A Discussion Paper on the Effects of Explosives on Fish and Marine Mammals in the Waters of the Northwest Territories

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A DISCUSSION PAPER ON THE EFFECTS OF EXPLOSIVES ON FISH AND MARINE MAMMALS IN THE WATERS OF THE NORTHWEST TERRITORIES

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF APPENDICES

GLOSSARY

Air Gun - A mechanical source of acoustic energy in which a volume of air under high pressure is suddenly released to the surrounding water.

Chemical Explosive - A chemical compound which when detonated creates a violent shock wave by rapid conversion of potential to kinetic energy.

Energy Flux Density (E_f) - The rate of energy transport across a unit area measured in units of joules/m^2.

Explosive - A substance or a device which when detonated or fired creates a violent shock wave in water.

Fish - Includes finfish, shellfish, crustaceans, marine animals and the eggs, spawn, spat and juvenile stages of finfish, shellfish, crustaceans and marine animals.

Impulse (I) - the time-integral of the pressure of a shock wave, measured in units of bar-msec (kg-msec/cm^2)

$I = {}_0T \;\; P(T)\, dt$

where I = impulse (bar-msec)

P = pressure (bars)

T = time (msec)

Lethal Range (R_L) - Range (distance) in metres at which a certain percentage of test organisms will be killed outright.

R_{L50} - 50% of the test organisms will be killed:

R_{L1} - 1% of the test organisms will be killed.

Linear Explosive - A chemical explosive energy source in which the explosive is in the form of a long small diameter cord rather than a cylinder or a sphere.

Non-Chemical Explosive Energy Source - A source of acoustical energy derived from means other than chemical explosives. This would include air guns, sleeve enclosed explosive devices, gas exploders, underwater sparkers, wire arc exploders, high pressure steam guns and/or displacement devices.

Peak Pressure (P_{max}) - The maximum pressure relative to hydrostatic pressure measured in 'bars' (kg/cm^2), generated by an underwater shock wave.

Safe Range (R_s) - Range distance (in metres) from an explosion at which there should be no explosion related injuries to test organisms.

ABSTRACT

Wright, D.G. 1981. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories. Can. Tech. Rep. Fish. Aquat. Sci. 1052: v + 16 p.

The use of explosives in the marine environment has been demonstrated to be harmful to both fish and marine mammals. The Department of Fisheries and Oceans may permit the use of explosives in the waters of the Northwest Territories when it can be demonstrated that it is not technically feasible to attain the objective by any reasonable means other than explosives; or in an emergency where lives and property are threatened; or for experimental scientific purposes; or if it can be reasonably demonstrated that there are no economically important and/or otherwise significant biological resources at risk.

Underwater shock waves resulting from the detonation of high velocity chemical explosives are potentially lethal to fish in that they can result in the rupture of the swim bladder and rupture and hemorrhage of the kidney, liver, spleen, gonads and sinus venosus. Smaller fish are more susceptible to effects of underwater shock waves than larger fish. Eggs and larvae of fish are also susceptible to damage from underwater explosions. Shock waves have been demonstrated to be lethal to marine mammals, and sublethal damage to their auditory systems could occur at considerable distances from explosions. Seismic exploration surveys in seal pupping areas may result in an abandonment of prime habitat and may weaken the mother-pup bonding response, resulting in decreased survival of the pups.

Several methods have been developed to predict the damage zone for underwater explosions, including peak pressure (P_{max}), energy flux density (E_f) and impulse (I). The impulse model appears to be the best of these in predicting lethal and safe ranges and has been chosen by the Department of Fisheries and Oceans to predict the zone of damage to fish and marine mammals. A description of the method and sample calculations are appended. Departmental policy on and guidelines for the use of explosives in the waters of the Northwest Territories are also appended.

Key words: explosives; explosions; fish; marine mammals; effects; policy; guidelines; Canadian Arctic.

RESUME

Wright, D.G. 1981. A discussion paper on the effects of explosives on fish and marine mammals in the waters of the Northwest Territories. Can. Tech. Rep. Fish. Aquat. Sci. 1052: v + 16 p.

Le recours aux explosifs dans l'environnement marin s'est avéré nuisible à la fois aux poissons et aux mammifères aquatiques. Le ministère des Pêches et Océans peut autoriser l'utilisation d'explosifs dans les eaux des Territoires du Nord-Ouest dans les cas où l'on peut prouver que l'objectif qu'on cherche à atteindre ne peut effectivement et techniquent être atteint par d'autres moyens raisonnables que les explosifs; ou dans les cas d'urgence où les biens et la vie sont menacés; ou à des fins expérimentales scientifiques; ou si l'on peut montrer qu'il n'y a pas de risque pour des ressources soit économiquement ou biologiquement importantes.

Les ondes de choc sous-marines provoquées par la détonation d'explosifs chimiques ultra-rapides peuvent être néfastes pour les poissons; elles peuvent rompre la vessie gazeuse et causer des hémorragies au foie, au speen, aux gonades, au sinus veineux, quand elles ne les rompent pas. Les poissons de petite taille sont plus sensibles aux effets des ondes de choc que ceux de taille plus grande. Les oeufs et les larves de poissons y sont également sensibles. Quant aux mammifères aquatiques, ils ne sont pas épargnés par les ondes de choc. Elles leur sont funestes, et même à des distances considérables, elles peuvent l'être, mais à un degré moindre, pour leur système auditif. Des sondages exploratoires séismiques dans des secteurs où il y a des bébés phoques, peuvent chasser ces derniers de leur habitat naturel et diminuer leur sens de perception et rendre, par là, plus difficile la communication avec leur mère, ainsi que leur survie.

On a mis au point plusieurs méthodes de prévoir l'étendue de la zone de dommage provenant d'explosions sous-marines, notamment celles de pression de crête (P_{max}), de densité de flux énergétique (E_f), et d'impulsion (I). La méthode d'impulsion, semble-t-il, est la meilleure pour déterminer la portée funeste et la portée sûre pour les poissons et les mammifères marins, et c'est elle qui a été adoptée par le ministère des Pêches et Océans. Nous avons annexé une description de la méthode et des exemples de calcul. Nous avons aussi joint le texte des politiques et des lignes directrices du Ministère sur l'utilisation des explosifs dans les eaux des Territories du Nord-Ouest.

Mots-clés: explosifs; poissons; mammifères aquatiques; effets; politiques; lignes directrices; Arctique canadien.

INTRODUCTION

During the past decade there has been considerable activity directed at the development of natural resources in the Northwest Territories. The use of high explosive charges for geophysical (seismic) exploration, for the destruction or weakening of sea ice and for general construction purposes has been an integral part of these activities. The potential for injury and/or death of fish and marine mammals resulting from the underwater detonation of explosive materials has been of concern to northern residents, particularly hunters and fishermen, to government resources managers faced with the problem of developing meaningful and environmentally sound guidelines governing the use of explosives and to industrial users of these materials. This discussion paper summarizes the known effects of explosives on marine mammals and fish; identifies a method for estimating the lethal range of an explosion; identifies needs for further research and was the basis for the formulation of a general Department of Fisheries and Oceans (DFO) policy on and guidelines for the use of explosives in the waters of the Northwest Territories.

LEGISLATION

The underwater detonation of chemical explosives has been demonstrated to cause injury and/or death to fish and marine mammals at sometimes considerable distance from the point of use. For this reason the DFO discourages the use of explosives and in particular point-source chemical explosives wherever possible. The general policy is reflected in the following sections of the Fisheries Act of Canada and the Northwest Territories Fisheries Regulations promulgated under this Act.

> Fisheries Act - Section 30. No person shall destroy fish by any means other than fishing except as authorized by the Minister or under regulations made by the Governor in Council under this Act.
>
> Fisheries Act - Section 31(1). No person shall carry on any work or undertaking that results in the harmful alteration or disruption or destruction of fish habitat.
>
> Northwest Territories Fisheries Regulations - Section 5(5). No person shall use an explosive for any purpose on or in any waters except under the authority of and in accordance with a licence issued by the Minister.

POLICY

Pursuant to Section 30 of the Fisheries Act and Section 5(5) of the Northwest Territories Fishery Regulations, the Minister may authorize the use of explosives in the waters of the Northwest Territories. As this Department is cognizant of the fact that there may be no alternatives but to use explosives in certain industrial and scientific operations, an authorization could be granted in the following situations:

a. if it can be demonstrated that it is not technically feasible to attain the objective by any reasonable means other than explosives;
b. in an emergency where lives and property are threatened;
c. for experimental scientific purposes, or
d. if it can be reasonably expected that there are no economically important and/or otherwise significant biological resources at risk.

RATIONALE FOR POLICY

Requests for permits to use explosives in water, fall into four general categories: geophysical (seismic) exploration; ice management; general construction and demolition, and scientific purposes.

GEOPHYSICAL EXPLORATION

In deep, open waters of the Arctic, two types of seismic reflection operations are common (Stuart 1975). The conventional operation utilizes air guns or similar nonchemical explosive systems as the source of acoustic energy and a towed hydrophone streamer cable. In ice-covered waters, the operation utilizes linear explosives lowered into the water as an energy source and geophones on the surface of the ice as detectors.

In nearshore waters with depths in the 3 - 12 metre range, industry has been permitted to operate shallow draft vessels using air guns and a bottom drag hydrophone array in a "stop-and-go" mode to obtain data (Stuart 1975).

In the very shallow areas, less than 3 m, winter operations from the ice using modified land-type acquisition systems with high explosives as energy sources have been permitted (Wournell 1975; FMS 1975). In order to protect fish from the destructive effects of chemical explosives, operators working from the ice in the very shallow areas are required to set charges a minimum of 18 m into the substrate according to the following schedule:

Explosive Weight (kg)	Burial Depth (m)
≤ 2.25	18
2.26 - 4.5	23
4.6 - 11.4	30
11.5 - 23	38
23.1 - 57	46
57 - 90	55

Where ice is fast to the bottom or where there is a low probability of encountering significant concentrations of fish, the above conditions may be relaxed. These conditions were derived through experimentation and consultation with industry personnel in an effort to limit the peak pressure of the shock wave at the sediment/water interface to less than 2.72 bars (40 psi) (FMS 1975).

In those areas inaccessible to conventional marine seismic survey vessels, due to the presence of ice cover, such as the inter-island channels of the Sverdrup Basin, chemical explosives as an energy source with geophones on the surface of the ice as detectors have been permitted in accordance with the following schedule (FMS 1975) developed in concert with the seismic operators:

Water Depth (m)	Charge Weight (kg)
15.1 - 23	≤.9
>23.1	≤.45

Recently, operators working from the ice have utilized linear explosives as energy sources as opposed to point source explosive charges.

In addition to the above described seismic reflection techniques, a type of seismic survey known as a seismic refraction survey is also used in NWT marine areas. This technique involves two vessels, a shooting boat and a ship containing the geophone array. These vessels may be several kilometers apart. Explosive charges up to 100 kg have been utilized in these programs. At present there are no alternative accoustical energy sources other than large quantities of high explosives available to undertake this type of survey, and so these have been permitted by DFO under specific terms and conditions.

ICE MANAGEMENT

The offshore drilling season in the Beaufort Sea is limited to a short open water season. Many times, although drilling locations may be clear of ice, ridged shore fast ice has prevented the drilling fleet from breaking out of their winter harbours. There have been several requests by drilling companies to use explosives placed beneath the ice to lift and weaken the ice so that it may be broken by ice strengthened supply vessels. Recent surveys by DFO (M. Lawrence, G. Lacho, pers. comm.) have shown these areas of ice ridging to contain significant numbers of fish.

GENERAL CONSTRUCTION

Explosives are frequently used in general construction and demolition work such as blasting trenches in bedrock for the placement of pipelines or for the removal of rock outcrops posing a hazard to navigation.

SCIENTIFIC USES

Explosives have been used in many scientific applications in the Beaufort Sea for the calibration of equipment to determine the effects of shipping noise on marine mammals and to calibrate earthquake sensing devices.

The current DFO policy and guidelines were developed to permit industrial and scientific uses of explosives but at the same time maximizing the degree of protection afforded to fish and marine mammals. These guidelines and policy were developed from the following technical considerations.

UNDERWATER SHOCK WAVES

Underwater shock waves are created naturally by earthquakes or artificially by explosive processes. Such shock waves are compressional waves having almost instantaneous rise time to a very high peak pressure, followed by a rapid oscillatory decay to ambient, or more usually below ambient, hydrostatic pressure. Bubbles created by the detonation process can also produce significant pressure peaks. The most commonly used sources for the creation of artificial underwater shock waves are chemical explosives and non-chemical explosives such as air guns. The theory of underwater explosions has been extensively treated by Cole (1948). Kramer et al. (1968) have prepared an excellent description of underwater shock waves from both chemical and non-chemical explosives in booklet form for United Geophysical Services. Similarly, Falk and Lawrence (1973), Trasky (1976) and Hill (1978) have prepared summaries of the available literature on the properties of underwater shock waves. Therefore, the subject will not be dealt with in this review.

EFFECTS OF SHOCK WAVES ON LIVING ORGANISMS

The rapid rates of change of pressure and the extremely high peak pressures generated by explosives can cause severe injury and/or death to fish and marine mammals.

EFFECTS ON FISH

Most of the reports in the literature cite the swim bladder as being the primary site of damage in fish (Alpin 1947; Hubbs and Rechnitzer 1952; Hubbs et al. 1960; Kearns and Boyd 1965; Christian 1973; Falk and Lawrence 1973; and Yelverton et al. 1975). Rupture and hemorrhage of the kidney, liver, gonads, spleen and sinus venosus, ribs torn loose from the body wall, torn adipose tissue and ruptured blood vessels in the body wall also have been reported as injuries caused by explosives (Tyler 1960; Falk and Lawrence 1973; Yelverton et al. 1975; and Sakaguchi et al. 1976).

Causes of damage

The high peak pressure (P_{max}), rapid rise times and rapid decay to below ambient hydrostatic pressure are those properties of chemical explosives which are most damaging to fish. Several workers (Hubbs and Rechnitzer 1952; Kearns and Boyd 1965; Christian 1973) have noted that blood and fragments of the swim bladder are blown into the abdominal cavity, suggesting that the swim bladder had exploded outward rather than collapsing inward. This observation indicates that the negative pressure wave produced by an oscillation of the produced gas bubble or by reflection of the shock wave at the air/water interface is the prime cause of damage to the swim bladder.

Sakaguchi et al. (1976) suggest that the peak pressure generated by an explosion is not a reliable indicator of the level of damage. Since the pressure signature resulting from an explosion is dependent on the type of explosive, the depth of the water, the depth of the detonation, the presence of ice cover and the type of bottom, explosions having the same peak pressure can have different rise times and peak pressure durations and thus can have different effects on fish. They found that the Energy flux density (E_f) was highly correlated with damage level. Yelverton et al. (1975) presented evidence to suggest that Impulse (I), an integration of pressure over time, of an explosion is strongly correlated to the degree of damage.

Effect of fish size

Yelverton et al. (1975) demonstrated that mortality was dependent upon weight. Fish ranging in weight from 0.02 g to 800 g were subjected to the same explosive conditions. The impulse required to cause 50% mortality increased considerably with body weight (Fig. 1). Thus, smaller fish are more likely susceptible to damage than larger fish.

Species differences

The swim bladder is one of the major sites of damage from shock waves. Thus fish possessing a swim bladder are more susceptible to shock waves than are those not possessing a swim bladder.

Fish possessing swim bladders may have either the swim bladder open to the alimentary canal (physostomous) or the swim bladder closed (physoclistous) (Table 1). The presence or absence of an opening to the gut makes little difference to the vulnerability of the fish since the opening is very small in relation to the size of the swim bladder and hence very little gas can escape during the passage of the shock wave (Gaspin 1975).

EFFECTS ON FISH EGGS AND LARVAE

The effects of explosive charges on fish eggs were investigated by Kostyuchenko (1973). Survival of eggs of four species were greatly reduced by the effects of small (50 g) charges of TNT. Damage to the eggs and developing embryos consisted of deformation and compression of the membrane, spiral curling of the embryo, displacement of the embryo and disruption of the vitelline membrane.

Larval fish are less sensitive to the effects of shock waves than are eggs or post-larval fish in which the swim bladder has developed. Rasmussen (1967) reports that newly hatched herring and salmon fry can survive pressures of 5 bars and were apparently not affected by rapid pressure changes. However, when the same fry reach 3 - 6 months of age, and have developed a swim bladder, a pressure change exceeding 2 bars will cause mortality within 24 hours.

EFFECTS ON MARINE MAMMALS

To date there has been virtually no experimental work undertaken to determine the vulnerability of marine mammals to explosive shock waves. Fitch and Young (1948) report that on at least three occasions California sea lions Zalophus californianus were killed during the course of seismic studies using black powder as an energy source but that California grey whales Eschrichtius robustus observed in the region of the blast were seemingly unaffected and were not frightened from the area. Wright (1971) reports that sea otters Enhydra lutris were injured by pressures of 6.9 bars (100 psi) and killed outright by 20.7 bars (300 psi). However, acute lethal pressure conditions for sea otters may be much less than indicated, since the pressure source, subterranean detonation of a thermonuclear device, did not have the characteristics of a high explosive blast. Fur seals Callorhinus alascanus were killed by an 11.4 kg (25 lb) dynamite charge exploded 23 m (75 ft) away (Hanson 1954).

Yelverton et al. (1973) undertook considerable experimental work using land mammals (dogs, sheep, monkeys) as test organisms. The principal damage sites were the lungs, the hollow viscera and the ear. Air emboli produced by sublethal lung damage can lodge in the heart or the brain resulting in death by cardiac arrest or stroke (Gouze and Hayter 1944).

While the quantity of explosives currently used in a typical seismic charge may not directly kill or severely injure marine mammals, there may be sublethal damage to their auditory systems. Yelverton et al. (1973) attempted to correlate the degree of ear damage to impulse level, using dogs as the test animal. The results of their studies are summarized in Table 2.

Hill (1978) has undertaken a review of the physiology of marine mammals and concludes that marine mammals are probably less vulnerable to gross physical damage from underwater shock waves than are land mammals of comparable size, primarily due to physiological adaptations to pressure changes encountered while diving and secondarily, due to the increased thickness of the body wall.

INDIRECT EFFECTS OF SEISMIC ACTIVITIES ON MARINE MAMMALS

In addition to possible direct damage to marine mammals as a result of the shock wave produced by explosives, seismic exploration activity may result in displacement of ringed seals Phoca hispida from critical habitat. Ringed seals are the most abundant species of marine mammal in Canadian Arctic marine areas. They are important to native peoples and are a significant prey species for polar bears and white foxes. The fast ice zone provides favourable habitat for breeding seals. Pups are usually born in snow caves on the fast ice in late March - early April. The Alaska Department of Fish and Game (ADFG) has made an annual effort to assess the abundance of ringed seals along the Alaska Beaufort Sea Coast and to assess possible effects of late winter - early spring activity by humans. Data from 2668 km^2 of survey trackline were examined and densities of ringed seals were determined for areas in which seismic operations had occurred and for adjacent control areas where no seismic operations had been undertaken (J. Scott Grundy, ADFG, pers comm). Densities in the control areas were two to four times greater than in seismic areas. On the average the density of seals in seismic areas was 0.18 animals/km^2 whereas there were 0.352 animals/km^2 in control areas. Displacement of seals from their subnivean lairs as a result of seismic activities could result in destruction or weakening of the mother-pup bonds and the death of the pup. Displacement of seals from prime habitat to less favourable areas in moving pack ice may increase their susceptibility to polar bear predation, while pups born on moving ice tend to be smaller, are weaned earlier and may have reduced survival (Grundy, pers. comm.). In light of the decreased density of seals in seismic areas and the

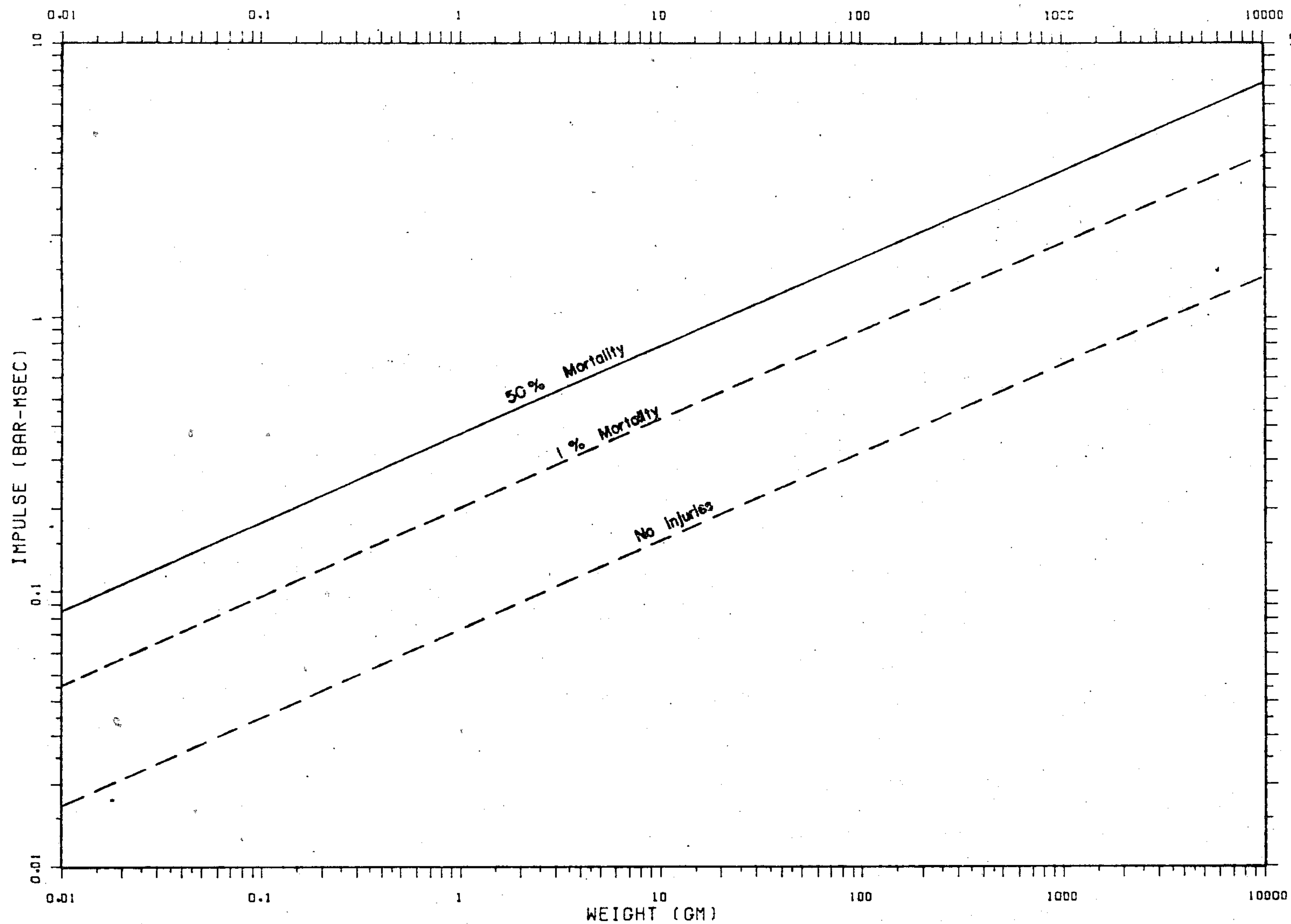

Figure 1. Lethal impulse vs. weight for fish (Hill 1978; after Yelverton et al. 1975).

Table 1. Swimbladder Characteristics of Typical Arctic Marine/Anadromous Fish

Common Name	Scientific Name	Swim Bladder - Absent/Present	Swim Bladder Type
Arctic Lamprey	*Lampetra japonica*	A	
Greenland Shark	*Somniosus microcephalus*	A	
Pacific Herring	*Clupea harengus pallasii*	P	0
Least Cisco	*Coregonus sardinella*	P	0
Broad Whitefish	*Coregonus nasus*	P	0
Inconnu	*Stenodus leucichthys*	P	0
Arctic Char	*Salvelinus alpinus*	P	0
Capelin	*Mallotus villosus*	P	0
Rainbow Smelt	*Osmerus mordax*	P	0
Ninespine Stickleback	*Pungitius pungitius*	P	C
Saffron Cod	*Eleginus glacialis*	P	C
Arctic Cod	*Boreogadus saida*	P	C
Greenland Cod	*Gadus ogac*	P	C
Rock Grenadier	*Coryphaenoides rupestris*	P	C
Roughead Grenadier	*Macrourus berglax*	P	C
Northern Sand Lance	*Ammodytes dubius*	P	C
Arctic Wolffish	*Anarhichas denticulatus*	P	C

Table 1. Swimbladder Characteristics of Typical Arctic Marine/Anadromous Fish (Cont'd)

Common Name	Scientific Name	Swim Bladder - Absent/Present	Swim Bladder Type
Slender Eel Blenny	*Lumpenus fabricii*	P	C
Fourline Snake Blenny	*Eumesogrammus praecisus*	P	C
Four Horn Scuplin	*Myoxocephalus quadricornis*	P	C
Arctic Staghorn Scuplin	*Gymnocanthus tricuspis*	P	C
Gelatinous Sea Snail	*Liparis koefoedi*	P	C
Dusky Sea Snail	*Liparis cyclostigma*	P	C
Arctic Flounder	*Liopsetta glacialis*	A	
Starry Flounder	*Platichthys stellatus*	A	
Greenland Halibut (Turbot)	*Reinhardtius hippoglossoides*	A	

A - Swimbladder Absent
P - Swimbladder Present
O - Swimbladder Open To Foregut (physostomatous)
C - Swimbladder Closed (physoclistous)

Table 2. Effects of different impulses on mammals diving beneath the water surface (from Yelverton et al. 1973).

Impulse		Effects
bar.msec	(psi.msec)	
2.76	(40)	No mortality. High incidence of moderately severe blast injuries, including eardrum rupture. Animals should recover on their own.
1.38	(20)	High incidence of slight blast injuries, including eardrum rupture. Animals should recover on their own.
0.69	(10)	Low incidence of trivial blast injuries. No eardrum ruptures.
0.34	(5)	Safe level. No injuries.

possibility of disturbance to breeding seals, ADFG has imposed a termination date of March 20 for all seismic activity in the fast ice zone beyond a water depth of 5.5 m.

LINEAR VS. CYLINDRICAL CHARGES AS ACOUSTICAL ENERGY SOURCES

In typical seismic exploration programs, high explosives in cylindrical shaped charges have been used. When these point-source charges are detonated, great quantities of energy are lost in the resultant gas bubbles. If detonation occurs at too great a depth, oscillations of the bubbles are set up and interfere with the seismic record. If the depth of detonation is decreased so that oscillations of the bubbles do not occur, a major portion of the energy is lost in the air blast, leaving only a small portion of the total energy available to form useful acoustic waves. Following experimentations with small charges, it was concluded that efficiency would be enhanced if the explosives were in the form of a long thin strand rather than a cylinder or a sphere. If such an explosive were detonated, the form of the bubble would produce insignificant oscillation so that the energy available as useable acoustic energy would be increased (I.C.I. 1968a). Imperial Chemical Industries (I.C.I.) Ltd. report that a 30 m (100 ft) length of "Aquaflex" containing 0.68 kg of explosive detonated 9 m (30 ft) below the surface will produce a seismic record comparable in quality to that secured from a conventional 23 kg (50 lb) charge. Hill (1978) reports that a formulation of "Aquaflex" containing 8.5 g explosive/m is currently being used for under-ice seismic work in the Arctic Archipelago. An 8 m length of the linear explosive would thus contain 68 g (0.15 lb) of explosive. Although the peak pressure generated by an exploding linear energy source is very similar to that generated by a point-source of the same explosive weight, the great reduction in explosive weight afforded by use of linear formulations over point-sources should decrease the impacts on fish and marine mammals (I.C.I. 1968b).

NON-CHEMICAL ACOUSTICAL ENERGY SOURCES

As was mentioned in a previous section, seismic operators are encouraged to use non-chemical explosive energy sources such as air guns wherever possible. Most of the currently available devices have been described by Kramer et al. (1968) and Falk and Lawrence (1973) and so they will not be discussed in this paper. The shock wave produced by an air gun or similar type unit differs from that of a chemical explosive shock wave in that its peak pressure is relatively low and both the rise time and the time constant of pressure decay are comparatively long (Hill 1978). All data collected to date indicate that air guns do not pose a hazard to fish. Falk and Lawrence (1973) tested the effects of a 4.9 L air gun operated at 138 bars on caged fish at various depths and ranges and calculated the lethal range (R_{L50}) to be between 0.6 and 1.5 m. Weinhold and Weaver (1973) tested the effects of both a single 0.33 L air gun and an 8-gun array of 3.9 L total volume on coho salmon Oncorhynchus kisutch fingerlings at distances of 1 to 10 m. No deaths or evidence of stress were recorded. Similarly, Kostyuchenko (1973) compared the effects of a 5 L air gun operated at 142 bars and small (50 g) charges of TNT on several species of fish eggs. The survival rates for eggs (control values in brackets) at a distance of 5 m from the source were as follows: TNT - 30.8% (98.2%); air gun 87.7% (92.3%). The TNT caused damage to the eggs while the air gun had little or no effect.

Since air guns have been demonstrated to be relatively harmless to fish, it is extremely unlikely that they would cause any gross damage to marine mammals. There may be slight damage to the animals' auditory system, but, at present, this is impossible to predict (Hill 1978).

ESTIMATION OF LETHAL RANGE

Methods have been developed to predict or estimate the lethal ranges of underwater explosions. These are reviewed below.

PEAK PRESSURE

Several investigations (Hubbs and Rechnitzer 1952; Hubbs et al. 1960; Falk and Lawrence 1973) have used the maximum shock wave overpressure (P_{max}) in order to predict lethal range. Indeed, the current guideline of DFO requiring operators working from the ice in the very shallow water zone to bury seismic charges at a minimum of 18 m, depending on charge weight, was arrived at in order to limit P_{max} at the seabed/water interface to less than 2.75 bars (40 psi). However, since lethal P_{max} is a function of the size of the fish, species of fish, orientation of the fish relative to the shock wave, the amount and type of explosive, the detonation depth, target depth, water depth and bottom type, it is not a good predictor of lethal range.

ENERGY FLUX DENSITY

Energy flux density (E_f) was found to be a good predictor of damage to fish in several different experiments (Sakaguchi et al. 1976). The lethal E_f was found to be 300 joules/m^2. However, E_f was calculated directly from recorded pressure signatures, using numerical methods, rather than relating the expected E_f to charge weight (Hill 1978).

MacLennan (1977) calculated the theoretical lethal range R_L (m) for an energy flux density of 300 joules/m^2 for point-source explosives of weight W (kg) in open water. The lethal range is estimated by the equation

$$R_L = 5.47 \times W^{0.496}.$$

The equation may underestimate the lethal range for fish near shallow bottoms or under ice cover because of the addition of the reflected pulse, and similarly, may overestimate the lethal range for fish near the surface because of the cancelling effect of the surface-reflected pulse.

Hill (1978) tested MacLennan's (1977) energy flux density predictor against several sets of experimental data. It did not predict the results of

Roguski and Nagata (1970) but did satisfactorily predict the results of Hubbs et al. (1960) and Falk and Lawrence (1973). The model was partially successful in predicting some of Tyler's (1960) data but did not predict the increase in lethal range which occurred with increasing depth of detonation.

LETHAL IMPULSE

Yelverton et al. (1975) presented data to support the hypothesis that the impulse (I) of the shock wave, an integration of pressure over time, is the best parameter for evaluating the effect of underwater explosions on fish and mammals. The authors tested eight species of fish in 13 different body weight groups and determined that the magnitude of the impulse required to kill the fish increased with the weight of the fish (Fig. 1). The hypothesis that impulse was a better damage predictor than P_{max} and E_f was confirmed in tests wherein one species of fish was exposed at three different depths. Carp Cyprinus carpio were tested at depths of 0.05 m, 0.3 m and 3 m. Lethal impulse values were not significantly different: 1.88 bar-msec for carp at 0.05 m; 1.62 bar-msec at 0.3 m and 1.81 bar-msec at 3 m. In contrast, the corresponding peak pressures associated with these lethal impulses varied considerably: 55.8 bars at 0.05 m; 23.1 bars at 0.3 m and 12.1 bars at 3 m. Similarly, the hypothesis that peak pressure was not the parameter responsible for the damage was also tested in experiments with small bluegill Lepomis macrochirus. Fish were placed at increasing depths but at a constant range from the explosive charge. Although peak pressure remained constant at 12.5 bars, impulse and mortality increased with the depth of the fish.

From these data, Yelverton et al. (1975) were able to develop a lethal range model which takes into consideration the variables of fish size, depth of fish, charge size and depth of detonation. Hill (1978) tested their lethal range hypothesis against the experimental results of several other researchers and found that the model roughly predicted the experimental results of Hubbs et al. (1960), Tyler (1960), Roguski and Nagata (1970) and Falk and Lawrence (1973). Sample calculations using this model follow in the section entitled ESTIMATION OF DAMAGE ZONE USING SHOCK WAVE IMPULSE and Appendix 1.

Yelverton et al. (1973) demonstrated that impulse of the shock wave was the prime damaging factor in a series of tests using submerged terrestrial mammals (sheep, dogs, monkeys) as test animals. These impulse levels and the corresponding degree of damage (Table 2) were found to be approximately constant for animals ranging in size from 5 to 40 kg. However, as mentioned previously in the section entitled EFFECTS ON MARINE MAMMALS, marine mammals may be less vulnerable to gross physical damage than are terrestrial mammals.

The auditory and echo location systems of marine mammals may be vulnerable to damage. Baleen whales and pinnipeds could suffer damage through ruptured eardrums, while toothed whales could suffer hearing damage from sublethal shock waves because of the direct sound conduction path to the inner ear via blubber and fat (Hill 1978).

Because of the larger size and physiological adaptations of marine mammals' the impulse levels shown in Table 2 may include a built-in safety factor when applied to marine mammals. A method to predict the range at which various levels of damage are likely, has been developed by Yelverton et al. (1973). Sample calculations using this model follow in the section entitled ESTIMATION OF DAMAGE ZONE USING SHOCK WAVE IMPULSE and Appendix 1.

ESTIMATION OF DAMAGE ZONE USING SHOCK WAVE IMPULSE

On the basis of comparison of the previously described techniques for the estimation of safe distances and lethal ranges for marine mammals and fish from underwater explosions, DFO has chosen the lethal impulse method developed by Yelverton et al. (1973, 1975). The reasons for this choice are as follows:

1) The model has successfully predicted the experimental results of several researchers (see section entitled LETHAL IMPULSE).
2) The model can be used to predict safe distances and lethal ranges.
3) The model takes into consideration fish weight, target depth, detonation depth and charge weight and can be used with all of the high detonation velocity explosives currently used for seismic exploration, demolition or construction.

However, if the water depth is shallow (less than five times either the detonation depth or the target depth, whichever is greater) or if the bottom is rocky, the method will underestimate the lethal range. In such cases, there may be considerable bottom reflected shock wave which will increase the impulse at any point. Similarly, if the charge is detonated under thick ice, a positive surface reflected wave may result, thus increasing the impulse and in turn, the lethal range. Under these conditions, the calculated, lethal ranges or safe distances should be doubled to ensure a conservative safety margin.

To use this method to calculate lethal ranges or safe distances, the following information is required:

i) typical weight of the species likely to be in the area (for fish only);
ii) depth of the target fish or marine mammal;
iii) depth of detonation of the charge, and
iv) weight of the charge.

To determine the range, the following steps are required:

1) Determine the impulse (I) corresponding to the degree of protection required for mammals (from Table 2) or for fish (from Fig. 1).
2) Calculate the scaled impulse by dividing the impulse found in Step 1 by the cube root of the charge weight.

$(I_{sc} = I/wt^{1/3})$

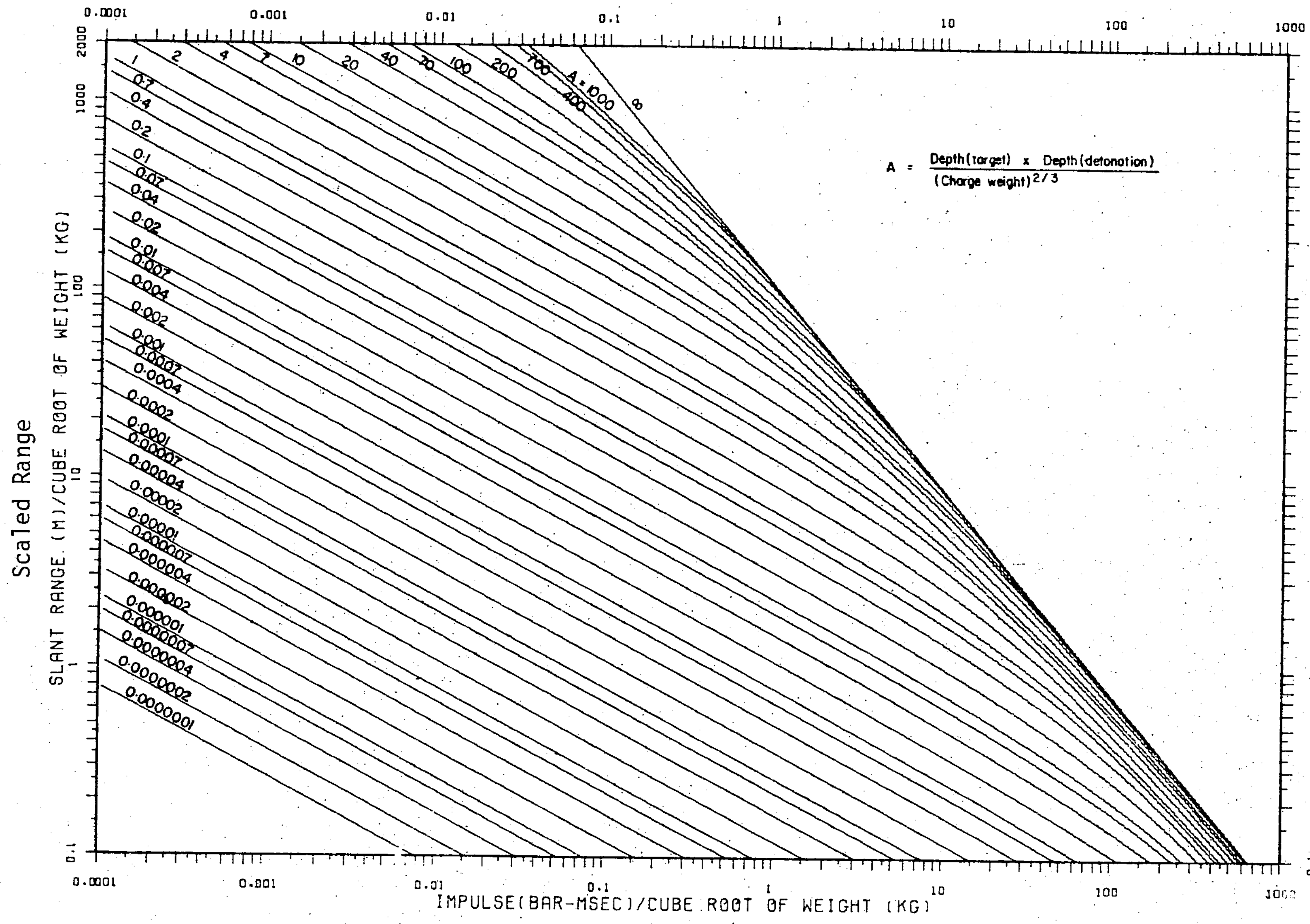

Figure 2. Curves for calculating lethal range from impulse (Hill 1978; after Yelverton et al. 1975).

3) Calculate parameter 'A', which is derived from the depth of the target fish or marine mammal, the depth of the detonation and the charge weight such that:

$$A = \frac{\text{target depth (m)} \times \text{detonation depth (m)}}{(\text{charge weight (kg)})^{2/3}}$$

4) From Fig. 2 find the best-fit curve to the calculated value of 'A' and using this curve, determine the value of the Scaled Range (R_{SC}) corresponding to the Scaled Impulse (I_{SC}) determined in Step 2.
5) Calculate the range (R) in metres by multiplying the Scaled Range by cube root of the charge weight.

$$R(m) = R_{SC} \times \text{charge wt}^{1/3}$$

NEEDS FOR FURTHER RESEARCH

Although there has been considerable research undertaken to determine the effects of various explosives on aquatic life, there are still several questions that need to be addressed. Yelverton et al. (1973, 1975) were able to develop a model to predict the lethal range of explosives on fish and mammals under certain test conditions. Department of Fisheries and Oceans is proposing to adopt this model in order to predict the lethality of explosives in Arctic waters. However, the applicability of this lethal range model has yet to be tested under ice cover. Hill (1978) suggests that reflection of the shock wave from the under ice surface could in effect double the lethal range of an explosion. In the past, researchers have used caged fish to determine the lethal range of underwater explosions. However, as a result of the work of Yelverton et al. (1975) there should be no further need to use caged fish. The level of impulse required to induce 0, 1 or 50% mortality of fish of a certain weight is known. Future studies should concentrate on electronic monitoring to measure the impulse at increasing distances from an explosion and calculating the lethal or safe ranges for each weight and type of explosive.

Similarly, there is a need to determine the magnitude of the impulse and the lethal range of explosives detonated within the ice to weaken or destroy ice ridges. Although an ice ridge may have a core of solid ice, the outer parts of a ridge may consist of slush ice (J. Steen, Canmar, pers. comm.). This region has acoustic properties intermediate between sea water and ice, thus forming an excellent couple between the two media and allowing a significant fraction of the incident energy to pass through the boundary into the water. It is recommended that any future program to evaluate the effectiveness of explosives to weaken or destroy ice ridges include a component to determine the range of the lethal impulse emanating from such an explosion.

Although there has been considerable research into the development of a lethal range model for fish, sound experimental data for marine mammals have yet to be obtained. Due to many logistical and political problems, experiments to collect these data may be impossible to conduct. Perhaps it may be better to use the blast effect criteria for marine mammals developed by Yelverton et al. (1973) rather than attempt to gather additional data.

POLICY AND GUIDELINES FOR THE USE OF EXPLOSIVES

The above discussion paper has summarized the effects of explosives on fish and marine mammals and has identified a suitable method to estimate the level and safe ranges to fish and marine mammals of underwater explosions. This paper was used as a background document to aid in the development of a DFO policy and guidelines for the use of explosives in the waters of the Northwest Territories. The policy and guidelines have been developed following extensive dialogue between the Department of Fisheries and Oceans, the Department of Energy, Mines and Resources and the prime user group of explosives: the Arctic Petroleum Operators Association and the Eastern Petroleum Operators Association and are appended as Appendix 2.

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APPENDIX 1

SAMPLE CALCULATIONS OF LETHAL RANGES FOR FISH AND SAFE RANGES FOR MARINE MAMMALS USING YELVERTON'S ET AL. (1973, 1975) IMPULSE MODEL

The following are sample calculations of lethal ranges for fish and safe ranges for marine mammals using the impulse model developed by Yelverton et al. (1973, 1975). Rationale for the use of this model was given in the section titled ESTIMATION OF DAMAGE ZONE USING SHOCK WAVE IMPULSE.

In order to use the model, the following must be known: the typical size (weight)of fish known to be in the area; the depth of the target fish or marine mammal; the depth of detonation of the charge and; the weight of the charge.

To determine the lethal or safe range the following steps must be followed:

1) Determine the impulse (I) corresponding to the assumed level of damage from Table 2 for mammals or from Fig. 1 for fish;
2) Calculate the scaled impulse by dividing the impulse determined in step 1 by the cube root of the charge weight

$$I_{SC} = I/wt^{1/3}$$

3) Calculate the parameter 'A', derived from the depth of the target fish or mammal, the depth of the detonation and the charge weight such that

$$A = \frac{\text{target depth (m) x detonation depth (m)}}{(\text{charge weight (kg)})^{2/3}}$$

4) From Fig. 2 find the best-fit curve to the calculated value of 'A' and using this curve determine the value of the Scaled Range (R_{SC}) corresponding to the Scaled Impulse (I_{SC}) determined in step 2.
5) Calculate the lethal or safe Range (R_L or R_S) in metres by multiplying Scaled Range (R_{SC}) by the cube root of the charge weight.

$$R = R_{SC} \times wt^{1/3}$$

EXAMPLE I

What is the lethal range (50% mortality) for a 5 kg charge, detonated at a depth of 5 m? The fish in the area are Pacific herring _Clupea harengus pallasii_ weighing 300 g, feeding on zooplankton at depths shallower than 10 m.

Weight of target fish	-	300 g
Depth of target fish	-	10 m
Depth of detonation	-	5 m
Weight of charge	-	5 kg

1) From Fig. 1, an impulse of 2.3 bar-msec causes 50% mortality to 300 g fish;
2) The scaled impulse is calculated

$$\frac{\text{impulse}}{(\text{wt of charge})^{1/3}} = \frac{2.3}{5^{1/3}} = 1.35$$

3) Calculate the parameter 'A' using 10 m as the target depth. This is the worst case since fish at shallower depth will experience a lower, less damaging impulse:

$$A = \frac{\text{target depth x detonation depth}}{(\text{charge weight})^{2/3}}$$

$$= \frac{10 \times 5}{5^{2/3}} = 17.1$$

Therefore we use the curve for A = 20 in Fig. 2;

4) Using the curve A = 20 in Fig. 2 the scaled range corresponding to a scaled impulse of 1.35 will be 48;
5) Lethal range is given by:

R_L = scaled range x charge weight$^{1/3}$
= $48 \times 5^{1/3}$ = 82.1 m

Thus 50% of all 300 g Pacific herring at depths of 10 m and at 82.1 m from the explosion will be killed outright.

EXAMPLE II

What is the lethal range (50% mortality) for a 10 kg charge detonated at a depth of 15 m? The fish in the area are Arctic cod, _Boreogadus saida_ feeding on epontic invertebrates at the ice-water interface to a depth of 10 m.

Weight of target fish	-	13 g
Depth of target fish	-	10 m
Depth of detonation	-	15 m
Weight of explosive	-	10 kg

1) From Fig. 1, an impulse of 0.9 bar-msec causes 50% mortality to 13 g fish;
2) The scaled impulse is calculated:

$$I_{SC} = \frac{I}{(\text{wt of charge})^{1/3}} = \frac{0.9}{10^{1/3}} = 0.42$$

3) Calculate the parameter 'A':

$$A = \frac{(\text{target depth})(\text{detonation depth})}{(\text{charge weight})^{2/3}}$$

$$= \frac{10 \times 15}{10^{2/3}} = 32.3$$

Thus we use the curve for A = 40 in the calculation of scaled range from Fig. 2;

4) From the curve A = 40 in Fig. 2 the scaled range corresponding to the scaled impulse 0.42 calculated in step 2 is 140;
5) Calculate the lethal range from the thus derived scale range using the relation:

$$R_L = R_{SC} \times (\text{charge weight})^{1/3}$$

$$= 140 \times 10^{1/3} = 302 \text{ m}$$

Since the charge will be detonated under thick ice there will be a positive rather/ than a negative surface reflected wave.

This increases the impulse and in turn, the lethal range should be doubled to ensure a conservative safety margin.

$$R_L \text{ (ice)} = R_L \times 2 = 302 \times 2$$

$$= 604 \text{ m}$$

Therefore 50% of all 13 g fish to depths of 10 m and at 604 m of the explosion will be killed outright.

EXAMPLE III

To predict the range at which various levels of damage to marine mammals is likely,the impulse levels presented in Table 2 can be substituted into the previous method. The depth of the animal, the depth of the detonation and the weight of the explosive charge are required to calculate the range of the explosion.

For example, what is the safe distance from a 10 kg charge detonated at a depth of 10 m for ringed seals feeding on pelagic invertebrates at depths to 30 m? The safe distance is calculated as follows:

1) From Table 2, 0.34 bar-msec is a safe impulse level resulting in no damages to submerged marine mammals;
2) The scaled impulse is calculated:

$$I_{SC} = \frac{I}{W^{1/3}} = \frac{0.34}{10^{1/3}} = .158$$

3) The parameter 'A' is calculated:

$$A = \frac{\text{(target depth)(detonation depth)}}{\text{(charge weight)}^{2/3}}$$

$$= \frac{30 \times 10}{10^{2/3}} = 64.6$$

The curve for A = 70 is used to calculate the scaled range from Fig. 2;
4) Using the curve for A = 70 in Figure 2, a scaled range of 310 corresponds to a scaled impulse of .158;
5) Safe range is calculated:

$$R_S = R_{SC} \times W^{1/3}$$

$$= 310 \times 10^{1/3} = 667 \text{ m}$$

Therefore provided the charge is detonated at least 667 m from the seals, there should be no risk of damage.

APPENDIX 2

POLICY AND GUIDELINES FOR THE USE OF EXPLOSIVES IN THE WATERS OF THE NORTHWEST TERRITORIES

GENERAL POLICY

The underwater detonation of chemical explosives has been demonstrated to cause injury and/or death to fish and marine mammals at sometimes considerable distance from point of use. For this reason the Department of Fisheries and Oceans discourages the use of explosives and in particular point-source chemical explosives wherever possible. The general policy is reflected in the following sections of the Fisheries Act and the Northwest Territories Fisheries Regulations promulgated under the Fisheries Act.

Fisheries Act - Section 30. No person shall destroy fish by any means other than fishing except as authorized by the Minister or under regulations made by the Governor in Council under this Act.

Fisheries Act - Section 31(1). No person shall carry on any work or undertaking that results in the harmful alteration or disruption or destruction of fish habitat.

Northwest Territories Fisheries Regulations - Section 5(5). No person shall use an explosive for any purpose on or in any waters except under the authority of and in accordance with a licence issued by the Minister.

Definition

For the purpose of these guidelines, "explosive" means: "any substance or device that when detonated or fired creates a violent shock wave in water." This definition includes all chemical type explosives (eg. dynamite, TNT, Ammonium Nitrate - Fuel oil (ANFO)) and non-chemical devices (eg. air guns, sleeve exploders, boomers).

POLICY

Pursuant to Section 30 of the Fisheries Act and Section 5(5) of the Northwest Territories Fishery Regulations, the Minister may authorize the use of explosives in the waters of the Northwest Territories. As this Department is cognizant of the fact that there may be no alternatives but to use explosives in certain industrial and scientific operations, an authorization could be granted in the following situations:

a. if it can be demonstrated that it is not technically feasible to attain the objective by any reasonable means other than explosives;
b. in an emergency where lives and property are threatened;[1]
c. for experimental scientific purposes, or

[1] It should be noted that "early breakout" or similar operational type programs or projects do not constitute emergency situations. Examples of emergency situations include ice jamming and consequent flood threat to a community, or ice impingement upon an artificial island.

d. if it can be reasonably expected that there are no economically important and/or otherwise significant biological resources at risk.

GUIDELINES

In order to assist proponents wishing to use explosives in the waters of the Northwest Territories, the following are guidelines for making applications for licences and in the use of explosives:

1. Pursuant to Section 5(5) of the Northwest Territories Fisheries Regulations, all persons desiring to use explosives (including chemical explosives and explosive acoustical energy sources such as air guns) for any purpose in the waters of the Northwest Territories must apply for a licence to do so from the Minister of Fisheries and Oceans through the District Manager, Department of Fisheries and Oceans, Northwest Territories District, P.O. Box 2310, Yellowknife, Northwest Territories.
2. The general use of explosives and in particular, point source explosives, is discouraged. Geophysical exploration (seismic) programs shall use non-chemical explosive acoustical energy sources wherever possible and where chemical type explosives must be used for geophysical exploration, linear type explosives are preferred.
3. i) Request to use explosives in other than emergency situations where lives and property are threatened, must be submitted at least 42 days prior to the anticipated starting date of the project.
   ii) In the event of an emergency where explosives must be used, notification must be made to the District Manager, Department of Fisheries and Oceans, P.O. Box 2310, Yellowknife, NWT, (403) 873-5831, prior to their use.
4. Applications must include the following information:
   i) name, address and telephone number of the applicant;
   ii) name, address and telephone number of the explosives contractor if different from i);
   iii) purpose of the project including justification as to why explosives must be used,
   iv) geographical location (coordinates of the project site including a map);
   v) anticipated starting and completion dates;
   vi) type (including trade name), weight and configuration (where applicable) of explosive to be used,
   vii) weight of individual shots and shot array configuration where multiple charges are used; and
   viii) detonation depth and method of detonation.
5. Where it is not technically feasible to undertake a seismic program without the use of chemical type explosives, the following conditions will apply:
   i) Where water depths are less than 15 m, explosive charges must be buried beneath the sea bed according to the following schedule:

Weight of Explosive (kg)	Burial Depth (m) (from top of uppermost charge to sea bed)
< 2.25	18
2.25 - 4.5	23
4.6 - 11.5	30
11.6 - 23	38
23.1 - 57	46
57.1 - 90	55

   Where ice is fast to the bottom or where there is a low probability of encountering significant concentrations of fish or where a program is carried out mostly in water depths greater than 15 m but includes some shot points in water depths less than 15 m, the above conditions may be relaxed at the discretion of DFO.
   ii) Where water depths are greater than 15 m, explosive charges suspended in the water column may be used according to the following schedule:

Water Depth (m)	Weight of Explosive (kg)
15 - 23	≤ .9
> 23	≤ .45

6. In all other situations for which the use of explosives is required, the proponent must provide a description of techniques to be used to limit the area of potential damage to living aquatic resources.
7. No explosive will be knowingly detonated within 500 m of any observed marine mammal.
8. All applications for an explosive licence, with the notable exception of routine seismic reflection programs, shall be accompanied by a brief (ie. one page) assessment by the proponent on the potential impact of the program on the fish and marine mammal resources of the area.
   This assessment could be presented either in a tabular format as per the attached example (Table 1) or in paragraph format and should include the following information:
   i) species potentially affected by the program (including the various stages in their life history);
   ii) times and locations (within the area of the permit application) critical to these species life cycles;
   iii) vulnerable stages in the life history of the species;
   iv) (quantitative) assessment of potential negative impacts on these species; and
   v) mitigation measures proposed to offset predicted negative impacts.
9. In addition to the above, additional terms and conditions may be affixed to the explosives licence to meet site and resource specific conditions not covered by the general guidelines.

TABLE 1. HYPOTHETICAL EXPLOSIVES IMPACT ASSESSMENT

Proponent:	Polar Petroleums Ltd., 1007 1st Street S.E., Calgary, Alberta (403) 263-0554
Explosives Contractor:	Blue Water Surveys Ltd., General Delivery, Nipper's Deep, Newfoundland (709) 737-4517
Purpose of Survey:	Seismic Refraction.
Location:	Baffin Bay 72 - 74° N Lat. 65 - 70° W Long.
Water Depth:	300 - 600 m.
Dates of Sruvey:	September 1 - September 15, 1984
Explosive:	Dupont Water gel. 45 kg/shot 400 shots 18,000 kg total.
Method:	Continuous shooting every 8 minutes. 1500 M between shots detonation depth - -4M bsl.

ASSESSMENT

Species Potentially Impacted	Vulnerable Life Stages	Critical Habitats	Critical Times	Predicted Impacts	Mitigation Proposed
Greenland Cod	Adult, fry, eggs	Inshore - Nearshore areas	Spawns Feb.-March	Predicted $L_{R_{50}}$ - 150 m. Few fish anticipated in deep offshore areas of survey.	Electronic fish finder on shooting vessel; will cease shooting if large schools of fish detected within 300 m.
Arctic Cod	Adult, fry, eggs	Associated with Pack ice	Spawns late winter-early spring, feeds on epontic invertebraetes mainly.	Predicted $L_{R_{50}}$ - 155 m. Fish should be dispersed through the water column.	as above.
Greenland Halibut (Turbot)	Adult, fry eggs	Inhabit deep offsnore waters.	Spawns late winter-early spring	Predicted $L_{R_{50}}$ - 180 m. Water depth in survey areas should preclude any impact.	
Harp Seal	Adults	Feeds and migrates in nearshore areas	Migration to south begins in early Oct. Returns in late June-early July.	Safe range - 700 m. Little impact as few seals in deep offshore areas.	Shooting to cease if seals observed in area.
Ringed Seal	Adults, pups	Nearshore areas.	Whelps - late March Moults - June	Safe range - 700 m. Little impact as seals will be well dispersed at time of survey.	as above.
Orca - Killer whale	Adults, calves	Casual visitor to area during open water period		Safe range - 700 m.	Shooting to cease if any whales observed in area.
Bowhead whale	Adults, calves	Casual visitor to area during open water period		Safe range - 700 m.	Shooting to cease if any whales observed in area.
Thick-billed murre	Adults, Juveniles	General	Swimming migrations of adults and young through study area to overwintering areas off southwest coast of Greenland in late August, early September.	Safe range for birds on surface - 65 m. Safe range for diving birds - 150 m.	Shooting to cease if any birds detected in area.