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Proceedings of the workshop on the development of research priorities for the northwest Atlantic blue whale population.

Compte-rendu de l'atelier sur le développement de priorités de recherche pour la population de rorquals bleus de l'Atlantique nord-ouest.

20–21 November 2002, Quebec City

20–21 novembre 2002, Québec

Véronique Lesage and/et Mike O. Hammill
Meeting Co-Chairs / Co-Présidents de réunion

Maurice Lamontagne Institute / Institut Maurice Lamontagne
P.O. Box 1000, 850 Route de la Mer / C.P. 1000, 850 Route de la Mer
Mont-Joli, QC G5H 3Z4

November 2003 / Novembre 2003

Canada

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PROCEEDINGS OF THE WORKSHOP ON THE DEVELOPMENT OF RESEARCH PRIORITIES FOR THE NORTHWEST ATLANTIC BLUE WHALE POPULATION

ABSTRACT

A workshop to identify research priorities for the Northwest Atlantic blue whale population was held in Quebec City on November 20-21st, 2002. Filling in knowledge gaps regarding this endangered species is a key element in the development and implementation of a recovery strategy, planned for 2003-2004. Presentations summarized existing research programs in Canada, the US and Iceland. Participants reviewed the knowledge gaps and threats to the blue whale as identified in the COSEWIC report. Important knowledge gaps that were identified included a lack of knowledge on seasonal distribution, abundance, stock structure and seasonal movements. Research priorities also identified a need to determine and define breeding and feeding areas, and the extent to which physical and biological processes determine distribution, behaviour, and movements. This information will help define critical habitat as requested by the *Species at Risk Act.* Participants also identified the most effective approaches for addressing particular knowledge gaps, and evaluated the pros and cons of each approach such as photo-identification, passive acoustics, visual surveys, genetics, telemetry etc. Actions to be undertaken were listed according to priorities. These recommendations will aid DFO managers in evaluating future research needs in light of the blue whale recovery strategy.

COMPTE-RENDU DE L'ATELIER SUR LE DÉVELOPPEMENT DE PRIORITÉS DE RECHERCHE POUR LA POPULATION DE RORQUALS BLEUS DE L'ATLANTIQUE NORD-OUEST

RÉSUMÉ

Un atelier sur le développement de priorités de recherche sur la population de rorquals bleus de l'Atlantique nord-ouest s'est tenu à Québec les 20 et 21 novembre 2002. L'obtention des connaissances manquantes pour cette espèce en voie de disparition constitue un élément clé du développement et de la mise en œuvre d'un programme de rétablissement, prévus pour 2003–2004. Les présentations ont résumé les programmes de recherche existants au Canada, aux États-Unis et en Islande. Les participants ont revu les lacunes au niveau des connaissances et les menaces concernant le rorqual bleu, tel qu'identifiées dans le rapport du COSEPAC. D'importantes lacunes ont été identifiées au niveau des connaissances de la distribution saisonnière, de l'abondance, de la structure des stocks et des mouvements saisonniers. La détermination et la définition des aires d'alimentation, et du pouvoir des processus physiques et biologiques à déterminer la distribution, le comportement et les mouvements des rorquals bleus devraient aussi constituer une priorité. Cette information aidera à définir l'habitat essentiel tel que requis par la *Loi sur les espèces en péril*. Les participants ont également identifié les approches les plus efficaces afin d'adresser les manques particuliers de connaissances, et ont évalué les pour et contre des différentes approches telles que la photo-identification, l'acoustique passive, les inventaires visuels, la génétique, la télémétrie, etc. Les actions à entreprendre ont été ordonnées en accord avec les priorités. Ces recommandations aideront les gestionnaires du MPO dans l'évaluation des besoins futurs de recherche en regard d'un programme de rétablissement pour le rorqual bleu.

REPRODUCTION, SEASONAL DISTRIBUTION AND USE OF CRITICAL HABITATS. ABUNDANCE, STOCK STRUCTURE AND POPULATION TRENDS, HUMAN-RELATED DISTURBANCES, SOURCES OF MORTALITY FOR THE NORTH ATLANTIC BLUE WHALE

APPROACH

In June 2003, Canada proclaimed the *Species At Risk Act* (SARA), a new legislation to prevent indigenous species, subspecies and distinct population of wildlife from becoming extirpated or extinct, and to permit the recovery of those species identified as being particularly at risk. Under this legislation, species or populations are examined by an independent committee, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), and an assessment is made as to their risk of extinction in Canada. Under this legislation, COSEWIC reports its assessments to the federal government, who has then to include this species on the official list of species at risk by regulation. The listing of a species under SARA will then result in legal protection and mandatory requirements, such as the development of a recovery strategy to outline broad objectives that will favour recovery. In the case of blue whales, the recovery strategy is to be developed within 3 years from its listing.

The blue whale is the largest of cetaceans and the largest mammal on Earth. In 2002, COSEWIC recommended that the blue whale be listed as endangered owing to an apparent significant reduction in numbers, continued low population size and small number of calves. As part of the Recovery planning process, DFO Quebec Region planned a 2-day workshop to examine in depth the scientific challenge of studying Blue Whale biology and ecology. Filling in knowledge gaps on this endangered species is a key element in the development, and implementation of a Recovery Strategy, which is scheduled to be written up by 2003-2004. Specific literature on North Atlantic Blue Whales is scarce. Therefore, the purpose of the workshop was to bring together research scientists from DFO and outside DFO to review current research efforts, and identify the most effective approaches to fill in knowledge gaps.

The workshop was limited to 15 participants. Guest speakers from Quebec and Newfoundland as well as from USA and Iceland were invited.

ISSUES TO BE ADDRESSED

- Review of North Atlantic population status, threats and knowledge gaps;
- Review of existing research programs in Canada, USA and Iceland;
- Applications and limits of different techniques such as photo-identification, aerial and ship-based surveys, passive acoustics, satellite telemetry to address knowledge gaps in blue whale biology and ecology.

OUTCOME

- Publication of presented papers, workshop discussion, synthesis and conclusions as a Workshop Proceedings;
- Advice to Species at risk (SAR) coordinators on the type of information needed to develop a more effective recovery strategy;
- Recommendations to DFO managers on research needs to meet DFO's mandate to promote blue whale recovery.

TERMS OF REFERENCE

OBJECTIVES

- Review knowledge gaps and threats identified in the report to the Committee on the status of Endangered Wildlife in Canada (COSEWIC). Add to the list if appropriate;
- Identify possible and most effective approaches to fill in knowledge gaps in blue whales biology and ecology;
- For each approach, identify potential limiting factors in the context of the knowledge gap to be filled;
- Outline existing information and format, and estimate efforts required in terms of time, money, material/networking to fill in a knowledge gap using a particular approach;
- Identify next steps for each knowledge gap;
- Recommend to regional managers of Fisheries and Oceans Canada (DFO) research activities required to better understand limiting factors that could have an impact on blue whale recovery

LIST OF PARTICIPANTS

Dr. Christopher Clark	Cornell University
Dr. Janie Giard	Groupe de recherche et éducation sur les mammifères marins (GREMM), Tadoussac
Mr. Jean-François Gosselin	Fisheries and Oceans Canada (DFO), Quebec Region
Dr. Mike Hammill	DFO, Quebec Region
Dr. Catherine Hood	DFO, Newfoundland

Ms. Anne Lagacé	DFO, Quebec Region
Dr. Jack Lawson	DFO, Newfoundland
Dr. Véronique Lesage	DFO, Quebec Region
Dr. Lena Measures	DFO, Quebec Region
Mr. Robert Michaud	GREMM, Tadoussac, Quebec
Mr. Richard Sears	Mingan Island Cetacean Study (MICS), Longue Pointe de Mingan, Quebec
Dr. Yvan Simard	DFO, Quebec Region
Dr. Kent Smedbol	DFO, Maritimes Region
Dr. Garry Stenson	DFO, Newfoundland
Mr. Gisli Vikingsson	Marine research Institute, Iceland

Main rapporteur: Mrs Virginie Chadenet, Québec

AGENDA

Wednesday, November 20th, 2002

TIME	THEME	PRESENTER	RAPPORTEUR
8:30-9:00	Introduction and terms of reference	Mike Hammill	Jean-François Gosselin
9:00-10:00	Status, knowledge gaps and threats; current research programs	Richard Sears	Jean-François Gosselin
10:00-10:30	Break		
10:30-11:30	Passive acoustics	Christopher Clark	Jean-François Gosselin
11:30-12:30	Lunch		
12:30-14:00	Discussion on applicability of passive acoustics to blue whale study in Canada		Garry Stenson
14:00-14:30	Research program in Icelandic waters	Gísli Vikingsson	Garry Stenson
14:30-15:00	Break		
15:00-15:15	Ice entrapments of blue whales in SW Newfoundland	Garry Stenson	Kent Smedbol

TIME	THEME	PRESENTER	RAPPORTEUR
15:15-15:30	Distribution of blue whales in Newfoundland and Labrador	Jack Lawson	Kent Smedbol
15:30-15:45	Other Sources of Mortality	Lena Measures	Kent Smedbol
15:45-16:00	Other themes		

Thursday, November 21th, 2002

TIME	THEME	MODERATOR	RAPPORTEUR
8:30-9:00	Opening remarks	Mike Hammill	Catherine Hood
9:00-10:00	Seasonal distribution, stock structure, abundance estimates and population trends		Catherine Hood
10:00-10:30	Break		
10:30-11:30	Reproductive rate, survival at age, sources of mortality		Anne Lagacé
11:30-12:30	Lunch		
12:30-14:30	Habitat use, availability of food resources and effects of climate change, effects of whale watching		Jack Lawson
14:30-15:00	Break		
15:00-16:00	Degree of exposure to, and effect of pollutants		Lena Measures
16:00-16:15	Closing remarks	Mike Hammill	

STATUS, KNOWLEDGE GAPS AND THREATS; CURRENT RESEARCH PROGRAM (MR. RICHARD SEARS)

ABSTRACT

STATUS OF THE BLUE WHALE IN EASTERN CANADIAN WATERS

Blue whale (*Balaenoptera musculus*) ecology was studied in the St. Lawrence predominantly from the Estuary to the Mingan Island / Anticosti region from 1979-2002. The main study area was the Mingan Island / Anticosti region with a total of over 24 field seasons, for a mean of 10,338.5 km covered per year. Other study areas included the St. Lawrence Estuary where observations were carried between 1983-2002, for a yearly mean of 1000.5 km travelled. Other areas of observation include the eastern tip of the Gaspé Peninsula and off Sept-Iles / Port-Cartier.

A photographic catalogue of 390 individuals has been compiled for eastern Canadian waters, with an additional 81 photo-identified for western Iceland and 20 for the Azores, Portugal. The sex of 139 individuals (67 females and 76 males) was determined from 190 skin biopsy samples taken from 1990-2002. While blue whales were reported in each month from the St Lawrence, the main sighting period was from April to December with peak sightings in August and September. Forty-one percent of photo-identified blue whales were seen only one year. The percentage of new animals discovered per year was at less than 3% by the 2002 field season, and only 12 calves were identified over 24 field seasons.

Of the 25 blue whales photo-identified outside the St. Lawrence in eastern Canadian and New England waters, nearly 50% matched to the St Lawrence. One blue whale sighted in the St Lawrence was also found off west Greenland, but there have been no photographic matches between Iceland or the Azores with eastern Canadian waters.

COMPLEMENTARY INFORMATION

Information on the distribution and stock identity of blue whales in the North Atlantic has been collected by the Mingan Island Cetacean Study (MICS) using different techniques, including photo-identification, genetics analyses of skin biopsies (analyses done by P.J. Palsbøll and M. Berubé), satellite and VHF telemetry.

Photo-identification work indicates that there would be two stocks: a western stock (Newfoundland, East US and West Greenland) and an eastern stock (Iceland, United Kingdom, Azores). The distribution information is based on *identified* individuals and not on all sightings. Some blue whales that were identified in the Gulf and Estuary of St. Lawrence were resighted in the Gulf of Maine, Nova Scotia, south of Newfoundland (Saint-Pierre and Miquelon) and west Greenland. There has been limited sighting efforts on the Grand Banks, but whales are “heard” there during winter (Chris Clark, Cornell University).

In the St. Lawrence, very little work has been done during winter (aerial surveys by Sears et al., 1982; Kingsley et al., 1996), and the majority of new sightings come from the Estuary, in the area from Forestville to Tadoussac, and from the summer and fall periods. Data on sightings are not normalized for effort. Gaspé is an area where there has been more effort over the last few years. The Sept-Îles area sightings are mostly due to "on call" effort, i.e. when whales are reported. The effort in the Mingan area and in the Estuary is more constant although effort in the Estuary is also higher when blue whales are known to be in the area. The effort in the Mingan area is more spread out in time The blue whale photo-identification work in St. Lawrence is up to date as of 2002. All photographs have been digitized on a Macintosh platform.

Efforts to obtain information on seasonal movements of blue whales were initiated by the MICS through the deployment of satellite transmitters. A first satellite transmitter deployed in 1997 with the help of Chris Slade (New England Aquarium) lasted for 19 days. A second satellite transmitter deployed in 2002 with the help of Nick Gales lasted for nearly a month. Complementary information on movements and habitat utilisation has been obtained by the deployment of a few time-depth-recorders and radio transmitters.

In addition to its work on the distribution and stock identity, the MICS is involved in several other projects. As an example, blubber samples, obtained through a biopsy program, are forwarded to Chris Metcalfe (Trent University) and Michael Moore (National Marine Fisheries Service, Woods Hole) for analyses of organochlorine contaminants, such as PAHs, and activity of cytochrome P450. The MICS also provides support to a doctoral student (Catherine Berchok, Penn. State University) involved in an acoustic study which aims at building a catalogue of blue whale calls and establishing geographical correlations.

Among the conservation issues that were raised during the presentation, collision with vessels and ice entrapment appear to represent the most serious threats. A total of 16% of the animals from the catalogue could have been hit by a boat. Five animals, scarred on both sides, were assumed to be scarred by ice while uneven scarring could likely be a sign of boat strike. Entanglement in fishing gear is not often observed, although it does happen. Disturbance by whale-watching activities and oil drilling were also raised as issues of concern.

SUGGESTIONS FOR FUTURE WORK

- Expand research effort both in time and space to reduce data heterogeneity and determine consistent population estimates;

- Use satellite telemetry to gain a better understanding of the distribution and movements of blue whales;
- Carry on monitoring of persistent contaminants;
- Acoustically monitor blue whale calls in various locations of the St. Lawrence year round (moored arrays combined with field observations)

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BLUE WHALE POPULATION ASSESSMENT USING PASSIVE ACOUSTICS (DR. CHRIS W. CLARK)

ABSTRACT

Passive Acoustic Detection and Monitoring of Blue Whales in the North Atlantic

Blue whales have been recorded throughout almost all of the world's oceans, with all recordings sharing characteristics that are species specific. Sounds are produced as long, patterned sequences of hierarchically arranged units (e.g., notes). Individual units are primarily low-frequency 15-40 Hz, long duration (5-20s) and intense (as high as 170-185 dB re 1 µPa) (Clark and Fristrup 1997; Stafford et al. 1998, 1999; Thode et al. 2000). All evidence supports the hypothesis that these signals are produced by males and serve, in part, as a reproductive display. These sounds are well adapted for long-range communication in the open ocean, and anatomical evidence supports the conclusion that blue whale ears are well adapted for low frequency hearing. Blue whale singers can be detected over enormous distances. For example, in the North Atlantic animals singing along the shelf edge of the Grand Banks can be detected off Bermuda and Puerto Rico. Variation in vocal activity has now been documented at ocean basin, regional (10,000 - 80,000 nmi^2), and local (100 – 2,500 nmi^2) spatial scales and over multi-year, seasonal, and diurnal temporal scales. From these observations several interesting results have emerged. Singing activity is highest during winter months but does occur during summer months in high latitudes. Often singing is associated with areas of generally high food abundance (Croll et al. 1998).

The acoustic detection range of a singing blue whale is usually at least an order of magnitude greater than the visual detection range. It is important to emphasize that oceanographic acoustic propagation conditions can have a profound affect on acoustic detection range and detection probability, with detection ranges varying by several orders of magnitude as a function of ocean conditions. Various models exist and are readily available for predicting acoustic transmission loss and therefore detection ranges for blue whale sounds under varying bathymetric and oceanographic conditions (e.g., Jensen et al. 1994). When conducting a passive acoustic survey or monitoring for blue whales such information is critical for estimating detection area and the probability of detection.

Although there are many factors that influence detection range, three of the most important are source level (SL), transmission loss (TL) and ambient noise (N), where source level is the intensity of the sound produced by the whale, transmission loss is the amount of intensity that the sound loses as it propagates through the ocean and ambient noise is the level of background noise at the receiving hydrophone, where the hydrophone could deployed from a vessel at the surface, mounted off the bottom, or a suspended beneath a sonobuoy. Ambient noise is therefore a critical limiting factor in detection range for blue whales. Ambient noise level is also a critical factor from the perspective of a blue whale attempting to communicate over long-range. Over the last century there is now good evidence indicating that in some regions of the Northern Hemisphere ambient noise levels have increased by one to two orders of magnitude (10-20 dB) in the 15-40 Hz frequency band (Wenz 1962; Curtis et al. 1999; Andrew et al. 2002). Under such conditions of high ambient noise communication range can decrease by several orders of magnitude (Payne and Webb 1971). Thus, in a pre-industrialized ocean a singing blue whale could be heard over 100-1000 nautical mile ranges, but in today's industrialized environment communication would be reduced to ranges of 10-100 nautical miles. The impacts of such a communication-reducing factor would only become evident over several generations.

Over the past 10 years there has been a dramatic improvement in methods available for collecting passive acoustic data and for automatically detecting, recognizing, locating and tracking vocally active blue whales. Many of the data collection methods have become relatively inexpensive making it quite feasible to implement them for monitoring or mitigation research. Methods include portable towed hydrophone arrays for locating and tracking individual animals (Croll et al. 2002) and autonomous seafloor recorders that can be deployed in remote areas for many months at a time (Clark et al. 2002).

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COMPLEMENTARY INFORMATION

Global perspective of blue whale calls

Blue whales appear to sing all year round. Vocal activity would therefore not seem to be only related to sexual behaviour. Blue whales have been heard singing on feeding grounds. However, the occurrence of vocal activity during active feeding has not been demonstrated. Passive acoustics provide insights into several aspects of the ecology of marine mammals, including their distribution, movements and social behaviour. The monitoring of call rates over several years might provide an index of abundance. The combination of the results obtained from this approach and other approaches such as aerial or ship-based surveys, food distribution and abundance assessments, fine-scale behavioural studies, etc. will likely provide the most useful information and will help to better place the individual within its social, ecological and evolutionary environment.

Recordings from the International Whaling Commission (IWC) Southern Ocean Whale and Ecosystem Research program (SOWER) indicate differences in calls (which are likely male voices) between blue whales from Antarctic (south of 60°S), Madagascar, Chile, western Australia, eastern North Pacific and eastern South Pacific. No distinction were made between eastern and western Atlantic, although North Atlantic blue whales are recognised as different from the other groups.

Some of the information that was gathered on whale vocal behaviour through the Integrated Undersea Surveillance System (IUSS) has been recently declassified and thus, allow some analyses of whale calls on a scale of ocean basins. For example, analyses of these data indicate that in 1993, there were large numbers of blue and fin whales off the continental shelf of Newfoundland (presumably singing males). Individuals were followed around the Grand Banks in July. In August, they moved generally south. Large numbers of blue whale calls are heard off the Grand banks during winter, whereas no calls are recorded during summer. In the southern North Atlantic, blue whale calls peak in January, and decrease progressively through April. In the northern North Atlantic, blue whale calls increase from April to August, and then progressively decrease in September. There exists no data for October and November.

DISCUSSION ON THE APPLICABILITY OF PASSIVE ACOUSTICS TO BLUE WHALE STUDY IN CANADA

The following points were raised during the discussion:

- On regional or local scales, towed arrays and autonomous bottom-set recorders (pop-up recorders), may provide very useful information on several aspects of whale ecology through the recording of their vocal behaviour, and this, at an affordable price. Hydrophone arrays are generally directional and may provide information on the position of vocalising animals in real time. These systems are now small enough for use on smaller vessels, and can be built for approximately $250 US.
- Similarly, movements of individual whales can be tracked using arrays of pop-ups disposed in strategic points. These autonomous, bottom-mounted recorders are small enough to be deployed and recovered from a small vessel such as

inflatable boats. They can be rented for approximately $7500 US, although costs are likely to go down in the near future. Using new lithium batteries, current pop-up recorders can stay at sea for 6 months at a time before a download is necessary. ‘Intelligent units’ which record only when animals are present are now available, which contributes to the extension of battery life and deployment period. As an example, 10 pop-up units are sufficient to cover any whale activities in the Cape Cod Bay. One drawback that must be kept in mind when using this technique resides in the fact that only vocal animals will be detected.

- On the 100-meter shelf, an array of 6 bottom-set recorders would cover a 20 nautical mile detection range. A net of hydrophones connected to land, such as the net installed off Cape Cod, could be set in strategic areas, such as Cabot Strait or Belle Isle Strait to obtain information on movements of blue whales in and out of the Gulf of St. Lawrence. A net of hydrophones in Cabot Strait might cost ~$1/4 million dollars, with additional costs for any damages (e.g. in heavily fished areas there is a liability of hydrophones being picked up or of a line getting cut). Bottom-set pop-up recorders are cheaper: ten units could cost approximately $112K US. However, pop-ups do not transmit information in real time, so a different system is needed in situations where there is a need for transmission of information on the presence of marine mammals in real time (e.g. right whales).The use of a network of hydrophones should be combined with an approach using surveys to obtain estimates of whale numbers in the area.

- Passive acoustics is being used to count bowhead whales at Point Barrow, Alaska, using a radio-transmitting system. Technology using moorings has been developed for right whales in the U.S. : the moorings record a whale, they can trigger a cell phone to call to a land base and give the *count* of whales that were passing through the area. This type of approach may be possible in other areas where whales are channelled, such as Cabot and Belle Isles Straits.

- The volume of collected data can be very large but a lot of the initial processing can be automated. For example, about 100 hours of recordings can be selected randomly for a manual quality check on portions of the recordings. Most of the software is developed in Chris Clark’s lab and is transferred to the various researchers, assuming a 4-day training. In the short term, Chris Clark would need a person to develop the basic programs.

- A combination of a visual survey and passive acoustics in the Baja area revealed that only 25% of the singers were picked up by observers during the aerial survey. During other studies, a reversed trend was observed with animals present in the study area being missed (non vocal) on recordings.

- There exists several propagation models available through the web, and which are built with the purpose of determining the impact of sound sources on marine mammals. One example is the model produced through the program Effect of Sound on the Marine Environment (ESME) which was sponsored by the Office of Naval Research.

A multispecies, multilevel, multinational approach

The bowhead whales work forced National Marine Fisheries Service to find ways to integrate visual and acoustic data. For blue whales, a combination of acoustic and visual seems the best approach since acoustics will likely provide information on males but not females; visual surveys may miss males especially if they are down singing for a long time.

A combination of the two approaches may require some modifications in the visual survey protocol used traditionally, for instance the speed of the vessel. Vessel speed during a standard visual survey is usually around 10 knots. However, vessel speed would need to be reduced to 4 to 6 knots in order to lower ambient noise and obtain a better acoustic coverage.

All participants agreed that international collaboration is essential, regardless of some difficulties such as different laws, etc. at the governmental level. There is now a trilateral agreement between US, Canada and Mexico.

Estimation of the effects of seismic activity and shipping

Propagation models evaluate the cumulative impacts of noise on the animals and provide an indication of what proportion of the population will be exposed to high noise levels. The model by Bill Ellison estimates received noise levels, cumulative impacts of noise over time and potential impacts on behaviour. The model by Christine Erbe (DFO) integrates information on hearing sensitivity. Both types of models are needed.

The structure of the St. Lawrence is very variable, and there are many parameters to deal with.

The impacts of seismic activities are still unclear. However, it is now difficult to identify blue whales on the Grand Banks because of seismic activity. The whales seem to be there but are masked by seismic sounds. Seismic noise likely affects the capacity of whales to hear each other and thus, to communicate and find each other over large distances. Recordings of the high speed catamaran in the Bay of Fundy by Sean Todd indicate that this vessel is relatively quiet (90 dB).

RESEARCH PROGRAMS IN ICELANDIC WATERS (GÍSLI VIKINGSSON)

ABSTRACT

Research on blue whales in Icelandic waters in recent decades has included studies on distribution, abundance and stock structure. Information on summer distribution is mainly derived from systematic sightings surveys, which have been

conducted regularly since 1987 in co-operation with other nations in the Northeast Atlantic (NASS surveys). Other sources of distributional data are observations from platforms of opportunity, such as whaling vessels during 1979-1988, whale watching operations since 1987 and fish surveys. During summer, the highest densities of blue whales are found on the continental shelf off west Iceland. Another area of relatively high summer abundance is north and northeast of Iceland. Limited data, based on satellite tracking, indicates a connection between these two main areas of blue whale distribution (Heide-Jørgensen *et al.* 2001). Abundance in Icelandic waters appears to be highest during July and August, although some blue whales have been seen in winter despite low searching effort.

Based on observations made onboard whaling vessels Sigurjónsson and Gunnlaugsson (1990) found an increasing trend of 5.2% p.a. in blue whale relative abundance during 1979 -1988.

Estimates of absolute summer abundance of blue whales in Icelandic and adjacent waters based on the NASS surveys in 1995 and 2001 are 1330 (CV 0.40; 95% C.I 795-2224) and 1159 (CV 0.22; 95% C.I. 716-1875) animals, respectively. This compares to estimates of 442 (Gunnlaugsson and Sigurjónsson 1990) and 878 (Sigurjónsson and Víkingsson 1997) blue whales from the 1987 and 1989 surveys.

Since 1996 a research project involving identification and biopsy sampling has been conducted in coastal waters off west Iceland. Around 80 blue whales have been identified from photographs and 40 biopsies have been taken. The data are being analysed in co-operation with Richard Sears (MICS). No match has been found between photographs taken in Icelandic and Canadian waters.

Four fin whale/blue whale hybrids have been genetically verified in Icelandic waters since 1984. Three of these were caught in Icelandic whaling operations during 1983-1989 (Spilliaert et al. 1991, Arnason et al. 1991) and one discovered from a biopsy specimen taken in 1998.

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COMPLEMENTARY INFORMATION

Information on distribution and abundance are obtained using different approaches including dedicated large-scale surveys (North Atlantic Cetacean Sighting Surveys or NASS surveys), platforms of opportunity, and whale-watching operations.

NASS surveys were conducted in 1987, 1989, 1995 and 2001 and are scheduled to occur every 5-years.Coastal areas were surveyed using both aerial and floating platforms, whereas offshore areas were surveyed using aerial platforms exclusively. Primary targets of NASS surveys are fin and minke whales. However in 1987 the survey range was extended with the purpose of improving knowledge of sei whale distribution**.**.

Observers **on fisheries research vessels (platforms of opportunity)** have also reported sightings of blue whales. There is little effort and no observations from February to April. First sightings of the year are reported in May to the east of Iceland despite fairly even effort. There are only a few sightings in June, but little effort. In July and August, there are sightings around Iceland with a large effort and regular surveys. From September to November there is very little effort and no sightings of blue whales.

Whale-watching vessels operate west of Iceland in June and July. They target blue whales that are found near the coast.

Stock structure and migration information are derived from harvest statistics and satellite telemetry. Information provided by whalers indicates that blue whales tend to occupy the continental shelf near the slope. Fin whales are found further out, minke whales, further in, and humpback whales closer to blue whales. The relative abundance of these sightings peaks in July-August.

Two blue whales were equipped with satellite transmitters. One animal was tracked for 3 weeks, and travelled from near Spitzbergen to near Iceland along Greenland (this track is believed to be a common migration route; Heide-Jorgensen *et al*. 2001). The second animal did not travelled much, and remained in the same area during the entire deployment period.

DISCUSSION

Participants have proposed to couple distributional data derived from sightings surveys with the distribution of prey and oceanographic structures

No satellite tagging is planned for 2003-2004. However, there are plans to continue this program in the future (work done by Richard Sears, MICS).In 2002, deployment of satellite transmitters were attempted successfully on minke whales using a harpoon. This is an approach that might be possible on blue whales.

Stock structure analysis (using genetics techniques) may be feasible in future since skin biopsy samples have been collected and will continue in the next few years.

ICE ENTRAPMENTS OF BLUE WHALES IN SOUTHWEST NEWFOUNDLAND: 1868-1992 (DR. GARRY STENSON)

ABSTRACT

Ice entrapments of blue whales, *Balaenoptera musculus*, in Southwest Newfoundland

Garry Stenson, J. Lien, J. Lawson and R. Seton

Since 1979, cetacean sightings, strandings and ice entrapments were reported on a province-wide system established by the Whale Research Group at Memorial University or to DFO. Between 1968 and 1992, over 75 ice entrapment events of cetaceans were reported throughout the island. These events involved over 600 animals from eight species including blue, finback, minke, humpback, killer whale, harbour porpoise, white-beaked dolphin and narwhal. Entrapments occurred around Newfoundland although they were most common in the larger bays along the northeast coast (Placentia, Conception, Trinity and Notre Dame) as well as along the southwest coast from Burgeo to the Port-aux-Port Peninsula. With the exception of blue whales, no geographical patterns in entrapments of each species were evident. In contrast, blue whales were reported entrapped along the southwest coast only.

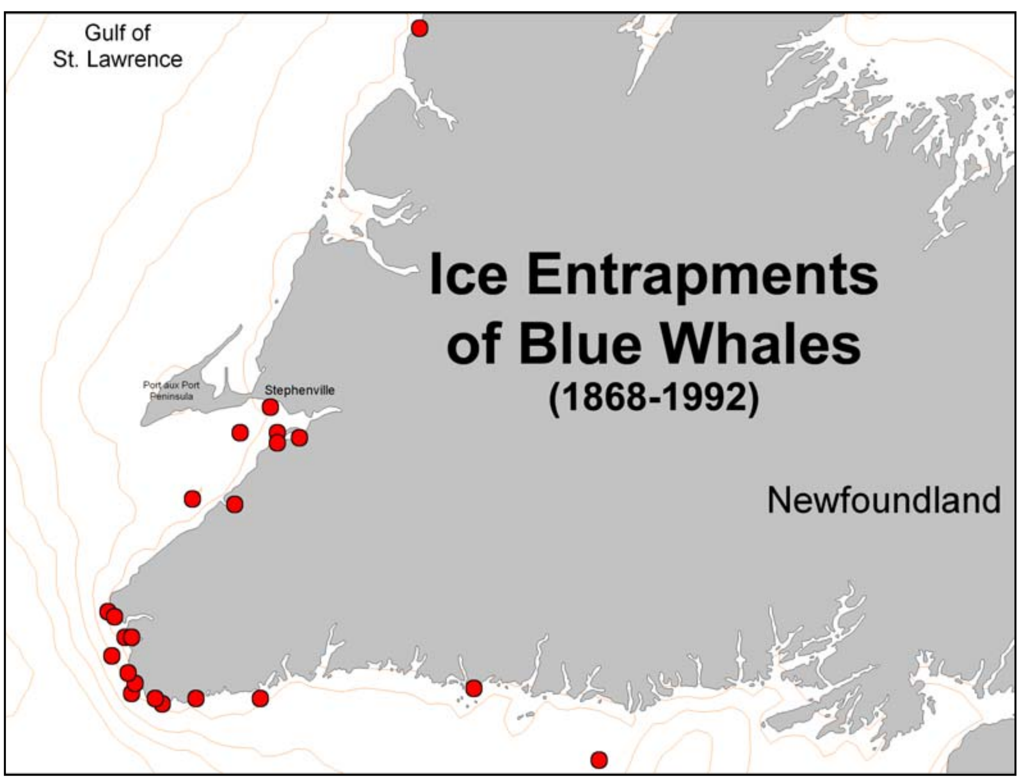
Ice entrapments of blue whales appear to be a regular occurrence along the southwest coast and were reported as early as 1868. A total of 23 blue whale ice entrapment events, involving approximately 41 individuals, were identified (Table 1). Individual events involved from one to four whales. Of those for which

information was available, all occurred during March and April. Twenty-eight of the whales were known to have died. Five escaped while the fate of eight others is unknown. When possible, stranded animals were examined. The majority ranged in length from 21-25 m, suggesting that many of these blue whales were adults. Two of the six animals sexed were females, one of which was pregnant.

Examination of ice and wind data for the area indicate that entrapments occurred only during years when ice coverage in the Gulf of St. Lawrence was extensive and ice extended into the Cabot Strait. The mean wind direction on days during which entrapments occurred was westerly (mean = 287^0, range = 250^0-300^0).

Geographic and meteorological factors provide a possible mechanism for these re-occurring ice entrapments. In these years of extensive ice, the maximum ice extent occurred in late February or early March and resulted in ice blocking entrance to the Gulf. However, due to the geography of the Port-au-Port Peninsula and the presence of a coastal current flowing into the Gulf, a strip of open water often persisted along the southwest coast of Newfoundland from Channel-Port aux Basques to the Port-au-Port Peninsula. The large number of sightings reported along the ice edge in this area suggests that blue whales utilise this open water area during the winter, possibly for feeding. Westerly (and possibly southerly) winds could drive ice into this open water and, if it is of sufficient strength and/or duration, could entrap blue whales and other cetaceans present along this area of the coast.

Figure 1 Locations of ice entrapments of blue whales (1868-1992) around Newfoundland



Discussion

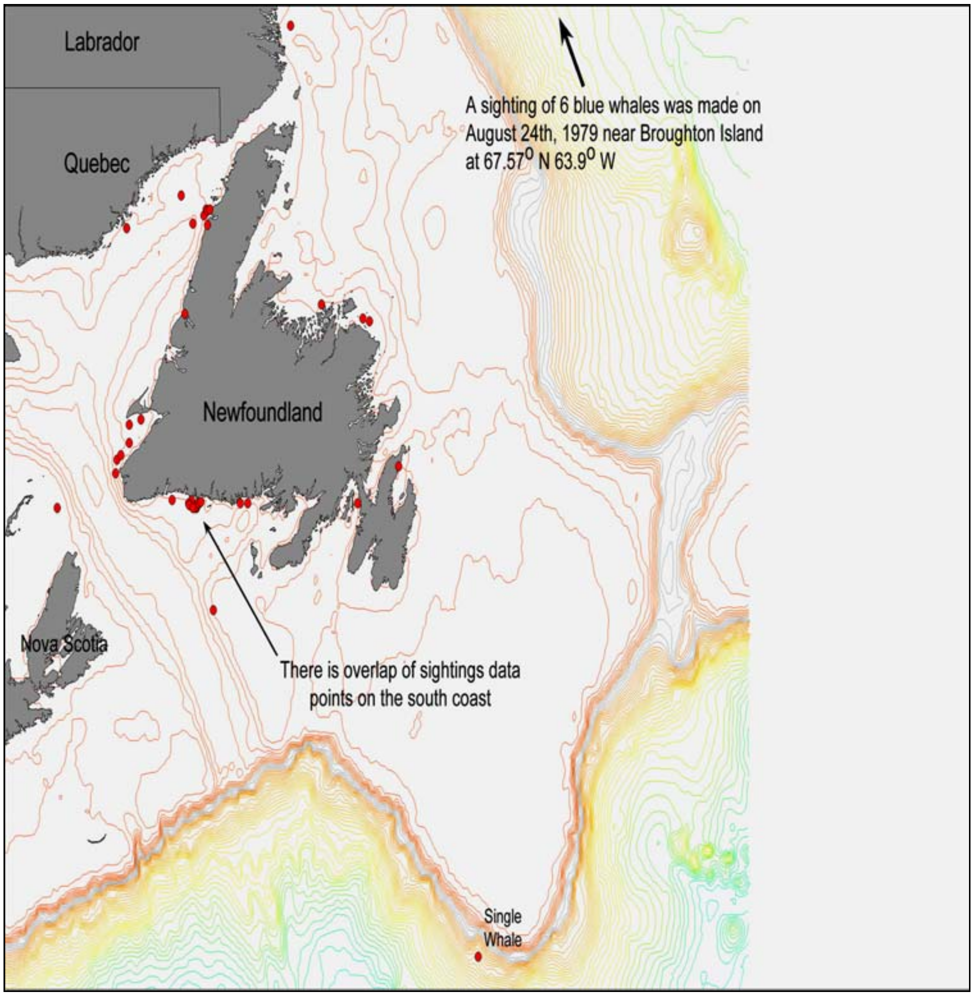
Relatively high abundance of euphausids can be found in the eastern areas of the Gulf of St. Lawrence. This zooplankton abundance may be the reason why blue whales are attracted to this area.

DISTRIBUTION OF BLUE WHALES IN NEWFOUNDLAND AND LABRADOR (DR. JACK LAWSON)

Abstract

Cetacean distribution around Newfoundland and Labrador has not been investigated systematically in the last several decades. What data exist have been derived from information provided in many small-scale and/or opportunistic sources (e.g., dedicated marine mammal aerial and shipboard surveys, fisheries officers, fisheries observers, tour boat operators, and marine vessel personnel on ferries, commercial shipping, supply vessels, commercial fishermen). Forty-three blue whale sightings, of 83 individual whales, have been made since 1958 (in 1958, 67, 75, 79, 80, 82, 83, 88, 90, 91, 92, 98, 99, 2002), and in all months of the year. There are also historical sighting records and whaling data that pre-date these years, but it is not possible to map many of these older sightings presently. Blue whales have been seen at locations around Newfoundland (with several on the Labrador coast), although this sighting pattern may be a function of sighting effort. More sightings have been made along the south and west coasts of Newfoundland, where there is indication that some individuals may overwinter. Blue whales were sighted primarily as single individuals, although up to seven whales have been seen at one time (mean=1.91 whales per sighting). Where known, most sighted blue whales were adults, and no mother/calves have been recorded in the database, or reported recently near Newfoundland.

Figure 2 Distribution map of blue whale sightings in Newfoundland and Labrador



COMPLEMENTARY INFORMATION

Sighting data are not corrected for effort. They are all georeferenced in MapInfo

DISCUSSION

A problem with data on blue whale sightings is that people have difficulty differentiating blue whales from fin whales: tour boat operators will often assume that large whales or blows are fin whales.

FUTURE WORK

- Use platforms of opportunity such as ferries on the south coast of Newfoundland and fishery vessels to obtain information on blue whale distribution
- Conduct surveys in Labrador (but logistically very expensive)

MORTALITY OF BLUE WHALES (DR. LENA MEASURES)

ABSTRACT

Blue whales like all rorquals pose certain problems in the study of causes of mortality and risks to recovery. Rorquals sink when dead, may not re-float due to formation of decompositional gases and are often found in advanced stages of decomposition (Code 3 and 4) compromising study of disease. The large size of blue and fin whales also require heavy equipment and a team of prosectors in order to conduct a detailed necropsy. From 1951 to 2002 some 40 blue whales have been reported dead on the east coast of Canada. Blue whales have been found dead in the Gulf of St. Lawrence and on Sable Island (Scotia-Fundy). Within the Gulf of St. Lawrence, carcasses have been found on the north shore of the Gulf, Anticosti Island, Baie des Chaleurs, Prince Edward Island and on the west coast of Newfoundland. In most cases the cause of death has not been determined. Differentiating carcasses of fin whales from blue whales can be problematic when non-specialists are involved in documenting mortalities. Collisions with large ships, ice entrapment and disease have been reported as causing the death of blue whales. Other threats to blue whales include contaminants (industrial, biotoxins, pathogens) and possibly predation by killer whales and fishing gear entanglement. Fast ferries and whale watching activities within the St. Lawrence estuary and elsewhere and environmental change affecting zooplankton biomass may also be significant threats to blue whales.

COMPLEMENTARY INFORMATION

A marine mammal health program has been in place since 1996 at the Maurice Lamontagne Institute.

As part of this program, marine mammal carcass preservation is coded from 2 to 5 (2 being excellent, Code 1 being a live animal). Because the skin sloughs off, it is difficult to identify large rorqual species based on colour when carcasses are coded 3 or 4. The examination of baleen is useful in identification. Dorsal fin placement is rarely useful as most large rorqual carcasses are found in dorsal recumbancy. Standard measurements, presence of parasites, pathogens or lesions are noted during necropsies.

A few live strandings of rorquals have been reported.

Since 1951, all documented mortalities of large rorquals in eastern Canada were immature animals. Possible causes of mortality include *Crassicauda boopis*, am up to 2-meter long nematode found in the urogenital system and its vasculature, mesenteric arteries and vena cava of 90 to 95% of fin whales in the North Atlantic (stranded and harvested animals). This parasite is reported to be fatal causing natural mortality of young fin whales in the North Atlantic. It is also reported in blue whales.

There was evidence of ship collision on some examined large rorqual carcasses. Some superficial scars were old, showing evidence of healing and were not associated with death. In other cases, there were broken bones with considerable local haemorrhage indicating the animal was alive at the time of collision. Ice entrapment is another known source of mortality for blue whales.

Potential threats to blue whales in the estuary and Gulf of St Lawrence include fishing gear entanglement, collision with large cargo, whale-watching vessels or fast ferries (e.g. CNM Evolution, linking Rimouski to Forestville, monitors whale activity during their traverse of the St Lawrence estuary), and ice entrapment. Predation by killer whales and contaminants (immunotoxins, endocrine disruptors, biotoxins) are also other potential threats to blue whales which may warrant future research.

DAY 2 OPENING REMARKS (DR. MIKE HAMMILL)

KNOWLEDGE GAPS OR THREATS TO BE DISCUSSED

- Seasonal distribution and habitat use
- Diet and food availability
- Abundance
- Noise exposure (seismic, whale watching, shipping)
- Stock structure
- Contamination
- Sources of mortality
- Population parameters

SEASONAL DISTRIBUTION (MODERATOR: DR. MIKE HAMMILL)

CURRENT KNOWLEDGE, GAPS AND THREATS

The participants reviewed the available information on seasonal distribution of blue whales and identified knowledge gaps and threats.

Table 1 summarizes existing data and information needed regarding seasonal distribution and habitat use of the Northwest Atlantic blue whales.

Table 1. Existing data and information needed regarding seasonal distribution of Northwest Atlantic blue whales

EXISTING DATA	INFORMATION NEEDED
• Estuary and northern Gulf of St Lawrence, between May and November (R. Sears, MICS) • Summer surveys near Cape Breton and on the Scotian Shelf (H. Whitehead, Univ. of Dalhousie; K. Smedbol, DFO) • Anecdotal reports (sightings and entrapments) in Newfoundland G. Stenson, J. Lawson, DFO) • NOAA surveys in north-eastern U.S. waters and on the Scotian Shelf	• Nova Scotia, Newfoundland, Labrador • Distribution information during winter everywhere.

EXISTING DATA	INFORMATION NEEDED
• Whaling data • Distribution of krill in the St Lawrence Estuary (Y. Simard, DFO)	

DISCUSSION ON APPROACHES AND TECHNIQUES

Surveys, passive acoustics, photo-identification and satellite telemetry were suggested as methods for addressing seasonal distribution and habitat use. Pros and cons of these approaches and techniques were reviewed.

The following table summarizes the advantages and disadvantages of ship-based sighting surveys to assess seasonal distribution and habitat use of the Northwest Atlantic blue whales.

Table 2. Pros and cons of ship-based visual surveys for the assessment of seasonal distribution of Northwest Atlantic blue whales.

PROS	CONS
Platforms of opportunity (POPs) can be conducted from a variety of platforms such as long line fishing vessels, fishery or oceanographic research vessels, etc. • Provides a platform from which a secondary vessel can be launched for photo-identification, biopsy sampling, etc. Cheap ! • Provides the opportunity for additional information on physical or biological oceanographic characteristics of the habitat such as water temperature and salinity, densities of phytoplankton, zooplankton, fish, etc. • Any survey could be designed to obtained information on other species • Possibility of coordination with neighbouring countries (e.g. NOAA) to simultaneously cover larger areas	**Platforms of opportunity (POPs)** • Sampling grid not designed for marine mammal surveys • Some whales available at the surface are missed • Blows at a distance are difficult to identify • Weather dependent • Slow, time consuming • Observers need training to ID whales • Large boats necessary for work in Newfoundland and offshore
Dedicated cruise • Can provide information on several species • Possibility of using smaller vessels in coastal areas • Possibility of combining visual surveys with passive acoustics using a towed array • Possibility to target productive areas	**Dedicated cruises** • Costs are very high (15K US$ per day) • Time-consuming

REMARKS:

J. Lawson (DFO) is working on a training package for observers. For observers training, G. Stenson recommends to focus on crew members (less turnover).

AERIAL SURVEYS

The following table summarizes the pros and cons of aerial surveys for assessing seasonal distribution and habitat use of the Northwest Atlantic blue whales.

Table 3. Pros and cons of aerial surveys for the assessment of the seasonal distribution of Northwest Atlantic blue whales

PROS	CONS
• Less expensive than ship-based surveys, especially with Cessna 337 as opposed to Twin Otter. • Large area can be covered in a short period • Possibility of photo-ID using digital cameras • Rapid, so can take advantage of short windows of good weather • A double-platform approach could yield better correction factors • Possibility of platforms of opportunity (POPs) through ice patrols flown at 1000-feet	• Very large correction factors for missed marine mammals • Ice patrol flights may be too high or too rapid to allow acceptable data acquisition

ACOUSTICS

The following table summarizes the pros and cons of acoustics research for assessing seasonal distribution and habitat use of the Northwest Atlantic blue whales.

Table 4. Pros and cons of passive acoustics for assessing seasonal distribution of Northwest Atlantic blue whales

PROS	CONS
• Technology is available, and several tools exist: pop-ups, existing arrays (NOAA), sonobuoys, towed arrays • Can provide information on several aspects	• Not all animals are vocal, so may provide only partial information • Expensive tools ($250K US for a full array), but costs are dropping

PROS	CONS
(distribution, relative abundance, stock structure, noise exposure, movements and habitat use) • Not weather dependent • Wide coverage: whales can be detected 20 nautical miles away when on the shelf, and 100 nautical miles away when off the shelf • Instruments reusable • Smaller instruments (e.g. sonobuoys) can be deployed from small crafts or plane. Larger instruments could be deployed by taking advantage of platforms of opportunity • Long-term monitoring (up to 6 mo at a time) for some of the instruments (e.g. pop-ups) • Data processing partially automated	• Data processing not all automated; costs associated with maintenance of the system, manual processing, development of processing software • Will need a good platforms to handle and process data, hi-power computers • Seismic and other noise (e.g. engine noise from towing vessel) may mask calls / reception of calls • Will provide mostly presence/absence of animals, not numbers • Should be deployed outside fishing areas to avoid loss of instruments; likely involves additional costs for replacement of lost or damaged instruments; more difficult to deploy in the winter • Difficult to tow arrays at regular speed, boat may need to slow down, not possible on all POPs

PHOTO-IDENTIFICATION

Photo-identification is a very powerful tool: it is the backbone of the long-term study of blue whales. It provides information on seasonal distribution and provides a longitudinal component.

Table 5 summarizes the pros and cons of photo-identification for assessing seasonal distribution and habitat use of the Northwest Atlantic blue whales.

Table 5. Pros and cons of photo-identification for the assessment of the seasonal distribution of Northwest Atlantic blue whales

PROS	CONS / NEEDS
• Provides information on different aspects of the biology and ecology of blue whales including seasonal distribution, social structure, reproductive rate, etc. • Provides longitudinal information on individual whales • Existing data base provides a good, long-term coverage of the St Lawrence Estuary and northern Gulf • Manual, but relatively rapid matching of	• Time consuming in both data acquisition and data treatment and maintenance of a catalogue • In order for this tool to be powerful, effort needs to be recorded and standardized, and needs to follow an acceptable statistical design • Need spatio-temporal improvement in sampling effort: no information in many areas

PROS	CONS / NEEDS
pictures (less than 15 minutes for an experienced observer).	• Need method and protocol standardization for date acquisition and data treatment • Need for a formal curator, networking agreements for data sharing, and regional. standard catalogues • Virtual web-based database with controlled access could solve data back up and data sharing provided that formal agreement on data access and sharing are in place

SATELLITE TAGGING

Table 6 summarizes the pros and cons of satellite tagging for assessing seasonal distribution and habitat use of the Northwest Atlantic blue whales.

Table 6. Pros and cons of satellite tagging for assessing seasonal distribution of Northwest Atlantic blue whales

PROS	CONS / NEEDS
• Relatively simple to deploy from a small craft • Provide fine scale information on movements and residency times • Costs relatively low for each tag ($5000 cdn). Additional costs for data transmission through ARGOS for organisations other than non-profit groups, • Current tags provide only information on position and surface temperature	• Relatively invasive technique compared to the other techniques available to obtain information on distribution and movements (complaints from animal rights groups) • Infection risks have not been assessed • Deployment duration with previous tags has been relatively short, but new designs show promise in terms of increased deployment duration • Provides a limited sample size • Costs rapidly become an issue when aiming at larger sample sized

RESEARCH PRIORITIES

The last section reviews the different techniques that could be used to acquire new data on seasonal distribution and habitat use of the Northwest Atlantic blue whales. Table 7 summarizes the research techniques suggested for short-term, medium-term (5-year horizon) and long-term assessments.

Table 7. Techniques recommended to assess seasonal distribution of Northwest Atlantic blue whales.

SHORT-TERM	5-YEAR-HORIZON
• Ship-based surveys • Aerial surveys • Passive acoustics • Photo-identification • Satellite telemetry	• Ship-based surveys • Platforms of opportunity with small craft access • NOAA surveys • Pop-ups • Observers network • Oceanographic buoys • Prediction of krill potential hot spots using modelling • Access to Chris Clark's database for Canadian waters • Satellite telemetry (medium term) • Photo-identification (medium term) • Methods providing multiple information should be preferred
LONG-TERM	Maintain most of these projects in the long-term

ABUNDANCE

KNOWLEDGE GAPS AND THREATS

In consensus with the COSEWIC report, all participants agreed that low abundance is the biggest concern for the Northwest Atlantic blue whale population. Actions that contribute to a better understanding of this item should have the highest priority. The basic research needs within five years, perhaps as part of a recovery strategy, are as follows:

(1) Clarification of the distribution of blue whales in the Northwest Atlantic: are all NW Atlantic blue whales found in the Gulf ? Where do they go when they are not in the Gulf? Are there other areas of residence, or other "stocks"? Do some whales *never* enter the Gulf?)

(2) Which of the platforms of opportunity, small craft access, NOAA surveys, or passive acoustics will provide useful information on the distribution and abundance of blue whales?

(3) How many whales are there now, and is this number changing?

DISCUSSION ON TECHNIQUES

Most of the techniques reviewed to assess seasonal distribution will also yield information on abundance. However, the approach to yield population estimates or only information on presence / absence of animals will be different. All techniques and platforms have pros and cons.

Because of COSEWIC, emphasis over the next 5 years should be on getting distribution and number estimates, as trends cannot be determined within five years.

To get some idea of variability, most techniques should be maintained for medium- and long-term horizons. The following table presents techniques that were suggested for assessing the abundance of the Northwest Atlantic blue whales, both in the short term and on a five-year horizon.

Table 8. Techniques or actions recommended for assessing abundance of the Northwest Atlantic blue whales

SHORT-TERM	5-YEAR-HORIZON

• Ship-based surveys
• Aerial surveys
• Passive acoustics
• Photo-identification
	• Dedicated ship-based / aerial surveys (in coordination with NOAA)
	• Acoustics - towed arrays (longer term)
	• Correction factors (TDRs / passive acoustics information)
	• Photo-identification
	  o Standardize sampling design and methods for photo-identification
	  o Expand photo-identification effort
	• Pilot studies
	• Take advantage of platforms of opportunity

STOCK STRUCTURE

The following table presents the techniques participants set forward to assess abundance of the Northwest Atlantic blue whales, both in the short-term and on a five-year horizon.

Table 9. Techniques recommended for assessing stock structure of the Northwest Atlantic blue whales.

SHORT-TERM	5-YEAR-HORIZON
• Existing data	• Existing data (short-term)
• Passive acoustics	• Photo-identification (long-term)
• Photo-identification	• Acoustics (long-term)
• Genetics	• Contaminants (long-term)
• Satellite telemetry for residency, migration and individual associations	• Satellite telemetry (long-term)
	• Genetics

DIET AND FOOD AVAILABILITY

The location of blue whale aggregations could be predicted using models of prey abundance (e.g., zooplankton data collected by DFO and others, oceanographic data and modelling) and aggregation. This data could then be used to stratify sampling using other approaches (e.g. aerial, ship-based surveys).

Yvan Simard (DFO) made a short presentation: "KRILL'N BLUES"

- A study from 1994 combined ship and aerial surveys near les Escoumins to examine the link between blue whale and krill distribution and densities. In general, the presence of blue whales appeared to be correlated with the richest krill aggregation areas. There were blue whales sighted in areas of greatest krill density, although there were situations when many blue whales were sighted, but no krill aggregations were detected);
- Krill distribution in the St. Lawrence estuary also seems to match the information obtained by Richard Sears on blue whale distribution, but more work needs to be done;
- The St. Lawrence estuary is one of the richest krill aggregation in the Northern Atlantic. Krill concentrates during daytime by upwelling at topographic boundaries where the flow is directed against the slope. These relationships between bathymetric, oceanographic hydrodynamics, meteorological, and biological factors that affect krill aggregation have been integrated into models. From these data, models of krill distribution have been created and predictions will be made of krill "patchiness" (François Saucier, DFO). A study is ongoing to ground-truth these models.

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The following table shows short-term and medium term research priorities to assess diet and food availability of the Northwest Atlantic blue whale.

Table 10 Techniques recommended for assessing diet and food availability of the Northwest Atlantic blue whales

SHORT-TERM	5-YEAR-HORIZON
• Zooplankton abundance and distribution data • Oceanographic modeling • Diet (dive patterns, fatty acids, stable isotopes, direct observations, faeces, stomach contents)	• Whale tagging (TDRs) coupled with acoustic surveys • More work on prey • Fatty acids • Stable isotopes in baleen and skin (medium term) • Evaluate potential for competition

HABITAT USE (overlaps with seasonal distribution)

Many approaches overlap with techniques discussed for research on seasonal distribution, prey availability, and physical oceanography. In the longer term, research on habitat use may yield information to identify critical habitats.

All of the above approaches could be improved and utilized in the medium and long-term. Table 11 reviews the techniques that could be used to identify habitat use of the Northwest Atlantic blue whale, both in the short- and long-term.

Table 11. Approaches recommended for assessing habitat use of the Northwest Atlantic blue whales.

SHORT-TERM	5-YEAR-HORIZON
• Dive patterns, migration routes, residency (TDRs, photo-identification, passive acoustics, physical environment)	• Identify critical habitat • Body condition evaluation (lipid contents, blubber thickness?)

POPULATION PARAMETERS

Reproduction and recruitment are key requirements to answer this question.

The following table summarizes both short-term and medium-term techniques for assessing population parameters of the Northwest Atlantic blue whale.

Table 12. Techniques recommended for assessing population parameters of the Northwest Atlantic blue whale

SHORT-TERM	5-YEAR-HORIZON
• Mortality rates and inter-calf ratio through mark-recapture (photo- identification) • Reproductive status through steroid hormones in the blubber • Sex ratios through genetics and biopsies	• Sex ratios and reproductive status • Whaling data for reproduction • Population model • Reproductive rate (long-term) • Mortality rate (long-term) • Modelling (Usher's Leslie Matrix work for the IWC)

HUMAN-RELATED ACTIVITIES (CONTAMINANTS, NOISE, COLLISIONS, MORTALITY, ETC.)

Table 13 summarizes short-term and medium-term techniques recommended by the participants for assessing impact of human-related activities on the Northwest Atlantic blue whale.

Table 13 Techniques recommended for assessing impact of human-related activities on the Northwest Atlantic blue whales

SHORT-TERM	5-YEAR-HORIZON
• **Contaminants** o Biopsies o Carcasses o Faeces analysis for stress hormones o Standardize storage of blubber samples • **Noise (seismic, shipping, whale-watching)** o Passive acoustics (source levels and signatures, propagation patterns, ambient noise) o Acoustic modeling (propagation models and noise impact models) o Whale tracking (TDRs -VHFs) o Auditory potential of blue whales • **Collisions and disease** o Detailed necropsies, standing network o Reporting collisions	o Most of short-term techniques can be maintained o Ice entrapment o Overlay ship and whale distribution o Stranding network o Harmful algal bloom o Pathogen pollution

CONCLUSIONS AND RECOMMENDATIONS

KNOWLEDGE GAP PRIORITIES

Participants agreed that a priority should be made of addressing knowledge gaps on seasonal distribution, abundance, stock structure and seasonal movements. A priority should also be made of determining and defining breeding and feeding areas, and the extent to which physical and biological processes determine distribution, behaviour, and movements. Critical habitats should be identified.

ACTIONS

To address these knowledge gaps, the following actions were generally recommended:

- Expand coverage and effort to improve information on abundance and distribution using a combination of techniques including visual surveys, photo-identification and biopsy sampling (by a co-ordination of effort in the different areas and data sharing, and expanded acoustic efforts)

- Setting up protocols for blue whale catalogue and sampling protocols and storage
- Take advantage of identified areas, build on existing knowledge
- Pilot studies: develop techniques and analytical approaches in areas where animals are known, or in known areas of frequentation
- Where strandings occur, efforts should be made to conduct complete necropsies on these animals in order to obtain information related to contaminant levels, nutritional condition, reproductive parameters and cause of death. These efforts should be coordinated through IML, the Atlantic Veterinary College, University of Montreal Veterinary College and possibly with provincial efforts in NF.
- Develop a virtual data bank.

The following table can be an additional tool to help managers evaluate the relevance of research projects on the Northwest Atlantic blue whale. The different techniques are categorized according to their capability of filling the various knowledge gaps.

Table 14. Relevance of techniques in addressing knowledge gaps on the Northwest Atlantic blue whales

	SEASONAL DISTRIBUTION AND ABUNDANCE	DIET AND FOOD AVAILABILITY	STOCK STRUCTURE	HABITAT UTILISATION	SOURCES OF MORTALITY	CONTAMINATION	SEISMIC, SHIPPING, DISTURBANCE	POPULATION PARAMETERS
Platform of opportunity - boat	y	y						
Platform of opportunity - plane	y							
Directed surveys –ship	y							
Directed surveys – aerial	y							
Photo-identification	y		y	y				y
Towed array	y							
Autonomous recorders (Pop-ups, others)	y		y	y			y	
Hydroacoustics surveys		y						
Physical environment	y	y		y				
Acoustic modeling							y	
Modeling prey distribution	y	y						
Satellite tagging	y			y				
TDR-VHF tracking		y		y			y	
Genetics			y					
Biopsies		y	y			y		y
Stranding network					y			

	SEASONAL DISTRIBUTION AND ABUNDANCE	DIET AND FOOD AVAILABILITY	STOCK STRUCTURE	HABITAT UTILISATION	SOURCES OF MORTALITY	CONTAMINATION	SEISMIC, SHIPPING, DISTURBANCE	POPULATION PARAMETERS
Detailed necropsies		y			y	y		
Reporting collisions					y			
Fatty acids		y						
Body condition evaluation				y				
Faeces analysis		y	y			y		