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Proceedings of the Regional Peer Review of Spatial Scale for the Assessment of Northern Shrimp in SFAs 4-7

August 12-13, 2014
St. John's, NL

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Editor: James Meade

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Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

A meeting of the Newfoundland and Labrador (NL) regional peer review process was held August 12-13, 2014 in St. John's, Newfoundland and Labrador (NL) to review spatial scales appropriate for the assessment of Northern Shrimp in the Northwest Atlantic, Shrimp Fishing Areas (SFA) 4-7.

Recent genetic analysis indicated that the Northern Shrimp stock in Northwest Atlantic Fisheries Organization (NAFO) Divisions (Divs.) 3LNO is part of a wider population spanning the NAFO Subarea 2 and at least Divs. 3KL. Currently, transport of shrimp across the management area boundaries is not accounted for in the assessment and therefore introduces additional uncertainty. In 2013, NAFO Scientific Council recommended exploration of alternative approaches that take into account the entire stock area. Since that time however, the management implications from the original analysis have been withdrawn. Instead, the paper explained how gene flow requires only a modest number of successful exchanges per generation in order to reduce genetic differentiation among populations to a very low level.

In support of Fisheries and Oceans Canada's (DFO) commitments made at the 2013 NAFO International Council for the Exploration of the Sea (ICES) Pandalus Assessment Group (NIPAG), DFO Science conducted a Regional meeting to investigate spatial scales appropriate for the assessment of Northern Shrimp in the Northwest Atlantic. The key objective of this meeting (see Terms of Reference – Appendix I) was to determine if there is understanding sufficient to support a change in the spatial aspects of Northern Shrimp assessment and management. The meeting examined the evidence relating to the options for changing the current spatial basis including eliminating the boundaries, or maintaining the boundaries but eliminating the assumption of independence between them.

The meeting concluded that it would be a mistake to ignore either the connections or the differences between SFAs, but that rules governing connections will be very difficult to discern. Even if there were a decision to treat the whole shelf "as a unit", this should not be taken to mean that internal structure and differences can be ignored.

This Proceedings Report includes an abstract and summary of discussion for each presentation, as well as the meeting conclusions and a list of research recommendations. The Terms of Reference and the list of participants are provided in Appendices I and II, respectively. Participation included personnel of DFO Science and Fisheries Management Branches, from both Newfoundland and Labrador Region and National Headquarters.

Compte rendu de l’examen par les pairs de l’échelle spatiale pour l’évaluation de la crevette nordique des zones de pêche à la crevette 4 à 7

SOMMAIRE

Une réunion régionale d’examen par les pairs de Terre-Neuve-et-Labrador (T.-N.-L.) a eu lieu les 12 et 13 août 2014 à St. John’s, à Terre-Neuve-et-Labrador (T.-N.-L.), afin d’examiner les échelles spatiales adaptées à l’évaluation de la crevette nordique dans le nord-ouest de l’Atlantique, zones de pêche à la crevette (ZPC) 4 à 7.

Une récente analyse génétique indiquait que le stock de crevettes nordiques dans les divisions 3LNO de l’Organisation des pêches de l’Atlantique Nord-Ouest (OPANO) fait partie d’une plus grande population qui couvre la sous-division 2 et au moins la division 3KL. À l’heure actuelle, le transport de crevettes au-delà des limites de la zone de gestion n’est pas pris en compte dans l’évaluation et, par conséquent, est une source d’incertitude supplémentaire. En 2013, le Conseil scientifique de l’OPANO a recommandé d’examiner d’autres approches qui tiennent compte de l’ensemble de la zone du stock. Depuis ce temps, toutefois, les mentions des répercussions sur la gestion provenant de l’analyse initiale ont été retirées. Au lieu de cela, le document explique la façon dont le flux génétique nécessite seulement un petit nombre d’échanges fructueux par génération afin de réduire la différenciation génétique entre les populations à un niveau très faible.

Afin de soutenir les engagements pris par Pêches et Océans Canada à la réunion de 2013 du groupe d’évaluation du Pandalus de l’OPANO du Conseil international pour l’exploration de la mer (CIEM), le Secteur des sciences de Pêches et Océans Canada a tenu une réunion régionale afin d’étudier les échelles spatiales appropriées pour l’évaluation de la crevette nordique dans l’Atlantique Nord-Ouest. Le principal objectif de cette réunion (voir le mandat, annexe I) consiste à déterminer si les connaissances actuelles permettent d’appuyer un changement dans les aspects spatiaux de l’évaluation et de la gestion de la crevette nordique. La réunion a permis d’examiner les éléments de preuve concernant les options qui consistent à modifier la base spatiale actuelle, y compris en éliminant les limites ou en les maintenant, mais en éliminant l’hypothèse de l’indépendance entre elles.

La réunion a permis de conclure que ce serait une erreur d’ignorer les liens ou les différences entre les ZPC, mais que les règles régissant les liens en question seraient très difficiles à discerner. Même si l’on prenait la décision de traiter l’ensemble du plateau « en tant qu’unité », cela ne doit pas signifier que la structure interne et les différences peuvent être ignorées.

Le présent compte rendu comprend un résumé et un sommaire des discussions de chacune des présentations, de même que les conclusions et une liste des recommandations qui concernent la recherche. Le mandat et la liste des participants figurent dans les annexes I et II respectivement. Les participants comprenaient des représentants du Secteur des sciences du MPO et de la Direction de la gestion des pêches du ministère, de la région de Terre-Neuve-et-Labrador et de l’administration centrale nationale.

PRESENTATIONS AND DISCUSSIONS

BACKGROUND INFORMATION FOR THE MEETING ON SPATIAL SCALE FOR THE ASSESSMENT OF NORTHERN SHRIMP

Presenter: D. Stansbury

Abstract

At the Northwest Atlantic Fisheries Organization (NAFO) International Council for the Exploration of the Sea (ICES) Pandalus Assessment Group (NIPAG) meeting held at NAFO headquarters in September, 2013 a paper was presented that investigated the genetic structure of Northern Shrimp in the Northwest Atlantic (Jorde et al. 2014). NIPAG concluded that the analysis of statistical power showed an inability to detect very low levels of genetic differentiation, should it exist. However, these analyses found that shrimp from the Flemish Cap and the Gulf of Maine were distinct from those found in the shelf areas of Labrador and Newfoundland (NAFO Divs. 2GHJ + 3KL). NIPAG also concluded that the results of the genetic analysis for shrimp in NAFO Subarea 2 and Divs. 3KL are consistent with the hypothesis of a single biological population, except for a sample in Div. 2H. Additional evidence given for the notion of a single population unit along the Newfoundland and Labrador shelf is the continuous distribution of shrimp in this area and the strong prevailing ocean currents, both of which make separate populations unlikely.

Following on from the NIPAG report, the Scientific Council of NAFO (2013) made a special comment in its advice on Northern Shrimp in Divs. 3LNO. “Recent genetic analysis shows that this stock is part of a wider population spanning NAFO Subarea 2 and at least Divs. 3KL. Migrations of shrimps across the management-area boundaries are not accounted for in the assessment and therefore introduce additional uncertainty. Scientific Council recommends exploration of alternative approaches that take into account the entire stock area”. In response to the recommendation, Canada committed to a workshop, to be held prior to the 2014 NAFO annual meeting, to investigate the appropriate spatial scale to assess Northern Shrimp in the Northwest Atlantic waters.

In June 2014, Jorde et al. published their findings with considerable revisions from that presented at NIPAG in 2013. Gone are the management implications for Northern Shrimp in Canadian waters (i.e. single biological population that should be assessed as a single unit). Instead the paper explained how gene flow is a highly potent homogenizing force, requiring only a modest number of successful exchanges per generation in order to reduce genetic differentiation among populations to a very low level. For shrimp, population size is generally counted in the billions, and theory (Wright 1931, Hössjer et al. 2013) then tells us that an exchange of even a tiny fraction (say, 0.000025%, or 250 individuals per billion) among populations per generation is sufficient to keep genetic differentiation among them at or below the lower detection limit of the present study. This means that apparent genetic homogeneity and absence of statistically significant differences can result even from a very low rate of exchange. Conversely, where significant genetic differences are detected, genetic exchange is likely to be very low, such as the Flemish Cap and Gulf of Maine which are distinct from the Newfoundland and Labrador (NL) shelf.

Oceanographic influence along the NL shelf areas is dominated by the strong southward-flowing Labrador Current and the possibility for transport of pelagic shrimp larvae with the currents is recognizable. Reduced genetic structure among shrimp collections from this area is thus likely a reflection of gene flow caused by transport of pelagic larvae among putative spawning

aggregations. The paper also concluded that such larval drift, or transfer, as the transport is generally unidirectional towards the south, implies that demographic events in the north (e.g. a large year-class) may influence the stock situation in the south, while not in the opposite (up-current) direction. On the other hand, the numerical calculations in the analysis indicate that for a species as numerous as shrimp, exchange and transfer of only a minute fraction of a population may be sufficient to eradicate genetic differences, yet is likely to have minor impact on the demography of the recipient. The authors suggest that, supplementary studies, including larval drift studies, should be carried out to elucidate the rate of exchange of individuals between the different NAFO Divisions (e.g. Pedersen et al. 2003).

Discussion

It was stated that the genetics paper seems to be irrelevant to the discussion on the spatial scale aspect of an assessment due to the change in its conclusions and the minute exchange that would suffice to mask any genetic structure in the population.

During the presentation there was some disagreement regarding a clause in the genetics paper. The statement "*On the other hand, the numerical calculations indicate that for a species as numerous as shrimp, exchange and transfer of only a minute fraction of a population may be sufficient to eradicate genetic differences, yet is likely to have a minor impact on the demography of the recipient*" is incorrect. It was recommended that the wording *"yet is likely to have"* be removed, or replaced with *"while having"* or "*and yet have only."*

There was a question regarding gene flow rates, and if there were any data in this regard. There was no information on flow rates or significance before the Scientific Council decision to call it a single stock and suggesting inability to show genetic differentiation. A small level of flow is enough to homogenize genetic results. Future investigations will attempt to find evidence that something more relevant is at play.

There was a comment that the genetics paper is able to show that the Flemish Cap is truly different. If there is an important exchange of animals on the shelf, then it must be 10,000 times stronger than exchange on Cap. Another participant commented that it would be difficult to demonstrate this difference from a physical oceanography standpoint. It was pointed out that cod have a similar population structure and the Flemish Cap is a unique environment of its own despite its proximity to shelf.

For clarification purposes, it was stated that shrimp hatch as larvae and there could be mixing of larvae due to transport, but mixing rate of adults among the current assessment units is unknown.

WHAT IS THE MEETING TRYING TO ACCOMPLISH?

Presenter: G. Evans

Abstract

Shrimp are assessed and managed in a set of four Shrimp Fishing Areas (SFAs) between the northern tip of Labrador and the Grand Bank. Shrimp tend to be distributed patchily along the shelf, and boundaries between SFAs were in general chosen to lie between the patches. SFAs are now assessed and managed as though they were independent units, with no influences of one on another. Obvious options for changing the spatial basis include eliminating the boundaries, or maintaining the boundaries but eliminating the assumption of independence between them.

The meeting was developed to examine the evidence bearing on either of these options: evidence both that an option is more accurate and that this matters for management purposes.

Plotting the history of fishable biomass estimates from the four SFAs in research surveys since 1996 reveals some similarities in trends, but also some strong differences. For SFAs 6 and 7 there is the same pattern of a rise until the middle of the time series followed by a fall to at or below the original level; but the rise and fall is a factor of maybe two in SFA 6 and maybe 15 in SFA 7. Further north, SFA 5 stays near its highest population until 2012; and SFA 4, whose survey only starts in 2005, has been generally increasing since then.

These results strongly suggest that, in addition to similarities, there are important differences between SFAs that assessments should report and management should take account of.

Discussion

The question was asked: As assessments are for managers, what conclusions would have to be reached to make them utilize the results/ do things differently? The response provided used snow crab as an example. Despite being one stock, there are many (boundary) lines for the management of crab, with different quotas in each, as opposed to just different allocations. Removing, or even moving, these lines may lead to groups trying to access areas they could not before. Lines allow management of effort, single stock or not.

There is no official definition of assessment. Is it simply analyzing data to determine how much of the resource is available, or about determining renewal rate? The initial response was it is always about both, but it is not always possible to determine both. Another participant agreed that both items (size and renewal) are needed whenever possible.

There was discussion about examples studying the boundaries and interdependence. Due to the Labrador Current, it may be useful to look at management areas, as they are now, compared to each other (i.e. linked stocks) and whether or not the differences are quantifiable. The example was salmon in Greenland where the investigators looked at stocks in North America vs. Greenland. Another example was mixing of 3Ps cod and Gulf cod, attempting to limit fishing mortality to when mixing is least.

The question was posed: What evidence would be enough to make spatial differences matter? Evidence will be provided to demonstrate this in an upcoming presentation re: Exploring Northern Shrimp Production Rate at Different Spatial Scales. Once a sense on magnitude of exchange is established, then simulations can be run to see what boundaries would be best based on level of exchange.

The current boundaries were set in the 1980s based on the fisheries in SFAs 4-6 (minimal survey work at that time). SFA 7 was merely a spillover and the Div. 3L line was used as a convenient border. Boundary position depends on the condition of the management measure that will be applied to the area.

A participant asked about the evidence for determining that there were no shrimp outside these areas during the late 1980s. There were some survey sets, but the absence of a fishery was likely the main determining factor.

CURRENT MANAGEMENT OF NORTHERN SHRIMP IN SFA 4-7

Presenter: L. Edgar

Abstract

Pre-moratorium, the NL fishery was a high volume, low value, primarily groundfish fishery with Northern Cod as the mainstay fishery on the east coast, supporting 4,500 enterprises.

Following the cod collapse in the early 1990s, crab emerged as the mainstay fishery, now supporting 1,800 inshore and midshore enterprises. Shrimp also expanded and now has higher landed value, but supports fewer (276) enterprises than crab.

The Northern shrimp fishery is an estimated $300M fishery stretching from Baffin Island in the north to southern Newfoundland. In the southern range of the fishery, SFAs 5–7 have experienced declines since 2010, with the most notable reductions occurring in SFAs 6 and 7.

The fishery consists of two principal fishing fleets and a number of special allocation holders:

- **the offshore fleet:** 17 traditional licenses (26% held by Northern Aboriginal interests), that process at sea;
- **the inshore fleet:** approximately 276 inshore enterprises supporting shrimp processing in plants on land in NL; and,
- **special allocation holders:** allocations have been provided to a number of Aboriginal and community-based groups who do not hold a commercial shrimp license.

Departmental scientific advice indicates the size of the Northern shrimp biomass has been trending downwards as much as 70% to 90% over the last 6-7 years. Decreases are greatest at the southern end of the range off of Newfoundland and Labrador where the inshore fleet has access.

Warming conditions are generally believed to hinder shrimp production and bottom water temperatures off the East Coast of NL have been increasing since the mid-1990s and are expected to remain high or continue to increase for more than a decade (Colbourne et al. 2014a).

Total allowable catches (all SFAs combined) have declined from a peak of 176,868 t in 2009 to 116,582 t for 2014.

Discussion

There was a comment regarding the 20% exploitation rate mentioned in the presentation, and how there is no basis for that rate. The basis may be that 20% is acceptable to MSC.

The Integrated Fish Management Plan (IFMP) used to have a target 15% exploitation rate, and then the wording was changed to a maximum of 15% (in healthy zone). The current proposal is: 20% healthy, 12-20% cautious, and 10% critical (provisional).

In response to the question of whether there are annual management plans vs multi-year plans, the answer was annual, although it used to be every two years. It was changed to annual due to declines and changes to the IFMP; each SFA is independent.

Currently there is a Northern Shrimp Precautionary Approach (PA) Working Group (PAWG). It was suggested that it may be possible to include renewal rate as part of PA. Regardless of what is driving the stock, it is important to set the exploitation rate to match renewal.

EXPLORING NORTHERN SHRIMP PRODUCTION RATE AT DIFFERENT SPATIAL SCALES AND IN RELATION TO POTENTIAL DRIVERS IN THE SOUTHERN LABRADOR AND NORTHERN NEWFOUNDLAND SHELVES (NAFO DIVS. 2J3KL)

Presenter: M. Koen-Alonso

Abstract

Changes in shrimp productivity were investigated in terms of different spatial scales and potential driving factors. Shrimp productivity was characterized on the basis of the per-capita production rate (P) estimated from the shrimp Research Vessel (RV) Fall survey total biomass index (B) and nominal annual shrimp catches (C) as $P_t=(B_t+C_t-B_{t-1})/B_{t-1}$. The candidate factors considered as potential drivers of shrimp production were shrimp stock size, fishing, environmental conditions, and predation.

The relationships between individual candidate drivers and shrimp production, as well as their trends over time were explored using non-parametric correlations (Spearman rank correlation coefficient *Rho*). The impact of drivers on a population's biological/ecological rates is unlikely to be instantaneous (it is mediated by changes in population state), and hence, the correlation between a driver and a rate would be expected to peak when the time lag that best match the actual biological/ecological mechanism underlying the relationship is considered. Therefore, driver-production relationships were investigated considering different time lags (1-5).

Two indices were used as proxies for the trajectory of stock size. These were the total shrimp RV Fall Biomass index (B), and the "leftover" shrimp biomass index ($LB_t=B_{t-1}-C_t$, where C_t is the annual nominal catch of shrimp). This last index was calculated as crude attempt to correct for catches of the shrimp biomass that exists at the time of spawning. Under simple density-dependent considerations, there is an expectation that P would negatively correlate with stock size.

Exploitation fraction ($F_t=C_t/B_{t-1}$,) was used as proxy for fishing. If fishing has a negative impact on production, it would be expected to show a negative correlation. Also, it should be kept in mind that by defining production rate P the way it has been (see above), only indirect effects of fishing would be detected by the analysis. Direct effects (i.e. biomass extraction) are factored out.

The composite environmental index (ENV) (Colbourne et al. 2010, 2014b) was used as a descriptor of the overall state of the climate system. Since this index increases with warmer/saltier conditions, and warming conditions are generally believed to hinder shrimp production, a negative correlation with P is expected if the environmental conditions have a detectable impact on shrimp production.

Predation pressure was characterized by the total RV Fall Biomass of fish functional groups which are potential predators of shrimp (PRED). These functional groups were piscivores, plank-piscivores, medium, and large benthivores. If predation is impacting shrimp production, a negative correlation would be expected between P and PRED. In this case, the analysis would detect the joint response to direct and indirect effects of predation.

Since it is unclear if current SFAs fully encompass reasonable shrimp demographic units, the correlation analyses between shrimp production and candidate drivers were performed at different combinations of spatial scales to investigate if emerging patterns in the correlation structures could inform towards identifying useful boundaries for shrimp assessment units. To this purpose, all indices were calculated at different levels of spatial aggregation (large-scale: Divs. 2J3KL, 2J3K, and 3KL, and small-scale: Div. 2J, 3K, and 3L), and correlation analyses

were performed considering different combination of scales for both shrimp production and candidate drivers:

a) large-scale driver and large-scale target area;

b) large-scale driver and small-scale target area, and

c) small-scale driver and small-scale target area.

The only exception was ENV which is only available for the large scale of the NL shelves.

Per capita shrimp production rate showed an overall declining trend in Divs. 2J3KL; this declining trend is more evident in the southern areas (NAFO Divs. 3KL) (Fig. 1). Only NAFO Div. 2J did not show a significantly decline in P over the study period. This result does not necessarily imply a continuous decline over time, but indicates higher production rates in the earlier years than towards the end of the time series.

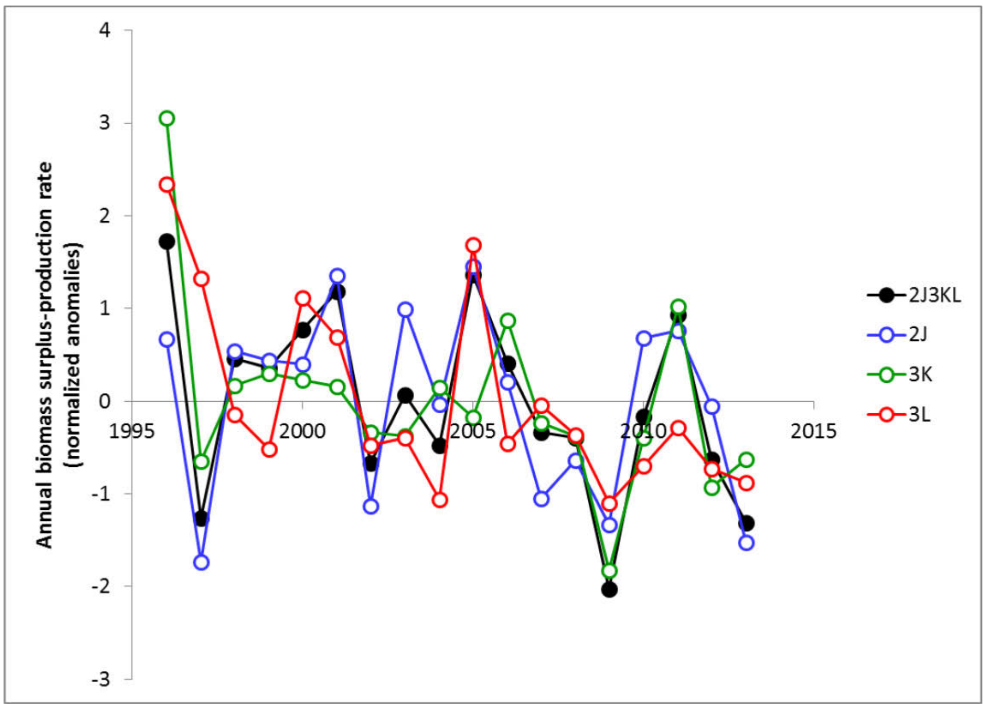

Figure 1. Normalized (mean=0; SD=1) per capita shrimp production rate for NAFO Divs. 2J3KL and for the individual NAFO Divs. 2J, 3K, and 3L.

No significant correlations were detected between per capita shrimp production rate and stock size.

Fishing, predation and environmental forcing showed detectable relationships with shrimp production. Fishing has significant negative effects on shrimp production; these effects appear with lags 2-4 and are more evident at large scales of aggregation. The warming trend in environmental conditions had a detectable negative impact on shrimp production. At least part of this signal may be associated with the timing of the phytoplankton bloom (current trend towards earlier blooms would be associated with lower shrimp production). Predation has the most consistent effect on shrimp production. The dominant negative effect appears at lag 3, but negative impacts with lags 1-2 are also common. The difference in the structure of the correlation results (different dominant significant lags) suggests that, at first glance, the effects of predation and fishing on shrimp production are not mediated by the same mechanisms

(Fig. 2). This is consistent with predation involving both direct and indirect effects, while the effects of fishing are only indirect ones. The detection of indirect effects of fishing is, in itself, an important finding.

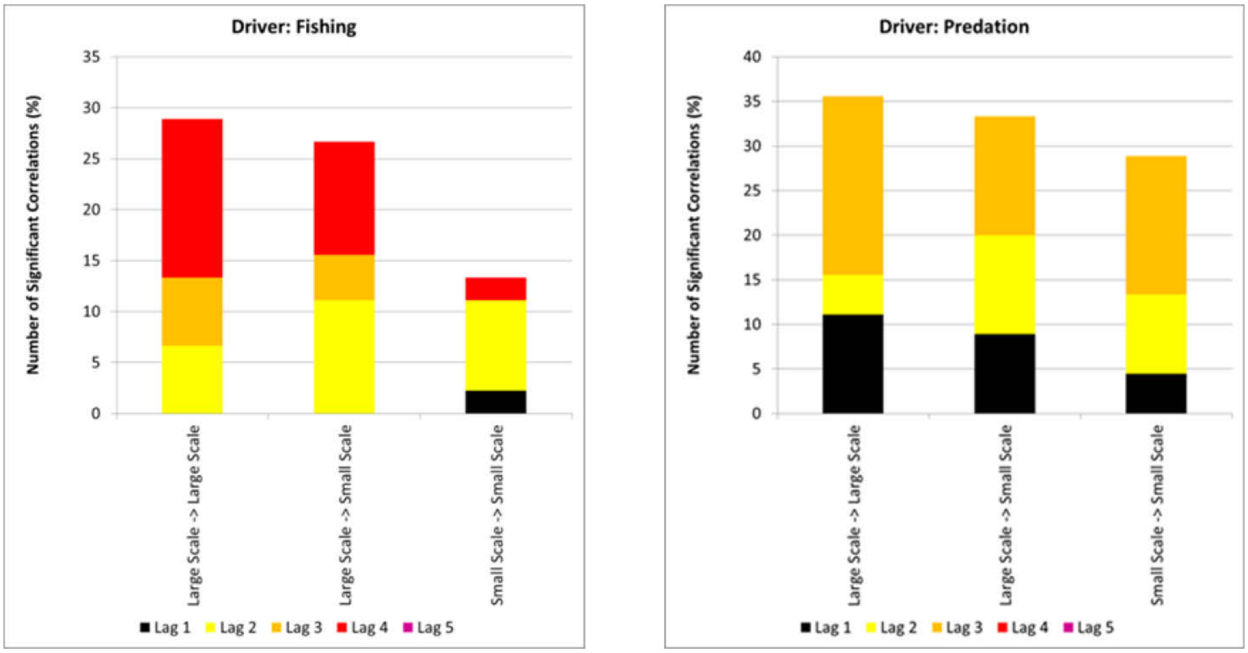

Figure 2. Summary comparison of lagged correlation results for fishing (A) and predation (B) as candidate drivers of the shrimp per capita production at different combinations of spatial scales. Results are presented as percentages of the total number of correlations in each class of spatial scales combinations.

An analysis of cumulated per capita shrimp production rates for individual NAFO Divs. 2J, 3K, and 3L was also conducted. In the absence of transfer between Divisions, it would be expected that cumulated curves for each area should overlay on top of each other if they were equally suitable for shrimp production, while areas with higher suitability would render cumulative curves that fall above the ones from areas with lower suitability. Since Div. 3L is not a traditional/core area for shrimp, it would be expected to have a lower suitability for shrimp production. Results indicate much higher per capita production rates in Div. 3L than in the northern divisions (Fig. 3). This suggests that there is an export of production from northern to southern areas, where production in Div. 3L appears to be significantly subsidized by upstream areas. Thus SFA 6 and SFA 7 (Divs. 2J3KL) would not constitute independent stocks; this does not necessarily mean a homogenous population in the entire area, but an entire region where there is at least sufficient connectivity among components so that impacts in some sub-areas would be expected to have measurable effects outside them.

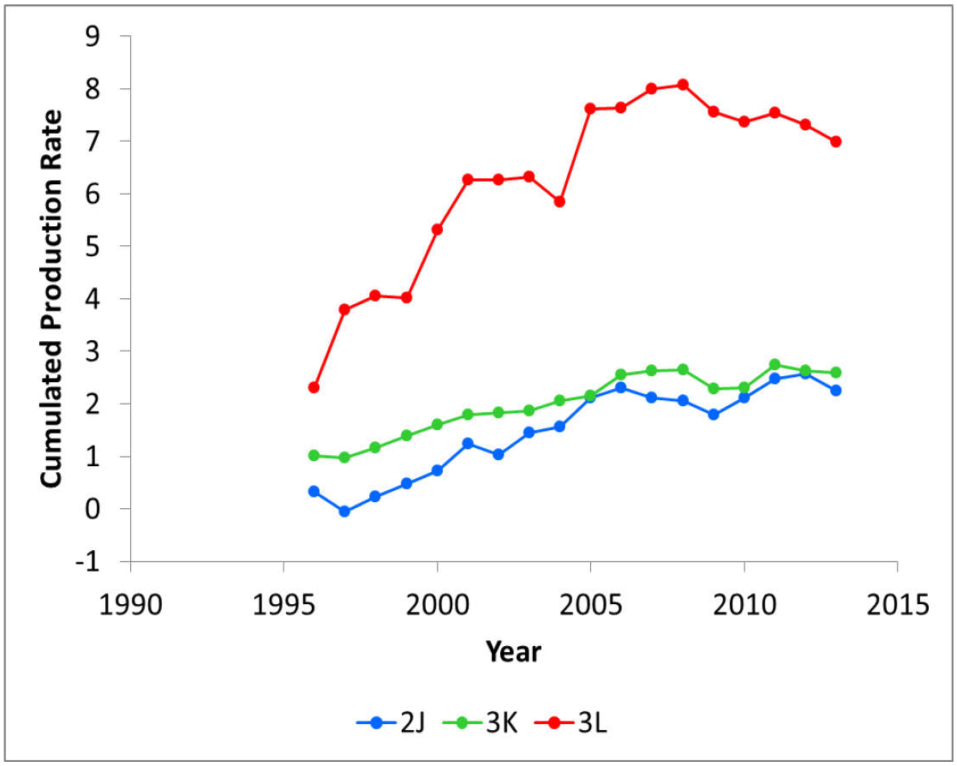

Figure 3. Cumulative per capita shrimp production rate by NAFO Division.

Discussion

There was a question of whether the predator index assumes equal per capita consumption by each species. The response given was the methods assume a constant effect by each species. Diet is not available for everything, so an alternative could be to select a few species that eat shrimp.

There was some discussion that correlations could possibly indicate a survey year effect. The results imply decreasing trends in production and biomass, an increasing trend in fishing, and an increasing trend in predator biomass. If something emerges, the effect will likely be seen in all divisions, but Div. 2J would be the division to stand out as different (least effect in Div. 2J).

There was a comment that there was no relationship between production and stock size (B or LB) with lags 1-4 years. There seems to be a longitudinal gradient for changes in environment, with the most significant lag as you move south. Lag effect may be from change in signal/signal strength.

It was suggested that when looking at the north as source and south as target, even if not significant, the correlation tends to be higher. However, it is difficult to make general conclusions based merely on correlation coefficients.

If production curves were as expected (Div. 2J best for production, Div. 3L worst, Div. 3K in between), under no-transfer assumptions, cumulative production rate plot shows the opposite which suggests Div. 3L production is subsidized by northern areas. This statement prompted the question: why imply the production must be due to Div. 3L being subsidized by north rather than Div. 3L just being better? The answer provided was if Div. 3L was the best area, then shrimp would likely have been found and fished there before. It was then suggested that maybe it is a density issue (i.e. smaller area with higher carrying capacity) rather than claiming just one reason for results.

There was a question regarding predation index - where is it now compared to the mid-1980s? The response was comparisons can be made, but data are likely not as accurate as desired. It is likely 30-50% from where we were prior to collapse. It is not unreasonable to suggest we are approaching groundfish levels (closer to 20%) that were sufficient to sustain shrimp in 1990s.

There was a comment that participants noted that the decrease in per capita production is obvious, more so than the spatial/ boundary issues that the meeting met to discuss. There has not been a constant population trend in anything. The idea underlying reference points (idea of constant B and F) is based on the thinking that parameters of the underlying model do not change. If the parameters of the underlying model are changing, there is no way to simultaneously have constant B and F and, consequently, the PA framework has no foundation.

The question was posed: in terms of the purpose of the meeting, would you draw conclusions? Would you report only amalgamated resource status rather than separate detail by SFA?

It was discussed that there is a strong linkage between SFAs and the influence of north on south. Ecologically, Divs. 2J3KL functions as a unit but depending on how it is managed, there may be a requirement to report more than the amalgamated resource status. Connectivity seems to be there, but how to quantitatively deal with that is a complex issue. The unit is not homogenous and how much recruitment is generated from Div. 3L versus imported from Divs. 2J3K cannot be determined. The import into Div. 3L has not been constant; more likely that it has been declining. Division 3L has shown the most severe decline in productivity, along with the most variability, as compared to Divs. 2J3K.

Enough information must be provided to advise management/decision makers of consequences of decisions; amalgamating doesn’t change anything if we are just providing the data separately to be added up with same management boundaries. If we look at the parts and how the parts are connected, overall dynamics is better represented by this overall figure. When advising managers we can either provide a single number, or provide separate and include the information on how to connect them.

There was some discussion on the concern expressed by one participant regarding 1-directional relationship. The concern was about the influence of Div. 2J on Div. 3K, and Div. 3K on Div. 3L, but not vice versa. There is some re-circulation and movement inshore where there are saddles and other landscape/ topology features that would allow it.

Based upon the discussion the chair asked if people thought the current method (reporting by separate SFAs) should be changed? While there were a few participants that said yes, it was agreed to return to discussion on this later; mostly conditional “yes.”

It was discussed and agreed by all participants that the work presented by M. Koen-Alonso should be finalized and submitted in a Research Document format as a product of the meeting.

SIMULATION WORK

Presenter: G. Evans

Abstract

A set of simulations explored the question: Supposing that reality is most like a row of boxes with independent population dynamic processes plus transfers of animals from one box to the next, what would be the effect of treating it either as a row of independent boxes, or as an undifferentiated whole?

The local population dynamics were simulated as an age-structured surplus production (though not Schaefer) model, with Beverton-Holt recruitment and linear natural mortality. There is transport of a fraction of the youngest age out of each box, some fraction of which flows to the next box downstream. (Some is simply lost because the washed-out larvae did not find a suitable place to settle). There is a question of whether the density-dependent saturation of Beverton-Holt takes place before or after transport; both options were investigated.

The total yield sustainable from the system if each box were to be managed without regard to its contribution to downstream boxes (`greedy msy'), or if all boxes were managed with the same exploitation rate (`one-stock msy') was compared with the maximum sustainable with any strategy (`very msy'). A range of scenarios was considered, seeking parameter sets for which the different strategies gave different results.

The strategies were compared according to two metrics: the total sustainable harvest, and the inequality between sustainable harvests in different boxes, expressed as the ratio of the smallest to the largest. The second metric was chosen to call attention to the fact that decisions made for one SFA can have large consequences for another. There was no attempt to decide what the inequality `ought' to be to take account of intrinsic differences in productivity of the boxes.

The loss in maximum yield sustainable with either of the suboptimal strategies, compared to the very-msy strategy, was rarely as much as 5%. The inequality between yields of different boxes could easily change by 25% between strategies. Surprisingly, perhaps, the greedy strategy was not always more unequal than the very-msy strategy.

This does not rule out the possibility that other parameter sets, or other formulations of the rules governing population dynamics, would yield larger differences between strategies even in the total yield sustainable from the whole system.

Discussion

The work has not found a set of parameters where it matters to msy, but it does matter how it is divided amongst management areas. To get the very best total yield requires top boxes to sacrifice, sometimes a considerable sacrifice.

There was a question regarding how fishing the source/ mining sink relates to a warming environment? The answer was that it is not known for certain as simulations were done with constant parameters. If warming is/was uniform then would results still be informative? Not necessarily since the model used is a non-linear model.

DRIFT AND DISPERSAL OF PLANKTONIC ORGANISMS ON THE NEWFOUNDLAND SHELF

Presenter: P. Pepin

Abstract

The aim of this presentation is to provide an overview of the present knowledge of the influence of transport on the drift (along current/shelf) and dispersal (across current/shelf) of planktonic organisms on the Newfoundland Shelf. Knowledge has been derived from studies of species other than shrimp but the principles that were identified for other species are likely to be equally applicable to larval shrimp, once the particular life history aspect of the focal species are taken into consideration. In general, currents from Hudson Strait to the Tail of the Grand Banks generally have an equatorward flow. There are two main branches of the Labrador Current. The offshore branch (shelf edge) flows at an average velocity of 2 cm/s at surface. There is a

strong onshore flow (10-20 cm/s) throughout the water column and the density-driven flow component dominates. At the southeastern edge of Hamilton Bank, there is a bottom intensified anti-cyclonic (clockwise) eddy that is fairly strong. The inshore branch extends ~ 50-80 km from the coast, flows at an average of 20-25 cm/s from surface to bottom, with both density- and wind-driven components being important. Currents are strongest in the fall/winter and weakest in spring/summer. Large scale wind forcing contributes significantly to seasonal variations in current strength.

Modelling studies of the dispersal of cod eggs and larvae confirmed the general circulation patterns on the Newfoundland Shelf (Pepin et al. 2013, Han et al. 2008, Pepin and Helbig 1997, Helbig et al. 1992). Dispersal is strongly influenced by perturbations in the weather band (i.e. wind driven events) with a periodicity of 4 to 15 days. Simulation revealed that the influence of wind-induced eddies served to increase drift and dispersal relative to models that simulate dispersal based on random motion of plankton. Furthermore, the track along which atmospheric pressure systems (e.g. storms) cross the shelf can have a very important influence of the drift path of plankton. Other simulation studies have revealed that drift and dispersal are strongly influenced by the vertical position of organisms in the water column. Drift and dispersal are greater for animals close to the surface than for those deeper in the water column. Because of the strong currents in both branches of the Labrador current, movement rates along and across the shelf are rapid. For example, drift from Hamilton Bank to the northern edge of the Grand Banks (roughly the length of SFA 6) can be completed in 60-80 days during periods with moderate currents (spring-summer). Modelling studies currently suggest that there is limited evidence of retention areas (i.e. areas where recirculation is strong enough to significantly delay or diminish loss from the region), but none of the models have considered the behaviour of plankton in their predictions. Transport onto the Grand Banks from either the inshore or offshore branches of the Labrador Current is limited and occurs principally for organisms that are spawned in the inshore branch relative to those produced along the continental slope.

In summary:

1. The inshore and offshore branches of Labrador Current are defining features in drift and dispersal of plankton in NL region;
2. The offshore branch has strong onshore component which is intensified in areas where bottom steering is possible (e.g. at the southern edge of banks and saddles);
3. Onshore transport is likely to be most important in spring, when LC strength is weaker;
4. Dispersal patterns are strongly influenced by wind events - changes in path, frequency and intensity of wind events likely to be critical in determining a stock's production potential; and
5. There is limited knowledge of Labrador Shelf but because of similarities in the main circulation features, the dynamics in that portion of the region are likely similar to those on the Newfoundland Shelf.

Discussion

It was calculated that at 25 cm/s current speed, larvae floating for 90-120 days could cover 2,000-2,400 km. It would be 500 km if speed is 5 cm/s however, recirculation is important when discussing larval shrimp.

There was a question regarding likelihood or locations of larval retention features. It is not likely that is the case, rather than re-circulation. Generally if there were retention features they would be known. For example, the Flemish Cap gyre feature is due to the Labrador Current meeting the Gulf Stream.

Currents suggest there are no boundaries so it would not take long for shrimp spawned on the NE shelf to be swept away. However, that does not mean there are no areas where larvae are more likely to end up. A slower moving water mass would mean more time for larvae to settle. It was noted that the strength of Labrador Current has substantially diminished over time.

There is a lot of uncertainty regarding how larvae react in water. If fully passive there would be nothing on the shelf. Forecasting settlement areas is difficult and rare; studies would need to superimpose behaviour on the model and this is not presently available for shrimp. Additionally, the extent of movement of adults is also unknown.

There was a comment that if oceanographic models are to be linked to this, the biology of larval shrimp needs to be better understood.

The question was asked: Do drogues move at speeds that models predict? The average speeds (1997) were 15-20 cm/s, and these results were consistent with models. The current fields were consistent with results of other studies.

It was asked what experiments would show that larvae take three months to settle? Given speed at which they move they can't be released to investigate where and when they settle. Ongoing DFO research at Institut Maurice-Lamontagne (IML) take shrimp from the NW Atlantic and put them in different temperatures (tank studies) to observe settling times. They are not actually measuring settlement, but trying to determine a stage or timeframe at which they might settle. Therefore, the passive vs. purposeful movement of shrimp larvae at different stages is still an unknown.

If larvae reach a stage where they could settle but don't have to so they move on until they find a suitable place (muddy, good temperatures, etc.) to settle, then the timing of chlorophyll bloom might have an impact.

CONCLUSIONS

Overall

There is enough data to conclude that important transfers between SFAs exist, but not enough to quantify them. Management measures within an SFA have important consequences not only for the harvest sustainable within that SFA but also for the harvest sustainable downstream of it.

There are therefore two opposite errors to be avoided. There is the error of treating each SFA as its own entity and not considering contributions from, and effects upon, other SFAs. There is also the error of thinking that, if one treats the whole shelf as one unit then it is sufficient to consider only one set of numbers, for the whole shelf, without examining spatial differences along the shelf.

As well as what the evidence says about transfers, it is impossible to overlook what it says about large changes even in the local rules that determine productivity of the resource. This greatly complicates the problems facing both assessment and management, including the very definition of management objectives.

The meeting concluded there was sufficient evidence to support a change in the spatial aspects in the Northern Shrimp assessments. However, transport rates of larval and adult shrimp and their interaction with life history events are not understood. Therefore, it is not possible at this time to specify what changes are required.

It was recommended that, as a starting point, consideration be given to integrating spawning stock biomass (SSB) in each SFA, as well as to SSB in upstream area(s), into advice/considerations. Reporting should be done at both the SFA and shelf-wide scale.

Northern Shrimp Production

If we assume that the shrimp surplus production that can be measured is largely incoming recruitment to the size that survey gear can sample, then we can ask how surplus production in one part of the shelf relates to conditions in another part some years earlier (i.e. when the year-class strength was formed). Data were restricted to NAFO Divs. 2J3KL, where enough survey information exists to estimate surplus production rates, and subdivided by NAFO division rather than SFA. There was evidence that stock size, exploitation rate, predation and environmental forcing within one geographical area affect shrimp production in that area and in other areas.

Divs. 2J3KL function as a unit rather than individual pieces, but the unit is not homogeneous. Divs. 2J3K emerge as the consistent core source area for driving shrimp production at the entire Divs. 2J3KL scale. The results also suggest a north to south export of production within Divs. 2J3KL. However, the rate of transfer is not known.

It was also noted that the physical environment and the population of predators, both of which have significant and easily explained connections with shrimp productivity, have experienced consistent trends during the time analyzed.

Simulations

The parameters used in the simulations were fairly arbitrary and the full parameter space remains unexplored, as does the full range of how to specify the model, including where density dependence takes place. Still, it appears that the difference in total yield among the different strategies is very small (less than 5% or well below the noise level of surveys), whereas the difference in equality can be as much as 25%. It would be easy to modify this simulation to consider real management objectives and constraints, should these become known.

Strategies can be compared by the maximum harvest they produce. In addition, considering how management actions in one SFA have consequences for the harvest sustainable in another, strategies can be compared by their equality (i.e. the ratio of maximum to minimum harvest among the different boxes).

The simulations were done on the basis of known parameters. Estimating the parameters to take into account transfers between boxes in addition to local changes with each box, as well as changes over time in the parameters themselves, has yet to be addressed.

Planktonic Drift and Dispersal

Drifter data and oceanographic circulation models compared with the duration of the pelagic larval phase suggest that shrimp larvae can easily be carried out of the NAFO division or shrimp fishing area in which they were spawned. A mean speed might be 400 km/month, which is from one end of SFA 6 to the other.

Transport is principally from north to south and there is evidence that changes in current direction around banks may reduce the extent of southerly transport of planktonic stages of shrimp. The physical or biological mechanisms to explain how some larvae manage to stop in time to mature in a relevant division or area are unknown. Features that are irrelevant to the mean flow may be crucial for retaining the occasional larva.

Although the models covered only the southern half of the shelf, enough is known about general physical principles to make us confident that the same considerations apply further north.

DATA GAPS

It was shown that there are large influences of one part of the shelf on another, and that such influences mean that management decisions in one part can affect the harvest sustainable in another. How to quantify the effect was not shown; it was revealed that quantifying is more difficult than previously realized. If transfers are important, then local data do not suffice to quantify the processes and feedbacks that determine surplus production. If, as other data indicate, even the local processes and feedbacks are changing, then not only is the estimation of the problem difficult, but some of the quantities traditionally estimated (e.g. a constant exploitation rate leading to a constant biomass) do not even exist. Management and precautionary approach methods that invoke such quantities will need to be rethought.

To determine where larvae spawned in one area are most likely to be retained if they are retained anywhere, data are needed on the probabilities of rare events or rare combinations of events including readiness of larvae to settle, cues that induce them to do so, and deviations (either systematic or episodic) from mean current velocity.

RESEARCH RECOMMENDATIONS

- Expanded analyses at the SFA scale including export/import effects to/from other areas to determine transfer rates between management areas;
- The biology of larval shrimp (if oceanographic models are to be linked); and
- Investigate the ability to differentiate between local and large scale drivers.

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APPENDIX I - TERMS OF REFERENCE

Review of Spatial Scale for the Assessment of Northern Shrimp in SFA 4-7

Regional Review Meeting - Newfoundland and Labrador Region

August 12-14, 2014
St. John's NL

Chairperson: Brian Healey

Context

Recent genetic analysis indicated that the 3LNO Northern Shrimp stock is part of a wider population spanning NAFO Subarea 2 and at least Div. 3KL. Currently, transport of shrimp across the management area boundaries is not accounted for in the assessment and therefore introduces additional uncertainty. NAFO Scientific Council recommended exploration of alternative approaches that take into account the entire stock area.

In support of DFO commitments made at the 2013 NAFO ICES Pandalus Assessment Group (NIPAG), DFO Science will conduct a Regional meeting to investigate spatial scales appropriate for the assessment of Northern Shrimp in the Northwest Atlantic.

Objectives

The key objective is to determine if there is understanding sufficient to support a change in the spatial aspects of Northern Shrimp assessment and management.

Expected Publications

- A Proceedings Report will be produced to record the meeting discussions and outcomes.

Participation

- DFO Science
- DFO Fisheries Management
- Academia

APPENDIX II - LIST OF PARTICIPANTS

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