Background Briefing Paper
for a Workshop on

Seismic Survey Operations: Impacts on Fish, Fisheries, Fishers and Aquaculture

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Introduction

This briefing paper seeks to answer some of the basic questions about seismic survey operations in the offshore environment and their impacts on fish, fisheries, fishers and other industry employees (such as divers) and aquaculture. It draws upon recent research reports and findings from Canada and other nations, most notably Norway, the U.S., the United Kingdom and Australia. Seismic testing takes place in all oil-bearing regions of the world. Different approaches to planning and conduct of surveys and to mitigation and monitoring of impacts have been used in different settings, although many elements of the approaches are common to most areas.

Presenters at the February 17, 2004 BCSA workshop will provide additional up-to-date information related to the subject matter of this report, including current research findings dealing with impacts on specific species. Additional pertinent current information may be found in the report of the Royal Society of Canada's Expert Panel to Facilitate Science Workshops for the Review of the BC Offshore Oil and Gas Moratorium. It is anticipated that this report will be released on the Royal Society Web site www.rsc.ca on Monday, February 16th. Material from that report will be provided to attendees at the BCSA February 17th workshop.

A detailed Web link and print bibliography is provided at the end of this briefing paper for those who wish to explore the subject in greater depth.

When and why is seismic testing done?

Seismic testing is an essential step in the exploration for oil and gas. It precedes the drilling, production, depletion and decommissioning phases. It seeks to identify precisely the character of prospective oil-bearing strata of the earth, deep below the ocean's bottom, so that the location of oil-bearing sediments can be pinpointed. Reservoirs can then be mapped accurately and drilling targets clearly established, even thousands of feet below the surface. Detailed seismic re-surveys may also take place if a reservoir is discovered during the drilling and production phases of a project.

In British Columbia, it is likely that a seismic operator would wish to conduct seismic surveys between June and October, in order to take advantage of better weather and to ensure minimal background (ambient) acoustic noise such as that developed by storms. This could create conflicts for fish and fisheries, since it would coincide with the migration of juvenile salmon and the larval stage of many shellfish species, herring and a number of other forage fish. (Allen Wood 2002).

How is seismic testing done?

Seismic survey work is done by equipment attached to specially-designed ships. These ships, usually 60-90 metres long, contain fully-equipped geophysical laboratories, and have communications equipment that makes possible global and constant connections. The data from a survey is usually analyzed for many months after it is collected.

The ships tow arrays of airguns, which are piston assemblies that discharge compressed air - and hydrophone assemblies (which record the sound waves as they bounce back from the sea bottom and the underlying rock layers.) The hydrophone streamers or cables trail the vessel for up to 10,000 metres, at depths of between 6 and 8 meters. Depending on the type of survey, there may be one or as many as 12 cables, spaced 100 metres or less apart. The total width of cable spread can be 800 metres. The hydrophones on each cable are spaced less than 1 meter apart. Devices on the cables keep them at a constant depth.

The ships move through the water at speeds usually in the range of 4.5 – 5.5 knots, or 10 km/hour. They try to maintain a constant speed, to insure high quality of recorded images. The airguns, usually towed in arrays of 10 to 30 guns or more at a distance of 6 metres below the surface, send downward directed acoustic bursts of sound into the rock layers below the sea bottom. These sound waves are recorded as they bounce back from the rock layers by to the streamers towed behind the ship in the water, and are used to create an image of the earth's crust. The system has been described as "a large echo sounder."

Survey operations in a given location can take place over a period of one or two months, or, as in the case of the recent small Cape Breton survey, over a period of a few weeks. It is common for survey vessels to operate 24 hours a day.

The most common types of surveys are two-dimensional or 2-D or three-dimensional (3-D), depending on the detail of the information (the image) that is required. A 2-D survey uses a single streamer or cable towed behind the survey vessel, while a 3-D survey uses several, as described above. Typically 2-D surveys are used to collect information about a broad area, while 3-D surveys focus on a relatively small area of interest (perhaps only several km wide) in a tight grid pattern. In British Columbia, it is likely that initial surveys would be two-dimensional (2-D), to fill in holes and gaps in existing data. For a brief history of seismic surveys in BC waters, see below. 3-D surveys might be used in some instances, where existing data is regarded as good.

A seismic ship travels on a pre-determined path or route, often quite large in area in the case of a 2-D survey. The fact that there is a pre-defined path helps with the definition of authorized routes of fishing vessels in the area, so that conflict can be avoided. The large size of the ship and related equipment and the need to maintain constant speed for best sound wave readings, mean that it is both difficult and undesirable to stop the ship quickly or to change its direction. As one fisheries consultant remarked: “you’ve got essentially an immovable object that’s three miles long, and it has a turning radius of about three or four miles as well.” However, in Atlantic Canada, seismic ships will break off a survey line if fishing gear is in their path.

The airgun arrays are towed approximately 50 meters behind the vessel. The sound bursts - at decibel levels in the 200-250 range at source– are repeated every 6 to 10 seconds. Each has a duration of 10 to 30 milliseconds. The (mostly) downward pressure pulse of the sound waves has a frequency between 10 and 300 Hz. The decibel level attenuates (weakens) as the sound wave travels outward and downward, the rate and amount of weakening affected by a number of variables unique to each case. These include local geography and geology, consistency of water depth, tides and temperature and salinity gradients.

For an illustration of a 3-D seismic survey operation, see:
http://www.pcf.ca/pdf/MarineSeismic.pdf

Will the presence of these seismic vessels and seismic activity create local jobs?

If experience in other geographic areas is a guide, local jobs will be primarily of a support and service nature – as, for example, provisioning, servicing and fueling the vessels. The seismic vessels are specialized ships, with specially trained crews that usually stay with the ship from assignment to assignment. Some short-term jobs may also be created for local fishing industry representatives, to deal with industry liaison and monitoring. In Atlantic Canada, two companies now have locally-registered ships with locally-registered crews.

Have seismic surveys been conducted in BC waters in the past?

A number of seismic surveys have taken place in BC waters since the 1960s. Most of them used 2-D configurations. (See the following section for description of technological developments.) To cite a few of the earlier survey efforts - between 1963 and 1967, Shell Canada conducted tens of thousands of line kilometers of 2-D surveys in Hecate Strait, Queen Charlotte Sound and Tofino Basin; Chevron surveyed tens of thousands of line kilometers (2-D) in Hecate Strait in 1971-72; and the Geological Survey of Canada surveyed 1000 kilometers (2-D) in Hecate Strait in 1988 and 1500 kilometers in the Strait of Georgia (2-D) in 1998.

How has the technology of seismic testing changed in recent years?

Seismic technology has become more sophisticated and analytically powerful in recent years, largely as a result of improved computer processing abilities. It has progressed from so-called two-dimensional (2-D) surveys to 3-D, and more recently to 4-D, which is used (relatively rarely) over producing pools. Airguns replaced the use of explosives as a sound source in the 1960s, with resultant reduced damage to fish.

Regional two-dimensional or “2-D” surveys are the least expensive (typically $400 to $600 US per line kilometre) and are often used in the earlier stages of exploration, for example, in an unexplored basin. They are designed with a number of single long lines, with spacing of 1 km or more. 2-D surveys provide far less rich and accurate data than 3-D surveys. 3-D surveys are more frequently used in basins with known oil and gas pools, such as those in the North Sea and the Gulf of Mexico.

Three-dimensional or “3-D” surveys use a dense grid of lines, using multiple hydrophone cables and two airgun arrays, which are fired alternately. The vessel sails along parallel lines. Each traverse of the vessel is spaced from 200 – 500 meters from the previous one. 3-D surveys are the most commonly used later in the exploration phase. They provide richer data results – which are particularly useful in areas of complex geology. A 3-D survey covering an area of 1,000 km2 would cost about $10 million US plus vessel location costs.

Four-dimensional, “4-D” or “time lapse” surveys are 3-D surveys repeated at different time periods. They give a picture over time – like a time lapse photograph - of production activity in an oil or gas reservoir, helping the producing company to squeeze the last oil or gas from the resource. At the present time, they are only rarely used. For example, the Hibernia Basin, which was originally surveyed in 1991 and has been in production since 1997, has seen only one limited seismic resurvey, that in 2001, over a small portion of the basin.

How does the noise generated by seismic testing differ from other types of noise that fish are subjected to?

As seismic techniques are perfected, more can be accomplished with lower decibels of sound. In some cases, other noise sources, such as nearby fishing or shipping vessels, may be as loud or louder than the seismic activity. In terms of decibels, seismic airgun arrays have maximum noise levels at source in the 200-250 decibel range. By comparison, open ocean ambient (normal) ocean noise ranges between 74-100 decibels; container ships and supertankers moving at speeds of 20-23 knots generate noise in the 190-200 decibel range (all measurements at source).

How far and how fast does the noise of seismic testing travel under water?

Sound travels four times faster in water than in air. Transmission loss in water is much lower. "Therefore, depending on local conditions, sound waves may travel long distances under water, and detection ranges can exceed 100 kilometres." (BC Offshore Hydrocarbon Development Report 2002). Adult fish would not be injured by an airgun array unless they were immediately adjacent to an airgun (Davis et al., Environmental Assessment of Seismic Exploration on the Scotian Shelf (1998)).

What are the impacts of seismic operations on fish, fisheries, fishers and aquaculture?

This section provides a brief description of the different types of impacts that seismic operations may have on fish, fisheries, fishers and other employees, and aquaculture.

Fishing vessel movement and patterns of fishing

When testing is taking place, fishing vessels may have to avoid the areas where the surveys are being done, or vice versa. Alternatively, they may have to synchronize the timing of their operations with those of the seismic ships, so that both can operate together in harmony. The potential exists for short-term inconvenience and disruption to the patterns of fishing – the amount and duration will be site-specific in each case.

Effects on catch rates and fishing time

The surveys may in some cases affect the catch rates of fish. One Norwegian study (Engas et al. 1993) analyzing impacts on catch rates of cod and haddock concluded that catch rates had been affected significantly in the short term. However, they noted that "the period of time required to attain normal catch rates following (completion of a survey) varies with season, locality, duration of shooting, availability of food, and whether fish are migrating. (BC Offshore Oil and Gas Technology Update. 2001, at 111).

In some cases, seismic programs can result in reduced fishing time. Pre-planning can help and has helped to minimize or eliminate this impact in some cases.

Effects on underwater employees, such as divers

Regulations generally require that divers not operate in areas undergoing surveys. Advance warnings are provided to ensure that they are able to vacate the areas in a timely manner.

Effects on aquaculture operations

Limited information has been found on effects on aquaculture operations. This may be in part because seismic is generally not shot close to shore, where aquaculture operations would be located. Seismic ships usually do not go into waters less than 30 metres in depth.

Direct damage to fish

The testing itself may cause direct damage to adult fish if they are within 1metre of an airgun. There may be physical damage to fish that have air-filled swim bladders. As a general rule, the likelihood of physical damage is related to the characteristics of the sound wave, such as peak pressure level, rise time of pressure increase, and decay time of the pressure wave, and the distance of the fish from the airgun source.

Hearing damage

The seismic sound waves may cause short-term (temporary) hearing damage to fish. These effects vary by species, with distance from airgun arrays, and in relationship to sound wave characteristics, among other factors. Given that fish avoid seismic noise, fish will not likely be exposed to levels of sound from an airgun array high enough to cause hearing damage. (LGL Ltd., Orphan Basin SEA Report, 2003).

Visual impacts and disorientation

Some impacts may be visual, causing the fish to swim toward disruptions in the water that are caused by the sound waves or, in some cases, away from the noise of the airgun. These changes may be either short-term or long-term, direct or indirect.

Differences in impact by life stage

Impacts on fish may vary according to their life stages – adult vs. larvae or eggs. While adult fish can swim away, planktonic stages can not. There is less good data on fish eggs and larvae than there is on adult fish.

Are there unique features of BC geography or fisheries that might affect impacts of seismic activities undertaken in the province?

Hecate Strait and the Queen Charlotte Sound are host to a concentration of migratory and non-migratory fish in the nearshore area, in part as the result of the region's geography, which confines much of the area by land on all sides. Some of the area serves as nursery grounds and rearing area.

What is the "state of the science" regarding these impacts?

In the case of seismic impacts, as with so many other areas in the field of fisheries science, there are some knowns and understood relationships between variables, but also many unknowns and unresolved research questions. Other factors, such as climate change, complicate the analysis. Impacts differ by species. Some of the research findings apply only to specific locations or individual species and are not easily replicated or transferable to other settings and species. Much of the research in this field has been criticized for not specifying clearly enough the acoustic properties of the sound waves used in the testing. (Gausland 2000). A research gap exists regarding impacts on invertebrates and plankton. Little is known, also, about "cumulative, chronic, and population-level impacts of noise on marine life."

A Halifax workshop held in 2001 examined in detail the kind of short-term and long-term research that would be needed to understand these impacts better (LGL and Griffiths Muecke 2001). DFO's recently-established Centre for Oil and Gas Environmental Research (COOGER), at the Bedford Institute of Oceanography in Nova Scotia, applies DFO research resources to deal with these questions and issues.

It is agreed that thorough, long-term monitoring by trained biologists is required to fully understand the impacts of seismic testing. However, funding for such long-term, comprehensive studies has not been forthcoming - either in Canada or anywhere else in the world. One research dilemma – a "catch 22" situation – is that impacts cannot be assessed unless and until some seismic testing takes place. However, the cost of doing seismic is so high that purely experimental seismic activity, not associated with oil exploration, is not financially feasible as a research technique. The BC Scientific Review Panel further noted, in 2002, that the types of comprehensive studies needed are "difficult to conduct," and that "there is little interest in doing them as long as a moratorium on these activities is maintained."

Allen Wood (2002) has pointed out the need for coordination of multiple research projects that might be related to seismic impacts on fish. This would make it possible for other stock assessment and behavioural studies, whether done by government, industry, or others, to be brought to bear on the topic.

Current research findings related to impacts on individual species will be presented at BCSA's February 17th workshop.

How is fishing industry knowledge and expertise used in analyzing and dealing with seismic impacts?

Fishing industry expertise and knowledge is used in various ways. Fishing logbooks have been used as sources of data in a number of studies dealing with catch impacts. Fishing industry input is a part of studies, environmental impact assessments, and research programs in Canada and elsewhere. Joint fishing industry-petroleum industry task forces and organizations have been established, some dealing with activity in a specific geographic area (as, UK, Moray Firth, where the Moray Firth Code of Conduct was jointly developed), others with province-wide relationships, such as Newfoundland and Labrador's One Ocean organization.

The One Ocean organization was formed in 2002 as an inter-industry organization to promote cooperation and understanding between the fishing and petroleum industries of Newfoundland and Labrador. It provides liaison between these two industries that operate in a common marine environment to enhance mutual knowledge and understanding. One Ocean is led by an advisory board of representatives from both industries, the Fish, Food, and Allied Workers (and other groups) and the Canadian Association of Petroleum Producers.

Fishing organizations are often consulted in the planning of seismic programs. They provide on-board observers during the program. They establish communications programs with the seismic operators which permit ongoing contact with fishing vessels that may be in the vicinity of the operation as it proceeds.

Some analysts have suggested that seismic operations may have positive as well as negative or constraining impacts on fishing operations. For example, Gausland notes that, despite fishermen's claims that seismic operations impair their fishing, "active fishing is often observed from the seismic vessels. There are also reports of fishermen getting larger catch rates if they follow in the immediate track of the seismic survey. The reason for this could be that the fish will move closer to the sea bottom when scared by the seismic sound, leading to higher concentration of fish in the area covered by bottom trawling." (Gausland 2003).

What are some of the variables in the seismic survey process that can make impacts on fish and fisheries greater or less?

The seismic survey process can be fine-tuned in a number of ways. These include: loudness of the airgun bursts; their frequency and duration; the way they are aimed; and the timing of the survey (e.g., with reference to fishing seasons or spawning or migration timing).

"Ramp-up" or "soft start" procedures can be used, whereby sound is gradually increased, not begun at full volume. Though these procedures are commonly used, and believed to be useful in reducing impacts on fish by giving them time to take evasive action, there have been no studies of their effectiveness.

The location and geographic area covered by the survey can also be varied. The near-field (close proximity) effects of seismic noise may be more injurious to fish than the far-field (more distant) effects.

Fisheries liaison/biological observers are required to be stationed on board seismic ships operating in some areas of Canadian waters, to deal with unexpected contingencies. Shutdown procedures can be observed, to bring the survey to a halt if conditions warrant.

What mitigating measures have been developed to deal with seismic impacts on fish and fisheries?

A number of different types of mitigating measures are now being used in Canada and around the world where seismic testing interacts with fish and fisheries. In addition to the "fine-tuning" measures described above, these include:

- Oil industry/fishing industry task forces to deal with issues on an ongoing basis
- Fishing industry or trained biological observers on board the seismic ships
- Communication techniques that enable readjustment of surveys in the case of surprise
- No seismic surveys during times of migration or spawning of identified species
- Establishment of survey-free spawning corridors and migration routes (Norwegian regulations)
- Design of airgun arrays to reduce horizontal leakage
- Compensation programs for gear damage and other fisheries impacts
- Standards for required separation between seismic and fishing gear, in fixed gear areas
- Limitations on night survey activity, to improve visual surveillance
- Pre-survey inventory to insure no mammals present within a 500 meter radius (suggested JNCC regulatory procedure)
- Designing surveys, or adjusting timing, to avoid active fishing areas, especially fixed gear.

For an example of the types of mitigating measures adopted in connection with a controversial seismic operation, see the requirements put in place by the Canada-Nova Scotia Offshore Petroleum Board for seismic activity in the Cape Breton area of Nova Scotia. www.cnsopb.ns.ca/Whatsnew/AdHoc030503.html

How is seismic testing activity regulated?

The types of mitigating measures described above are required by law in many areas. They have been recommended by BC task forces and scientific review panels which examined this subject in 1986 and 2002. International professional organizations such as the International Association of Geophysical Contractors (IAGC) and regulatory agencies such as the UK's Joint Nature Conservation Committee (JNCC) have established standards for seismic operations as they affect fisheries. The US National Marine Fisheries Service (NMFS) has established standards for shutdown procedures.

Regulation of seismic survey activity in eastern Canada is the responsibility of the joint federal-provincial boards – the Canada – Newfoundland Offshore Petroleum Board (CNOPB) and the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB). Some regulations and/or policies apply uniquely to specific geographic areas, in recognition of unique biological factors there – as, for example, Nova Scotia's Sable Gully, Georges Bank and the South Gulf of St. Lawrence (Cape Breton area).

Under the Canadian Environmental Assessment Act (CEAA), all oil and gas seismic programs require a separate environmental assessment (screening) of potential impacts specific to the proposed program. In the course of this assessment, specific mitigation measures are identified. Additional conditions may be imposed before a permit is issued by the regulatory authority.

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US National Marine Fisheries Service (NMFS) www.nmfs.noaa.gov
(shutdown standards)

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