone 12 fishery.

- Parameter estimates on moulting rates, skip rates, trawl efficiency and mortality rates were estimated from the adolescent part of the population.

- Projections of populations of various categories were made using observed frequency distributions.
- Projections for recruitment to the commercial part of biomass based on recent years observations of immature crab were shown to increase until the 2004 and 2005 survey year.
- The second part of the presentation dealt with the modelling of the mature portion of the crab population.
- Parameters included mortality of various portions of the mature population and probabilities of transfer to subsequent groups.
- Effects of various exploitation rates on the commercial portion of the population were shown.

Discussion Points

- Trawl catchability, selectivity, trawl efficiency. There is the possibility of a gradual size-based selectivity effect instead of a usually assumed sharp demarcation.
- Discussion of survivability results obtained in the length-based model. Discussion of where model error stems from: process versus observation error.
- Homogenisation of two models: Is it possible to have two models (length based and instar based) with the same underlying hypotheses.
- Population model has not changed since the last ZAP meeting in Montreal. It's important to do "baby" steps while doing model development, testing and incorporating biological information into the model. Model development as it is may be too complex to adequately test. Criticisms: model has biases (Loess demonstration). Problems in the assumptions (mortality is 0 and trawl efficiency is 1). Maybe add some parameters to represent these factors and perform regression again; test for parameter correlation problems. There probably isn't enough information to estimate all of the parameters in such a model.
- How do we bring risk analysis into our stock assessment recommendations? Kriging really underestimates the variance in relation to the "true" value. What is being done to improve upon risk estimation in relation to stock estimation? What can you

say to people who say that catchability is not related to stock size?

- What recommendations can we give to improve error-variance estimation during the RAP sessions?
- Enumeration of underlying assumptions for the Southern Gulf must be stated clearly.
- It's difficult to define what the goal of stock recommendation is supposed to be.
- Science produces relative biomass estimate and management relies rather single-mindedly as it being an absolute estimate. What is the role of science in this? Pass the value; provide weak points and precautions.

E. Area-Swept Estimation – T. Surrette

Using data gathered during the 2001 Southern Gulf-Scotian Shelf trawl surveys, an area-swept estimation procedure was proposed.

- The data were gathered using a Minilog depth-temperature probe and Netmind acoustic sensor system, both synchronized and combined with position data from the GPS system.
- The general model used was that of a definite integral between touchdown and liftoff trawl times of an instantaneous area-swept variable (the surface area covered per unit time). The latter was calculated as being the trawl width times the trawl speed at a given time.
- Various aspects of data pre-processing, such as smoothing of trawl speed, outlier detection, and filtering of the trawl width time series were discussed.
- The problem of accurate touchdown and liftoff time determination was also discussed and a novel analytical method using mixture model clustering was using in our particular case.

Discussion Points

- Different bottom types could be a factor in action of trawl.

F. Instar Separation and Local Abundance Estimation –T. Surette

Gaussian mixture models (GMMs) were discussed and applied to Southern Gulf trawl survey samples.

- Initial application of general version GMMs proved too ambiguous and solutions obtained were not deemed realistic, and a proposed version of a "structured" GMM showed more promising results.

- The structured-GMM incorporated functional forms to iteratively describe component means and variances, given an initial starting point, provided by a fully defined "initial" instar component.

- Given a linear model linking up component means and a linear model linking up component variances, in a given sample year, we are able to account for the modality of smaller instars fairly well while "propagating" some of this structure for larger, less well resolved modes.
- The formulation of this model allows for some flexibility and future development.

Discussion Points

- Growth rates and other parameters could be used as limits.
- The analysis assumes the process is homogeneous, however, the probability of moulting depends on the size within an instar. This also affects the mean size within an instar.

G. Instar distribution and adult movement - M. Moriyasu

The results of instar separation mentioned above (an example of 2000) were applied to assess the male and female instar distribution in the southern Gulf of St. Lawrence.

- There is a general tendency of movement of concentration patches from the north-western Gulf towards the south-eastern Gulf. This suggests that either there is a movement towards the southeaster part of the Gulf as crab grows or crab grows to larger sizes in the south-eastern part of the Gulf.

- Tagging study on the commercial sized adult males in the southern Gulf and eastern Nova Scotia suggested that there may be a directional movement towards favourable habitat when the stock is in declining phase in the southern Gulf.

- An active seasonal movement was found in the south-eastern Gulf (western Cape Breton) and northern Scotian Shelf. Intermixation of commercial-sized adult crab was frequently observed amongst fishing areas (18,19,20,21 and 22) within areas 23 and 24.
- Due to the highly active seasonal movement of commercial-sized males, the timing of trawl survey seemed to be an important factor to assess accurate abundance of commercially exploitable crab in certain area (e.g. areas 20,21 and 22).
- There seemed to be a seasonal movement of commercial-sized males between the survey and fishing season in areas 18 and 19 (south-eastern Gulf), which may be influenced by the abundance of crab in and outside of the area and corresponding fishing effort.

Discussion Points

- The impact of kriging on the older instars, which used a very small influence instar, was discussed. It could be that the change in decorrelation length scale is likely to be artificial. It could be the same correlation of the random effect, but the existence of large-scale spatial scale will lead to a small-scale smoothing window.
- Can the negative abundances of the kriging be avoided or not?
- From the tagging it was noted that when the abundance declined the crab moved back toward the centre of the fishery.
- Model assumes one more instar moult than was reported for Bonne Bay.

NEWFOUNDLAND AND LABRADOR

Presentations

Two presentations were made: the first dealt with the snow crab fishery and how fishery performance was assessed, while the second outlined progress in the analyses of data collected from 3L inshore time-series research cruises.

A. Data from the commercial fishery. – D. Taylor

The principal tool used in assessing fishery performance is catch rates calculated from logbook data. This is done by NAFO Division or by snow crab management areas. Each year CPUE's are compared with values from a long-term index derived from a sub-sample on unadjusted CPUE's calculated over previous years. Where possible, reported catch rates are compared to those from at-sea observers deployed in the same area at the same time. Sample figures of all three data sources were presented.

Discussion Points

- It was recommended that the timeliness and completeness of logbook data entry be improved.

- It was recommended that effects of annual variation in seasonality of catch rates should be explored e.g. compare CPUE for first 3 weeks of fishery for year to year variability.

B. Time Series Inshore Research Cruises – D. Taylor & S. Sutton

The presentation describing the data analyses from the 3L inshore research cruises consisted of 2 parts. The first presentation covered areas that have been examined for a number of years such as commercial fishery catch rates compared with those from the cruise; % skip-molting by area/year, pre-recruit abundance and Bitter Crab Disease prevalence.

The second presentation dealt with new initiatives undertaken recently to fully analyse trawl and trap data to determine what predictive capability they might have in terms of short-term forecasting of fishery performance.

(i) Paired trap/trawl stations

The fishing strategy deliberately tried to fish traps and trawls in a paired manner in order to determine whether there is a relationship between catches from the 2 gear types.

Numerous treatments failed to show any consistent or meaningful relationship between the gear types.

Discussion Points

- It was suggested that the sequence of sampling on a paired station be examined. It may be possible that if traps were used first, trawl catches may have been affected.

(ii) Comparison of survey trap catches with commercial catch rates

Comparison of trap survey catch rates with commercial catch rates the following year and 2 years later showed a positive but weak correlation for both commercial (>94 mm) and pre-recruit (75 mm-94 mm) size groups.

Discussion points

- It was suggested that new-shelled crabs be excluded from the calculation of survey catch rates to see if the relationship could be improved.
- Survey design, sampling levels and spatial variation should be examined to determine their influence on survey indices.

C. Influence of trap mesh size and soak time on snow crab catch rates – D. Taylor

During research cruises conducted in inshore areas of 3L in 2001 experiments were conducted to see if trap mesh size and soak time had an effect on catch rates and size-frequency distribution of captured snow crab. While larger meshed traps were more effective in removing undersized crabs from the catch there was very little advantage in increased mesh size for excluding small legal-sized crabs.

D. Review of methodologies relevant to bottom trawl surveys in the Newfoundland Region and evaluation of the snow crab indices derived. – E. Dawe

This presentation initially reviewed the survey methodology and methods of data analysis used to generate indices of snow crab resource status. It then evaluated the validity of the assumptions associated with the derivation of these indices and assessed performance of survey indices in relation to fishery performance. The survey series is of only 7 years, beginning in 1995 with the introduction of the Campelen 1800 shrimp trawl as the standard survey bottom trawl. The fall survey series is used, encompassing the continental shelf from southern Labrador to the Grand bank (NAFO Div. 2J3KLNO).

These stratified random surveys were not designed specifically for snow crab, but are multispecies in scope. Survey coverage has varied among years and each assessment has limited the data from the most recent two years to only common strata, for direct comparison. There has been some seasonal variation in survey timing, but it has generally extended from mid-September to late-December, and is utilised as a post-fishery survey.
Confidence intervals about mean survey biomass indices of legal-sized crabs have ranged within 13-22% of the mean for the entire survey area. Precision is lower for divisional estimates, especially for the most southern divisions (Div. 3NO) where the distribution is highly aggregated. A projected exploitable biomass index is calculated as the sum of the adult legal-sized (>94 mm CW) male biomass during the survey plus the biomass of males that will result from moulting in spring to produce legal-sized but new-shelled males during the subsequent fishery. This biomass of new-shelled males is calculated by applying a constant growth increment to all adolescent males larger than 75 mm CW. New-shelled males have not represented an important component of the landed catch in recent years, when most of the catch has been taken during spring. The ratio of the commercial catch to the projected exploitable biomass index is compared with that of previous years, as a possible indicator of change in exploitation rate.

The projected biomass of older-shelled males showed a strong positive relationship with subsequent commercial CPUE in the most northern area (Div. 3L), but this relationship deteriorated to the south, becoming strongly negative in Div. 3L. Strong year effects were evident, affecting survey indices of all male size groups. Such year effects, and poor relationships of survey indices with CPUE, may be related to yearly changes in trawl efficiency due to changes in crab distribution with respect to depth and substrate type. It is also possible that CPUE does not directly reflect annual changes in exploitable biomass. CPUE may remain high as biomass declines, if the distribution contracts, maintaining high density at commercial fishing depths. Fishing practices may also change to maintain high CPUE as the biomass declines.

Discussion Points

There was discussion regarding whether this annual fall survey should be considered a post-season survey or a within-season survey, because the fishing season has differed considerably among years since 1995. It was recognised that the portion of the total annual catch that has been taken after the fall survey commenced has varied among years. However most of the commercial catch in recent years has occurred in spring and commercial catches during fall would not be so large as to affect the relationship between survey indices and commercial CPUE in the next year.

There was extensive discussion surrounding projection of biomass and interpretation of recruitment indices from projections. In particular, it was pointed out that the new-shelled component of the projection, that would result from moulting of adolescents, includes males that would be adults (with large claws) and so would be fully recruited as older-shelled males in one additional year (R-1's). However also included within this new-shelled component would be animals that remained adolescent after moulting and so would moult one more time and not be fully recruited as older-shelled crabs until two additional years later (R-2's). This discussion extended to a consideration regarding the relative value of new-shelled males in contributing to successful mating in the spring immediately following the survey. It was pointed out that the new-shelled component is not projected either to serve as a recruitment index for one specific year, nor to serve as an index of mating assurance for any given year. Rather it is intended to provide an index of the biomass that would support recruitment to the fishery as well as insemination of females in the short term.

It was suggested that estimates of density from the Campelen trawl should be compared with those of other trawls in other regions. Such comparisons could be considered in relation to regional CPUE comparisons to infer some approximate differences in efficiency between trawls.

The perceived importance of survey indices relative to all other information pertaining to resource status was discussed. It was noted that in some other regions annual TAC's are set directly in relation to survey estimates. It contrast it is well recognised in the Nfld. Region that survey indices do not approximate absolute biomass or exploitation levels. Survey indices are summarised and evaluated together with all other relevant indices using the Traffic Light Approach.

There was discussion of regional differences in definitions of recruitment. Whereas new-shelled crabs are not considered to be recruited in other regions with spring-only fisheries they have been considered to represent new recruits in the Nfld. Region because they may contribute to the commercial catches during fall. Late-season increase in CPUE has commonly been observed in the Nfld. Region and has been attributed to an increase in proportion of new-shelled crab in landings.

It was suggested that a seasonal decline in CPUE could reflect most competent fishermen having completed fishing and hence there is a seasonal decline in commercial fishing efficiency.

E. Results of a study of the efficiency of the Campelen 1800 survey trawl in sampling snow crab, September 2001. – E. Dawe

A small-scale study was carried out during September 2001 to directly estimate the efficiency of the Campelen 1800 survey trawl in sampling snow crab. The study consisted of carrying out standard-type survey tows (i.e. 15-min duration at a speed of 3.0 knots), but with secondary trawls attached to the main Campelen fishing line to collect snow crabs that did not enter the main trawl. Three secondary trawls (bag trawls) were attached to a common 8 in. diameter continuous rubber set of footgear and they jointly spanned the entire length of the Campelen rockhopper footgear. Trawl efficiency was estimated as the ratio of the catch from the main Campelen codend to the total catch from all four codends. These estimates assume that overall efficiency of the gear, equipped with auxiliary trawls, is 1.0. Bottom contact sensors were attached to the main or auxiliary footgear and provided data that were examined immediately following each set. The experiment was conducted in Conception Bay (Div. 3L) and was limited to only three days sampling due to operational problems that were unrelated to the sampling gear. However, within those three days 15 successful sets were executed across two survey depth strata and more than 10,000 crabs were collected and sampled.

Data from the ROXANNE Seabed Classification System were collected and used to categorise substrate type. They showed that the deep (>183 m) stratum had a soft mud substrate whereas the shallower (91-183 m) stratum was one of mixed harder substrate types. Trawl efficiency across all snow crab sizes was similar between the sexes and markedly different between depth strata, being generally about 0.6-0.8 in the deep stratum but only about 0.2 in the shallow stratum. Trawl efficiency for male snow crabs showed a clear decrease with decreasing carapace width; efficiency was particularly low for small males in the shallow stratum with hard substrate type. Size relationships were similar to those found for Eastern Bering Sea snow crab, based on a similar experiment.

Results from earlier experiments in other inshore areas were reviewed. Comparative sampling, using two research vessels concurrently, in both 1998 and 1999, showed that, relative to traps, the Campelen trawl performed much more poorly in catching snow crabs in shallow inshore strata (<300m) than in deeper strata (300-500m). Application of estimates of area fished by both those gear types suggested that trawl efficiency was considerably lower than 1, was highly variable, and declined with stratum depth and crab size. Another comparison, based on common stations, indicated that crab catches were consistently higher when the trawl was equipped with a tickler chain, than when it was not modified.

Discussion Points

- It was noted that in the deeper stratum trawl efficiency decreases with decreasing size but becomes unclear for smallest males. It may prove practical to model this relationship only down to some minimum size (e.g. about 65 mm CW). However such a model would still allow about a 3-year projection of recruitment.
- It was also noted that an increase in efficiency from intermediate to smallest sizes, modelled for eastern Bering Sea snow crab, was partly attributed to very small crabs entering through the mesh in the belly of the trawl.
- There was some discussion of other sources of variability in trawl efficiency that were not addressed in this experiment. These included diel effects and possible sex differences. Other studies have shown that trawl efficiency is higher at night than in the day because crabs burrow in the substrate during the day. It was noted that trawl efficiency may also be a function of density.

- It was suggested that, because trawl efficiency is low and variable, survey indices would likely be improved by application of even preliminary estimates of trawl efficiency. A practical approach to deriving such approximations was proposed that would involve analysing available Roxanne seabed classification data to develop a minimum set of substrate categories and then developing a catchability function for each substrate category using the Campelen trawl equipped with bag trawls.

4. GENERAL DISCUSSION

A. The straitjacket – G. Evans

This does not describe what the scientists believe. It describes the beliefs that are implicit in the models used, the simplifications that are employed to enable calculation and prediction.

Those things that are believed to be true and important, of which no formal notice is as yet taken, can be described in a companion loosejacket file.

What does an assessment produce?

NG: Rank the prospects for the next year or two, and for the next five years, against those seen in the past. Several indicators are used, all indicating, in various ways, the phase of the population relative to a multi-year recruitment pulse.

SG: From an autumn survey, predict the population the following spring of legal-size crab, including its distribution in space. Predict the numbers in the size classes that will recruit in the following two years. Other indicators are presented but clients pay little attention to them. There is a risk analysis, based on computed variance in survey estimates.

NF: Project next year's biomass in new and old shell categories. From an autumn survey to a spring fishery. "TACs are not set on the basis of surveys." Scientists provide a variety of indicators and decide which of them are the most informative.

NF: The spatial structure of management is complicated. The important spatial structure of the crab population is what? There are two separate research indices, which pertain to two different subsets of the whole management structure.

Population dynamics

How do crabs enter the modelled population?

ALL: No model or theory - just observe numbers at some early size, typically the smallest size that might reach legal size 2 years later. Although many of the interpretations in the assessment conclusions are based on an assumption that runs of good or poor recruit years are much more common than random.

NG, SG: Good year-classes, when they occur, tend to occur several years in succession.

How do crab grow?

ALL: All crab molt every opportunity until terminal moult. The moult increment is a deterministic function of initial size (the precise function differs in different regions). For crab that need two moults to recruit to legal size, the fraction whose first moult will be terminal is an unknown to be estimated as part of the assessment. SG uses a function for this estimation based on size. So does NG at least in a research project.

What is meant by recruitment?

Reaching legal size and acceptable shell condition. Newly moulted crabs have soft shells and do not feed - therefore do not trap. But there are crabs that have soft shells and do trap. Their “recruitment” status is unclear.

How do crab die?

ALL: No crabs die except perhaps for those in shell stage 5.

SG: Crabs in shell stage 5 all die between the time of the survey and the time of the fishery.

Spatial pattern

NG, SG: The prerecruit and recruited age groups are distributed differently in space, suggesting a mixing of the population as a whole over a broad area.

SG: Crab do not move between the survey and the fishery. (Important because harvesters are given maps of survey distribution.)

Measurements

Commercial CPUE

NG, NF: The unit is catch per trap haul.
SG: The unit is catch per trap hour. CPUE is affected by the harvesters knowing the survey distribution of crabs.

Trawl surveys

NG, SG: The random process that generates the spatial pattern of crabs is one that makes kriging an appropriate tool. There is no correction for depth.

ALL: There is no difference in catchability as a function of size (for the sizes used in the assessment.)

NG: There is a systematic effect of depth, and the survey design is optimised for it. The trawl survey is only for part of the region.

SG: Clients act as if the catchability were 1.

NF: The trawl survey does not always include inshore strata. These typically contain a small percent of the total biomass, and only a slightly larger percent of the commercial catch.

Trap surveys

NG: There are no nearby traps to affect the spatial distribution (gradient) of attractant.

NF: Trap surveys are confined to nearshore areas.

B. Improvements:

Trawl survey, Area 17

- Survey design: the spatial organisation of stations and their placement must be explained or rationalised more clearly.

- Does the kriged estimate of population abundance reflect the random assumption mean?
- Is the small variance about kriged means compatible with observed variability of raw data and variance about random assumption means?
- Is cross-shore versus along-shore variability well captured by sampling design (variability should be greater with depth than along shore)? Measured north to south and east to west anisotropy is inconsistent with Southeast to northwest orientation of coast and sampling area. Compare cross-shore with along-shore variograms.
- Points raised with Southern Gulf geostatistics should be considered here as well.
- The robustness of the geostatistical analysis to the highly skewed frequency distribution of observations should be examined.

Inconsistency between trap and trawl survey predictions for fishery CPUE in 2000 and 2001

- Regress trap survey CPUE and trawl survey CPUE.
- How do changes in spatial distribution of effort among years influence CPUE? Use spatial mapping tools to evaluate.

Compare at-sea observer CPUE with commercial fishery CPUE for comparability of trends.

Take into account skip-moulters and SC 5 when projecting trends in recruitment and fishable biomass.

There is decline in information about stock status as one goes west to east. No quick and inexpensive activities to address this problem were identified.

Because there is not quantitative population estimate, there is no opportunity for formal risk analyses of many aspects of basis for advice.

Try to develop more systematic process for presenting information on the uncertainty in the various indicators, and for inferring conclusions on stock status and necessary management action from the indicators.

Gulf Region Snow Crab Group

Proposed improvement

1. Gulf stock assessment

- The evidence of continuous negative residuals resulted from forward checking model indicate the necessity of taking mortality factor in account.

- Catchability coefficient for Nephrops trawl net has also to be evaluated.

- What Gulf is presenting is not the absolute biomass estimates (because of the above mentioned reasons), and should be considered as an abundance index. Therefore the application of exploitation rate is scientifically incorrect and this exercise traditionally adopted by managers and client has to be stopped. [JCR – Overstates the recommended action. It may be the case that the product of 0.35 and the biomass estimate is a catch that, on average, will be sustainable. That hypothesis should be examined with historical information. If so, corrections to the possible biases in the annual biomass estimates would have to be compensated for in adjustments to the proportion of the biomass taken as the TAC.]
- [JCR] Concerns about underestimation of uncertainty in population status from kriging need to be explored quickly, so risk management practices can be more reliable.

Immediate remedy

- No QUANTITATIVE correction for the "biomass discrepancy". Report that it is present, has been present, and in at least past has been in neighbourhood of 15%. Also report that it is likely to be due to both survivorship and catchability not being 1. Will explore how to treat best analytically.
- [JCR] Calculate variance in biomass estimate using cross-validation step, not the variance of the mean from the kriging program.
- By doing this exercise, we provide a perspective of uncertainty "biomass estimates" so that fishery managers and client can be discussed for setting an appropriate quota.

Mid-term improvement

- Mortality rate will be estimated by supposing that the negative residuals are due to the mortality.
- Catchability coefficient (range) will be introduced to the model. [JCR – where will it come from? Only add it if it improves the model.]
- Verify whether mortality rate varies in relation to the sex, size, shell-condition - also catchability in relation to sex, size, depth, bottom type. And apply new findings to the model.
- Conduct catchability project to estimate the above mentioned parameters (e.g. by depletion method).
- [JCR] Explore the implications and possible use of a state-space model such as Smith outlined in general terms.

2. Length-based population model

- Length-based model presented requires a rigorous parameter setting such as (survival rate; catchability; selectivity; moulting rates to terminal, skip, normal; growth rate).

Improvement

- Each parameters used in the length-based model will be verified (e.g. verify the current data whether probability of moulting to different phases is size dependent) and refined for further improvement of output.
- [JCR] Two models including growth were presented and discussed (Toby & Elmer). One was assuming errors are normal and the other uses a gamma error distribution. One or the other should be chosen on objective grounds (biological and/or statistical) and used consistently.
- The potential value of the model for other Regions was acknowledged and inter-regional collaboration was encouraged.

3. Geostatistics as tool for abundance and distribution estimations

- Kriging variance is not comparable with variance derived from finite-based survey theory.
- Questions on the covariance effect on the resource mapping and abundance estimation were not clearly answered. Possibility of

using secondary information (example – temperature) should be explored further.

[JCR] among the concerns was the apparent change in decorrelation that led to using very low influence radius for some of the older shell – types. This could be an artefact and should be investigated.

Also concerns about how models are handling model error vs. process error. These issues need to be clarified.

Action

- Consult with geostatisticians to clarify the issues.
- If necessary organise a workshop on the application of geostatistics to the marine resource assessment.
- [JCR] Use the cross-validation option in the package to estimate the forecasting variance. Use that as indication of uncertainty in survey estimates that are used in management calculations & risk management.
- [JCR] Further discussions with statisticians and mathematicians regarding what "stochastic simulations" will be informative for insights into population status and dynamics. Should include range of experts. The comparison of kriging and ogmap is one path to pursue.
- [JCR] Suggestion to explore other tools/models of depth – abundance relationship (Smith-Perry analysis; GAMs).
- [JCR] The negative abundances that come out of the point-kriging used in some mapping applications are unrealistic. Options, which don't produce them, should be explored and a suitable one adopted.

4. Structured mixture model for the analysis of length frequency distributions.

- The number and size of certain instar seem to be different compared to the published information (e.g. Saint-Marie et al. and Comeau et al.).

Action

- Consult with published information and check the output.

For the survey in Eastern Nova Scotia, the differences in topography, substrate and the fishery mean that survey designs other than grid should be considered.

The following project did not have major problems and will be carried on:

- Estimation of trawl swept surface.
- Geographic distribution of instars (Complete for the past 11 year data analyses).
- Quantify seasonal movement (fall-spring survey comparison will be carried on in Area 19 every 2-3 years).

Suggestions/Recommendations, Newfoundland

Inshore Surveys

Not currently used in assessments. This is a source of data that could help.

The comparison of trap survey catch rate with CPUE in the following year showed a poor relationship, possibly because new-shelled crabs were included in the trap survey catch rates. This relationship should also be examined with new-shelled crabs not included, since they may predominate in the trap surveys in some years but contribute little to subsequent fishery CPUE.

The pooling of data from three seasonally different survey areas is inappropriate for examining the relationship of fishery CPUE to trap survey catch rates.

Survey design, sampling levels and spatial variation in sampling should be evaluated as possible sources of variation in annual indices.

The order of setting of traps vs. trawl on common stations should be considered as a possible factor affecting the relationship between their catch rates.

The utility of multiple regression analysis should be explored for relating CPUE to trap survey catch rate in the previous year using immediate prerecruits as an additional variable.

Logbook Data

Improve timeliness and completeness of logbook data.

Effects of annual variation in seasonality of the fishery should be considered by developing an early-season index that does not include the initial period of spatial exploratory fishing.

Multispecies Trawl Surveys

Trawl survey indices contain strong year effects.

Intermediate sized crabs are poorly sampled. Modes in size composition do not show any progression over the time series.

A very limited direct study of efficiency of the Campelen trawl (catchability) showed that catchability is considerably lower than 1 and is a function of crab size and bottom type. A more extensive study of catchability should be undertaken to provide a basis for adjusting survey indices for catchability effects, and, potentially, improving the reliability of survey indices.

Other

The performance of different candidate abundance indices, from different trap and trawl surveys, will be compared in the context of a structured population model.

Assumptions and strengths/weaknesses

	S.Gulf	N. Gulf	Nfld.
Assumptions Recruitment	**cyclic**	**cyclic**	**-**
M			
Growth			
Molt frequency			
Sex ratio	-	important	-
Strengths			
Trawl Surveys	directed	directed	-
	Broad	**localised**	**Broad**
	High Q	Q?	**-**
	Time series	Time series	**-**
CPUE data	-	-	**-**
Trap surveys		-	**-**
Indices considered	-	-	**-**

5. BIOLOGICAL REFERENCE POINTS

There has been no new information on this subject since the discussion at the Montreal Workshop in 2001. Stephen Smith stated that a Workshop on Biological Reference Points in Invertebrates is being planned for the fall. We need indicators that tell us something about sustainability of a stock. Also with the new definition of the Precautionary Approach adopted by the government we need to be able to define when additional harvesting will result in serious harm. Reference Points will also be required as part of the OBFM (Objective-Based Fisheries Management).

There are a number of things, which could be looked at for snow crab. These could include the proportion of shell condition 5 in the mature population, sex ratio, proportion of primiparous females, proportion of males maturing below the legal size. Snow crab will be one of the species discussed at the Workshop.

6. CONCLUSIONS

- All regions are using a combination of data obtained from research surveys and from the commercial fishery to evaluate the condition of the crab resource in their respective regions. Regional assessments have to take into consideration differences in the biology of species related to local environment, differences in the fisheries and trawl survey (e.g. directed for crab in the Gulf and part of a multispecies survey in Newfoundland).
- The trawl surveys provide a relative index of abundance and should not be considered as an absolute value.
- Variation in catchability has been identified depending on bottom type and season. Catchability should be studied in all areas for consideration in future analysis.

APPENDIX I: AGENDA

ATLANTIC SNOW CRAB

ZONAL METHODS WORKSHOP

ST. JOHN'S NF

JANUARY 14-18, 2002

AGENDA (revised)

January 14, 2001
pm: Opening Remarks
Review of Agenda
Northern Gulf

January 15, 2002
am: Northern Gulf
pm: Southern Gulf

January 16, 2002
am: Southern Gulf
pm: Newfoundland

January 17, 2002
am: Newfoundland
pm: Issues Arising

January 18, 2002
am: General Discussion
pm: Discussion and Conclusions

APPENDIX II: TERMS OF REFERENCE

SNOW CRAB ZONAL TECHNICAL WORKSHOP

TERMS OF REFERENCE

PURPOSE:

The snow crab (*Chionoecetes opilio*) is an important component of the fishery in Atlantic Canada. All stocks are assessed annually through the Regional Assessment Process (RAP). In order to ensure that the best scientific approaches are being used in all areas to determine stock status, the Zonal Technical Workshop (ZTW) will examine the results of recent scientific studies relevant to stock assessment and their implications for the assessment approaches and methods currently employed in each Region. The ZTW will review the analytical components of the assessments of status of each crab stock in Atlantic Canada. It will result in consensus conclusions on the most suitable analytical methods to be used in estimating attributes of stock status from quantitative indicators and methods for constructing such indicators from data. The results of the ZTW, evaluating the major analytical component of each assessment will be taken to RAPs on each stock. The ZTW results can be discussed and combined with other information on stock status contributed by RAP participants, to produce the final conclusions on stock status, to be released in SSRs prepared regionally.

SPECIFIC ITEMS FOR CONSIDERATION

1) Review the analysis and conclusions of the assessment related studies conducted as part of the 2001-2002 zonal snow crab project and the Newfoundland catchability study to determine how these can be incorporated into the assessment process

2) Review the assessment methodology and analytical techniques currently being utilised in each region and identify weaknesses and strengths. Recommendations for improvements should be identified.

3) Compare the techniques among regions and if possible with techniques used to assess crab stocks in other areas. Opportunities should be sought for strengthening current methodologies or identifying alternate techniques for consideration.

4) Consideration is to be given to progress on application of the Precautionary Approach, establishment of Biological Reference Points and risk evaluation for Atlantic snow crab.

PARTICIPATION

As this is a technical workshop, participation is restricted to technical experts in the areas of invertebrate assessment methodology and related fields such as survey design and environmental influences. Experts, external to DFO, may also be invited to participate.

APPENDIX III: PARTICIPANTS

Jake Rice - Ottawa
John Moores - Ottawa
Greg Workman - Nanaimo
Bernard Sainte-Marie - Mont-Joli
Réjean Dufour - Mont Joli
Jean-Claude Brêthes - UQ-Rimouski
Mikio Moriyasu - Moncton
Elmer Wade - Moncton
Tobie Surette - Moncton
Stephen Smith - Dartmouth
Earl Dawe - St. John's
Dave Taylor - St. John's
David Orr - St. John's
Geoff Evans - St. John's
Gerry Ennis - St. John's
Sam Naidu - St. John's
Noel Cadigan -St. John's
Steve Walsh - St. John's
Barry McCallum -St. John's
Stephen Sutton - St. John's
David Schneider - St. John's