Potential Impacts of Seismic Energy on Snow Crab

Background

On October 20, 2000, the Canada Nova Scotia Offshore Petroleum Board (CNSOPB) received a directive from the federal and provincial energy ministers to conduct a Public Review on the effects of potential oil and gas exploration and drilling activities off the coast of Cape Breton. In order to provide scientific information to the commissioner, DFO scientists reviewed a series of working papers at a meeting of the Maritimes Regional Advisory Process (RAP) in 2001 (DFO Maritime Provinces Regional Habitat Status Report 2001/001).

This meeting concluded that there was a lack of information on the potential impacts of seismic activities on snow crab, specifically:

- *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.*

The RAP also concluded that the area of interest off the west coast of Cape Breton is the location of a large and economically important snow crab fishery and an important area for larval settlement. All benthic phases and size groups of snow crab inhabit the area of interest and there are high landings and catch per unit of effort in the fishery.

In March 2003, DFO organized a workshop to produce an inventory of ecological factors that should be considered when dealing with referrals for seismic surveys in Canadian waters (DFO National Capital Region Habitat Status Report 2004/002). Some highlights from this report include:

- *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.*

In recognition of the stated lack of knowledge on the potential effects of seismic activities on the health of the resident snow crab populations in Atlantic Canada, the Environmental Studies Research Fund (ESRF) funded a scientific study on the effects of seismic energy on snow crab (Chionoecetes opilio). The results of this preliminary study suggested no obvious effects on adult crab behaviour, health or catch rates (Christian et al., 2003). However, some uncertainty remained as the eggs of one female showed significant effects on development when exposed to seismic signals at a very close range (2 m).

In November 2003, the CNSOPB granted a permit to industry to conduct a seismic survey off the western coast of Cape Breton Island, Nova Scotia. DFO formed a partnership with CNSOPB, NS Department of Energy, Area 19 Snow Crab Fishermen's Association and Corridor Resources Inc. to conduct a collaborative study on the potential impacts of seismic energy on the reproductive biology of female snow crab. DFO's role was 1) to augment industry's regulatory compliance monitoring program based on sound-field measurements and 2) to expand the crab studies beyond a repeat of the preliminary study parameters undertaken by Christian et al. (2003) by adding a comprehensive cage-study design. The sources of funding, including in-kind contributions, are provided below:

Corridor Resources	*$170,000*
(field support and sound propagation studies)	
NS Dept of Energy	*$42,500*
DFO	*$223,500*
(logistical support, salary and partnership contribution to St. Francis Xavier U.)	
ESRF	*$100,000*
(field support – spring program)	
Total	*$536,000*

Summary

1. There were three definitive observations:
   - This 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.
   - Survival of embryos being carried by female crabs, and locomotion of the resulting larvae after hatch, were unaffected by the seismic survey.
   - In the short term, gills, antennules and statocysts (balance organs) were soiled in the test group but they were found to be completely cleaned of sediment when sampled five months later.

2. There were several significant differences between experimental results of test and control groups, even after five months. It was not known if these differences were due to environmental differences between the test and control sites. As a consequence, nothing definitive could be said about the results until further work is done:
   - The hepatopancreas (similar function to a liver) was found to be bruised in the test site.
   - Ovaries from animals at the test site were found to be bruised and had dilated oocytes with detached chorions (the outer membrane).
   - In one test group, embryo hatch was delayed by 5 days on average and resulting larvae were slightly smaller than controls.
   - Orientation (turnover rate), as measured by the time an overturned crab needs to right itself, was different between the test and control groups.

3. This experiment was the first of its kind in the world to test the potential impact of seismic exposure on snow crabs and it demonstrated the importance of careful experimental design and the type of work required in conjunction with future seismic surveys.

Introduction

On September 29, 2004 a scientific peer review was completed on the results of experiments designed to study the potential impacts of seismic energy on snow crab. This review evaluated the results from a preliminary study on the potential impact 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. The study included caging and laboratory experiments conducted in winter 2003 and spring 2004. The caging experiment was conducted at the location of potential hydrocarbon deposits off the western coast of Cape Breton. It also bordered the site of one of the highest concentrations of snow crab in the world. The caging experiment examined short (12 days) and medium (5 months) term differences in the morphology and physiology of snow crab at test and control sites. Snow crabs from both groups were also observed under laboratory conditions for differences in mortality, morphology, physiology, feeding and orientation (turnover rate) over a five month period.

The study was organized on short notice to take advantage of an operational seismic survey in late 2003. It was developed by a partnership with Corridor Resources, Area 19 snow crab fishermen, CNSOPB, NS Dept. of Energy and DFO. The study was preliminary because it was designed to reveal observations or issues that would merit more detailed investigation. The study was designed to accompany a seismic survey in late 2003 and because of the short preparation time, there were constraints on its scope and the amount of resources available. As a result it was decided to focus the study entirely at one test and control site and because of concerns about reproduction, on the same type of mature female snow crab.

It is important to note that the test and control sites were quite different in temperature, substrate and food availability, which 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 when compared to the control site. Temperature is an important variable controlling 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.

Finally, animals in the short- and medium-term experiments received different exposures of seismic energy. Forty-two hours of seismic testing were done after retrieving animals for the short-term experiments.

Responses to the Questions

1. Is there evidence from this study that indicates irreversible harm (including death) to female snow crab caused by these seismic operations?

- There were no significant differences in mortality between the test and control groups.
- In one of the four laboratory studies, observations of greater leg loss within the seismic test group may be linked to other causes such as conditions of transport.

2. Is there evidence from this study that seismic energy produced mortality or morbidity in female snow crab carrying eggs?

- There was no evidence of mortality or morbidity in the test group.

3. Is there evidence from this study that seismic energy produced long-term effects on the behaviour of female snow crab?

- This study was unable to adequately address this question, except there was a trend towards faster turnover rates in seismic-exposed crab.
- Over several months of observations in the laboratory, there was no difference in food consumption between test and control animals.

4. Is there evidence from this study that seismic energy produced long-term effects on the characteristics and morphology of gills and internal organs of female snow crab?

- There were differences between test and control groups in the characteristics of antennules, statocysts, gills, hepatopancreas and ovaries.
- Animals at the test site were found to have sediment (associated with organic material) in the antennules, statocysts and gills but they were clean when examined five months later.
- In the test group, there were changes in the cellular structure of the hepatopancreas consistent with a response to stress in both short- (12 days) and medium- (5 months) term conditions. It is not known if the noted differences were related to dissimilarity of control and exposed samples and/or different holding conditions in the environment instead of seismic exposure per se.
- There were abnormalities and some hemorrhaging in the ovaries of the test group. In addition, the mean diameters of oocytes from this group were also larger due to dilation. The cause is not known: see statement above.
- In terms of metabolic indices, levels of enzymes in the haemolymph (blood) were comparable between the seismic and control groups, suggesting no major cellular damage to organs like the hepatopancreas for fed animals kept in laboratory conditions.

5. Is there evidence from this study that seismic energy produced effects on the hatch of embryos carried by exposed female snow crab and subsequent morphology and locomotion of larvae?

- The rates of embryo survival to hatch were similar between the two groups.
- Embryo development within animals recovered from the vicinity of the seismic site appeared to be delayed. Furthermore, the larvae from the seismic site were smaller and had proportionally (to body size) smaller spines and eyes than the control larvae. This observation may be caused by environmental factors, such as temperature differences. In addition, 45

crab retrieved after 12 days from test and control groups were observed in the laboratory for differences in time to hatch and none were noted. In fact larvae from the test group appeared two days before those from the control group.

- There were no differences observed in swimming behaviour of larvae hatched from the two sites.

6. What further research would be useful, if any?

There are a number of short-term research initiatives that would help clarify the results:

- Biomass surveys were conducted both before and after the seismic survey. These surveys should be examined for changes in abundance of different categories of snow crab to see if there was any evidence of elevated natural mortality or redistribution. In addition densities of caged animals and wild animals should be compared.
- It would be helpful to summarize observations of egg loss for laboratory studies where possible and this information needs to be corrected for parental size because larger females produce more eggs.
- There was some evidence of bruising in gills of test animals and these observations should be completed for all test and control animals.
- Measurements of background or ambient sound were taken prior to the seismic testing and this information should be summarized.
- Information on leg loss should be summarized for all laboratory studies.
- Sediment from the test and control sites should be compared.
- An additional study was conducted in May 2004 to examine the dragging of cages during their retrieval and its impact on sediment observed in gills, statocysts and antennules. This work should be summarized.
- There were concerns that some of the observations could be related to size of animals. Thus a smaller subset of comparisons could be done with the same-sized animals for test and control observations.

This experiment was the first of its kind in the world and revealed the importance of careful experimental design and the value of continuing this type of work in conjunction with future seismic surveys. Examples of the type of work that would be helpful are:

- Baseline animals should be examined at test and control sites before any experiments are done.
- Video monitoring of snow crab behaviour in the field would be very helpful. Note that there were limited behavioural observations in the current study.
- It would be helpful to examine different categories of animals. For example the multiparous females (females carrying eggs that are not their first batch) examined in this study may not necessarily be the most sensitive stage.
- Future field work should include multiple control and test sites.
- Laboratory studies should be conducted under blind or double-blind conditions to ensure that there is no bias or observation error.
- It would be useful to understand how sound affects animals, i.e. sound pressure or motion of particles. It remains to be determined if seismic noise causes stress and if snow crab can actually hear the seismic signals.
- It would be useful to examine expected worst-case scenarios under controlled conditions. The advantage of lab study is that signal and exposure can be controlled precisely and a whole range of behavioural and physiological questions could be asked that are difficult or impossible to address in the field.
- It would be useful to examine other parts of the benthic community for potential impacts.
- Future work should examine effects of exposure to seismic signals when animals are buried in the sediment because signal levels may be higher in the substrate than the water column. The caging experiments did not allow animals to bury themselves.

- Future work should ensure that animals receive the maximum exposure to seismic energy that they are likely to encounter and the experiment should measure ambient and cumulative exposure to sound, including peak sound levels (RMS) and sound exposure levels (SEL).
- Future field experiments should include observations for longer time periods, up to one year to assess if there are long-term effects and/or recovery.
- It would be useful to examine exposure-distance relationships for the effects on egg development.
- Finally, it is important that information on potential impacts of seismic energy be communicated to other scientists working on these questions in other parts of Canada and globally.

7. How applicable are the results and conclusions of this study to other crustacean species (e.g. other crab species and lobster)?

- This work is very helpful because snow crab is a species that lives closely associated with fine bottom sediments and there are very few studies on the potential impact of seismic energy on substrate dwelling animals.
- Observations on larvae may be applicable to other animals with this life-history stage, such as other crab species and lobster.
- The questions and experiments raised by this study will help to guide future work.

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