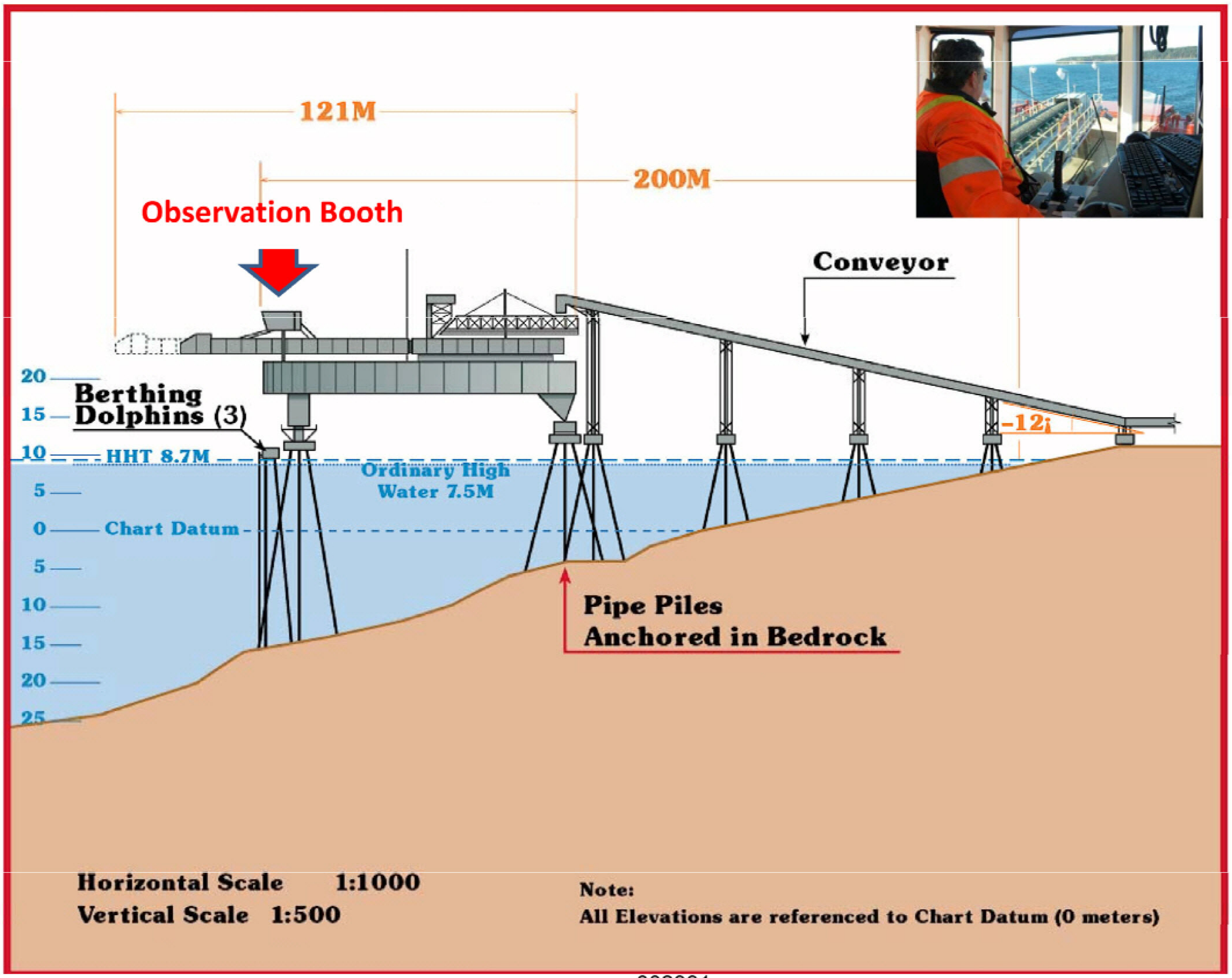

121M
200M
Observation Booth
Conveyor
20
15
10
5
0
5
10
15
20
25
Berthing Dolphins (3)
HHT 8.7M
Ordinary High Water 7.5M
Chart Datum
12
Pipe Piles Anchored in Bedrock
Horizontal Scale 1:1000
Vertical Scale 1:500
Note:
All Elevations are referenced to Chart Datum (0 meters)

002331

Undertaking #3

To provide volume calculations of quarriable stone inside and outside the current 800 m setback distance, with and without the Whites Cove Road transecting the property

Response:

Bilcon can advise that it has calculated the quantity of quarriable rock outside the current 800 metre setback distance to be approximately 32 million metric tons.

This quantity does not include the rock within the Whites Cove Road which could generate a further 1.9 million metric tons (approximately).

These quantities were established assuming a 100 metre environmental preservation zone along the coastal strip.

The total remaining quantity of quarriable rock on the property inside the current 800 metre setback distance is approximately 70 million metric tons not including rock within the Whites Cove Road. It is estimated that approximately a further 1 million metric tons would be available from within the Whites Cove Road.

UNDERTAKING # 4

To describe the worst case scenario of settling ponds outflow, channel flow rates, and effects on downstream vegetated channel.

Drawing down the retention ponds prior to an anticipated storm event is considered a worst case scenario and not a part of the regular quarry operation. It is an unlikely event potentially associated with a storm event that may occur within a 100 year time frame (100yr-storm event).

The proposed wetland will be designed as a channel with variable dimensions with respect to channel width and slope in the embankments. This will provide for increased habitat diversity. To increase the effectiveness of the wetland, the channel will be built with a series of check dams. Armor stone (rip rap) will be used in combination with plant material to protect the channel against erosion. The plant species used will be native species typical for local wetland habitats and will include grass, herbaceous and shrub species.

The stabilization of the wetland channel will be developed during detailed design stage with the objective to withstand 100yr-storm events and associated draw downs. Should any such event cause erosion or damage to the wetland vegetation, this is expected to be of short duration and very localized. Any erosion damage would be immediately repaired. If required, new armor stone would be placed. Vegetation is expected to quickly re-establish itself through seeds dormant in the wetland soils and root systems below and between the armor stone. If required, new stabilizing vegetation will be planted and/or seeded.

The proposed wetland provides supplementary polishing functions but is not a requirement for retaining water or trapping sediment. Any short term failure of the wetland therefore is not compromising the effectiveness of the Quarry's storm and process water management system. The drainage channel for conveying water from the retention ponds to the Bay of Fundy has been proposed as an open wetland type channel for habitat purposes only. The alternative would have been an enclosed discharge pipe without habitat value.

In addition to the above, Bilcon has reviewed the total pond storage volume requirements and worst case draw down requirements for emergency flood storage. This review concludes that neither under the 100-yr/24-hr rainfall nor the 100-yr/5-day rainfall sceneraio would be required (see attached text from Conestoga Rovers).

Whites Point Quarry Project - Panel Hearings
Undertaking Information

The following information is provided to Bilcon NS in response to the Undertaking request from the Panel during the June 16, 2007 Panel Hearing Day. The information summarizes pond storage volume requirements and worst case scenario drawdown requirements for emergency flood storage.

The 5 sediment storage ponds proposed to handle site runoff to the north of Whites Cove Rd. are considered in this summary. The ponds are proposed by Bilcon to provide storage for treatment (i.e. sediment settling), supply and flood purposes.

Table 1 summarizes the pond volumes required, assuming all runoff from the 143 ha drainage area to the north of Whites Cove Rd. is directed to the ponds. Based on the water balance completed by CRA, maximum supply storage would range from 0.9 m under average conditions to 2.4 m for drought conditions. This represents the maximum amount of storage required to provide enough supply over the course of the summer dry period.

Flood storage requirements were calculated based on information for the combined climate stations at Yarmouth, NS (ID's 8206500 and 8206490) with a period of record from 1871 - 2006. The data indicated a 100-yr/24-hr rainfall amount of 149.7 mm and a 100-yr/5-day rainfall amount of 191.2 mm (note that previous analyses used a 100-yr/24-hr rainfall of 124.6 mm, which was based on outdated IDF data provided by MSC from only one of the Yarmouth stations for the period 1971 - 1996). This translates to a flood storage requirement of 2.2 m for the 100-yr/24-hr storm and 2.9 m for the 100-yr/5-day storm, averaged over the 5 sediment ponds. Note that these are conservative estimates of flood volume assuming all precipitation runs off to the ponds. In reality, this is not the case as losses due to infiltration, interception, depression storage and other abstractions will occur. Note that storage volume requirements for sediment storage are not reflected in Table 1. It is assumed that the bulk of sediment will be removed in the sediment forebay Bilcon is proposing for Pond 5, and the conservative estimates of flood volume should also more than compensate for sediment storage requirements.

Based on the storage requirements in Table 1, potential drawdown depths required to ensure sufficient flood storage is available are calculated, assuming a 4 m deep sediment pond and minimum of 0.3 m of freeboard is required. The data indicate a worst case condition of 1.6 m of drawdown required or approximately 149,000 m^3, for the case of storage maximized for drought conditions and the 100-yr/5-day storm occurring. Assuming a 24 hour drawdown period, the average drawdown flowrate required would be 1.7 m^3/s.

It is noted that the analysis indicated that the dry period extends from July through October under average conditions and from May through November under drought conditions. For the remaining months, there is a surplus of water so that the amount of water in storage during these months can be reduced providing more room for potential flood storage requirements. In other words, the risk period for worst case conditions runs from May through November when drought storage would be in effect. Pond operating principles could be designed to reflect this, thereby reducing the risk period. Furthermore, the amount of water held in storage could be incrementally reduced as the summer progresses, should drought conditions not be realized for a particular month. For example, if storage is maximized in May at 2.4 m but May and June prove to be surplus months (i.e. as for average conditions), then storage could be reduced from July onward. Again, this reduces the risk period for worst case conditions of ponds at maximum storage and a 100-yr storm occurring, using operational planning measures.

Also, holding times for particle settling will typically be less than 5 days, thus the requirement to hold the entire 5-day flood volume is likely excessive as treated water will be released over the course of the 5-day period and allow for additional runoff volume storage. As such, the 1.6 m of maximum drawdown referred to above should be considered a conservative, absolute maximum.

In order to reduce the required drawdown amounts calculated above, an additional calculation of drawdown requirements was completed based on the fact that some of the runoff during a flood could be diverted away from the ponds. The analysis described above considered flood runoff from the entire 143 ha catchment above the ponds. It is noted that 64 ha of this area is the undisturbed watershed above the property boundary. Thus runoff from this area will not necessarily require treatment and does not need to pass through the sediment ponds in a flood situation. As such, this runoff could potentially be diverted prior to entering Pond 5, directly into the Bay of Fundy. A diversion structure at the inlet to Pond 5 could be designed to allow normal flows to pass into the ponds for supply collection, but would divert larger flood flows around the pond.

Table 2 shows the results of storage requirements and drawdown assuming flood runoff from the property area only (79 ha). The data indicates that flood storage requirements drop to 1.2 m and 1.6 m for the 100-yr/24-hr and 100-yr/5-day floods, respectively. The worst case drawdown condition then falls to 0.3 m or approximately 26,000 m^3. A 24-hr drawdown flowrate of 0.3 m^3/s would be required. Again, these are highly conservative estimates assuming no abstraction losses. If one assumes a conservative runoff coefficient for the property area of 0.85 (i.e. that 85% of precipitation during a storm runs off), the drawdown requirements become negligible, and the 4 m ponds have sufficient capacity to handle the 100-yr/5-day storm event combined with maximum drought supply storage of 2.4 m.

The above information provides data for preliminary planning purposes and represents worst case conditions. Detailed runoff volume calculations would be completed for final pond sizing during industrial approval, using a detailed hydrologic model developed for the site. Residence time requirements and outflow rates for treated water would also be calculated to ensure adequate treatment and outlet design.

Table 1 - Pond Depths
Total Catchment Area[1] Contributing

Scenario	Storage Requirements[2] (m)			Drawdown Requirement[3]		
	Supply[4]	Flood[5]	Total[6]	Depth (m)	Volume (m^3)	Flowrate[7] (m^3/s)
100-yr/24-hr Storm / Average Supply Conditions	0.9	2.2	3.1	-	-	-
100-yr/24-hr Storm / Drought Supply Conditions	2.4	2.2	4.6	0.9	89,870	1.0
100-yr/5-day Storm / Average Supply Conditions	0.9	2.9	3.8	0.1	5,094	0.1
100-yr/5-day Storm / Drought Supply Conditions	2.4	2.9	5.3	1.6	149,094	1.7

Notes:
1. Total contributing catchment area of 143 ha, consisting of quarry property to the north of Whites Cove Rd. and upslope w atershed drainage.
2. Averaged over 5 ponds with total plan area of 9.6 ha.
3. Amount of draw dow n required to provide at least 0.3 m of freeboard at maximum containment for 4 m deep ponds.
4. Maximum cumulative depth of storage required to satisfy demand during summer dry period.
5. Depth required to fully contain runoff volume from 149.7 mm 100-yr/24-hr storm or 191.2 mm 100-yr/5-day storm. Assumes no abstraction losses (conservative).
6. Does not consider sediment depth - additional depth required for sediment storage depending on removal efficiency of sediment forebay, sediment load and cleanout frequency.
7. Average flowrate assuming a 24 hour draw dow n period.

Table 2 - Pond Depths
Property Area Only[1] Contributing

Scenario	Storage Requirements[2] (m)			Drawdown Requirement[3]		
	Supply[4]	Flood[5]	Total[6]	Depth (m)	Volume (m^3)	Flowrate[7] (m^3/s)
100-yr/24-hr Storm / Average Supply Conditions	0.9	1.2	2.1	-	-	-
100-yr/24-hr Storm / Drought Supply Conditions	2.4	1.2	3.6	-	-	-
100-yr/5-day Storm / Average Supply Conditions	0.9	1.6	2.5	-	-	-
100-yr/5-day Storm / Drought Supply Conditions	2.4	1.6	4.0	0.3	26,472	0.3

Notes:
1. Total contributing catchment area of 79 ha - runoff from 64 ha natural w atershed area above property assumed diverted.
2. Averaged over 5 ponds with total plan area of 9.6 ha.
3. Amount of draw dow n required to provide at least 0.3 m of freeboard at maximum containment for 4 m deep ponds.
4. Maximum cumulative depth of storage required to satisfy demand during summer dry period.
5. Depth required to fully contain runoff volume from 149.7 mm 100-yr/24-hr storm or 191.2 mm 100-yr/5-day storm. Assumes no abstraction losses (conservative).
6. Does not consider sediment depth - additional depth required for sediment storage depending on removal efficiency of sediment forebay, sediment load and cleanout frequency.
7. Average flowrate assuming a 24 hour draw dow n period.

UNDERTAKING # 5
To identify the dimensions of the grid
required to define upper flow/middle flow contact of basalt layers
given the known topographical variation of 7m over 300 m

Bilcon Approach

The topographical variation of the middle flow unit is unknown on the Whites Point site. On the assumption that a topographical variation of 7 metres over 300 metres could occur, Bilcon will adopt the following approach to define the upper flow/middle flow contact ahead of each production blast.

Bilcon will establish a 50 metre by 50 metre grid surrounding the blast area and will drill blast holes at the four corners of the blast hole configuration (note: front blast holes will be set back from the quarry face). These blast holes will be drilled, as will all blast holes, with a rotary percussion drilling machine. The high compressor strength upper flow basalt will require a constant down pressure from the drilling machine to penetrate the rock. As the middle flow unit is contacted the required pressure will decrease. At this point the drilling will cease and a minimum 2 metre "standoff" of crushed stone will be replaced in the borehole. The contact zone will also be noted by a colour change in the drill cuttings.

The location of the contact zone will be logged and a database will be developed. This database will enable Bilcon to map the variation in the topography of the contact zone.

Undertaking # 7
To provide a measure of precision of the concentrations of copper occurring in the basalt found on the quarry site

The mean copper concentration of the basalt on site was calculated with data from the analysis of the six core samples taken by Bilcon plus the two values of the basalt till from the NSDME (1982) analysis that were on or very close to the site (Whites Cove, 341A and Whale Cove, 342A). The mean is 99.0 mg/kg and the standard deviation is 69.8.

The 95.0% confidence interval for the mean is 40.7 to 157.3 mg/kg.

The statistical calculations are provided in the Attachment (stats package print out).

Undertaking #7

ATTACHMENT
Statistical Calculations
(stats package print out)

Data

39, 230, 91, 27, 48, 80, 107, 70

Percentiles for Col_1

Percentiles	Sample
1.0%	27.0
5.0%	27.0
10.0%	27.0
25.0%	43.5
50.0%	85.5
75.0%	138.5
90.0%	230.0
95.0%	230.0
99.0%	230.0

Statistical Interpreter

This table shows sample percentiles for Col_1. The percentiles are values below which specific percentages of the data are found. You can see the percentiles graphically by selecting Q-Plot.

Data Summary

Number of data columns: 1
Number of rows: 8

Column Name	Non-missing Values	Numeric Values	Minimum	Maximum
Col_1	8	8	27.0	230.0

Statistical Interpreter

This panel displays a summary of the data you have entered. The number of non-missing data values is displayed, together with information on any valid numeric values.

Summary Statistics

Variable	Count	Mean	Median	Std. deviation
Col_1	8	99.0	85.5	69.7711

Variable	Minimum	Maximum	Range	Std. skewness
Col_1	27.0	230.0	203.0	1.21564

Variable	Std. kurtosis
Col_1	0.233667

Statistical Interpreter

This table shows various statistics for each of the 1 variables. It includes measures of central tendency, measures of variability, and measures of shape. To study a selected variable in more detail, select the One Variable Analysis statlet.

Estimation of Population Mean for Col_1

Sample size = 8
Mean = 99.0

95.0% confidence interval for mean: 99.0 +/- 58.3302 [40.6698,157.33]

t-test

Null hypothesis: mean = 0.0
Alt. hypothesis: not equal
Computed t-statistic = 4.01333
P-value = 0.00510266
Reject the null hypothesis for alpha = 0.05

Statistical Interpreter

This table displays the result of a t-test performed to test the null hypothesis that the mean of the population from which the sample data come equals 0.0 versus the alternative hypothesis that the mean is not equal to 0.0. Since the P-value for this test is less than 0.05, we can reject the null hypothesis at the 95.0% confidence level. Also shown is a 95.0% confidence interval for the population mean. In repeated sampling, 95.0% of all such intervals will contain the true mean.

Undertaking # 8

To provide an estimate of the volumes of fines to be generated and to be used as part of the reclamation

The generation of fines is expected to amount to 4% of the annual production rate. Therefore, with the proposed production of 2,000,000 t/year a total of 80,000 t/year of fines are expected to be stockpiled for use in the reclamation process.

Undertaking # 9

To provide reference for the 3 to 4% figure for the production of fines during quarrying

See attached letter of June 25, 2007 from George Bickford (LB&W) to John Wall (Bilcon).

LB&W
ENGINEERING, INC.

June 25, 2007

BILCON OF NOVA SCOTIA
PO Box 2113
Digby, Nova Scotia B0V 1A0

Attention: Mr. John Wall
Reference: Generated Fines Quantity
LB&W Engineering, Inc. Project No. 207128 R.1

Dear Mr. Wall:

As a result of your request for information regarding the amount of fines generated from the White's Cove crushing operation, we have developed the following data.

- The normal crushing/screening process utilized for this project will develop a total volume of approximately 7% of -200 mesh fines, relative to the total tonnage to be crushed.
- We have designed the crushing circuits with a combination of jaw crusher/cone crusher utilization in order to minimize the amount of fines to be generated.
- Of this total 7%, the aggregate product specifications will allow 3% of the fines to remain in the washed product. We anticipate 2 ½% to be retained in the fine aggregate and 1% in the coarse aggregate products.
- This fines retention within the material stream is quality controlled and adjusted by the application of hydra-cyclones for recovery of –200 mesh fines from the wash water circuit. These fines are then metered back into the product stream within specification levels for shipment of the product.
- The 4% non-product fines generated within the facility will ultimately be stock-piled and mixed with soils to be graded over the final sloping rock surface. In the event that greater fines are generated, a deeper layer of cover material will be applied to the site.
- This soil will provide a working terrain for post mine reclamation grading and development.

As we can be of additional assistance, do not hesitate to call upon us.

Yours very truly,

George C. Bickford
President

/mwj

961 MARCON BLVD. • SUITE 401 • ALLENTOWN • PA 18109
610•264•8191 FAX: 610•264•8227

Undertaking #10
Accounting of GHG emissions for marine transportation over the life of the project

Based on the CSL Spirit, the Geenhouse Gas emissions associated with the 45 round trips per year would be 997 ktons (CO_2 equivalent) emissions (22.15 ktons/trip) plus a minor amount from support hotels to assist in docking. If the ship is loaded by another user in the return voyage, rather than returning in ballast, the quantity should be discounted.

Undertaking #11
To provide references for the levels of residual ammonia resulting from modern blasting techniques

Bilcon has been aware of the concern for potential for ammonia residuals from blasting and investigated the issue in context of the EA for the Whites Point Quarry.

Although reference is made to ammonia residuals from the application of ANFO for quarrying purposes in some technical literature, no sources have been identified to date that define typical levels of residues in percent of explosives used in quarrying

A publication by Gordon R. Revey proposes practical methods to reduce ammonia and nitrate levels in mine water (Gordon R. Revey, 1996). This publication has been included in EIS Appendix Volume III file Blasting Protocol 9C and is provided again as attachment to this Undertaking. In consultation with DFO, Bilcon has agreed to incorporate the Revey protocols regarding AN residue into its blasting protocol.

Bilcon's discussion of the issue of AN residue with DFO has been documented in the minutes of the meeting between DFO representatives and Bilcon staff of (7 February, 2005). A copy of the minutes are included in EIS Appendix Volume III file Blasting Protocol 9D. A copy of the text has also been attached to this undertaking.

DFO advised Bilcon that, if the Revey recommendations were incorporated in its blasting protocol "there will be little in the way of residual impacts accruing from this aspect of the protocol" (DFO Minutes of Meeting, 7 February, 2005).

Through written communication, the author Gordon R. Revey stated that "The percentage ammonia nitrate residue would not be measurable if best practices are used" (e-mail Gordon R. Revey to John Wall, 19 June 2007). This confirms the personal experience of Bilcon's professional blasting expert. John Melick has experience with managing the detonation of more than 400 million pounds of ammonium nitrate based explosives.

It is in Bilcon's interest to achieve maximum blast efficiency from both an environmental and economic perspective. Bilcon's goal is to have 0% Ammonia residue from blasting. To achieve this objective, Bilcon's blasting protocol incorporates the following best practices:

- Multiple priming with a TNT cast booster of a dia. >/= 1/3 hole dia.
- Confirmation of detonation velocity by means of a VODR (velocity of detonation recorder) which will indicate extinction.
- Borehole diameters > 3"diameter (ANFO has a "critical diameter" of approximately 2". In small dia. boreholes (<3"dia.), ANFO is susceptible to low order or incomplete detonation. A 4.5" dia. borehole has 5 times the borehole area of a 2" hole, and a 6.5" borehole has more than 10 times the borehole are of a 2" hole.)
- Acknowledgement of existing borehole water conditions as borehole loading is undertaken (most important practice to adhere to).

Bilcon will development and implementation a training program for the blast crew to promote blasting competency and environmental awareness. In addition, appropriate materials handling and spill response procedures specific to ANFO will also be developed and implemented. These training programs will be documented.

As a precautionary and confirmatory measure Bilcon intends to undertake periodic monitoring of NO3/NH4 concentrations of the process water (settling pond) and the discharge from the detention ponds. Monitoring frequency and a regulatory discharge criterion will be established in consultation with DFO and NSDEL. If required, risk-based criteria will be established.

Source:

Revey, G. F. 1996. Practical methods to control explosives losses and reduce ammonia and nitrate levels in mine water. Mining Engineering, 48(7): 61-64.

UNDERTAKING #15

To provide an estimate of the percentage of the number of job seekers who reside on Digby Neck and the Islands

Following is a percentage breakdown by County of the 241 Applications received as of June 8th, 2007, for Employment at the Whites Point Quarry and Marine Terminal

Table 1: Formal Job Applications

Percentage	County	# of Applicants
16%	Digby Neck Area and Islands	40
56%	Digby County	135
16%	Annapolis County	38
12%	Other	28
Total		**241**

Note: Bear River is comprised of both Annapolis and Digby County, and, therefore, a few applicants' locations were unknown whether Digby or Annapolis County

Table 2:
Verbal Job Applications / Inquiries/ Participation Regarding Employment Opportunities

Source	Residence	# of Applicants/Inquiries/ Participants
2007 Communication Log	No information obtained	27
2006 Communication Log	No information obtained	34
Job Fare - Annapolis Royal March 07*	No information obtained	138
Job Fare – Digby High School Royal April 2007 (DALA)*	No information obtained	18
Bilcon employment information sessions (four sessions held in Towle House, Little River, Digby Neck – average participation 20/session)*	No information obtained	80
Total		**297**

* some of the attendees may have dropped off applications subsequent to participation in the information session/fair

2006 Addendum to Butterfly Habitat and Host Plant Survey of White's Cove, Digby Co., N.S.

Entomologist: Dr. Kenneth A. Neil, BSC., PhD, PDF **Client:** Paul Buxton
259 Black Hole Road P.O. Box 98
RR5 Canning, Annapolis Royal
Nova Scotia Nova Scotia
B0P 1H0 B0S 1A0

Introduction. The following report summarizes the 2006 field season on a property belonging to Bilcon of Nova Scotia situated in the vicinity of White's Cove, Digby Co., Nova Scotia (for coordinates, see **Butterfly Habitat and Host Plant Survey of White's Cove, Digby Co., N.S. (2005)**.

The purpose of this survey was to determine the presence or absence of four butterfly species ranked as Sensitive, of Special Concern, or Undetermined, by COSEWIC and the Nova Scotia General Status, which may occur, as both the larval host plant or proper habitat were observed at the above locality in 2005. (For websites, see **Butterfly Habitat and Host Plant Survey of White's Cove, Digby Co., N.S. (2005)).** These species are:

Dauaus plexippus (L.)(Monarch Butterfly), ranked as of Special Concern by COSEWIC, and as Yellow (Sensitive) by the Nova Scotia General Status.

Polygonia satyrus (W.H. Edws.) (Satyr Comma), ranked as Yellow (Sensitive) by the Nova Scotia General Status.

Polygonia gracilis (G.&R.) (Hoary Comma), ranked as Yellow (Sensitive) by the Nova Scotia General Status.

Pieris oleracea Harr.(Mustard White),ranked as Undetermined (Insufficient information to determine status) aby the Nova Scotia General Status.

A general survey of butterflies found at this site was also conducted. Four collecting trips were made to the White's Cove site, on 19 June, 1 July, 30 July, and 27 August, respectively. The first trip was terminated due to inclement weather conditions. Specimens were collected using a standard aerial net, and identifications were made. Most specimens were released, but a few voucher specimens were retained. In addition to these methods, 'sugar bait' was applied to tree trunks, rocks, and tree stumps at approximately twenty-five locations on the property. 'Baiting' is a common method used to attract many butterfly and moth species. 'Sugar bait' is composed of molasses, brown sugar, overripe bananas, other fruit, and alcohol, which is allowed to ferment naturally. The bait was checked regularly for specimens which may have been present. The nomenclature and systematic arrangement used here follow that proposed by Laberry et. al (1998)(see References, **Butterfly Habitat and Host Plant Survey of White's Cove, Digby Co., N.S.).**

-2-

List of species collected at the White's Cove site during the 2006 field season.

Hesperiidae

Erynnis icelus (Scud. & Burg.)
Ancyloxypha numitor (Fab.)
Thymelieus lineola (Ochs.)
Polites peckius Kby.
Polites themistocles (Latr.)
Poanes hobomok (Harr.)
Euphyes vestris metacomet (Bois)

Papilionidae
Papilop canadensis R&J
Pieridae
Peiris rapae (L.)
Colias philodice Godt.
Lycaenidae
Lycaena phlaeas (L.)
Celastrina ladon (Cram.)
Celastrina neglecta (W.H. Edwards)
Glaucopsyche lygdamus couperi Grt.
Nymphalidae
Speyeria cybele novascotiae (McD.)
Speyeria atlantis (W.H. Edwards)
Boloria selene atrocostalis (Huard)
Phyciodes cocyta (Cramer)
Vanessa atlanta (L.)
*Limenitis arthemis (*Drury)
Limenitis archippus (Cramer)
Coenonympha tulia inornata W.H. Edwards
Cercyonis pegala nephele (Fab.)
Danaidae
Danaus plexippus (L.)

Species Summary. With the exception of the Monarch Butterfly (*Danaus plexippus*) (L.), all of the abovementioned species are commonly found on mainland Nova Scotia.

(*Danaus plexippus*)(L.) (Monarch Butterfly). Five adult specimens (3 males, 2 females) of this species were collected and released on 30 July, 2006. (Collecting locality: 44°27.445'N; 66°08.342'W, elevation approximately 268 ft.). In 2006, this species was particularly common throughout mainland Nova Scotia, especially in the southern half of the province, in areas where the host plant (*Ascelepias* sp.) is known to occur. The immature stages were found, or verified reports of the immature stages were received from various localities in the western portion of the Annapolis Valley (Port Williams, Canning, Kentville, Coldbrook, and Cambridge Station in Kings County; Annapolis Royal and Belleisle in Annapolis County; Bear River, Digby County), as well as Dartmouth (HRM Halifax County).

No breeding populations were found at the White's Cove site, due to the lack of host plant, which has not been recorded from this locality (R.E. Newell, see References, **Butterfly Habitat and Host Plant Survey of White's Cove, Digby Co., N.S. (2005)).**

Polygonia satyrus (W.H. Edws.) (Satyr Comma) and *Polygonia gracilis* (G.&R.)(Hoary Comma). Neither of these species were observed or collected/released at the White's Cove site. Some reasons why these species were not found may be their general rarity (last known specimen
of *P. satyrus* collected in Armdale, 1968 (K. Neil collector), and of *P. gracilis* collected in Truro, 1927. (Collector unknown). (K. Neil, **The Butterflies of Nova Scotia** (in prep.)), and inclement weather during the flight period..

Pieris oleracea Harr. (Mustard White). No specimen of this species was observed or collected/released at the White's Cove site. Again, the localized distribution of this species (see

014861

C0918-020

Butterfly Habitat and Host Plant Survey of White's Cove, Digby Co., N.S.(2005), as well as inclement weather during its flight period, may be reasons why it was not observed.

JOHN A. AMIRAULT, MENG, PENG.
CONSULTING ENGINEER

27 June 2007

Mr. Paul Buxton, PEng.
Bilcon of Nova Scotia
P.O. Box 2113
Digby N.S. B0V 1A0

Dear Mr. Buxton:

Re: - Whites Point Quarry and Marine Terminal Joint Review Panel
Public Hearings
Undertaking # 17 - Additional information on NS quarries.

Uwe Wittkugel has requested that I assist in the provision of information for undertaking # 17. The undertaking states : "*To provide additional information on the list of 45 to 50 quarries in NS that are greater than 4ha and if any are greater than 150 ha in the area.*".

I have placed a request with a senior NSEL manager to provide a list of permitted Quarries / Mines in Nova Scotia. At the time of this letter I have not received any information from NSEL. I have also requested NSDNR to provide quarry production data. They advise that this information is not published.

In the interest of meeting the requirement of UT #17, I have compiled the attached table from a variety of sources that I believe to be reliable and consistent with my general background knowledge of the minerals industry in Nova Scotia. The footprint of disturbed areas has been assessed using available mapping. The actual permitted areas may be larger. No quarries operated by or for the construction of public highways have been included. Quarry production data has been provided where that information was immediately available to the researcher.

While I believe that the list will cover most of the quarries / mines of significance in the province, I caution that there may be others that we have not found within the time available. I trust that this information will be of use to Bilcon. Please advise if you need any additional information.

Yours very truly

John A. Amirault, MEng.,PEng.

Attach: Table of selected Mines and Quarries

33 GREENMOUNT DRIVE
DARTMOUTH, NOVA SCOTIA, CANADA B2V 2L7
TEL: (902) 462-8794 FAX: (902) 462-4856 CELL : (902) 499-0430
Email: john.a.amirault@ns.sympatico.ca

C0918-023

Ref. note	Selected Quarry or Mine Name 5	Location	County Municipality	Owner Operator	Status	Footprint ha 1	Product type	Production Tonnes pa 2, 3, 4
1	Wentworth Road	Windsor	West Hants	Fundy Gypsum Company	operating	332	Gypsum/Anhydrite	
2	Little Narrows	Little Narrows	Victoria	Little Narrows Gypsum Company	operating	490	Gypsum/Anhydrite	1,060,590
3	Sugar Camp	Melford	Inverness	Georgia Pacific	operating	165	Gypsum	1,569,606
4	Millers Creek	Windsor	West Hants	Fundy Gypsum Company	operating	314	Gypsum	
5	Milford Quarry	East Milford	Hants	National Gypsum Ltd.	operating	254	Gypsum	2,905,217
6	Big Brook	River Denys	Inverness	Georgia Pacific	not operating	567	Gypsum	
7	Little Pond Mines	Alder Point	CBRM	Brogan Mining Company Ltd.	operating	32	Coal	20,000
8	St. Rose Mine	St. Rose	Inverness	Evans Coal Mines Ltd.	operating	88	Coal	3,000
9	Stellarton Mine	Stellarton	Pictou	Pioneer Coal Ltd.	operating	47	Coal	284,000
10	Coalburn Mine	Coalburn	Pictou	Thorburn Mining Ltd.	operating	95	Coal	51,779
11	Thorburn Mine	Thorburn	Pictou	Thorburn Mining Ltd.	operating	138	Coal	30,000
12	Lafarge Brookfield	Brookfield	Colchester	Lafarge Canada Inc.	operating	95	Limestone	741,492
13	Mosher Limestone	Upper Musquodoboit	HRM	Mosher Limestone Company Ltd.	operating	16	Limestone/Dolomite	26,197
14	Glen Morrison	Glen Morrison	CBRM	Nova Scotia Power Inc.	operating	60	Limestone	100,670
15	Ridge Brokers	Southside Harbour	Antigonish	Ridge Brokers Inc.	operating	9	Limestone	18,553
16	Kelly Cove	Kelly's Cove	Victoria	Scotia Limestone Ltd.	operating	16	Limestone	3,000
17	Brookfield Barite	Brookfield	Colchester	E-Z-EM	operating	+/_ 8 ha	Barite	493
18	Shaw Clay pit	Milford	Hants	Shaw Brick	operating	+/_ 5 ha	Clay	27,216
19	Nine Mile River	Nine Mile River	Hants	Shaw Resources	operating	13	Silica Sand	84,345
20	Nictaux Quarry	Nictaux West	Annapolis	Heritage Memorials Ltd.	operating	small	Dimension Stone	252
21	Wallace Quarry	Wallace	Cumberland	Wallace Quarries Ltd.	operating	small	Dimension Stone	
22	Gateway	Kearney Lake	HRM	Gateway	operating	41	Aggregate	
23	Municipal / Solvereign	Rocky Lake	HRM	Sovereign Resources Ltd.	operating	199	Aggregate	
24	Conrad Bros.	Dartmouth	HRM	Conrad Brothers	operating	150	Aggregate	
25	Gallant	Elmsdale	East Hants	Basin Contracting	operating	19	Aggregate	
26	Folly Lake	Folly Lake	Colchester	Lafarge Canada Inc.	operating	137	Aggregate	
27	Parker Mountain	Parker Mountain	Annapolis Co	Lowe Bros.	operating	20	Aggregate	
28	Rio Kemptville Tin	East Kemptville	Shelburne	BHP Billiton	operating	473	Former tin mine	
29	Black Bull	Off Highway 203	Yarmouth	Black Bull Resources Ltd.	operating	6	Silica, clay	
30	Keddy Aggregate Operation	Coldbrook	Kings	Shaw Resources	operating	60	Aggregate	
31	Martin Marietta	Porcupine Mountain	Guysborough	Martin Marietta Materials Canada	operating	120	Aggregate	
32	Municipal / Stevens	Sydney Forks	CBRM	Municipal Ready - Mix Ltd.	operating	48	Aggregate	
33	Doug Burns	Beachmont	CBRM	Doug Burns Excavation Contracting Ltd.	operating		Aggregate	
34	Stellarton Surface Coal Mine Extension	Stellarton	Pictou	Pioneer Coal Ltd.	approved	50	Coal	n/a
35	Prince Mine Reclamation	Point Aconi	CBRM	Pioneer Coal Ltd.	approved	85	Coal	228,500
36	Point Aconi Phase 3 Surface Coal Mine	Point Aconi	CBRM	Thomas Brogan and Sons Construction	approved	8	Coal	50,000
37	Bond Road Sand Pit Operations	Waterville	Kings	Twin Mountain Construction Ltd.	approved	58	Sand/Soil	100,000
38	Leitches Creek Quarry	Leitches Creek	CBRM	Alva Construction Ltd.	approved	18	Aggregate	n/a
39	Rhodena Rock Quarry Expansion	Porcupine Mountain	Guysborough	Rhodena Rock Ltd	approved	63	Aggregate	n/a
40	Kemptown Road Quarry Expansion Project	Kemptown	Colchester	Dexter Construction Co. Ltd.	approved	16	Aggregate	n/a
41	East Uniacke Quarry Expansion Project	East Uniacke	Hants	S.W. Weeks Construction Ltd	approved	32	Aggregate	200,000
42	Cambridge Pit	Cambridge	Kings	Lawson Bennett Trucking Ltd	approved	201	Aggregate	n/a
43	Troy Quarry Expansion	Troy	Inverness	S.W. Weeks Construction Limited	approved	20	Aggregate	n/a

Note
1 Disturbed footprint area estimated from available mapping , approved areas may be larger
2 Tonnage estimate from available public sources where available
3 Tonnage estimates for approved sites were projected at time of approval
4 Production statistics for individual mines / quarries not available to public.
Production data stated above derived from available publications believed to be generally reliable sources.

John A. Amirault, MEng.,PEng.
Consulting Engineer

33 Greenmount Dr.
Dartmouth, NS
B2V 2L7

Tel (902) 462-8794
Fax (902) 462-4865
Email: john.a.amirault@ns.sympatico.ca

UNDERTAKING # 18

Quantify electrical power requirements for the project

The estimated connected load has been estimated to be approximately 7000 horsepower (=5.2 MW). Based on an expected load factor of 55% this translates into an electrical power requirement of approximately 3 MW.

Note:
The total horsepower (hp) estimate for quarry equipment provided in Undertaking #23 is larger than 7000 hp. The numbers provided in Undertaking #23 are the result of early conceptual plant designs which were used to estimate the total GHG generation. By the time the electric power requirements were determined the plant design had been advanced resulting in a total of 7000 horsepower (=5.2 MW) as stated above. For example, the initial plant configuration included 4 crushers of 1000hp each. This has been revised to 3 crushers of 600 hp each. For consistency purposes the estimated GHG generation of approximately 80,000t/yr that is presented in Undertaking #23 was not updated. Based on the 7000hp / 5.2 MW requirements stated in this Undertaking it would be obviously lower.

From: Josephine Monk Lowry [josephine.lowry@ns.aliantzinc.ca]
Sent: Wednesday, June 20, 2007 12:18 PM
To: Myles,Debra [CEAA]
Cc: uwe Wittkugel
Subject: Panel Undertakings - metric conversion

Debra

In response to the Panel's request for metric conversion of the screen opening size, please be advised that the size of the opening of a 140 mesh screen is .1041mm.

Thanks
Josephine

June 28, 2007
#21

NOVA SCOTIA

Transportation and Public Works
Government Services
Real Property Services

5th Floor
Johnson Building
1672 Granville Street
Halifax NS B3J 3Z8

PO Box 186
Halifax NS B3J 2N2

Bus: 902 424-5253
Fax: 902 424-0583
E-mail: poiriesc@gov.ns.ca

Our File Number:

MEMORANDUM

TO: Paul Stone, Area Manager, Annapolis-Digby
TPW, Middleton Office

FROM: Shona Poirier, Acquisition and Disposal Officer
TPW Head Office, Halifax

DATE: June 27, 2007

SUBJECT: Aerial Photos, White Cove Road, Digby County

Enclosed please find 4 aerial photos which I obtained from the Registry here in Halifax showing the subject road. Also enclosed are photo copies of two photos which are currently being sent from Ottawa.

Should you require anything further please let me know.

Sincerely,

Shona Poirier
Acquisition and Disposal Officer

SCP/

enclosures

DEPT OF TRANSPORTATION
RECEIVED
JUN 28 2007
AREA MANAGER
MIDDLETON, N.S.

002290

002291

S.W. Cor.
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88-6-24
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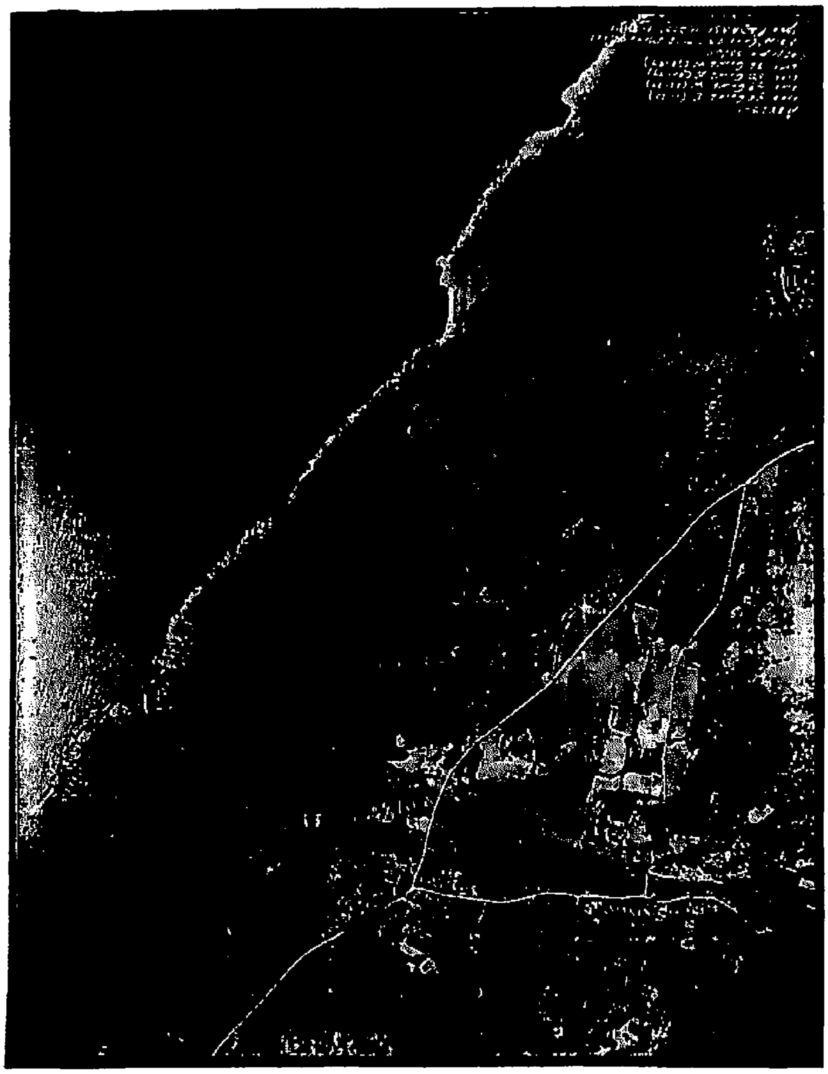
MARITIME RESOURCE MANAGEMENT SERVICE ; COUNCIL OF MARITIME PREMIERS - AMHERST, N.S.
24-6-70
N.S. A 30273-6



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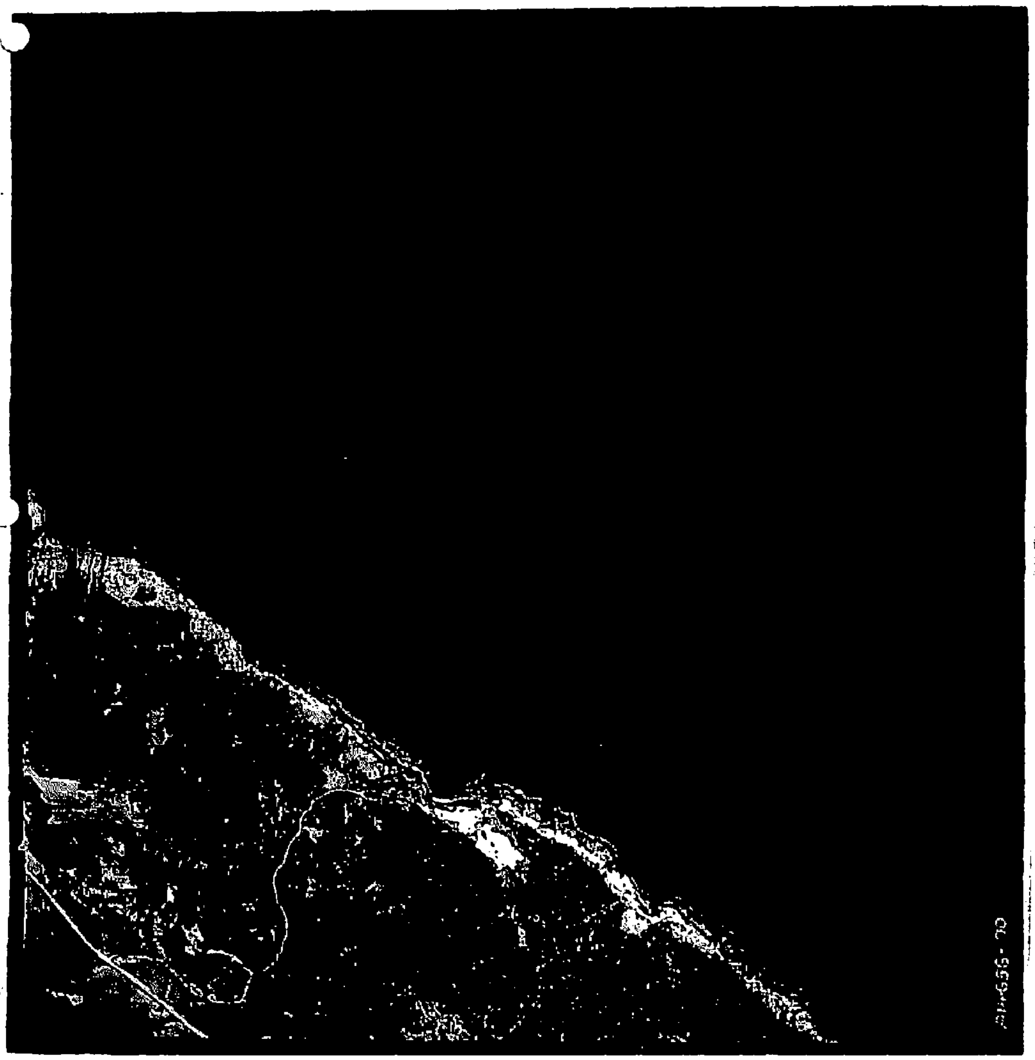

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Health Canada Response to Undertaking #22

<u>Question:</u>
Will advise if shipping related noises were included in the evaluation conducted by the department.

<u>Response:</u>
Health effects were assessed for whatever noise sources were evaluated by the proponent. In Section 9.1.11, the proponent predicts sound levels from ship loading at night at Whites Point Quarry based on noise measurements from ship loading at another rock quarry at Sechelt. The nearest receptor to the ship loading noise source is given as 1500 m at Whites Point Quarry. In Sechelt, the sound levels were found to attenuate to 45 dBA at 1480 m. The proponent assesses the situation as worst case i.e. the sound levels at Whites Point Quarry are expected to be smaller because of extra mitigation factors there compared to the measurement situation at Sechelt.

The night time ship loading noise was assessed separately from the other operational noise with respect to sleep disturbance as described below. The noise was not foreseen as possibly being intermittent or regular impulsive so no comparison was made to the WHO guideline level for intermittent noise.

The proponent predicts a worst case sound level less than 45 dBA from ship loading. A sound level of 30 dBA indoors is the guideline level for the onset of sleep disturbance effects for a continuous noise as per the WHO (1999). Typically, there is a 15 dB attenuation from outdoors to indoors with partially opened windows. Therefore, with open windows, a 30 dBA indoor sound level typically corresponds to an outdoor level of 45 dBA.

An assessment was made of the adjusted day-night sound level by the proponent in the June 1, 2007 Bilcon letter, assuming regular impulsive noise during the day and non-impulsive ship loading noise at night for two possibilities – (i)a quiet rural area or (ii)not a quiet rural area.

Health Canada's calculations yielded similar results to those given by the proponent. In response to the panel's request, Health Canada's results are presented in more detail below and include an even more stringent possible worst case condition not considered before; the night time noise also being all regular impulsive noise. The numbers have been rounded off to the nearest percent. This last result is given to provide a potential worst case; Health Canada does not know if it is a realistic expectation for all the ship loading noise to be regular impulsive. The proponent has already provided similar corresponding day-night sound levels for the other 3 conditions.

% highly annoyed (not quiet rural)	% highly annoyed (quiet rural)	Condition

2	2	Baseline
4	12	Plant operation + ship loading all non-impulsive
4	14	Plant operation regular impulsive + ship loading non-impulsive
6	19	Plant operation + ship loading all regular impulsive

Health Canada accepted the proponent's analysis indicating that all receptors except, potentially, R3 are not quiet rural areas. Regarding R3, the proponent addressed Health Canada's concerns by stating in the June 1, 2007 Bilcon letter,

"It is understood that since R3 may fall under a different community category due to its distance from Highway 217. As suggested in the response to Health Canada's comment No. 5, R3 is recommended to be a future noise monitoring station to further assess noise levels at the site potential noise impacts related to operations at Whites Point quarry."

Health Canada assumed that this monitoring included ship loading.

Health Canada's conclusions presented at the panel hearing are not changed by the analysis and clarifications provided here.

U # 23

To provide calculations behind Bilcon's GHG emissions estimate of 80,000 t

Greenhouse Gas (GHG) emissions were presented in Section 9.1.1.2, Volume VI of the EIS. As stated in the text, the operation at Whites Point Quarry comprises five different stages including: primary treatment, secondary treatment, fine crushing, the washing plant, and load out procedures. All five of these stages require a variety of equipment utilizing electric motors including such units as conveyor belts, screens, feeders, and pumps, which can require engine power within a wide range of approximately 10-300 horsepower (hp). Detailed power rating information for each stage was provided by Bilcon and used in the GHG emissions evaluation.

Assumptions used in calculating GHGs included:

- Equipment operated at 85 percent of its maximum power;
- Equipment was operational for 85 percent of the time to practically portray working conditions; and
- An emission factor was used to calculate Carbon Dioxide Equivalent (CO_2e) emissions (Reference: Nova Scotia Power, VCR Inc. 2000 Annual Report).

A breakdown of GHG emissions according to each operational stage is shown below.

Table 1 CO_2e Emissions for the Primary Stage of Operation

Machine	Quantity	Engine Power (hp)	Power Usage of 85% (85% of the Time) (hp)	Power Usage of 85% (85% of the Time) (kWh)	CO_2e Produced (kg/hr)
Jaw	1	300	217	162	151
Feeder	1	75	54	40	38
Pecker	1	30	22	16	15
Oil lube system	1	10	7	5	5
Lighting	1	15	11	8	8
Miscellaneous	1	25	18	13	13
Take away belt	1	40	29	22	20
Stacker to screen	1	125	90	67	63
Screen #1	2	60	87	65	60
Conveyor to surge	1	75	54	40	38
Conveyor to shuttle	2	60	87	65	60
TOTAL					470

Table 2 CO_2e Emissions for the Secondary Stage of Operation					
Machine	Quantity	Engine Power (hp)	Power Usage of 85% (85% of the Time) (hp)	Power Usage of 85% (85% of the Time) (kWh)	CO_2e Produced (kg/hr)
Tunnel Belt	1	75	54	40	38
Secondary	2	500	723	539	503
Conveyor to Screens	1	125	90	67	63
Conveyor to Secondary Surge	1	100	72	54	50
Conveyor to Stacker	2	60	87	65	60
Feeder in tunnel	4	40	116	86	80
Lighting miscellaneous	1	30	22	16	15
Conveyor to Tertiary Surge	1	100	72	54	50
Miscellaneous	10	100	723	539	503
Screen	4	120	347	259	241
TOTAL					1,604

Table 3 CO_2e Emissions for the Fine Crushing Stage of Operation					
Machine	Quantity	Engine Power (hp)	Power Usage of 85%(85% of the Time) (hp)	Power Usage of 85%(85% of the Time) (kWh)	CO_2e Produced (kg/hr)
Feeders in tunnel	4	40	116	86	80
Conveyor to feed box	1	100	72	54	50
Belt feeders to crushers	2	50	72	54	50
Crushers	4	1000	2890	2156	2,011
Controls, belt scales, misc.	2	100	145	108	101
TOTAL					2,293

Table 4 CO_2e Emissions for the Washing Plant					
Machine	Quantity	Engine Power (hp)	Power Usage of 85%(85% of the Time) (hp)	Power Usage of 85%(85% of the Time) (kWh)	CO_2e Produced (kg/hr)
Feeder in tunnel	4	40	116	86	80
Conveyor to Screens	1	100	72	54	50
Screen	4	160	462	345	322
Conveyor to Shuttle Belts	10	300	2168	1617	1,509
Stackers	6	450	1951	1455	1,358
Sand Screw	2	100	145	108	101
Dewater Screens	2	30	43	32	30
10x8 Pumps	2	100	145	108	101
Feed Water Pump	1	250	181	135	126
Make Water Pump	1	30	22	16	15
Lighting	1	60	43	32	30
Miscellaneous Controls Scale	1	60	43	32	30
TOTAL					3,751

Table 5 CO_2e Emissions for the Load Out Stage of Operation					
Machine	Quantity	Engine Power (hp)	Power Usage of 85% (85% of the Time) (hp)	Power Usage of 85% (85% of the Time) (kWh)	CO_2e Produced (kg/hr)
Main tunnel	1	300	217	162	151
2nd tunnel	1	250	181	135	126
Shuttle	1	300	217	162	151
Loader	1	300	217	162	151
Bin belt	1	150	108	81	75
Bin controls	1	40	29	22	20
Belt feeder	6	100	434	323	302
Transverse	1	50	36	27	25
Lighting, miscellaneous control	1	200	145	108	101
TOTAL					1,101

The CO_2e emissions produced by three heavy diesel vehicles were also incorporated into the GHG determination for Whites Point Quarry operations. The values presented in Tables 1-5 and the CO_2e emissions resulting from the diesel vehicles are summarized in Table 6.

Table 6 GHG Emissions Summary for Whites Point Quarry Land-Based Operations		
STAGE	CO_2e PRODUCED (kg/hr)	CO_2e PRODUCED (tonne/year)
PRIMARY	470	4,119
SECONDARY	1,604	14,052
FINE CRUSHING	2,293	20,088
WASHING PLANT	3,751	32,863
LOAD OUT	1,101	9,647
HEAVY DIESEL VEHICLES X3	114	997
TOTAL	**9,220**	**81,765**

Review of Regulations Pertaining to Coastal Buffer Zones

June 26, 2007

Prepared for the Joint Review Panel, Whites Point Quarry and Marine Terminal Project by Peter Neily, RPF, Forest Ecologist, with additional information by Hugh Gillis, Planning and Development Officer; NS Department of Natural Resources.

In **Nova Scotia** a 20 meter special management zone is required along all watercourses, including salt water under the “Wildlife Habitat and Watercourses Protection Regulations”. These regulations are designed to protect water quality and to maintain various elements of wildlife habitat on all forest harvest sites. Forest harvesting is only permitted to reduce the standing volume to 20 square meters of basal area (a fully stocked mixedwood forest would have about 50 square meters of basal but on average most un-managed forests will be in the 30 square meter range). Wider zones up to 60 meters are prescribed depending on slope of the land. There is a 7 meter machine exclusion zone adjacent to the watercourse.

The Halifax Regional Municipality Regional Plan (August 2006), established a 20 meter minimum riparian buffer, which prohibits development within the buffer, but provisions are made for a number of ancillary uses including fences, public road crossings, driveway crossings, wastewater, storm and water infrastructure, marine dependent uses, fisheries uses, boat ramps, wharfs, and small-scale accessory buildings or structures. In addition, no alteration of land levels or the removal of vegetation in relation to development will be permitted. The buffer requirement does not apply to some lands used for port/industrial related uses in Halifax Harbour and Sheet Harbour.

Other jurisdictions reviewed included Maine, New Brunswick, and Prince Edward Island. A review of publications and resources of the *Gulf of Maine Council on the Marine Environment* was also performed.

Maine - a 250 foot (75 meter) buffer width is required above the high water line. Partial harvesting of forest cover is permitted but there is to be no cleared opening within 75 feet of the high water line. Buffer widths can be altered depending upon the site hazard sensitivity requiring Bureau of Forestry approval.

New Brunswick - site specific regulations are made under the Community Planning Act. Three Bay of Fundy communities - St. Martins, St. Andrews, and Saint David, have regulations in place and each are specific to the locale. Limits are placed on certain activities within a specified distance, eg. 30 meter at St. Martins. Land use designation identifies locations of new quarries and guidelines are imposed on development. General rural use of coastlines is guided within 100 meter by requiring development to protect the character of these areas in terms of environmental, ecological, geological, historical and architectural structure. Specifics regarding the objectives are to be determined through a planning and approval process and includes the public.

New Brunswick's Coastal Areas Protection Policy released in 2002 (but not adopted) proposes a 30 meter buffer above the highest normal tide level along coastal areas.

Prince Edward Island - Depending on the land use activity the coastal buffer ranges from 20 meters to 90 meters. Restrictions on forested buffers limit harvesting to a percentage of the standing volume. "No farm" zones are also regulated depending on slope and run-off sensitivity. Specific land use guidelines and regulations are also developed for individual estuaries.

Whites Point Quarry Undertaking

Estimated GDP Per Person Year of Employment in Nova Scotia
Primary Resource Sectors 2004

Primary Industry	GDP(1) (000,000)	Employment (Person Years)	GDP/Person Year
Mineral industry	$232.0	1,350(2)	$171,852
Fishery	$319.0	7,500(3)	$42,535
Agriculture	$196.0	5,500(4)	$35,635
Forestry	$176.0	4,300(5)	$40,930

(1) Estimates of GDP derived by Gardner Pinfold using data from the Nova Scotia Statistical Review. GDP for mining industry derived by Gardner Pinfold as part of an Economic Impact Study of the industry completed for the Department of Natural Resources in 2005.

(2) Estimated by Gardner Pinfold as part of an Economic Impact Study of the industry completed for the Department of Natural Resources in 2005.

(3) Derived by Gardner Pinfold as part of a study titled "Economic Value of the Nova Scotia Oceans Sector" prepared for the Office of Economic Development.

(4) Taken from Nova Scotia Statistical Review published by Department of Finance.

(5) Taken from "The Economic Impact of the Nova Scotia Forest Industry" prepared by the Atlantic Provinces Economic Council, 2005.

From: MacCaull, Garry [MACCAUG@tc.gc.ca]
Sent: Friday, June 22, 2007 9:01 AM
To: Myles,Debra [CEAA]
Cc: Cormier, Jim; Balaban, Mihai; Prentiss, Jon
Subject: Answers to questions 27 & 28 from Review Panel on White's Point EA

Debra - Here are the answers and references to the questions asked by the Review Panel regarding Transport Canada presentation on 20 June 2007 in Digby.

Question 27: Clarify the regulatory requirements for the release of bilgewater from a bulk carrier while in port and engaged in loading of material.
To be more specific, my understanding of the question was regarding bilgewater that contained cargo residues other than a cargo residue that is a pollutant. Under the "Regulations for the Prevention of Pollution from Ships and for Dangerous Chemicals" this type of bilgewater would not be allowed to be discharged while the vessel is in port. This type of cargo residue is allowed to be discharged as far as practicable from the nearest land but under no circumstances shall the discharge from the nearest land be less than 3 nautical miles at the time of discharge [reference Division 5, subdivision 2, section 140 (c) of the regulation].

Question 28: Clarify if ballast water exchange required by regulation results in a 100 per cent exchange.

Answer, reference section 8 of "Ballast Water Control and Management Regulations".

Ballast Water Exchange Standard
8. (1) A measurement of volumetric exchange or ballast water salinity does not include the sediment that has settled out of ballast water within a ship.
(2) A ship that exchanges ballast water shall attain
(a) an efficiency of at least 95 per cent volumetric exchange; and
(b) a ballast water salinity of at least 30 parts per thousand, if the exchange of ballast water is conducted in an area not less than 50 nautical miles from shore.
(3) In the case of a ship that exchanges ballast water through flow-through exchange, pumping through three times the volume of each ballast tank shall constitute 95 per cent volumetric exchange, unless the ship provides evidence in its ballast water management plan that pumping through less than three times that volume achieves 95 per cent volumetric exchange.

The links to the above noted regulations are:
http://www.tc.gc.ca/acts-regulations/GENERAL/C/csa/regulations/400/csa450/csa450.html
http://www.tc.gc.ca/acts-regulations/GENERAL/C/csa/regulations/400/csa448/csa448.html

I trust this answers the Panel's questions. Request that you acknowledge receipt of this email, thank you.

Garry MacCaull
Senior Marine Inspector
Marine Safety - Transport Canada

Undertaking #30 for Whites Point Quarry Panel Review

Provide the value of the lobster fishery in the project area relative to other areas in the province.

The value of the lobster fishery is provided for the six areas in Fig. 1. The values are for the 2004-05 and 2005-06 lobster seasons*. The data are from DFO databases. Lobster Fishing Areas (LFAs) are the management units for the lobster fishery in Atlantic Canada. The grids within the LFAs are not management units but are used in mandatory logs for fishermen to report fishing catch and effort. The smaller areas highlighted in Fig. 1 adjacent to the proposed quarry are within LFA 34 and are not management units. They are displayed only for the purpose of this undertaking.

The single most highly valued LFA in Atlantic Canada is LFA 34 ($252 million in 2004-05). Considering only that portion of LFA 34 adjacent to Digby Neck, the landed value was approximately $11 million in 2004-05 and $10 million in 2005-06. If the Saint Mary's Bay and outer Bay of Fundy portion is added, the value rises to $46 million in 2004-05 and $38 million in 2005-06. The areas adjacent to the proposed quarry are of high value area relative to adjacent Lobster Fishing Areas.

Table 1. Landed value in 2004-05.

AREA	WEIGHT(LBS)	Average price per lb ($)	VALUE ($)
Bay of Fundy – Digby Neck	1,693,807	$ 6.69	$ 11,331,569
Saint Mary's Bay & NS side of outer Bay of Fundy	5,311,867	$ 6.69	$ 35,536,387
LFA 34 (including above 2 areas)	37,779,914	$ 6.69	$ 252,747,625
LFA 35	2,508,206	$ 6.47	$ 16,228,093
LFA 36	2,264,013	$ 6.19	$ 14,014,242
LFA 38	2,763,066	$ 6.48	$ 17,904,668

Table 2. Landed value in 2005-06.

AREA	WEIGHT(LBS)	Average price per lb ($)	VALUE ($)
Bay of Fundy – Digby Neck	1,787,902	$ 5.71	$ 10,208,920
Saint Mary's Bay & NS side of outer Bay of Fundy	4,440,655	$ 5.71	$ 25,356,139
LFA 34 (including above 2 areas)	37,400,845	$ 5.71	$213,558,822
LFA 35	2,648,554	$ 6.04	$ 15,997,264
LFA 36	2,558,083	$ 5.87	$ 15,015,948
LFA 38	3,019,791	$ 5.74	$ 17,333,600

*In these areas fishing seasons run over two calendar years. LFA 34 for examples runs from late November until the following May 31.

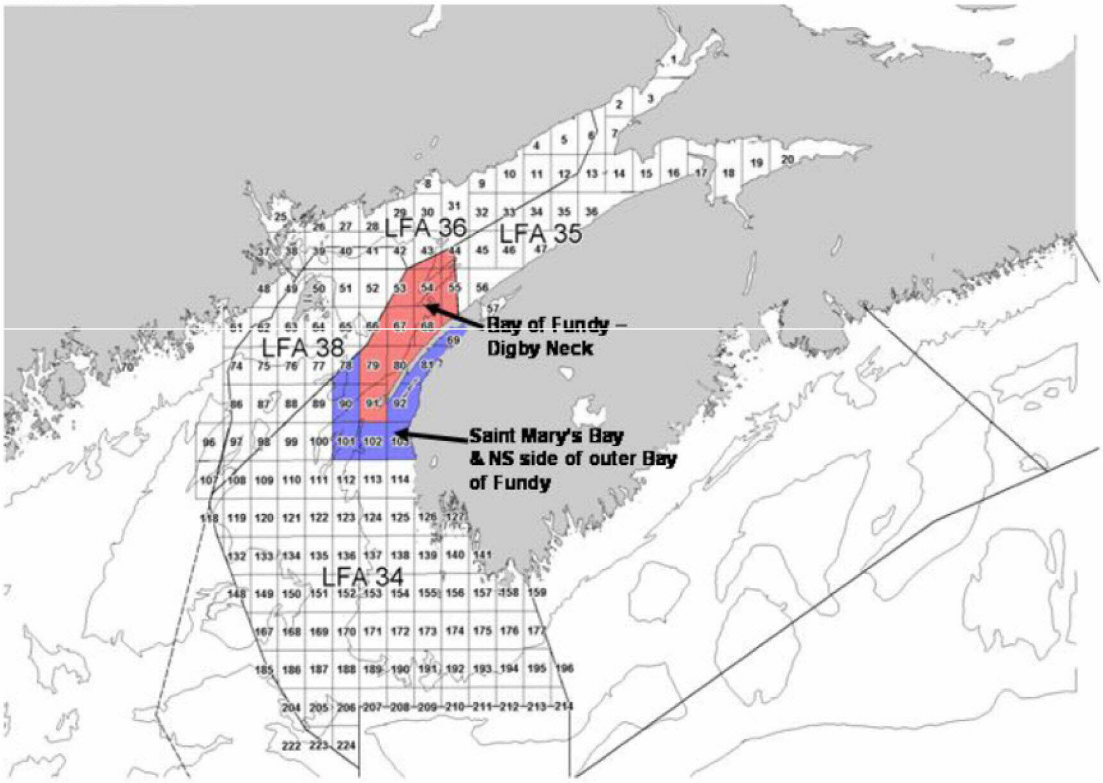

Fig. 1. Lobster Fishing Areas (LFAs) in the Gulf of Maine and Bay of Fundy. Highlighted areas adjacent to the proposed quarry are part of LFA 34 and are not management areas.

John Tremblay and Cheryl Frail
Population Ecology Division
Science Branch, Fisheries and Oceans Canada
Bedford Institute of Oceanography

Undertaking # 33

To provide engine emission estimates for all project sources influencing air quality, including heavy equipment and vessel traffic.

Engine emission rate estimates for the heavy equipment used in the operations for Whites Point quarry were calculated. The duty cycle of each piece of equipment was approximated based on its estimated load and actual operating time. The emission factors used in calculating the emission rates were taken from the U.S. Environmental Protection Agency's (EPA) Tier 3 Non-Road Diesel Engine Emission Standards. Bilcon has committed to adhering to the more stringent Tier 3 engine emission standards; therefore, the corresponding emission factors were used where applicable. Tier 3 engine emission standards for particulate matter (PM) have not been adopted by the U.S. EPA so Tier 2 emission standards are used in this case. Emission rates will increase as the equipment ages, but aggressive maintenance will minimize the deterioration rate.

Emission rates for non-methane hydrocarbons and nitrogen oxides (NMHC+NOx), carbon monoxide (CO), and PM were evaluated (Table 1.1).

Table 1.1 Project Operations - Engine Emission Estimated for Heavy Equipment

Unit		Power (hp)	Duty Cycle (%)	Effective Power (hp)	Effective Power (kW)	Emission Factors			Emission Rates		
						NMHC+NOx (g/kWh)	CO (g/kWh)	PM (g/kWh)	NMHC+NOx (g/s)	CO (g/s)	PM (g/s)
1	Rock Drill	350	85	298	222	4	3.5	0.2	0.247	0.216	0.012
2	Truck 1	450	50	225	168	4	3.5	0.2	0.187	0.163	0.009
3	Truck 2	450	50	225	168	4	3.5	0.2	0.187	0.163	0.009
4	Bobcat	200	75	150	112	4	3.5	0.2	0.124	0.109	0.006
5	Excavator	400	85	340	254	4	3.5	0.2	0.282	0.247	0.014
6	Dozer	400	85	340	254	4	3.5	0.2	0.282	0.247	0.014
7	Water Truck	200	10	20	15	4	3.5	0.2	0.017	0.015	0.001

The emission rates of NMHC+NOx, CO, and PM generated by heavy equipment were then determined for a year of operation. In doing so, it assumed there is a 16 hour work day, 6 days per week for 44 weeks. As stated in the Project description, 8 weeks have been set aside as a maintenance period at the quarry site. Table 1.2 summarizes the engine emissions from heavy equipment for a year of operation.

Table 1.2 Project Operations – Annual Engine Emission Estimates for Heavy Equipment				
		Emission Rates		
Unit		NMHC+NOx (tonne/year)	CO (tonne/year)	PM (tonne/year)
1	Rock Drill	3.7	3.3	0.19
2	Truck 1	2.8	2.5	0.14
3	Truck 2	2.8	2.5	0.14
4	Bobcat	1.9	1.7	0.09
5	Excavator	4.3	3.7	0.21
6	Dozer	4.3	3.7	0.21
7	Water Truck	0.3	0.2	0.01
Total Emissions from Heavy Equipment		20.1	17.6	1.0

Engine emissions from vessel traffic were also calculated. Vessel traffic associated with quarry operations consist of one ship. Figures for fuel consumption and speed were based on those obtained for the CSL Spirit, a vessel of similar capacity that is also used for transporting aggregate (Table 1.3).

Table 1.3 Fuel Consumption for the CSL Spirit				
Activity	Speed		Main Engine (tonnes/day)	Generators (tonnes/day)
	Loaded	Ballast	IFO	MDO
At Sea	15.3 knots	15.9 knots	46	0.1
Loading/Discharge			7	0.3

The ship used for Whites Point quarry will travel an approximate distance of 604 nautical miles for round-trip voyage, which translates to a travel time of 3.23 days. Fuel consumption was determined for the ship during its time at sea and during the loading/discharge phase. Loading and unloading time was assumed to be 1 day (12 hours each).

Table 1.4 Whites Point Quarry Ship Fuel Consumption	
	Fuel Consumed Per Round-Trip (tonnes)
Sea	149
Loading/Discharge	7

Emission factors for vessels underway and for auxiliary engines, used while loading and unloading, were obtained from Levelton Engineering Ltd. The emissions of NOx, CO and PM were determined for the ship for a round-trip voyage (Table 1.5).

Table 1.5 Vessel Traffic Emission Estimates for Whites Point Quarry							
		Emission Factors			Emissions Per Round-Trip		
Activity	**Fuel Consumed Per Round-Trip (tonnes)**	**NOx (kg/tonne fuel)**	**CO (kg/tonne fuel)**	**PM (kg/tonne fuel)**	**NOx (tonnes)**	**CO (tonnes)**	**PM (tonnes)**
At Sea	149	9.3	7.4	7.6	1.39	1.10	1.13
Loading/Discharge	7	53.4	4.7	6.3	0.37	0.03	0.04

The ship will be making a round-trip once per week so the total annual emissions of NOx, CO and PM for the year is summarized in Table 1.6.

Table 1.6 Project Operations – Annual Engine Emission Estimates for Vessel Traffic			
	Emissions Per Year		
Activity	**NOx (tonnes)**	**CO (tonnes)**	**PM (tonnes)**
At Sea	72	57	59
Loading/Discharge	19	2	2
Total Emissions from Vessel Traffic	91	59	61

Therefore, taking both heavy equipment emissions and vessel traffic emissions into account, there is estimated to be approximately 110 tonnes NOx, 77 tonnes CO, and 62 tonnes of PM produced annually.

Environment Canada / Environnement Canada
Environmental Stewardship Branch
16th Floor Queen Square
45 Alderney Drive
Dartmouth, NS B2Y 2N6

June 29, 2007 File No.: 4194-82/2

Ms. Debra Myles
Panel Manager
Whites Point Quarry and Marine Terminal Project – Joint Review Panel
c/o Canadian Environmental Assessment Agency
160 Elgin Street
Ottawa, ON K1A 0H3

Dear Ms. Myles:

RE: Whites Point Quarry and Marine Terminal Undertakings 34-36 EAS# 2002-395

Please find attached the information requested from Environment Canada as Undertakings 34 through 36 from the Whites Point Quarry and Marine Terminal public hearings. I trust this information will be of assistance.

If you have any questions, do not hesitate to contact Kevin Blair by phone at (902) 426-6892, or by email at kevin.blair@ec.gc.ca, who is coordinating the Department's participation in the panel review.

Yours truly,

Maria Dober
A/Regional Director
Environmental Protection Operations Directorate
Atlantic

Attachment

cc: J. Abraham
K. Moir
I. McCracken
B. Jeffrey
K. Blair
MT Grant

Environment Canada Responses to Undertakings #34-36
Whites Point Quarry and Marine Terminal Joint Panel Review

Undertaking 34 - To provide the number of prosecutions and convictions under the *Fisheries Act* during the past 15 years. To provide the number of enforcement personnel currently employed by EC.

In the past 15 years, 46 prosecutions under the *Fisheries Act* were initiated against companies or individuals by Environment Canada in the Atlantic Provinces. These prosecutions resulted in convictions of 22 companies and 11 individuals. It is important to note that, in some cases, prosecutions against companies and individuals were related to the same incident or offence and charges against the individuals were withdrawn by the Department of Justice.

Environment Canada reports on current and historical legal activities under the *Fisheries Act* and the *Canadian Environmental Protection Act*. Reports for the period between 1988 and 2005 are available on the national website of Environment Canada's Enforcement Branch (www.ec.gc.ca/ele-ale).

Currently, Environment Canada – Atlantic has a total of 37 employees in the Enforcement Branch, 24 in Environmental Enforcement and 13 in Wildlife Enforcement.

Undertaking 35 - To provide information on enforcement options and the ranges of penalties provided in the Acts administered by EC.

A variety of enforcement measures are available to Environment Canada enforcement officers in addressing contraventions of legislation and regulations for which the Department has mandated responsibilities. Depending on the violation and the legislation or regulation in question, available enforcement measures may include warnings, tickets, Ministerial orders, injunctions, and prosecutions.

Some offence and penalty provisions of the *Fisheries Act* (Section 36), *Canadian Environmental Protection Act*, *Migratory Birds Convention Act*, and *Species at Risk Act* are highlighted below as examples. Additional information can be found in the legal text for each *Act*, which are available on the Department of Justice website (www.doj.ca). Further information on enforcement measures is also available on the national website of Environment Canada's Enforcement Branch (www.ec.gc.ca/ele-ale). It is important to note, however, that penalties are ultimately decided by the courts.

Fisheries Act (Section 36)

Offence and Punishment
40. (2) Every person who contravenes subsection 36(1) or (3) is guilty of

(a) an offence punishable on summary conviction and liable, for a first offence, to a fine not exceeding three hundred thousand dollars and, for any subsequent offence, to a fine not exceeding three hundred thousand dollars or to imprisonment for a term not exceeding six months, or to both; or

(b) an indictable offence and liable, for a first offence, to a fine not exceeding one million dollars and, for any subsequent offence, to a fine not exceeding one million dollars or to imprisonment for a term not exceeding three years, or to both.

Canadian Environmental Protection Act

Part 10: Enforcement - Offences and Punishment

Contravention of the Act, the regulations or agreements
272. (1) Every person commits an offence who contravenes
(*a*) a provision of this Act or the regulations;
(*b*) an obligation or a prohibition arising from this Act or the regulations;
(*c*) an order or a direction made under this Act;
(*d*) an order, direction or decision of a court made under this Act; or
(*e*) an agreement respecting environmental protection alternative measures within the meaning of section 295.

Penalties
(2) Every person who commits an offence under subsection (1) is liable
(*a*) on conviction on indictment, to a fine of not more than $1,000,000 or to imprisonment for a term of not more than three years, or to both; and
(*b*) on summary conviction, to a fine of not more than $300,000 or to imprisonment for a term of not more than six months, or to both.

Application in respect of ships
(3) For the purposes of this section, a ship is deemed to be a person in respect of every provision of this Act or the regulations that expressly applies to ships.

Migratory Birds Convention Act

Contravention of Act or regulations
13. (1) A person or vessel commits an offence if the person or vessel contravenes
(*a*) a provision of this Act or the regulations;
(*b*) an obligation or prohibition arising from this Act or the regulations;
(*c*) an order or direction made under this Act; or
(*d*) an order, direction or decision of a court made under this Act.

Penalties
(1.1) Every person or vessel that commits an offence is liable
(*a*) on conviction on indictment, to a fine of not more than $1,000,000 or to imprisonment for a term of not more than three years, or to both; and
(*b*) on summary conviction, to a fine of not more than $300,000 or to imprisonment for a term of not more than six months, or to both.

Species at Risk Act

Contraventions
97. (1) Every person who contravenes subsection 32(1) or (2), section 33, subsection 36(1), 58(1), 60(1) or 61(1) or section 91 or 92 or any prescribed provision of a regulation or an emergency order, or who fails to comply with an alternative measures agreement the person has entered into under this Act,

(*a*) is guilty of an offence punishable on summary conviction and is liable

(i) in the case of a corporation, other than a non-profit corporation, to a fine of not more than $300,000,
(ii) in the case of a non-profit corporation, to a fine of not more than $50,000, and
(iii) in the case of any other person, to a fine of not more than $50,000 or to imprisonment for a term of not more than one year, or to both; or

(*b*) is guilty of an indictable offence and is liable
(i) in the case of a corporation, other than a non-profit corporation, to a fine of not more than $1,000,000,
(ii) in the case of a non-profit corporation, to a fine of not more than $250,000, and
(iii) in the case of any other person, to a fine of not more than $250,000 or to imprisonment for a term of not more than five years, or to both.

Undertaking 36 - To use the 1870 to 2006 daily rainfall dataset to find the year with the worst drought conditions.

The daily rainfall dataset used to provide rainfall return period does not also allow an analysis of a "100-year drought" value. However, Environment Canada has used rainfall data from Yarmouth, NS since 1880 to provide a ranking of driest to wettest years based on the entire year (Table 1) and summer months of each year (Table 2). No specific trend was detected from this analysis; however, climate models are projecting increasing annual precipitation amounts and a shift to more extreme events over fewer days, thus extending the dry periods.

In Tables 1 and 2 below, years including 2000 onward are highlighted. The letter "M" in place of a value means data was not available.

Table 1 - Ranking of Driest to Wettest Years (1880-2006, Yarmouth) - ranking based on total year

Year	January	February	March	April	May	June	July	August	September	October	November	December	Sum	Rank
1965	82	119.4	20.1	63	24.9	71.9	27.4	83.6	28.4	80.3	104.6	101.1	806.7	1
1921	71.4	106.7	79.8	68.6	39.4	47.8	73.9	57.9	58.9	50.5	124.7	80.5	860.1	2
1911	106.7	67.8	65.3	75.4	38.1	43.9	33.3	67.1	136.9	41.1	159.5	55.4	890.5	3
1894	97.5	57.9	57.2	79.5	67.1	78	20.6	31.5	118.1	87.1	113	86.6	894.1	4
1914	78	99.6	78.2	73.4	75.7	99.6	27.9	96.3	53.3	70.9	74.4	96.5	923.8	5
1915	144.8	73.2	8.1	64.5	88.4	40.6	32.5	74.2	30	168.1	101.1	121.2	946.7	6
1966	109.2	73.2	68.3	17.3	146.6	64.5	33	85.9	98.3	78.2	94.5	111	980.0	7
1922	71.4	74.2	47.2	50	54.1	73.2	187.2	198.6	109.2	85.9	36.1	M	987.1	8
1978	182.5	26.2	79	129.2	47.1	76.3	33.5	56.8	70	110.7	49	131.4	991.7	9
1924	154.4	47.5	61	68.6	79.5	59.2	40.6	158.8	102.4	89.9	61	82	1004.9	10
2001	92.8	68.2	116	58.6	72.4	97.2	54.8	98.6	18.8	101	118.4	108.7	1005.5	11
1923	M	53.8	105.7	134.1	73.7	74.4	53.3	67.6	82	85.3	104.6	174.2	1008.7	12
1905	118.1	100.1	36.8	32.3	91.4	91.7	65	79.8	124	37.6	154.7	78	1009.5	13
1910	177.3	95.5	64.5	142	39.6	130.3	48.5	42.9	97	49.5	68.8	75.9	1031.8	14
1930	98.6	121.2	110.2	62.7	44.5	17.5	166.4	51.1	13	127	70.4	157.2	1039.8	15
1992	86.1	123.2	90.5	81.6	30	82.1	62.4	63.8	79.5	98.4	149	100	1046.6	16
1909	90.7	85.9	133.9	96.3	128.5	50	87.4	32	105.4	67.8	125.7	47.8	1051.4	17
1941	147.1	51.8	101.6	27.7	104.1	54.1	97.5	121.9	35.3	113.5	111.3	94.5	1060.4	18
1960	85.3	193.8	101.3	76.7	124.5	80.5	47.5	24.9	48.8	94.5	69.6	125.7	1073.1	19
1971	112.8	115.3	95	58.2	115.6	22.4	59.4	145.3	37.3	51.8	141.2	128.3	1082.6	20
1925	84.6	47.8	83.1	74.2	53.1	176	108.2	44.2	75.7	148.8	108.5	78.7	1082.9	21
1957	184.2	57.7	64.3	122.7	85.6	23.4	84.3	52.8	65.8	79.2	176.5	89.7	1086.2	22
1907	101.3	108.2	56.4	70.6	55.9	38.4	50.8	120.9	115.3	121.4	133.9	114	1087.1	23
1916	73.7	100.1	137.7	73.7	64.3	170.7	92.7	36.1	58.2	80.8	55.1	149.1	1092.2	24
1912	86.9	75.2	82.3	88.4	131.6	38.6	98	67.3	70.4	98.3	101.3	157.7	1096.0	25
1982	211.5	66.6	80	126	23.4	136.2	52.3	84	66.1	49.6	126.1	77.6	1099.4	26
1949	138.7	85.3	83.6	116.8	76.5	50	27.2	60.5	132.3	52.8	135.9	143.8	1103.4	27
1955	61	69.3	138.9	74.4	41.7	48.8	107.7	133.1	137.2	79	141.2	74.2	1106.5	28
1886	162.1	111.5	95.5	20.8	126.7	40.4	71.4	111.8	144.8	88.1	M	134.6	1107.7	29
1934	85.1	194.1	92.7	85.3	42.7	66.5	19.6	25.1	75.9	86.4	191	143.3	1107.7	30
1932	175.3	125.5	78.7	84.1	61	96.8	101.6	76.2	72.6	62.5	108.5	67.1	1109.9	31
1883	105.9	97.8	116.1	70.9	128.3	33.5	77.5	87.4	67.6	128.5	63.2	146.1	1122.8	32
1989	61.4	128.4	116.8	83.6	116	90.2	69.6	43.2	52.4	90.8	184.6	89.2	1126.2	33
1913	99.6	100.8	147.1	126.5	183.4	36.3	97.8	15.7	32.8	143.3	30.5	114.6	1128.4	34
2000	170	60.8	103.4	76	84.5	16.7	64	98.2	90.8	126.5	94.6	145.8	1131.3	35
1880	134.6	163.1	94.2	88.4	115.8	17.5	97.3	46.7	93.2	104.9	84.6	92.2	1132.5	36
1935	165.4	116.6	80.3	68.1	53.3	102.1	81.3	113	106.9	53.3	96.3	100.8	1137.4	37
1999	122.1	63	140.4	31.7	62.2	16.6	119	107.6	116.8	137.8	91.9	128.5	1137.6	38
1940	118.6	113.8	84.1	122.2	48.3	79.8	58.9	15.5	172.7	50.8	121.9	157.2	1143.8	39
1884	100.1	195.6	100.3	77.5	64.5	38.6	149.9	108.2	22.4	68.8	85.9	139.2	1151.0	40
1920	74.7	180.1	81	122.9	59.7	79.8	137.4	64.3	95.3	27.7	108	121.2	1152.1	41
1904	140	141.5	69.3	175.5	100.6	37.1	64.3	106.4	76.7	103.4	64.5	77.2	1156.5	42
1961	90.4	86.4	85.9	105.2	103.1	54.4	118.1	44.7	54.1	179.6	152.1	84.3	1158.3	43
1908	128.5	80.5	69.6	142.5	96.8	51.3	86.1	106.9	58.2	134.1	45.2	159.8	1159.5	44
1947	122.7	62.5	145.5	144.5	151.6	144.8	56.1	5.6	101.9	22.9	112.3	103.4	1173.8	45
1926	148.6	138.2	131.8	105.7	50	119.4	37.8	26.9	87.1	133.9	74.2	128	1181.6	46
1882	157.7	197.4	155.7	91.2	34.8	84.1	16.8	16	122.7	183.9	38.4	83.3	1182.0	47
1987	179.6	47	58	55	109.2	86.6	30.4	29.2	207.6	126.8	128.4	129.2	1187.0	48
1896	50	108.2	177.5	35.8	94.5	89.2	146.8	109.5	78.7	113.8	95.8	88.6	1188.4	49
1939	123.4	115.1	171.7	155.7	52.6	81.8	78.7	48.3	89.7	127.5	29.7	117.6	1191.8	50
1901	128.5	77.5	123.4	115.1	130.3	65	69.9	73.2	107.7	61.2	77	163.3	1192.1	51
1995	107.6	134.6	51	87.4	63.2	109.8	153.6	30.8	58.8	104.2	174.4	117.6	1193.0	52
1944	39.9	150.4	132.3	128.5	17.3	128.3	75.2	25.1	125.5	157.2	120.4	93.7	1193.8	53
1970	38.1	92.5	93.5	107.2	82	91.4	59.7	209	97.8	95.5	78	150.4	1195.1	54
1928	152.7	137.2	75.7	152.9	82.6	79.2	108.5	53.6	106.9	23.9	64.5	160.8	1198.5	55
1980	77.6	56.5	151.3	88.9	48.6	112.6	99.8	11.6	100.7	95	181.9	174	1198.5	56
1881	84.8	137.2	120.1	60.7	194.6	103.1	68.3	73.2	47	87.1	87.1	138.4	1201.6	57
1998	235.1	79.6	144.2	49.3	71.7	95.3	44.3	82.4	112.1	143.1	89.1	57.2	1203.4	58
1968	148.1	62.2	105.4	59.7	98.6	184.2	11.7	56.6	42.9	119.6	163.1	156.7	1208.8	59
1969	105.7	94	68.3	146.1	81.8	18.8	121.4	56.4	113	61.7	127.3	221.7	1216.2	60
1889	89.4	154.4	76.7	150.9	66.3	110.2	139.4	77	38.1	119.9	140.2	62	1224.5	61
2003	110.5	161.4	171.7	78.9	62	99.2	30.6	155.6	53	121.2	80.2	108	1232.3	62
1899	158	86.4	182.9	56.6	49.8	73.9	179.8	37.8	56.6	163.6	86.4	103.6	1235.4	63
1974	98.8	148.8	83.3	97	124.5	74.7	36.8	115.1	135.4	95.3	143	84.6	1237.3	64
1895	150.6	85.3	133.1	76.2	134.1	59.2	38.1	122.2	66.8	77	189.7	107.4	1239.7	65

1962	98.6	102.4	25.7	182.9	28.2	78	52.1	107.4	159	75.9	197.6	133.4	1241.2	66
1938	119.1	86.9	112.5	117.1	68.8	149.6	138.9	24.6	150.1	70.1	88.1	117.1	1242.9	67
1942	164.8	68.3	181.1	69.6	83.8	100.3	40.1	52.6	100.1	151.4	103.4	129.3	1244.8	68
1985	94	84.4	107.6	61.3	140.5	163.4	45	205.2	22.2	74.6	161.9	86.2	1246.3	69
1931	131.6	142.7	107.7	97	117.6	145.8	33.3	91.4	121.4	115.6	27.9	114.6	1246.6	70
1946	104.9	184.7	50.5	171.5	126.2	77	42.2	93.7	116.6	50	52.6	177	1246.9	71
1885	151.4	95.8	154.2	62.5	75.7	49.3	57.9	173.7	33.3	81.3	84.3	235.2	1254.6	72
1936	148.8	62.5	117.1	89.2	37.3	117.6	48.3	92.7	150.1	126.2	81.5	187.7	1259.0	73
1997	146.4	112.4	193.6	131.8	138.9	94.4	13.4	72.2	60	44.4	138.8	114.9	1261.2	74
1918	86.6	103.6	64.3	58.7	41.1	64.5	150.4	37.6	222.8	123.2	175.8	132.8	1261.4	75
2002	122.4	59.2	138.2	94	73.6	93.8	82.4	25.8	140.2	73.8	249.9	110	1263.3	76
2004	89.4	138.8	90.6	153.8	72.4	26.8	127.4	87.9	63.6	67.8	194.5	156.8	1269.8	77
1917	124	145.3	123.4	144.5	116.1	87.9	47.2	53.6	48.3	205.2	90.2	86.1	1271.8	78
1988	83.6	145.8	46.8	118	33.2	114	178.6	60.4	92.4	131.4	196.4	73.4	1274.0	79
1927	96.3	105.9	31	72.1	98.6	33	130.3	252	77.5	118.1	127.8	134.1	1276.7	80
1937	105.4	43.4	83.6	121.9	149.9	119.9	93.5	89.7	107.7	97	125	147.3	1284.3	81
1983	91.8	101.1	148.7	150.1	155.8	36.5	126.1	105.8	20	72.9	138.9	137.1	1284.8	82
1991	114.6	57.7	157.3	100.4	40.2	31.2	113.5	160.4	113.5	97.6	174.4	125.7	1286.5	83
1993	99.2	107	108.9	84.2	82.4	107.4	42.4	28.4	102.8	180.6	133.4	210.6	1287.3	84
1951	137.2	86.6	65.5	90.2	135.4	26.4	105.4	131.8	96.5	65.5	192.5	164.8	1297.8	85
1972	128	112.5	94.5	95.8	148.8	86.1	38.6	33.8	90.9	124.7	208.3	138.9	1300.9	86
1952	268	129.8	64.5	49.3	102.4	118.6	24.6	259.8	51.1	101.6	38.4	98.3	1306.4	87
1976	187.2	96.8	77	56.9	153.2	68.8	52.6	30.7	148.3	157	69.6	215.9	1314.0	88
1892	229.1	65.3	175.5	65.3	139.2	39.4	64.5	112.8	73.4	50.5	190.5	115.6	1321.1	89
1897	171.7	57.9	132.8	180.8	165.1	133.1	99.8	88.4	32	19.8	188	52.8	1322.2	90
1975	186.7	73.9	108.5	79	44.7	50.3	68.8	52.3	113	171.2	186.4	191.5	1326.3	91
1929	187.2	117.1	104.6	114.3	109.5	34.8	40.4	108.5	171.7	89.2	118.6	132.3	1328.2	92
1906	86.6	120.4	179.1	98.8	158.2	51.8	168.7	27.4	72.9	80	113	174.5	1331.4	93
1964	124.5	184.2	119.6	113.3	30.2	72.1	90.9	164.6	72.9	100.8	78.5	179.8	1331.4	94
1891	142	177	86.6	91.2	58.7	64.8	107.7	88.9	141	191.3	42.2	143	1334.4	95
1990	127	108.8	44.8	134.8	192.8	124.8	145.2	8.4	82.6	113.2	97.6	154.8	1334.8	96
1890	125	126.5	190.5	61.7	82	108.5	65.8	89.4	118.9	111	92.7	164.8	1336.8	97
1902	82.6	79.2	273.1	99.8	81.5	136.7	92.7	61.5	112.3	88.6	78.2	151.4	1337.6	98
1979	230.9	178.8	122.3	104.8	148.9	94.6	68.7	M	M	135	165	105.7	1354.7	99
1887	168.9	107.7	137.2	144.8	61.7	58.2	13.2	243.6	64.8	33	125.5	200.4	1359.0	100
1943	100.6	172.7	84.1	79	127.3	128	133.1	89.9	75.7	95.3	185.9	95.3	1366.9	101
1893	126.7	187.2	49.8	88.9	107.7	92.7	61.2	140.2	133.6	112.8	56.1	218.7	1375.6	102
1986	139.4	93.6	159.2	91.8	79.4	141	137.4	84.8	125.4	98	114.8	116.8	1381.6	103
1984	144.8	193.4	147.4	149.1	150.8	150.6	77.2	84.6	66	55.8	38.8	123.8	1382.3	104
1898	120.7	73.9	72.4	109.7	53.1	51.6	168.4	160.8	116.8	141	214.4	109.5	1392.3	105
1973	86.4	156.2	93.2	133.9	80.8	203.5	176	87.6	33.3	88.1	93.5	163.6	1396.1	106
1954	155.7	136.1	103.4	86.1	89.2	128.5	82	93	71.9	169.9	150.1	144.3	1410.2	107
1963	127.5	143.3	122.4	126.2	121.9	47.5	40.4	143.8	81.3	67.8	238.3	152.9	1413.3	108
1945	179.8	110.7	93.7	69.1	217.2	172.5	35.6	73.2	34	135.1	169.4	136.1	1426.4	109
1919	127.8	70.1	92.5	113	197.1	44.5	113.3	123.4	87.4	132.1	236	89.7	1426.9	110
1977	158.6	75.9	130.7	120.4	40	112.6	122.6	57	114.4	197.7	107.5	189.7	1427.1	111
1956	312.2	159	158.2	88.4	136.1	34.8	59.9	134.9	60.7	66.8	110.5	106.2	1427.7	112
2006	76.6	96.6	38.8	91.8	126.4	263.4	166.6	71	53	163.8	162.6	126.4	1437.0	113
1933	108.7	123.2	151.9	92.7	98.3	51.6	78	92.5	125	196.9	130.3	208	1457.1	114
1958	208.3	127	32.3	151.1	144.8	87.4	60.7	181.4	141.7	89.4	136.4	102.6	1463.1	115
1981	161.6	76.7	96.3	95.8	99.6	112.6	170.2	30.8	99	159.7	144.6	226.3	1473.2	116
1950	197.6	91.2	113.5	105.4	51.8	88.4	79.8	112.8	91.9	50.3	291.8	204.5	1479.0	117
1953	149.4	196.1	261.6	88.4	87.4	22.9	148.6	127.8	133.1	92.2	35.3	148.1	1490.9	118
1994	162	56.2	267	145.8	209.2	81.8	17.4	124.8	99.6	57	148.2	159	1528.0	119
1900	178.6	122.7	144.5	106.2	120.4	76.5	67.3	83.3	131.1	289.1	124.2	89.2	1533.1	120
1903	134.6	71.1	185.2	156.2	23.6	169.7	90.4	118.4	126.2	146.6	157.2	158	1537.2	121
1948	249.9	111	144.5	117.9	245.9	136.7	54.9	26.2	21.1	156	190	101.3	1555.4	122
1996	95.4	140.9	107.5	148.1	120	131.6	116.4	61.2	363.4	122.7	61.3	143	1611.5	123
1967	121.2	150.4	108.5	75.7	126.2	65.5	196.1	105.4	111.5	190.8	161.8	275.8	1688.9	124
1959	172.5	121.7	113.5	101.1	30	218.9	106.7	34.8	82	381.5	248.7	121.4	1732.8	125
2005	165.2	66	101.4	188.8	282.8	45.8	85	85.8	136.6	262.2	167	164.6	1751.2	126
1888	192.3	120.7	138.7	90.2	81	73.4	213.9	125.5	139.2	255.8	217.4	152.9	1801.0	127
												average	1240.1	
												Median	1237.3	

Table 2 - Ranking of Driest to Wettest Summers (1880-2006, Yarmouth) - ranking based on summer months (June - August)

Year	January	February	March	April	May	June	July	August	September	October	November	December	Sum	Rank
1934	85.1	194.1	92.7	85.3	42.7	66.5	19.6	25.1	75.9	86.4	191.0	143.3	111.2	1
1882	157.7	197.4	155.7	91.2	34.8	84.1	16.8	16.0	122.7	183.9	38.4	83.3	116.9	2
1894	97.5	57.9	57.2	79.5	67.1	78.0	20.6	31.5	118.1	87.1	113.0	86.6	130.1	3
1949	138.7	85.3	83.6	116.8	76.5	50.0	27.2	60.5	132.3	52.8	135.9	143.8	137.7	4
1911	106.7	67.8	65.3	75.4	38.1	43.9	33.3	67.1	136.9	41.1	159.5	55.4	144.3	5
1987	179.6	47.0	58.0	55.0	109.2	86.6	30.4	29.2	207.6	126.8	128.4	129.2	146.2	6
1915	144.8	73.2	8.1	64.5	88.4	40.6	32.5	74.2	30.0	168.1	101.1	121.2	147.3	7
1913	99.6	100.8	147.1	126.5	183.4	36.3	97.8	15.7	32.8	143.3	30.5	114.6	149.8	8
1976	187.2	96.8	77.0	56.9	153.2	68.8	52.6	30.7	148.3	157.0	69.6	215.9	152.1	9
1960	85.3	193.8	101.3	76.7	124.5	80.5	47.5	24.9	48.8	94.5	69.6	125.7	152.9	10
1940	118.6	113.8	84.1	122.2	48.3	79.8	58.9	15.5	172.7	50.8	121.9	157.2	154.2	11
1972	128.0	112.5	94.5	95.8	148.8	86.1	38.6	33.8	90.9	124.7	208.3	138.9	158.5	12
1957	184.2	57.7	64.3	122.7	85.6	23.4	84.3	52.8	65.8	79.2	176.5	89.7	160.5	13
1880	134.6	163.1	94.2	88.4	115.8	17.5	97.3	46.7	93.2	104.9	84.6	92.2	161.5	14
1979	230.9	178.8	122.3	104.8	148.9	94.6	68.7	M	M	135.0	165.0	105.7	163.3	15
1978	182.5	26.2	79.0	129.2	47.1	76.3	33.5	56.8	70.0	110.7	49.0	131.4	166.6	16
1909	90.7	85.9	133.9	96.3	128.5	50.0	87.4	32.0	105.4	67.8	125.7	47.8	169.4	17
1975	186.7	73.9	108.5	79.0	44.7	50.3	68.8	52.3	113.0	171.2	186.4	191.5	171.4	18
1993	99.2	107.0	108.9	84.2	82.4	107.4	42.4	28.4	102.8	180.6	133.4	210.6	178.2	19
2000	170.0	60.8	103.4	76.0	84.5	16.7	64.0	98.2	90.8	126.5	94.6	145.8	178.9	20
1921	71.4	106.7	79.8	68.6	39.4	47.8	73.9	57.9	58.9	50.5	124.7	80.5	179.6	21
1997	146.4	112.4	193.6	131.8	138.9	94.4	13.4	72.2	60.0	44.4	138.8	114.9	180.0	22
1965	82.0	119.4	20.1	63.0	24.9	71.9	27.4	83.6	28.4	80.3	104.6	101.1	182.9	23
1966	109.2	73.2	68.3	17.3	146.6	64.5	33.0	85.9	98.3	78.2	94.5	111.0	183.4	24
1929	187.2	117.1	104.6	114.3	109.5	34.8	40.4	108.5	171.7	89.2	118.6	132.3	183.7	25
1926	148.6	138.2	131.8	105.7	50.0	119.4	37.8	26.9	87.1	133.9	74.2	128.0	184.1	26
1917	124.0	145.3	123.4	144.5	116.1	87.9	47.2	53.6	48.3	205.2	90.2	86.1	188.7	27
1942	164.8	68.3	181.1	69.6	83.8	100.3	40.1	52.6	100.1	151.4	103.4	129.3	193.0	28
1923	M	53.8	105.7	134.1	73.7	74.4	53.3	67.6	82.0	85.3	104.6	174.2	195.3	29
1969	105.7	94.0	68.3	146.1	81.8	18.8	121.4	56.4	113.0	61.7	127.3	221.7	196.6	30
1883	105.9	97.8	116.1	70.9	128.3	33.5	77.5	87.4	67.6	128.5	63.2	146.1	198.4	31
2002	122.4	59.2	138.2	94.0	73.6	93.8	82.4	25.8	140.2	73.8	249.9	110.0	202.0	32
1989	61.4	128.4	116.8	83.6	116.0	90.2	69.6	43.2	52.4	90.8	184.6	89.2	203.0	33
1912	86.9	75.2	82.3	88.4	131.6	38.6	98.0	67.3	70.4	98.3	101.3	157.7	203.9	34
1947	122.7	62.5	145.5	144.5	151.6	144.8	56.1	5.6	101.9	22.9	112.3	103.4	206.5	35
1904	140.0	141.5	69.3	175.5	100.6	37.1	64.3	106.4	76.7	103.4	64.5	77.2	207.8	36
1901	128.5	77.5	123.4	115.1	130.3	65.0	69.9	73.2	107.7	61.2	77.0	163.3	208.1	37
1992	86.1	123.2	90.5	81.6	30.0	82.1	62.4	63.8	79.5	98.4	149.0	100.0	208.3	38
1939	123.4	115.1	171.7	155.7	52.6	81.8	78.7	48.3	89.7	127.5	29.7	117.6	208.8	39
1907	101.3	108.2	56.4	70.6	55.9	38.4	50.8	120.9	115.3	121.4	133.9	114.0	210.1	40
1946	104.9	184.7	50.5	171.5	126.2	77.0	42.2	93.7	116.6	50.0	52.6	177.0	212.9	41
2005	165.2	66.0	101.4	188.8	282.8	45.8	85.0	85.8	136.6	262.2	167.0	164.6	216.6	42
1892	229.1	65.3	175.5	65.3	139.2	39.4	64.5	112.8	73.4	50.5	190.5	115.6	216.7	43
1961	90.4	86.4	85.9	105.2	103.1	54.4	118.1	44.7	54.1	179.6	152.1	84.3	217.2	44
1948	249.9	111.0	144.5	117.9	245.9	136.7	54.9	26.2	21.1	156.0	190.0	101.3	217.8	45
1895	150.6	85.3	133.1	76.2	134.1	59.2	38.1	122.2	66.8	77.0	189.7	107.4	219.5	46
1910	177.3	95.5	64.5	142.0	39.6	130.3	48.5	42.9	97.0	49.5	68.8	75.9	221.7	47
1998	235.1	79.6	144.2	49.3	71.7	95.3	44.3	82.4	112.1	143.1	89.1	57.2	222.0	48
1933	108.7	123.2	151.9	92.7	98.3	51.6	78.0	92.5	125.0	196.9	130.3	208.0	222.1	49
1886	162.1	111.5	95.5	20.8	126.7	40.4	71.4	111.8	144.8	88.1	M	134.6	223.6	50
1914	78.0	99.6	78.2	73.4	75.7	99.6	27.9	96.3	53.3	70.9	74.4	96.5	223.8	51
1980	77.6	56.5	151.3	88.9	48.6	112.6	99.8	11.6	100.7	95.0	181.9	174.0	224.0	52
1994	162.0	56.2	267.0	145.8	209.2	81.8	17.4	124.8	99.6	57.0	148.2	159.0	224.0	53
1974	98.8	148.8	83.3	97.0	124.5	74.7	36.8	115.1	135.4	95.3	143.0	84.6	226.6	54
1900	178.6	122.7	144.5	106.2	120.4	76.5	67.3	83.3	131.1	289.1	124.2	89.2	227.1	55
1971	112.8	115.3	95.0	58.2	115.6	22.4	59.4	145.3	37.3	51.8	141.2	128.3	227.1	56
1944	39.9	150.4	132.3	128.5	17.3	128.3	75.2	25.1	125.5	157.2	120.4	93.7	228.6	57
1956	312.2	159.0	158.2	88.4	136.1	34.8	59.9	134.9	60.7	66.8	110.5	106.2	229.6	58
1963	127.5	143.3	122.4	126.2	121.9	47.5	40.4	143.8	81.3	67.8	238.3	152.9	231.7	59
1930	98.6	121.2	110.2	62.7	44.5	17.5	166.4	51.1	13.0	127.0	70.4	157.2	235.0	60
1905	118.1	100.1	36.8	32.3	91.4	91.7	65.0	79.8	124.0	37.6	154.7	78.0	236.5	61
1962	98.6	102.4	25.7	182.9	28.2	78.0	52.1	107.4	159.0	75.9	197.6	133.4	237.5	62
1928	152.7	137.2	75.7	152.9	82.6	79.2	108.5	53.6	106.9	23.9	64.5	160.8	241.3	63
2004	89.4	138.8	90.6	153.8	72.4	26.8	127.4	87.9	63.6	67.8	194.5	156.8	242.1	64
1999	122.1	63.0	140.4	31.7	62.2	16.6	119.0	107.6	116.8	137.8	91.9	128.5	243.2	65

1908	128.5	80.5	69.6	142.5	96.8	51.3	86.1	106.9	58.2	134.1	45.2	159.8	244.3	66
1881	84.8	137.2	120.1	60.7	194.6	103.1	68.3	73.2	47.0	87.1	87.1	138.4	244.6	67
1906	86.6	120.4	179.1	98.8	158.2	51.8	168.7	27.4	72.9	80.0	113.0	174.5	247.9	68
2001	92.8	68.2	116.0	58.6	72.4	97.2	54.8	98.6	18.8	101.0	118.4	108.7	250.6	69
1968	148.1	62.2	105.4	59.7	98.6	184.2	11.7	56.6	42.9	119.6	163.1	156.7	252.5	70
1918	86.6	103.6	64.3	58.7	41.1	64.5	150.4	37.6	222.8	123.2	175.8	132.8	252.5	71
1936	148.8	62.5	117.1	89.2	37.3	117.6	48.3	92.7	150.1	126.2	81.5	187.7	258.6	72
1924	154.4	47.5	61.0	68.6	79.5	59.2	40.6	158.8	102.4	89.9	61.0	82.0	258.6	73
1891	142.0	177.0	86.6	91.2	58.7	64.8	107.7	88.9	141.0	191.3	42.2	143.0	261.4	74
1951	137.2	86.6	65.5	90.2	135.4	26.4	105.4	131.8	96.5	65.5	192.5	164.8	263.6	75
1890	125.0	126.5	190.5	61.7	82.0	108.5	65.8	89.4	118.9	111.0	92.7	164.8	263.7	76
1983	91.8	101.1	148.7	150.1	155.8	36.5	126.1	105.8	20.0	72.9	138.9	137.1	268.4	77
1931	131.6	142.7	107.7	97.0	117.6	145.8	33.3	91.4	121.4	115.6	27.9	114.6	270.5	78
1982	211.5	66.6	80.0	126.0	23.4	136.2	52.3	84.0	66.1	49.6	126.1	77.6	272.5	79
1941	147.1	51.8	101.6	27.7	104.1	54.1	97.5	121.9	35.3	113.5	111.3	94.5	273.5	80
1932	175.3	125.5	78.7	84.1	61.0	96.8	101.6	76.2	72.6	62.5	108.5	67.1	274.6	81
1990	127.0	108.8	44.8	134.8	192.8	124.8	145.2	8.4	82.6	113.2	97.6	154.8	278.4	82
1885	151.4	95.8	154.2	62.5	75.7	49.3	57.9	173.7	33.3	81.3	84.3	235.2	280.9	83
1950	197.6	91.2	113.5	105.4	51.8	88.4	79.8	112.8	91.9	50.3	291.8	204.5	281.0	84
1919	127.8	70.1	92.5	113.0	197.1	44.5	113.3	123.4	87.4	132.1	236.0	89.7	281.2	85
1945	179.8	110.7	93.7	69.1	217.2	172.5	35.6	73.2	34.0	135.1	169.4	136.1	281.3	86
1920	74.7	180.1	81.0	122.9	59.7	79.8	137.4	64.3	95.3	27.7	108.0	121.2	281.5	87
2003	110.5	161.4	171.7	78.9	62.0	99.2	30.6	155.6	53.0	121.2	80.2	108.0	285.4	88
1955	61.0	69.3	138.9	74.4	41.7	48.8	107.7	133.1	137.2	79.0	141.2	74.2	289.6	89
1902	82.6	79.2	273.1	99.8	81.5	136.7	92.7	61.5	112.3	88.6	78.2	151.4	290.9	90
1899	158.0	86.4	182.9	56.6	49.8	73.9	179.8	37.8	56.6	163.6	86.4	103.6	291.5	91
1977	158.6	75.9	130.7	120.4	40.0	112.6	122.6	57.0	114.4	197.7	107.5	189.7	292.2	92
1893	126.7	187.2	49.8	88.9	107.7	92.7	61.2	140.2	133.6	112.8	56.1	218.7	294.1	93
1995	107.6	134.6	51.0	87.4	63.2	109.8	153.6	30.8	58.8	104.2	174.4	117.6	294.2	94
1935	165.4	116.6	80.3	68.1	53.3	102.1	81.3	113.0	106.9	53.3	96.3	100.8	296.4	95
1884	100.1	195.6	100.3	77.5	64.5	38.6	149.9	108.2	22.4	68.8	85.9	139.2	296.7	96
1953	149.4	196.1	261.6	88.4	87.4	22.9	148.6	127.8	133.1	92.2	35.3	148.1	299.3	97
1916	73.7	100.1	137.7	73.7	64.3	170.7	92.7	36.1	58.2	80.8	55.1	149.1	299.5	98
1937	105.4	43.4	83.6	121.9	149.9	119.9	93.5	89.7	107.7	97.0	125.0	147.3	303.1	99
1954	155.7	136.1	103.4	86.1	89.2	128.5	82.0	93.0	71.9	169.9	150.1	144.3	303.5	100
1991	114.6	57.7	157.3	100.4	40.2	31.2	113.5	160.4	113.5	97.6	174.4	125.7	305.1	101
1996	95.4	140.9	107.5	148.1	120.0	131.6	116.4	61.2	363.4	122.7	61.3	143.0	309.2	102
1984	144.8	193.4	147.4	149.1	150.8	150.6	77.2	84.6	66.0	55.8	38.8	123.8	312.4	103
1938	119.1	86.9	112.5	117.1	68.8	149.6	138.9	24.6	150.1	70.1	88.1	117.1	313.1	104
1981	161.6	76.7	96.3	95.8	99.6	112.6	170.2	30.8	99.0	159.7	144.6	226.3	313.6	105
1887	168.9	107.7	137.2	144.8	61.7	58.2	13.2	243.6	64.8	33.0	125.5	200.4	315.0	106
1897	171.7	57.9	132.8	180.8	165.1	133.1	99.8	88.4	32.0	19.8	188.0	52.8	321.3	107
1889	89.4	154.4	76.7	150.9	66.3	110.2	139.4	77.0	38.1	119.9	140.2	62.0	326.6	108
1964	124.5	184.2	119.6	113.3	30.2	72.1	90.9	164.6	72.9	100.8	78.5	179.8	327.6	109
1925	84.6	47.8	83.1	74.2	53.1	176.0	108.2	44.2	75.7	148.8	108.5	78.7	328.4	110
1958	208.3	127.0	32.3	151.1	144.8	87.4	60.7	181.4	141.7	89.4	136.4	102.6	329.5	111
1896	50.0	108.2	177.5	35.8	94.5	89.2	146.8	109.5	78.7	113.8	95.8	88.6	345.5	112
1943	100.6	172.7	84.1	79.0	127.3	128.0	133.1	89.9	75.7	95.3	185.9	95.3	351.0	113
1988	83.6	145.8	46.8	118.0	33.2	114.0	178.6	60.4	92.4	131.4	196.4	73.4	353.0	114
1970	38.1	92.5	93.5	107.2	82.0	91.4	59.7	209.0	97.8	95.5	78.0	150.4	360.1	115
1959	172.5	121.7	113.5	101.1	30.0	218.9	106.7	34.8	82.0	381.5	248.7	121.4	360.4	116
1986	139.4	93.6	159.2	91.8	79.4	141.0	137.4	84.8	125.4	98.0	114.8	116.8	363.2	117
1967	121.2	150.4	108.5	75.7	126.2	65.5	196.1	105.4	111.5	190.8	161.8	275.8	367.0	118
1903	134.6	71.1	185.2	156.2	23.6	169.7	90.4	118.4	126.2	146.6	157.2	158.0	378.5	119
1898	120.7	73.9	72.4	109.7	53.1	51.6	168.4	160.8	116.8	141.0	214.4	109.5	380.8	120
1952	268.0	129.8	64.5	49.3	102.4	118.6	24.6	259.8	51.1	101.6	38.4	98.3	403.0	121
1888	192.3	120.7	138.7	90.2	81.0	73.4	213.9	125.5	139.2	255.8	217.4	152.9	412.8	122
1985	94.0	84.4	107.6	61.3	140.5	163.4	45.0	205.2	22.2	74.6	161.9	86.2	413.6	123
1927	96.3	105.9	31.0	72.1	98.6	33.0	130.3	252.0	77.5	118.1	127.8	134.1	415.3	124
1922	71.4	74.2	47.2	50.0	54.1	73.2	187.2	198.6	109.2	85.9	36.1	M	459.0	125
1973	86.4	156.2	93.2	133.9	80.8	203.5	176.0	87.6	33.3	88.1	93.5	163.6	467.1	126
2006	76.6	96.6	38.8	91.8	126.4	263.4	166.6	71.0	53.0	163.8	162.6	126.4	501.0	127

Undertaking 37

To advise on any quarries in the province that have undergone a environmental assessment, that have expanded after the assessment, and to advise on how each expansion approval was obtained.

Responses:

Sydney	No records meeting search criteria.
Hawkesbury	
Antigonish	
Pictou	
Truro	No records meeting search criteria.
Amherst	
Bedford	Tidewater went thru an Environmental Assessment back in 1984-86 and when Municipal purchased the property from Tidewater in early 2000 the property went thru an EA to expand the footprint and remove the restriction the production limit of 90,000 tonnes of material . 1.**Sovereign Resources Inc.** (subsidiary of Municipal Enterprises) located in Waverley/Bedford obtained an EA Approval for expansion in 2005 after holding an Industrial Approval #84-073. This is the former Tidewater quarry which went through an environmental assessment review of the day in 1984 -1986. The EA trigger for Sovereign was based on the Minister's discretion for expansion beyond the originally approval 18 hectare site.
Yarmouth	Bruce- no sites meeting search criteria
Bridgewater	Kristen-South Shore Sand and Gravel in Robinsons Corner currently have a quarry approval. They have submitted an ammendment application to expand the quarry in 2005. We are still waiting on more information as the application is incomplete. The EA branch was consulted in 2005 (yes, that application has been incomplete for some time but they are working on it!), and whereas the new quarry boundary was not an increase in "land holding", the expansion would not initiate an EA.
Kentville	

NSEL Response to Undertakings 38 and 39

Undertaking 38
To provide the most recent 5 year inspection record for the Aulds Cove Coastal Quarry

There have been 8 inspections during the last five year time period. The facility is listed as a medium risk facility (with a risk score of 42) requiring at least one inspection per year. Copies of the complete field inspection reports are available from the Port Hawkesbury office.

Undertaking 39
To provide information on whether or not blast residues and/or ammonia have been NSDEL regulatory issues at the Porcupine Mountain Quarry.

There is no requirement in regards to Groundwater monitoring outlined in the approval to operate the quarry at Porcupine Mountain (Approval # 2000-016493). However there has been some documented sampling and monitoring relating to the Bulk Coal Solids Handling Facility (Approval # 2000-017919-R01). The Bulk Coal Solids facility is on Martin Marietta property and is under approval to them.

a) Sampling Data Results:

The background sampling data results submitted by CBCL Limited which is included in the file is listed below:

Date Sampled	Parameter	Results	CCME
Background data	Nitrate/Nitrite	< 1.2 mg/L	10
Spring of 2002	Nitrate/Nitrite	<0.06 mg/L	10
July 2, 2003	Nitrate/Nitrite	<0.06 mg/L	10

The 2003 and 2004 sampling data results submitted by Environmental Services Lab Inc. which is included in the file is listed below:

Date Sampled	Parameter	Results	CCME
July 2, 2003	Nitrate/Nitrite	<0.06 mg/L	10

May 18, 2004	Nitrate/Nitrite	<0.06 mg/L	10

There have been no reported exceedences relating to Nitrates/Nitrites in the groundwater monitoring well over the past five years.

Natural Resources Canada / Ressources naturelles Canada

Whites Point Quarry and Marine Terminal Project

UNDERTAKING #41. Provide advice on the use of basalt fines as a soil conditioner and implications relating to copper mobility under those conditions.

Natural Resources Canada's Response:
Given that the stockpiled overburden is slightly acidic, mixing the basalt fines with such material will slightly enhance leaching of copper in the basalt. The extent of copper leaching will depend on how (i.e. in what form) copper occurs in the basalt, the grain size of the basalt fines and, the amount of basalt fines used in the soil production. However, the presence of organic matter in the stockpiled material will provide ample sorption sites for copper, attenuating its aqueous transport. In addition, it is well known that soluble copper-organic compounds are much less toxic than copper in its ionic form. That is why the threshold value of most water quality criteria for copper (e.g. those set by USEPA) increases with dissolved organic carbon content. Furthermore, to reduce the acidity or control the pH of the prospective soil to be used for reclamation, appropriate amounts of lime can be incorporated during soil preparation. Thus, if due care and precautionary measures are taken in the soil production process, copper leaching should not be a major concern in incorporating basalt fines as a component of the soil mixture to be used for site reclamation.

Whites Point Quarry and Marine Terminal Project

UNDERTAKING #42: Provide advice on the presence of explosive residues in the storage piles and its influence on the pH and Eh of wash water

Natural Resources Canada's Response:
(Based on the official transcript of the public hearing, it appears that there is some confusion regarding the composition of the explosive residues. It is perhaps useful to expand on the chemical reactions involved so as to improve understanding.) Ammonium Nitrate Fuel Oil (ANFO) is a powerful explosive made up of ammonium nitrate mixed with fuel oil. Upon intonation, nitrogen gas is generated, leading to an instantaneous, large increase in volume, which breaks up the target material. Nitrogen gas in itself is non-reactive and mostly dissipates into the atmosphere. Most of the environmental consequences associated with the use of ANFO derive from the unreacted remnants of ammonium nitrate. Ammonium nitrate will dissolve in water to give ammonium and nitrate ions (Equation 1). The former in turn will dissociate to some extent into dissolved ammonia and hydrogen ion (Equation 2). Dissolved ammonia is toxic and the released hydrogen ion can lower the pH. However, the ammonium ions are also in equilibrium with dissolved ammonia as expressed by Equation 3. The occurrence of the three reactions together limits the variation of pH of most of the affected natural waters to between 5.5 and 8.5, a range too narrow to significantly affect copper mobility from the basalt.

$$NH_4NO_3 \rightarrow NH_4^+ + NO_3^- \qquad \text{Equation 1}$$

$$NH_4^+ \rightarrow NH_3 + H^+ \qquad \text{Equation 2}$$

$$NH_3 + H_2O \leftrightarrow NH_4^+ + OH^- \qquad \text{Equation 3}$$

Although nitrogen is a multi-valence element with nitrogen gas being the most stable phase under atmospheric conditions, various compounds containing nitrogen in different oxidation states (e.g., nitrate, nitrite, etc.) do occur. The transformation of nitrogen-containing compounds in nature (i.e. nitrification and denitrification) is generally mediated by microorganisms. For that reason (i.e. slow reaction kinetics), the presence of explosive residues in the washed water and aggregates is not expected to significantly change the Eh environment or the extent of copper leaching.

PARTNERSHIP FOR SUSTAINABLE DEVELOPMENT
OF DIGBY NECK & ISLANDS SOCIETY

27 Bay Road (Box 25, Sandy Cove, NS B0V 1E0) (902) 834-2205
e.mail: mstanton@ns.sympatico.ca www:savedigbyneck.org

RECEIVED

TO: SECRETARIAT
JOINT REVIEW PANEL
PUBLIC HEARINGS
DIGBY PINES CONFERENCE CENTRE

FROM: MARILYN STANTON
TREASURER, PARTNERSHIP

DATE: MONDAY, JUNE 25, 2007

Undertaking 43

SUBJECT: UNDERTAKING: OVERVIEW OF THE SOCIETY

In response to the Panel's request for a summation of the structure and basic organizational data of the Partnership, I wish to submit the following documentation:

a) Summary Document: Society Organization; Membership of the Society; Financial Profile

b) Most recent Newsletter sent to the Society Membership. Page 6 of this newsletter depicts the roles assumed by the key players in the Society.
The Executive Committee: Kemp Stanton, Chair
Don Mullin, Vice-Chair
Marilyn Stanton, Treasurer
Ashraf Mahtab, Acting Secretary

c) Pamphlet of the Society for general distribution.

d) Copy (one only) of the Chronology that was prepared for a Professor of Environmental Studies in the USA.. When this was prepared one year ago, I made an extra copy for the Panel, but did not submit it, as I was not sure it was appropriate to do so. During the past five years, these Chronologies have been prepared for Nova Scotia Universities, as well. My understanding is that that these have provided material for case studies, used in Environmental Courses.

Respectfully submitted.

Marilyn Stanton, Treasurer

PARTNERSHIP FOR SUSTAINABLE DEVELOPMENT
OF DIGBY NECK & ISLANDS SOCIETY

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Prepared by: Marilyn Stanton, Treasurer
June 25, 2007

I SOCIETY ORGANIZATION

(PUBLIC) INAUGURAL MEETING HELD ON SEPTEMBER 20, 2002

CERTIFICATE OF INCORPORATION, SOCIETIES ACT, DATED JANUARY 22, 2003.

....

Board of Directors registered on Sept. 20, 2002 was 12 Directors, which included Chair, Vice-Chair, Secretary, and Treasurer.

Board of Directors registered after Annual Meeting held on August 15, 2006 was 14 Directors, which included Chair, Vice-Chair, Secretary and Treasurer.

....

Management of the affairs of the Society is carried out through Board Meetings of Directors (all Public welcome to attend, but seldom do so), which meets with adjusted frequency: as often as twice a week and as little as once a month. Meetings are held at the Sandy Cove School, monthly. The meetings in the summer are attended by 20 or more people; this number decreases to ten or less in the winter.

Administrative work is accomplished via e.mail through all Board Members, to facilitate operations, as it is strictly a volunteer effort.

The Board has no employees, but does retain the services of Lisa Mitchell, as an Environmental Consultant. Lisa often represents the Society, but is not a member and does not receive minutes of meetings.

****

AIMS & OBJECTIVES OF THE SOCIETY:

PARTNERSHIP FOR THE SUSTAINABLE DEVELOPMENT OF DIGBY NECK & ISLANDS SOCIETY

The objects of the Society are:

(a) TO PRESERVE THE PRISTINE NATURE OF DIGBY NECK AND ISLANDS AND TO PROMOTE SUSTAINABLE DEVELOPMENT THAT ENHANCES THE QUALITY OF LIFE.

(b) TO PROMOTE THE PRINCIPLE THAT THE COMMUNITY AFFECTED APPROVE ANY DEVELOPMENT PROPOSED.

©) TO CREATE A HEIGHTENED AWARENESS WHICH WILL NURTURE THE PRESERVATION AND STEWARDSHIP OF DIGBY NECK AND ISLANDS AND THE SURROUNDING WATERS.

(d) TO WORK WITH OTHER GROUPS HAVING SIMILAR AIMS AND OBJECTIVES.

(e) TO STOP THE MEGA-QUARRY FOR WHITE'S COVE, LITTLE RIVER, DIGBY NEC K, AND TO ACTIVELY OPPOSE OTHER DEVELOPMENTS WHICH ARE INCONSISTENT WITH THE ABOVE CRITERIA.

II MEMBERSHIP OF THE SOCIETY

Members in the Society have to signify that they are in agreement with the Aims and Objectives of the Society. Membership fee is $10 and the majority of members voluntarily pay their renewal each year. Membership is open to residents of Canada and United States.

Benefits of Membership: These are all intangible. They are joining with others to signify solidarity in preserving Digby Neck and receive all Newsletters, relevant information, Annual Reports, etc. Each member has the status of voting member at the Annual Meeting, of which they receive written notification, where officers are elected for the upcoming year and the auditors report is received to validate the financial statements of the Society.

Benefit to Society (Partnership)

a) A way to identify supporters and maintain records of donations, so that we will not be accused of the same thing we were in the early stages -- having school children sign our petition to swell the numbers and magnify the support enjoyed by our organization.

b) Have a pool of supportive individuals to whom to appeal when funds are required. These appeals have only had to be made several times, as members semi-regularly send donations for the work of the Society. These monies augment what we are able to raise at fund-raising dinners in Sandy Cove, which generally result in revenue of $5,000 to $7,000, each event.

****

III PROFILE OF MEMBERSHIP

- 540 Members belong to the Society. 99% of these are adults
- 350 Mailing pieces are needed to send materials to members, as there are a considerable number of multiple members at the same address.

Based on an analysis of the postal codes in the mailing addresses, the following is the breakdown of the 350 mailings (representing 540 Members):

55	USA Deliveries in Fall & Winter months. The majority of these are summer residents, usually here for five or six months of the year, and who own properties in the area. The few who do not fit this category are usually close family members of summer residents. For convenience sake, they are classed as 'tourists', but they are usually visiting close family on Digby Neck.
36	Canadian – outside of the Province of Nova Scotia
42	Nova Scotia – outside of Digby Neck & Islands
11	Town of Digby
178	Digby Neck
28	Islands

NOTE:
There are approx. 400 households on Digby Neck
There are approx. 400 households on The Islands (combined)

IV FINANCIAL PROFILE
(Society incorporated January, 2003)

PERIOD	RECEIPTS	EXPENDITURES
July 2002 – June 2003	$ 22,494.92	$ 15,887.64
June 2003 – May 2004	20,889.71	22,52329
June 2004 – May 2005	32,224.54	19,791.12
June 2005 – May 2006	15,375.06	28,703.88
June 2006 – May 2007	32,594.18 (E)*	28,200.00 (E)**
TOTALS	$ 123,578.41	$ 115,105.93

* Includes $11,625 advance – Participant Funding
** Includes $11,625 expenditures – Participant Funding

SUMMARY: Over $100,000 was raised by the Community through Lobster Chowder Suppers, Membership Monies and Donations from Supporters during the five-year period.

Outside of Participant Funding, there are no other Grants or Corporate Donors. EXCEPT, the thousands of dollars represented by the pro-bona work of the Experts. As a guesstimate, we have identified the following:

$20,000	Drs. Meinhard & Peter Duinker. ($120 per hr., 80 hrs. each)
70,000	15 experts that worked with us on the submission and the panel hearings (40 hours each)
6,000	10 experts contributing 5 hours each.
$96,000	SUGGESTED TOTAL DONATION

5 FTE -- Members of the executive along with some key supporters of the Partnership would probably represent the equivalent of five full-time staff members.

NEWSLETTER

Partnership for the Sustainable Development of Digby Neck and Islands Society

Volume Two June 2006

STOP the QUARRY

FROM THE EDITOR

Well, it has finally arrived – all 3,000 pages in 17 Volumes of the EIS (Environmental Impact Statement), produced by Bilcon of Nova Scotia, commonly referred to as 'The Proponent'.

Everyone is excited and awed at the wealth of detail provided, and concerned that they might not understand enough of the jargon or intent of the publication, to make a meaningful response. DON'T BE – AND HERE IS WHY NOT!

No amount of "mitigation" will bring back the beauty and peace once it's destroyed

At the first public meeting in May 2002 (attended by federal and provincial officials and the Proponent's local representative), we were told that "Panel Reviews" do not stop quarries. We were incensed and angry at the very idea! To us, the very idea of 'the highest review in the land' was a measure of success beyond our wildest dreams (especially since everyone told us we could never elevate this project to that exalted status.)

Today, we are much sadder and wiser. A panel review is simply a review to assess the environmental impacts on an area where a project is proposed .We have over 40 experts and two consultants, along with selected individuals, who will assess every word of that statement – all 3,000 pages. This 'assessment team' will point out where the guidelines have not been met and/or where the information is inadequate. One vital component of that review, according to the draft guidelines, is the impact on the people – their health and happiness – their quality of life and the things they value. We, the membership of the Society, the ordinary people, are the 'experts' in this vital area! We do not need to read any document produced by Bilcon or anyone else to know how a mega-quarry would affect our way of life. We don't need anyone to tell us that we do not want the beauty of this peaceful, serene area disturbed and distorted by the industrialization that a quarry must cause! WE MUST MAKE THIS KNOWN, FAR AND WIDE. EVERYTHING TO DATE HAS BEEN A DRESS REHEARSAL (including the first round of the panel's public meetings to review the guidelines.)

So, you see, we don't even need to read the EIS to make the Panel, The Proponent, The Federal and Provincial Government and our fellow-Nova Scotians aware that we do not wish this Industrialization in our area. There is no possible 'mitigation' or 'remediation' the Proponent or anyone else can offer, that would compensate for the fact that our culture and the ambience of our area would be shattered by the blasting and grinding of a rock quarry.

The Proponent (and the Government) would be very happy if we merely 'followed the process' and stayed within the confines of the Review and the EIS (Environmental Impact Statement). This would greatly simplify matters. HOWEVER, the EA Consultants

Continued on next page...

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C0918-065

Remember the heavy rains in June? Wonder what was happening down at the quarry site?

June has been wet. Very wet. Down at the quarry site during one very rainy day, our friend Jerome was trekking around with his camera. And what he found was water overflowing everywhere, from sediment ponds, through ditches, over roads. Any sediment caused by earlier quarry operations had pretty much been washed away.
Most likely, most of it ended up in the Bay of Fundy. We admit these rains have been heavy this June. Many are now worried that if the sediment from a small quarry can't be contained, what will happen when and if they develop the mega quarry and we get another heavy rainfall.

EDITORIAL...from page one

assure us that the EIS is only ONE aspect of the assessment. There are other, equally important factors in the final decision. Please remember that the Panel Review could find that the proposed Quarry would be ecologically detrimental and the Environment Ministers could decide to take that under advisement and PROCEED TO ISSUE THE PERMIT TO QUARRY, in spite of the recommendations of the Panel.

THAT'S WHERE WE COME IN! WHAT CAN WE DO?

We've got to 'take this to the people' – meetings from Yarmouth to Halifax, to make people aware of this project. Many people think this is a benchmark project – if a mega-quarry is acceptable on a narrow peninsula in the Bay of Fundy, given the delicate ecosystem of the area, a case can be made to have it anywhere in Nova Scotia! Or Canada-wide, as this is a Federal Review!

The Society, with its small complement of six or eight active board members, representing 450 registered members, has taken this fight as far as they can go. Over four years, they have raised adequate funds to assure a complete, professional review of the EIS (Environmental Impact Statement). Through the efforts of our Environmental Consultants (who will see this through to an official report to the Panel on behalf of the Society), 40 plus, 'experts' will work on this on a "no-fee" basis.

The next step is totally in the hands of the people! We need funds and we need volunteers to raise those funds and to spread the word! We have secured the services of a Public Affairs Coordinator, who will orchestrate objections to the mega-quarry through the Public sector, the Political arena and the Press This is not possible through a volunteer board, no matter how dedicated. Politicians and Proponents spend hundreds of thousands of dollars to generate their public images. We do not have the deep pockets of the Proponents, but we have something priceless that cannot be purchased for many hundreds of thousands: We have love of our land, our homes and our heritage and we will fight to the end, to save them from resource exploitation by our own government!

This will be our last opportunity to show we care. As one supporter stated recently, it's 'CRUNCH TIME'.
The Editor

WHAT HAVE YOUR SOCIETY CONTRIBUTIONS ACCOMPLISHED?

(Please forgive the length of this list – it could have been longer, but we merely wanted to overview for you, how much has been accomplished with your support.$73,849 has been expended by the Society since June of 2002. This money was raised by what some call the 'bake-sale/church supper' approach. (This does not include the $5668.00 that was provided by the participant-funding program, for the first round of public meetings.)

THROUGH OUR ENVIRONMENTAL CONSULTANTS:

- petitioned for a panel review to elevate the environmental assessment from a Comprehensiv Study to a Review Panel, the most stringent review used in Canada.
- networked throughout province, to locate the best possible expertise available to the Society, of experts willing to work with an advocacy group.
- organized a workshop for NGO (non-government organization) groups who were interested in opposing the quarry.
- through our environmental consultants, generated an official, expert assessment of the generic guidelines with complete and detailed recommendations to make the ultimate guidelines specific to the Digby Neck.
- supported community in presenting viewpoints – "Our Neck on the Line" & 'VEC's' (valued environmental components) presentations to the panel

SOCIETY MEMBERS HAVE ADDRESSED THE FOLLOWING GROUPS:

- Town Council, Digby
- Digby Municipal Council
- Enviro Clare
- Digby Bd. Of Trade
- Annual Meeting, Council of Canadians, Halifax
- Standing Committee of Fisheries and Oceans, Halifax
- Power Point Presentation – Acadia/ Wolfville
- Power Point Presentation – Digby Public Meeting
- Power Point Presentation – Digby Neck Public Meeting
- STQ was one of four groups fighting provincial water issues who were invited by the Council of Canadians to participate in the symposium for World Water Day – Halifax, 2006

THE SOCIETY HAS PROVIDED THE HOSPITALITY TO VISITING INDIVIDUALS AND/ OR GROUPS.

- Politicians who have visited the site, at the request or invitation of the Society
- Gulf of Maine Kayakers who studied the Bay of Fundy environs several years ago, interacting with group over a three-day period.
- Student Groups from St. Xavier, ST. Mary's Univ. and Anna. Valley High School, providing hospitality and information suitable to the depth of study and interest of the relevant group.
- Last summer, hosted the lobster chowder dinner and presentations to the International Sierra Club representatives who were visiting Nova Scotia to attend their AGM on the Eastern Shore of N.S.

THE SOCIETY HAS PROVIDED INTERFACE WITH UNIVERSITIES:

- ACADIA – power point presentation – Janet Eaton
- DALHOUSIE – power point presentation – LJM Environmental Consulting
- DALHOUSIE – sequential events list for assessment as potential case study for environmental/law students in spring of 2006.
- ST. MARY'S UNIVERSITY &
- ST. XAVIER UNIVERSITY — documented materials provided in the form of a 'progression of events' scrapbook sent to both universities for use in teaching environmental course, as a 'case study'

THE SOCIETY HAS PROVIDED 'A FACE AND A VOICE' FOR THE COMMUNITY AND THOSE INTERESTED IN PRESERVING IT, MAKING IT POSSIBLE TO GENERATE MEDIA COVERAGE, AND CONTINUES TO PROVIDE INFORMATION AND UPDATE TO PROVINCIAL PUBLICATIONS:

- focus has been expanded from the presentation

Continued on next page...

of a Little River quarry to the recognition and realization of the potential impact upon the entire North Mountain, from Cape Blomidon to the tip of Brier Island and beyond – i.e. opening the door to industrialization.

Society members meet with scientists and other organizations to work out strategy in the fight against the quarry

- The perceived magnitude of the projected environmental threat that would be caused by a mega-quarry was well demonstrated by the fact that the Digby Neck Quarry Issue was recognized as one of the top ten environmental issue during the provincial election of 2003. The list was reprinted with suitable commentary from the Ecology Action Centre on the occasion of acquiring a new Premier this year, whose tenure of office will be judged through his effectiveness in dealing with the 'list of 10'.
- evolved a website to update interested persons and members of the society
- generates articles for local publications: "Passages, the Long and Brier Island News", published by the Freeport Community Development Association, and "Hello Digby Neck", published by the Digby Neck Community Development Association.
- provides updates and information to publications such as The Blomidon Naturalist Society, as well as 'The Sandpiper' published by the Sierra Club.
- The Chair of the Society has always been willing to meet with media reps. who wish to do investigative reporting or wish to focus upon the projected devastation to the ecosystem of the Bay of Fundy. This willingness has extended to many a visitor, as well, who could be treated to one of his famous tours of the waterway around the lower part of the Peninsula, from Bay to Bay.
- The Chair of the Society and his family were featured in the CBC award-winning film: "The Last Weir", by Tim Wilson.

NETWORKED WITH OTHER GROUPS:

- NMPG (North Mountain Preservation Group) in Granville Ferry/Annapolis area.
- EAC (Ecology Action Centre)
  - EnviroClare
  - DNCDA
  - Sierra Club of Canada
  - Sierra Club, Atlantic Chapter
  - Council of Canadians
  - Council of Canadians, Wolfville Chapter
  - Coastal Communities Network

ACTIVITIES OF THE SOCIETY:

- Established a membership program and encourages annual renewal of membership.
- The Society has enabled the Community to best utilize the human resources available to provide stewardship of the land. Through the membership program, eight to ten directors are able to represent the interests and wishes of a membership of four hundred and fifty individuals. Today's technology provides the Society the capability of very quickly contacting the seasonal residents of the group when support or input is required at the administrative level.
- The Society is represented by a singing group based on the style of the 'Raging Grannies'. The group has sung with the Grannies who are willing to perform on behalf of the Society, whenever they are requested to do so to raise funds and/or awareness. The Society's Group, 'The Blue Tartans' provide an excellent medium for making our point in a non-confrontational way, and provide entertainment at fund raising events, where they are well received.
- established a reputation for down-home dinners that are well supported, by both local people and tourists.

SUMMARY:

We believe there are two conclusions that must be reached through our list of accomplishments:

First, the Society helped create an awareness of the area by being featured in such publications as the National Post – weekend edition, a three-page spread, complete with pictures and a feature of the Noah Richler Column, *Books, National Post.*

Secondly, we firmly believe that without your support of the Society, a quarry would be operational today, crushing, grinding and shipping – all disrupting the tranquility and beauty of this fragile Peninsula, we call Digby Neck.

Who's next?

Quarry developers go fishing for basalt on Brier Island

By Don Mullin

Imagine your surprise upon seeing a strange vehicle with three men inside driving across a property behind your back yard. Further, imagine that upon approaching that vehicle, and asking the purpose of their "trespassing", they call you by name but you have no idea who they are and only one will give you his name. Finally, imagine that they tell you that they are looking for a road on the property that runs all the way to the Bay of Fundy shore and you suddenly realize that one of the vehicles occupants is at the centre of the proposed quarry on Digby Neck. Upon investigation, you discover that the property in question is a 70 acre 2-piece lot due to be auctioned off in two days for taxes and fees owing. That's exactly what happened to a Brier Island resident last week. Frantic calls to the property owners were made and the outstanding amount of taxes and fees owed were paid and the property was "rescued".

Since then, it has been learned that a person with the same last name as the only person in the strange vehicle mentioned above who was willing to give his name has been making inquiries about another large piece of property offered for sale on the internet in the area of Pea Jack Cove. One need not be paranoid to conclude that Brier Island's basalt has become attractive to quarry developers.

Beautiful basalt formations - properly blasted and ground up - make good roads. Developers don't much care where it comes from.

If you have been following the story of land acquisition in the White Cove area, you will know that the original area controlled by the quarry proponent has expanded from 380 acres to 689 acres (Passages, November, 2005). Since then, the proponent is reported to have shown interest in other properties on Digby Neck and, now, Brier Island? If permission is given to the proponent for a proposed marine terminal at Whites Cove, basalt from anywhere on the Bay of Fundy coast could be barged to the terminal and loaded for shipment from there. When the Stop The Quarry Group said they considered all of North Mountain from Blomidon to Brier Island to be at risk from quarry developers, we weren't exaggerating. If you are not presently involved in this issue, I suggest you become involved because your back yard might be next.

ARTICLE FROM 'PASSAGES' & 'HELLO DIGBY NECK' APRIL, 2006

(Editor's note): It appears that the area is rife with speculators and carpetbaggers, but there are still those who do not realize that the planned industrialization would alter and destroy the lifestyle we currently enjoy. As the article says, if you object to this potential industrialization, now is the time to get involved. One has only to read the daily papers to see that this is happening all across our Province.

IT'S "CRUNCH TIME" – THE TIME WE MOST NEED YOUR HELP IS RIGHT NOW! MANY HAVE SAID THEY WOULD HELP, WHEN NEEDED. WE HAVE EVOLVED A STRATEGY FOR THE NEXT 12 TO 18 MONTHS. WHETHER WE ARE ABLE TO FULLY IMPLEMENT THAT STRATEGY OR NOT, IS TOTALLY IN YOUR HANDS. WITHOUT ADDITIONAL AND GENEROUS CONTRIBUTIONS, THE BOARD OF DIRECTORS OF THE SOCIETY HAS GONE AS FAR AS THEY CAN GO!

PLEASE SEND YOUR CONTRIBUTIONS TO:

STOP THE QUARRY GROUP,
P.O. BOX 25, SANDY COVE, NOVA SCOTIA, B0V 1E0

Who Does What?

PARTNERSHIP FOR SUSTAINABLE DEVELOPMENT OF DIGBY NECK & ISLANDS SOCIETY (STOP THE QUARRY GROUP)

450 REGISTERED MEMBERS
EXECUTIVE COMMITTEE: CHAIR, VICE-CHAIR, SECRETARY & TREASURER

ENVIRONMENTAL ASSESSMENT CONSULTANTS

- LOCATE EXPERTISE TO REVIEW THE EIS (Environmental Impact Statement)
- FACILITATE THE REVIEW THROUGH COORDINATION OF MEETINGS WITH EXPERTS AND NGO'S (Non-Governmental Organizations)
- COMPILE EXPERTS' FINDINGS INTO SOCIETY'S OFFICIAL REPORT TO PANEL. 40 + experts to review EIS for completeness and effectiveness and prepare presentations.

PUBLIC AFFAIRS COORDINATOR

- GENERATE AND OVERSEE ACTIVITIES IN THE THREE 'NON-ACADEMIC' AREAS
- ENCOURAGE PUBLIC TO VOLUNTEER AND BE INVOLVED IN THE PROCESS UNDER THE DIRECTION AND GUIDANCE OF THE BOARD EXEC. AND THE CONSULTANTS
- FACILITATE ACTIVITIES OF THE 'STOP THE QUARRY COALITION'

PUBLIC
General Public Meetings
Society Public Meetings
Specific Interest Groups
Kitchen Meetings
Stop Sign Campaign

Range: Yarmouth to Halifax, emphasis on Annapolis Valley, Digby Neck and Islands

POLITICAL
Organize a letter writing campaign

Groups & individuals request special meetings with relevant politicians

News Media
Provide information to news media

Advise media of plans for special events

NOTE: Timing is important. We will be assessing and advising – for instance, the 'Political' approach will not be formally organized until after the Panel Hearings. Remember, the Environment Ministers, Federal and Provincial, will accept the findings of their appointed Panel, and make their final decision, based on all aspects of the proposed mega-quarry and marine terminal, including the wishes of the people!

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C0918-070

The Quarry EIS: CAN FAIRYTALES COME TRUE?

By Don Mullin

The 17 volume, 3,000 page Environmental Impact Statement (EIS) has arrived. This article provides a brief description of some of its contents. At first glance, the document appears well written and organized. Unfortunately, the Plain Language Summary is, in parts, anything but plain. I am still trying to figure out what "Construction aggregate operations have been used to enhance recharge via artificial surface recharge" means (and that's the "plain language" version).

The report paints a bleak picture of Digby Neck/ Islands and its future as seen in the following quote: "The area appears to be a community in decline". Citing another report on communities suffering severe population losses, the report went on to say that "such areas may lose their social and economic viability in terms of maintaining services and supporting healthy, independent communities." This despite reporting that income among those who file income tax returns "has been on a par with the provincial average since 1999." In fact, "the area actually experienced somewhat better relative and absolute growth in average income over the period 1989 to 2003 relative to provincial and national averages." So which picture to believe?

The proponent paints Digby Neck and Islands as an economy in decline. Fishermen and tourism operators probably wouldn't agree.

If you accept the bleak picture – not to worry, the proposed quarry apparently is the answer to our woes! Among other effects, the report concludes that not only will the quarry create four significantly positive effects (with no significantly negative effects) but that "projects of this type can be successfully carried out without damaging the environment or causing long-term ecological damage". So, you "tree-huggers" chill out; go back to sleep; there's nothing to worry about.

Those involved in tourism will take heart from the report's comment that "(The) total payroll of $1.2 million paid to 80 workers in the tourism industry is approximately equal to the $1.2 million payroll that will be paid to operate the Whites Point quarry annually." I guess that means that if we lose all the tourists, we won't be any worse off because someone else will be making the money tourist operators once did. But maybe we won't lose our tourists. After all, the Visitor Centre manager at Port Hasting, in sight of the large quarry at Cape Porcupine, says that "they have not heard anyone express a view that the quarry operation has ruined their opinion of Cape Breton…." The manager admits that perhaps 20 people a day make comments "that could concern questions related to the environment. This is especially the case if dust levels are visibly high".

Periwinklers and berry pickers will not be inconvenienced – unless you count getting permission from the quarry office each time you want to visit the site as inconvenience. At this point it is unclear whether lobster fishermen will also need to get permission. The report states that "(R)egistration at the quarry office (will be required) when harvesting in the coastal zone", although it is unclear whether this is limited to the intertidal area. In fact, lobster fishermen do not get a lot of attention in this report. The developer states they will set up a committee to compensate fishers for loss of traps and gear due to damage from the bulk carriers, but no mention is made for loss of access to their fishing areas for a day or so a week, for the time spent in repairing/replacing gear, possible reduction in catch which the report states may happen, etc.. The safety of fishermen also is ignored in the report. While workers on-site will take cover during

Continued on next page...

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You can help stop this quarry. Start thinking about what you'd like to say to the review panel when the next round of public hearings are called. We can help you with a presentation.

Remember, the public hearings are when you can tell the panel you don't want Digby Neck blown up to pave highways in New Jersey.

Fairytale... from page 7

blasting to avoid harm from flyrock, no mention is made of the risk to fishermen or non-human species.

Overall, the report states that the proposed quarry and marine terminal will have 70 environmental impacts. Of these, four (4) are significantly positive (terrestrial species at risk, quarry employment – during construction and operation, and municipal tax revenue). Eighteen (18) are rated as insignificantly positive, twenty eight (28) are assessed as having neutral (no) effect, and thirty (30) are assessed as insignificant negative in impact. But wait a second! How do they define significant and insignificant? I'm glad you asked. I quote: "The determination of whether an effect is considered *insignificant* or *significant* is based primarily on the level of spatial scale (local, regional, provincial, national/international) and after mitigation measures are considered. Generally, to be considered *significant* the influence of **effect would have to be greater than a regional scale – e.g., provincial or national/international in spatial scale.**" (bold added.) In other words, if lobstering in LFA 34 was destroyed, this would have to be considered an *insignificant* negative effect because it only affected people locally or regionally. On the other hand, the developer's willingness to protect *Glaucous rattlesnake-root* plants found on the property is considered a *significant positive* effect. (In fairness, it must be noted that this plant had not been seen in Nova Scotia for 50 years and was thought to be *extirpated* - in other words, extinct.) But does it seem right to you that protecting a plant species is considered significant while protecting the income of fishermen is insignificant?

Other effects considered as negative but insignificant include: greenhouse gas emissions (after all its only 4 million tonnes during the life of the project!); sky glow at night, migratory land birds (risk of collision with ship, especially during low visibility conditions); marine mammals and waterbirds – nearshore; marine mammals (including Right Whales) from blasting; tourism; land value; quality of life – environmental; and the list goes on.

Given the definition the developer has used for environmental impacts, it is not surprising that they promote this project as a positive contribution to the community. After all, they say the "...proposed development would contribute to the present sparsely developed industrial coastline." It would also increase "community cohesion" (after all this "fuss" of environmental review is over). The quarry site will, apparently become a haven for wildlife (some even during quarry operation!). In fact, we should just be grateful overall because, unlike other developments that are occurring (such as campgrounds or cottages), the quarry and marine terminal require an environmental assessment. I wonder why that is?? Oh, ballast water and invasive species? – don't worry about that. The developer doesn't consider that their responsibility; that's up to the carriers. I'll sleep better tonight.

The "evil opponents" of the proposed quarry (the Partnership for Sustainable Development for Digby Neck & Islands Society) are planning to hold a series of information sessions in local communities. There is much more to comment on than this space would allow. Please attend these sessions to get more of the story.

(This article is reprinted from 'Passages - The Long and Brier Island News', with permission).

UNDERTAKING #44

To check on the availability of a more current CV for the archaeologist who conducted the archaeological report for the project.

Please see attached CV for Dr. Watrall

CURRICULUM VITAE

Note: Please refer to page 21 for updated information

NAME **Charles R. Watrall**
BIRTHPLACE New York City, New York
DATE OF BIRTH January 1, 1944

CURRENT ADDRESS P.O. Box 446
Bridgetown, N.S. B0S 1C0

PHONE 902 665 4164

CURRENT APPOINTMENT Associate Professor, Department of Anthropology, University of Regina, Saskatchewan, Retired.

APPOINTMENTS

January – June 1992	Acting Head, Department of Anthropology
1986 – 1991	Instructor. Introduction to Silver-smithing, Neil Balkwell Civic Arts Centre.
Summer 1983 – 1991	Summer Instructor. Nipissing University College, North Bay, Ontario
1976	Associate Professor, University of Regina
Summer 1976	Instructor. University of Brandon
1978 -79	Post Doctoral Research Associate Anthropology Department, University of Minnesota
1973	Assistant Professor, University of Regina
1971	Special Lecture, University of Regina
1971	Instructor. Lakewood Jr. College, White Bear, Minnesota
1970	Instructor. Macalaster College, St. Paul, Minnesota
1968	Instructor. Extension Division, University of Minnesota

1965 Teaching Assistantship. University of Minnesota

EDUCATION

1961 – 1965	Hunter College of the City University of New York.
1965 – 1970	University of Minnesota – Resident.
1970 – 1976	University of Minnesota – Thesis only.

DEGREES

1965	B.A., Anthropology, Hunter College.
1968	M.A., Anthropology, University of Minnesota.
1970	Ph.D., Candidate, Anthropology, University of Minnesota.
1976	Ph.D., Conferred, University of Minnesota.

AWARDS

1961 – 1965	New York State Regents College Scholarship.
1983	Transportation Funding, President's Fund, University of Regina.

FIELDWORK

1963 – 1964	Three weeks part-time archaeological excavation on Several Woodland sites in New Jersey and one Archaic – Early Woodland site in western coastal Long Island.
Summer 1965	Eight weeks field experience in Posey Co., Indiana, on the Mann Site, a Middle Woodland-Middle Mississippian habitation site. Excavation under the direction of Dr. James H. Kellar, Anthropology Department, University of Indiana
Summer 1965	Eight weeks excavation on the Orwell Site, Otter Tail County, Minnesota, under the direction of Dr. Elden Johnson, Anthropology Department, University of Minnesota.

FIELDWORK cont

	Three weeks archaeological site survey, Grant County, Minnesota, after completion of excavation on the Orwell Site.
Summer 1966	Six weeks excavation as Archaeological Field Assistant on the Cooper Site (21-ML-9), a Late Woodland-Early Historic habitation site in Mille Lacs County, Minnesota, under the direction of Prof. Elden Johnson, Anthropology Department, University of Minnesota.
Summer 1967	Twelve weeks excavation as Field Director in charge of archaeological operations at Fort Snelling, Hennepin County, Minnesota. This project consisted of the total excavation of refuse material in the Hexagonal Tower and in the determination of the foundation location of one other large building of this 1829's stone fort.
Summer 1968	Four months Project Director of the Minnesota Highway Archaeological Reconnaissance Program. This project consisted of the initial formulation of a program of archaeological survey of proposed State and Federal Highway construction projects.
October '68 – July '69	Part-time appointment as Project Archaeologist, Minnesota Highway Archaeological Reconnaissance Program.
Summer 1969	Archaeological survey conducted in Savanna River Portage State Park, Aitkin County, Minnesota. Recommendations made for preservation, reconstruction, and constructional activities within the Park.
June 1969	Project Director, Minnesota Highway Archaeological Reconnaissance Program.
July – August 1969	Archaeological Field Director, University of Minnesota Archaeological project. Excavation of a Middle and Late Woodland habitation site, the Maplewood Site, Otter Tail County, Minnesota. Archaeological survey conducted in the surrounding area to provide data for regional chronological interpretations.
July '70 – Fall '73	Intermittent archaeological survey on prehistoric sites in southern Saskatchewan. Such surveys will form the basis for future research on cultural adaptation to ecotone ecologies.

FIELDWORK cont

February 2-13, 1972	Anthropology consultant for proposed Department of Northern Affairs in Saskatchewan under the direction of Mr. Ted Bowerman. Observations made in a variety of Chipewyan, Cree and Métis communities (Walliston Lake, Paturnak, etc.). Responsibilities consisted of acting in an advisory capacity only.
1974	Saskatchewan Timber Harvesting Project Archaeological Component Phase I – Short-term field study of proposed timbering areas in Northern Saskatchewan and timbering methodology. Initial report on archaeological component Phase I submitted to Saskatchewan Department of the Environment through Schultz International Co., British Columbia.
Summer 1975	Director, Saskatchewan Timber Harvesting Project Archaeological component – Environmental impact study in proposed clear-cut timber harvesting project. Final report submitted to Saskatchewan Department of the Environment through Schultz International Co., British Columbia.
Summer 1976	Six weeks intensive excavation at the Stott Site, southwest Manitoba, as Field Director for Brandon University, Department of Anthropology and Sociology, for "Field Methods in Archaeology". Continued analysis and involvement with the results derived from this Blackduck phase village site will be utilized as evidence for a generic interpretation of Plains Periphery prehistoric adaptation patterns.
Summer 1977	Six weeks investigation of Lake Midden Site (EfNg–1), a Late Prehistoric bison processing, fall-winter habitation site near Bulyea Saskatchewan. Initial investigations begun under "Qu'Appelle Basin Archaeological Project" title at the Lake Midden Site included establishment of datum and grid, initial test excavations, soil sampling, botanical inventory, and initial areal survey. Photographic documentation of ceramic materials from the Lake Midden Site in the collections of the National Museum of Canada was also completed during this initial investigation period.

FIELDWORK cont

Summer 1978	Six weeks investigation at a variety of southern Saskatchewan sites (i.e. Medicine Wheels, Tipee Rings, Habitation Sites, etc.). These investigations will be conducted in conjunction with a class: Introduction to Field Methods in Archaeology (Anthropology 399). A portion of this class will be spent with continuing excavations at the Lake Midden Site.
Summer 1981	Touchwood Hills, Provincial Park, Saskatchewan Archaeological Impact Study. Duration one week.
Summer 1981	Bar G Ranch Project, White City, Saskatchewan Archaeological Impact Study. Duration one week.
Spring 1982	Dallas Valley Ranch Project. Archaeological Impact Study near Lumsden, Saskatchewan. Duration one week.
Summer 1982	Ducks Unlimited Saskatchewan Archaeological Impact Studies 1) Neale-Edmonds Basin Lloydminster; 2) Dumas, Saskatchewan. Project A and B; 3) Wellington Marshes. Duration four weeks.
Summer 1990	Archaeological Survey of Iron Island Lake Nipissing, Ontario. Duration 2 days.

PAPERS

November 1966	"Site 21-ML-9, A Late Woodland-Early Historic Site in Mille Lacs County, Minnesota", 24th Plains Conference, Lincoln, Nebraska.
April 1967	"Deer and the Buffer Zone in the Late Prehistoric Period in Minnesota", Minnesota Academy of Science Annual Meeting.
Spring 1968	"Analysis of the Unmodified Stone Materials from the Cambria Site", Minnesota Academy of Science Annual Meeting.
Fall 1969	"Preliminary Report on the Maplewood Site", Council for Minnesota Archaeology Annual Meeting.

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PAPERS cont

Fall 1970	Chairman, Council for Minnesota Archaeology Meeting.
Spring 1972	"Physical Anthropology ad Archaeology", Annual Meeting, Regina Archaeological Society.
Spring 1973	"The Social Consequences of Early Food Production", Biology Department Colloquia, University of Regina.
Spring 1974	"The Arts of the Japanese Sword", Opening Address for exhibit (same title), Norman MacKenzie Art Gallery, Regina.
Spring 1975	"Prehistoric Adaptation Strategies in the Ecotone Regina of West Central Minnesota", University of Regina Anthropological Mini-Conference (also Conference Chairman).
Spring 1976	"Archaeological Survey of Northern Saskatchewan", Annual Meeting of Regina Archaeological Society.
Fall 1976	"Implications of Ecotone Adaptations Strategies in the North-East Plains Periphery Region", Plains Conference.
Fall 1976	"The 1976 Field Season at the Stott Site" Annual Meeting of Professional Archaeologists of Manitoba.
Fall 1977	"Qu'Appelle Basin Archaeological Project: Initial Investigations at the Lake Midden Site", Qu'Appelle Basin Citizens Advisory Board.
Fall 1977	Participant, Northern Plains Ceramic Symposium – Lake Midden Ceramics. Plains Conference, Lincoln, Nebraska.
Spring 1978	"Recent Investigations at the Lake Midden Site", Regina Archaeology Society.
Spring 1978	"Recent Investigations at the Lake Midden Site", Annual Meeting, Saskatchewan Archaeological Society, Saskatoon, Saskatchewan.
Spring 1979	"Mimbres Pottery", University of Minnesota Fine Arts Gallery, Minneapolis.

PAPERS cont

Fall 1980	"Namban Kodogu", Annual Meeting, Midwest Token Society, Milwaukee, Wisconsin.
Spring 1981	"The Japanese: A View From the Prairie", Western Association Sociologists and Anthropologists, Winnipeg, Manitoba.
Fall 1981	Namban Kodogu: Further Researches on the Kodogu of Higo and Hizen Provinces – Joint meeting Japanese Sword Society of United States and Token Study Group.
Spring 1982	A Structural Comparison of the Maplewood, Stott and Lake Midden Sites. Solicited paper UNIC III Conference March 1982, University of Minnesota.
Spring 1982	Ceramics in Their Social Context: Banff School of Fine Arts Workshop. Three day solicited workshop. Banff School, Banff, Alberta.
Fall 1982	Southern Iron: Social and Economic Factors of Kyushu Affecting Kodogu Production During the Momomaya and Early Edo Periods. Joint JSSUS/Token Study Group Annual Meeting, Chicago, Illinois.
Fall 1982	Southern Iron: Joint Coordinator Kyushu Kodogu Exhibit joint JSSUS-Token Study Group Annual Meeting.
November 1983	"Mimbres Pottery from the Galaz Site, N. Mexico; A Community Assessment" Chocmool Conference, University of Calgary.
August 1983	"Mimbres Pottery from the Galaz Site", Artsperience Ceramic Workshop, Canador College, North Bay, Ontario.
August 1984	"Namban Kodogu", Nipissing College University
August 1984	"Anthropology and Art", Radio Interview, North Bay, Ontario.

PAPERS cont

October 1984	"Introduction to Japanese Pottery", Art Education Dept., University of Regina.
1984	"Public Interpretation of the Anthropology Community", WASA Conference, Opening lecture, Regina, Saskatchewan.
1984	"Anthropology and the Concept of Culture", Regina Police College, University of Regina (4 hour lecture).
Fall 1990	"Anthropology and the Concept of Culture", Regina Police College, University of Regina (4 hour lecture).
Fall 1990	"Prehistoric Dakota Culture", Saskatchewan and Early Historic, Saskatchewan Indian Federated College (4 hour lecture).
Winter 1991	"Anthropology and the Concept of Culture", Regina Police College, University of Regina (4 hour lecture).

PUBLICATIONS AND REPORTS

1966	A Late Woodland-Early Historic Site in Mille Lacs County, Minnesota Archaeological Newsletter Nos. 10-11, Minneapolis, Minnesota.
1967	A Late Woodland-Early Historic Site in Mille Lacs County, Minnesota. Plains Anthropologist 12-36, Lincoln, Nebraska.
1968a	Virginia Deer and the Buffer Zone in the Late Prehistoric-Early Protohistoric Periods in Minnesota. Plains Anthropologist 13-40, Lincoln, Nebraska.
1968b	Analysis of the Bone, Stone and Shell Materials from the Cambria Focus. Unpublished M.A. Thesis, Department of Anthropology, University of Minnesota.
1968c	Analysis of Unmodified Stone Materials from the Cambria Site. Journal of the Minnesota Academy of Science, Vol. 35(1), Minneapolis, Minnesota.

PUBLICATIONS AND REPORTS cont

1969a	Final Report of the Commissioner 1968-69 for the Minnesota Highway Archaeological Reconnaissance Program. Printed by the Minnesota Historical Society for distribution to highway departments with Archaeological salvage programs in the U.S.
1969b	Highway Archaeological Reconnaissance Program 1968-69. Archaeological Survey, Savanna River, Portage State Park, 1969, Minnesota Archaeological Newsletter, Minneapolis, Minnesota.
1974a	"The Arts of the Japanese Sword", Exhibition Catalogue, Norman MacKenzie Art Gallery, Regina, Saskatchewan.
1974b	Subsistence Pattern Change at the Cambria Site – A Review and Hypothesis. In: Aspects of Upper Great Lakes Anthropology – Papers in Honour of Lloyd A. Wilford, Minnesota Prehistoric Archaeology Series, Minnesota Historical Society.
1975a	Introductory Remarks, Conference Schedule, University of Regina Anthropological Mini-Conference.
1975b	Recent Activities of the Anthropology Department, University of Regina, Saskatchewan Archaeological Newsletter.
1975c	Initial Report, Saskatchewan Timber Harvesting Project Phase I – Manuscript submitted to Saskatchewan Department of the Environment.
1976a	Final Report – Saskatchewan Timber Harvesting Project, Archaeological Component Phase II – Manuscript submitted to Saskatchewan Department of the Environment.
1976b	Ecotones and Environmental Adaptation Strategies in the Prehistory of North Western Minnesota. Unpublished Ph.D. Thesis, Department of Anthropology, University of Minnesota

PUBLICATIONS AND REPORTS cont

1976c	Implication of Ecotone Adaptation Strategies in the North East Plains Periphery Region, Plains Conference Abstracts 1976.
1976d	Abstract – The 1976 Field Season of the Stott Site – Archae Facts, Journal of the Archaeological Society of South West Manitoba.
1976e	A Note on the Souris Gravels. Archae Facts: Journal of the Archaeological Society of South-Western Manitoba, Vol. 4(2), Brandon, Manitoba.
1976f	The Stott Site: 1976 Field Report. Archae Facts: Journal of the Archaeological Society of South-Western Manitoba, Vol. 4(2), Brandon, Manitoba.
1977a	Lorraine Malach: Saskatchewan Muralist. Arts West, Vol. 2(4), Calgary, Alberta.
1977b	Randy Woolsey, Potter. Arts West, Vol. 2(5), Calgary, Alberta.
1978	A Note on the Japanese Spearhead From the Ruins of the Government Museum at Nagasaki. Central States Archaeological Journal, Missouri.
1979a	Photo credits "Ezo Fittings Part I", Bushido, Vol. I (1), July 1979.
1979b	Photo credits "Ezo Fittings Part II", Bushido, Vol.I (2)
1979c	Lake Midden Preliminary Report – Prepared for Saskatchewan Department of Culture and Youth.
1980a	Lake Midden Site Preliminary Report. Saskatchewan Archaeologist.
1980b	Review: Kodogu Exhibit, Dunlop Gallery, Regina, Saskatchewan. Bushido, Vol. II.
1980c	"Corn Ezo Menuki: a Commentary". Bushido.

1981a	Archaeological Impact Study: Touchwood Hills Provincial Park, Saskatchewan. Report submitted to Saskatchewan Department of Highways and Saskatchewan Department of Culture and Youth, Heritage Division.
1981b	Archaeological Impact Study: Bar G Ranch Estates. Report submitted to Saskatchewan Department of Culture and Youth, Heritage Division.
1982a	Archaeological Impact Study: Dallas Valley Ranch Project. Report submitted to Saskatchewan Department of Culture, Heritage Division.
1982b	Archaeological Impact Study: Neale-Edmonds Basin, Lloydminster, Saskatchewan. Report prepared for Ducks Unlimited Saskatchewan. Submitted to Saskatchewan Department of Culture, Heritage Division.
1982c	Archaeological Impact Study: Dumas Saskatchewan Project A and B. Report prepared for Ducks Unlimited Saskatchewan. Submitted to Saskatchewan Department of Culture, Heritage Division.
1982d	Archaeological Impact Study: Wellington Marshes. Report prepared for Ducks Unlimited Saskatchewan. Submitted to Saskatchewan Department of Culture, Heritage Division.
1983	"Mimbres Pottery from the Galaz Site, N. Mexico; A Community Assessment", Chocmool Conference Abstracts, University of Calgary.
1983 / 85	"A Structural Comparison of the Maplewood, Stott, and Lake Midden Sites", UNIC III Conference, University of Minnesota. Reprints in Anthropology, Vol.31, J. and L. Reprint Co. Lincoln, Neb. (original publication, not reprint).
1990	"Environmental Impact Statement: A Brief Archaeological Survey of Iron Island, Lake Nipissing, Ontario.

PAPERS AND PUBLICATIONS IN PREPARATION AND ONGOING RESEARCH PROJECTS

- Revision of "Ecotone Adaptation Strategies"
- Analysis of Fish Scales from the Maplewood and Stott Sites
- A note on Blackduck Double Mouth Mortuary Vessels
- A Reconstructed Ceramic Vessel from the Maplewood Site
- Re-Analysis of the Non-Ceramic Materials from the Cambria Site
- Analysis of Japanese Swords and Sword Fittings of Higo Province.
- In Preparation – A Note on Some Brief Investigations and Lithic Analysis at the Gompf Site
- Analysis of Mimbres pottery from the Galaz Site
- Bibliography of Oriental Ceramics published in European Languages

MAJOR RESEARCH INTERESTS AND AREAS OF EXPERTISE

- Ecological Analysis of Human Adaptation Patterns – ecological and subsistence pattern changes and their relationships to levels of socio-cultural integration, social stratification, craft and vocational specialization, etc.

- Ethnology and Archaeology of North America – especially Plains, Plains Periphery and North Eastern North America. Emphasis on analysis and theoretical frameworks of archaeological materials derived from ecotone environments, i.e., transitional ecotones in Wisconsin, Minnesota, Manitoba and Saskatchewan.

- Ethnology and Prehistory of Japan and China.

- North American Lithic Technology

- Ceramic Technology – North American and Far Eastern Focus

- Contemporary North American and Asian Studio and Folk Ceramics and Arts and Crafts.

- Ethnobotony: especially non-subsistence plant exploitation.

- Research Methodology.

SPECIAL SKILLS

- Ceramic Technology and Analysis
- Archaeological Faunal Analysis
- Geology – especially Paleontology

CONSULTATION ACTIVITY

- See Fieldwork Activities, February 1972, consultation duties for Department of Northern Saskatchewan.

- Fall 1972 – Member of Yoyogi Museum of Tokoyo KBTHK Cultural Attribution Board (Shinsa).

- Consultation on a continuing basis with Museum of Natural History, Regina, Saskatchewan, concerning both display and research activities.

- Consultation activities initiated Fall 1973 with Wild Animal Park, Moose Jaw, Saskatchewan. Consultative activities concerning acquisition, care and display of various primate species.

- Archaeological Consultant – Minnesota Historical Society / Minnesota Highway

- Department Consultation for Identification and Appraisal of Asian and North American Archaeological and Ethnographic Materials – Ongoing.

- Research Advisor, Saskatchewan Falconry Association, 1972-73.

- J.A.C. Struthers and Associates, January – June 1973.

- Qu'Appelle Basin Study – Archaeological and Historic Component, 1974-75, Saskatchewan Department of Tourism and Renewable Resources.

- 1975-76 Archaeological Consultant to Saskatchewan Department of the Environment (Subcontract through C.D. Schultz and Co., British Columbia).

- 1976 Consultant to University of Brandon – Stott Site.

- 1977 Director "Qu'Appelle Basin Archaeological Project".

- 1978 Consultant to Saskatchewan Department of Culture and Youth – assessment contract for Lake Midden Site.

PROFESSIONAL AND PUBLIC SERVICE

1983-84	President Elect – Anthropology Section Western Anthropology and Sociology Association
1984	WASA - Anthropology Section symposium organizer for WASA annual conference, Regina
	Liaison consulting between Anthropology Department, U of R and Regina Archaeology Society.
	Member Regina Philatelic Society
	Special consultant to RCMP and coroner's office: a) identification and analysis of restricted animal parts; b) special (forensic and) consultant on autopsy work of coroners department (Fall 1983 – homicide victim analysis).
Fall 1983	Southern Iron: Joint Coordinator Kyushu Kodogu Exhibit joint JSSUS – Token Study Group Annual Meeting.
1986	Anthropology Liaison to Saskatchewan Indian Federated College Health Care Program.
1990-91	Anthropology representative to Saskatchewan Indian Federated College – Joint Department Curriculum Development Museology Certificate Program.

PROFESSIONAL AND COMMUNITY ASSOCIATIONS

- Token Kenkyukai Shinsa Conference, Dallas Texas, 1972.
- Ex. Japanese Sword Society of the United States.
- Nihon Bijutsu Token Hozan Kyokai (Society for the Preservation of Japanese Swords).
- Midwest Token Group.
- Saskatchewan Weapons Collector Association.
- Council for Minnesota Archaeology.
- Ex. Society for American Archaeology.
- Sioux Archaeological Society (Honorary Member).
- Ex. Current Anthropological Association.
- Saskatchewan Archaeological Society.
- Plains Anthropological Society.
- University of Regina Faculty Association.
- Ex. Saskatchewan Falconry Association.

PROFESSIONAL AND COMMUNITY ASSOCIATIONS cont

- Regina Archaeological Society.
- Saskatchewan Archaeologists' Professional Group (Founding Member).

DEPARTMENTAL, UNIVERSITY AND COMMUNITY ACTIVITIES

- Social Science Faculty Colloguia, University of Regina, 1971
- "B" Member, Department of Sociology, University of Regina, 1971-72
- Chairman, Committee for Open House Arrangements, University of Regina Anthropology Department 1971.
- Shinsa Cultural Attribution Member, Token Kenkyukai, Dallas, Texas 1972
- Bijutsu Submissions Token KenKyukai, Dallas, Texas, 1972.
- Organizer, gallery exhibit, "The Arts of the Japanese Sword" Norman MacKenzie Art Gallery, Regina, Saskatchewan, 1974
- Participant, Anthropology in Saskatchewan – Conference of Anthropology Departments, University of Regina and University of Saskatchewan, 1974
- Search Committee for Associate Dean of Arts – Anthropology Department member, University of Regina, 1974
- Chairman 1974-75-76, University of Regina Anthropology Department Seminar Colloquium
- Member, Library Committee, 1972-present, Department of Anthropology, University of Regina
- Laboratory Supervisor, 1972-present, Department of Anthropology, University of Regina
- Chairman and Co-ordinator, University of Regina, Anthropological Mini-Conference, 1975
- Alternate Member, Executive Committee, Division of Social Sciences, University of Regina
- Chairman, Anthropology Department Subcommittee on Anthropological Displays, 1974-75
- Member, Faculty of Arts Review Committee, 1977-present
- Saskatchewan Professional Archaeologist Group
    - Founding Member
    - Member, Subcommittee, General Information
    - Member, Subcommittee, Antiquity and Heritage Legislation
- Committee on Admission and Studies, University of Regina, 1979-82

REFERENCES

George W. Arthur
3177 Pearks Road
Victoria, BC V9C 2L7

O. Elden Johnson
Department of Anthropology
University of Minnesota
Minneapolis, Minnesota USA 55455

Roman Brozowski
Dean of Arts
Nipissing University College
North Bay, Ontario

C. Thomas Shay
Department of Anthropology
University of Manitoba
Winnipeg, Manitoba

Leigh Simms
Curator of Anthropology
Museum of Man
Winnipeg, Manitoba

TEACHING EXPERIENCE

Teaching Assistant for Introductory Physical Anthropology and Archaeology (1A) and Introductory Cultural Anthropology (2A) 1965-66, 1966-67, 1967-69, 1969-70 (Total of twelve quarters at the University of Minnesota).

Research Assistant, Fall 1968 – Spring 1969.

University of Minnesota

Fall 1968	-	Anthropology 1A Semester – U of Minnesota
Spring 1969	-	Anthropology 1A Semester – U of Minnesota
Fall 1969	-	Anthropology 1A Semester – U of Minnesota
Fall 1969	-	Anthropology 1A Quarter – U of Minnesota
Spring 1970	-	Anthropology 1A Semester – U of Minnesota
Spring 1970	-	Anthropology 90 (North Archaeology) Semester
Spring 1970	-	Anthropology 2A Quarter
Fall 1970	-	Anthropology 1-001 (Introduction Physical Anthropology and Archaeology) Quarter, U of Minnesota
	-	Anthropology and Archaeology (Quarter, U of Minnesota)
	-	Ethnology of North America (Quarter, U of Minnesota)
	-	Cultural Ecology (Semester, Macalaster College, St. Paul, Minnesota)
Winter 1971	-	Anthropology 1-001 (Quarter, U of Minnesota)
	-	Introductory Cultural Anthropology (Quarter, Lakewood Jr. College, White Bear, Minnesota)
Spring 1971	-	Cultural Ecology (Semester, Macalaster College)
	-	Old World Archaeology (Quarter, U of Minnesota)

Department of Anthropology, University of Regina

Fall 1971	-	Anthropology 100 (Introduction of Anthropology)
	-	Anthropology 250 (Introduction to Physical Anth)
Spring 1972	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 232 (Ethnology of Oceania)
	-	Anthropology 290 (Reading Class – Ethno-Ornithology)
Summer 1972	-	Anthropology 231 (Ethnology of North America)
Fall 1972	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 250 (Introduction to Physical Anth)
	-	Anthropology 390 (Reading Class)
Spring 1973	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 232 (Ethnology of Japan)
	-	Anthropology 390 (Reading Class, Paleo-ethnology of Australopithecenes)

ADDENDUM

Spring 1973	-	Anthropology 100 (Introduction to Anthrolopology)
	-	Anthropology 232 (Ethnology of Japan)
	-	Anthropology 390 (Reading Class, Paleo-ethnology of Australopithecenes)
Spring 1973	-	Anthropology 100 (Introduction to Antropology)
Fall 1973	-	Anthropology 233 (Ethnology of North America)
		Anthropology 250 (Introduction to Physical Anth)
	-	Anthropology 391 (Reading Class, Australopithecinae)
	-	Anthropology 490 (Reading Class, North American Ethnology)
Spring 1974	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 232 (Ethnology of Japan)
	-	Anthropology 390 (Reading Class)
Summer 1974	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 250 (Introduction to Physical Anth)
	-	Anthropology 233 (Ethnology of Oceania)
Spring 1975	-	Anthropology 100 (Introduction to Antropology)
	-	Anthropology 322 (Theory and Method in Archaeology)
	-	Anthropology 304 (Partial Theory in Anthropology)
	-	Anthropology 490 (Directed Reading Class)
Summer 1975	-	Anthropology 100 (Introduction to Antropology)
	-	Anthropology 250 (Introduction to Physical Anth)
	-	Anthropology 226 (Archaeology of China, Korea, Japan)
	-	Anthropology 492 (Directed Reading Class)
	-	Anthropology 496 (Directed Reading Class)
	-	Anthropology 498 – 499 (Honours Thesis)
Spring 1976	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 239 (Ethnology of Japan)
	-	Anthropology 499 (Honours Thesis)
Summer 1976	-	Field Methods in Archaeology – Brandon University
Fall 1976	-	Anthropology 250 (Introduction to Physical Anth)
	-	Anthropology 234 (Introduction to North American Ethnology)
	-	Anthropology 390 (Reading Class)
Spring 1976	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 232 (Archaeology of Eastern North America)
	-	Anthropology 250 (Introduction to Physical Anthropology)
	-	Social Studies 491 (Reading Class)
Spring 1977	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 232 (Eastern North American Archaeology)
	-	Anthropology 390 (Reading Class)
Summer 1977	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 390 (Reading Class)
	-	Anthropology 397 (Field Methods in Archaeology)

ADDENDUM

Fall 1977	-	Anthropology 221 (Introduction to Prehistory in the Americas)
	-	Anthropology 226 (Archaeology of China, Korea, Japan)
	-	Anthropology 390 (Reading Class)
Spring 1977	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 239 (Ethnology of Japan)
	-	Anthropology 390 (Reading Class)
	-	Anthropology 890 (Graduate Reading Class)
Spring 1978	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 239 (Ethnology of Japan)
	-	Anthropology 390 (Reading Class)
	-	Anthropology 399 (Introduction to Archaeological Field
	-	Methods)
Fall 1979	-	Anthropology 208 (Art and Culture)
	-	Anthropology 250 (Human Evolution and Development)
Spring 1980	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 239 (Ethnology of Japan)
	-	Anthropology 390 (Reading Class, Ethnozoology)
Fall 1980	-	Anthropology 208 (Art and Culture)
	-	Anthropology 226 (Archaeology of China, Korea, Japan)
	-	Anthropology 391 (Analysis of Prehistoric Fish Remains)
	-	Anthropology 490 (Reading Class)
Winter 1981	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 209 (Pre-Industrial Agriculture)
	-	Anthropology 392 (Reading Class)
	-	Anthropology 498 (Honours Thesis)
Fall 1981	-	Anthropology 208 (Art and Culture)
	-	Anthropology 250 (Human Evolution and Development)
	-	Anthropology 392 (Reading Class)
	-	Anthropology 499 (Honours Thesis)
Winter 1982	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 239 (Ethnology of Japan)
	-	Anthropology 390 (Reading Class)
	-	Anthropology 490 (Reading Class)
	-	Anthropology 499 (Honours Thesis)
Fall 1982	-	Anthropology 391 (Reading Class)
	-	Anthropology 400 (Seminar)
	-	Anthropology 498 (Honours Thesis)
Winter 1983	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 208 (Art and Culture)
	-	Anthropology 499 (Honours Thesis)
Fall 1983	-	Anthropology 208 (Art and Culture)
	-	Anthropology 250 (Human Evolution)
	-	Anthropology 390 (Reading Class)
	-	Anthropology 400 (Seminar)

ADDENDUM

	-	Anthropology 490 (Reading Class)
	-	Anthropology 498 (Honours Thesis)
Winter1984	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 226 (Archaeology of China, Korea, Japan)
	-	Anthropology 390 (Reading Class)
	-	Anthropology 491 (Reading Class)
	-	Anthropology 499 (Honours Thesis)
Summer 1984	-	Anthropology 397 (Reading Class)
Fall 1984	-	Anthropology 100 (Introduction to Anthropology)
-	-	Anthropology 239 (Ethnology of Japan)
	-	Anthropology 392 (Reading Class)
	-	Anthropology 490 (Reading Class)
Winter 1985	-	Anthropology 208 (Art and Culture)
	-	Anthropology 322 (Theory & Method in Archaeology)
	-	Anthropology 498 (Honours Thesis)
	-	Anthropology 499 (Honours Thesis)
Fall 1985	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 250 (Human Evolution & Development)
	-	Anthropology 491 (Reading Class)
	-	Anthropology 492 (Reading Class)
	-	Anthropology 498 (Honours Thesis)
Winter 1986	-	Anthropology100 (Introduction to Anthropology)
	-	Anthropology 208 (Arts and Culture)
	-	Anthropology 499 (Honours Thesis)
Fall 1986	-	Sabbatical Leave
Winter 1987	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 239 (Tradition Japanese Society)
	-	Anthropology 491 (Reading Class)
Fall 1987	-	Anthropology 208 (Art and Culture)
	-	Anthropology 250 (Human Evolution & Development)
	-	Anthropology 491 (Reading Class)
Winter 1988	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 226 (Archaeology of China, Korea, Japan)
	-	Anthropology 491 (Reading Class)
	-	Anthropology 493 (Reading Class)
Fall 1988	-	Anthropology 221 (Intro to Prehistory of North America)
	-	Anthropology 239 (Traditional Japanese Society)
	-	Anthropology 390 (Reading Class)
	-	Anthropology 493 (Reading Class)
Winter 1989	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 209 (Pre-Industrial Agriculture)
	-	Anthropology 499 (Honours Thesis)

Fall 1989	-	Anthropology 208 (Art and Culture)
	-	Anthropology 250 (Human Evolution & Development)
	-	Anthropology 400 (Seminar)
	-	Anthropology 490 (Reading Class)
	-	Anthropology 498 (Honours Thesis)
	-	Anthropology 499 (Honours Thesis)
Winter 1990	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 226 (Archaeology of China, Korea, Japan)
	-	Anthropology 491 (Reading Class)
	-	Anthropology 499 (Honours Thesis)
Fall 1990	-	Anthropology 239 (Traditional Japanese Society)
	-	Anthropology 250 (Human Evolution & Development)
	-	Anthropology 390 (Reading Class)
	-	Anthropology 498 (Honours Thesis)
Winter 1991	-	Anthropology 100 (Introduction to Anthropology)
	-	Anthropology 208 (Art and Culture)
	-	Anthropology 394 (Reading Class)
	-	Anthropology 492 (Reading Class)
	-	Anthropology 499 (Honours Thesis)
1991 – 1999	-	Associate Professor, Anthropology, University of Regina
1998 – 1999	-	Taught in Department of History and Department of Fine Arts, University of Regina
1999 – present	-	Associate Professor of Anthropology (Retired)

Directed Reading and Research Classes

- Ethno-Ornithology
- Paleo-Ethnology of Australopithecenes
- Australopithecinea
- Ethnology of Chippewya and Plains Cree
- Saskatchewan Ethnology
- Advanced Economic Anthropology
- Ecology in Anthropology
- Statistical Thecniques of Ceramic Analysis
- Introduction to Primatology
- Soils Analysis and Archaeology
- Northern Plains Ceramics
- China / Japan Pottery

ADDENDUM

Courses in Preparation

200 level	-	Anthropology and Science Fiction Literature
	-	European Archaeology of Egypt
300 level	-	Introductory Ethnobotony
400 level	-	Social Stratification in Archaeological and Ethnological Perspective
	-	World Survey Ceramic Technology
	-	Ceramic Experimentation
	-	Ceramic Analysis

Thesis Advisor and Reader

G. Neil, Honours – April 1974
R. Hersche, Honours – December 1975
B. Balon, Honours – August 1976
S.B. Ebell, Honours – September 1976
J. Light, Honours – September 1976
R. Grace Morgan, M.A. – February 1978
Bohdan Szuchewycz, Honours – 1978 (Reader)
Lauree Garvin, Honours – 1979
Edwin Rodger, Honours – 1980 (Reader)
Marvin Thomas, Honours – 1981 (Supervisor)
Joanna Rummens, Honours – 1982 (Supervisor)
Carol Dorman, Honours – 1982 (Supervisor)
Oliver Brass, Ph.D. – 1983 (Supervisor)
Thora Cartlidge, M.A. – 1983 (Supervisor)
Dale Walde, Honours – 1983 (Supervisor)
Donald Dean Smith, Honours – 1984
Donalee Deck, Honours – 1984 (Supervisor)
Daryl Trithart, Honours – 1985
Eric Wood, Honours – 1985 (Supervisor)
Hendrikus VanGinneken, Honours – 1987
John Lind, Honours – 1987
Sean Goldsmith, Honours – 1989 (Supervisor)
Joan Kanigan, Honours – 1989 (Supervisor)
Raymond Ambrosi, Honours – 1989 (Supervisor)
Kirsten Fromback, Honours – 1990 (Supervisor)
Vanessa Thorson, Honours – 1991 (Supervisor)
Kirsten Frombach, Honours – 1991 (Supervisor)
Tammy McJannet, Honours – 1992 (Supervisor)
Mark Lawrence, Honours – 1992 (Supervisor)

Other Teaching

Summer 1983	-	Nipissing College University, North Bay, Ontario Introduction Cultural Anthropology "Peoples of the World"
1984	-	Introduction to Physical Anthropology and Human Evolution
	-	Introduction to Archaeology
1985	-	Human Evolution
	-	North American Indians
1986	-	Peoples of the World
	-	Introduction to Archaeology
1987	-	Introduction to Physical Anthropology and Human Evolution
	-	North American Indians
1988	-	Peoples of the World
	-	Introduction to Archaeology
1989	-	Peoples of the World
	-	Introduction to North American Indians
1990	-	Peoples of the World
	-	Introduction to Archaeology

-----Original Message-----
From: Westport Library [mailto:westport@nsy.library.ns.ca]
Sent: Thursday, June 28, 2007 2:00 PM
To: Myles,Debra [CEAA]
Subject: Undertaking 46

Undertaking #46
I wanted to forward this e-mail detailing some of the specifics needed to fully understand the underwater blasting issue.
thanks You
June Swift

------- Forwarded message follows -------
Date sent: Wed, 27 Jun 2007 22:34:16 -0300
To: westport@nsy.library.ns.ca
From: Lindy Weilgart <lweilgar@dal.ca>
Subject: Re: help needed for infomration on noise from blasting and stranding whales

Hi,

You are quite right that underwater blasting of a certain magnitude will almost certainly be destructive to all sort of marine animals, including whales. If they are close enough, they will be killed outright. If they are further away, they would be deafened. And if they are still further away, their behaviour may be quite altered, to the point that they may clear out of the area and/or compromise their feeding, breeding, navigating, group cohesion, etc. The destructive impacts of underwater explosions on marine life are not controversial. The exact distances and levels of destruction together with the magnitude of the explosion, species, etc. are somewhat up for debate, but the concept is not.

I would not, however, equate explosions with naval sonar. They are entirely different in character. As such, I know of no scientific literature that states that explosions cause strandings, unless it would be of already dead animals killed outright by explosions. Strong explosions are usually much more destructive than sonar. They are louder, generally, and have a pressure wave (shock wave) in a addition to an acoustic wave. Their quick rise time makes them especially dangerous. There are equations of how loud certain amounts of TNT are, for instance. This can be calculated, if you knew the strength of the explosion (how much explosive was used). But even without the shock wave, at greater distances away, the acoustic wave would still have the potential to cause great damage to behavior.

The acoustic effect would also depend on the propagation conditions of the area. The substance and contour of the ocean bottom, the temperature profile, etc. would all affect how far the sound wave would travel. This should be modelled and then tested in the area to accurately determine how far the sound might impact animals.

Did the panel actually want the papers in hand or just the references? It's pretty hard to get your hands on some of these papers, so I'd hope they would be reasonable in being satisfied by the references for now.

What I have written on explosions in a review article on undersea noise (not yet published):

"Blast waves cause a dramatic pressure drop over a very short duration (sharp rise-time) and are relatively broadband in frequency, resulting in mechanical impact. Organ damage and the rupture of gas-filled cavities such as lungs, sinuses, and ears can occur (Richardson et al. 1995). A 5,000 kg explosion apparently caused severe injury to the temporal bones of two humpback whales found dead nearby (Ketten 1995)."

Refs:

Ketten, D.R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. In Sensory systems of aquatic mammals. Edited by R.A. Kastelein, J.A. Thomas, and P.E. Nachtigall. De Spil Publishers, Woerden, The Netherlands. pp. 391-407.

Richardson, W.J., Greene, C.R., Jr., Malme, C.I., and Thomson, D.H. 1995. Marine mammals and noise. Academic Press, New York, 576 pp.

Other quotes:
From:
Hildebrand, J.A. 2005. Impacts of anthropogenic sound. In Marine mammal research: conservation beyond crisis. Edited by J.E. Reynolds, III, W.F. Perrin, R.R. Reeves, S. Montgomery, and T.J. Ragen. Johns Hopkins University Press, Baltimore, Maryland. pp. 101-124.

"Intense pressures from sources such as explosions can damage air-filled cavities, such as lungs, sinuses, ears, and intestines (Cudahy et al. 1999). A dramatic pressure drop, such as occurs from blast waves, may cause air-filled organs to rupture. Research on blast damage in animals suggests that the mechanical impact of a short-duration pressure pulse (positive acoustic impulse) is best correlated with organ damage (Greene and Moore 1995). Peak pressures of 222 dB re 1 microPa result in perforation and hemorrhage of air-filled intestines in rats (Bauman et al. 1997). Lethal peak pressures of 237 dB re 1 microPa cause pulmonary contusion, hemorrhage, barotraumas, and arterial gas embolisms in sheep (Fletcher et al. 1976). Two humpback whales were found dead following a nearby 5,000-kg explosion, and examination of the temporal bones in their ears revealed significant blast trauma (Ketten et al. 1993)."

Refs:

Cudahy, E., E. Hanson and D. Fothergill 1999. Summary Report on the Bioeffects of Low Frequency Water Bourne Sound. Naval Submarine Medical Research Laboratory, Groton, CT 29 pp.

Greene, C. R. J. and S. E. Moore 1995. Man-made Noise. Pp 101-158 in Marine Mammals and Noise. D. H. Thomson (ed.), Academic Press,San Diego.

Bauman, R. A., N. Elsayed, J. M. Petras and J. Widholm (1997). Exposure to sublethal blast overpressure reduces the food intake and exercise performance of rats. Toxicology 121(1): 65-79.

Fletcher, E. R., J. T. Yelverton and D. R. Richmond 1976. The thoraco-abdominal system's response to underwater blast. Final Technical Report for ONR contract N00014-75-C-1079, Arlington, VApp.

Ketten, D. R., J. Lien and S. Todd (1993). Blast injury in humpback whale ears: Evidence and implications. J Acoustic Soc Am 94: 1849-1850.

Hope this helps. I would recommend you stay away from referring to naval sonars, however. You're much better off sticking to actual blast injury references. I was approached years (?) ago about this project and said I was willing to help oppose it if given some specifics on how loud the blasts would be, for instance, but the people never followed up on my offer. BTW, I will be gone from June 30-July 13.

Good luck!

Lindy Weilgart

Lindy Weilgart, Ph.D.
Research Associate and Assistant Professor
Department of Biology
Dalhousie University
Halifax, Nova Scotia B3H 4J1 Canada
Ph.: (902) 494-3723
Fax: (902) 494-3736
E-mail: lweilgar@dal.ca

At 06:04 PM 6/27/2007, you wrote:
>Hi Linda
>My name is June Swift and I live in Westport Brier Island. I went
>before the Quarry panel and
>presented some of my concerns. One of those concerns is blasting
>underwater and it being
>linked to whale strandings. The panel wants me to sumit scienific
>papers on this subject by
>Friday. Do you know where I can obtain this information? Can you
>please help me? I know it
>is not a lot of time but they didn't give me much time to produce
>evidence. I did refer to Naval
>sonar references in the US.
>Thanks for your help
>June Swift--
>Westport Branch Library
>P.O.Box 1194
>Westport, NS B0V 1H0 Canada
>westport@nsy.library.ns.ca
>www.westerncounties.ca
>(902)839-2955

Lindy Weilgart, Ph.D.
Research Associate and Assistant Professor
Department of Biology
Dalhousie University
Halifax, Nova Scotia B3H 4J1 Canada
Ph.: (902) 494-3723
Fax: (902) 494-3736
E-mail: lweilgar@dal.ca
------- End of forwarded message ---------
Westport Branch Library
P.O.Box 1194
Westport, NS B0V 1H0   Canada
westport@nsy.library.ns.ca
www.westerncounties.ca
(902)839-2955

Green Party of Nova Scotia
P.O. Box 36044
5665 Spring Garden Road
Halifax, Nova Scotia
B3J-3S9

Dr. R. Fournier (chair), Dr. J. Grant, Dr. G. Muecke
Joint Review Panel for the Whites Point Quarry and Marine Terminal
c/o Debra Myles, debra.myles@ceaa-acee.gc.ca

Re: Undertaking 47

Panel members:

The Green Party of Nova Scotia has no specific official policy on the use of aggregates as yet; however, the Green Party of Nova Scotia recognizes the need for raw materials, such as aggregates, in the manufacturing of building materials. The Green Party of Nova Scotia holds that the extraction of these materials must be done with stringent environmentally sustainable methods now and in the future. The Green Party of Nova Scotia is opposed to aggregate mining developments that threaten our Provincial coastlines, communities, ecosystems, biodiversity, and atmosphere.

Sincerely,

William Lang
Deputy Leader, Green Party of Nova Scotia

Undertaking # 48
To provide the refusal rate for the AMEC attitude

The refusal rate for the 2005 survey was 64%. This is calculated by adding up the total number of refusals and terminations (2,004) and dividing it by the total asked (3,151). The total numbers attempted for this project were 5,447.

The refusal rate for the 2006 survey was 51%. This is calculated by adding up the total number of refusals and terminations (569) and dividing it by the total asked (1,105). The total numbers attempted for this project were 1,974.

Undertaking # 49

To provide a refined delineation of the numerical characteristics of the AMEC attitude surveys, e.g. the number of participants

The 2005 attitude survey had 542 respondents initially – 139 had never heard of the project, 403 continued the survey. 55 extra surveys were completed with respondents from Centreville, Freeport, Sandy Cove, Little River, Tiverton and Westport, leading to an overall total of 458 completed surveys.

The 2006 attitude survey had a sample size of 200 respondents, all having heard of the project. The purpose of the second survey was to determine if the opinions of the population had changed within a one year time period and if so, to what degree had they changed.

Both surveys are considered accurate at a ± 5.0% at 95% confidence level

Undertaking #50
To identify contributors to AMEC Health and Wellness study and their respective contributions to the study.

The AMEC Human Health and Community Wellness Assessment (The Assessment) was submitted to Bilcon of Nova Scotia on November 30, 2005. The Assessment was authored by Jacinthe David, an employee of AMEC at that time. Prior to joining AMEC, Ms. David had over three years impact and risk assessment experience with Health Canada. Her expertise encompasses the identification, assessment, management and communication of environmental and human health impacts and risks associated with development projects and contaminated sites. She holds a Bachelor of Science Degree in Environmental Geography and a Master's of Science Degree in Geography, both from the University of Montreal.

The survey information provided in The Assessment is part of an AMEC-led Health Survey conducted in 2005. The survey was authored by Jacinthe David and conducted by Market Quest Research Group, Inc. Located in St. John's, Newfoundland and Labrador, Market Quest is a full-service marketing research firm offering an integrated range of quantitative and qualitative research services. The survey was managed by Kathy-Jane Elton, an AMEC Consultant with over 20 years of experience in research, strategic planning, policy/program planning and review, and project management. Ms. Elton holds a Bachelor of Arts (Honours) and a Master's in Business Administration from Memorial University of Newfoundland.

The overall contract for the Assessment was managed by Susan Sherk. Ms. Sherk is a Senior Associate with AMEC and has over 30 years experience in socio-economic impact assessment, public consultation and strategic planning. She holds a Bachelor of Arts Degree in Sociology from Wheaton College, Norton Massachusetts.

UNDERTAKING 51

To provide a breakdown of the geographic background of the 57 participants in the TEK study, i.e. whether they live now and where they lived previously.

At the time of the interviews, the individuals interviewed resided within the following parameters. Using a compass and the Digby Neck and Islands Tour Map that was published by the Digby Neck Economic Development Association, the following applies:

Within 5km	of the Whites Cove site =	13
Within 10Km	of the Whites Cove site =	15
Within 15km	of the Whites Cove site =	6
Within 25km	of the Whites Cove site =	2
Within 35km	of the Whites Cove site =	18

Three others reside 100km or more away. Dr. L.R. Denton, who grew up in Little River and has since published on a limited basis a family genealogy and a narrative historical description of his early life in Little River, resides in Truro, NS. This publication is referenced in the study. Copies of this publication are available at the Admiral Digby Historical Society, Acadia University, The Public Archives of Nova Scotia, and Dalhousie University.

One of these three was a highway engineer for #217 who stayed in Little River and could speak to his personal memory of the Whites Cove Area for aggregate. A third was a business man who now resides out of the area who was involved in the development of fish processing plants, including Mink Cove.

The sources were asssured that they would be protected. Two of the sources have indicated some distress over the negative nature of the contacts made by persons opposed to this project. As this is a small area, even this geographic breakdown could cause some anxiety to participants or, in the case of deceased persons, their families.

3701

www.npd.no/NR/rdonlyres/5CFDA786-2670-48F1-91A0-1BDC093F27A3/0/boomanengelsk.pdf

SUMMARY

Fish in their early life stages as eggs, larvae, and fry are in the most exposed positions for harmful impacts from seismic explorations. They are physiologically vulnerable, and unlike to larger fish, they are not able to move away from the volumes around the air guns.

The background for this project was that previously conducted experiments up to 1990 did not directly elucidate particular aspects of actual Norwegian problems. The fish species used were not fully representative of Norwegian waters, and all actual sizes of air guns were not applied during previous Norwegian experiments. Additionally one should apply histological and pathological competance to verify different internal injuries at both instantaneous mortality of larvae and fry and at sublethal conditions. The main goal of this study was thus to provide new and supplementary knowledge to describe and evaluate harmful effects on eggs, larvae, and fry from seismic surveys applying air guns in order to contribute to fishery management.

The field work was conducted at the Austevoll Aquaculture Station of the Institute of Marine Research. We applied three experimental set-ups to simulate the impact from offshore seismic explorations. During the field seasons 1991-92 a great number of exposures by air guns of several fish species at different development stages were carried out. The project activities and preliminary results by March 1993 were reported to the previous Norges Fiskeriforskningsråd (The Norwegian Fisheries Research Council) in 1993.

The species used in the project should be commercial important species and representative for Norwegian waters. They should further possess different physiology such as species having either closed or open swimbladders and being different physically robust. We used cod and saithe as species having closed swimbladder, and herring having open swimbladder. Among flatfish species we chose turbot and plaice because turbot have temporary closed swimbladder through the larval stages, while the plaice have no swimbladder at all, and that they represented flatfish species in the North Sea and the Barents Sea respectively. Although the flatfish species are related to the bottom as adults, they appear pelagic as larvae and are therefore available for seismic impacts.

Some of the species were followed from early egg stages, as yolk sac larvae, larvae, post-larvae, and fry (Norwegian notation of larval stages) while for others only specific stages were studied. We observed and analyzed materials and data after the air gun shooting to look for hatching success of eggs, instantaneous and long-term mortality rates, startfeeding success, buoyancy, growth, injuries of tissues, and behaviour prior to and after the air gun exposures.

C0918-108

We used two air gun set-ups which for characteristics like released energy, rise time of the transmitted sound pulses, and the number of shots that the organisms can be exposed to, reflected typical set-ups used offshore. We measured the acoustic output from the air guns and estimated the transmitted energy and rise times. The distances from the air gun or the center of the air gun cluster were in the range 0,75 m to 6,0 m, corresponding to sound pressure levels of 242 to 220 dB // 1 µPa.

From the experiments with eggs we found no statistically significant differences of the mortality rate of cod and saithe between the exposed groups and the control ones. However for saithe eggs at early gastrulation the group exposed at 0,75 m and sound pressure level $L_p = 242$ dB // 1 µPa showed a pronounced trend of increased mortality rate compared to the other groups. We observed no significant difference of hatching of cod eggs between the exposed groups and the control ones. For the startfeeding success we observed no significant reduction for cod larvae exposed at early gastrulation.

At the yolk sac stage we observed a small, but not significant increase of the mortality rate for cod at short distance (0,75 m, $L_p = 242$ dB // 1 µPa) with an average mortality rate of 29 % in relation to 16 % in the control group. For turbot we observed significantly increased mortality rate out to maximum distance of exposure, 3 m, ($L_p = 224$ dB // 1 µPa). The average mortality rate was three times as high in the exposed groups as that of the control group. For herring we did not detect any difference of the mortality rate between the exposed groups and the control ones as the mortality rate was very high in all groups - between 70 and 80 %. For cod exposed two days after hatching we found no difference in the mortality rate between the exposed groups and the control one by testing for startfeeding success four days after hatching. For herring we did not detect any impact on the startfeeding success.

By microscopic investigations of cod yolk sac larvae no changes of any tissues were detected. Our results did not confirm Russian results demonstrating delaminations of the fish eyes. For turbot yolk sac larvae we demonstrated strong vacuolation in the brain, the spinal marrow, and the eyes at exposing distances out to 1,6 m. We detected abnormal great increase in volumes of the nerve cells at 0,75 m. The characteristics of the cell expansions implies that they are caused by strong and rapid pressure influence, and must be regarded as a real pathological alteration. As these serious alterations were proved in the brain, this may influence the normal growth of the nervous system and therefore the condition of the larvae and its ability to survive. Until further information is available, this injury must be regarded as a sublethal effect.

The lateral line system of fish may be vulnerable to pressure impacts, especially among larvae

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where the free neuromasts in many cases are representing the lateral line prior to this being completely formed. Investigations of turbot yolk sac larvae demonstrated injuries of the free neuromasts in all groups. Completely cutting of all the sensory celia of each neuromast was only appearent in the exposed groups. Injuries to the free neuromasts may affect larval survival through a reduced ability to avoid predatores.

At the larval stage the mortality rates were high in both the exposed groups and the control ones as the organisms were rather sensitive to handling. The mortality caused by handling made it impossible to observe any effects on saithe. At this stage we observed higher mortality rates of cod in the exposed groups than in the control ones for exposure distances 2-5 m from the air guns. The mortality rate was significantly higher for the group being exposed 5 m below the gun cluster (L_p = 223 dB // 1 μPa) compared to the control group.

At the post larval stage the cod showed significant mortalality at 0,75 m, and slightly increased, but not statistical significant out to 1,5 m from the air guns (L_p = 235 dB // 1 μPa). From experiments in a pen where the post larvae were 1-1,5 m to the side of and below the air gun cluster, the mortality rate in the exposed group were twice that of the control group. For herring we found slightly increased, but no significant mortality rate out to 1,3 m distance. For plaice and turbot we found slightly increased, but no significant mortality rate out to 1,6 and 2 m distance respectively.

For cod and turbot changes in their buoyancy were observed immediately after being exposed. Specimen from both species from groups being exposed at distances out to 2 m showed over-floatation.

Investigations of cod post larvae showed injuries of the neuromasts in all groups after a two week testing on feeding, the injuries were more pronounced within the exposed groups. Specimens of all groups showed good growth.

For cod fry we observed up to 20 % mortality rate at 0,9 m, up to 3 % at 1,3 m and no mortality at 1,7 m from the air guns, and in the control group respectively. We observed injuries of internal organs as broken swimbladders, contracted swimbladders, gas bubbles under the swimbladder membranes, broken kidney membranes with effusion of blood in the kidneys, and coagulated blood in the abdomens and the swimbladders. Some of these injuries healed over time.

Among fish not being killed, we observed many fishes getting stunned and some having

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abnormal swimming behavior. Some of the fish which fainted died during the first day after the shooting, while others having special behaviour patterns usually recovered to normal behaviour 0,5 to 1 hour after shooting. Behaviour changes like this are severe for all stages, but they could only be observed when the specimen had become over a certain size.

Relating kind and extent of observed effects to tramsmitted power or distance between the fish and the air guns we can summarize and conclude that the existing mortality and injuries are near-distance incidents. Highest mortality rates and most frequent injuries were observed out to 1,4 m distance, while low and no mortality rate and more infrequent injuries were observed out to 5 m distance.

This study should be followed up by another one dealing with what effects the total mortality and internal injuries of larvae and fry from air gun seismics may have on the fish stock level.

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

Canada

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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ISSN 1708-6272 (printed)
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La version française est disponible à l'adresse ci-dessus.

Correct citation for this publication

DFO, 2004. Potential Impacts of Seismic Energy on Snow Crab. DFO Can. Sci. Advis. Sec. Habitat Status Report 2004/003.

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Comments to the Federal Advisory Committee on Acoustic Impacts on Marine Mammals

Sunday 2/1/04

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My purpose in writing is to express concern with the limited charge of the Committee with regard to the marine biota.

While it is clear that the issues driving the concern about the effects of human-generated (anthropogenic) sound in the marine environment center around marine mammals, these animals make up only a small portion of the aquatic biomass, and an even smaller number of total species in the marine environment. Indeed, just considering vertebrates alone, there are over 27,000 extant species of fish and elasmobranchs. Moreover, a large portion of the fishes, and the vast majority of the elasmobranchs, are marine.

The basis for my concern regarding the charge of the Committee, and the study it will undertake, is several-fold:

1. Many species of fish make up a major portion of the diets of many marine mammals. Any effect on fish populations could impact the survival of marine mammals due to a scarcity of food supply.

2. Fishes make up a major portion of the human diet, and any effects on fish populations could impact humans very directly.

3. Fishes, unto themselves, make up the largest group of vertebrates and show the greatest biological diversity of any vertebrates. Any harm to fish populations has the potential of harming fishes which are now, or could become, endangered.

4. A number of invertebrate species have ear-like structures (e.g., octopus and squid). While we do not know if these, or other, marine invertebrates are able to hear or be affected by sound, their well-being needs to also be recognized and considered since they, like fishes, make up a portion of the diets of marine mammals and humans.

The concerns I express are not unique to me. If you examine the last three NRC reports, each talks about the impact of anthropogenic sound on fishes (and other marine organisms). And, these reports suggest and/or simply that we must consider the effects of these sounds on marine mammals, just as we do on fishes.

I will not go into the body of literature demonstrating that fishes detect and use sound in many important ways, or the literature showing that high intensity sounds can have the same kinds of effects on fishes as they do on mammals. (I have, however, taken the liberty of attaching a recent article of mine that outlines what is known about some aspects of the effects of anthropogenic sounds on marine mammals and would appreciate this being shared with the Committee.)

I will summarize and point out that we have a strong body of data showing the following (all are from peer-reviewed publications):

1. Anthropogenic sounds (e.g., seismic air guns) can destroy the sensory hair cells in the ears of at least one species of fish. (Interestingly, parallel experiments cannot be done on marine mammals, and so the fish data may be highly relevant for the work of the Committee.)

2. Other high intensity sounds have been shown to damage/destroy sensory hair cells in the ears of several other fishes.

3. Exposure to lower intensity sounds, even for as short a time as 10 minutes, can result in temporary threshold shift. Longer exposure to such sounds can result in TTS that lasts for weeks.

4. Stress effects, as manifest in hormone levels, may be caused by moderate levels of sound stimulation.

There are also critically important questions that have yet to be considered for fishes in peer-reviewed studies.

1. Effects on other aspects of behavior than hearing

2. Impact on eggs and larvae. (There are data in the literature, but it is old and studies did not follow the effects through the whole developmental process.)

3. Effects on other organ systems (brain, liver, swim bladder, etc.)

Note that I am not suggesting that the Committee move away from its charge, or add members with expertise on fishes. However, I am suggesting that within the Scope and Objects of the Committee, it should be possible to include appropriate information on fishes in each of the four areas outlined for the Committee without extending very far from the work on marine mammals. Such an addition would add value to the work of the Committee, and provide a broad view of the oceans biodiversity that would clearly be lacking in any report that does not recognize the presence and importance of fishes and invertebrates.

Needless to say, if I can provide information to the Committee I would be pleased to do so.

Sincerely,

Arthur N. Popper

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fisheries research **feature**

Effects of Anthropogenic Sounds on Fishes

ABSTRACT

There is increasing concern regarding the effect of human-generated (anthropogenic) sounds on marine organisms. While most concern is focused on marine mammals, many of the lower frequency (under 1,000 Hz) sounds are also likely to affect fish. Anthropogenic sounds can range from very intense signals such as noise generated by ships and their sonars to far less intense signals such as background sounds in hatcheries and oceanariums. The sounds may affect behavior and/or physiology, although very little is specifically known about how sounds affect fish. Limited data suggest that short- or long-term exposure to loud sounds may alter behavior, and also result in temporary or permanent loss of hearing. In order to better understand this issue, a series of studies are needed that systematically explore both behavioral and physiological effects of different types of sounds on a select group of species at different stages of their development.

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The past several years have seen a significant increase in questions and interest related to the effects of anthropogenic (human-made) sounds on marine mammals (e.g., NRC 1994, 2000, 2003; Richardson et al. 1995). This has arisen because of increased public awareness of the level of anthropogenic sound being generated in the marine environment and also by public concern for the safety and health of marine mammals (e.g., NRDC 1999). This interest has not only led to attempts to understand the sources and levels of anthropogenic sounds, but also to attempts to assess the potential effects of such sounds on marine mammals. These concerns have also led to litigation in attempts to control some of the anthropogenic sources.

Though the majority of concerns, research efforts, and even litigation have been focused on marine mammals, the sounds that affect marine mammals also have the potential to affect the safety and well-being of other marine organisms including fish, turtles, aquatic birds, and perhaps even invertebrates (e.g., NRC 1994, 2000, 2003). Fishes are of particular concern since many species use sounds to find prey, to avoid predators, and for social interactions. Moreover, the sensory receptors used by fishes to detect sounds are very similar to those of marine (and terrestrial) mammals, and, as a consequence, sounds that damage or in other ways affect marine mammals could have similar consequences for fishes.

Notes on terminology

Before discussing anthropogenic sound, it is important to define a few terms. Sound levels in this article, and in the literature, are always referenced relative to some arbitrary value. In water, this value is relative to 1 microPascal (mPa). Use of this reference value allows investigators to compare levels recorded in different places and at different times (see www.earthisland.org/immp/eii_sonar_chart.pdf). In contrast to the reference value in water, the reference value in air is 20 mPa. This value was selected using the convention that it is the level of the human hearing threshold at 1,000 Hertz (hz, cycles per second).

Different reference values (20mPa vs. 1 mPa) are used in air and water due to differences in density of the two media. Thus, one cannot directly say that a sound of a certain level in air is the same as that in water. As a general comparison, acousticians will add 61 decibels (dB) to an airborne sound level to get an equivalent sound pressure in water for a stimulus of the same magnitude. To give some sense of how loud various sounds are, 105 dB re 1 mPa (in water) is about the same loudness as a classroom (in air) of 44 dB re 20 mPa, while 151 dB re 1 mPa is equivalent to a New York City subway, and 186 dB re 1 mPa, the sound of some large tankers underway, is about the sound level at which a human listener will feel pain from the loudness of the sound.

What are the sources of anthropogenic sounds?

Humans generate a great deal of sound in the aquatic (and terrestrial) environment. Some of the most frequently cited sources relevant to marine mammals (and all aquatic organisms) are shipping, seismic exploration, and sonar, but there are many other sources (e.g., Richardson et al. 1995; NRC 2003). Shipping is probably the most extensive source of noise in the oceans, especially along major shipping channels (e.g., from Alaska to California for supertankers carrying oil) (e.g., Wales and Heitmeyer 2002). While there is broad variation in the sound levels produced by shipping, the frequency range of the sounds is generally below several hundred hertz. In certain locations, and for extended periods of times, air guns used for seismic exploration can also be extremely loud (e.g., McCauley.

It was probably the Acoustic Thermography of Ocean Climate (ATOC) study in the early 1990s (Baggeroer and Munk 1992) that most directly

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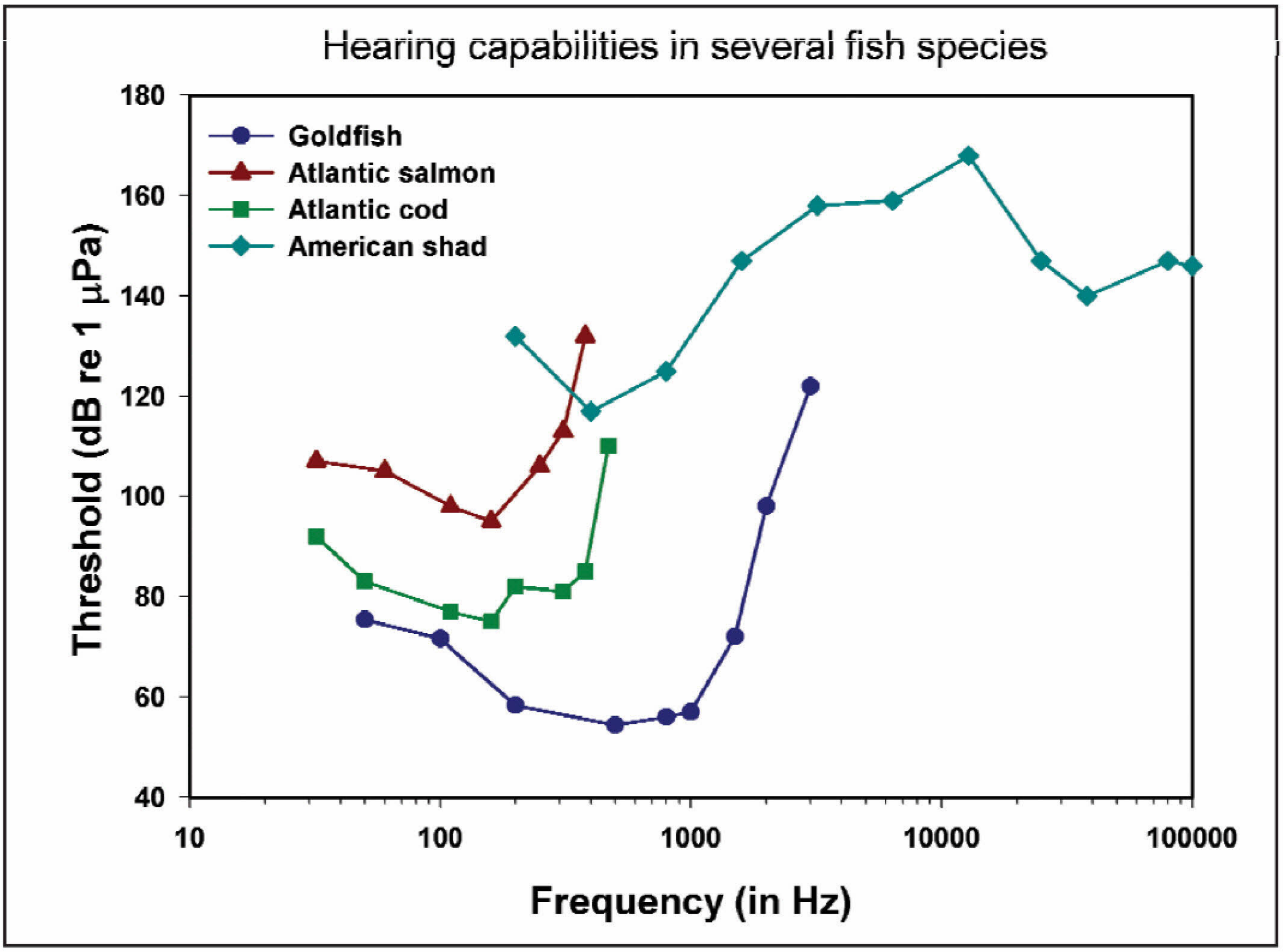
brought anthropogenic sound to the public interest. The goal of that study was to examine changes in global temperatures by projecting a sound over great distances in the ocean and, from information about time of arrival of the sound at the receiver, determine an average ocean temperature. At the same time, public concern arose as to the potential effects of these sounds on marine mammals and whether the sounds could potentially affect their behavior and/or health. In particular, concerns focused on the relatively high intensity of these sounds and the intent to produce sounds over periods of many years to determine changes in ocean temperature over time.

More recently, there has been considerable concern about use of very high intensity low-frequency sonars by the U.S. and other navies (SURTASS LFA 2001; NRC 2003), and their potential effect on the health and well-being of marine mammals. Other kinds of sound sources such as mid-frequency sonars, seismic air guns, and pile driving have also raised concern about effects on marine mammals and fishes.

In most cases, the sounds produced by humans are relatively low in frequency, with the bulk of the energy below 1,000 Hz. Thus, these sounds are within the hearing range of fishes (Figure 1) and so have the potential to affect fish as well as marine mammals. While the problem for fish would be lessened if the sounds were limited to deep water, an increase in sound often occurs near the shoreline as a result of boat operations (U.S. Maritime Administration 1999). Indeed, with increased inshore shipping, the level of ship-generated sounds in the habitat of many fishes and other aquatic

Figure 1. Hearing thresholds (the lowest sound detectable) of four representative species of fish determined using behavioral methods. Goldfish is considered to be a hearing specialist, while Atlantic cod and Atlantic salmon are not. Note that the American shad, which may also be considered a hearing specialist based on its very broad hearing bandwidth, probably has the widest hearing range of any fish, if not vertebrate species, and has evolved mechanisms to detect the ultrasonic echolocation signals of dolphins. In interpreting these curves (also referred to as audiograms), lower values indicate better hearing. (*Data for Atlantic salmon, Atlantic cod, and goldfish in Fay 1988; American shad from Mann et al. 2001.*)



organisms will increase even further. Moreover, there is now also concern that higher frequency sonars, as well as echo sounders used by fishing vessels, could affect some fishes because a number of species of clupeid fishes (American shad, menhaden, alewives) can detect sounds at frequencies to over 200 kHz (Mann et al. 2001).

Although the concern regarding the effect of anthropogenic sounds is most often directed at wild animals, the issue is of similar importance with respect to captive animals. Because humans do not hear well under water (Brandt and Hollien 1967) and since the impedance differences between a body of water and air is such that sounds in one environment do not easily get transmitted across the air-water interface (e.g., Akamatsu et al. 2002) (e.g., almost 99.9% of sound generated under water is reflected back from the air-water interface), we are often unaware that human-made environments such as aquaculture facilities, fish hatcheries, and large oceanarium tanks are often relative noisy environments.

A striking parallel is the interest and concern of the federal government on the health of workers in environments where there is long-term exposure to noise (e.g., factories). Importantly, noise does not have to be particularly loud to affect human health. Instead, the effects of exposure appear to be cumulative (NIH 1990), and so a longer exposure to a low intensity noise can be just as damaging as short-term exposure to a very loud noise.

How do fish use sound?

Hearing evolved very early in the history of vertebrates, and fish can perform the same basic auditory tasks, such as discrimination between sounds, determining the direction of a sound, and detecting biologically relevant sounds in the presence of noise, as do terrestrial vertebrates (including mammals) (e.g., Fay and Popper 2000; Popper et al. 2003). Indeed, it has been shown that all species of fish (both bony and cartilaginous) that have been tested are able to hear. Fishes of a number of species including the otophysans (e.g., goldfish, catfish) have specializations that have evolved to enhance hearing capabilities (Figure 1) (reviewed in Popper and Fay 1999; Popper et al. 2003). These fishes, often referred to as "hearing specialists," can detect sounds to over 3,000 Hz, with best hearing sensitivity from about 300 to 1,000 Hz. In addition, some fishes in the family Alosinae, including American shad (*Alosa sapidissima*) and blueback herring (*A. aestivalis*), can detect ultrasonic sounds to over 200 kHz (Mann et al. 2001). Thus, higher frequency sonars, echosounding devices, pingers, and other sources could affect these species.

In contrast, the majority of fishes do not have known hearing specializations and only detect sounds up to 500 to 1,000 Hz, with best hearing from 100 to 400 Hz (Figure 1). Generally, best hearing sensitivity in a specialist is better than in a nonspecialist. However, it should be noted that all fishes are able to detect sounds within the frequency range of the most widely occurring anthropogenic sounds.

It might be argued that the only fishes that would be affected by anthropogenic sounds are species that make and use sound for communication (see Myrberg 1980 and Zelick et al. 1999 for reviews of fish sounds and fish acoustic communication). However, while many species do not make sounds or use sound for intraspecific communication (e.g., goldfish), all species are likely to obtain a good deal of information about their environment from the overall acoustic milieu (e.g., Tavolga 1976; Myrberg 1980; Fay and Popper 2000). Keep in mind that a human can enter a dark room and determine a good deal about the room just from sound that she emits or from the sounds in the room itself. Similarly, it is likely that fishes (and all animals) glean a good deal of information about their environment from sounds that might include waves breaking on the shore, currents moving across the reef, or other diverse sources. This detection of the acoustic environment takes on additional importance when one realizes that if fish had to depend on sight alone to learn what is going on in the world around them, they would have very limited information about potential predators and prey and of their "world," particularly at night or in murky waters. Again, using a human analogy, sound provides us with information from the whole world around us, including the space that is not within our visual field, and a similar use of sound has been demonstrated for at least one fish, the marine catfish (*Arius felis*; Tavolga 1976).

Indeed, it is very likely that the evolution of hearing in vertebrates (and probably in invertebrates) was not for acoustic communication per se but, instead, to broaden the space around the animal from which there was a constant flow of information (see Popper and Fay 1999; Fay and Popper 2000; Popper et al. 2003). It was only later in the course of vertebrate evolution that hearing capabilities in fishes extended to include communication sounds. Additional selective pressures for changes or improvement of hearing probably are related to specific acoustic environments. Perhaps the best example of this is found in a number of fishes that have a broad hearing bandwidth such as the otophysan fishes (e.g., goldfish, catfish), mormyrids (elephant nose fishes), and clupeids (herring, shad) (Popper and Fay 1999; Popper et al. 2003). Many of these fishes are not known to produce sounds or use sounds in reproductive or other behaviors. At the same time, these fishes can detect sounds to over 3,000 Hz as compared to most other fishes (including most sound-producing fishes) which generally can detect sounds to no more than 1,000 Hz (Popper and Fay 1999; Popper et al. 2003). Although the broad hearing bandwidth in these species perplexed investigators for several decades, we now know that only higher frequency sounds propagate beyond a

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few meters from the source in the shallow waters in which these species presumably evolved (Rogers and Cox 1988). Thus, it is likely that the evolution of high frequency hearing in these fishes most often (though certainly not always) occurred in those populations able to gain more distant information in the shallow water acoustic environment.

Since fishes live in a naturally "noisy" environment (Myrberg 1980) and since they have probably evolved to gain environmental information from this noise, anything that hampers the ability to detect biologically relevant signals will have a potentially deleterious effect on the survival of fish and the health of fish populations.

In what ways might anthropogenic sounds affect fishes?

Anthropogenic sound may have no effect on fish. In other words, fish may not detect such sounds, or, if they detect the sounds, there may be no deleterious effects on either behavior or physiology. However, if one assumes that fish respond like other organisms (including humans) to excessive sound in their environment, there are several different possible outcomes that may vary depending upon the life stage and species of the animal being affected and its specific behavioral and physiological response to the sound.

Behavioral responses to loud noises may include the fish swimming away from the sound source, thereby decreasing the potential effect of the sound, or the animal "freezing" and staying in place, thereby leaving the fish open to considerable damage. In cases where the fish swims away or alters behavior in other ways, the actual effect could be slight or it could be substantial. Just as a human walking down a street might cross the street to avoid the sound of a jackhammer and then return to a normal path, a fish might just move away from the source and then resume normal behavior.

Alternatively, the responses to the sound could affect behavior more extensively and result in the fish leaving a feeding ground (e.g., Engås et al. 1996) or an area in which it would normally reproduce or in some other way affect long-term behavior and subsequent survival and reproduction. Of course, the changes may be insignificant, but there may also be a more permanent long-term effect if feeding or reproduction is impeded. Moreover, if fishes such as Alosinae herring that are being sampled or tracked by ultrasonic sound pulses change their behavior and distribution in response to the sound, the data collected will be biased.

Another behavioral effect might occur if the increased ambient noise prevented fish from hearing biologically relevant sounds. This interference, called masking, is a consequence of noises being in the same frequency range as communication or other biologically relevant sounds. As a result of the presence of the masker, a fish may not be able to hear biologically important sounds (e.g., Myrberg 1980), just as a human has trouble hearing a fellow speaker in a noisy restaurant or when near a jackhammer or a loud rock band. For example, sharks, which are not known to be sound producers, are attracted to the sounds of struggling fish (or humans!) which serve as their prey (e.g., Myrberg et al. 1976). If there is excess noise in the environment, it would lessen the chances that the shark would hear the prey, thereby decreasing its ability to find food.

Of recent concern are the increased environmental sounds in the vicinity of coral reefs. Larval reef fish of many species spend part of their lives offshore and away from reefs and then settle on a reef where they will live for the remainder of their lives (e.g., Leis and McCormick 2002). Recent evidence suggests that at least some larval fish use the reef sounds to find the reefs and that the fish will go to regions of higher level sounds (e.g., Tolimieri et al. 2002). Thus, intense offshore sounds may confuse larval fish. Alternatively, such sound may mask reef sounds, again preventing larval fish from finding the reef.

Physiological and physical effects are also potentially similar to those found in other vertebrates. Humans and other organisms having long-term exposure to sound may show changes in stress levels (imagine a human adult having to sit near a loud rock band for an evening) or may experience temporary loss of hearing that may last from minutes to days (e.g., Hattingh and Petty 1992). While it is hard to predict the consequences of changes in stress levels on fish (or any organism), a temporary loss of hearing (whether it be full or partial) could mean that a fish loses some ability to detect predators or prey, communicate acoustically, and/or determine the structure of the acoustic environment. Clearly such effects would alter the survival of a fish.

Longer-term effects are also possible. It is known that exposure to very intense sounds, even for short periods of time, will cause permanent loss to the sensory cells of the ears of humans and other terrestrial animals, and loss of such cells means deafness (Lehnhardt 1986). Since the sensory cells of fishes are virtually the same as found in terrestrial vertebrates (see Popper et al. 2003), it is likely that exposure to loud sounds might permanently deafen fish and, again, decrease the survival chances. (Of course, there is evidence that fishes, unlike mammals, are able to regenerate sensory hair cells in the ear {Figure 2}, at least after exposure to certain ototoxic drugs [Lombarte et al. 1993]. However, there is yet no evidence as to whether fishes will regenerate sensory hair cells after noise damage.)

What is the evidence for the effect of anthropogenic sounds on fishes?

There have been only a few studies on the effect of anthropogenic sounds on fishes. The data are limited partially because this has not been an issue

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of interest until recently and partly because the experiments are often hard to do. Since sounds needed to do the appropriate experiment are very loud, they are not easily done in a lab where people or other animals might be bothered.

Engås and colleagues (Engås et al. 1996; Engås and Løkkeborg 2002) examined the effect of seismic air guns on catch rate off the coast of Norway (also see Wardle et al. 2001). Air guns are air-powered devices used for underwater oil exploration as well as for general oceanographic geologic studies. They produce intense low-frequency sounds that are fired repetitively for hours or days in the same general area, and the sound is directed downwards. Sound levels can be up to 255 dB re 1 mPa in the frequency range of 20 to 150 Hz (Engås and Løkkeborg 2002). The echoes from the sounds reflect the nature of the sub.bottom geology. Engås et al. (1996) first determined catch rate in a normal fishing area. An air gun was then brought into the area for a period of time. Results showed a significant decline in catch rate that lasted for several days after termination of air gun use, and then the rate returned to normal. The conclusions were that the air gun caused the decline in catch rate and suggested that the fish may have left the fishing grounds for a period of time in response to the sound. It is not known if the sound just scared fish away or if the fish in the area were damaged (or killed) and others moved into the area to replace those lost. Similar results were found in a rockfish fishery where a single air gun at 186-191 dB re 1 mPa caused a decline of 52% in catch rate (Skalski et al. 1992).

There is also some evidence that low-frequency noise produced by fishing vessels and their associated gear may cause fish to avoid the vessels (e.g., Suzuki et al. 1980). While all of the data on the effect of sounds on fishing need replication, they do suggest that sounds may affect fish behavior and thereby, fisheries. Of course, we also do not know the way in which the sounds affect the fish—do they scare the fish from the fishing site? Do they kill the fish? Clearly, movement of fish from a feeding area, or killing them, could have an adverse effect on the higher members of a food chain, and therefore have long-term consequences despite not killing or maiming the predatory fish themselves.

In addition to behavioral changes, there is evidence of physiological changes that may be temporary or permanent. Several studies have shown that presentation of loud sounds for a few minutes to a few hours will result in a temporary loss of hearing in several different species including goldfish (*Carassius auratus*), tilapia (*Oreochromis nilotica*), and sunfish (*Lepomis macrochirus*) (e.g., Popper and Clarke 1976; Scholik and Yan 2002; Smith, Kane, and Popper, unpublished data). In each case, hearing was measured before and after exposure to loud sounds. Hearing sensitivity was substantially reduced when measured just after the end of the presentation of the loud sounds but improved over time. In studies in our laboratory, we found that it took two weeks for hearing to return to normal in goldfish after seven days of stimulation. In contrast, Scholik and Yan (2001) did not always find recovery 14 days after the termination of 24 hours of noise exposure in the fathead minnow (*Pimephales promelas*).

The actual amount of hearing loss appears to be related to the level of the sound above the hearing threshold, or sensitivity, (Figure 1) of a fish (Smith, Kane, and Popper, unpublished data). Thus, a 170 dB sound will cause hearing loss in goldfish when the sound is about 80 dB above the lowest sound level that the fish can normally detect (threshold), but it would take a 210 dB sound to cause an equivalent loss in tilapia since the threshold of this fish is well above that of goldfish. Very loud sounds may have long-term implications for fish that hear well, although the sounds may have less effect on fishes that normally do not hear very well (see also Scholik and Yan 2002).

Do loud sounds affect the hearing organs of fishes (Figure 2)? Only a few studies have attempted to answer this question. Enger (1981) found that pure tone sounds above 180 dB re 1 mPa

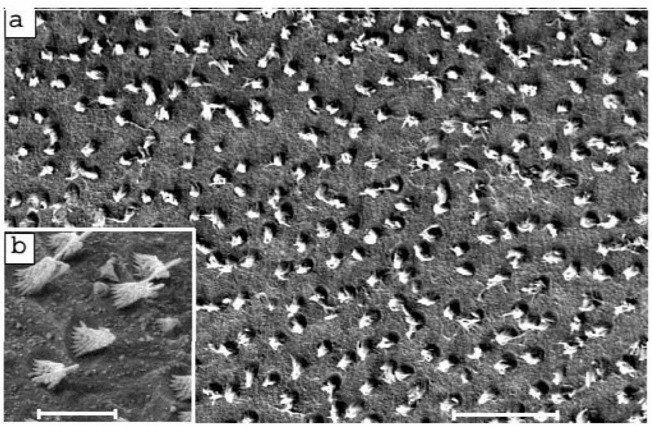

Figure 2. Scanning electron micrograph of a normal sensory epithelium from the saccule (one of the otolithic end organs of the ear involved in hearing) of the pink snapper (*Pagrus auratus*). (a) shows a normal expanse of epithelium while (b) shows a higher magnification of just a few ciliary bundles. These ciliary bundles sit on top of the sensory hair cells of the epithelia of each inner ear end organ. Bending of these bundles, as a result of relative motion between the epithelium and the otolith which lies above the epithelium, occurs during sound stimulation. Bending produces changes in channels in the walls of these cilia and causes the release of neurotransmitter which stimulates the nerve innervating the sensory cells, and sends a signal of "sound" to the brain. Scale bar in (a) is 20 mm while in (b) it is 2 mm. (From McCauley et al. 2003, with permission.)

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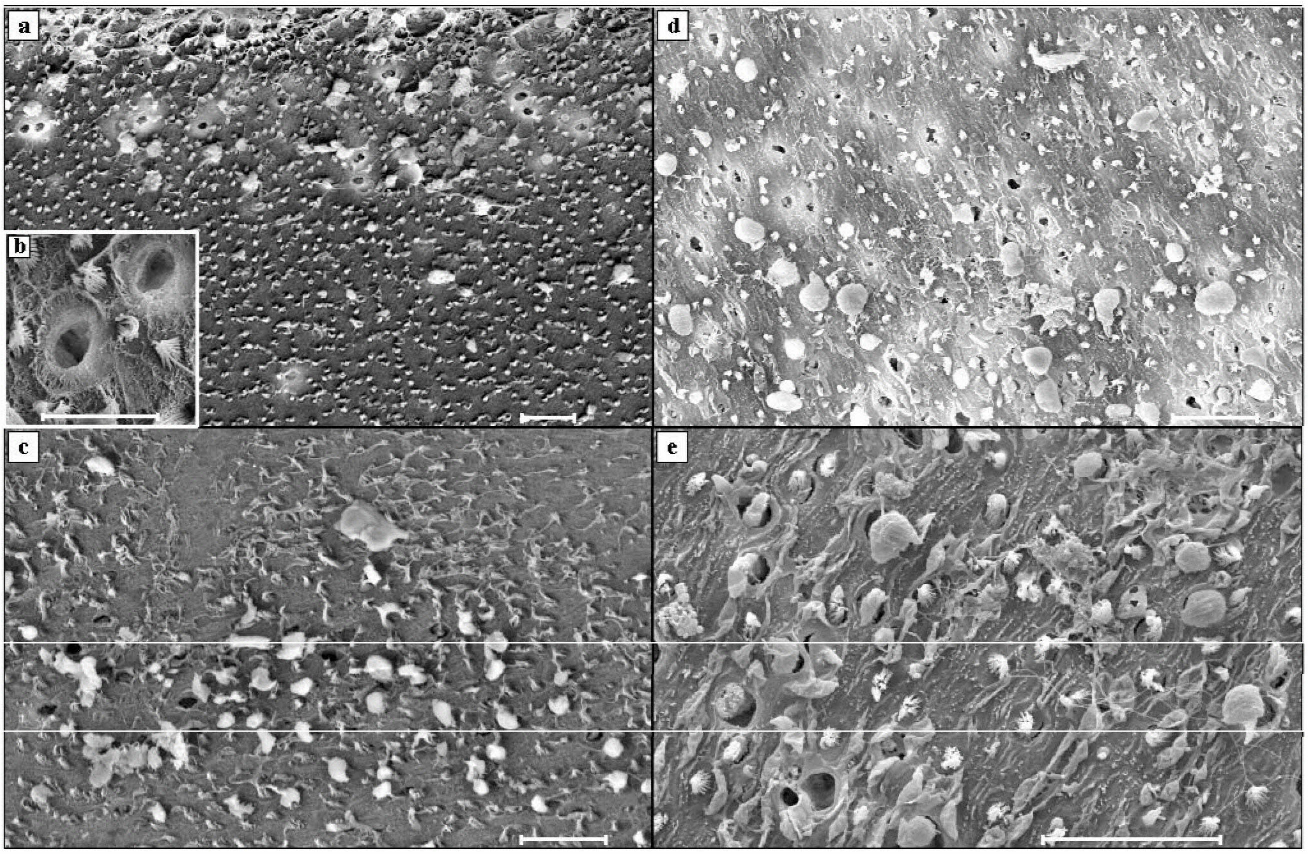
presented for several hours will damage the ears of Atlantic cod (*Gadus morhua*), and Hastings et al. (1996) obtained similar results in the oscar (*Astronotus ocellatus*). In both cases, scanning electron microscopy (SEM) was used to examine the sensory epithelium of the ear, and the results showed loss of ciliary bundles which are found on the apical ends of the on the sensory hair cells (Figure 2). Loss of the ciliary bundles results in loss of function of these mechanosensory cells.

The most recent study assessing the effects of sounds on fishes investigated the effect of a seismic air gun on the ears of caged fish. In this study, McCauley et al. (2003) exposed fish to a stimulus paradigm that is similar to what a fish in the wild might encounter during an air gun survey. The only (and important) difference was that the fish were caged and so could not escape the air gun during several hours of intermittent exposure. The results showed little or no damage 18 hours after stimulation, but after 24 hours, extensive damage was evident. Sensory cells were actually missing from the epithelium and there was considerable evidence of dying cells (Figure 3). Interestingly, damage was present even as long as 58 days after exposure to the air gun, and there was little or no evidence for repair of the ear, although repair has been shown in the oscar after exposure to drugs that kill sensory hair cells in the ear (Lombarte et al. 1993).

The results from these studies clearly show that intense sounds are able to damage the sensory hair cells of the ears of fishes. (Because the same kind of sensory hair cells are found in the lateral line, it is conceivable that this end organ is also affected, but no studies have addressed this issue.) Even if the sounds do not kill the fish directly, permanent (or even temporary) loss of hearing will clearly affect the chances of survival of exposed fish.

However, it is necessary to be cautious in interpreting the experiments done to date for several reasons. For example, the fish used in all of the studies were kept near the sound source and could not get away. In the normal environment, fish have the potential to escape loud sounds, and if they can get away fast enough, the effect of the sound may be

Figure 3. Scanning electron micrographs of the ear of the pink snapper (*Pagrus auratus*) after exposure to an air gun (see McCauley et al. 2003). (a to c) Scanning electron micrographs of saccular sensory epithelia from fish 18 hours after exposure to the air gun. The photographs show numerous holes and "blebbing" where normal sensory cells should be found. The holes represent sensory cells that have died and have been lost from the epithelium, while the "blebs" are presumed to be dying sensory cells. (a) shows the edge of an epithelium, while (b) shows an enlargement of one of the holes to show the space in which a sensory hair cell should have been, and (c) shows a more central epithelial region. (d and e) Electron micrographs from saccular epithelia of fish that were examined 58 days after exposure. This tissue shows far more extensive damage than the tissue from animals sacrificed 18 hours after exposure. These results show the massive damage imposed by a short exposure to a seismic air gun (in caged fish). They also support an argument that tissue examined right after exposure to an anthropogenic sound may not show much damage but that the damage will continue to grow over time. Scale bars: a, 20 mm; b, 2 mm; c, d, e, 20 mm. (From McCauley et al. 2003, with permission.)



mitigated. Of course, the normal "fright" response of many fishes is to freeze in place, and many other fishes do not move very fast, and so the effect on these animals could be considerable.

Another "caveat" to the results to date is that only a few species have been studied, and most have little or no commercial importance. It is not clear how reasonable it is to extrapolate from the species studied to other species. At the same time, it is important to note that the auditory systems of the species studied so far are similar enough to those of commercially important species to suggest that we can extrapolate, with caution.

Finally, the sounds used in most studies, other than the air gun investigation, were generally pure tones and thus different from most anthropogenic sounds since they generally contain energy over a broader range of frequencies. Thus, more extensive studies are needed on sounds similar to those produced by shipping, sonar, or other sources. Such studies need to include sounds of the appropriate intensity, duration, and duty cycle as common anthropogenic sounds.

The behavioral and physiological results suggest that loud sounds can affect fish and clearly point to the need for much more data. We need to know the levels of sounds that can affect fish, the differentiation between sound levels that cause temporary and permanent hearing loss, and the behavior of fish in response to the loud sounds (will they escape or will they adapt to the sound and stay put, thereby increasing exposure). Moreover, while it is impossible to ascertain the effect of anthropogenic sounds on all fishes, data are needed for a range of different species with different ear structures, different hearing sensitivities, and different behavioral responses and uses of sound.

Conclusions

While there is still a lack of extensive data, the data that we do have on fish and on other animals (including humans) strongly suggest that all animals may be affected by an increase in anthropogenic sound in the environment. The effect may be minimal and have nothing but a short-term effect on the animal. Or the effect may be longer lasting and affect the survival of an individual animal or a group of animals.

Although we most often think in terms of very loud sounds as having the most potential effect on animals (and humans), it is well documented that longer exposures to any anthropogenic sounds may also affect the health and well-being of a human (or an animal). Thus, we need to be concerned about the effect on fish of sounds in aquaria and in other facilities where fish have long-term exposure to sounds that are significantly above the normal ambient acoustic environment in which they evolved. If nothing else, it will be important to ask the right questions to determine if the effects are present and important or if they have little or no long-term consequence to the animal. Moreover, we might consider the effects of long-term acoustic tagging on fishes that can detect the ultrasonic sounds of the tags.

It thus becomes clear that we really have very few answers regarding the effects of anthropogenic sounds on fishes. Many questions posed here have yet to be answered, and there are many other questions that have yet to be considered at all. For example, while there have been a few studies on the effects of anthropogenic sounds on fish eggs and developing fish (e.g., Banner and Hyatt 1973), none of the studies have been over long-term nor have there been more than the most cursory analyses of the structure and physiology of the eggs or developing larvae as a consequence of noise exposure. There have been few studies on the effects of sounds on stress factors in fish, and no studies have systematically looked at the effect on fish of very intense environmental sounds such as pile driving or blowing up off-shore oil rigs. Both low- and high-frequency sonar, especially at the power levels currently in use, may have a considerable effect on fishes, and this area is in serious need of investigation.

Moreover, while this article has concentrated on the effects of sound on the ear, the lateral line of fishes has the same type of sensory cell as found in the ear, and it is possible that this very important sensor could also be affected by sound. In addition, it is possible that other aspects of fish physiology may be affected by exposure to anthropogenic sounds, and so future studies should consider things like stress effects and the physiology of other organ systems.

Finally, it must be remembered that fish make up only a small portion of the aquatic animal biomass. While very little is known about sound detection in invertebrates, many species have mechanosensors that have some resemblance to vertebrate ears (e.g., Popper et al. 2001), and so it would be important to examine the effect of anthropogenic sounds on a wider range of marine fauna.

Acknowledgements

I am grateful to Dennis Higgs, David Mann, Carl Schilt, Michael Smith, and William N. Tavolga for reading and making suggestions that substantially improved this article.

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C0918-126

3721

Effect of Seismic Energy on Snow Crab (*Chionoecetes opilio*)

By

LGL LIMITED
environmental research associates

and

Oceans LTD.

For

Environmental Studies Research Fund
444-7th Avenue S.W.
Calgary, AB
T2P 0X8

File No.: CAL-1-00364

7 November 2003
SA694

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Effect of Seismic Energy on Snow Crab (*Chionoecetes opilio*)

by

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The correct citation for this report is:
John R. Christian, Anne Mathieu, Denis H. Thomson, David White and Robert A. Buchanan
Effect of Seismic Energy on Snow Crab (*Chionoecetes opilio*) 7 November 2003. Environmental Research Funds Report No. 144. Calgary. 106 p.

The Environmental Studies Research Funds are financed from special levies on the oil and gas industry and administered by the National Energy Board for The Minister of Natural Resources Canada and The Minister of Indian Affairs and Northern Development.

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Published under the auspices of the
Environmental Studies Research Funds
ISBN 0-921652-56-9

C0918-129

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EXECUTIVE SUMMARY

Introduction

LGL Limited of St. John's, Newfoundland and Labrador was contracted by the Environmental Studies Research Fund (ESRF) to conduct a study of the effects of seismic air gun noise on snow crab (*Chionoecetes opilio*) and snow crab catches. Loud noise has the potential for detrimental effects on animals by physical damage to sensitive organs (e.g., ear structures in the case of vertebrates), by causing increased stress, or by causing changes in behaviour. At present, the snow crab fishery in Atlantic Canada is concentrated in Newfoundland and Labrador and it is the most important commercial fishery there. The snow crab is also an important commercial species for fishers in the southern Gulf of St. Lawrence and off southern Nova Scotia, particularly for those who fish the waters off Cape Breton's west coast.

The study was one of the recommendations of an ESRF workshop convened in Halifax, Nova Scotia (September 2000) where seismic issues were discussed by local, national and international experts. Until recently, most of the concerns related to seismic exploration have focused on certain species and/or life stages of marine mammals and fish that are known to have sensitive hearing abilities. Little research has been conducted on the effects of seismic noise on invertebrates in general, and crab in particular, because these species do not have hearing structures, although some can detect pressure waves. Furthermore, unlike vertebrates, the bodies of marine invertebrates are generally the same density as the surrounding water and therefore, theoretically speaking, sudden changes in pressure, such as that caused by sudden loud noise, would be unlikely to cause physical damage. Nonetheless, concern has been expressed by commercial fishers in Cape Breton, Nova Scotia that seismic surveys may affect the health and/or behaviour of snow crab. In addition, there also have been anecdotal suggestions in Newfoundland that seismic surveys may affect crab trap catch efficiency. Given the concerns of the fishers, the high value of the fishery, the general lack of hard evidence for or against effects, and the increasing amount of seismic exploration in waters inhabited by snow crab, the ESRF commissioned the present study.

The study, conducted in the fall of 2002, examined a number of health, behavioural, and reproductive variables before, during, and after, seismic shooting in a preliminary attempt to assess potential effects on physical, biochemical, or activity patterns in the subject animals. The research had four main objectives:

1. to conduct an experimental commercial fishery for snow crab before and after commencement of seismic shooting to determine whether there was a change in snow crab catch rate,

2. to observe snow crab during initial exposure to seismic sound to determine their responses to the sound,

3. to monitor snow crab activity using telemetric techniques to determine whether post-seismic activity patterns were different from pre-seismic activity patterns, and

4. to expose snow crabs and fertilized eggs to various seismic noise exposure levels to determine whether the seismic energy had any acute and/or chronic physiological and/or pathological effects on haemolymph (invertebrate 'blood'), various organs and associated tissues, adult crab and egg mortality, and embryo development.

Methodology

The study required a wide variety of expertise. LGL Limited assembled a team composed of experts in decapod crustacean biology and behaviour (LGL), histopathology (Oceans Limited), seismic noise (Jasco), and the snow crab fishery (H. Thorne and C. Hyde, commercial crab fishers).

Study Sites

A study site was selected in Conception Bay about five kilometers north-northeast of Cape St. Francis, after screening of potential sites. The site was chosen partly on logistic considerations such as proximity to the St. John's base of operations and a sheltered location with electrical power (Cape St. Francis). It was also considered to be typical 'prime' crab grounds by the commercial fishers, with mud-gravel substrate, a relatively level bottom, and a water depth of 165-175-m. Some of the video work was conducted in Freshwater Bay, just outside St. John's Harbour at a water depth of 50-m.

Logistic support was provided by two commercial fishing longliners (10-m and 15-m in length) operated by registered crab fishers.

Noise Sources

Seismic air guns were used for noise sources, including two 10 cubic inch (in^3) sleeve air guns, one 20-in^3 gun, and four 40-in^3 guns. The air guns were used singly (40-in^3) and combined in an array of seven guns (200-in^3). For each firing session, the guns were set at two metres below the surface of the water and fired 200 times at 10-second intervals. The number of shots was chosen to be representative of the dosage that an individual animal might be exposed to during an operational seismic program.

Temperature Profiling

Water column temperature data were collected on each day of seismic shooting using a CTD.

Catchability

Fishing was conducted in a controlled manner using both standard (14-cm mesh) and modified (5-cm mesh) crab traps, baited with squid, and set in lines ('fleets') of 40 traps each by the commercial fishers. Seven sets were made prior to shooting and six after shooting. The sets were made close to the sound source and start and end points recorded using a GPS.

Crabs available to the experimental fishery were exposed to shots with the seven gun array (200-in^3). Numbers of shots that crabs were exposed to varied from 200 to 1,000 and times after exposure varied between two and 292 hours.

Captured crabs were counted, measured and categorized into four groups based on carapace width (legal >95-mm carapace width; sublegal <95-mm), shell condition, and sex.

Behaviour

Movements of crabs after exposure to air gun shots were to be monitored by four Lotek wireless hydrophones deployed on moorings several hundred meters apart and data retrieved via radio and stored at a land-based station. A manual tracking hydrophone on the boat was also deployed. Eight crabs (legal-size adults, not previously exposed to seismic) were tagged with acoustic transmitters manufactured by Lotek of St. John's. However, due to technical difficulties and severe weather-related problems, only one hydrophone was operational during firing and thus movement data were much coarser than originally intended.

Video (Silicon Intensified Target or SIT camera) was also used to observe potential startle behaviour of crabs deployed in cages, first in the water column, and then sitting on the bottom in 50-m of water.

Crab Health

The following experiments were conducted to assess potential indictors of stress (e.g., haemolymph chemistry) and physical damage (e.g., injury to statocysts, hair-like structures that crabs may use to detect vibration and balance) that might result from exposure to seismic surveys.

A series of experiments were conducted in the field by exposing caged crabs (legal and sublegal size males) to either the single 40-in^3 gun at 2, 10, or 15-m depths or the 200-in^3 array at 4, 50, 85, or 170-m depths. Each exposure consisted of 200 air gun shots fired at a rate of one every 10 seconds for a total exposure of 33 minutes. Excluding the fishing and telemetry experiments a total of 92 crabs were exposed to seismic and 92 were handled in a similar manner but not exposed (i.e., the controls). Crabs were processed after exposure for subsequent lab analyses but twenty animals plus controls were brought to the Fisheries and Oceans (DFO) wet lab in St. John's for long term observation and sampling.

In addition to the above, DFO provided six egg-carrying females. One batch of eggs (about 4,000) showing a similar level of development were divided into two groups that were handled in an identical manner except that one group was exposed to 200 shots with the 40-in^3 gun at a distance of two metres. Eggs were held in the DFO aquarium for 12 weeks before fixing and preserving.

Crab were sampled for haemolymph, hepatopancreas and heart, heads (statocysts, green glands, and brains), gills and gonads. Unanalyzed samples were archived.

Haemolymph was analyzed for the following variables:

- Relative concentrations of total dissolved substances in serum
- Serum proteins
- Serum enzyme activity screening
- Haemocyte types

Crustacean haemolymph represents the analogue of blood in vertebrates and can be inexpensively analysed for various chemical parameters such as dissolved substances (solutes) in haemolymph, and proteins and enzymes in serum. The blood cells or haemocytes found in haemolymph play a pivotal role in disease defence and can be examined by light microscopy for overt change in structure and/or abundance.

Haemolymph solute contains a composite of dissolved sugar, minerals, proteins, etc., and can be used to assess changes in haemolymph dilution or concentration, possibly an indication of disturbances in important physiological functions such as osmoregulation. Changes in solute concentration can be measured through changes in refractive indices by refractometry. This method is commonly used in studies of blood and other body fluids in human and veterinary medicine (George 2001).

Serum or urine protein is a classical analyte in clinical chemistry, and its determination in crustacean haemolymph can shed light on stress related to changes in haemolymph dilution and concentration (as discussed above with total dissolved substances). Based on concepts derived from mammalian studies, protein level determination has the potential to indicate either non-normal release of relatively large amounts of protein from other body compartments into the haemolymph or non-normal clearance of protein from the haemolymph.

Serum enzymes are widely used in human medicine to diagnose damage to specific organs and tissues. Their measurement is based on the principle that cells of various organs contain characteristic enzymes which leak into the blood in highly elevated concentrations due to various types of tissue damage or disease states (Ettlinger and Feldman 1995; Kaneko et al. 1997). For example, in the case of humans, enzymes associated with cardiac infarction can reach levels 10 times the normal level, and enzymes associated with liver damage can reach levels 150 times the normal level.

Haemocytes are believed to play a key role in crustacean immunology and have considerable potential for assessing animal health or specific pathological processes (Noga 2000). Three major types of haemocytes (hyalinocytes, semi-granulocytes and granulocytes) have been described on the basis of morphological and functional characteristics in most crustacean species (Bauchau 1981; Soderhall and Cerenius 1992). Changes in relative numbers of different haemocyte types (differential haemocyte counts), a possible threat to immunodefence (Baier-Anderson and Anderson 2000) are useful indicators of stress or physiological dysfunction in crustaceans (Jussila et al. 1997; Fotedar et al. 2001).

Organ and tissue pathology consisted of examination of statocysts for physical damage by light microscopy and scanning electron microscope and examination of hepatopancreas and heart for physical damage by light microscopy.

Pathology has traditionally been a pillar of human and veterinary medicine. Pathology is also proposed to be one of the most reliable indicators for assessing health impairment in aquatic organisms caused by anthropogenic activities (Myers et al. 1987; Hinton et al. 1992). Pathological parameters studied in snow crab included visible signs of external damage to the carapace and appendages, and microscopic analysis of selected organs including statocysts, hepatopancreas and heart.

Immediate lethal effects appear to be relatively uncommon in invertebrates exposed to even high levels of acoustic energy. Delayed mortality of adult animals has received virtually no attention to date and an important component of this study was to determine if lethality occurred three months after exposure.

Effect on reproduction and productivity is one of the main concerns when evaluating potential impacts on animal populations. Early developmental stages of marine organisms are commonly known to be sensitive to stressors. Embryonic development in snow crab includes a number of stages based on morphological and physiological features and it lasts approximately two years in Atlantic waters (Moriyasu and Lanteigne 1998). This long incubation period is unique in crustaceans and most likely increases the probability of egg mortality due to parasitism and physical damage as compared to the other species with shorter reproductive cycles. Additional stressors would increase this probability more.

Results and Discussion

Acoustics

The received air gun sound levels were estimated based upon a combination of direct measurements and interpolation. Depending upon water depth under the 40-in^3 gun, experimental animals were exposed to peak received broadband sound levels of 201 to 227 dB re 1 μPa and energy densities of 183 to 187 dB re 1 μPa^{2}Hz at frequencies between 24 and 31 Hz. Received levels from the 200-in^3 array were 197 to 237 dB re 1 μPa, depending upon distance from the source, and a maximum energy density of 175 dB re 1 μPa^2/Hz within the 17 to 19 Hz frequency range.

The above-received sound levels, at least on the high end of the ranges, are representative of the levels that would be encountered by an adult crab sitting on the bottom while seismic surveys were being conducted at the surface.

Temperature Profiles

During the course of the study, bottom temperatures ranged from -0.5 to -1.5ºC. The primary thermocline was located at about 20-m at the beginning of the study but moved to 40-85-m by the latter part of October. It is likely that the severe prolonged winds experienced in the fall of

2002 hastened this deepening of the thermocline. The position of the thermocline was monitored to help explain some of the acoustic dynamics observed during the telemetry program.

Effects on Behaviour

Snow crab were observed reacting slightly to sound in the laboratory when sharp sounds were made near them. However, in the field while being observed with a video camera, caged crab sitting on the bottom showed no readily visible reactions to the 200-in^3 array being fired 50-m above them.

Due to technical difficulties and weather-related problems, the telemetry system was unable to discriminate fine scale movements. Of the six tagged crabs that were being monitored clearly by the one remaining wireless hydrophone prior to shooting with the 200-in^3 array, all six were still being received 48 hours after shooting, all within the approximately 200-m radius of the range of the hydrophone. The tagged crabs did not undergo any large-scale movements out of the area.

Effects on Fishing

There was considerable variability in the durations of the experimental fishing periods of the commercial fishery traps (i.e., soak times), the likely received levels of sound experienced by the crab, and the experimental fishery catch data. The catch data were examined using a number of standardization, filtering and statistical techniques. Post-seismic catches were higher than pre-seismic catches but this was likely due to physical, biological, or behavioral factors unrelated to the seismic source. There was no significant relationship between catch and distance from the seismic source.

Effects on Health

A wide variety of health variables were examined using chemical and biochemical techniques. The data were subjected to statistical analyses (mostly Unpaired t-test or Mann-Whitney Rank Sum Test). It was concluded that there were no seismic effects on the health of the snow crabs, as measured by this suite of variables, prior to and after shooting.

The preliminary experiment conducted with 4,000 eggs from one female suggested that exposure to high levels of received sound (221 dB at 2-m depth) may retard the development of eggs. This result, if it is further confirmed, is similar to results with other marine animals and other types of disturbances that the young stages are often the most sensitive part of a species life history. Kostyuchenko (1973) and Booman et al. (1996) found indications of seismic effect on fish eggs when shot at close distance. While Holliday et al. (1987) and Saetre and Ona (1996) observed effects of seismic on fish larvae, Pearson et al. (1994) did not observe any statistically significant effects on Dungeness crab larvae shot as close as 1-m from a 231 dB source.

Other life stages of fish have also been investigated in seismic effect studies. Fish fry were the subjects of work by Booman et al. (1996) while effects on fish eggs and larvae were studied by a number of other researchers (Kostyuchenko 1972; Holliday et al. 1987; Booman et al. 1996; Saetre and Ona 1996).

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Conclusions

The present study was a pilot study that evaluated a wide variety of techniques for relevance and viability in testing hypotheses concerning the potential effects of seismic surveys on snow crabs and on the snow crab fishery. The study showed no obvious effects on crab behaviour and no significant effects on the health of adult crabs. While the study did not indicate an overall reduction in snow crab catch rate due to seismic shooting, post-seismic catches were greater than pre-seismic catches, probably due to biological, behavioural, or physical factors unrelated to the seismic source. Statistical analyses of the catch data by distance from the seismic source indicated that there was no significant relationship between these variables. The eggs of one female showed significant effects on development when exposed at a very close range of 2-m. The exposed eggs were much slower to develop than were the unexposed controls. It should be noted that the females carry the eggs on the bottom where received sound levels are much lower than at the 2-m test distance. Future research should probably focus on the sensitive reproductive stages and determine at what distance the effect on eggs, if it occurs in all cases, tapers off. These data would be useful for both impact assessment and mitigation design purposes.

C0918-140

RÉSUMÉ

Introduction

LGL Limited, de St. John's (Terre-Neuve et Labrador), a été contactée par les responsables du Fonds pour l'étude de l'environnement (FEE) pour mener une étude portant sur l'effet de l'utilisation des canons sismiques à air sur le crabe des neiges (*Chionoecetes opilio*) et la pêche de ce crustacé. Les bruits intenses peuvent nuire aux animaux en entraînant des lésions dans les organes sensibles (l'oreille interne dans le cas des vertébrés), un stress croissant ou des changements de comportement. La pêche du crabe des neiges dans les eaux canadiennes de l'Atlantique est présentement centrée sur les côtes de Terre-Neuve et du Labrador où elle est la plus importante des pêches commerciales. Le crabe des neiges est également une espèce commerciale importante pour les pêcheurs qui travaillent dans le sud du golf du Saint-Laurent et au large du sud de la Nouvelle-Écosse, en particulier pour ceux qui pêchent dans les eaux de la côte ouest du cap Breton.

L'étude faisait partie des recommandations formulées à l'issu de l'atelier du FEE organisé à Halifax (Nouvelle-Écosse) en septembre 2000, au cours duquel les enjeux liés à la prospections sismique ont été débattus par des experts locaux, nationaux et internationaux. Jusqu'à récemment, la plupart des préoccupations concernant ce type de prospection avaient été émises à l'égard de certaines espèces et/ou étapes de vie de mammifères marins et de poissons réputés avoir une ouïe sensible. Très peu d'études ont été conduites sur les effets que pourrait avoir la prospection sismique sur les invertébrés en général et sur les crabes en particulier, parce que ces espèces ne possèdent pas de structures spécialisées pour l'ouïe même si certaines d'entre elles sont capables de détecter les ondes de pression. De plus, contrairement au corps des vertébrés, celui des invertébrés marins a généralement la même densité que l'eau environnante et en théorie, les changements brusques de pression dans l'eau, tels que ceux causés par des bruits intenses, ne sont donc pas susceptibles d'entraîner des dommages physiques. Les pêcheurs commerciaux du cap Breton (Nouvelle-Écosse) ont cependant fait part de leurs préoccupations concernant les relevés sismiques qui, selon eux, pourraient affecter la santé et/ou le comportement des crabes des neiges. De plus, on a suggéré plusieurs fois à Terre-Neuve que les relevés sismiques pourraient nuire à l'efficacité des pièges à crabe utilisés par les pêcheurs. Compte tenu de ses préoccupations, de la valeur de cette pêche, du manque général de preuves solides établissant l'existence ou l'absence d'effets et de l'intensification de l'exploration sismique dans les eaux fréquentées par le crabe des neiges, le FEE a demandé que soit effectuée la présente étude.

Cette étude, menée à bien au cours de l'automne 2002, a consisté à examiner un certain nombre de variables sanitaires, comportementales et reproductives avant, pendant et après le déclenchement de plusieurs déflagrations sismiques afin de tenter, dans un premier temps, d'évaluer les effets potentiels de tels bruits sur le physique, la biochimie et l'activité des animaux étudiés. Les quatre objectifs principaux suivants avaient été fixés pour l'étude :

1. effectuer une pêche commerciale expérimentale des crabes des neiges avant et après le début des déflagrations sismiques afin de mettre en évidence un éventuel effet sur le rendement des pièges à crabe,

2. observer les crabes des neiges pendant l'exposition initiale aux ondes sismiques afin de déterminer la manière dont ces animaux répondent à de telles perturbations,

3. surveiller l'activité des crabes des neiges à l'aide de techniques télémétriques afin de déterminer si cette activité était affectée par les ondes sismiques,

4. exposer des crabes des neiges et des œufs fécondés à différents niveaux d'ondes sismiques afin de déterminer dans quelle mesure l'énergie sismique avait des effets physiologiques ou pathologiques aigus ou chroniques sur l'hémolymphe (le «sang » des invertébrés), sur divers organes et les tissus associés, sur la mortalité des crabes adultes et des œufs et sur le développement des embryons.

Méthodologie

L'étude a nécessité la mise en œuvre d'une vaste gamme d'expertises. LGL Limited a mis sur pied une équipe composée d'experts en biologie et en comportement des crustacés décapodes (LGL Limited), en histopathologie (Oceans Limited), en bruits sismiques (Jasco) et en pêche du crabe des neiges (H. Thorne et C. Hyde, pêcheurs de crabes professionnels).

Site étudié

Un site d'étude a été choisi dans la baie Conception, à environ cinq kilomètres au nord-est du cap St. Francis, après évaluation d'un certain nombre de sites potentiels. Le site a été choisi en partie à cause de ses avantages, soit la proximité de la base d'opération de St. John's et le caractère abrité du site qui bénéficie en outre de l'électricité (Cap St. Francis). Les pêcheurs commerciaux considèrent de plus ce site comme un habitat idéal typique pour les crabes des neiges, doté d'un substrat de vase et de graviers, d'un fond relativement plat et d'une profondeur variant entre 165 et 175 m. Certaines séquences vidéo ont été tournées dans la baie Freshwater, juste à l'extérieur du port de St. John's, à une profondeur de 50 m.

Le soutien logistique a été assuré par deux palangriers commerciaux (de 10 m et de 15 m) pilotés par des pêcheurs de crabe inscrits.

Sources de bruit

Des canons à air sismiques ont été utilisés pour générer les ondes sonores. Il s'agissait de deux canons de 10 pouces cubes (po^3), d'un canon de 20 po^3 et de quatre canons de 40 po^3. Les canons de 40 po^3 étaient utilisés individuellement ou combinés en réseau de sept cannons (200 po^3). Lors des séances de tirs, les canons étaient plongés à deux mètres sous la surface et 200 coups étaient tirés à la cadence d'un coup toutes les 10 secondes. Le nombre de coups tirés était censé être représentatif de l'exposition subie par un animal marin durant un programme réel d'exploration sismique.

Profil de la température

Les données décrivant le gradient de température dans la colonne d'eau ont été enregistrées à l'aide d'un capteur CTD à chaque fois qu'une série de tirs étaient effectuée.

Rendement des pièges

La pêche a été effectuée d'une manière contrôlée à l'aide de pièges à crabe traditionnels (mailles de 14 cm) et de pièges modifiés (mailles de 5 cm), appâtés avec des calmars et disposés en lignes de 40 pièges chacune par les pêcheurs commerciaux. Sept lignes ont été relevées avant les déflagrations et six après. Les lignes ont été posées près de la source des déflagrations et la position exacte de leurs extrémités enregistrée à l'aide d'un GPS.

Les crabes accessibles à la pêche expérimentale ont été exposés à des ondes sismiques provenant du réseau de sept cannons (200 po^3). Les crabes ont été exposés à un nombre de tirs variant entre 200 et 1 000 et la durée après l'exposition variait entre 2 et 292 heures.

Les crabes capturés ont été comptés, mesurés et répartis en quatre groupes suivant la largeur de leur carapace (taille réglementaire : largeur supérieure à 95 mm; taille non réglementaire : largeur inférieure à 95 mm), l'état de leur carapace et leur sexe.

Comportement

Le mouvement des crabes après l'exposition à un tir de canon à air devait être surveillé par l'intermédiaire de quatre hydrophones Lotek sans fil déployés le long du mouillage, à plusieurs centaines de mètre d'intervalle, les données étant transmises par radio et enregistrées dans une station terrestre. Un hydrophone de suivi manuel avait également été installé sur le bateau. Huit crabes (adultes de taille réglementaire, n'ayant pas été exposés à des ondes sismiques) ont été munis d'émetteurs acoustiques fabriqués par Lotek (St. John's). Des difficultés techniques et des problèmes liés à une météo peu clémente ont cependant fait que seulement un hydrophone s'est avéré opérationnel durant les déflagrations. Les données décrivant les mouvements ont dont été beaucoup plus grossières que prévu à l'origine.

Des séquences vidéo (caméras «SIT » [Silicon Intensified Target]) ont également été utilisées pour observer les sursauts éventuels de crabes installés dans des cages, d'abord entre deux eaux, puis sur le fond, à une profondeur de 50 m.

Santé des crabes

Les expériences suivantes ont été conduites pour évaluer les indicateurs potentiels du stress (p. ex. chimie de l'hémolymphe) et des changements physiques (p. ex. lésions des statocystes, ces sortes de poils que les crabes peuvent utiliser pour détecter les vibrations et pour s'équilibrer) qui peuvent résulter de l'exposition aux relevés sismiques.

Une série d'expériences a été effectuée sur le terrain par l'exposition des crabes encagés (mâles de taille réglementaire et non réglementaire) à des tirs du canon de 40 po^3 à des profondeurs de 2, 10 et 15 m et à des tirs du réseau de 200 po^3 à des profondeurs de 4, 50, 85 et 170 m. Chaque exposition consistait à tirer 200 coups de canon à air à la fréquence d'un coup toutes les 10 secondes pendant 33 minutes. Sans compter les expériences de pêche et de télémétrie, un total de 92 crabes ont été exposés aux ondes sismiques et 92 ont été manipulés de la même manière mais n'ont pas été exposés (groupe témoin). Après exposition, les crabes ont été envoyés au laboratoire pour subir les analyses prévues; vingt d'entre eux ainsi que des crabes «témoins » ont été envoyés au laboratoire humide de Pêches et Océans Canada (MPO) de St. John's pour faire l'objet d'une observation et d'un échantillonnage à long terme.

MPO a en plus fourni six femelles porteuses d'œufs. Un ensemble d'œufs (environ 4 000) apparemment au même niveau de développement a été divisé en deux groupes ultérieurement manipulés de la même façon sauf que l'un des groupes a été exposé à 200 tirs du canon de 40 po^3 situé à 2 m des oeufs. Les œufs ont été gardés 12 semaines dans l'aquarium de MPO avant d'être fixés et préservés.

Des échantillons d'hémolymphe, d'hépatopancréas, de cœur, de tête (statocystes, glandes vertes et cerveau), de branchies et de gonade ont été prélevés sur les crabes. Les échantillons non analysés ont été archivés.

Les variables suivantes ont été mesurées dans l'hémolymphe :

- Concentration relative des substances dissoutes dans le sérum
- Protéines sériques
- Activité des enzymes sériques
- Typologie des hémocytes

L'hémolymphe des crustacés est l'analogue du sang des vertébrés. On peut y mesurer à peu de frais la concentration de divers produits chimiques tels que les substances dissoutes (en solution) ainsi que les protéines et les enzymes sériques. Les cellules sanguines (hémocytes) présentes dans l'hémolymphe jouent un rôle crucial dans la défense des organismes contre les vecteurs pathogènes. On peut les examiner à l'aide d'un microscope optique afin de déceler d'éventuels changements évidents de structure ou d'abondance.

Les matières dissoutes dans l'hémolymphe sont entre autres des sucres, des minéraux et des protéines qui peuvent être dosées pour évaluer les changements de concentration et du taux de dilution dans l'hémolymphe. De tels changements peuvent refléter des perturbations au niveau d'importantes fonctions physiologiques telles que l'osmorégulation. Les changements de concentrations peuvent être mesurés par réfractométrie, en évaluant le changement d'indice de réfraction. Cette méthode est communément utilisée pour l'étude du sang et d'autres fluides corporels en médecine humaine et en médecine vétérinaire (George 2001).

Les protéines présentes dans le sérum et dans l'urine sont couramment mesurées dans le domaine des analyses cliniques chimiques. Leur concentration dans l'hémolymphe des crustacés peut renseigner sur le degré de stress qui a pu entraîner des changements à ce niveau (comme discuté ci-dessus au sujet des substances dissoutes). Grâce aux concepts dérivés des études sur les mammifères, la détermination de la concentration de ces protéines peut révéler la sécrétion anormale de quantité relativement importante de protéines dans l'hémolymphe ou l'élimination anormale de ces mêmes protéines de l'hémolymphe.

Les enzymes sériques sont utilisés à grande échelle en médecine humaine pour diagnostiquer la présence de lésions dans des organes ou des tissus. Leur mesure est basée sur le principe selon lequel les cellules des organes contiennent des enzymes spécifiques qui se répandent dans le sang en concentrations élevées à la suite d'un dommage ou d'un état pathologique (Ettlinger et Feldman 1995; Kaneko et al. 1997). Dans le cas des humains, par exemple, les enzymes associées à un infarcissement peuvent atteindre une concentration dix fois plus élevée que la concentration normale tandis que les enzymes associées aux liaisons hépatiques peuvent atteindre des concentrations cent cinquante fois plus élevées que la normale.

On pense que les hémocytes jouent un rôle clé dans le système immunitaire des crustacés et qu'elles nous permettraient donc d'évaluer de façon très efficace la santé de ces animaux ou de diagnostiquer des processus pathologiques spécifiques (Noga 2000). Trois types principaux d'hémocytes (hyalinocytes, semi-granulocytes et granulocytes) ont été décrits en fonction de leurs caractéristiques morphologiques et fonctionnelles chez la plupart des espèces de crustacés (Bauchau 1981; Soderhall et Cerenius 1992). Les changements observés au niveau du nombre relatif des différents types d'hémocytes (comptage différentiel des hémocytes), qui peuvent refléter une attaque sur le système immunitaire (Baier-Anderson et Anderson 2000) sont des indicateurs utiles du stress ou de disfonctionnements physiologiques chez les crustacés (Jussila et al. 1997; Fotedar et al. 2001).

La pathologie des organes et des tissus a consisté à détecter des dommages physiques éventuels dans les statocystes à l'aide d'un microscope optique et d'un microscope électronique à balayage et dans l'hépatopancréas et le cœur à l'aide d'un microscope optique.

La pathologie a toujours été un des piliers de la médecine humaine et de la médecine vétérinaire. Elle est aussi l'instrument de choix pour évaluer les effets sanitaires des activités anthropogéniques sur les organismes aquatiques (Myers et al. 1987; Hinton et al. 1992). Les paramètres pathologiques étudiés dans le cas du crabe des neiges comprennent entre autres les signes visibles de dommages sur la carapace et les pattes et l'analyse microscopique d'organes choisis tels que les statocystes, l'hépatopancréas et le cœur.

Il semble que les ondes acoustiques, même de forte intensité, n'entraînent que très rarement la mort immédiate des invertébrés exposés. Cependant, la mortalité différée des animaux adultes n'a pratiquement jamais été étudiée jusqu'à présent et une composante importante de cette étude consistait à détecter une éventuelle mortalité trois mois après l'exposition.

L'effet éventuel des ondes sismiques sur la reproduction et la productivité est l'une des principales questions qui doivent être abordées lors de l'évaluation des impacts potentiels sur les populations animales. Les premières phases de développement des organismes marins sont souvent sensibles aux facteurs de stress. Chez le crabe des neiges, le développement embryonnaire comprend un certain nombre d'étapes faisant intervenir différentes caractéristiques morphologiques et physiologiques et il dure approximativement deux ans dans les eaux de l'Atlantique (Moriyasu et Lanteigne 1998). Cette période d'incubation est unique chez les crustacés et sa durée contribue probablement à augmenter la probabilité que les œufs meurent à cause d'agents parasites ou de dommages physiques, comparé à d'autres espèces pour lesquelles le cycle de reproduction est plus court. L'existence de facteurs de stress supplémentaires contribuerait encore à augmenter cette probabilité.

Résultats et discussion

Acoustique

Les niveaux sonores émis par les canons à air ont été estimés à partir de mesures directes et à partir d'interpolations. Suivant la profondeur de l'eau sur le site de tir du canon de 40 po^3, les animaux étudiés ont été exposés à des niveaux de son de large bande de 201 à 227 dB à 1 µPa et à des densités d'énergie de 183 à 187 dB à 1 $\mu Pa^2 Hz$, avec des fréquences allant de 24 à 31 Hz. Les niveaux reçus du réseau de 200 po^3 variaient entre 197 et 237 dB à 1 µPa, suivant la distance de la source, avec une densité d'énergie maximale de 175 dB à 1 $\mu Pa^2/Hz$ entre 17 et 19 Hz.

Les niveaux sonores reçus décrits ci-dessus, du moins pour ce qui est des valeurs supérieures, sont représentatifs des niveaux auxquels serait exposé un crabe adulte évoluant sur le plancher océanique tandis que des relevés sismiques seraient effectués en surface.

Profils de température

La température de l'eau, au fond, est restée entre –0,5 et –1,5º C pendant toute la durée de l'étude. La thermocline primaire était située à environ 20 m de profondeur au début de l'étude puis à 40-85 m vers la fin octobre. Il est probable que les vents forts et prolongés qui ont soufflé pendant l'automne 2002 ont précipité la descente de la thermocline. La position de la thermocline a été suivie pour mieux comprendre la dynamique acoustique observée dans le cadre des mesures télémétriques.

Effets sur le comportement

En laboratoire, les crabes des neiges ont réagi faiblement à des bruits intenses produits près d'eux. Sur le terrain, les crabes encagés au fond de la mer et surveillés par caméra vidéo n'ont cependant pas réagi de manière visible aux détonations produites par le réseau de 200 po^3 situé 50 m au-dessus d'eux.

Des problèmes techniques et des problèmes liés à la météo ont fait qu'il a été impossible d'enregistrer précisément les mouvements des crabes à l'aide du système de télémétrie. Les six crabes porteurs d'un émetteur qui étaient suivis clairement par le seul hydrophone sans fil restant avant les tirs du réseau de 200 po^3 étaient toujours détectés, 48 heures après les détonations, à moins de 200 m de l'hydrophone. Les crabes porteurs d'un émetteur ne se sont donc pas systématiquement éloignés du secteur des détonations après le début des tirs.

Effets sur la pêche

La durée d'immersion des pièges utilisés pour la pêche commerciale expérimentale a varié de manière considérable, tout comme le niveau sonore probablement reçu par les crabes et, en général, les données issues des prises capturées dans le cadre de la pêche expérimentale. Ces données ont été examinées en mettant en œuvre un certain nombre de techniques de normalisation, de filtrage et d'analyse statistique. Le nombre de crabes capturés après les tirs s'est avéré supérieur au nombre de crabes capturés avant mais cette différence est probablement attribuable à des facteurs physiques, biologiques et comportementaux qui ne sont pas liés aux tirs. Aucune corrélation n'a été relevée entre le nombre de crabes capturés et la distance de la source sismique.

Effets sur la santé

Une grande variété de variables sanitaires ont été examinées à l'aide de diverses techniques chimiques et biochimiques. Les données ont été soumises à une analyse statistique (mettant principalement en jeu le test t et le test de Mann-Whitney). Il a été conclu que l'analyse de ces variables mesurées avant et après les tirs montrait que les ondes sismiques n'avaient aucun effet sur la santé des crabes des neiges.

L'expérience préliminaire menée avec 4 000 œufs provenant d'une femelle a montré que l'exposition à de hauts niveaux d'ondes sonores (221 dB à 2 m) peut retarder le développement des œufs. Ce résultat, s'il est confirmé, serait similaire à ceux observés chez d'autres animaux marins avec d'autres types de perturbations, c'est-à-dire que les premières phases de développement des espèces sont souvent les plus sensibles aux perturbations extérieures. Kostyuchenko (1973) et Booman et al. (1996) ont relevé des signes montrant que les ondes sismiques avaient un effet sur les œufs de poisson lorsque ces ondes étaient générées près des œufs. While Holliday et al. (1987) et Saetre et Ona (1996) ont quant à eux observé des effets sur des larves de poisson mais Pearson et al. (1994) ont conclu qu'une source de 231 dB située à 1 m de larves de crabes dormeurs n'avait aucun effet statistiquement significatif sur ceux-ci.

Des études ont porté sur l'effet des ondes sismiques sur d'autres étapes du cycle de vie des poissons. Booman et al. (1996) ont par exemple étudié les effets de telles perturbations sur des alevins tandis que d'autres chercheurs (Kostyuchenko 1972; Holliday et al. 1987; Booman et al. 1996; Saetre et Ona 1996) ont étudié comment réagissaient les œufs et les larves.

Conclusions

Ces travaux ont été réalisés dans le cadre d'une étude pilote visant à évaluer une vaste gamme de techniques permettant de tester la viabilité d'hypothèses concernant les effets possibles des relevés sismiques sur les crabes des neiges et sur la pêche de ces crustacés. L'étude n'a pu mettre en évidence aucun effet évident sur le comportement des crabes ni aucun effet important sur la santé des crabes adultes. L'étude n'indique pas que les ondes sismiques entraînent une réduction du rendement des pièges à crabe, et au contraire, les prises effectuées après les tirs étaient supérieures aux prises réalisées avant, probablement à cause de facteurs biologiques, comportementaux et physiques qui n'étaient pas liés aux tirs. L'analyse statistique du nombre de crabes capturés en fonction de la distance à laquelle se trouvait la source sonore a montré qu'il n'existait aucune corrélation significative entre ces deux variables. Des effets significatifs ont cependant été observés sur des œufs prélevés sur une femelle et exposés à une source sonique intense placée très près (2 m). Les œufs exposés se sont développés beaucoup plus lentement que les œufs témoins qui n'avaient pas été exposés. Il faut noter que les femelles transportent leur sac sur le fond, où les niveaux sonores reçus sont bien inférieurs à ceux reçus dans le cadre de l'exposition en laboratoire, lorsque la source est située à 2 m des oeufs. Des travaux supplémentaires devraient être effectués pour étudier les effets sur les étapes sensibles de la reproduction et déterminer à quelle distance les effets sur les œufs, si présents dans tous les cas, commencent à diminuer. Ces données pourraient être utiles pour les évaluations d'impacts et l'élaboration de mesures destinées à atténuer ceux-ci.

ACKNOWLEDGEMENTS

This study was a complex research project that involved the cooperation and expertise of a large number of people. Mr. D. Burley of CNOPB coordinated the study for the ESRF Technical Advisory Committee. Dr. R. Davis of LGL Limited served as senior advisor and reviewer. Dr. J. Richardson of LGL provided valuable scientific advice on study design. Dr. J. Payne and J. Wells of DFO provided valuable advice and laboratory support; DFO technical personnel collected the female crab during surveys in White Bay. Dr. J. Hall of Memorial University gave key support in regard to scientific equipment.

The following subcontractors and personnel provided important services without which this project could not have been successfully completed.

- Skipper H. Thorne and crew of the *Rough and Wild*
- Skipper C. Hyde and crew of the *Melanie and Jasmine*
- R. Sullivan, LGL fisheries technician
- J. Nielsen, seismic equipment operator
- D. Hannay, Jasco acoustics expert
- R. Soper, J. Slade, P. Chafe, and B. French, Oceans technicians
- Afonso Diving Contractors

Ms. R. Martin of LGL provided administrative support and desktop publishing services.

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INTRODUCTION

LGL Limited, environmental research associates of St. John's, Newfoundland and Labrador, conducted a pilot study during the fall of 2002 to assess the effects of seismic energy on the behaviour and physiological health of the snow crab (*Chionoecetes opilio*). The study, funded by Environmental Studies Research Fund (ESRF), was conducted on a natural snow crab ground off the Newfoundland coast near St. John's. Such a study had been suggested during a September 2000 Halifax workshop conducted to develop methodologies for conducting research on the effects of seismic exploration on the Canadian East Coast Fishery (Thomson et al. 2001).

There were two main phases to the pilot study.

1. Determination of whether or not commercial-sized snow crab can 'hear' seismic sounds, and whether or not there are any discernible changes in behaviour and physiology.

2. Based on lessons learned from the first phase, the design and execution of a field study to determine the potential effects of seismic pulses on the snow crab fishery.

Phase 1 involved a combination of laboratory work (e.g., preliminary exposure of snow crabs to non-seismic underwater noises; post-treatment holding, observation and sampling of egg-bearing females and egg masses; physiological and pathological effects analyses) and fieldwork (e.g., videography of snow crab behaviour in response to onset of seismic shooting; observation of acute behavioural effects of seismic pulses). Phase 2 was accomplished primarily through fieldwork (e.g., experimental commercial snow crab fishery; telemetric monitoring of snow crab behaviour before and after exposure to seismic pulses).

The overall null hypothesis (H_0) tested during the study was as follows:

> ***H_0*: Sounds emitted during seismic exploration do not cause a significant decrease in the catch per unit effort of snow crabs.**

In the event that the overall null hypothesis was rejected, the following overall alternative hypothesis (H_A) would be accepted.

> ***H_A*: Sounds emitted during seismic exploration do cause a significant decrease in the catch per unit effort of snow crabs.**

The overall null hypothesis was evaluated by testing a series of null sub-hypotheses related to the two main phases of the study. The five relevant null and alternative sub-hypotheses are stated below.

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Phase 1

Detection of sound and subsequent reactions to sound

1. *Snow crabs do not exhibit observable reactions to sound, including those kinds of sounds emitted by seismic sources.*

   OR

   Snow crabs do exhibit observable reactions to sound, including those kinds of sounds emitted by seismic sources.

Physiological effects of sound

2. *Seismic sounds do not damage snow crab statocysts and associated tissues.*

   OR

   Seismic sounds do damage snow crab statocysts and associated tissues.

3. *Seismic sounds do not cause other physiological damage to snow crabs.*

   OR

   Seismic sounds do cause other physiological damage to snow crabs.

Phase 2

Effects on activity patterns

4. *Snow crabs remain in an area when exposed to seismic sounds regardless of received sound levels.*

   OR

   Snow crabs leave an area when exposed to seismic sounds.

5. *Snow crabs do not return to their original area within a few days of leaving that area in response to seismic sound.*

   OR

   Snow crabs do return to their original area within a few days of leaving that area in response to seismic sound.

The specific objectives of the study were as follow:

- To conduct an experimental commercial fishery for snow crabs before and after commencement of seismic shooting to determine whether there was a change in snow crab catch rate (i.e., catch per unit effort – CPUE). The pre-seismic fishery also collected the crab specimens required for other components of the pilot study.

- To observe the initial responses of snow crabs to seismic sounds.

- To monitor snow crab activity using telemetric techniques to determine whether pre-seismic activity patterns were different from post-seismic activity patterns.

- To treat snow crabs and fertilized eggs with various seismic exposure levels to determine whether the seismic energy had any acute and/or chronic physiological and/or pathological effects on haemolymph, various organs and associated tissues, adult crab and egg mortality, and embryo development.

THE FOLLOWING SECTIONS DETAIL THE MATERIALS AND METHODS USED DURING THIS PILOT STUDY; RESULTS ARE PRESENTED AND INTERPRETED AND CONCLUSIONS DRAWN. APPENDIX 1 CONTAINS SOME OF THE RAW ACOUSTIC DATA.

MATERIALS AND METHODS

Study Site

The study was conducted on a commercially fished snow crab ground off the northeast Avalon Peninsula, Newfoundland, approximately five kilometres north-northeast of Cape St. Francis in the mouth of Conception Bay (47º 50.7' N, 52º 45.4' W). The fieldwork occurred between mid-September and mid-December, 2002. Water depth at the study site was approximately 165 to 175-m. One aspect of the study was performed in Freshwater Bay, located immediately south of the St. John's Harbour Narrows, at a site with a water depth of 50-m (Figure 1).

The principal vessel used during the study was a 15-m longliner, the *FV Rough and Wild* (Figure 2). A 10-m longliner, the *FV Melanie and Jasmine*, was used as a secondary vessel.

Seismic Array

The seismic system used in this study consisted of a Price Compressor Co. A-300 4-Stage 300 SCFM compressor (Figure 2), four 40-in^3 Texas Instrument (TI) sleeve air guns, one 20-in^3 TI sleeve air gun, two 10-in^3 TI sleeve air guns (Figure 3), a 5,000 psi air tank with pressure regulator set @ 2,000 psi, a 50-m multihose and firing line umbilical via distribution panel, and a Macha International Inc. gun firing box, Model TGS-8.

Each shooting session consisted of 200 shots at a firing rate of one every 10 seconds (i.e., approximately 33 minutes per session). The seismic source was set at a two-metre depth during all shooting sessions. The number of shots was chosen to be representative of the dosage that an individual animal might be exposed to during an operational seismic program.

Measurement of Seismic Acoustic Signals

A RESON TC4014 hydrophone was attached to the topsides electronics via a 200-m cable. The hydrophone output was fed to a Wavetek System 816 multi-channel filter that was configured as a 48dB/octave, 8-pole Butterworth low pass filter with a 500 Hz cutoff frequency. This band-limited the analog hydrophone signals prior to sampling and the analog-to-digital conversion to prevent 'aliasing' of out-of-band components into the frequency band of interest.

The filtered hydrophone signal was brought to a Datel PCI-416 data acquisition board housed in an Advantech industrial computer. The Datel C++ source code was modified for this project to provide the necessary data collection, graphics and storage routines for the hydrophone data.

The data were collected in 16-second file blocks at a sampling rate of 2,048 Hz resulting in at least one seismic shot (1 shot every 10 seconds) being included in each data file. The data files were scanned for the start of the sleeve gun burst and this offset in the file was recorded with the filename for the subsequent data processing. Many of the files contained data from two shots. The graphic plots (time-amplitude signature, and energy density spectrum) for each shooting session are representative of the mean values obtained from that specific session.

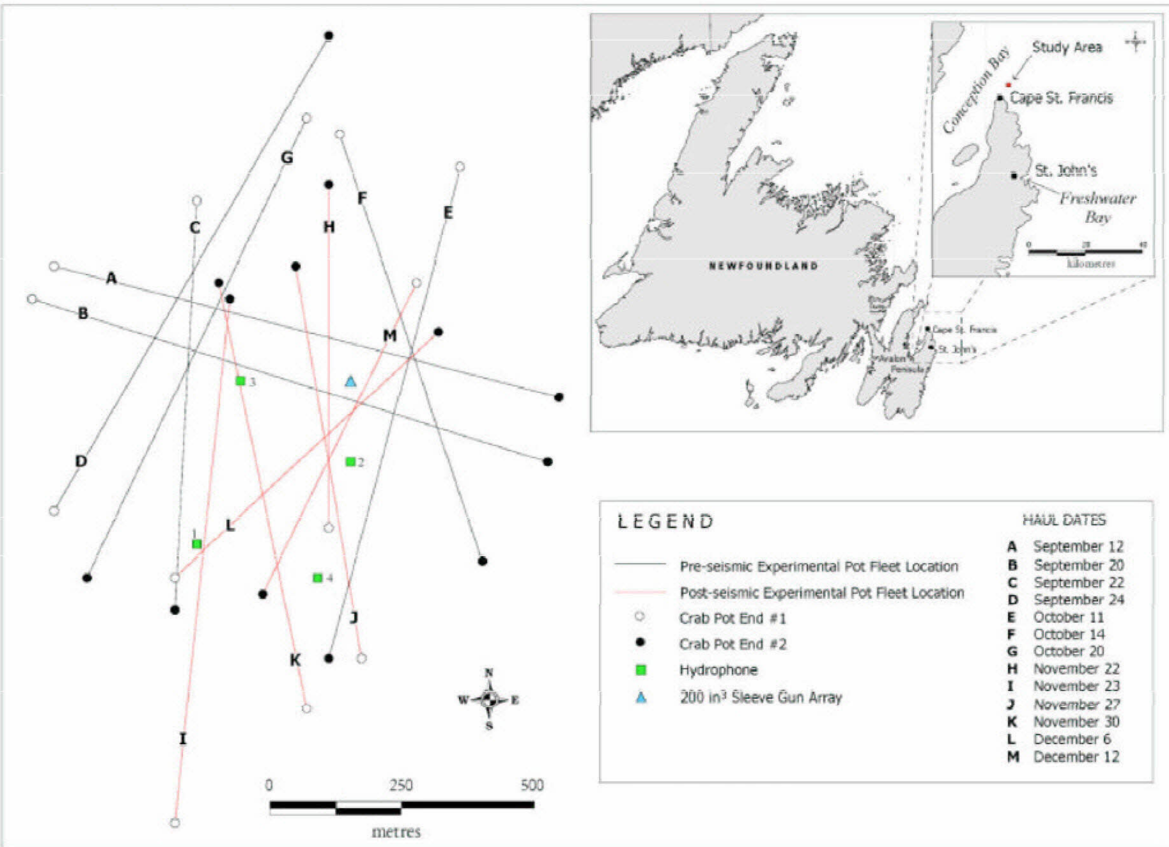

Figure 1. Study area site locations and experimental fishery set locations.

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Figure 2. Price compressor situated at the stern of *FV Rough and Wild*.

Figure 3. 200-in^3 seven-air gun array in frame.

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Water Column Profiling

On each day of seismic shooting, water column temperature profiling was conducted with a CTD. These data provided real time measurements of bottom water temperature and indicated the position of the primary thermocline. Knowledge of the position of the thermocline was needed to help to explain certain aspects of the telemetry program.

Experimental Commercial Fishing

Controlled experimental commercial snow crab fishing was conducted at the study site before and after experimental seismic shooting. Crab traps were set and retrieved by Skipper Henry Thorne and crew of the longliner *FV Rough and Wild,* and Skipper Clyde Hyde and crew of the longliner *FV Melanie and Jasmine*. Both skippers have over 20 years experience as commercial fishers, many of those as snow crab fishers. Both crews baited, set and retrieved the traps in the same manner they would during the regular commercial snow crab fishery. Mr. Thorne and his crew conducted most of the experimental fishing. The study was conducted after closure of the regular snow crab commercial fishing season to eliminate any interference from normal crab fishing activities. Each conical crab trap was 1.25-m in diameter at the base, 1-m in height and baited with squid (Figure 4). For each experimental set, 40 crab traps were deployed approximately 36-m apart on a line approximately 1.4-km in length, although the line was never perfectly straight on the bottom. In crab fishing terminology, each of these lines is called a fleet. All but one of the traps of the experimental fleet were made up with 14-cm mesh. The eighth trap was made up with five-centimetre mesh. The small mesh trap was designed to fish for female crabs that are substantially smaller than the males. Seven sets were made before seismic

Figure 4. Example of crab trap used during the study.

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shooting activity and six after. All sets were made such that the centre of each fleet was closest to the seismic source. The 200-in^3 seven-gun array was the seismic source used in the commercial fishing experiment. Prior seismic shooting with the single gun was performed at least five kilometers away from the fishing area. Snow crabs in the experimental fishery after the commencement of seismic shooting were exposed to 200 shots on 21 November (shooting day 1), 400 shots on 27 November (shooting day 2), and 400 shots on 30 November (shooting day 3). Three sets were conducted between shooting days 1 and 2: (1) from two to 18 hours after exposure, (2) from 20 to 45 hours after exposure, and (3) from 45 to 143 hours after exposure. One set was conducted between shooting days 2 and 3: (4) from 40 to 60 hours after exposure. Two sets were conducted after shooting day 3: (5) from two to 146 hours after exposure, and (6) from 148 to 292 hours after exposure. Obviously, there was cumulative exposure for the animals not caught during the first post-seismic fleet set. The timing of sets after shooting days was determined by the weather in the area.

Crabs captured in each retrieved pot were counted, measured and categorized into one of four groups based on carapace width, shell condition and sex: (1) hard shelled legal-sized males: = 95-mm; (2) hard shelled sublegal-sized males: < 95-mm; (3) soft shelled males, all sizes; and, (4) females. The number of animals in each category was recorded for each trap. Carapace widths were measured with calipers provided by the company that provides personnel for the Crab Observer's Program. Shell condition was determined by observation of the animal and by application of pressure with the thumb to the underside of the right cheliped. As they grow, crabs discard their old shell and the new larger shell is soft for several weeks after this molt. These assessment methods are the standard ones employed by Department of Fisheries and Oceans (DFO) observers when sampling crab catches. All snow crabs caught during the post-seismic fishing were released at a location at least five kilometers from the experimental fishing site.

In order to standardize catch per unit effort (CPUE), catch rates were calculated as the number of crabs caught per trap per 24-hour period. Fleets spent a variable amount of time in the water (i.e., soak time) so this temporal standardization was necessary (Table 1). Crab fishermen indicated to us that squid bait generally does not last longer than 48 to 96 hours. Thus, most of the CPUE statistics were based on data from sets that were in the water no longer than 96 hours. Because of the mesh size used, catch rates of only legal-sized crab (= 95-mm) were considered reliable if soak times exceeded 48 hours. Smaller animals could escape through the mesh and bias the number of sublegal-sized crab (< 95-mm) in the trap.

Hard shelled legal-sized and sublegal-sized crab were retained from the pre-seismic exposure fishing and kept in small meshed baited holding traps on the ocean bottom to be used as experimental animals in subsequent experiments. Some of these unexposed hard-shelled legal-sized males were also transported to the Department of Fisheries and Oceans, St. John's, for holding in saltwater tanks.

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Table 1. Dates, soak times and positions of experimental commercial snow crab fishery fleet sets.

Designation On Map	Set Date (d/m/y)	Haul Date (d/m/y)	Soak Time (hr)	Position of End #1	Position of End #2	Distance Between Ends (m)
A	18/09/02	19/09/02	19	47° 50' 58'' 52° 45' 39''	47° 50' 50'' 52° 44' 53''	990
B	19/09/02	20/09/02	27	47° 50' 56'' 52° 45' 41''	47° 50' 46'' 52° 44' 54''	1,025
C	20/09/02	22/09/02	44	47° 51' 02'' 52° 45' 26''	47° 50' 37'' 52° 45' 28''	775
D	22/09/02	24/09/02	45	47° 50' 43'' 52° 45' 39''	47° 51' 12'' 52° 45' 14''	1,040
E	09/10/02	11/10/02	43	47° 51' 04'' 52° 45' 02''	47° 50' 34'' 52° 45' 14''	965
F	11/10/02	14/10/02	68	47° 51' 06'' 52° 45' 13''	47° 50' 40'' 52° 45' 00''	855
G	14/10/02	20/10/02	141	47° 51' 07'' 52° 45' 16''	47° 50' 39'' 52° 45' 36''	960
H*	21/11/02	22/11/02	16	47° 50' 42'' 52° 45' 14''	47° 51' 03'' 52° 45' 14''	650
I*	22/11/02	23/11/02	25	47° 50' 24'' 52° 45' 28''	47° 50' 56'' 52° 45' 23''	995
J*	23/11/02	27/11/02	96	47° 50' 34'' 52° 45' 11''	47° 50' 58'' 52° 45' 17''	750
K*	29/11/02	30/11/02	20	47° 50' 31'' 52° 45' 16''	47° 50' 57'' 52° 45' 24''	825
L*	30/11/02	06/12/02	144	47° 50' 39'' 52° 45' 28''	47° 50' 54'' 52° 45' 04''	680
M*	06/12/02	12/12/02	144	47° 50' 57'' 52° 45' 06''	47° 50' 38'' 52° 45' 20''	660

Sets marked with an '*' caught snow crabs exposed to seismic energy

Field Observations of Behaviour

Behavioural reactions to seismic were observed using acoustic tags and video cameras.

Telemetry

Crabs were tagged with acoustic transmitters. The signals emitted by the transmitters were to be picked up by hydrophones on 4 moorings. Data received by each mooring was to be transmitted to a base station. Crab movements were estimated by examination of signals received at each mooring.

Crabs used in the telemetry study were caught during the pre-seismic experimental commercial fishery and held in baited crab traps at a depth of 170-m. Eight legal-sized male crabs were tagged with Lotek Model CAFT16-1 acoustic transmitters. Transmitters were attached to the crab carapaces using a 'transmitter saddle' (Figure 5).

Figure 5. Snow crabs outfitted with 'transmitter saddles'.

It was necessary to develop a technique for attachment of the acoustic transmitters to the crabs. Cold resistant vinyl tubing with an inner diameter slightly less than the transmitter outer diameter was used to make the saddle. Pieces of tubing approximately 10-cm long were longitudinally split open at one end (~ 4-cm length) to form four separate strips hanging from the unaltered piece of tubing. A transmitter was then inserted into the unaltered end of the tubing leaving only the transmitting end of it exposed. After drying, lightly sanding and cleaning the crab carapace, the four 'tendrils' on the altered end of the tubing were spread out in roseate fashion and attached to the top of the carapace with Loctite 454 epoxy. All inner surfaces of the tubing were lightly washed with acetone before application of the epoxy to them. This 'transmitter saddle' resulted in the transmitter being oriented upwards and slightly angled to the back of the carapace. There remained enough flexibility in the section of tubing between the bottom of the transmitter and the top of the carapace to allow for some front to back flex in the saddle. This method was successfully tested in the Fisheries and Oceans laboratory before the field study to ensure that the saddle remained attached to the carapace and that crab behaviour was not drastically altered.

Four moorings were deployed at the study site in a diamond-like configuration. Distances between adjacent moorings were approximately 250 to 300-m (see Figure 1). Each mooring consisted of a Lotek WHS_1000 Series wireless hydrophone that was electronically cabled to an inflatable surface buoy-radio antenna unit. The hydrophone was about seven to eight metres below the surface. Wire rope was used as the main mooring line between the surface buoy-radio antenna unit and a point approximately four to five metres below the hydrophone. Half-inch polypropylene rope made up the remainder of the mooring line between lower end of the wire rope and the 250 lb anchor at bottom. An additional surface buoy with high-flyer was added to each hydrophone mooring. Mooring positions were determined using differential GPS. The Canadian Coast Guard was notified and marine advisories were subsequently issued to warn marine traffic.

Assuming each hydrophone could pick up a transmitter within a radius of at least 200-m, the spacing of the hydrophones in the diamond-shaped configuration would theoretically provide a coarse bottom grid based on the overlap regions of the four areas of coverage. While not able to determine fine-scale positions of the tagged animals with the equipment used in this study, we hoped to be able to locate the animals within the grid (see Figure 1). There are radio acoustic positioning systems available that do provide more finely resolved positional data but they were not believed to be appropriate for the present study given the considerable water depth and high energy at the study site.

In addition, a manual tracking system was deployed from a boat. It consisted of a Lotek LHP_1 hydrophone, SRX_400 receiver with antenna, and an Upconverter.

A base station was established in the remaining structure of a lighthouse that had once been located at Cape St. Francis. A six-element YAGI antenna was secured outside the structure in order to pick up the radio signals transmitted from the hydrophone buoys at the study site. Signals detected by the YAGI antenna were sent to a Lotek SRX_400 radio receiver established within the structure. Absence/presence data were stored in the receiver unit.

Video Camera

A SIT (Silicone Intensified Target) camera was used to monitor the behaviour of the experimental animals caged within a crab trap. Specifics of the camera include 400-line resolution, zero lux @f/2.6 light sensitivity, 85° wide angle field of view, and a six inch to optical infinity focal range.

A rigid bracket was fabricated and mounted onto the crab trap used to hold the animals during experimentation. The bracket was fully adjustable, allowing the video technician to angle the camera in order to optimize the field of view. The experimental snow crabs were recorded in real time VHS format on topsides electronic equipment.

Monitoring of the crab with the SIT camera was initially attempted with traps suspended in the water column beneath the seismic source but there was far too much motion due to water movement to detect any observable startle response by the crab.

Instead, a shooting session was conducted in Freshwater Bay located just outside the St. John's Narrows. We conducted the session in a 50-m water depth and rested the experimental crab trap on the ocean bottom in relatively calm water. Twelve hard shelled legal-sized male snow crabs were placed in the trap and observed during the shooting session.

Field Experiments on Crab Health

The field experiments on crab health using a single 40-in^3 air gun were conducted a minimum of five kilometers from the experimental fishing site prior to the post-seismic component of the

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experimental fishery. It was assumed that energy from the single gun at such a distance would have negligible effects on the snow crabs occurring at the experimental fishing site.

Male snow crabs used in the field experiments on effects of seismic on crab health belonged to two size classes; (1) legal-sized animals ranging between 95 and 115-mm carapace width (CW), and (2) sublegal-sized animals ranging between 75 and 95-mm CW (Figure 6). The mean carapace widths of all experimental groups are presented in Table 2.

Figure 6. Experimental male snow crab.

Two types of seismic shooting were conducted during this phase of the study:

1. Hard shelled legal-sized crabs, hard shelled sublegal-sized crabs, egg-bearing female crabs and detached fertilized eggs were exposed to the seismic energy from a single 40-in^3 sleeve air gun (~ 226 dB re 1 μPa-m 0 to peak). A trap holding these animals/eggs was placed at distances from the air gun ranging between 2 and 15-m.

2. Only hard shelled legal-sized crab were exposed to seismic energy from the 200-in^3 seven-air gun array. The array was suspended within a rectangular steel frame (1.25-m width x 1.25-m height x 2.5-m length). Four large inflatable buoys were attached to the top corners of the frame to provide floatation. The experimental trap was suspended directly below this array at depths appropriate for the specific treatments (i.e., 4 to 170-m).

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Table 2. Specific details of seismic shooting, including date, exposure volume, exposure distance, number of specimens and the mean crab sizes for all experimental groups.

Date (d/m/y)	Treatment [T] Or Control [C]	Seismic Source (cu. in.)	Distance Between Seismic Source and Crabs (m)	Crab Number (n)	Crab Category	Mean Carapace Width ± s.d. (mm)
03/10/02	T1	40	10	4	L	102.8 ± 5.7
03/10/02	C1	-	10	4	L	109.3 ± 3.9
03/10/02	T2	40	10	4	L	103.3 ± 2.8
03/10/02	C2	-	10	4	L	107.8 ± 4.3
26/10/02	T3	40	10	4	SL	86.5 ± 3.4
26/10/02	C3	-	10	4	SL	89.5 ± 1.3
26/10/02	T4	40	10	4	SL	86.3 ± 5.9
26/10/02	C4	-	10	4	SL	88.3 ± 3.1
26/10/02	T5	40	2	4	SL	84.8 ± 3.6
26/10/02	C5	-	2	4	SL	85.8 ± 2.2
26/10/02	T6	40	2	4	SL	86.8 ± 3.6
26/10/02	C6	-	2	4	SL	88.5 ± 2.6
10/11/02	T7	40	2	4	L	104.8 ± 4.6
10/11/02	C7	-	2	4	L	106.5 ± 4.8
10/11/02	T8	40	2	4	L	103.8 ± 1.7
10/11/02	C8	-	2	4	L	103.5 ± 2.6
10/11/02	T9	40	15	4	L	104.8 ± 5.1
10/11/02	C9	-	15	4	L	111.5 ± 1.7
10/11/02	T10	40	15	4	L	113.5 ± 1.3
10/11/02	C10	-	15	4	L	106.8 ± 6.2
21/11/02	T11	40	15	4	SL	89.0 ± 4.2
21/11/02	C11	-	15	4	SL	92.0 ± 2.7
21/11/02	T12	40	15	4	SL	91.0 ± 1.6
21/11/02	C12	-	15	4	SL	92.8 ± 1.0
21/11/02	T13	200	170	4	L	97.3 ± 1.0
21/11/02	C13	-	170	4	L	96.8 ± 1.5
27/11/02	T14	200	170	4	L	106.5 ± 5.7
27/11/02	C14	-	170	4	L	108.3 ± 8.2
27/11/02	T15	200	85	4	L	100.5 ± 3.1
27/11/02	C15	-	85	4	L	105.8 ± 5.2
30/11/02	T16	200	4	4	L	105.3 ± 7.9
30/11/02	C16	-	4	4	L	108.0 ± 8.5
30/11/02	T17	200	50	4	L	113.5 ± 6.4
30/11/02	C17	-	50	4	L	107.3 ± 7.8
01/12/02	T18	200	50	4	L	102.5 ± 5.8
01/12/02	C18	-	50	4	L	100.5 ± 5.8

'L' = legal-sized male, 'SL' = sublegal-sized male

During each experiment, crabs were exposed to 200 air gun shots at a firing rate of one shot every 10 seconds for a period of 33 minutes.

Other than the snow crabs exposed to seismic energy during the post-seismic experimental commercial fishing and the telemetry component, a total of ninety-two snow crabs were treated with seismic energy and then either processed onboard or returned to DFO to be held alive in tanks. An equal number of control animals were also retained. Treatments using the 40-in^3 gun included fifty-nine snow crabs (thirty-two legal-sized males, twenty-four sublegal-sized males, and three females bearing eggs). All were processed onboard the study vessel except for eight legal-sized males and the three females. These 11 animals were taken to DFO and placed into holding tanks. One sample mass of fertilized eggs was also treated with seismic energy and returned to DFO. There were controls for all 59 crabs and the egg mass. Treatments using the 200-in^3 seven-gun array included only legal-sized male crabs. Thirty-three legal-sized male crabs were treated during the second phase. Twenty-four of them, along with 24 control animals, were processed onboard the vessel. The remaining nine treated animals and their controls were taken to DFO and placed into holding tanks. The breakdown of each shooting session is provided below in Table 3.

Table 3. Specifics of the experimental seismic treatments, including dates, exposure volumes, exposure distances, number of specimens and subsequent sampling/handling of the specimens.

Date (d/m/y)	Seismic Source (in^3)	Distance between gun and crabs (m)	Number of treated crabs	Number of control crabs	Processing specifics
03/10/03	40	10	8 (L)	8 (L)	OB(16L)
26/10/03	40	10	8 (SL)	8 (SL)	OB(16SL)
26/10/03	40	2	8 (SL)	8 (SL)	OB(16SL)
02/11/03	40	2	3 (F)	3 (F)	DFO(6)
10/11/03	40	2	16 (L) 1 (EM)	16 (L) 1 (EM)	OB (16L) DFO (16L) DFO (2EM)
10/11/03	40	15	8 (L)	8 (L)	OB (16L)
21/11/03	40	15	8 (SL)	8 (SL)	OB (16L)
27/11/03	200	170	8 (L)	8 (L)	OB (16L)
27/11/03	200	85	4 (L)	4 (L)	OB (8L)
30/11/03	200	4	13 (L)	13 (L)	OB (8L) DFO (18L)
30/11/03	200	50	4 (L)	4 (L)	OB (8L)
01/12/03	200	30-50	4 (L)	4 (L)	OB (8L)

'L' denotes legal-sized males; 'SL' denotes sublegal-sized males; 'F' denotes females
'EM' denotes fertilized egg mass; 'OB' denotes full onboard processing;
'DFO' denotes placement in holding tank at DFO.

Exposure of Male Crabs to a 40-in^3 Air Gun

Two replicate samples of four animals each of both legal-sized males and sublegal-sized males were caged and suspended at depths of 2, 10 and 15-m below a 40-in^3 air gun (Table 4). After each 33 minute exposure to seismic sounds, four control animals were lowered to the same depth as the four treated animals for thirty minutes. After thirty minutes, both the treatment and control animals were brought to surface. Samples of haemolymph (crustacean blood) and tissue were taken immediately from the eight animals.

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Table 4. Specifics of exposure of male crabs to the seismic energy of a 40-in^3 air gun from various distances.

Distance between seismic source and crabs (m)	Gun volume (in^3)	Number of crab samples			
		Legal-sized males		Sublegal-sized males	
		Control (N x number of replicates)	Treatment (N x number of replicates)	Control (N x number of replicates)	Treatment (N x number of replicates)
2	40	4 x 2	4 x 2	4 x 2	4 x 2
10	40	4 x 2	4 x 2	4 x 2	4 x 2
15	40	4 x 2	4 x 2	4 x 2	4 x 2

Exposure of Male Crabs to a 200-in^3 Air Gun Array

Samples of four legal-sized male crabs were caged and suspended at distances of 4, 50, 85 and 170-m below the 200-in^3 seven-gun array. Exposures at 50-m and 170-m were replicated twice (Figure 7; Table 5). After each treatment, four control crabs were lowered to the same depth as the treatment animals for thirty minutes. After thirty minutes, both the treatment and control animals were brought to surface. All eight crabs were immediately sampled for haemolymph and tissue required for the subsequent analyses.

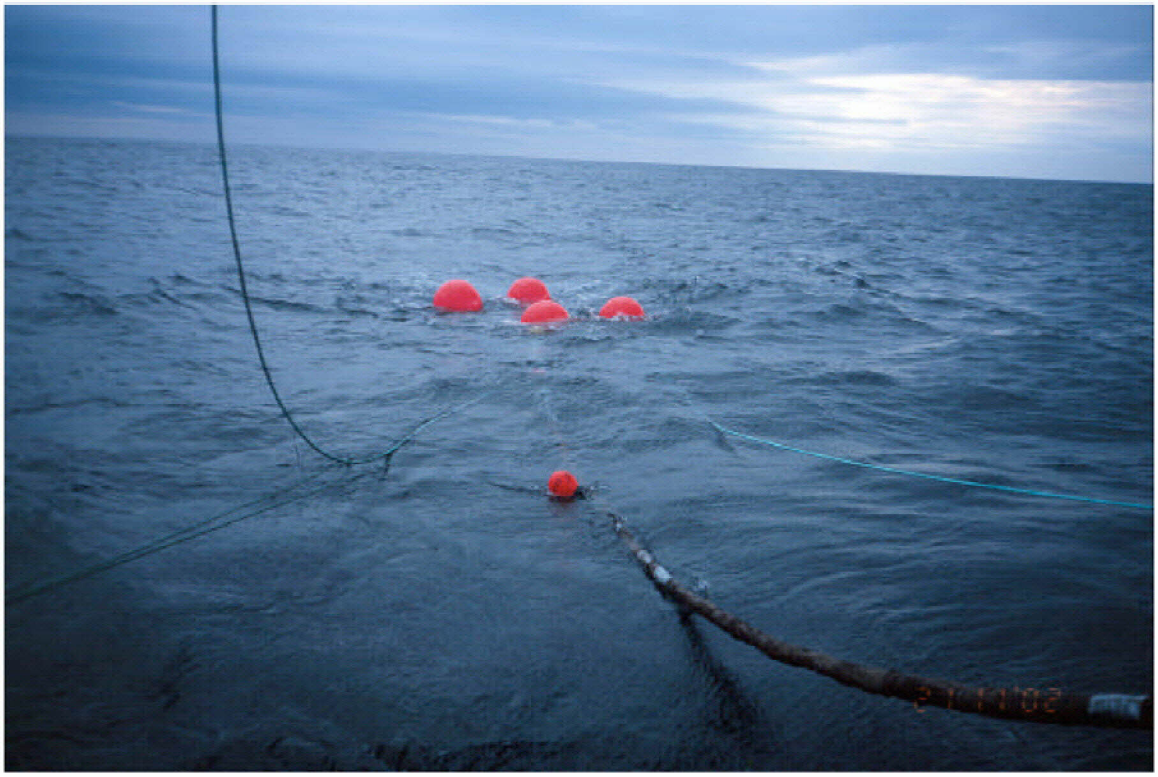

Figure 7. 200-in^3 array firing off the stern of *FV Rough and Wild*.

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Table 5. Specifics of exposure of male crabs to the seismic energy of a 200-in^3 sleeve gun array from various distances.

Distance between seismic source and crabs (m)	Array volume (in^3)	Number of legal-sized male crab samples	
		Control (N x number of replicates)	Control (N x number of replicates)
4	200	4 x 1	4 x 1
50	200	4 x 2	4 x 2
85	200	4 x 1	4 x 1
170	200	4 x 2	4 x 2

Testing for Delayed Effects of Exposure to Seismic Energy

Immediately following each seismic treatment, the exposed animals were observed closely for signs of morbidity and/or mortality. Male and female crabs that had been exposed to seismic energy were observed for a period of twelve weeks at the DFO in case of any delayed lethal and/or sub-lethal effects. All treated animals had associated controls. Eight legal-sized male crabs exposed to energy from the 40-in^3 sleeve gun at 2-m and 9 legal-sized male crabs exposed to energy from the 200-in^3 7-sleeve gun array at 4-m (Table 6) were returned to the Department of Fisheries and Oceans (DFO) in St. John's and held in aquaria. An equal number of control animals were also moved to the DFO facility. These animals were taken to the DFO for observation and examined to determine whether there were delayed or sub-lethal effects.

Four weeks after exposure, samples of haemolymph were taken from both the treatment and control crabs. Samples from all of the crabs were fixed for haemocyte counts while only the samples from treatment and control animals associated with exposure to the 200-in^3 7-sleeve gun array were subjected to protein and enzyme analysis. Samples of sera and fixed organ tissue have been archived at – 80°C.

Table 6. Specifics of exposure of 'delayed effects' male crabs to seismic energy from both the single 40-in^3 gun and the 200-in^3 seven-gun array.

Distance between seismic source and crabs (m)	Gun/array volume (in^3)	Post-exposure time of sampling (wks)	Number of legal-sized male crab samples	
			Control	Treated
2	40	4	8	8
4	200	2	9	9

Exposure of Fertilized Eggs and Egg Carrying (Berried) Female Crabs

The DFO, St. John's, provided the berried female crabs used in this study. The crabs were collected by the DFO in White Bay during a stock assessment survey.

Fertilized eggs containing developing embryos were stripped from the females and successfully incubated in 1-litre chambers at 4°C for a period of approximately two months. A 4°C temperature was chosen in order to enhance development (Mallet et al. 1993) to meet project timelines and to reduce the potential for onset of disease, a problem in rearing crustacean eggs and larvae under laboratory conditions (Fisher et al. 1978; Aiken and Waddy 1985). Eggs were not disinfected in order to avoid increased potential for sub-lethal effects. Approximately 4,000 eggs showing essentially the same level of eye development were divided into two masses and placed into two small nylon mesh bags. Both the treatment and control egg samples were taken to the experimental field site. One sample was exposed to the energy from a 40-in^3 sleeve gun at two metres (Table 7). As was the case during the other shooting sessions, a total of 200 shots were fired, one every 10 seconds. The exposed and control eggs were returned to the laboratory and held in aquaria at 4°C. The eggs were monitored closely for the onset of disease. Twelve weeks after exposure to the seismic energy, the treated and control eggs were fixed in formalin for subsequent analysis.

Six female crabs that were carrying eggs were also transported to the field for experimentation. Three of the female crabs were exposed to the 40-in^3 sleeve gun (Table 7). After exposure, the control and treatment animals were returned to the DFO laboratory and held at ambient temperature in flow-through aquaria to be monitored for delayed mortality of both eggs and crabs. Pending the absence of crab mortality and egg disease, the eggs will eventually be removed from the females, fixed and archived. This will occur outside the time frame of this study because the eggs will be allowed to develop until just before larval hatching, sometime between April and June.

Table 7. Specifics of exposure of fertilized eggs and egg carrying female crabs to seismic energy from the single 40-in^3 air gun.

Distance between seismic source and crabs (m)	Gun volume (in^3)	Post-exposure time of sampling (wks)	Number and type of samples	
			Control	Treated
2	40	12	1 egg mass	1 egg mass
2	40	Ongoing*	3 berried females	3 berried females

* Outside the time frame of this study

Onboard Sampling for Physiological Analysis

Some analyses were conducted onboard the vessel immediately after each treatment, but most samples were preserved for later analysis at the laboratory. Specifics associated with each type of sampling are presented below.

Haemolymph

Haemolymph was withdrawn at the body-leg joint of the 2nd or 3rd thoracic legs of live snow crab using three millilitre sterile syringes with 23-gauge needles. The refractive index of haemolymph was recorded by placing a drop on a Westover Model RHS-10ATC hand held refractometer (s.g.1.000 to 1.070). The refractometer had automatic temperature compensation. Half a millilitre of haemolymph was gently expelled from the syringe into a tube containing 10% buffered formalin for subsequent haemocyte counts. Another 1.5-ml of haemolymph withdrawn with a syringe was centrifuged for two minutes at 2000 rpm and the supernatant or serum was frozen immediately on dry ice. Upon return to the laboratory, it was placed in –60°C freezer for subsequent biochemical analysis.

Hepatopancreas and Heart

A portion of hepatopancreas and the heart were removed from each dissected animal and placed in 10% buffered formalin for later histological processing.

Head

The head sample, which included the statocyst, green gland and brain, was fixed in 10% buffered formalin. In the laboratory, the statocysts were carefully dissected out of the sample and the other tissues were archived.

Gills and Gonads

Two gills from the right side of each crab and a portion of the gonads were placed in 10% buffered formalin and archived.

Archiving of Samples

All unanalyzed samples were fixed in 10% buffered formalin and archived. These included all samples from snow crabs exposed to the 200-in^3 array at a distance of 85-m. These samples were archived because analyses were conducted on replicate samples from animals exposed to the array at distances less than and greater than 85-m.

At some time after completion of this study, tissue samples will also be removed from the remaining live crabs still held in the laboratory for observation on delayed mortality and chronic sublethal effects. Tissues that will be sampled include hepatopancreas, heart, fertilized eggs, and head region (statocyst, green gland, brain). All of these archived tissues are fixed in 10% buffered formalin.

Laboratory Sample Analysis

Haemolymph

Haemolymph solutes

Relative concentrations of total dissolved substances in serum were determined by refractometry. Comparisons between control and treatment groups were conducted using the unpaired t-test or the Mann-Whitney Rank Sum test if the groups were not normally distributed. Probabilities = 0.05 were considered significant.

Serum proteins

The protein concentration in each serum sample was determined using the Lowry protein method (Lowry et al. 1951). Comparisons between control and treatment groups were conducted using the unpaired t-test or the Mann-Whitney Rank Sum test if the groups were not normally distributed. Probabilities =0.05 were considered significant.

Serum enzymes

Frozen serum samples were thawed, diluted to 20% with distilled water, and examined with the API ZYM[R] system, a commercial product that provides a coarse quantitative method for rapidly screening 19 enzymatic reactions (Monget 1978; Mathieu et al. 2001). The colorimetric technique is applicable to all specimens including biological fluids and tissues homogenates. Pilot studies were initially conducted to establish that this system could also be applied to snow crab serum and tissues when it was diluted to a 20% solution of distilled water. The system consists of a strip with 20 microwells containing enzyme substrates and buffer for assaying various hydrolases including phosphatases, esterases, aminopeptidases and glycosidases. Seventy-five µl of diluted serum were placed in each microwell. The metabolic byproducts produced during the 45-minute incubation period at room temperature change the colour of the fluid. The reactions were then graded visually, depending on the intensity of colour, from 0 to 5 (0 – no enzymatic activity detected, 5 – maximum intensity of the reaction), with reference to the API ZYM colour reaction chart. These tests can detect only gross differences in enzyme activity between treatment and control groups, not subtle ones.

Relative Numbers of Haemocyte Types

Pilot studies were conducted to determine how best to preserve and fix haemocyte smears. Addition of ethylenediaminetetracetic acid, citrate or N-ethylmaleimide to haemolymph to prevent agglutination and coagulation (Bang 1970; Durliat and Vranck 1981; Martin et al. 1991) and the fixation of haemolymph in formalin produced generally unsatisfactory results. After various trials, it was determined that fixation of haemolymph in formalin followed by washing and re-suspension of pelleted haemocytes in a solution of methanol and acetic acid gave satisfactory results. It was also observed that, in order to avoid haemocyte "clumping", it was best not to prepare smears from haemolymph that had been left in formalin for extended periods. Therefore smears were prepared within a few hours of the haemolymph sampling.

Haemolymph fixed in 10% buffered formalin onboard the vessel was subsequently centrifuged in the laboratory. Resulting pellets were washed three times with distilled water. The pelleted haemocytes were then re-suspended in a 4:1 methanol/acetic acid solution. A drop of cell suspension was placed on a microscope slide and smeared, air dried, stained with GIEMSA and examined with a Wild Leitz Aristoplan bright field microscope in order to identify the three types of haemocytes (hyalinocytes, semi-granulocytes and granulocytes) described in previous studies on crustaceans (Bauchau 1981; Soderhall and Cerenius 1992). Estimations of size of the three types of haemocytes were made on 10 cells of each type using a Leitz calibrated linear scale. A differential count was performed on the three types of cells and expressed as a percentage of each type of 200 haemocytes counted per slide. Analysis scatter plots of raw and transformed data and results of regression analysis, including residuals, showed that percentages needed to be transformed using arcsin square root before comparisons between control and treatment groups could be done using the unpaired t-test or Mann-Whitney Rank Sum test (Sokal and Rohlf 1981). Probabilities = 0.05 were considered significant.

Organ and Tissue Pathology

Statocyst Examination

The head regions of crabs, including antennules, were excised in the field and immediately fixed in 10% buffered formalin for at least 96 hours. Basal segments of antennules were removed from the front of the head and, using a Wild Heerbrugg stereomicroscope, the statocysts were carefully dissected out in the following manner. The lateral outside wall of the shell of the antennular segment was removed to expose the statocyst capsule in the lumen of the segment. The interior of the capsule, including the strap of setae (sensory hairs) projecting inside the capsule, was then examined for microstructural differences between the control and treatment groups.

Preliminary studies indicated that the sensory hairs were of sufficient diameter and length to allow for inspection of sensory hair fields by light microscopy. Moreover, statocysts of individual crabs were noted to contain only one distinct sensory hair field. This permitted observation of the statocysts of a large number of crabs for visible signs of hair ablation in their sensory hair fields. Representative pictures were taken with a Nikon digital camera.

Some representative samples were also prepared for scanning electron microscopy. These samples were dehydrated in a series of ethanol solutions before being placed in 100% ethanol for 12 h. The samples were then placed in a desiccator for twenty-four hours, after which conducting graphite paint was used to glue the preparations to a scanning electron microscope stub. They were sputter coated with gold and examined with a scanning electron microscope.

Hepatopancreas and Heart Histopathology

Both the hepatopancreas and heart samples were processed using standard histological methods (Lynch et al. 1969) with an Autotechnicon Tissue Processor. A graded ethyl alcohol series (70%, 80%, 95% and two changes of 100%) was used to dehydrate the samples. The organs were then cleared in three changes of citrisolv™. Finally, the tissues were impregnated with three changes of molten embedding media, Tissue Prep 2™. The processed tissues were embedded in steel molds using molten embedding media and topped with labelled embedding rings. After cooling, the hardened blocks of embedded tissues were removed from their base molds. The blocks were then trimmed of excess wax. Sections were cut at 6µ on a Leitz microtome, floated on a 47^{0}C water bath containing gelatin, and then picked up on labelled microscope slides. After air drying, the slides were fixed at 60 ^{0}C for approximately 2 hours to remove most of the embedding media and allow the sections to adhere properly to the slide. Sections were stained using Mayers Haematoxylin and Eosin method (Luna 1968). Coverslips were then applied using Entellan ® and the slides were left overnight to air dry and harden.

Slides were then examined under different magnifications by transmission light microscopy using a Wild Leitz Aristoplan bright field microscope for any microstructural differences between the control and treatment groups.

Egg Development

Fertilized eggs that had been exposed to seismic energy were held at DFO in one-litre mason jars filled with seawater at 4°C. They were observed for delayed lethal and/or sub-lethal effects for a period of twelve weeks. After the twelve-week observation period, eggs were fixed in formalin, washed in deionised water and examined under a Wild Heerbrugg stereomicroscope. Preliminary examination indicated that the eggs could be divided into 2 categories based on colour criteria; "beige" and "orange-brown". The orange-brown eggs were further divided into 3 categories based on eye size criteria; "no eyes", "small eyes", and "big eyes". Measurements were made of the greatest width and length of one eye per embryo for 12 representative fertilized eggs for each 'eyed' category. A Leitz calibrated linear scale was used to measure the eyes.

The percentages of eggs in all categories were calculated and statistically analysed using the z-test. Resultant probabilities = 0.05 were considered to indicate statistically significant differences. Representative pictures of the different categories were taken with a Nikon digital camera.

RESULTS AND DISCUSSION

Acoustic Measurements

The sound levels received by the experimental crab and fertilized eggs from different source volumes and distances were measured in the field and are reported in two ways: (1) broadband peak pressure (0-P) in Pa and the equivalent dB level, and (2) energy density (dB re 1 μPa^2/Hz) over a frequency range up to 500 Hz. It appears that saturation of the acoustic measuring system occurred in treatments using the 40-in^3 gun at two and five metres, and the 200-in^3 array at four metres. Therefore, the broadband peak levels presented for these treatments (Table 8) are lower than the actual levels (see Appendix 1 for graphic representations of broadband signal signatures and energy density spectra).

Table 8. Results of measurements of received sound levels. Received levels at distances of 2 and 5-m from the 40-in^3 air gun were not measured accurately. Received sound levels at 2 and 5-m shown in brackets were interpolated by estimating source levels using the 10-m data and assuming spherical spreading from the source.

Date (d/m/y)	Seismic Source Volume (in^3)	Seismic Source to Hydrophone Distance (m)	Number of Shots	Mean 0-Peak (Pa)	Mean Equivalent dB Level (re 1 μPa)
03/10/02	40	10	156	11,350	201.1
03/10/02	40	10	138	11,482	201.2
26/10/02	40	10	91	15,488	203.8
26/10/02	40	10	145	14,622	203.3
26/10/02[a]	40	5	13	15,668	203.9 (213)
26/10/02[a]	40	2	6	16,032	204.1 (221)
26/10/02[a]	40	2	97	15,311	203.7 (221)
02/11/02[a]	40	2	109	15,488	203.8 (221)
10/11/02[a]	40	2	83	15,488	203.8 (221)
10/11/02[a]	40	2	46	15,668	203.9 (221)
10/11/02[a]	40	2	59	15,311	203.7 (221)
10/11/02	40	15	136	14,289	203.1
10/11/02	40	15	36	14,454	203.2
27/11/02	200	85	131	7,413	197.4
30/11/02[a]	200	4	176	15,311	203.7
01/12/02[b]	200	50	26	12,303	201.8
01/12/02[c]	200	50	72	13,804	202.8

[a] possible saturation
[b] maximum energy density in low frequency (< 100 Hz)
[c] maximum energy density in high frequency (> 100 Hz)

Unsaturated received peak broadband levels from the 40-in^3 gun at 10-m ranged from 201.1 to 203.8 dB re 1 μPa (11,350 to 15,488 Pa). Unsaturated received peak broadband levels from the 40-in^3 gun at 15-m ranged from 203.1 to 203.2 dB re 1 μPa (14,289 to 14,454 Pa). The peak source level estimated using the 10-m data and assuming spherical spreading propagation from the source was 224 to 227 dB re 1μPa at 1-m. This source level and assumed spherical spreading was used to interpolate received levels at 5-m as 213 dB and at 2-m as 221 dB. The received peak levels from the 200-in^3 array at 50 to 85-m ranged from 197.4 to 202.8 dB re 1 μPa (7,413 to 13,804 Pa). The signals from the 200-in^3 array at 50-m was split into two frequency ranges (< 100 Hz and 100 to 500 Hz) because two energy density peaks were observed (Table 9; Appendix 1). The estimated peak source level estimated using the 50-m data and assuming spherical spreading from the source was 237 dB re 1μPa at 1-m. This is the equivalent source level for a point. A receiver 4-m from the array is with in the near field of the array and receives sound from individual air guns rather than from the integrated array as a whole; thus, the actual received levels at 4-m could not be estimated.

Table 9. Specifics of energy density spectra of measured seismic shots.

Date (d/m/y)	Seismic Source Volume (in^3)	Seismic Source to Hydrophone Distance (m)	Maximum Ambient Energy Density (dB re 1 μPa^2/Hz)	Maximum Seismic Energy Density (dB re 1 μPa^2/Hz)
03/10/02	40	10	110.7	153.5[a]
26/10/02	40	10	99.5	154.3[a]
26/10/02	40	5	99.5	170.0[a]
26/10/02	40	2	99.5	183.2[a]
02/11/02	40	2	114.9	182.6[a]
10/11/02	40	2	86.6	186.7[a]
10/11/02	40	15	86.6	146.9[a]
27/11/02	200	85	98.5	130.0[b]
30/11/02	200	4	102.0	175.2[c]
01/12/02	200	50	95.2	149.5[d]

[a] maximum energy density in frequency range 24-31 Hz
[b] maximum energy density in frequency range 106-260 Hz (mean = 170 Hz)
[c] maximum energy density in frequency range 17-19 Hz
[d] some maximum energy densities in frequency range 16-20 Hz; others in frequency range 107-244 Hz (mean = 164 Hz)

The energy density measurement results were not affected by the system saturations. The highest maximum energy density levels occurred as a result of shoots with the 40-in^3 gun at 2-m. These energy densities ranged from 182.6 to 186.7 dB re 1 μPa^2/Hz at frequencies between 24 and 31 Hz. The maximum energy density observed with the 200-in^3 array was 175.2 dB re 1 μPa^2/Hz within the 17 to 19 Hz frequency range. The maximum ambient energy densities during the days with seismic shooting ranged between 86.6 to 114.9 dB re 1 μPa^2/Hz (Table 9). Energy is a more meaningful measure of exposure because it includes an element to account for the duration of the pulse. Two pulses of equal peak pressure can, depending on their durations, have radically different energy levels.

Water Column Temperature Profiling

Bottom temperatures at the study site during the fieldwork component ranged from –0.5 to –1.5 ° C. The primary thermocline was located about 20-m from surface at the onset of the fieldwork but by the later part of October to completion, it had shifted to between 40 and 85-m (Appendix 2).

Existing Knowledge of Invertebrate Sound Detection

Acoustic detection by invertebrates has been the subject of various papers over the last few decades (Wiese 1976; Janse 1980; Tautz and Sandeman 1980; Hawkins and Myrberg, Jr. 1983;

Budelmann 1988; Breithaupt and Tautz 1990; Goodall et al. 1990; Budelmann 1992; Cate and Roye 1997; Popper et al. 2001). Decapod crustaceans have a variety of external and internal sensory receptors that are potentially responsive to sound and vibration. Many of these receptors resemble vertebrate receptors that respond to hydrodynamic stimulation, particle motion and, possibly, pressure. However, by virtue of their body plan and the constraints thus imposed upon sensory structure, aquatic decapods appear specialized to respond to particle displacement components of an impinging sound field and not to the pressures. The belief that decapods have a limited ability to detect acoustic stimuli is plausible considering that aside from the exoskeleton, most decapod crustaceans are basically the same density as water and do not have any air-filled spaces such as those associated with pressure detection in fish (Hawkins and Myrberg Jr. 1983; Breithaupt and Tautz 1990; Popper and Fay 1999).

Many decapods have an extensive array of hair-like receptors both within and upon the body surface that most probably respond to water- or substrate-borne displacements (Breithaupt and Tautz 1990). Decapods also have an abundance of proprioceptive organs that could serve secondarily to perceive vibrations (Burke 1954).

Effects on Experimental Commercial Fishing

Specifics of Fishery Sets

The experimental commercial fishing was conducted by licensed commercial fishermen using their normal gear and procedures (Refer to 'Materials and Methods' for more detail). The normal complement of traps in each fleet was 40. The pre-seismic commercial fishing was conducted from 18 September to 20 October 2002 (Table 10). Seismic shooting for the crab health experiments was initiated on 3 October 2002. It was limited to two sessions with the single 40-in^3 gun and was conducted at a location at least 5-km from the experimental fishing site. No more seismic shooting occurred until 26 October. It has been assumed that those two sessions (400 shots) on 3 October had negligible impact on the behaviour of the crabs at the fishing location and did not affect the subsequent three pre-seismic fishery sets between 9 and 20 October. Therefore, the period of seismic shooting indicated on Figures 8 and 9 is from 26 October to 30 November (Table 11). Again, the adverse weather conditions during the fall months of 2002 prohibited the completion of fieldwork within a shorter time period. Unfortunately, there was a wider than intended temporal separation between the pre-seismic fishing and the post-seismic fishing.

Two of the six post-seismic fishing sets were deployed immediately after completion of shooting sessions with the 200-in^3 array, one after a 200 shot session and the other after a total of 400 shots. Another set was deployed within one day (20 hours) of a 200 shot session with the seven-gun array, and two other sets were deployed within two days (40 and 47 hours) of the completion of seismic shooting with the array. The sixth set was deployed approximately six days (148 hours) after 400 shots of the array (Table 11).

Table 10. Specifics of experimental commercial snow crab fishery before and after exposure to seismic.

Haul Date (d/m/y)	Soak Time (h)	Traps Fishing (n)	Legal-sized Males (n)	Sublegal-sized Males (n)	Number of Soft-shelled Males	CPUE for Legal-sized Males (n/trap/24h)	CPUE for Legal-sized Males (n/trap/soak time)	CPUE Sublegal-sized Males(n/trap/24 h)
Pre-Seismic								
19/09/02	19	40	195	636	10	6.2	4.9	20.1
20/09/02	27	40	82	415	6	1.8	2.0	9.2
22/09/02	44	40	103	337	6	1.4	2.6	4.6
24/09/02	45	40	284	509	8	3.8	7.1	6.8
11/10/02	43	40	128	250	83	1.8	3.2	3.5
14/10/02	68	39	100	223	41	0.9	2.6	2.0
20/10/02	141	39	104	189	22	0.5	2.7	0.8
Post-Seismic								
22/11/02	16	37	90	355	0	3.6	2.4	16.0
23/11/02	25	38	255	540	7	6.4	6.7	13.6
27/11/02	96	36	138	92	29	1.0	3.8	0.6
30/11/02	20	36	139	290	16	4.6	3.9	9.7
06/12/02	144	36	114	88	0	0.5	3.2	0.4
12/12/02	144	35	120	78	0	0.6	3.4	0.4

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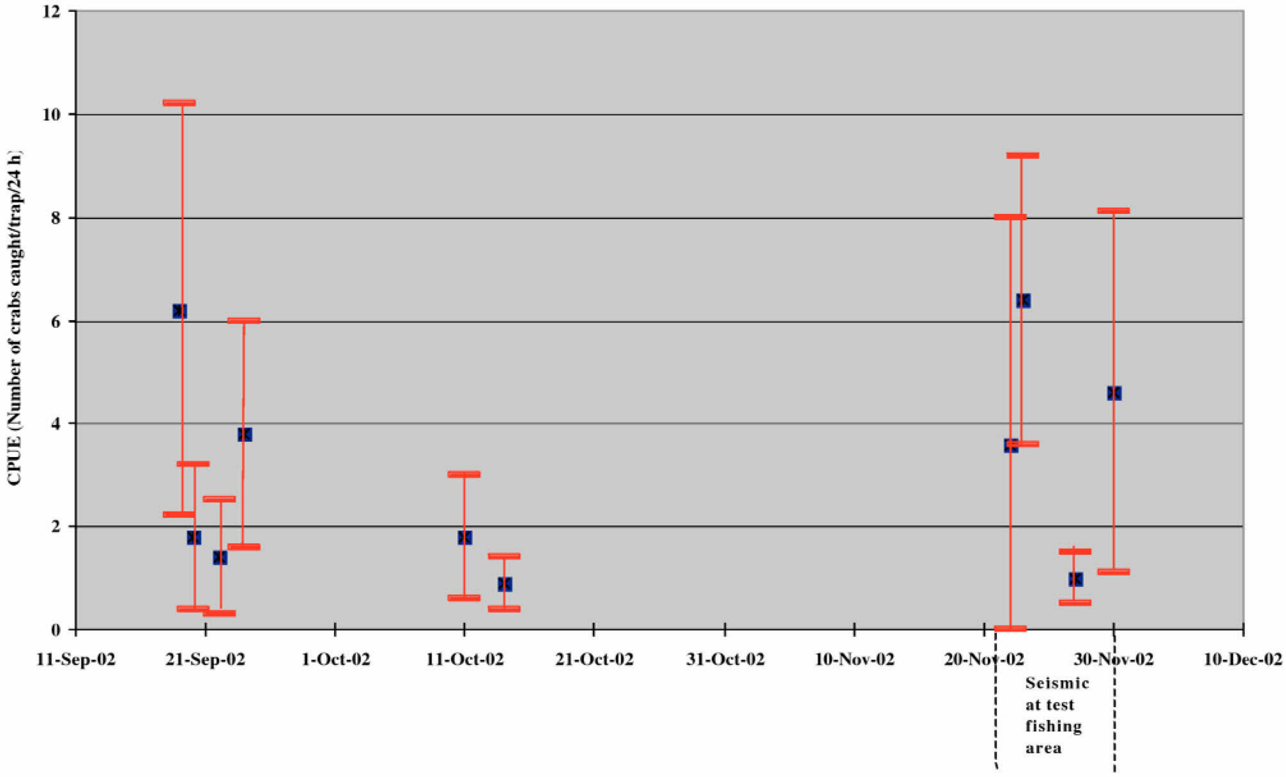

Figure 8. Mean standardized number of legal-sized snow crabs caught in the experimental commercial fishery trap fleet sets with soak times of 96 h or less. Upper and lower limits of standard deviation (red bars) are shown for each mean value (black box). Catch data are on fleet retrieval dates.

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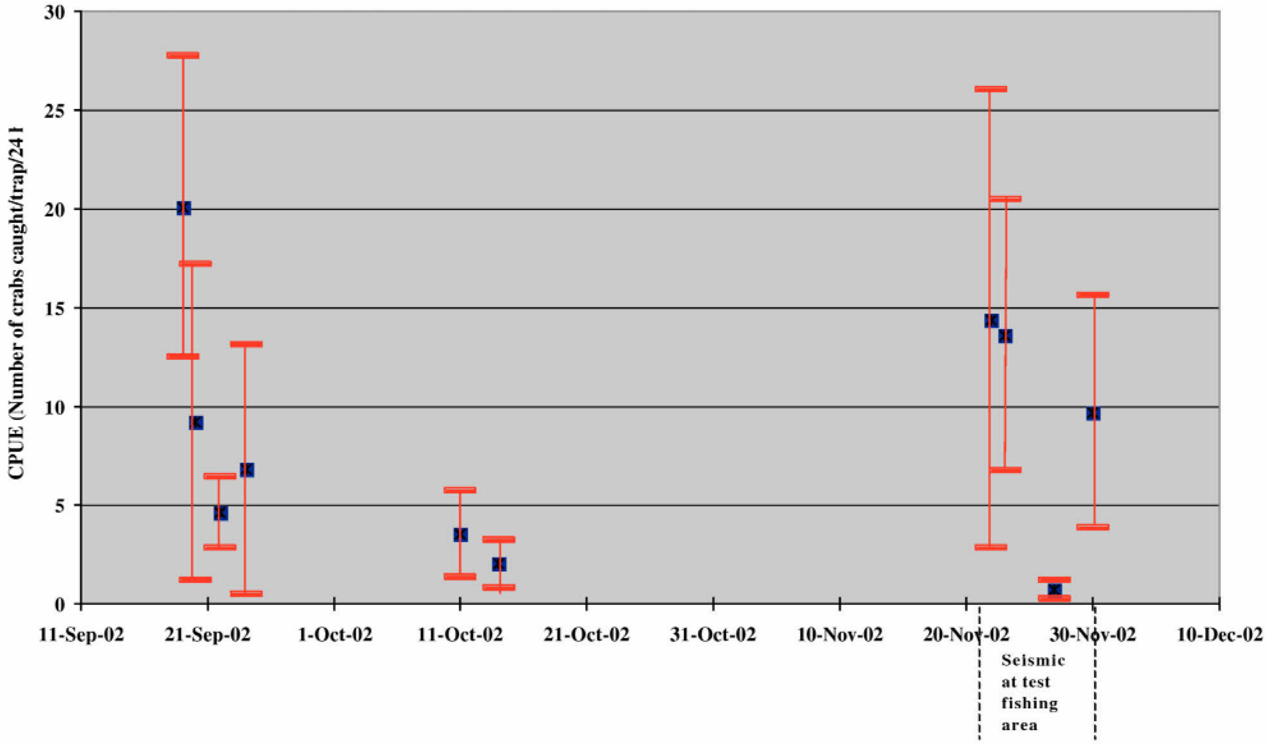

Figure 9. Mean standardized number of sublegal-sized snow crabs caught in the experimental commercial fishery trap fleet sets with soak times of 96 h or less. Upper and lower limits of standard deviation (red bars) are shown for each mean value (black box). Catch data are on fleet retrieval dates.

Table 11. Temporal and spatial relationships between seismic shooting and post-seismic experimental commercial fishing.

Date	Seismic Source	Location of Shooting	Number of Shots	Deployment and Haul Dates of Fishing Sets	Time Between End of Last Seismic Session and Set Deployment (h)	Time Between End of Last Seismic Session and Set Haul (h)
26 Oct	40-in^3	> 5-km	800[a]			
10 Nov	40-in^3	> 5-km	800[a]			
21 Nov	40-in^3	> 5-km	400[b]			
	200-in^3	Fishing site	200[c]	21-22 Nov	2	18
				22-23 Nov	20	45
				23-27 Nov	47	143
27 Nov	200-in^3	Fishing site	400[b]	29-30 Nov	40	60
30 Nov	200-in^3	Fishing site	400[b]	30 Nov-6 Dec	2	146
				6-12 Dec	148	292

5-km indicates that location of shooting was at least 5-km from experimental fishing location
[a] 4 shooting sessions
[b] 2 shooting sessions
[c] 1 shooting session

Geographic coordinates of fleet start and end points were recorded (see Figure 1 for locations). This provided a means of examining the potential effect of seismic shooting on catch rate from the perspective of distance from the seismic source.

Fishing gear soak times for the seven pre-seismic sets ranged from 19 to 141 hours, averaging about 55 hours per set (see Table 10). During the post-seismic experimental fishing period, the soak times ranged from 16 to 144 hours and averaged about 74 hours per set (see Table 10). The average number of legal-sized crabs caught per set (142) during the pre-seismic fishing was almost the same as for the post-seismic fishing (143). The average soak time during post-seismic fishing was almost 20 hours longer than during pre-seismic fishing due to poor weather conditions. The average number of traps fishing per set during post-seismic fishing (36.3) was slightly less than that used during pre-seismic fishing (39.7). When the data from all thirteen sets are considered, these differences are not significant but for the <96-h data, they are significant. Therefore, it was necessary to standardize the catch data to a 24-h period (known as catch-per-unit-effort or CPUE).

Initial Comparison of Pre- and Post-Seismic CPUE

Catch data have been standardized and presented as catch-per-unit-effort (CPUE), defined as the number of crabs caught per trap per 24-hour period. Only traps that were recovered and intact were used in the tables and analyses that follow. Traps that were set but not recovered or that were recovered in a damaged condition were not included. CPUE for legal-sized males during pre-seismic fishing ranged from 0.5 to 6.2 crabs/trap/24h compared to a range of 0.5 to 6.4 crabs/trap/24h during the post-seismic fishing (see Figure 8; Table 10). Similarly, CPUE for sublegal-sized males during pre-seismic fishing ranged from 0.8 to 20.1 crabs/trap/24h compared to a range of 0.4 to 16.0 crabs/trap/24h during post-seismic fishing (see Figure 9; Table 10). The smaller sublegal-sized crabs will leave the traps by crawling through the large mesh once the bait

Pre-seismic	=96	259	2.7 ± 2.7	0.005	Yes
Post-seismic		147	4.0 ± 3.7		
Pre-seismic	=48	200	3.0 ± 2.9	< 0.0001	Yes
Post-seismic		111	4.9 ± 3.8		
Pre-seismic	=30	80	4.0 ± 3.7	0.046	Yes
Post-seismic		111	4.9 ± 3.8		

All CPUE data are presented as ‘mean ± standard deviation’
[a] Calculated using Mann-Whitney Rank Sum Test

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MILITARY

Explosives - Injuries

Bombs and explosions can cause unique patterns of injury seldom seen outside combat. The predominant post explosion injuries among survivors involve standard penetrating and blunt trauma. Blast lung is the most common fatal injury among initial survivors. Explosions in confined spaces (mines, buildings, or large vehicles) and/or structural collapse are associated with greater morbidity and mortality. Half of all initial casualties will seek medical care over a one-hour period. This can be useful to predict demand for care and resource needs. Care providers expect an "upside-down" triage - the most severely injured arrive after the less injured, who bypass EMS triage and go directly to the closest hospitals.

- Explosives
- Explosives - Primary
- Explosives - Booster
- Explosives - Nitroaromatics
- Explosives - Nitramines
- Explosives - Nitrate esters
- Explosives - Compositions
- Explosives - ANFO
- Explosives - Mining Types
- Explosives - Mining Industries
- Liquid Explosive Compositions
- Novel Energetic Materials
- Insensitive Explosives
- Insensitive Munitions (IM)
- Dense Inert Metal Explosive (DIME)
- Triacetone Triperoxide (TATP)
- Explosives - Injuries
- Explosives - Classes
- Explosives - ATF List
- Explosives - UN List
- Explosives & the Environment

Background

Explosions can produce unique patterns of injury seldom seen outside combat. When they do occur, they have the potential to inflict multi-system life-threatening injuries on many persons simultaneously. The injury patterns following such events are a product of the composition and amount of the materials involved, the surrounding environment, delivery method (if a bomb), the distance between the victim and the blast, and any intervening protective barriers or environmental hazards. Because explosions are relatively infrequent, blast-related injuries can present unique triage, diagnostic, and management challenges to providers of emergency care.

Few U.S. health professionals have experience with explosive-related injuries. Vietnam era physicians are retiring, other armed conflicts have been short-lived, and until this past decade, the U.S. was largely spared of the scourge of mega-terrorist attacks. This primer introduces information relevant to the care of casualties from explosives and blast injuries.

Classification of Explosives

Explosives are categorized as high-order explosives (HE) or low-order explosives (LE). HE produce a defining supersonic over-pressurization shock wave. Examples of HE include TNT, C-4, Semtex, nitroglycerin, dynamite, and ammonium nitrate fuel oil (ANFO). LE create a subsonic explosion and lack HE's over-pressurization wave. Examples of LE include pipe bombs, gunpowder, and most pure petroleum-based bombs such as Molotov cocktails or aircraft improvised as guided missiles. HE and LE cause different injury patterns.

Explosive and incendiary (fire) bombs are further characterized based on their source. "Manufactured" implies standard military-issued, mass produced, and quality-tested weapons. "Improvised" describes weapons produced in small quantities, or use of a device outside its intended purpose, such as converting a commercial aircraft into a guided missile. Manufactured (military) explosive weapons are exclusively HE-based. Terrorists will use whatever is available – illegally obtained manufactured weapons or improvised explosive devices (also known as "IEDs") that may be composed of HE, LE, or both. Manufactured and improvised bombs cause markedly different injuries.

Blast Injuries

The four basic mechanisms of blast injury are termed as primary, secondary, tertiary, and quaternary (Table 1). "Blast Wave" (primary) refers to the intense over-pressurization impulse created by a detonated HE. Blast injuries are characterized by anatomical and physiological changes from the direct or reflective over-pressurization force impacting the body's surface. The HE "blast wave" (over-pressure component) should be distinguished from "blast wind" (forced super-heated air flow). The latter may be encountered with both HE and LE.

Table 1: Mechanisms of Blast Injury

Category	Characteristics	Body Part Affected	Types of Injuries
Primary	Unique to HE, results from the impact of the over-pressurization wave with body surfaces.	Gas filled structures are most susceptible - lungs, GI tract, and middle ear.	Blast lung (pulmonary barotrauma) TM rupture and middle ear damage Abdominal hemorrhage and perforation - Globe (eye) rupture- Concussion (TBI without physical signs of head injury)
Secondary	Results from flying debris and bomb fragments.	Any body part may be affected.	Penetrating ballistic (fragmentation) or blunt injuries Eye penetration (can be occult)
Tertiary	Results from individuals being thrown by the blast wind.	Any body part may be affected.	Fracture and traumatic amputation Closed and open brain injury
Quaternary	All explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms. Includes exacerbation or complications of existing conditions.	Any body part may be affected.	Burns (flash, partial, and full thickness) Crush injuries Closed and open brain injury Asthma, COPD, or other breathing problems from dust, smoke, or toxic fumes Angina Hyperglycemia, hypertension

LE are classified differently because they lack the self-defining HE over-pressurization wave. LE's mechanisms of injuries are characterized as due from ballistics (fragmentation), blast wind (not blast wave), and thermal. There is some overlap between LE descriptive mechanisms and HE's Secondary, Tertiary, and Quaternary mechanisms.

Table 2: Overview of Explosive-Related Injuries

System	Injury or Condition

*FBI; pg. 3

Explosives - ANFO (Ammonium Nitrate - Fuel Oil)

- Explosives
- Explosives - Primary
- Explosives - Booster
- Explosives - Nitroaromatics
- Explosives - Nitramines
- Explosives - Nitrate esters
- Explosives - Compositions
- Explosives - ANFO
- Explosives - Mining Types
- Explosives - Mining Industries
- Liquid Explosive Compositions
- Novel Energetic Materials
- Insensitive Explosives
- Insensitive Munitions (IM)
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- Explosives - Injuries
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- Explosives - UN List
- Explosives & the Environment

Ammonium nitrate-fuel oil (ANFO) blasting agents represent the largest industrial explosive manufactured (in terms of quantity) in the United States. This product is used primarily in mining and quarrying operations. The components are generally mixed at or near the point of use for safety reasons. The mixed product is relatively safe and easily handled and can be poured into drill holes in the mass or object to be blasted.

Melvin A. Cook's life is intimately connected with the history of explosives, he is a scientist,, inventor, teacher, businessman, theorist, consultant, expert witness, entrepreneur, and author. Cook, a professor of metallurgy at the University of Utah, was a businessman and author of works on explosives. He also published works on creationism, particularly on the relationship between science and Mormonism. Cook's personal involvement in both the theoretical and practical aspects of the field of explosives spans more than fifty years.

Cook's greatest commercial explosives invention was formulated in December of 1956, when he created a new blasting agent using an unusual mixture of ammonium nitrate, aluminum powder, and water. The safety and efficiency of this new explosive were apparent, and the use of water was revolutionary. Tests that followed resulted in the development of a new field of explosives: slurry explosives. This invention converted the commercial explosives industry from "dangerous dynamite" to "safe slurry" and dry blasting agents [ANFO]. In 1972 Cook developed the BLU-82, the largest and most powerful chemical bomb, using aluminized slurry.

Blasting agents consist of mixtures of fuels and oxidizers, none of which are classified as explosive. Nitrocarbonitrate is a classification given to a blasting agent under the US Department of Transportation regulations on packaging and shipping. A blasting agent consists of inorganic nitrates and carbonaceous fuels and may contain additional nonexplosive substances such as powdered aluminum or ferrosilicon to increase density. The addition of an explosive ingredient such as TNT changes the classification from a blasting agent to an explosive. Blasting agents may be dry or in slurry forms. Because of their insensitivity, blasting agents should be detonated by a primer of high explosive.

Ammonium nitrate- fuel oil has largely replaced dynamites and gelatins in bench blasting. Denser slurry blasting agents are supplanting dynamite and gelatin and dry blasting agents. The most widely used dry blasting agent is a mixture of ammonium nitrate prills (porous grains) and fuel oil. The fuel oil is not precisely CH2, but this is sufficiently accurate to characterize the reaction. The right side of the equation contains only the desirable gases of detonation, although some CO and N02 are always formed. Weight proportions of ingredients for the equation are 94.5 percent ammonium nitrate and 5.5 percent fuel oil. In actual practice the proportions are 94 percent and 6 percent to assure an efficient chemical reaction of the nitrate.

Uniform mixing of oil and ammonium nitrate is essential to development of full explosive force. Some blasting agents are premixed and packaged by the manufacturer. Where not premixed, several methods of mixing in the field can be employed to achieve uniformity. The best method, although not always the most practical one, is by mechanical tier. A more common and almost as effective method of mixing is by uniformly soaking prills in opened bags with 8 to 1O percent of their weight of oil. After draining for at least a half hour the prills will have retained about the correct amount of fuel oil.

Fuel oil can also be poured onto the ammonium nitrate in approximately the correct proportions as it is poured into the blasthole. For this purpose, about i gal of fuel oil for each 100 lb of ammonium nitrate will equal approximately 6 percent by weight of oil. The oil can be added after each bag or two of prills, and it will disperse relatively rapidly and uniformly. Inadequate priming imparts a low initial detonation velocity to a blasting agent, and the reaction may die out and cause a misfire. High explosive boosters are sometimes spaced along the borehole to as sure propagation throughout the column.

As in other combustion reactions, a deficiency of oxygen favors the formation of carbon monoxide and unburned organic compounds and produces little, if any, nitrogen oxides. An excess of oxygen causes more nitrogen oxides and less carbon monoxide and other unburned organics. For ammonium nitrate and fuel oil (ANFO) mixtures, a fuel oil content of more than 5.5 percent creates a deficiency of oxygen.

Ammonium nitrate and fuel oil (ANFO) has a broad spectrum of Velocities of Detonation according to numerous references. However, some of these references are more specific when establishing parameters. A military catering charge lists a VOD of 10,700 feet per second (fps). A 4" diameter steel tube confinement is at 10,000 fps, while a 16" diameter tube is at 16,000 fps. In charge diameters of 6 in. or more, dry blasting agents attain confined detonation velocities of more than i2,000 fps, but in a diameter of 1- 1/2 in., the velocity is reduced to 60 percent. When ANFO is used in boreholeing, the VOD has a positive slope as a function of depth, the VOD increases as the detonation front progresses down the borehole. Enhanced effects of very large quantities, which is essentially self tamping, the VOD is expected to be in the 13,000-15,000 fps range. A ballpark approximation for very large quantities of blasting agents, which is accepted in the commercial industry, is roughly half the VOD of C-4/plastics, which equates to 13,000 fps. The recognized VOD of urea nitrate, however, is 11,155 to 15,420 fps.

The specific gravity of ANFO varies from 0.75 to 0.95 depending on the particle density and sizes. Confined detonation velocity and charge concentration of ANFO vary with borehole diameter. Pneumatic loading results in high detonation velocities and higher charge concentrations, particularly in holes smaller than 3 in. (otherwise such small holes are not usually recommended for ANFO blasting).

The simple removal of a tree stump might be done with a 2-step train made up of an electric blasting cap and a stick of dynamite. The detonation wave from the blasting cap would cause detonation of the dynamite. To make a large hole in the earth, an inexpensive explosive such as ANFO might be used. In this case, the detonation wave from the blasting cap is not powerful enough to cause detonation, so a booster must be used in a 3- or 4-step train. The yield from the blasting caps and safety fuses used in these trains are usually small compared to those from the main charge, because the yields are roughly proportional to the weight of explosive used, and the main charge makes up most of the total weight.

Advantages of insensitive dry blasting agents are their safety, ease of loading, and low price. In the free-flowing form, they have a great advantage over cartridge explosives because they completely fill the borehole. This direct coupling to the walls assures efficient use of explosive energy. Ammonium nitrate is water soluble so that in wet holes, some blasters pump the water from the hole, insert a plastic sleeve, and load the blasting agent into the sleeve. Special precautions should be taken to avoid a possible building up of static electrical charge, particularly when loading pneumatically. When properly oxygen- balanced, the fume qualities of dry blasting agents permit their use underground. Canned blasting agents, once widely used, have unlimited water resist-ance, but lack advantages of loading ease and direct coupling to the borehole.

In 2001, US explosives production was 2.38 million metric tons (Mt), 7% less than that in 2000; sales of explosives were reported in all States. Coal mining, with 69% of total consumption, continued to be the dominant use for explosives in the United States. Kentucky, West Virginia, Indiana, Wyoming, and Virginia, in descending order, were the largest consuming States, with a combined total of 46% of US sales.

After completing an investigation into dumping of ammonium nitrate from Ukraine that was begun in 2000, the US International Trade Commission (ITC) issued its final determination in August 2001. The ITC determined that imports of ammonium nitrate from Ukraine were sold in the United States at less than fair market value and that critical circumstances did not exist with regard to these imports. As a result of the negative determination regarding critical circumstances, the duties were not retroactive and only apply to ammonium nitrate that has been imported since March 5, 2001. The antidumping duty of 156.29% ad valorem that was finalized by the International Trade Administration in July 2001 was applied.

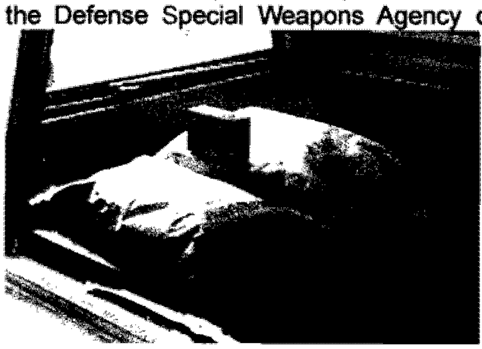
Sales of ammonium-nitrate-based explosives (blasting agents and oxidizers) were 2.34 Mt in 2001, which was an 8% decrease from that of 2000, and accounted for 98% of US industrial explosives sales. Sales of permissibles and other high explosives increased slightly. Data for 2001 are not exactly comparable to the 2000 data. One company, Nelson Brothers LLC, did not provide data to the Institute of Makers of Explosives (IME) in 2001, and no estimate for its sales was included in the totals.

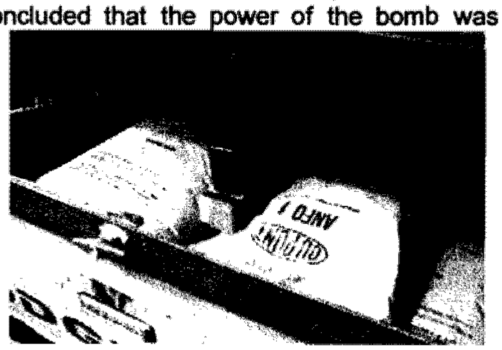
By 2001 engineers in the Fuels and Lubricants Group of Shell Co. of Australia developed a technique to blend waste oil with ANFO for a product that can be used in blasting. Mines throughout the world produce thousands of liters of waste fuel oil that needs to be disposed of in an environmentally safe manner. By using the fuel oil in a blasting compound, transporting the waste oil is eliminated, the quantity of fuel oil needed for blasting is reduced, and potentially toxic hydrocarbons in waste oil can be destroyed by the high blast temperature. Shell tested the ANFO-waste oil blend at Hamersley Iron's Marandoo mine site, and found that the ratio of waste oil to ANFO blend could be as much as 50-50 without any detrimental effect to the final blasting performance.

Urea nitrate is also considered a type of fertilizer-based explosive, although, in this case, the two constituents are nitric acid (one of the ten most produced chemicals in the world) and urea. A common source of urea is the prill used for de-icing sidewalks. Urea can also be derived from concentrated urine. This is a common variation used in South America and the Middle East by terrorists. Often, sulfuric acid is added to assist with catalyzing the constituents. A bucket containing the urea is used surrounded by an ice bath. The ice serves in assisting with the chemical conversion when the nitric acid is added. The resulting explosive can be blasting cap sensitive. Urea nitrate has a destructive power similar to ammonium nitrate.

By one estimate, the bomb used to attack the Alfred Murrah Federal Building in Oklahoma City on April 19, 1995 consisted of an ANFO explosive main charge of approximately 4,000 pounds, based on an estimate of the Velocities of Detonation [VOD] of approximately 13,000 fps. Other estimates claim that the 1995 explosion that collapsed portions of the Murrah Federal Building in Oklahoma City contained 4,800 pounds of ammonium nitrate and fuel oil. Later estimates suggested that the bomb had in excess of 6,200 pounds of various energetic materials, including explosives other than ANFO, equivalent to 5,000 pounds of TNT. In the Salameh World Trade Center bombing case resulting from the bombing of the World Trade Center (WTC) on February 26, 1993, FBI Explosives Unit examiner David Williams opined that the main explosive used in the bombing consisted of 1,200 pounds of urea nitrate explosive. The FBI chemists specializing in the examination of explosive residue, however, did not find any residue identifying the explosive at the World Trade Center.

Not all large truck bombs have used ANFO. On June 25, 1996, Saudi terrorists sponsored by Iran attacked the Khobar Towers barracks, a high-rise building complex in a densely populated urban environment in Saudi Arabia. T tanker truck loaded with at least 5,000 pounds of plastic explosives was driven into the parking lot in front of the Khobar Towers residential complex in Dhahran. Nineteen American service members were killed in the blast, and hundreds of other service members and Saudis were injured. There is no doubt that the extent of the casualties at Khobar Towers resulted, in part, from the extraordinary size of the terrorist bomb. Reports initially estimated that the bomb contained the equivalent of 3,000 to 8,000 pounds of TNT, but a study by the Defense Special Weapons Agency concluded that the power of the bomb was actually closer to 20,000 pounds of TNT.





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The Oklahoma City Bombing

by Kevin Caruso

On April 19, 1995, at 9:02 a.m. local time, a massive truck bomb exploded in front of the Alfred P. Murrah Federal Building in Oklahoma City, Oklahoma, killing 168 people (including 19 children) and injuring over 800.

The explosion destroyed about half of the Federal Building, damaged or destroyed an additional 300 buildings, and was felt as far as 30 miles away.

The Alfred P. Murrah Federal Building after the explosion

The truck bomb was a rented Ryder truck filled with about 5,000 pounds of explosives, including ammonium nitrate, nitromethane, and agricultural fertilizer, and was driven by Timothy McVeigh, who was pulled over 90 minutes after the bombing for driving without a license plate. McVeigh was arrested on a firearms charge, spent two days in jail, and was then charged with the bombing.

Terry Nichols, McVeigh's accomplice, was arrested at a later date in Kansas, and was charged in the bombing on May 10.

Over 12,000 individuals assisted in the relief and rescue operations after the bombing, and many of them have suffered from post-traumatic stress disorder, clinical depression, anxiety, and additional problems because of the deeply traumatic nature of the bombing and its aftermath.

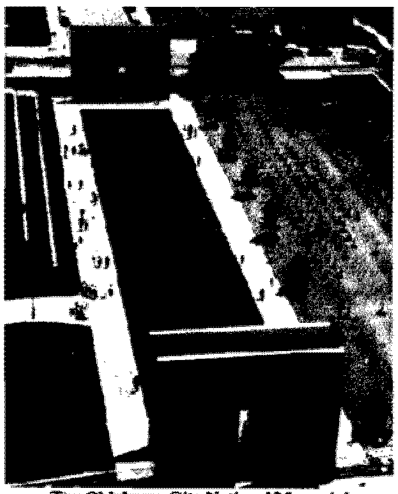
The Federal Building was demolished on May 23, 1995.

But the resilience, hope, love, and indomitable spirit of the wonderful people of Oklahoma has been an inspiration to the entire world.

The spectacular, beautiful, honorable, and inspirational Oklahoma City National Memorial was established on October 9, 1997, at the site of the Federal Building (see below).

God bless the people of Oklahoma.

And God bless America



The Oklahoma City National Memorial

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MILITARY

Explosives - Injuries

Bombs and explosions can cause unique patterns of injury seldom seen outside combat. The predominant post explosion injuries among survivors involve standard penetrating and blunt trauma. Blast lung is the most common fatal injury among initial survivors. Explosions in confined spaces (mines, buildings, or large vehicles) and/or structural collapse are associated with greater morbidity and mortality. Half of all initial casualties will seek medical care over a one-hour period. This can be useful to predict demand for care and resource needs. Care providers expect an "upside-down" triage - the most severely injured arrive after the less injured, who bypass EMS triage and go directly to the closest hospitals.

- Explosives
- Explosives - Primary
- Explosives - Booster
- Explosives - Nitroaromatics
- Explosives - Nitramines
- Explosives - Nitrate esters
- Explosives - Compositions
- Explosives - ANFO
- Explosives - Mining Types
- Explosives - Mining Industries
- Liquid Explosive Compositions
- Novel Energetic Materials
- Insensitive Explosives
- Insensitive Munitions (IM)
- Dense Inert Metal Explosive (DIME)
- Triacetone Triperoxide (TATP)
- Explosives - Injuries
- Explosives - Classes
- Explosives - ATF List
- Explosives - UN List
- Explosives & the Environment

Background

Explosions can produce unique patterns of injury seldom seen outside combat. When they do occur, they have the potential to inflict multi-system life-threatening injuries on many persons simultaneously. The injury patterns following such events are a product of the composition and amount of the materials involved, the surrounding environment, delivery method (if a bomb), the distance between the victim and the blast, and any intervening protective barriers or environmental hazards. Because explosions are relatively infrequent, blast-related injuries can present unique triage, diagnostic, and management challenges to providers of emergency care.

Few U.S. health professionals have experience with explosive-related injuries. Vietnam era physicians are retiring, other armed conflicts have been short-lived, and until this past decade, the U.S. was largely spared of the scourge of mega-terrorist attacks. This primer introduces information relevant to the care of casualties from explosives and blast injuries.

Classification of Explosives

Explosives are categorized as high-order explosives (HE) or low-order explosives (LE). HE produce a defining supersonic over-pressurization shock wave. Examples of HE include TNT, C-4, Semtex, nitroglycerin, dynamite, and ammonium nitrate fuel oil (ANFO). LE create a subsonic explosion and lack HE's over-pressurization wave. Examples of LE include pipe bombs, gunpowder, and most pure petroleum-based bombs such as Molotov cocktails or aircraft improvised as guided missiles. HE and LE cause different injury patterns.

Explosive and incendiary (fire) bombs are further characterized based on their source. "Manufactured" implies standard military-issued, mass produced, and quality-tested weapons. "Improvised" describes weapons produced in small quantities, or use of a device outside its intended purpose, such as converting a commercial aircraft into a guided missile. Manufactured (military) explosive weapons are exclusively HE-based. Terrorists will use whatever is available – illegally obtained manufactured weapons or improvised explosive devices (also known as "IEDs") that may be composed of HE, LE, or both. Manufactured and improvised bombs cause markedly different injuries.

Blast Injuries

The four basic mechanisms of blast injury are termed as primary, secondary, tertiary, and quaternary (Table 1). "Blast Wave" (primary) refers to the intense over-pressurization impulse created by a detonated HE. Blast injuries are characterized by anatomical and physiological changes from the direct or reflective over-pressurization force impacting the body's surface. The HE "blast wave" (over-pressure component) should be distinguished from "blast wind" (forced super-heated air flow). The latter may be encountered with both HE and LE.

Table 1: Mechanisms of Blast Injury

Category	Characteristics	Body Part Affected	Types of Injuries
Primary	Unique to HE, results from the impact of the over-pressurization wave with body surfaces.	Gas filled structures are most susceptible - lungs, GI tract, and middle ear.	Blast lung (pulmonary barotrauma) TM rupture and middle ear damage Abdominal hemorrhage and perforation - Globe (eye) rupture- Concussion (TBI without physical signs of head injury)
Secondary	Results from flying debris and bomb fragments.	Any body part may be affected.	Penetrating ballistic (fragmentation) or blunt injuries Eye penetration (can be occult)
Tertiary	Results from individuals being thrown by the blast wind.	Any body part may be affected.	Fracture and traumatic amputation Closed and open brain injury
Quaternary	All explosion-related injuries, illnesses, or diseases not due to primary, secondary, or tertiary mechanisms. Includes exacerbation or complications of existing conditions.	Any body part may be affected.	Burns (flash, partial, and full thickness) Crush injuries Closed and open brain injury Asthma, COPD, or other breathing problems from dust, smoke, or toxic fumes Angina Hyperglycemia, hypertension

LE are classified differently because they lack the self-defining HE over-pressurization wave. LE's mechanisms of injuries are characterized as due from ballistics (fragmentation), blast wind (not blast wave), and thermal. There is some overlap between LE descriptive mechanisms and HE's Secondary, Tertiary, and Quaternary mechanisms.

Table 2: Overview of Explosive-Related Injuries

System	Injury or Condition

* FBI; pg. 3

Explosives - ANFO (Ammonium Nitrate - Fuel Oil)

- Explosives
- Explosives - Primary
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Ammonium nitrate-fuel oil (ANFO) blasting agents represent the largest industrial explosive manufactured (in terms of quantity) in the United States. This product is used primarily in mining and quarrying operations. The components are generally mixed at or near the point of use for safety reasons. The mixed product is relatively safe and easily handled and can be poured into drill holes in the mass or object to be blasted.

Melvin A. Cook's life is intimately connected with the history of explosives, he is a scientist,, inventor, teacher, businessman, theorist, consultant, expert witness, entrepreneur, and author. Cook, a professor of metallurgy at the University of Utah, was a businessman and author of works on explosives. He also published works on creationism, particularly on the relationship between science and Mormonism. Cook's personal involvement in both the theoretical and practical aspects of the field of explosives spans more than fifty years.

Cook's greatest commercial explosives invention was formulated in December of 1956, when he created a new blasting agent using an unusual mixture of ammonium nitrate, aluminum powder, and water. The safety and efficiency of this new explosive were apparent, and the use of water was revolutionary. Tests that followed resulted in the development of a new field of explosives: slurry explosives. This invention converted the commercial explosives industry from "dangerous dynamite" to "safe slurry" and dry blasting agents [ANFO]. In 1972 Cook developed the BLU-82, the largest and most powerful chemical bomb, using aluminized slurry.

Blasting agents consist of mixtures of fuels and oxidizers, none of which are classified as explosive. Nitrocarbonitrate is a classification given to a blasting agent under the US Department of Transportation regulations on packaging and shipping. A blasting agent consists of inorganic nitrates and carbonaceous fuels and may contain additional nonexplosive substances such as powdered aluminum or ferrosilicon to increase density. The addition of an explosive ingredient such as TNT changes the classification from a blasting agent to an explosive. Blasting agents may be dry or in slurry forms. Because of their insensitivity, blasting agents should be detonated by a primer of high explosive.

Ammonium nitrate- fuel oil has largely replaced dynamites and gelatins in bench blasting. Denser slurry blasting agents are supplanting dynamite and gelatin and dry blasting agents. The most widely used dry blasting agent is a mixture of ammonium nitrate prills (porous grains) and fuel oil. The fuel oil is not precisely CH2, but this is sufficiently accurate to characterize the reaction. The right side of the equation contains only the desirable gases of detonation, although some CO and N02 are always formed. Weight proportions of ingredients for the equation are 94.5 percent ammonium nitrate and 5.5 percent fuel oil. In actual practice the proportions are 94 percent and 6 percent to assure an efficient chemical reaction of the nitrate.

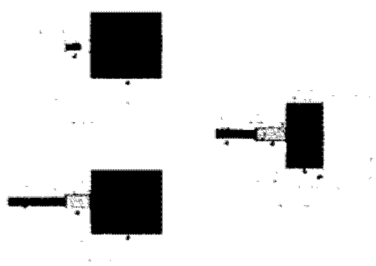
Uniform mixing of oil and ammonium nitrate is essential to development of full explosive force. Some blasting agents are premixed and packaged by the manufacturer. Where not premixed, several methods of mixing in the field can be employed to achieve uniformity. The best method, although not always the most practical one, is by mechanical tier. A more common and almost as effective method of mixing is by uniformly soaking prills in opened bags with 8 to 1O percent of their weight of oil. After draining for at least a half hour the prills will have retained about the correct amount of fuel oil.

Fuel oil can also be poured onto the ammonium nitrate in approximately the correct proportions as it is poured into the blasthole. For this purpose, about i gal of fuel oil for each 100 lb of ammonium nitrate will equal approximately 6 percent by weight of oil. The oil can be added after each bag or two of prills, and it will disperse relatively rapidly and uniformly. Inadequate priming imparts a low initial detonation velocity to a blasting agent, and the reaction may die out and cause a misfire. High explosive boosters are sometimes spaced along the borehole to as sure propagation throughout the column.

As in other combustion reactions, a deficiency of oxygen favors the formation of carbon monoxide and unburned organic compounds and produces little, if any, nitrogen oxides. An excess of oxygen causes more nitrogen oxides and less carbon monoxide and other unburned organics. For ammonium nitrate and fuel oil (ANFO) mixtures, a fuel oil content of more than 5.5 percent creates a deficiency of oxygen.

Ammonium nitrate and fuel oil (ANFO) has a broad spectrum of Velocities of Detonation according to numerous references. However, some of these references are more specific when establishing parameters. A military catering charge lists a VOD of 10,700 feet per second (fps). A 4" diameter steel tube confinement is at 10,000 fps, while a 16" diameter tube is at 16,000 fps. In charge diameters of 6 in. or more, dry blasting agents attain confined detonation velocities of more than i2,000 fps, but in a diameter of 1- 1/2 in., the velocity is reduced to 60 percent. When ANFO is used in boreholeing, the VOD has a positive slope as a function of depth, the VOD increases as the detonation front progresses down the borehole. Enhanced effects of very large quantities, which is essentially self tamping, the VOD is expected to be in the 13,000-15,000 fps range. A ballpark approximation for very large quantities of blasting agents, which is accepted in the commercial industry, is roughly half the VOD of C-4/plastics, which equates to 13,000 fps. The recognized VOD of urea nitrate, however, is 11,155 to 15,420 fps.

The specific gravity of ANFO varies from 0.75 to 0.95 depending on the particle density and sizes. Confined detonation velocity and charge concentration of ANFO vary with borehole diameter. Pneumatic loading results in high detonation velocities and higher charge concentrations, particularly in holes smaller than 3 in. (otherwise such small holes are not usually recommended for ANFO blasting).



The simple removal of a tree stump might be done with a 2-step train made up of an electric blasting cap and a stick of dynamite. The detonation wave from the blasting cap would cause detonation of the dynamite. To make a large hole in the earth, an inexpensive explosive such as ANFO might be used. In this case, the detonation wave from the blasting cap is not powerful enough to cause detonation, so a booster must be used in a 3- or 4-step train. The yield from the blasting caps and safety fuses used in these trains are usually small compared to those from the main charge, because the yields are roughly proportional to the weight of explosive used, and the main charge makes up most of the total weight.

Advantages of insensitive dry blasting agents are their safety, ease of loading, and low price. In the free-flowing form, they have a great advantage over cartridge explosives because they completely fill the borehole. This direct coupling to the walls assures efficient use of explosive energy. Ammonium nitrate is water soluble so that in wet holes, some blasters pump the water from the hole, insert a plastic sleeve, and load the blasting agent into the sleeve. Special precautions should be taken to avoid a possible building up of static electrical charge, particularly when loading pneumatically. When properly oxygen- balanced, the fume qualities of dry blasting agents permit their use underground. Canned blasting agents, once widely used, have unlimited water resist-ance, but lack advantages of loading ease and direct coupling to the borehole.

In 2001, US explosives production was 2.38 million metric tons (Mt), 7% less than that in 2000; sales of explosives were reported in all States. Coal mining, with 69% of total consumption, continued to be the dominant use for explosives in the United States. Kentucky, West Virginia, Indiana, Wyoming, and Virginia, in descending order, were the largest consuming States, with a combined total of 46% of US sales.

After completing an investigation into dumping of ammonium nitrate from Ukraine that was begun in 2000, the US International Trade Commission (ITC) issued its final determination in August 2001. The ITC determined that imports of ammonium nitrate from Ukraine were sold in the United States at less than fair market value and that critical circumstances did not exist with regard to these imports. As a result of the negative determination regarding critical circumstances, the duties were not retroactive and only apply to ammonium nitrate that has been imported since March 5, 2001. The antidumping duty of 156.29% ad valorem that was finalized by the International Trade Administration in July 2001 was applied.

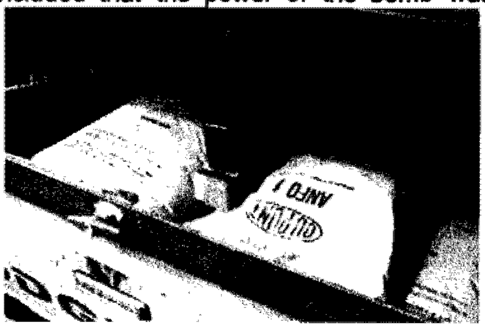
Sales of ammonium-nitrate-based explosives (blasting agents and oxidizers) were 2.34 Mt in 2001, which was an 8% decrease from that of 2000, and accounted for 98% of US industrial explosives sales. Sales of permissibles and other high explosives increased slightly. Data for 2001 are not exactly comparable to the 2000 data. One company, Nelson Brothers LLC, did not provide data to the Institute of Makers of Explosives (IME) in 2001, and no estimate for its sales was included in the totals.

By 2001 engineers in the Fuels and Lubricants Group of Shell Co. of Australia developed a technique to blend waste oil with ANFO for a product that can be used in blasting. Mines throughout the world produce thousands of liters of waste fuel oil that needs to be disposed of in an environmentally safe manner. By using the fuel oil in a blasting compound, transporting the waste oil is eliminated, the quantity of fuel oil needed for blasting is reduced, and potentially toxic hydrocarbons in waste oil can be destroyed by the high blast temperature. Shell tested the ANFO-waste oil blend at Hamersley Iron's Marandoo mine site, and found that the ratio of waste oil to ANFO blend could be as much as 50-50 without any detrimental effect to the final blasting performance.

Urea nitrate is also considered a type of fertilizer-based explosive, although, in this case, the two constituents are nitric acid (one of the ten most produced chemicals in the world) and urea. A common source of urea is the prill used for de-icing sidewalks. Urea can also be derived from concentrated urine. This is a common variation used in South America and the Middle East by terrorists. Often, sulfuric acid is added to assist with catalyzing the constituents. A bucket containing the urea is used surrounded by an ice bath. The ice serves in assisting with the chemical conversion when the nitric acid is added. The resulting explosive can be blasting cap sensitive. Urea nitrate has a destructive power similar to ammonium nitrate.

By one estimate, the bomb used to attack the Alfred Murrah Federal Building in Oklahoma City on April 19, 1995 consisted of an ANFO explosive main charge of approximately 4,000 pounds, based on an estimate of the Velocities of Detonation [VOD] of approximately 13,000 fps. Other estimates claim that the 1995 explosion that collapsed portions of the Murrah Federal Building in Oklahoma City contained 4,800 pounds of ammonium nitrate and fuel oil. Later estimates suggested that the bomb had in excess of 6,200 pounds of various energetic materials, including explosives other than ANFO, equivalent to 5,000 pounds of TNT. In the Salameh World Trade Center bombing case resulting from the bombing of the World Trade Center (WTC) on February 26, 1993, FBI Explosives Unit examiner David Williams opined that the main explosive used in the bombing consisted of 1,200 pounds of urea nitrate explosive. The FBI chemists specializing in the examination of explosive residue, however, did not find any residue identifying the explosive at the World Trade Center.

Not all large truck bombs have used ANFO. On June 25, 1996, Saudi terrorists sponsored by Iran attacked the Khobar Towers barracks, a high-rise building complex in a densely populated urban environment in Saudi Arabia. T tanker truck loaded with at least 5,000 pounds of plastic explosives was driven into the parking lot in front of the Khobar Towers residential complex in Dhahran. Nineteen American service members were killed in the blast, and hundreds of other service members and Saudis were injured. There is no doubt that the extent of the casualties at Khobar Towers resulted, in part, from the extraordinary size of the terrorist bomb. Reports initially estimated that the bomb contained the equivalent of 3,000 to 8,000 pounds of TNT, but a study by the Defense Special Weapons Agency concluded that the power of the bomb was actually closer to 20,000 pounds of TNT.



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Oklahoma City Bombing.com
OCBombing.com

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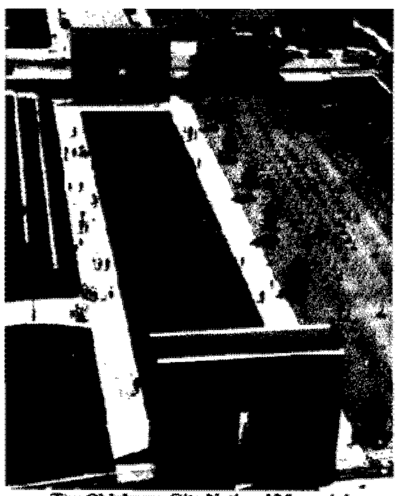

The Oklahoma City National Memorial

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WPQ Undertaking 56
Don Mullin

RECEIVED
JUN 28 2007

Here is everything I could dig up. The following is a collection of court cases and news articles pertaining to the Clayton Company, Amboy Aggregates, and Great Lakes Dredge and Dock. I have organized everything first by corporation involved, and then by date.

The Clayton Company
Started by William Clayton, supplying concrete to the developers of Ocean County, New Jersey.
Company services New York, Philidelphia, but mainly New Jersey.

Group of companies:

Ralph Clayton and Sons

provides ready-mix concrete for highway, residential and commercial.

Clayton Block

architectural and specialty blocks of concrete

Clayton Sand

sand supplier

From their website:
"Several years ago the company responded to the growing enviromental and industry demands to dispose of old concrete and masonry products in a safe and commercially viable fashion. The result has been the successful operation of Clayton recycling plants which produce an end product that meets with the approval of numerous government agencies."

Blatterfein v. Larken Assocs
A-7370-97T3F , SUPERIOR COURT OF NEW JERSEY, APPELLATE DIVISION , 323 N.J. Super. 167; 732 A.2d 555; 1999 N.J. Super. LEXIS 262, December 1, 1998, Argued, July 15, **1999**, Decided, Approved for Publication July 15, 1999.

Plaintiffs were families who purchased homes from Larken (an architecht). The homes had serious structural flaws. Clayton Block was named as a co-defendant, along with all other contractors involved in the building of the homes. My assumption is that they supplied the concrete.

In re N.J. Dep't of Envtl. Prot., Div. of Coastal Res. Regulation, N.J.A.C. 7:7-2.1(b)1.iii, No. A-2460-85T7 , Superior Court of New Jersey, Appellate Division , 214 N.J. Super. 579; 520 A.2d 794; 1987 N.J. Super. LEXIS 1011, December 10, 1986, Argued, January 12, 1987, Decided, Approved for Publication February 3, **1987**

Ralph Clayton Jr. wanted to gain approval for a shopping centre in coastal zone with a parking lot of a size greater than three acres. The Coastal Area Facility Review Act limits the size of "highways" and "roads" in "public spaces", and Clayton tried to argue that the Act should not apply to shopping centre parking lots. The court ruled against him.

Amboy Aggregates Inc.
I had a difficult time finding actual jurispudence involving Amboy. I did, however, find some news articles concerning their practices:

http://www.injersey.com/day/story/1,2379,1o5643,00.html
Mines sand from the bottom of the ocean in New Jersey
"Located in the outskirts of South Amboy, the company has had run-ins with residents since it opened in 1984. Neighbors, organizing themselves as Resident Opposition for a Safe Environment, protested noise and dust they contended came from the site. The sight of 45-foot-high piles of sand was an eyesore, some residents said, and their homes and cars were covered with sand."

http://www.gsenet.org/library/11gsn/2000/gs00303b.php Garden State EnviroNet:
Has a bullitin from March 3, 2000 about Abboy Aggregates seeking a lease sale to mine sand. Citizens were shut out of the meeting by labour interests arriving early. Did not allow formal statements, only one point comments, at the public hearing.
Project would remove millions of tons of offshore habitat

Amboy Aggregates v. Mayor and Council of the City of South Amboy, et al., Docket No. MID-L-7998-03

Amboy are challenging the designation of the commercial property they own as an area in need of redevelopment under the Local Redevelopment and Housing Law, which challenge also touched upon the port use rules under the Coastal Zone Management regulations. I cannot find the result of this decision

http://www.knowviews.com/node/1094
South Amboy v. Amboy Aggregates which is currently making its way from the Middlesex County Court to the appeals courts in NJ. Essentially, the City of South Amboy wants to take Aggregates property to develop as waterfront properties just across the water from Staten Island. Nice views of the Verzzano Narrows Bridge, I must say. Anyhow, Aggregates is a sand company. Yep, they dredge sand off the bottom of the ocean off Sandy Hook, NJ. The irony of this case is that in order to get sand for the construction project, they contractors would normally have bought their sand for cement from Aggregates. Now they will have to pay a premium for sand trucked from South Jersey. The argument in court was: Sand Piles are ugly. Apartments are not ugly. Aggregates site is blighted. Middlesex County can take it.

http://www.allbusiness.com/north-america/united-states-new-jersey/915390-1.html=

"Richard Rosamilia, president of Amboy Aggregates, says the company wants the undersea mining rights because the Ambrose Channel sand quality is declining. That adversely affects his company's sales, which have taken a downturn from $15 million in 1999. Presently, all the company's sand comes from Ambrose Channel.

He says Northern New Jersey doesn't have suitable sand and, due to Pinelands Preservation Commission restrictions, no new licenses are being authorized to quarry sand from much of Central New Jersey."

Great Lakes Dredge and Dock Corp.
owns half of Amboy Aggregates

Barker Marine Ltd. v. Great Lakes Dredge & Dock Co., Nos. 00-9170(L), 00-9289(C), UNITED STATES COURT OF APPEALS FOR THE SECOND CIRCUIT, 8 Fed. Appx. 137; 2001 U.S. App. LEXIS 10502, May 17, **2001**, Decided

Barker Marine successfully sued Great Lakes Dredge and Dock Company and Ralph Clayton & Sons Materials, LP, d/b/a Amboy Aggregates Joint Venture T/A McCormack Aggregates for breach of a towage agreement
Appeals court.

United States v. Great Lakes Dredge & Dock Co.,
UNITED STATES DISTRICT COURT FOR THE SOUTHERN DISTRICT OF FLORIDA, SOUTHERN DIVISION, 1999 U.S. Dist. LEXIS 17612, September 27, 1999, Decided, September 27, **1999**, Filed

This cause came before the court on claims by plaintiff, United States of America, against defendants for damage caused by a grounded tugboat and dredge pipe to the **Florida Keys National Marine Sanctuary**. Plaintiffs sought damage and response costs pursuant to the National Marine Sanctuaries Act (NMSA), 16 U.S.C.S. §§ 1431, et seq. The court found that NMSA was a remedial statute, therefore defendant was strictly liable under NMSA for damage to the sanctuary because defendant held ultimate control over the other defendant. The court entered a judgment in favor of plaintiff against defendant for damages and found that plaintiff was entitled to compensation for the cost of physical and biological monitoring of the site. Plaintiff was also entitled to recover its response and assessment costs.

This decision was affirmed on appeal.
No. 00-12002., UNITED STATES COURT OF APPEALS FOR THE ELEVENTH CIRCUIT, 259 F.3d 1300; 2001 U.S. App. LEXIS 16955; 53 ERC (BNA) 1250; 31 ELR 20880; 14 Fla. L. Weekly Fed. C 1058, July 30, 2001, Decided, **July 30, 2001**, Filed, Certiorari Denied March 25, 2002, Reported at: 2002 U.S. LEXIS 1961.

Great Lakes v. The City of Chicago
No. 93-1421, UNITED STATES COURT OF APPEALS FOR THE SEVENTH CIRCUIT, 3 F.3d 225; 1993 U.S. App. LEXIS 21586; 1993 AMC 2409, April 26, 1993, Argued, August 24, 1993, Decided, Petition for Rehearing with Suggestion for Rehearing En Banc Denied October 7, 1993, Reported at: **1993** U.S. App. LEXIS 26477

A breach occurred in the roof of a freight tunnel running beneath the river, which disrupted business in defendant city's downtown district and maritime traffic. Chicago contended that Great Lakes negligently installed pile clusters at five bridge sites along the Chicago River.
Great Lakes ended up settling, by assigning it's insurance rights to the city.
Described in another case. "The dredging company damaged a tunnel, which eventually flooded a city."

Gerrie v. Great Lakes Dredge & Dock Co.,
91 C 7909, UNITED STATES DISTRICT COURT FOR THE NORTHERN DISTRICT OF ILLINOIS, EASTERN DIVISION, 1993 U.S. Dist. LEXIS 8576, June 23, 1993, Decided, June 24, **1993**, Docketed

Gerrie was fired by Great Lakes and alleged that it was because of her age (too old). The court found in her favour, but denied that Great Lakes inflicted undue emotional distress.

NOTE** I found four other cases of alleged race/age discrimination by former employees, but all were dismissed.

Complaint of Chevron Transport Corp.
Case Nos. 75-114-Civ-J-M, 75-126-Civ-J-M, 77-635-Civ-J-M, UNITED STATES DISTRICT COURT FOR THE MIDDLE DISTRICT OF FLORIDA, JACKSONVILLE DIVISION, 613 F. Supp. 1428; **1985** U.S. Dist. LEXIS 17688, July 19, 1985, Decided, July 15, 1985, Filed

Wrongful death suit. An employee was killed on the job, working for Great Lakes. Great Lakes was found to be negligent, and therefore, partially liable.

Lydon Dredging & Construction Co. v. Canada (Minister of the Department of Public Works) – Lydon is subsidiary of Great Lakes Dredge. Sued Government for payment on a dredging operation.
[**1984**] F.C.J. No. 347

Save Our Sound Fisheries Asso. v. Callaway,
Civil Action No. 5297, UNITED STATES DISTRICT COURT FOR THE DISTRICT OF RHODE ISLAND, 387 F. Supp. 292; 1974 U.S. Dist. LEXIS 12001; 7 ERC (BNA) 1445; 4 ELR 20437, March 5, **1974**

Great Lakes Dredge and Dock was joined as a defendant with Callaway and the Chief of Engineers in the U.S. Army. They were sued by the environmental organization for failing to obtain the proper permits to dump dredged spoil at an ocean dumping site. The court found in the favour of Save our Sound Fisheries, and stopped Great Lakes from dumping until they obtain the proper permits. The main defendant was the military, and I supposed that Great Lakes was contracted to do the actual work, and as such, were named along with the military in the suit.

Walling v. Great Lakes Dredge & Dock Co.,
No. 8648, UNITED STATES CIRCUIT COURT OF APPEALS, SEVENTH CIRCUIT, 149 F.2d 9; 1945 U.S. App. LEXIS 3381; 9 Lab. Cas. (CCH) P62,609. April 24, **1945**

Great Lakes attempted to classify thier employees on a barge as "seamen", to avoid a proper wage requirement included in The Fair Labor Standards Act. The court found that they could not do this, and were required to pay their employees the proper amount.

CANADA S. S. LINES, Limited, v. GREAT LAKES DREDGE & DOCK CO.
No. 5414, Circuit Court of Appeals, Seventh Circuit, 81 F.2d 100; 1935 U.S. App. LEXIS 3960, December 31, **1935**
- charged with libel, but suit is dismissed.

Note: Florida Rock Industries, or whatever current name it is operating under, is involved in the Bayshore quarry in New Brunswick and operates in partnership with New York Sand and Stone and is thereby linked with Amboy and Clayton. It was not included in this examination of case law.

Whites Point Quarry Undertaking

Estimated GDP Per Person Year of Employment in Nova Scotia Primary Resource Sectors 2004

Primary Industry	GDP[1] (000,000)	Employment (Person Years)	GDP/Person Year
Mineral industry	$232.0	1,350[2]	$171,852
Fishery	$319.0	7,500[3]	$42,535
Agriculture	$196.0	5,500[4]	$35,635
Forestry	$176.0	4,300[5]	$40,930

(1) Estimates of GDP derived by Gardner Pinfold using data from the Nova Scotia Statistical Review. GDP for mining industry derived by Gardner Pinfold as part of an Economic Impact Study of the industry completed for the Department of Natural Resources in 2005.

(2) Estimated by Gardner Pinfold as part of an Economic Impact Study of the industry completed for the Department of Natural Resources in 2005.

(3) Derived by Gardner Pinfold as part of a study titled "Economic Value of the Nova Scotia Oceans Sector" prepared for the Office of Economic Development.

(4) Taken from Nova Scotia Statistical Review published by Department of Finance.

(5) Taken from "The Economic Impact of the Nova Scotia Forest Industry" prepared by the Atlantic Provinces Economic Council, 2005.

Climate and Blasting – Assigned number not yet received by Bilcon

June 20- 2007

In response to the Panel's question with respect to the effect of climatic conditions on blasting, we would refer the Panel to the following IR Response:

9.1.9 Noise and Vibration – Blasting

The text on pg 67 and pg 68 cites an example of blasting effects under specific parameters using a considerable amount of jargon. Clarify the meaning of this paragraph and explain the relevance of this example to the blasting proposed for the operation.

The EIS states that no blasting will be permitted if there is a thermal atmospheric inversion or low cloud cover or fog conditions. These criteria are highly subjective. Provide numerical criteria and describe the manner in which they will be implemented.

RESPONSE

This paragraph presents an example of blast monitoring results from a comparable quarry and a predictive model for a specific blast proposed at the Whites Point Quarry.

The monitoring results for a production blast at the comparable quarry indicate the NSDEL thresholds for concussion (128 dBA) and ground vibration (12.5 mm/sec) were met at the given distances for the given blast design. It should be noted that the weight of explosives in this case was 214 kg per delay.

Also, a predictive model was used to illustrate ground vibration for an initial blast proposed at the Whites Point site. The nearest structure from the location of this initial blast is approximately 1120 m. Using a 45 kg weight of explosive per delay, a ground vibration of 1 mm/sec is predicted at the nearest structure. This is well within the threshold contained in the NSDEL "Pit and Quarry Guidelines" of 12.5 mm/sec.

The cooling of the air by the Bay of Fundy waters can create a thermal inversion. Since the water temperature in the Fundy area ranges from 1 – 6 degrees Celsius in the winter and up to 12 – 15 degrees Celsius in summer, and the predominate air flow is from the southwest to south-southwest, where air temperatures are generally above these levels in the respective seasons, there is a likelihood of thermal inversion over the Fundy coast of Nova Scotia in winter, spring, and early summer. The general occurrence of significant marine inversions is probably in the range of 15 – 25% of the time for the period January through June and less than 5% for the remainder of the year (*pers. com.* Mac MacLeod, Scotia Weather Services Inc. 2006). Marine thermal inversions are easily forecast with relative reliability as the atmospheric models handle the ground thermal structure quite well and the water temperature changes slowly so the cooling of the air near the water surface is easy to calculate and the general low level wind flow will determine if the thermal inversion will occur over the coastal area under forecast.

Research concerning blasting/thermal inversions did not reveal any published thresholds or numeric criteria to indicate when blasting should or should not be undertaken. Communications with the NSDEL, the regulatory agency for blasting activities in Nova Scotia, indicated "there are no numerical criteria existing with respect to thermal inversions" (*pers. com.* D. Bruce Arthur, P. Eng. NSDEL).

Further, according to representatives of the blasting industry and NSDEL, it is standard industry practice for blasters to communicate with the Weather Service before initiating a blast (*pers. com.* D. Morehouse, Dyno Nobel North America and D. Bruce Arthur, P. Eng. NSDEL). Regarding inversions, Bilcon intends to follow existing industry and regulatory procedures during its blasting activities. Also, Bilcon is committed to conducting blasting activities (construction and production) within the thresholds established by the NSDEL's "Pit and Quarry Guidelines" and DFO's "Guidelines for the Use of Explosives in or Near Canadian Fisheries Waters".

In summary, Bilcon will conduct blasting in accordance with NSDEL's "Pit and Quarry Guidelines" paragraph VIII Blasting (6). Blasting will not be conducted if a thermal inversion is forecast. The presence of a thermal inversion will be determined in consultation with the Environment Canada Weather service (1-900-565-5555). Cloud cover (ceiling) and visibility information, as applicable, will also be obtained from the Weather Service. This information will be verified on-site by a Certified Blaster before a blast is initiated. Blasting will generally be conducted between the hours of 1100 and 1600 hours. Information on weather conditions including ceiling, temperature, and wind speed and direction will be recorded for each blast on the Blast Report.

Addendum – June 20, 2007

Blasting/Visibility-ceiling

Environmnent Canada has provided analysis of hourly cloud ceiling and visibility data for Yarmouth for the period 1953-2007. This analysis uses the duration of Instrument Flight Rule (IFR) episodes at Yarmouth. As indicated by Environment Canada, Bilcon will use the following thresholds when deciding whether to allow a blast to proceed:

Visibility greater than ½ mile (805m) and /or ceiling greater than 1000 feet (305m).

Reference: Whites Point Quarry and Marine Terminal Project – Environment Canada's Written Submission to the Joint Review Panel June 15, 2007