Proceedings of a workshop held 23 January 2007 at the Gulf Fisheries Center
Potential Impacts of Seismic Energy on Snow Crab:
An Update to the September 2004 Review

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TABLE OF CONTENTS

LIST OF APPENDICES

RÉSUMÉ

En Novembre 2003, un test sismique à l'ouest du Cap-Breton (Nouvelle-Écosse) fut approuvé par L'Office Canada – Nouvelle-Écosse des hydrocarbures extracôtiers (OCNEHE). Le test, effectué par Geophysical Services Incorporated de la part de la société Corridor Resources Inc., fut considéré comme une bonne opportunité pour effectuer une étude scientifique pour tester les impacts potentiels de tests sismiques sur le crabe des neiges (*Chionoecetes opilio*). Une attention particulière fut portée sur la santé du crabe des neiges puisque la zone d'intérêt pour l'exploration et le forage de pétrole et de gaz est aussi à proximité d'une des plus grandes concentrations de crabes des neiges au monde. L'objectif primaire de l'étude était de déterminer s'il y avait des impacts des tests sismiques sur la reproduction et la survie des crabes femelles. Cette étude fut réalisée grâce à un partenariat conclu entre le Ministère des Pêches et Océans Canada, l'Office Canada-Nouvelle-Écosse des hydrocarbures extracôtiers, le ministère de l'Énergie de la Nouvelle-Écosse, l'Association des pêcheurs de crabe des neiges de la zone 19 et la société Corridor Resources Inc. Pour tester les impacts potentiels des bruits sismiques, des femelles furent placées en cages au site d'exploration sismique, ainsi que 41 km plus loin à un site témoin. Les femelles furent maintenues en cages pour une court (12 jours) et une moyenne (5 mois) durée. Par la suite, les crabes furent ramenés au laboratoire afin d'évaluer des différences au niveau de leur comportement, leur morphologie et leur physiologie. Certains crabes furent gardés en aquarium pour une durée de 6 mois pour déterminer leur survie, leur état et leur comportement. Les résultats de cette étude furent évalués dans le cadre d'un examen par les pairs réalisé à Moncton (N.-B.) le 29 septembre, 2004. Les résultats présentés démontrèrent des observations définitives, comme aucune mortalité aiguë ou à mi-terme causée par le bruit sismique, mais aussi des différences significatives entre le groupe d'essai et le groupe témoin qui justifièrent des études antérieures. Le document suivant est un compte rendu d'une réunion réalisée à Moncton le 23 janvier 2007 pour évaluer les résultats des études antérieures conçues pour répondre à sept questions engendrées à la réunion de septembre 2004.

ABSTRACT

In November 2003 a seismic survey off the western coast of Cape Breton Island, Nova Scotia was approved by the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB). The survey, conducted by Geophysical Services Incorporated on behalf of Corridor Resources Inc., was considered an excellent opportunity to conduct a scientific study to test potential impacts of seismic activity on snow crab (*Chionoecetes opilio*). There was particular concern for the health of snow crab because the area of interest for oil and gas exploration is also the site of one of the highest concentrations of snow crab in the world. The primary objective of the study was to determine whether there were any impacts of seismic activity on survival and reproduction of female snow crab. This study was carried out as a partnership among the Department of Fisheries and Oceans Canada, CNSOPB, NS Department of Energy, Area 19 Snow Crab Fishermen's Association and Corridor Resources. To test potential impacts of seismic noise, female snow crab were caged, for

short (12 days) and medium (5 months) duration, at the seismic survey site and at a control site located 41 km away. Exposed snow crabs were then brought to the laboratory to assess differences in their behaviour, morphology and physiology. Crabs were also held in captivity in the laboratory over a 6 month period to measure mortality, condition and behaviour. Initial results of this study were presented at a scientific peer review on September 29, 2004. While there were definitive observations, such as no acute or mid-term mortality of the crab exposed to seismic activity, there were also significant differences between the experimental group and control group, which warranted further studies. The following is the proceedings of a meeting held on January 23, 2007 to evaluate the results of additional studies conducted to answer seven specific questions formulated at the September 2004 meeting.

BACKGROUND

In 2001, a Maritimes Regional Advisory Process (RAP; DFO Maritime Provinces Regional Habitat Status Report 2001/001) took place to review working papers on potential effects of oil and gas exploration and drilling activities off the coast of Cape Breton. This meeting was held in response to a request from the federal and provincial Energy Ministers to the Canada Nova Scotia Offshore Petroleum Board (CNSOPB). The RAP stressed the fact that the area of interest for oil and gas exploration, off the west coast of Cape Breton, is also the location of a large and economically important snow crab (*Chionoecetes opilio*) fishery and an important area for larval settlement. All benthic phases and size groups of snow crab inhabit this area and there are high landings and catch per unit of effort in the fishery. Specifically, this meeting concluded that there was a lack of information on the potential impacts of seismic activities on snow crab, such as:

- Acute mortality of eggs, larvae, juveniles, adolescents and adult males and females.
- Physiological impacts including structural damage to hearing, digestive and reproductive organs, the respiratory system, digestive tracts and embryos and functional damage to hearing and communicating capacity and the capacity of molting, feeding and hatching.
- Abnormal behaviour during mating or molting.
- Movement and migration during all life stages.
- Impact on catch rate in the fishery.

In March 2003, DFO organized a workshop to develop a "Decision Framework for Seismic Survey Referrals" which produced an inventory of ecological factors that should be considered when dealing with referrals for seismic surveys in Canadian waters (DFO Can. Sc. Advis. Sec. Habitat Status Report 2004/002). Conclusions regarding invertebrates included the following:

- Information is lacking to evaluate the likelihood of sub-lethal or physiological effects on crustaceans during pre-molt, molting and post-molt periods.
- The ecological significance of the effects is expected to be low, except if effects of exposure to seismic sounds were to influence reproductive or growth activities.
- The potential for seismic sound to disrupt communication, orientation, detection of predator/prey, locomotion and other functional uses of sound has not been studied.

Because this workshop illustrated the many uncertainties related to the potential impacts of seismic exploration, a preliminary study to determine the effects of seismic energy on the health of the resident snow crab population was funded by the Environmental Studies Research Funds (ESRF). This study reported that there were no apparent effects on adult crab behaviour, health or catch rates but there was a significant effect on egg development from a female exposed to seismic signals at a very close range (2 m; Christian et al., 2003).

In the winter of 2003 and spring 2004, studies were conducted on short notice by DFO to coincide with an operational seismic survey taking place off the western coast of Cape Breton. The study was developed through a partnership with Corridor Resources, Area 19 Snow Crab Fishermen's Association, Canada-Nova Scotia Offshore Petroleum Board, Nova Scotia Department of Energy and DFO. It included a cage-study and laboratory experiments on potential impacts of low-level seismic energy (132 hours of survey time, low-volume 1,310 in^3 air-gun array) on the reproductive biology of female snow crab, with the intention of addressing concerns about potential reproductive effects identified in the Christian et al. (2003) study. Snow crabs for the cage-study were collected by trapping and trawling, sorted to be as similar as possible, caged (25 crabs/cage) and placed at the seismic test site or 41 km away at a control sites (M. Moriyasu, DFO Moncton, NB, unpublished data). The caging experiment examined differences in the morphology and physiology of snow crab caged short-term (12 d) or medium-term (5 months). Snow crabs from both groups were also observed under laboratory conditions for differences in mortality, morphology, physiology, feeding and orientation (turnover rate) over a six-month period. The study was considered to be "preliminary" in nature with an aim to identify issues that would merit more detailed investigation. This research was funded and conducted as a collaboration between Corridor Resources, NS Dept of Energy, DFO and ESRF. Results of the study were peer-reviewed on 29 September 2004 and reported in Habitat Status Report 2004/003 and in DFO, 2004c.

The study produced three definitive observations including: (1) the seismic survey did not cause any acute or mid-term mortality of the crab, nor was there any evidence of changes to feeding in the laboratory; (2) survival of embryos being carried by female crabs, and locomotion of the resulting larvae after hatch, were unaffected by the seismic survey; and (3) in the short-term, gills, antennules and statocysts (balance organs) were soiled in the test group but were found to be completely cleaned of sediment when sampled five months later.

In addition, there were several significant differences between experimental results of test and control groups, even after five months, including (1) the hepatopancreas (similar function to a liver) was found to be bruised in the test site; (2) ovaries from animals at the test site were found to be bruised and had dilated oocytes with detached chorions (the outer membrane); (3) in one test group, embryo hatch was delayed by 5 days on average and resulting larvae were slightly smaller than controls; and (4) orientation (turnover rate), as measured by the time an overturned crab needs to right itself, was different between test and control groups. Further work was recommended to help verify and resolve these differences. To address these concerns, seven specific questions (see Introduction below) were formulated and assigned to collaborating partners for further analyses. Funds for the additional analyses were provided by DFO. The following is the proceedings of a meeting held on 23 January 2007 to discuss the results of these subsequent analyses through the presentation of working papers.

POTENTIAL IMPACTS OF SEISMIC ENERGY ON SNOW CRAB:

AN UPDATE TO THE SEPTEMBER 2004 REVIEW

Introduction

On January 23 2007, a meeting was held to review additional studies conducted to address topics of concern expressed at a September 2004 DFO Science Advisory meeting. The purpose of the September 2004 meeting was to review the results of a cage-study which assessed impacts of seismic exposure to egg-bearing snow crab. To answer the concerns expressed at this meeting, collaborating partners conducted additional field studies, additional laboratory investigations and also analyzed pre-existing data. The field studies included a cage-study to determine if histological abnormalities observed in female snow crab ovaries and hepatopancreas were due to exposure to seismic energy or to differing environmental conditions between the seismic exposed site and the control site, such as differences in temperature, substrate and food availability. A dragging experiment also took place to test the origin of the fouling of the gills, antennules and statocysts. Additional laboratory investigations included reexamining histological slides of ovary and hepatopancreas under double-blind conditions to ensure that there was no bias with observation error. Further work was also undertaken to refine the techniques employed to assess developmental rate and stage of snow crab embryos and larvae. Comparisons with existing data were made to compare leg loss between laboratories that held snow crab following the experiment and also to evaluate if seismic exposure had an impact on the abundance of snow crab in the survey area. These additional studies were undertaken to answer seven specific requests formulated at the September 2004 DFO Science advisory meeting (DFO, 2004), which were:

1. Verification by an independent histopathologist of interpretations made in September 2004 of gonad and hepatopancreas tissue from snow crab caged within and outside the seismic survey area.
2. Investigation of the origin of histopathological abnormalities observed in the hepatopancreas and ovary of caged crab through an additional caging experiment.
3. Investigation of the effect of dragging of cages on gill fouling.
4. Investigation of the hypothesis that exposure to seismic energy resulted in leg loss in caged crab
5. Evaluation of current stock assessment data for evidence of reduced snow crab abundance within the December 2003 seismic survey area.
6. Refinements of survival estimates for embryos carried by crabs caged in the original experiment
7. Estimation of sound pressure levels encountered by crabs in the December 2003 seismic survey and reference areas.

The meeting was conducted as follows. Four working papers (agenda, Appendix 1) were presented to address the seven specific requests of the September 2004 meeting. Each

senior author presented the results of their working paper. External referees were asked to provide comments, after which the floor was opened to a general discussion.

The product of this meeting was an ESRF Report (ref), which consists of the working papers presented at the meeting, and a proceedings document (current document) which includes a summary of the working papers, questions and answers, the comments by the referees and the general discussion (list of participants, Appendix 2). The answers to the seven specific requests are given and sources of uncertainty and future research recommendations are included. Originally, the product of this meeting was to be published as a Habitat Stock Status Report (letter of invitation, Appendix 3). However, because the working papers presented at the meeting did not produce any new scientific knowledge and also because further statistical analyses were required to draw definite conclusions on the histopathological evaluation (see Chapter 5 ESRF Report), the outcome of the meeting was presented as an ESRF Report and a proceedings document.

HISTOPATHOLOGICAL EVALUATION OF HEPATOPANCREAS AND OVARIES FROM CAGED SNOW CRABS, *Chionoecetes opilio*, FAILS TO DISCERN CONTROL AND SEISMIC EXPOSED SAMPLES DUE TO CONFOUNDING EFFECTS FROM CONFINEMENT, STARVATION AND/OR HANDLING STRESS

Written by: Lucy E.J. Lee (llee@wlu.ca) and Michael A.R. Wright (Wilfrid Laurier University, Waterloo, ON, Canada)

Presented by: Lucy Lee

Summary

The aim of this study was to compare the histological appearance of hepatopancreas and ovaries of snow crabs held in cages at control and seismic exposed sites. Tissues were retrieved after short (12 d) or long confinement (5 months) and processed for general histology. Four hundred and seven hepatopancreas slides and 352 ovarian slides were examined by light microscopy in a blind study. Tissues were assessed for trauma, hemocytic infiltration, edema, nuclear changes, detachment from basement membranes, intracellular and extracellular changes, etc, and subjectively given numerical values by an independent evaluator indicating the degree of abnormality. After the histological evaluation, the identity of the slides was revealed and the hepatopancreas and ovary slides were analyzed. Of these, 53.4 % of the seismic exposed hepatopancreas slides correlated with the blind histological analysis of pathological findings, and 51.8 % could be correlated with the seismic exposed ovaries. However, control slides did not correlate well and only 38.4% of the evaluated control hepatopancreas slides correlated with the key and 35.8% with the ovary control slides. When considering length of time that crabs were caged, a high degree of correlation could be discerned with degree of pathological abnormalities. Crabs maintained in cages for 5 months following seismic exposure received higher pathologic indices than those caged for shorter times. Commonly observed abnormalities included inflammatory infiltration, scar tissue formation, disruption of basement membrane integrity, vacuolation of cells which could have been brought about by physical impact as well as from confinement stress. It is concluded that caged crabs do not provide appropriate information following seismic exposure, and that perhaps, single large enclosures at control and seismic sites with crabs held for short periods following exposure would provide sufficient information as to histological damage that may be sustained following seismic impacts.

11 parameters were evaluated for the hepatopancreas:

1) Midget cell (M-cell) numbers and positioning relative to the basal lamina
2) Nuclear morphology of epithelial cells
3) Size of nucleus
4) Thickness of epithelial wall
5) Level of vacuolization of R-cells
6) Fixed phagocytes in the hemal space

7) Encapsulation and parasites
8) Delamination of basal lamina
9) State of peritrophic membrane
10) Necrosis/Autolysis of the tissue
11) Abundance of collagen

9 parameters were evaluated for the ovaries:

1) Delamination of chorionic membrane
2) Atresia of the follicles
3) Packing density of oocytes
4) Granulocytes infiltration of the tissue
5) Bruising
6) Delayed maturation of the oocytes
7) Peculiarity of the staining
8) Edema or homogenization of cellular components
9) Encapsulation & parasites presences

Scores were given per slide for normal and abnormal comparisons.
For each of these parameters, there was a score on a scale from 1 (normal) to 5 (abnormal) for a minimum of 9 X 1 = 9 and 11 X 1 = 11 and for a maximum of 9 X 5 = 45 and 11 X 5 = 55 for the ovaries and hepatopancreas respectively.

Questions/comments

Participant: How many sections did you have per slide?
Lucy Lee: We had 4 to 8 sections per slide.

Participant: When you give a score does it reflect all the sections on that slide or just one?
Lucy Lee: It reflects all the sections, but this is a subjective score.

Participant: How consistent were you in the subjectivity? Is there a test of consistency?
Lucy Lee: Yes because it was done by the same person (student Michael Wright).

Participant: Still there is no test of consistency. You did not check to see if his work was done consistently.
Lucy Lee: At the end of a day, there might be slight variations from his scores to mine, but in the overall picture, we have a consistent base.

Participant: The student, what was his background?
Lucy Lee: He's an undergraduate student who got high marks in histology. He has worked for me before and I trained him to do this work.

Lucy Lee: Variations would vary naturally from day to day. Everything was random, the experiment is double blind.

Participant: On the scale, what is the Y?
Lucy Lee: The relative score is the full sum of the pathology for the 11 parameters that we have measured. Anything under the line is considered normal, anything above is abnormal.

Participant: When you add five variables together or in this case some of the variables, you are essentially taking away measures and you are loosing valuable information. Is this the most appropriate test for abnormality? You can have one or two factors showing extreme abnormalities, but the other factors would dilute that.
Lucy Lee: Qualitatively we could record each slide…

Participant: What is the general background of the people who designed the score?
Lucy Lee: My student and I for general histology, but Dr Moriyasu would be a better crustacean histologist.

Participant: When looking at the slides, did you get any indications of the whereabouts the slides were coming from?
Lucy Lee: No. I was given no indications of their locations. I just received the slides and I was blind to their locations until after the evaluation.

Participant: Were there animals caught away from the seismic test site?
Lucy Lee: Yes. The controls were 41 km away. (*Editors note* – crabs in this study were captured off Margaree Harbour (NS) and then caged at the seismic site and 41 km away at a control site.)

Participant: Do you have any idea of the sequence of a normal cycle? How the ovaries might change?
Lucy Lee: Yes

Participant: How did you account for that, the natural ovarian cycle?
Lucy Lee: We are not using one value. Anything below the range should be normal and anything above abnormal.

Participant: Could the majority of the examples of the atresia of the follicles be due to a natural internal cycle of the ovaries of the snow crab?
Lucy Lee: Yes. It could be.

Participant: Rapid decay of tissue?
Lucy Lee: I did not prepare the tissue; they were prepared by Mikio's team in Moncton.

Participant: Was the tissue fixed immediately after the animal was taken out of the water?
Lucy Lee: All crabs were alive, but they were not fixed on the boat, they were fixed in Moncton about 5-7 hours later

Participant: What's the normal variation in the tissue for animals that you go out and collect?

Chairman's cut: let's keep the big questions for this afternoon.

Participant: You made a comment about overcrowding, was it from the 6000 per km^2?
Lucy Lee: Yes I took it from the literature which comes from the annual survey the Moncton DFO team does here.

Participant: Did you take samples outside the control area?
Lucy Lee: I did not take any samples. I only analyzed the slides.

Participant: What's the basis for linking mortality to the starvation you mentioned as an example?
Lucy Lee: The height of the epithelium level decreases when starvation is found.

Participant: So there is a direct biological line between a starving crab and the decreasing of the epithelium?
Lucy Lee: There are deviations from the normal, but we are not sure if it is that one specific reason.

UPDATE OF THE STUDY ON THE EFFECTS OF SEISMIC NOISE ON FEMALE SNOW CRAB (*Chionoecetes opilio*) EVALUATED BY A CAGING STUDY CONDUCTED OFF WESTERN CAPE BRETON ISLAND IN 2003-2004

Written by: Mikio Moriyasu, (Mikio.Moriyasu@dfo-mpo.gc.ca), Elmer Wade, Renée Allain, Khadra Benhalima, Marcel Hébert and Christine Sabean (Department of Fisheries and Oceans, Moncton, NB, Canada)

Presented by: Mikio Moriyasu

Summary

Additional results to the original seismic study were presented including experimental trawling (dragging) of female snow crabs (*Chionoecetes opilio*) in mesh bags on the ocean floor in order to assess the effect of drifting cages on eyes, antennules, gills and statocysts. This study also includes the comparison of the abundances and distributions of different categories of snow crab before (September 2003) and after (June 2004) the seismic testing. These comparisons were made with data collected by the annual bottom trawl survey (September 2003) and an additional bottom trawl survey conducted prior to the 2004 fishing season (June 2004).

There was no apparent effect of trawling on the eyes, antennules, gills and statocysts suggesting that the possible drift of cages in the test site during the 2004-2005 study may not be the cause of dirty gills, antennules and statocysts found in female snow crab. There was no clear evidence of decreases in abundance or changes in distribution patterns which might have been caused by seismic testing in any category of snow crab assessed. Our results suggest that a global comparison of abundance and distribution of snow crab may not be a robust tool to assess possible effects of seismic testing.

Questions/Comments

Participant: The crabs that were in the previous slide (adolescent males, ≥ 56mm), shouldn't they have gone in this grouping here (adult males, ≥ 95mm) and then shouldn't we have seen that?
Mikio Moriyasu: No because those molting (adolescent males) are not counted and this one only contains hard shell (adult males).

Participant: Isn't it the case that we have three bottom trawl surveys and all with the exception of the seismic year, we had an increase of the order of twenty to thirty percent in the population?
Mikio Moriyasu: There is only two. We did three but one was in May and the other in June, we used June.

Gerard Conan.: I think it is a good idea to visualize and try to map, but on the other hand if you use a different technique for mapping you're going to get completely different maps. It's a well known fact when you use GIS that they are highly unreliable

and when you come to the idea of comparing maps, it's difficult to do visually. You can't do that just by looking at the maps. You have to use some statistical technique to compare the maps themselves. This is an interesting start, but I think you can't go very far in discussing these results. If I was actually explained how the mapping is being done, I probably wouldn't agree with the technique being used.
Mikio Moriyasu: Yes this mapping helps us to visualize the distributions of crab but is not in itself sufficient to test the hypothesis of seismic effect.

Jae Choi: You should use a variogram specific to the area that you are interested in and you could see that it is changing across time.
Mikio Moriyasu: Yes.

Participant: We don't have enough evidence yet. You don't have enough history to see what was happening before so to speak, and now with the seismic, to draw a conclusion. We are still wondering what is going to happen afterwards.

Participant: Can you explain the rational behind the choice of two hours of dragging for the effect of the sediment disturbance on the variance factors. Why two hours?
Mikio Moriyasu: It was arbitrary and the best we could manage with the vessel available.

Participant: The crabs that were dragged were they on the bottom during the seismic or were these from a fresh batch?
Mikio Moriyasu: We used a fresh batch.

Participant: The ones used for the seismic were they weakened before the seismic?
Mikio Moriyasu: No.

Participant: Maybe it's not dragging the crabs on the bottom but keeping them in a cage. If you keep crustaceans in a closed environment for a long while, their carapace will become dirty. They have to clean themselves and if they are not able to move properly, they are not going to clean themselves. The fact of keeping the animals in cages did seem to affect the results.
Mikio Moriyasu: I have mentioned in the paper that in the test traps only some animals accumulated dirtiness and after 5 months they were all clean and in the control site we did not see any dirtiness.

Participant: With the cage studies, there were 45 individuals per category, but in the majority of the results there were much fewer control individuals. What happened to the others?
Mikio Moriyasu: We carefully eliminated the senile female.

ACOUSTIC MEASUREMENTS

Written by: Marjo H. Laurinolli, Scott A. Carr, Melanie E. Austin and Alex O. MacGillivray

Presented by: Marjo Laurinolli

Summary

Corridor Resources Ltd implemented a field monitoring program as a means to document underwater sound production by their 2003 2-D seismic program off western Cape Breton, Nova Scotia, to determine the resulting ensonification of the marine environment over a large area, and to monitor the exposure of caged snow crab for later analysis. To that end, JASCO Research Ltd conducted an acoustic monitoring program that is detailed in this report. The following is a summary of the pertinent results.

Close range measurements of distance to 180 and 190 dB levels
Sound pressure measurements were made at close ranges to the airgun array. It was noted that maximum levels were received broadside of the array. The maximum ranges to which root-mean-square (RMS) levels of 180 dB re µPa and 190 dB re µPa were received were determined (by extrapolation of measured data) to be 744 m and 236 m respectively.

Propagation of sound horizontally away from the array
Levels received broadside to the array were noted to be approximately 10 dB greater than levels received from the array endfire. The levels were seen to decrease with range in accordance with a standard, empirical transmission loss curve.

Sound levels received at long ranges from the array
At long ranges from the airgun array it was noted that low frequency sound energy was decreased due to ocean bottom and surface interactions. Sound that propagated to the crab cage control site passed over varying bottom topography and resulted in lower received levels than those received at corresponding ranges at the crab test cage site where the sound traveled over a smoother bottom.

Sound levels measured at the caged snow crab holding locations
The maximum RMS sound pressure levels received at the caged snow crab test site measured 178 dB re µPa and occurred at ocean bottom seismometer-P (OBS-P) as the vessel, the Admiral, passed by along line CHT-108-08 at a range of 138 m. The 1/3-octave band spectral levels of this airgun event showed a peak of 162 dB re µPa2 at the 125 Hz centered band. The maximum RMS sound pressure level received at the control site was observed at OBS-T as the vessel, the Admiral, passed by along line CHT-101-01 and measured approximately 118 dB re µPa at a range of 23 km.

The ambient noise levels at the caged crab control site OBS-T had broadband sound levels up to as high as about 95 dB re µPa. The 1/3-octave band spectral levels measured

were about 68 – 75 dB re µPa^2 from 25 – 100 Hz and about 75 – 79 dB re µPa^2 at 300 – 400 Hz. These levels were 83 – 94 dB re µPa^2 less than the highest 1/3-octave band spectral level observed during the loudest airgun event experienced by the caged crabs.

Questions/Comments

Participant: Was there noise of the seismic survey detectable at the control site itself?
Marjo Laurinolli: Yes.

Participant: What extrapolation method did you use to determine the RMS from the TL curve?
Marjo Laurinolli: I'm not the statistician to answer this. I did not do this part.
On the chart, a solid line is fit (Marsh and Schulkin) of TL greater than 1 km, dashed line is fit at lesser than 1km.

Participant: This bothers me because this short, short, short range is very important because it is underestimating that influence. At less than 1 km range, you're dramatically underestimating with this fit the transmission loss.

Participant: Who did the work?
Marjo Laurinolli: Melanie Austin

Participant: The range has a little bit more signal when the ship is closer. Do these devices have seismometers?
Marjo Laurinolli: Yes.

Participant: Is there a particle motion detector on board?
Marjo Laurinolli: Yes, but I'm not sure if these were recorded.

Participant: That's a major oversight.
Marjo Laurinolli: I'm not sure if they have recorded the information.

Participant: The reason is that these animals are on the bottom and there is a tremendous amount of particle motion associated with the bottom. The signal is not direct from the ship, but it's significantly coming back from the substrate and that can impact the signal that you receive. It also causes particle motion. These animals are probably more particle motion sensitive than they are pressure sensitive. I'm not saying that it's just possible… I know it is.
Marjo Laurinolli: We were not contracted to do that.

Participant: The reference for the key was 23 km but you mentioned 41 km, what's the difference between the two?
Marjo Laurinolli: That's how close the vessel got to the control site. So the control site was 41 km away from the seismic site but the seismic vessel got to 23 km from the control site.

Participant: How long was it monitored?
Marjo Laurinolli: They were there for 83 hours.

Participant: Do we know if the ship was 23 km from the site? Do we have a pattern to follow, the footprint of the boat? Do we know for sure they never came in more than 23 km?
Marjo Laurinolli: The Northern most line is the 101 and I don't think they got closer than the 23 km line. We could check to see. I don't think they would get closer to the line.

Participant: Any thought of the broadband noise? It is not natural, it is artifact noise.
Marjo Laurinolli: No, it is natural noise levels.

Participant: When the boat passes over crab traps, it was about 200 to 300 meters away?
Marjo Laurinolli: 130 meters.

Participant: If the crabs were under the array, how much noise would be recorded?
Marjo Laurinolli: I don't have the measurement with me, but we don't have a reading directly from underneath. The levels should be higher underneath it. On the map, line 108 was supposed to be the closest.

Participant: When arrays were being used, how much were received by receivers?
Marjo Laurinolli: I don't know.

Participant: A dB is a dB is a dB – same in water/air. Humans are not adapted to hear under water and we are making a misassumption that these animals are hearing these sounds. For example, a fish can make noise right beside you in the water and you won't hear it. There are no data on whether they hear or not. Point: other effects of the sound (such as particle motion)

UPDATES ON THE 2004 SNOW CRAB RECAGING EXPERIMENT, THE SYNTHESIS OF LEG LOSS DATA AND REFINEMENT OF EMBRYO-LARVAL SURVIVAL ESTIMATES

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Presented by: Simon Courtenay

Summary

This working paper discussed three of the recommendations from the September 2004 DFO Science Advisory meeting. Included is (1) the investigation of the origin of histopathological abnormalities observed in the hepatopancreas of caged crab through an additional caging experiment, (2) the investigation of the hypothesis that exposure to seismic energy resulted in leg loss in caged crab and (3) the refinements of survival estimates for embryos carried by crabs caged in the original experiment.

1) Results from the caging experiment for short- (12 d) and mid-term (5 months) immersion periods demonstrated that animals from both the seismic site and the control site showed lesions of internal organs (DFO, 2004). Since the protocol did not account for an observation of multiparous females before they were caged, these lesions could not be attributed to the seismic activity. Therefore, it was decided to cage some multiparous females for 12 d in December 2004 at both the former seismic and former control site, with some observations on females caught in the wild. The external observations of appendages of females collected in December 2004 showed that they were clean and in good condition. However, histological observations of the hepatopancreas revealed that the majority of these females had haemorrhage. Hence, the sample collected from the wild, with no treatment, already showed signs of internal anomalies with massive haemorrhage observed in 62% of these females. Their physiological condition (condition of the hepatopancreas in terms of haemorrhage) is somewhat similar to those that were exposed to seismic activity in 2003 and their control, and also to those caged for 12 d in December 2004 ($p=0.09$). Furthermore, females caged in December 2004 at the former control site showed the highest percentage of severe haemorrhage of the hepatopancreas. Thus, it is not possible to draw any conclusion from the 2003 experiment because the protocol used (unknown status of the females before treatment) does not allow assessing the null hypothesis, i.e. a possible impact of seismic activity on snow crab females.

2) Following the seismic testing of December 2003, snow crabs were distributed among three research facilities including: DFO facilities in St. John's (NF) and Moncton (NB) and the St. Francis Xavier University (SFX) in Antigonish (NS). During their stay from December 2003 to June 2004 at the St. John's DFO facility, the seismic exposed group lost a total of 26 legs compared to only 3 in the control group. One of the recommendations of the September 2004 DFO Science Advisory meeting was to submit

information on snow crab leg loss for each of the facilities participating in the research program to determine if this occurred in all seismic-exposed groups or if it was an isolated incident with an unrelated cause (DFO, 2004). No information was recorded on leg loss at SFX, therefore the comparison below is limited to NF and NB. It is important to note that the NF and NB snow crabs were from different treatment groups. The ones housed at NF were caged for 12 d whereas the ones housed at NB were caged for 5 months.

There was no significant difference between crab caged at the seismic and control sites in number of missing legs upon arrival at NB (Pearson Chi-square $X^2_3 = 5.602$; $P = 0.133$). Similarly, there was no significant difference between groups in number of missing legs at the end of the experiment at NB 47 days later ($X^2_3 = 4.695$; $P = 0.196$). Therefore, it is quite likely that leg loss in the seismic exposed group housed at NF was not caused by exposure to seismic sound but rather was caused by something else such as rough handling of the seismic crabs in transit to NF. This hypothesis was supported in further studies done by Dr. J. Payne (NF) in which crabs were exposed to dB levels as high as 220dB, peak to peak, without leg loss difference. The most recent exposure was in December 2006 (200dB peak to peak) in which there was the loss of one leg in each of 34 control and 34 exposed crabs, one month post exposure.

3) One of the main objectives of the December 2003 seismic research study was to address questions raised by Christian et al. (2003) about the effects of seismic energy exposure to snow crab progeny. Following the long-term caging (5 months) associated with the seismic testing of December 2003, egg-bearing female snow crab were brought back to the DFO Moncton aquarium facility to determine possible impacts of seismic exposure on snow crab egg and larvae. Initial results suggested that embryos from exposed females hatched later than control embryos which resulted in smaller, less developed, embryos. During the DFO Science Advisory meeting (DFO, 2004), suggestions were made to refine the techniques employed to assess developmental stage. Samples were re-analyzed following these suggestions. The proportion of each developmental stage (orange eggs, black eggs, pre-zoea and zoea) was determined in all samples collected, with a 5 mL Stempel pipette. The mean weight of each stage was determined by weighing a group of 100 individuals of each stage separately, for 5 samples. Results indicated that progeny from seismic-exposed females developed at a slower rate than the control group. The mean proportion of the different life stages for each group and the mean weight of each life stage indicate that an equal number of progeny from the two groups would be expected to differ in weight by 23%. The actual difference in weight between groups was 22%, very close to the 23% difference that would be expected. Therefore it appears that there was little difference in total number of progeny from the two groups but that the rate of development was slower in seismic than control embryos (later hatch, more pre-zoea and fewer zoea in seismic than control group). This difference in rate of development could be related to seismic energy or to cooler temperature at the seismic than control site.

Questions/Comments

Participant: Were all these crabs from the same stations?
Simon Courtenay: Yes.

Participant: Did Lucy have a category for haemorrhage?
Simon Courtenay: Yes.

Participant: Can the leg loss be caused by an exposure to seismic noise versus non-seismic noise?
Simon Courtenay: We don't know, but conceivably it could be a cumulative thing from seismic noise, to transport, to manipulation (exposure to manipulation).

Participant: What was the temperature in the tanks at the Gulf Fisheries Center?
Simon Courtenay: + 4 to 5 degrees. It is as cold as we can get in a tank environment.

Participant: How do you explain the relatively large abundance of females that didn't release their eggs that appeared in the June 2004 trawl survey?
Simon Courtenay: I was not involved with the June 2004 trawl survey.

Participant: Are you able to draw a conclusion based on 5 degree water versus the norm?
Simon Courtenay: Most of the embryo stage was spent in the wild, not the aquarium so yes, we think that the results we saw were representative.

Participant: These smaller animals are they going to stay small...pygmy?
Simon Courtenay: The seismic larvae may have been smaller than controls because they were less developed and possibly because they came from slightly smaller females. I would expect them to catch up to the others.

Participant: If you are smaller, you will eventually have higher mortality rates than if the crabs are larger, it's just the nature of the beast.

Participant: 100% of the animals, the ones that went to the control group and the ones that went to the test group, didn't originate in either of those two locations, they originated from somewhere else and they all came from identical habitat. They didn't start out in two different worlds. That's the point I'm trying to make here.
Simon Courtenay: That is true, crabs caged in the two different sites both originated from the same area, an area between the two caging sites. Despite an attempt to allocate crabs randomly to the two cage sites, the females at the control site were slightly larger then the seismic females. Possibly the different size of their progeny was related to this maternal difference.

REFEREES - QUESTIONS AND ISSUES

Gerard Conan: Are we measuring the right things? A paper in Nature measured hydrostatic pressure. The authors thought a seismic blast might affect the sensory organs.

Art Popper: There is no data on what a crab hears or how.

Gerard Conan: DFO needs to move towards accessing expertise beyond DFO. DFO could coordinate these studies.

Gerard Conan: It might also be important to look at disturbance of behaviour.

Gerard Conan: I had hoped for more statistical analyses and follow-up, for example, do we have a follow-up on crab righting response?

Jerry Payne: We did some follow-up experiments in which crabs and lobsters were exposed to up to 230 dB and we found no effects. We also did follow-up experiments on leg loss. This will all come out in ESRF reports.

Linda Weilgart: Do you see any difference as to a tank environment and a natural environment?

Art Popper: Yes there are.

- The behaviour of the animal in a tank is different from the behaviour of the animal in the wild. It's as simple as that.
- The acoustics in tanks are horrific. You cannot calibrate the tank very successfully; in fact it's almost impossible. It is going to be very difficult to duplicate the same effect from a tank to a natural environment. The particle motion in a tank is going to be gigantic vs field particle motion. If the sound field is not the same as in the wild, you wouldn't know what affects the animal. DB level is not as significant as rise level.

Jai Choi:

- Lucy's study although very nice lacks in statistical analysis and is problematic. I think that needs to be addressed. Factors such as the condition of the individual crab should have been used as co-variants. Statistical techniques such as Mancovas, Manovas, Mantelpas, Montevariants methods should have been tested. Essentially, there were twenty variables and they were condensed to two variables without any real thought to the process. That needs to be addressed.
- In respect to Mikio's dragging experiment, I had problems with that because the time frame was short, but I understand the rationale.
- In respect to the use of abundance estimates there are a lot of problems as we all know. We can't do anything about that but overall there seems to be no gross change in abundance as a result of the seismic.

- I am disappointed that the crabs were not tested directly under the blast to see its maximum effect and see an impact if there is one. Unfortunately no crabs were directly underneath the blast. I am also disappointed that there were no acoustic measurements under the cages themselves.
- There were two very interesting results:
  - Larval survival study: Identify the mechanism for the delay in time between the test and the control sites.
  - Hepatopancreatic haemorrhage study: Area 12 indicated there is no high prevalence of haemorrhaging. Why are we seeing haemorrhage in area 19 crabs and not area 12? How recent is it? Is it something due to seismic? Field test suggestion: ensonification?

Lucy Lee: I assumed that someone else would do the statistical analyses. We did some multivariate analyses which showed that all variables were significant.

Marjo Laurinolli: It would be hard to put an OBS under a cage so we didn't do this, but I could ask Alex what he thinks levels might have been underneath the cage.

Art Popper:

- I have concerns related to the histology. My concern is only one person (undergraduate) was doing this work. I would've liked to see you or someone as qualified as you do at least 25% of the samples to see if you get the same answer.
- Another concern is the scoring 1-16 normal; and above 16, not normal. It's not statistical, seems wishy-washy. If you looked at the slides with an epidemiologist expert, you would not get the same results. There are better ways to analyze this data. Maybe use standard deviation or something. This data should be analyzed by a powerful statistician.
- No difference between test and control is interesting. More damage in 5 months maybe due to lack of food but maybe damage builds up (tissue degrades) over time.

Mikio Moriyasu: Caged crab can eat. The stomach of crabs at the end of the experiment were not empty.

Art Popper:

- Another thing is the diminishing of the epithelial layer, you said it was due to hunger, stress, etc, but it is also due to accumulation of damage. You can be in a crowded room and you can be shoved in a crowded room (they may not want to be there) and have a different histology.
- For the acoustic field I am concerned that we do not have particle motion data. One hundred and eighty or 190 level of db is it relevant? Based on nothing! One hundred and ninety dB doesn't bother fish at all. I would look at the field thoroughly and I would redesign this differently.
- We are trying to save the data from this experiment. It is a good preliminary experimental design, but I would use this and redesign the experiment and do it over again. I come to the same conclusion I did 3 years ago. We're trying to pull

conclusions from something that is not there. The answer is not in this preliminary experiment. We would need lots of money and lots of expertise.
- What does the statocyst of snow crab do? We need research on this.

Edwin DeMont: I agree with Art. We've tried to solve questions from the 1st meeting and now we have more questions. We really need a better experiment. We are going around in circles now. We should move on.

Linda Weilgart:
- We're spinning our wheels. The biggest drawback was no baseline data and no warning of seismic activity and everything had to be rushed together. I don't know if the petroleum board could advise science on future seismic surveys.
- This study raised red flags ...
  - Don't know how to get better information on baseline.
  - Have those ocean bottom seismometers (OBS) down for the entire survey. This time the seismic vessel got delayed by weather so we ran out of battery. We should have better coordination between scientists and seismic operators.
  - Calculate the sound exposure level (SEL) by putting acoustic tags on a few animals.
- My main issue with many of these studies is that we're always going to have problems working in the real environment like noise.
- We should be picking several control sites and making them long-term. Since seismic surveys are long why not do it with that exposure.
- Ecosystem effects: huge can of worms we're not addressing.
- This project doesn't tell us that seismic has an effect but we cannot assume that seismic has no effect. The way things were phrased is like there is no evidence on the effect of the seismic survey on the larval studies. We manage to say we don't have any evidence that seismic had an impact but no evidence that seismic has no impact!
- We have to be very careful that the seismic survey does not do any damage. We need to do more work. We cannot draw any conclusions.
- The focus isn't so much on short-term/catastrophic effects. We often see subtle sub-lethal consequences and in most cases, long-term/small changes in growth rate/reproduction produce more devastating effects. Subtle effects are hard to find.
- To management: there is enough here to raise concerns and to use the precautionary way. I would like to see common sense measures (ex: avoiding sensitive stages of life cycle).

Participant: Are we going to do another experiment? We shouldn't lose the opportunity to pick brains to continue project; what are the better experiments?
Participant: In reality, there was not an in house project. This research needs to be done by experts, we are the experts.

Arthur Popper: Steve Campana and I are trying to put together a project with fish. The idea is to put transducers into a lot of fish and get a grid of receivers. We also want to

cage fish to look at their physiology. We have been working on this project for 1 ½ years and the project is very expensive. We thought about including the crab studies as a part of the fish studies and the opportunity to bring in groups (ex: experts on seismic devices) together (same issues). Budget is now ~ 5 million. There are already experts from across the world, therefore it would make sense to collaborate.

Presenter: We have proved that the seismic didn't kill the snow crab. The animals put down in the cage didn't die.

Referee: You have tested a very small segment of the entire population. I think in terms of making a conclusion that is not a conclusion, can you comment to Linda's point about that one.

Simon Courtenay: I think what we said was that we had no compelling evidence of negative effects of seismic energy on the snow crab larvae and I think that this is right. Now your other point is could you have picked up an effect. Well we could have seen them all dead, if all of the embryos being carried by those females had been killed, we would have picked that up. We didn't see that. Also we didn't present all the developmental end-points that we measured, we didn't see any developmental effects.

Fred Kennedy: I need to ask a question about the temperature difference. The fact that you did all your work and you drew those conclusions under conditions that in no way reflects their natural environment.

Simon Courtenay: The snow crab that we looked at were from the 5 month caging group. So they were caged at the seismic and control sites for most of the late embryo stage.

Fred Kennedy: You brought them into the hospital, and made them better and they are not in the blizzard anymore. The other ones are in the blizzard now, it's minus one, you're at plus five. I want to know if that necessarily voids your results and maybe you are just cutting too quickly to the conclusions you are drawing. We have found thousands of the black egg females in the trawl in June. We found hundreds of those in the fishery and you can't tell me that there is no relationship to the seismic test that took place that year. We don't find them any other time.

Mikio Moriyasu: How about the studies by Bernard St-Marie on the north shore, he talks about it in his report. We have the numbers.

Fred Kennedy: Well let's read the report Mikio and see what that says. I just can't believe this. I want to see the report, that's all.

Gord MacDonald: We rushed through an experiment for which we didn't have baseline information and multiple control sites would certainly help. There is the sediment issue, there's the leg loss issue, there's organ damage both in the control and in the others and the hepatopancreatic damage that doesn't exist necessarily in area 12 as a whole. The

concept that you are going to get more damage in the crab that you trap as opposed to the crab that gets dragged up in the trawl survey is slightly ridiculous. You can make the same argument that in this experiment seismic killed all of the snow crab, because all of the histological exams were performed on dead crabs based on the seismic experiment. As retarded as that sounds, it's the same except in the opposite sense that I read in this paper. Seismic is completely clean, it's fair game lets just go right ahead, there is no evidence of damage. There are so many things that stick out here at the end of the day that we need to do more work. We need to design another experiment; we need to try again because this was our first crack at it. While it doesn't tell us that seismic is damaging, it doesn't tell us that it is not. What it tells us is that there is a heck of a lot more work that needs to be done. Everybody has grand ideas about what we can do to improve this process, but what's going to come out of this is that seismic did not have any impact on the snow crab and that's going to be the end of that issue. This is not what I'm hearing around the table from the scientists or the referees, but it seems to be there's a push in place to answer the questions in a specific way that allows us to go ahead. This won't answer all of the concerns that have been raised which are significant. Anytime you do a scientific experiment, sometimes you have to get your feet wet because you get the opportunity and so you do your best. Then people come in and criticize because they don't like the result and very easily you can attribute the leg loss to "You know they just dropped that crate" and that could be true because everybody knows that this can be a possibility, but there is no evidence that this is what really happened. It is the same for each and every one of these steps where you have managed to find a way to say well we can't say that the seismic survey did this so the seismic survey has no effect. Well, yeah, that is right, but it is not the truth. There is no evidence that the seismic survey caused the impact, but there is no evidence that it did not! It could have had a long-term negative effect that did cause death or because over a long period of time, the damage might cause mortality. We can't sit here and give them a clean sheet. We have to be careful in a way to not illustrate that seismic does not create any problems. There are so many red flags.

Linda Weilgart: I want to make sure that the focus is not on short-term effects, but that it is often the subtle sub-lethal effects that really have more population consequences in the long-term. We haven't been able to come up with a suitable alternative explanation (either by dragging or the one year after study) to replicate soiled gills.
I think if this could be translated to management there is enough here to raise concern and to use this work in a management scenario, it would be to work in a precautionary way by avoiding sensitive life stages.

Bruce Cameron: I'm wondering if we will have an opportunity to organize this in a structured way. I like to think we could pick everyone's brain to come up with an effective plan.

Kenneth Lee: Originally this was not a DFO in-house project, it included people from the outside, Jasco, Lucy Lee, PEI veterinary school and in terms of pathology towards the species of snow crab, there are no people out there who specialize in this species. These are the first results and Lucy, Kadra and Mikio are the first ones giving results. This is it; we are the experts on the pathology of snow crab.

There has been an issue regarding this report and saying this is the end of the research, it is never the end of the research. We need to come out with the knowledge of what we know now that is definitive and at the same time to make sound decisions as to what needs to be done. We need a research manager to manage the research program. The problem is that there are no specialists available.

RESPONSES TO THE SEVEN TOPICS OF CONCERN

1. Independent verification by an external histopathologist indicated abnormalities in the hepatopancreas and ovary of Area 19 multiparous female snow crab caged at the seismic and control site during the December 2003 experiment. Results indicate that 53.4 % of the seismic exposed hepatopancreas slides and 51.8 % of ovaries correlated with the blind histological analysis of pathological findings, but only 38.4% of the evaluated control hepatopancreas slides and 35.8% of the ovary control slides correlated with the key. Correlation between the blind pathological evaluation and the coded slides was either not significant (hepatopancreas: $r = -0.08238$, $r^2 = 0.0067$, $P = 0.0970$) or negatively correlated (ovaries: $r = -0.1298$, $r^2 = 0.1298$, $P = 0.0148$). However, a significant correlation was observed between length of caging (12 d vs 5 months) and pathological abnormalities; longer confinement producing higher pathological indices.
2. Results of the additional caging experiment of December 2004, conducted to test the origin of the lesions of the internal organs observed in the 2003 study, showed a high incidence (62%) of haemorrhaging in pre-treatment females collected from the wild. Therefore, lesions observed in the 2003 seismic assessment cannot be linked to seismic exposure because this may have been a pre-existing condition in female snow crab of this population.
3. Short-term dragging of mesh bags containing multiparous females (i.e., ~2 hours) did not cause gill fouling. Moreover, the analyses of gills of crabs collected from a replica of the original experiment in the control site at the same dates one year after the original experiment showed no fouling.
4. Snow crab sent to DFO-NFLD in 2003 lost 26 legs in the seismic exposed group compared to 3 in the control group during their 6 month stay at this facility. However, there was no significant difference in leg loss at their arrival at the Moncton DFO facility, 63 legs lost in the control group vs 86 legs lost in the seismic group ($X^2_3 = 5.602$, $P = 0.133$) nor was there a significant difference at the end of their stay, 77 legs lost in the control group vs 94 legs lost in the seismic group ($X^2_3 = 4.695$, $P = 0.196$). A laboratory experiment in which snow crab were exposed to dB levels as high as 220dB, peak to peak, did not produce any increased incidence of leg loss (Dr. J. Payne, DFO, St. John's, Newfoundland).
5. No changes in snow crab abundance or distribution due to the seismic survey could be resolved through analysis of current stock assessment data. However, current stock assessment methodologies do not have the resolution to show statistically significant changes in snow crab distribution or abundance due to a seismic survey.
6. Overall, results indicate that exposure to seismic energy did not kill snow crab embryos (87% survival in the seismic group including black eggs, pre-zoea and zoea compared to 89% in controls). Larvae carried by crab caged at the seismic site were lighter (pre-zoea: $F_{1, 8} = 5.43$, $P = 0.0482$ and zoea: $F_{1,8} = 8.87$, $P = 0.0176$) and less developed (smaller proportion of zoea larvae, a larger proportion

of pre-zoea and unhatched eggs; $X^2_3 = 820$, $P < 0.0001$) than larvae carried by crab caged at the control site, which can have important consequences upon long-term survival. However, temperature differences are known to have occurred at these two sites, and slower development may have resulted from lower incubation temperatures during caging at the seismic site than the control site.

7. Snow crab caged outside of the seismic survey area (i.e., controls) were still exposed to some degree of seismic sound pressure (approximate maximum root-mean-square (RMS) sound pressure received was 118 dB re µPa), compared with crab caged within the seismic area (178 dB re µPa).

SOURCES OF UNCERTAINTY

During the initial 2004 analysis of study results, a number of constraints associated with the study design were identified. These constraints are equally applicable to the analysis presented here and are reiterated.

Test and control sites were quite different in temperature, substrate and food availability, and these factors made it difficult to clearly interpret the results. The test site was colder, shallower and may have had sediments with elevated levels of organic material as compared to the control site. Temperature is an important variable controlling development, metabolism and healing of marine animals. In addition, it appeared that snow crab placed at the control site were slightly larger than crab at the test site despite both groups originating from the same place and time.

Logistical and safety constraints limited the 2003 study to one test and one control site. Furthermore, based on the results of a previous study by LGL Limited (Christian et al. 2003) that raised concerns about reproduction, the study was focused on mature female snow crab.

No pre-seismic data were collected on the condition of snow crab in Area 19 to compare to post-seismic crabs. This lack of baseline information made it difficult to determine whether sublethal pathologies observed post-seismic resulted from exposure to seismic energy or were already present in the population.

While sound pressure levels were measured near the crabs caged within the seismic and control areas, particle motion produced by the seismic device, which may also affect animals, was not measured. In addition, animals in the short- and medium-term experiments received different levels of exposures of seismic energy. Forty-two hours of seismic testing were done after retrieving animals for the short-term experiments. It should be noted that the seismic array was a comparatively small one, and that the control site received some seismic exposure, though considerably less than the experimental site.

CONCLUSIONS

While the 2003 caging study provided some definitive findings on the potential effects of seismic energy on snow crab (e.g., no immediate mortality), many questions remain. For example, while there were some differences observed between snow crab that were caged in close proximity to a seismic survey and snow crab that were caged at a "control" location, it was unclear how confounding factors such as differing environmental condition and handling/caging procedures may have influenced these results. Subsequent studies and analysis have been unable to separate the influence of these confounding factors from potential impacts resulting from exposure to seismic noise. Study design limitations suggest that further analysis of these results is unlikely to provide additional information or insight, though repeating the study using the results and experiences acquired to date as a guide could further our understanding of this issue. The 2003 study clearly demonstrated the importance of careful experimental design and the need for pre-seismic baseline data. Several additional studies have been recommended to assess the impact of seismic surveys on invertebrate species of concern in Atlantic Canada. These include:

- Investigation of the natural histopathology of snow crab hepatopancreas and ovaries and further exploration of the reason(s) for observed "abnormalities."
- Investigation of the use of spatial analytical tools for detecting impacts of non-fisheries related activities using fisheries and DFO survey information.
- Investigation of the influence of incubation temperature on larval development of snow crab.

It is also recommended that future experiments related to the effects of seismic noise on invertebrates include measurement of particle motion in addition to sound pressure levels.

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APPENDIX 1. Agenda

Science Advisory Process on Update to September 2004 Review of Potential Impacts of Seismic Energy on Snow Crab

Processus consultatif scientifique concernant la mise à jour de l'examen des impacts possibles de l'énergie sismique sur le crabe des neiges réalisé en septembre 2004

January 23, 2007
Gulf Fisheries Centre,
Miramichi Room
Moncton, NB

Le 23 janvier 2007
Centre des pêches du Golfe
Salle Miramichi
Moncton (Nouveau-Brunswick)

Agenda

Ordre du jour

Time	Presenter	Subject
9:00-9:15	Ken Lee & Simon Courtenay	Introduction and format of meeting / Mot de bienvenue et explication du déroulement de la réunion
9:15-10:00	Lucy Lee	Independent histopathological evaluation / Évaluation histopathologique indépendante
10:00-10:15	Break / Pause	
10:15-11:00	Mikio Moriyasu	Experiment on gill fouling and population assessment data / Expérience sur saleté des branchies et évaluation des données de la population
11:00-11:30	Marjo Laurinolli	Acoustic monitoring off Western Cape Breton / Surveillance acoustique au large de la côte ouest du Cap-Breton
11:30-12:00	Simon Courtenay	Updates: - 2004 snow crab recaging experiment - synthesis of leg loss data - refinement of embryo/larval survival estimates Mise à jour: - expérience d'encager les crabes des neiges de 2004 - synthèse de donnée de perte de pattes - raffinage des estimés de survie embryon/larve
12:00-1:00	Lunch / Repas	

1:00-1:30	Referees / Examinateurs	Questions and issues / Questions et sujets de préoccupation
1:30-2:00	Other participants / Autres participants	Questions and issues / Questions et sujets de préoccupation
2:00-3:00	Ken Lee & Simon Courtenay	Responses to the nine questions / Réponses aux neuf questions
3:00-3:15	Break / Pause	
3:15-4:00	Ken Lee & Simon Courtenay	Summary of main conclusions and action items / Sommaire des principales conclusions et des points auxquels il faut donner suite
4:00-5:00	Ken Lee & Simon Courtenay	Communications plan / Plan de communications

APPENDIX 2. List of participants

Scientific Referees	Position	Expertise	Location
Arthur Popper, Ph.D.	Professor	Acoustic detection in decapods	U. Maryland, MD, USA
Linda Weilgart, Ph.D.	Professor	Whale bioacoustics	U. Dalhousie, NS
Jae Choi, Ph.D.	Research Scientist	Snow crab assessment scientist	DFO, NS
Gerard Conan, Ph.D.	Consultant	Life history of snow crab	NF
Co-chairs			
Simon Courtenay, Ph.D.	Research Scientist		DFO, NB
Kenneth Lee, Ph.D.	Head COOGER		DFO, NS
Industry participants			
Brian Adams	Area 19 Snow Crab Fishermen's Association		NS
Fred Kennedy	Area 18 Snow Crab Fishermen's Association		NS
Bill MacDonald	Area 19 Snow Crab Fishermen's Association		NS
Basil McLean	Area 19 Snow Crab Fishermen's Association		NS
Gord MacDonald	Area 23 Snow Crab Fishermen's Association		NS
Gretchen Fitzgerald	Ecology Action Center		NS
Jay Lugar	SPANS		NS
Eric Thériault	CNSOPB		NS
Provincial Participants			
Pierre Bédard	MAPAQ		QC
Bruce Cameron	Department of Energy		NS
Robert MacMillan	Fisheries and Aquaculture		PEI
Greg Roach	Fisheries and Aquaculture		NS
Peter Noel			
DFO Participants			
Ross Alexander	Oil and Gas Coordinator		
Renée Allain	Snow Crab Technician		
Mike Chadwick	RDOS		
Michel Comeau	Section Head Lobster		
Françoise Labonté	Science Advisor, Environment and Biodiversity Science		
Jerry Payne	Research Scientist		
Tana Worcester	Coordinator of the Center for Science Advice - Maritimes		
Ben Zisserson	Offshore crab technician		
University Participants			
Edwin DeMont	Professor, St.FX University, NS		
Scientific Presenters			
Lucy Lee	Wilfrid Laurier University, ON		
Mikio Moriyasu	Research Scientist - DFO		
Marjo Laurinolli	JASCO, NS		
Simon Courtenay	Research Scientist - DFO		

APPENDIX 3. Letter of invitation to the meeting.

Please note that the meeting could not take place on October 31 as originally scheduled. It was rescheduled to January 23, 2007.

Gulf Region
Oceans and Science Branch
P.O. Box 5030
Moncton, NB E1C 9B6

September 19, 2006

Distribution

Subject: Peer review of potential impacts of seismic energy on snow crab (Update)

You are invited to participate in an update of the scientific peer review of potential impacts of seismic energy on snow crab at the Gulf Fisheries Centre (Miramachi Room) on Oct 31 (9:00-5:00).

The purpose of this meeting is to conduct a thorough peer review of supplemental scientific work on this topic and to determine if outstanding issues identified in the September 2006 meeting have been resolved or if further research is required. Your participation is required to ensure that the review is of the highest quality

The meeting will be conducted as follows: Scientists will begin by providing an overview of their results and conclusions, including limitations and sources of uncertainty. The presentations will be followed by comments from the scientific referees. Finally, at the end of each session, invited industry participants will be asked to provide comments.

Attendance at this meeting is by invitation only.

Working papers will be sent to scientific referees prior to the meeting. They will be available for other participants at the meeting.

A revised Habitat Stock Status Report will be prepared at the meeting. Meeting minutes will be published as a Proceedings Document.

Région du Golfe
Direction des océans et des sciences
C.P. 5030
Moncton (N.-B.) E1C 9B6

Le 19 septembre 2006

Liste de diffusion

Objet : Examen par les pairs des impacts possibles de l'énergie sismique sur le crabe des neiges (mise à jour)

Nous vous invitons à participer à une mise à jour de l'examen scientifique par les pairs des impacts possibles de l'énergie sismique sur le crabe des neiges, qui aura lieu au Centre des pêches du Golfe (salle Miramichi) le 31 octobre (de 9 h à 17 h).

Il s'agira de procéder à examen exhaustif par les pairs des travaux scientifiques complémentaires réalisés à ce sujet et de déterminer si les questions restantes mises en évidence à la réunion de septembre 2006 ont été résolues ou si d'autres travaux de recherche sont nécessaires. Votre participation sera un gage de la haute qualité de cet examen.

La réunion se déroulera comme suit : les chercheurs présenteront un aperçu de leurs résultats et conclusions, y compris toute lacune et incertitude. Chaque exposé sera suivi de commentaires des examinateurs scientifiques. À la fin de chaque séance, on demandera aux participants de l'industrie qui auront été invités de formuler à leur tour des commentaires.

Seules les personnes invitées peuvent prendre part à la réunion.

Les documents de travail seront envoyés aux examinateurs scientifiques avant la réunion. Les autres participants pourront en obtenir des copies sur place.

Une version révisée du Rapport sur l'état des habitats sera rédigée à la réunion. Un compte rendu des délibérations sera publié par la suite.

We greatly appreciate your contribution to this valuable exercise and look forward to seeing you in October.

Original Signed by

Regional Oceans and Science Director
Gulf Region

Votre apport à cette activité essentielle est grandement appréciée. Au plaisir de vous voir en octobre.

Original signé par

Directeur régional des océans et des sciences
Région du Golfe