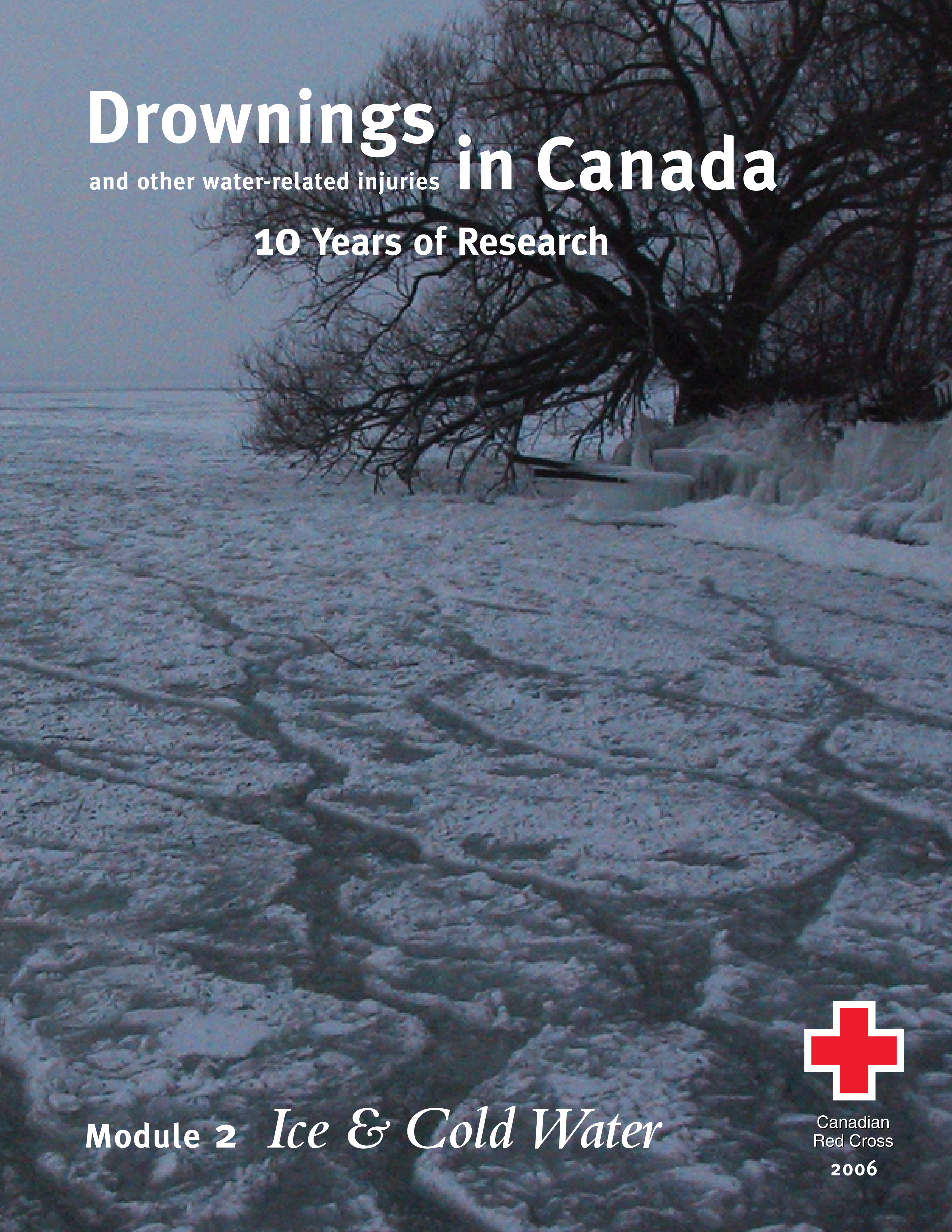
Drownings in Canada

and other water-related injuries

10 Years of Research



Module 2 *Ice & Cold Water*

Canadian Red Cross

2006

This research is dedicated to the 2,007 persons who died of cold immersion in Canada during 1991-2000. May the evidence of the circumstances of their deaths be a guide to safety for the many Canadians who venture forth on the ice or cold water for recreation, daily life, or work, and for professionals and decision makers with a duty to protect the vulnerable.

Throughout the days and nights there was much conversation as to how and why it had all happened. Everyone agreed that my father was "a good man on the ice" and it was true that they had crossed over the same route earlier in the day. It was true, also, that the currents and tides were running freely and had perhaps eaten away more of the underside of the ice than anyone had realized. And, it was, after all, the end of March and the sun had been shining, although it did not seem to have been that strong. It all remained somehow, most inconclusive.

It was generally decided that it was an "act of God", as the insurance companies might term it, although clann Chalum Ruaidh *referred to it as "God's will" and trusted in His Mercy. Some others who had read or misread the Book of Job saw it as an example of God's justice and his punishment, and cast about for reasons.*

– Alistair MacLeod, *No Great Mischief*, 1999

Drownings and Other Water-Related Injuries in Canada, 1991-2000
Module 2: Ice & Cold Water

For a pdf version of this module, please visit our website at www.redcross.ca

This Visual Surveillance Report was developed and written by Dr. Peter Barss, in collaboration with Christy-Ann Moore of the Canadian Red Cross, and with the assistance of Cait Beattie of Résolutique Globale. Sophie Lapointe, research technician, carried out the data analysis.

Data collectors included volunteers and staff of the Canadian Red Cross and the Lifesaving Society. Data collection was made possible through the assistance and co-operation of provincial coroners, medical examiners, their statistical staff, and the National Association of Coroners. Financing of the work was done collaboratively by sharing resources and staff. Data collection mainly involved the Canadian Red Cross, the Lifesaving Society, and provincial coroners. Data coding, verification, and entry were supported by the Canadian Red Cross and the Lifesaving Society, and carried out by Isabelle Masson, Peter Barss, and Sophie Lapointe.

The National Search and Rescue Secretariat and the Canadian Red Cross Society funded data analysis and writing, as well as editing, design, and layout of this 10-year report. Christy-Ann Moore of the Canadian Red Cross coordinated this process. Monique Edwards of the Canadian Red Cross supervised translation and revision in French, with the assistance of Martin Côté and Mariella Choo Fon. The Canadian Coast Guard and Transport Canada sponsored the project and monitored its progress. The Research Institute of the McGill University Health Centre provided administrative support for data management. Health Canada supplied data for snowmobile deaths from trauma, i.e. collisions. The Cook-Rees Memorial Fund For Water Search And Safety supported the printing of this module.

Thanks to the following experts who kindly reviewed the document and provided helpful input to the introduction and conclusions: Dr Michel Ducharme, Head/Human Protection and Performance Group, Dr Peter Tikuisis, Defence R&D Canada; and Dr Chris Brooks, Survival Systems, Halifax.

For the initial six years, the National Drowning Report and related special interest reports were generously supported by The Injury Prevention Module of the Régie régionale de la santé et des services sociaux de Montréal-Centre, a member of the World Health Organization's Collaborating Centre for Injury Prevention and Safety Promotion. Rosemary Hong, former coordinator for drowning research at the Canadian Red Cross, inititated this 10-year modular project.

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Ce rapport est aussi publié en français.

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Death in cold water is frequent in northern countries such as Canada. All Canadians should be familiar with the main activities associated with death from cold immersion, together with the most appropriate preventive measures.

Deaths from immersion mainly occur from drowning and/or hypothermia. An immersed non-swimmer who is not wearing a flotation device may drown right away from submersion of the airways under water, which causes aspiration of water into the lungs resulting in lack of oxygen for vital organs.

Immersion in cold water adds an extra element of risk and can cause death from drowning, hypothermia, and occasionally from cardiac effects such as arrhythmia. There are four sequential stages of the physiological effects of immersion in cold water, and death can occur at any stage. Stage 1 involves initial skin cooling, stage 2 is short-term immersion with cooling of superficial nerves and muscles, stage 3 is long-term immersion with cooling of deep organs, and stage 4 includes post-immersion changes during and after rescue (Tipton and Golden, 2006; Golden and Hervey, 1984).

The first and immediate stage of cold immersion is characterized by gasping and rapid breathing or hyperventilation as a reflex response to sudden immersion in cold water. If the victim's head is not kept well above the surface of the water by a flotation device, or if waves are breaking over their head, he/she may aspirate water and die from drowning within 5 minutes. Occasional victims may die of reaction by the heart to the sudden impact of cold on the body.

The second stage of cold immersion is characterized by impaired muscle contraction and nerve conduction in the extremities, leading to inability to hold on to an overturned boat or other floating object, inability to swim, inability to maintain body orientation to avoid aspirating waves, and difficulty in self-rescue. The victim then aspirates and drowns. This stage has its onset after the victim manages to survive 10 to 20 minutes, or longer if the victim is wearing protection from cold.

The third stage of cold immersion is hypothermia, which occurs after some hours of immersion, as in the case of a person wearing flotation sufficient to keep the airways clear of water. Cooling of vital organs such as the brain and heart leads to decreasing levels of consciousness, cardiac arrhythmias, and death.

The fourth stage of cold immersion involves collapse during and after rescue. The underlying mechanisms may be cardiovascular changes such as low blood pressure or hypoxia from aspiration of water, i.e., drowning.

It is believed from experimental and field observations that most deaths in cold water occur from drowning either immediately by submersion of the airways or during the first two stages of cold immersion. Unfortunately, routine data from coroners and police do not tend to include observations that are sufficiently detailed to distinguish drowning that results from simple inability to swim with submersion, or within one of the four stages of cold immersion. Therefore, in the results section of this report we do not differentiate deaths within the four stages of death from cold immersion, only between drowning (with or without hypothermia) and hypothermia without drowning. When a victim dies during prolonged cold immersion while wearing a flotation device and autopsy shows no evidence of drowning, i.e., fluid in the lungs, it is probable that hypothermia, the third stage of cold immersion, was the cause.

In this research report, we assess the most frequent activities on the ice and activities in, on, or around the water that were associated with cold water immersion deaths, together with the determinants for each activity. The report focuses on the incidence or rate of death and trends during 1991-2000, and on personal, equipment, and environment risk factors. In the discussion, we consider the most appropriate prevention measures, based upon the epidemiological data and other research.

The report has been prepared to provide an epidemiologic profile for prevention. Injury incidents are often multifactorial. Nevertheless, a favourable change in a single factor can be sufficient to tip the balance sufficiently away from danger in favour of safety to prevent an incident from occurring. This is pre-emptive action in the pre-event phase. Appropriate safety equipment or reaction can prevent injury even if an incident does occur; in this case, injury is aborted or attenuated in the event phase. Finally, post-event phase activities after an injury has occurred, such as rapid intervention with lifesaving, first aid, appropriate methods of rewarming, CPR, and so forth, can minimize, stop, or reverse the progression of damage from any injuries sustained during the event phase.

The main activities associated with cold water immersion deaths include boating, snowmobiling, other types of land and air transport, non-aquatic activities such as walking, playing, and skating on ice, and other non-aquatic activities. As for the purposes of activities leading to cold water immersion deaths, recreational, daily life, and occupational activities are all implicated in descending order of frequency.

While as human beings we are not well-equipped in our natural state to deal with cold immersion, with available knowledge and education most cold water immersions should be avoidable, or at worst, survivable with appropriate safety equipment, evidence-based action, and timely rescue.

The main emphasis of this report is ice-related immersions, resulting from snowmobiles and other vehicles on ice, and from non-motorized activities on ice such as walking, playing, skating and fishing. Boating deaths are described in detail elsewhere in this series; however, since this category dwarfs all others for cold water immersions, we have also included a section on boating. Limited details are also provided for non-ice-related aquatic and non-aquatic activities, as well as for land and air transport.

First, consider **snowmobiles**. There are two main lethal hazards associated with snowmobiling: collision and cold water immersion. These hazards share certain risk factors, but differ with regard to others.

Most research on snowmobile fatalities has been based on hospital data with an emphasis on collisions. On that basis, snowmobiling is reported to be one of the most dangerous recreational activities in Canada, second only to cycling (Canadian Institute for Health Information, 2003). Unfortunately, that report included only in-hospital deaths, so it was an inconclusive guide to overall mortality from sporting activities. Hospital data are biased towards survivors, and those who die before arrival at hospital tend to be forgotten, and under-reported. Indeed, if we were to include cold immersions and trauma from collisions, and consider the number of severe and fatal injuries per participant hour of exposure, snowmobiling would surely be ranked the most dangerous recreational activity in Canada.

Snowmobiling is an activity where safety is a function of the interaction of multiple risk factors. These include personal factors relating to the driver, equipment factors relating to the snowmobile and safety devices, and environment factors. Personal factors include age, sex, alcohol, ethnicity, and fatigue. Equipment factors include features of the snowmobile such as speed, weight, flotation, lighting and braking systems, and safety equipment such as hypothermia-flotation suits, ice picks, face protection and mitts to cut wind and cold, and helmets. Environment factors include type of body of water, currents and tides, ice conditions, visibility, season, and geographic region. Rescue factors include the presence of other snowmobilers and availability and skilled use of safety equipment such as throw bags.

Snowmobiles are used for recreational, daily living or subsistence, and occupational travel. Snowmobiling itself may be the main activity, or it may be subsidiary to another activity such as ice fishing, hunting, or travel.

Immersion incidents result from driving into an open hole in the ice, breaking through thin ice, driving into the open ocean at the edge of ice, or trying to skim across open water between ice floes at high speed. Most incidents should be avertable by careful documentation of risk factors followed by implementation of appropriate countermeasures.

Second, consider **immersions from non-motorized activities on ice**. Such incidents tend to involve mainly children playing on ice or adults walking on ice. Ice fishing, skating, and hunting are the other main activities associated with such incidents. Personal factors include age and sex, alcohol and other drugs, and ethnicity. Equipment factors, seldom recorded in official reports, include whether ice picks were carried and use of protective clothing for body, face, and hands to prolong life and enhance the capacity for self-rescue. Environment factors include the type of body of water, current, ice conditions, visibility as affected by time of day, month, geographic region, and for children, adult supervision.

Finally, cold immersion deaths from **boating** primarily involve adult males, particularly during spring and autumn months in coastal and northern regions and ocean waters. Fishing is a frequent activity, and includes recreational, occupational, and daily living incidents. Subsistence hunting and boat travel are also essential activities of daily life for aboriginal peoples.

This report is based on annual data collected by coroners and police, and recorded in provincial and territorial coroners' files across Canada. The details of each incident were recorded in a 15-page structured questionnaire and converted into electronic format for analysis. The abstraction of information for these reports required more than 10 years of dedicated work by Red Cross volunteers and other data collectors, project managers, and research professionals. It is our hope that this report will help prevent more unnecessary deaths due to cold water immersion, an important hazard of our northern climate in Canada.

METHODS

STUDY POPULATION AND TIME PERIOD All drownings and other water-related injury deaths in Canada were monitored between 1 January 1991 and 31 December 2000. During this period there were 5,900 water-related deaths, including 5,535 drownings (with or without hypothermia reported), 92 immersion hypothermia deaths without drowning, and 273 other injuries where neither drowning nor hypothermia were major causal factors, including head injuries from boating collisions, air embolism from scuba diving, and so forth (Canadian Red Cross 2005). In the 1996 census, the total population of Canada was 30,300,000. Thus, the cold and ice immersion deaths in 1991-2000 occurred on the background of about 300 million person years of exposure to risk for all ages. As denominators for incidence and trends for 1991-1995 we used 1991 census data, for 1996-2000, the 1996 census population, and for 1991-2000 the mean of the 1991 and 1996 census populations. We chose these two years since they are actual census data, and not the less valid inter-censual projections.

DEFINITION OF COLD IMMERSION DEATH Since many coroners, injury investigators and pathologists have not received specific training in diagnosis of death from the different stages of cold immersion, including hypothermia, and since autopsy findings even when available may not always be definitive, we did not attempt to distinguish the physiological stages of cold immersion. Rather, we developed a practical epidemiological approach to select cases of cold-water immersion within the limitations of the data source. Most readers will probably accept that cold was indeed a factor in the death when ice was known to be present, as in snowmobiling, other vehicles travelling on ice, and people who fell through ice. Other criteria could perhaps be challenged in specific incidents.

Our selection criteria for cold water immersion deaths included: drowning and immersion hypothermia as reported by coroner, immersion hypothermia without drowning as reported by coroner, immersion hypothermia and some other cause as reported by autopsy, hypothermia and some other cause as reported by the Red Cross or Lifesaving data collector, immersion death in the presence of ice as reported by coroner or police report, immersion death in presence of extremely cold water temperature (<10°C) as reported by coroner or police, cold month of incident, defined as November to April, and snowmobile travel. We did the selection in a descending manner, not counting or reselecting previously included incidents twice. This gave a total of 2,007 cold immersion deaths.(See Table 1, p. 7.) We excluded incidents in bathtubs, swimming pools, and hot tubs, unless hypothermia was a factor, such as a fall into an outside pool during the winter.

As a sensitivity analysis, we broadened the selection criteria to also include cold water temperature 10-20°C as reported by coroner or police (506 additional deaths) and to include October and May as cold water months (525 additional deaths). Thus using these broader selection criteria added another 1,031 cold immersion deaths. However, we limited our detailed analyses to the 2,007 deaths selected using the narrower selection criteria. We analysed incidents involving snowmobiles and other ice incidents from non-motorized activities separately in greater detail. Incidents involving boating were also assessed separately, though with less detail, since boating is discussed elsewhere in these modules.

DROWNING AND IMMERSION HYPOTHERMIA For the purposes of this paper, an immersion death was classified as a drowning if drowning was included in the coroner's report, based upon the autopsy or other findings. The death was classified as hypothermia without drowning only if the autopsy or other coroner's finding excluded drowning as among the causes of death. 166 of the 232 snowmobile drowning victims underwent autopsy.

Of 14 snowmobile victims with hypothermia without drowning, 9 underwent autopsy. Drownings with and without hypothermia were analyzed together. This was done because hypothermia is reported inconsistently due to inexperience of many coroners with immersion deaths and due to a lack of clear criteria for such a diagnosis. On the other hand, a classification of immersion hypothermia without drowning is generally based on lack of autopsy findings of drowning and on other factors that tend to exclude drowning, such as wearing of a flotation device.

ICE AND LAND TRANSPORT INCIDENTS For motor vehicles other than snowmobiles, the questionnaire used for data collection during 1991-1992 did not distinguish clearly between incidents on and off ice. Hence we estimated the number of such deaths that occurred on ice for 1991-1992 based upon the proportion of similar incidents during 1993-2000, added this to the total of on-ice incidents, and subtracted them from the total of incidents not reported to involve travel on ice.

ETHNICITY Because of greater exposure among aboriginal peoples to boat and snowmobile travel, and the location of many communities or homes near the water, the proportion of aboriginal victims is provided. Aboriginal peoples, including First Nations, Inuit and Metis, are believed to represent about four percent of the Canadian population. Aboriginal status was considered definite if the victim was classified as such by the coroner, police, or pathologist. Probable aboriginal status was assigned if the address corresponded to a known reserve and if the family name was known to be aboriginal.

NATIONAL SURVEILLANCE DATABASE In the early 1990's, the Canadian Red Cross implemented a national drowning surveillance database (Barss, 2006). This was developed with collaboration of public health injury prevention professionals, all provincial coroners, and other water-safety organizations including the Coast Guard and Lifesaving Society. The database was funded to provide a sound research basis for national water-safety programs, by monitoring the incidence and circumstances of all water-related injury deaths in Canada on an annual basis. It includes annual information from 1991 onwards (Canadian Red Cross, 2001). An epidemiologic profile of all water-related injury deaths is available (Red Cross 2003, 2005).

DATA COLLECTION The surveillance database relies upon annual structured reviews of the mandatory coroner and police reports for all water-related deaths. A questionnaire with 48 questions is used to obtain data on cause of death, activity and purpose of activity, along with personal, equipment, and environment risk factors. Project managers supervise volunteer data collectors in each province.

Since snowmobile drownings are generally classified with traffic deaths, they are frequently not reported as drownings. Hence during annual retrieval of files by data collectors in each province and territory, a special request was made to coroners for files of snowmobiling deaths from drowning and/or hypothermia. Deaths from trauma without immersion, due to snowmobile collisions, were excluded from the water-related injury fatalities database.

DATA VERIFICATION AND ANALYSIS All completed questionnaires are verified and corrected at the national level by a medically trained injury epidemiologist and demographer. Verification is highly structured and includes such issues as admissibility, completeness, internal consistency of responses, and consistency from year to year. Data entry is done with appropriate quality controls, including double entry and compare. Data are analyzed annually, but for this paper 10 years of data were used. Since coroners take a year or more to finalize all cases and data collection and analysis takes nearly another year, reporting tends to lag the incidents by about two years. This is not of major consequence for prevention, since major trends usually occur slowly.

In the early development years, the analytical work was considered research. In later years, much of the analysis was done by a research technician and was considered surveillance. Detailed reports on new topics, such as the present paper, were considered research. Hence it was possible to provide both a surveillance and a research basis for new programming. Recommendations were also supported by periodic monitoring of the scientific literature on injury prevention in international citation databases.

RESULTS

COLD WATER IMMERSION

Based on our selection criteria for this research (see Table 1), there were 2,007 cold water immersion deaths in Canada during 1991-2000. This represents 35% (2,007/5,764) of all cases of drowning and immersion hypothermia. If we exclude from the total the 13% of deaths where cold water immersion is very rare, including 387 bathtub drownings, 332 swimming pool drownings, and 39 hot tub drownings, the proportion of immersion deaths associated with cold water rises to 40% (2,007/5,006).

There were 59 deaths where the secondary death factor was extremely cold water, but the main death factor was neither drowning nor hypothermia. The activities for these deaths included: aquatic 20, falls into water 13, boating 13, motor vehicle 12, and aircraft 1. These deaths are described further in the appropriate section.

ACTIVITIES The largest category of activity was boating, followed by activities on ice such as motorized travel using snowmobiles and other vehicles, and other activities such as walking, playing, and skating (Figure 1).

PURPOSE OF ACTIVITY Recreational activities were the most frequent, followed by daily life, including subsistence activities, and occupational activities (Figure 2).

ACTIVITIES ON ICE Falls through ice during activities on ice represented about 22% of cold water immersion deaths. Major categories of activity were snowmobiling, 55%, other motorized travel on ice, 11%, and non-motorized activities on ice, 34%.

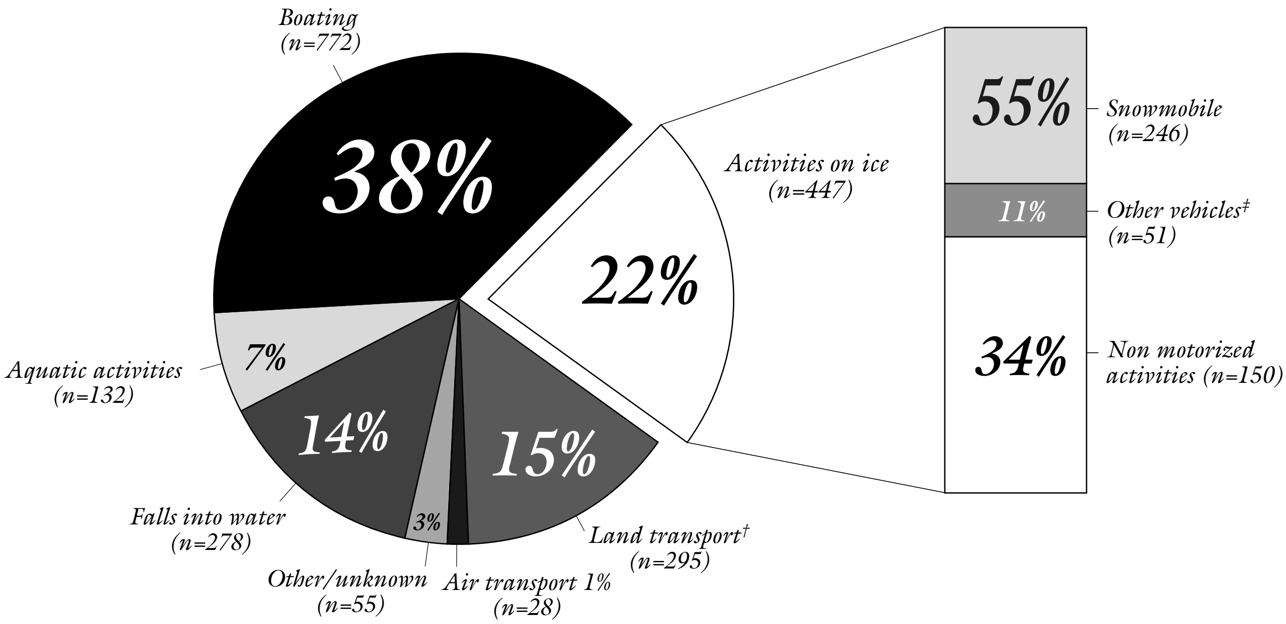
Table 1 **INCLUSION CRITERIA FOR COLD WATER IMMERSION DEATHS, CANADA 1991-2000 (n=2,007)**

INCLUSION CRITERIA*	Opinion from	Total number	Number excluding preceding categories
Drowning and hypothermia	Coroner	547	547
Hypothermia (without drowning)	Coroner	92	92
Hypothermia and other cause	Autopsy	283	35
Hypothermia and other cause	Data collector	496	102
Ice present	Coroner or police report	526	283
Extremely cold water (<10° C)	Coroner or police report	1,250	547
Very cold month (November – April)†	Coroner or police report	1,245	398
Snowmobiling	Coroner or police report	246	3
Total (cumulative)			**2,007**
Other cold water deaths by more liberal selection criteria‡			
Cold water (10° – 20° C)	Coroner or police report	628	506
Cold month (October, May)	Coroner or police report	881	525

** These criteria were established for this report; on the basis of coroner and police data, it is not generally feasible to distinguish between the four stages of cold immersion † Excludes bathtub, hot tub and pool ‡ These deaths are not discussed further*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

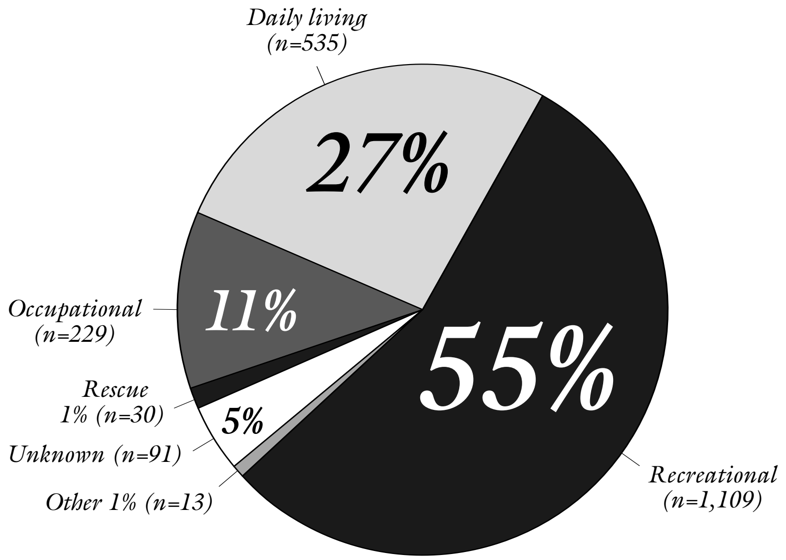
Figure 1 **COLD WATER IMMERSION DEATHS* BY ACTIVITY, CANADA 1991-2000 (n=2,007)**



* *Includes victims for whom one or more of these factors were reported: hypothermia with or without drowning, the presence of ice or extremely cold water (<10° C), cold weather month (November through April), or snowmobiling*
† *Excludes snowmobiles and other vehicles on ice* ‡ *51 is an estimate based on 41 cases for 1993-2000; 10 cases for 1991-1992 were included here and deducted from "Land transport", so the total of 293 for that category is also an estimate*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 2 **COLD WATER IMMERSION DEATHS* BY PURPOSE OF ACTIVITY, CANADA 1991-2000 (n=2,007)**



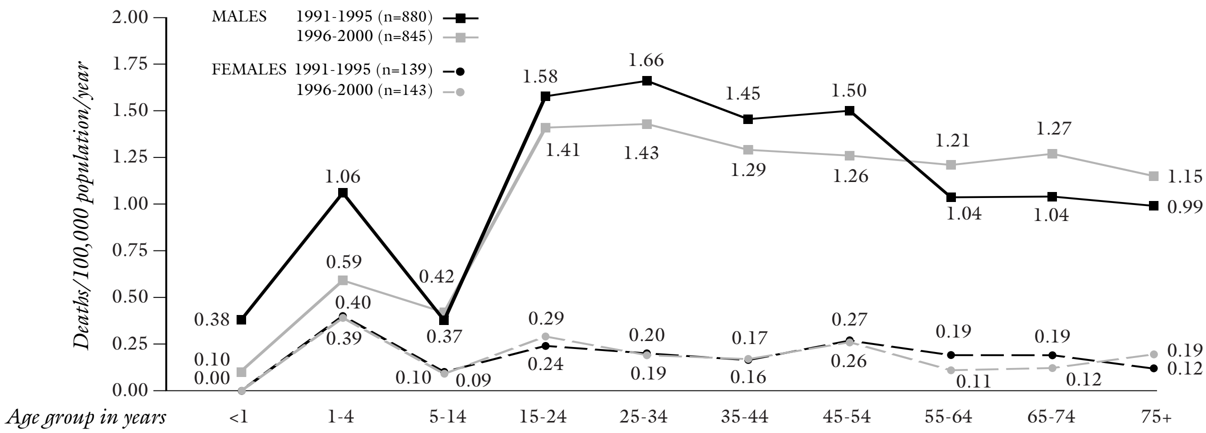
* *Includes victims for whom one or more of these factors were reported: hypothermia with or without drowning, ice or extremely cold water, cold weather month (November through April), or snowmobiling*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

PERSONAL RISK FACTORS

AGE & SEX Males 15 and over were at highest risk, followed by 1-4-year-old toddlers (Figure 3). Between 1991-1995 and 1996-2000 there was a significant improvement in rates for male toddlers; however, a slight decline in rates for adult males 15-54 years old was offset by an increase for males 55 and over.

Figure 3 **COLD WATER IMMERSION DEATHS* BY AGE & SEX, CANADA 1991-2000 (n=2,007)†‡**



Number of deaths in age group

		<1	1-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	75+
MALES	1991-1995	4	42	36	162	213	162	114	62	45	24
	1996-2000	1	24	43	145	172	162	119	76	61	32
FEMALES	1991-1995	0	15	9	24	25	18	20	12	10	5
	1996-2000	0	15	9	28	22	21	25	7	7	9

** Includes victims for whom one or more of these factors were reported: hypothermia with or without drowning, ice or extremely cold water, cold weather month (November through April), or snowmobiling*
† Age unknown for 23 victims: males 22 (13, 9); females 1 (1, 0)   ‡ Age & sex unknown for 4 victims, imputed male (3, 1)
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

ALCOHOL Alcohol was associated with at least 40% of deaths of victims 15 years and older, and most blood levels were very high (Figure 4).

OTHER DRUGS Illegal drugs were reported in 4% of cases and suspected in 1%. Illegal drugs included mainly marijuana/hashish and cocaine, with less than 1% PCP/ecstasy, heroin, morphine or LSD.

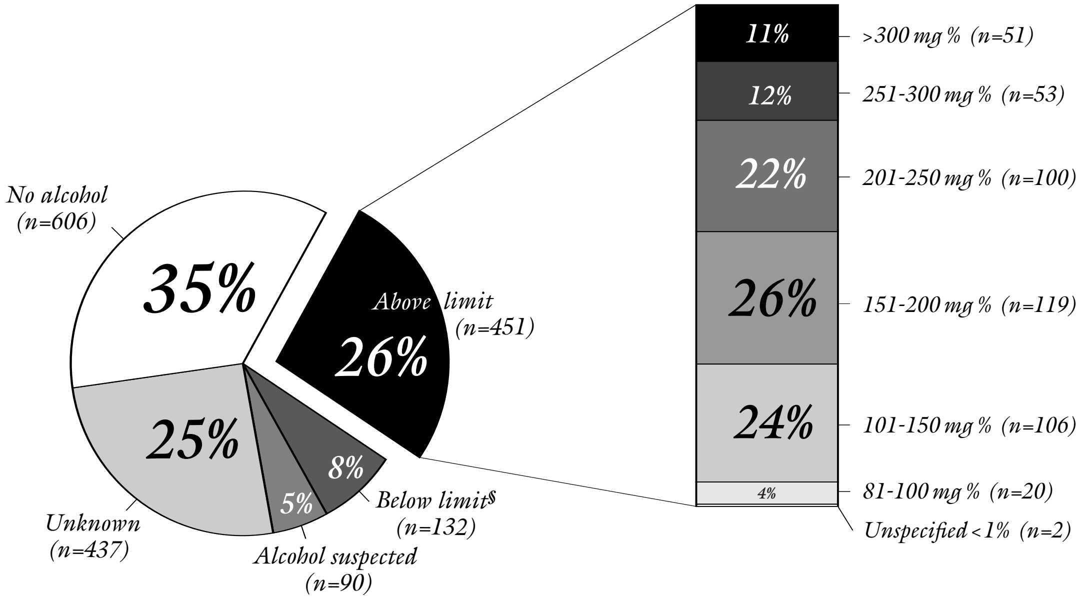
ETHNICITY Aboriginals, who constitute about 4% of the population, were over-represented among cold water immersion victims, accounting for 15% of deaths (14% were definite aboriginals and 1% were probable). The true proportion was probably higher, since if ethnicity was not specified in the file, it had to be left unknown.

ENVIRONMENTAL RISK FACTORS

BODY OF WATER BY REGION Lakes were the most frequent body of water for cold water immersion deaths, followed by rivers and oceans (Figure 5). In central inland provinces, lakes were most frequent, in coastal provinces oceans, and in Quebec, rivers.

VISIBILITY: LIGHT CONDITIONS 40% of incidents occurred during known daylight, 9% during twilight and 30% in darkness; light conditions were unknown for 21%. Where light conditions were unknown, 90% of deaths occurred between 18:00 and 05:59.

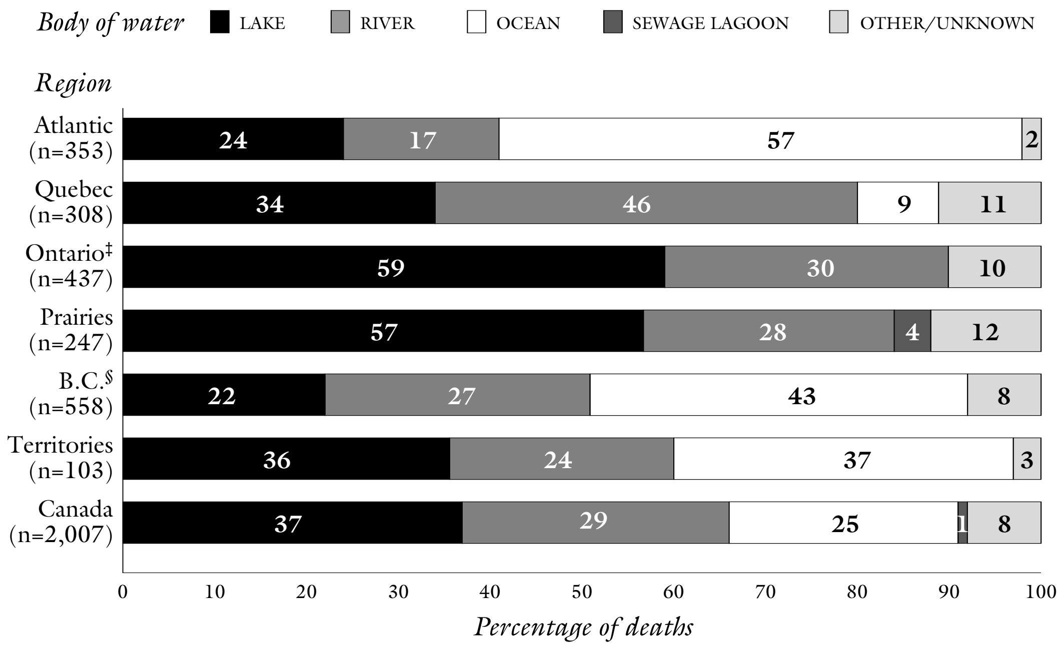
Figure 4 **BLOOD ALCOHOL LEVELS* FOR COLD WATER IMMERSION DEATHS,† CANADA 1991-2000 (VICTIMS ≥15 YEARS OF AGE; n=1,809)‡**



* *Legal limit is 80 mg %* † *Includes victims for whom one or more of these factors were reported: hypothermia with or without drowning, ice or extremely cold water, cold weather month (November through April), or snowmobiling*
‡ *This figure excludes 93 victims; decomposition rendered blood alcohol unreliable* § *69 at 1-49 mg %, 51 at 50-80 mg %, 12 unspecified*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 5 **RATE AND NUMBER OF COLD WATER IMMERSION DEATHS* BY BODY OF WATER BY REGION, CANADA 1991-2000 (n=2,007)†**

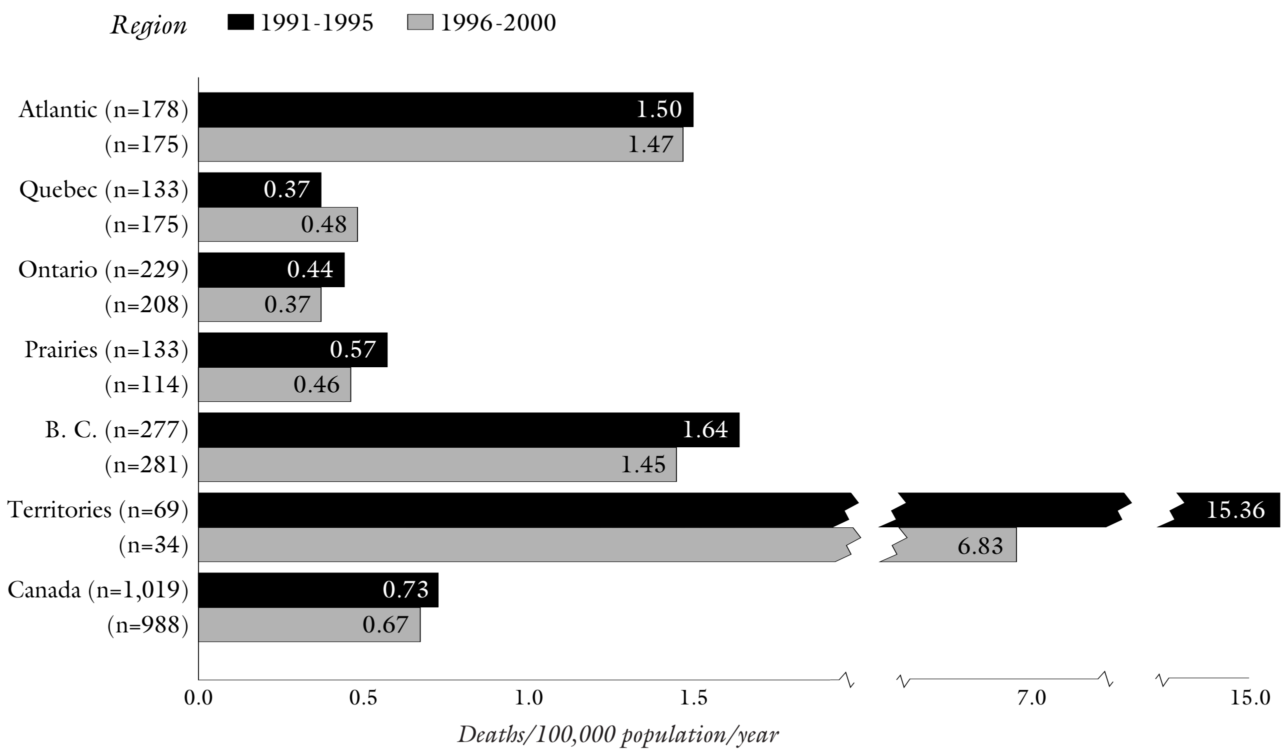


* *Includes victims for whom one or more of these factors were reported: hypothermia with or without drowning, ice or extremely cold water, cold weather month (November through April), or snowmobiling* † *Region unknown for 1 death*
‡ *There was 1 ocean death in Ontario (0.2%)* § *There were 2 sewage lagoon deaths in B.C. (0.4%)*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

REGIONAL INCIDENCE & TRENDS Cold water immersion death rates were about 3 times higher in British Columbia and the Atlantic region than in other provinces (Figure 6). Rates in the northern territories were initially about 20 times higher than the Canadian average, but fell to 10 times higher. With the exception of Quebec, where there was a 30% increase, there was a small decrease in rates overall and for other provinces.

Figure 6 **RATE AND NUMBER OF COLD WATER IMMERSION DEATHS* BY REGION, CANADA 1991-2000 (n=2,007)†**



** Includes victims for whom one or more of these factors were reported: hypothermia with or without drowning, ice or extremely cold water, cold weather month (November through April), or snowmobiling † Region unknown for 1 death (0, 1)*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

ACTIVITIES ON ICE

During 1991-2000, there were 246 immersion deaths involving snowmobiles, and 150 deaths during non-motorized activities on ice. For other motor vehicles on ice, there were 41 deaths in the 8-year period from 1993-2000. If we compare annual averages for immersion deaths during activities on ice, snowmobiles accounted for 55%, non-motorized activities for 34%, and other vehicles on ice for 11%.

SNOWMOBILE

There were 246 snowmobile immersion deaths in Canada during 1991-2000, including 232 drownings with or without hypothermia and 14 deaths from hypothermia without drowning. Snowmobiles accounted for 12% of cold water immersion deaths (246/2,007).

ACTIVITY & PURPOSE Recreational snowmobiling and daily living travel were the main activities reported for snowmobile immersion deaths. Other activities included trapping, fishing, and rescue (Figure 7). Recreational activities accounted for nearly three quarters of incidents, daily living or subsistence activities for nearly one quarter. The few remaining cases involved occupational, rescue or unknown activities (Figure 8).

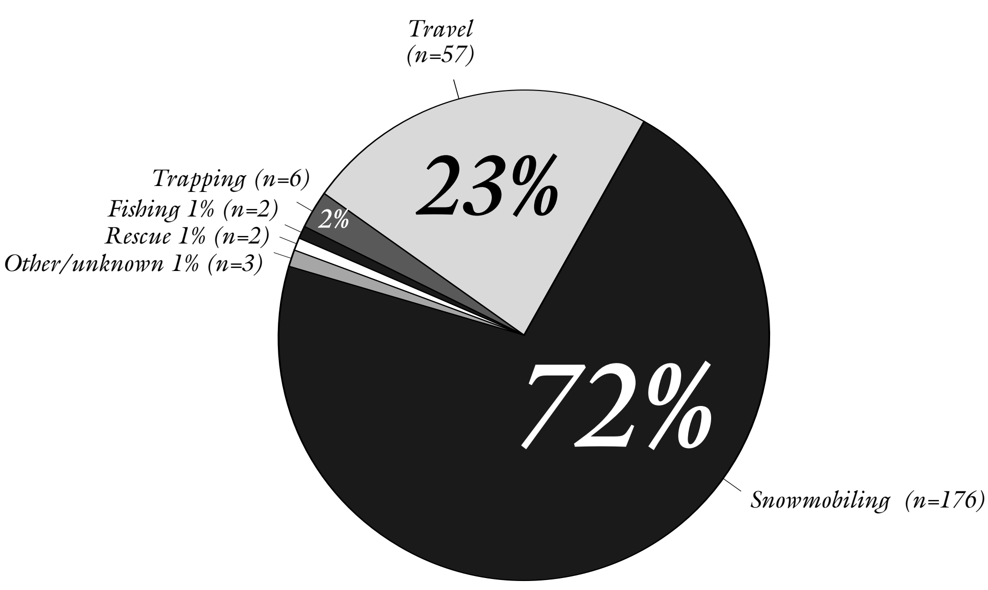
TYPE OF INCIDENT Of the 180 snowmobile immersion deaths during the 8-year period from 1993-2000, 170 resulted from travel on ice, 4 from going off a road, 3 from going off a bridge, 2 other and 1 unknown. These data were not available for 1991-1992.

MULTIPLE-VICTIM INCIDENTS Based upon data from 1993-2000, 34% (62/180) of victims died in multiple-victim incidents. These data were not available for 1991-1992.

INCIDENCE & PERSONAL FACTORS

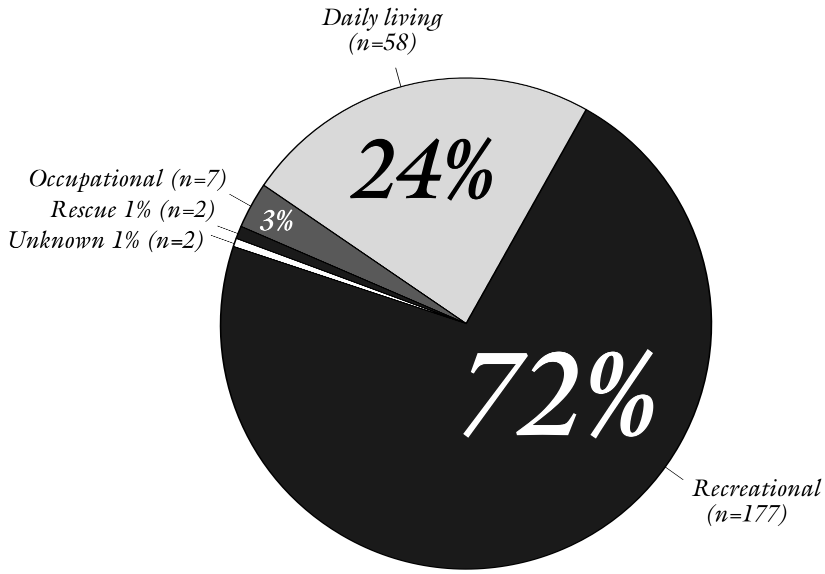
The average incidence rate was 8.1 snowmobile immersion deaths per million population per year. The incidence fell from 9.2 per million during 1991-1995 to 7.0 during 1996-2000, a decrease of 24%. This decrease was apparent in all age groups of males between 15 and 74 (Figure 9).

Figure 7 **SNOWMOBILE IMMERSION DEATHS* BY ACTIVITY, CANADA 1991-2000 (n=246)**



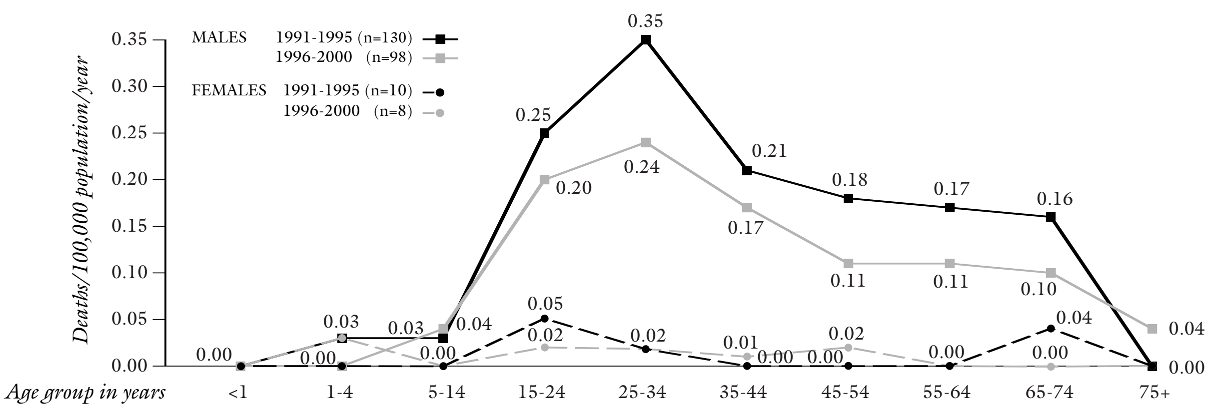
** Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 8 **SNOWMOBILE IMMERSION DEATHS* BY PURPOSE OF ACTIVITY, CANADA 1991-2000 (n=246)**



** Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 9 **RATE AND NUMBER OF SNOWMOBILE IMMERSION DEATHS* BY AGE & SEX, CANADA 1991-2000 (n=246)†‡**



Number of deaths in age group

		<1	1-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	75+
MALES	1991-1995	0	1	3	26	45	23	14	10	7	0
	1996-2000	0	0	4	21	29	21	10	7	5	1
FEMALES	1991-1995	0	0	0	5	3	0	0	0	2	0
	1996-2000	0	1	0	2	2	1	2	0	0	0

** Includes drowning with or without hypothermia and hypothermia without drowning † Age unknown for 1 male victim (1, 0)*
‡ Included recreational 177 (95, 82), daily living 58 (38, 20), occupational 7 (4, 3), attempting rescue 2 (1, 1) & unknown 2 (2, 0)
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

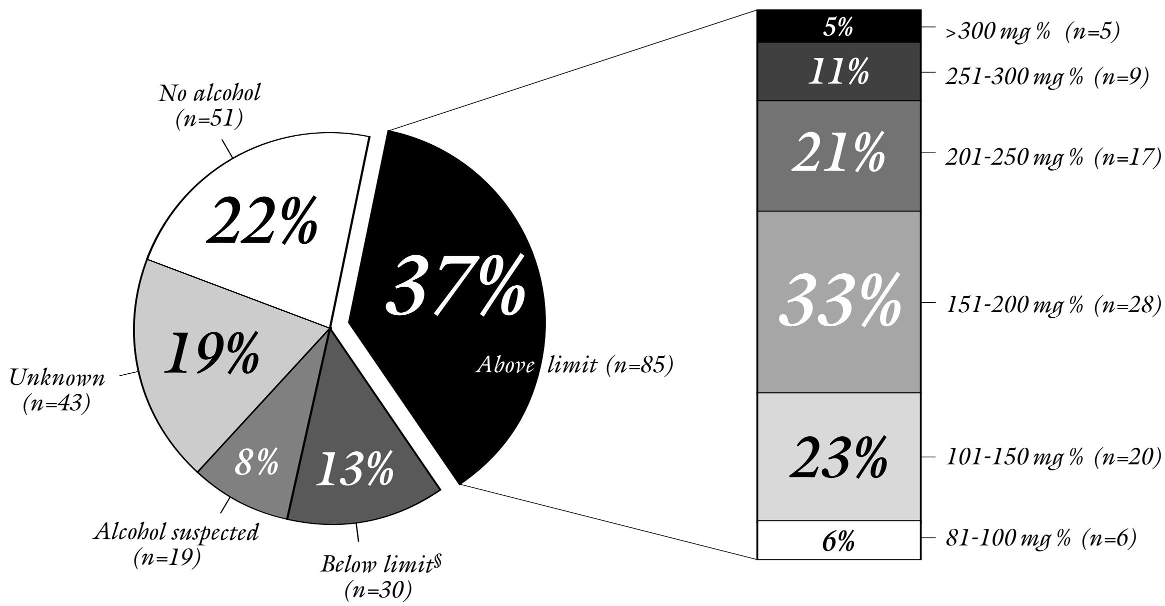
AGE & SEX The major risk group for snowmobile immersion deaths was 15-74-year-old males, who accounted for 89% of victims, with the peak incidence among 25-34 year olds. Children under 15 represented only 4% of victims (Figure 9).

ALCOHOL Alcohol was a factor for 59% of victims ≥15 years of age; this is probably an underestimate, as 19% did not have a blood sample. Blood levels were extremely high in many cases (Figure 10). Alcoholism was reported for 10% (23/237) of victims. By purpose of activity, 40% of recreational snowmobile victims had alcohol >80mg%, 15% 1-80mg%, 6% suspected, 23% none, and 16% unknown. For daily living activities, the same figures were 33%, 11%, 17%, 19%, 20%, and for occupational, 14%, 0%, 0%, 43%, 43%.

OTHER DRUGS Among 237 victims ≥15 years of age, 15 (6%) had consumed an illegal drug, including 13 marijuana and 2 cocaine. This is likely an underestimate, as many victims did not have a blood sample taken for drugs.

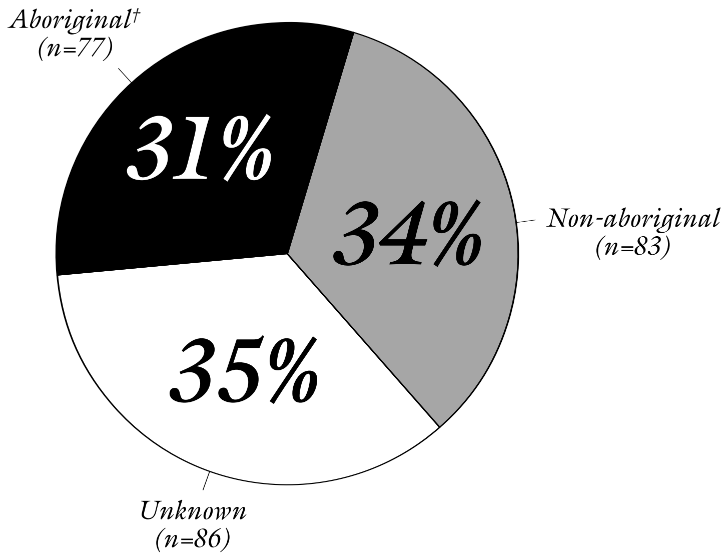
ETHNICITY Aboriginals were over-represented among snowmobile immersion victims, accounting for 31% of deaths (68 definite and 9 probable aboriginals); the true proportion was probably more, since if ethnicity was not specified in the file, it had to be left unknown (Figure 11). Hence aboriginal peoples could comprise up to 40% of deaths, while representing only about 4% of the population.

Figure 10 **BLOOD ALCOHOL LEVELS* FOR SNOWMOBILE IMMERSION DEATHS,† CANADA 1991-2000 (VICTIMS ≥15 YEARS OF AGE; n=237)‡**



** Legal limit is 80 mg %   † Includes drowning with or without hypothermia and hypothermia without drowning*
‡ This figure excludes 9 victims; decomposition rendered blood alcohol unreliable   § 16 at 1-49 mg %, 13 at 50-80 mg %, 1 unspecified
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 11 **SNOWMOBILE IMMERSION DEATHS* BY ETHNICITY, CANADA 1991-2000 (n=246)**



** Includes drowning with or without hypothermia and hypothermia without drowning*
† Includes definite & probable aboriginals (First Nations, Inuit & Métis)

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

EQUIPMENT FACTORS

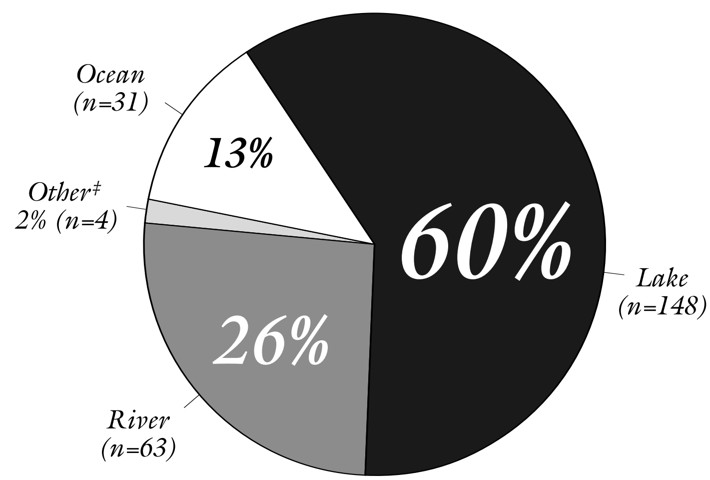
FLOTATION DEVICES The presence or absence of a flotation device such as personal flotation device (PFD) or flotation hypothermia-protective snowmobile suit was specified for only 28% of victims. Only 4% of all victims were reported to be wearing a flotation device. Although rarely used with snowmobiles, a simple boating PFD may be helpful for survival, as reported in one coroner's records. An aboriginal boy's mother put a PFD on him before he left as a passenger on a snowmobile — he lived while adults died.

Seldom recorded by coroners and police is use of flotation-hypothermia suits, rescue throw bags with rope, ice picks for crawling out of water onto ice, and machine factors such as weight, speed, lighting, and braking capabilities.

ENVIRONMENT FACTORS

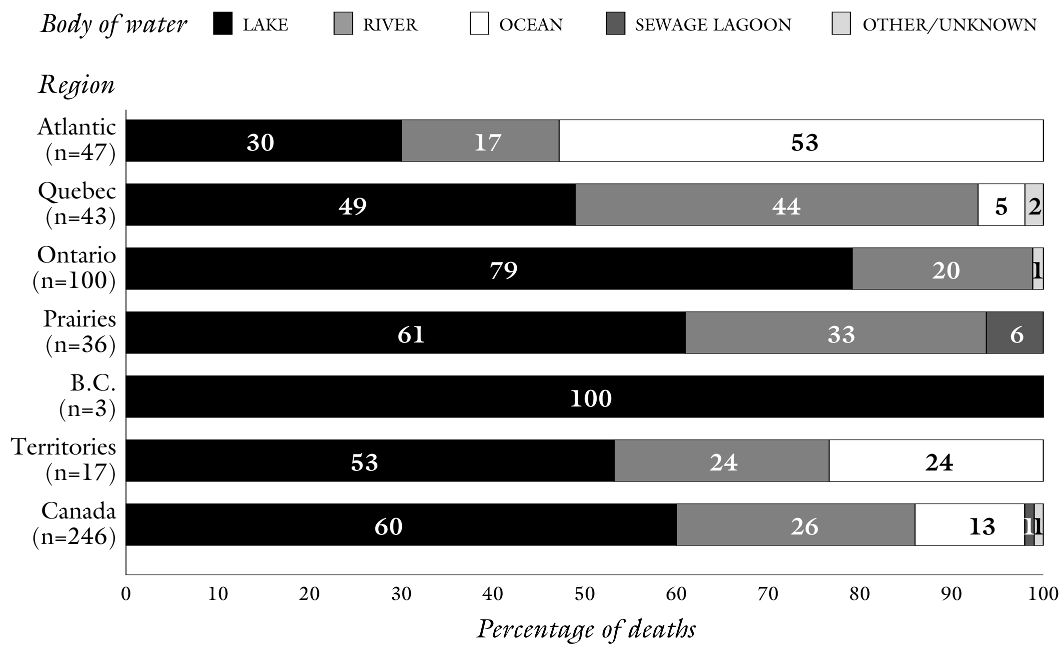
BODY OF WATER Lakes were the most frequent body of water for snowmobile immersion deaths, followed by rivers and the ocean (Figure 12). The predominant type of body of water varied by region (Figure 13). The ocean is a frequent site in the Atlantic region, mainly Newfoundland, and to a lesser extent in the northern territories. In Quebec, rivers are nearly as frequent a site as lakes.

Figure 12 **SNOWMOBILE IMMERSION DEATHS* BY TYPE OF BODY OF WATER,† CANADA 1991-2000 (n=246)**



** Includes drowning with or without hypothermia and hypothermia without drowning*
† Lake includes pond & reservoir ‡ Included sewage lagoon 2, canal 1, ditch 1
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

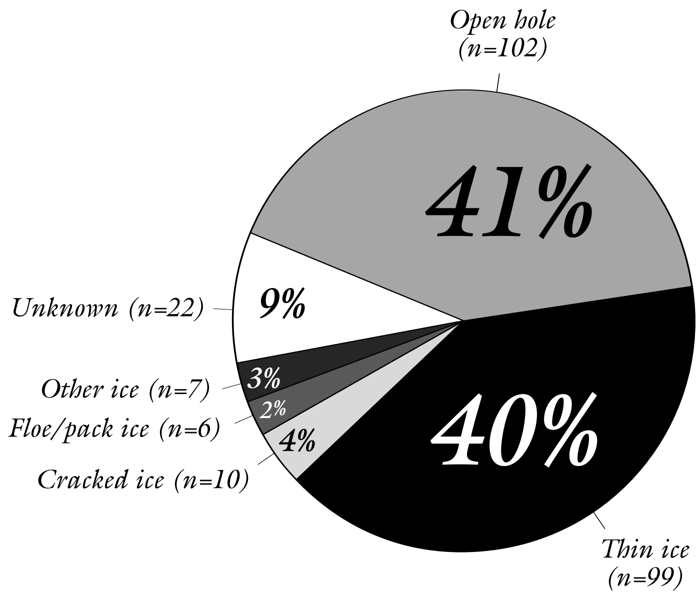
Figure 13 **SNOWMOBILE IMMERSION DEATHS* BY BODY OF WATER† BY REGION, CANADA 1991-2000 (n=246)**



** Includes drowning with or without hypothermia and hypothermia without drowning*
† Lake includes pond & reservoir
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

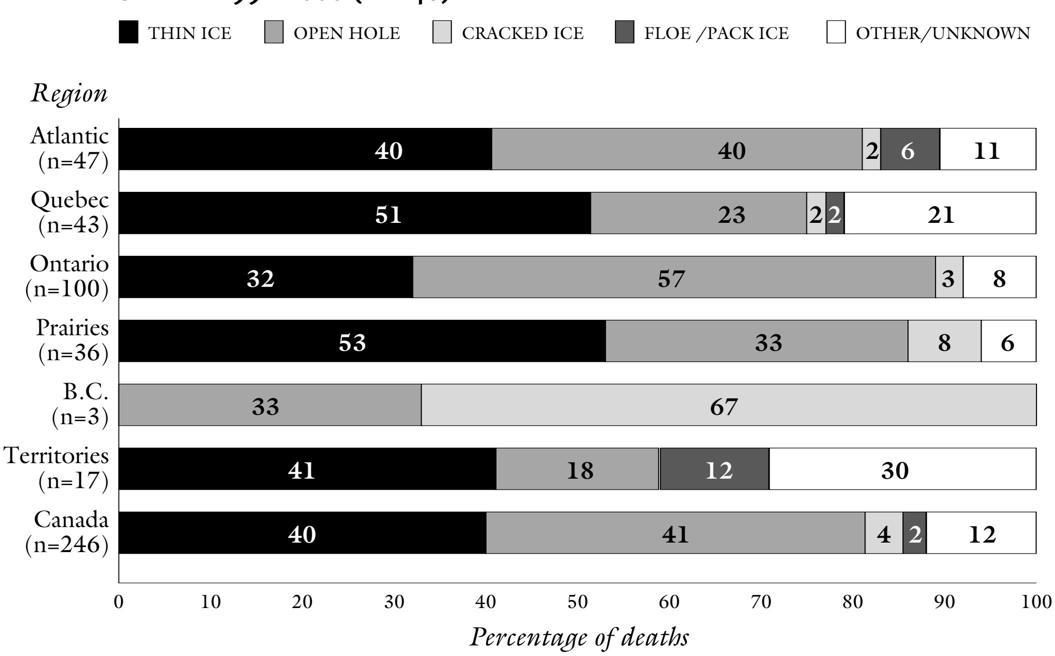
ICE CONDITIONS The most frequent ice conditions were an open hole in the ice, 41%, and thin ice, 40% (Figure 14). This differed from the situation for people who fell through the ice while walking or playing, in which case thin ice accounted for 57% of incidents and an open hole for only 21% (Figure 29). There were regional differences in ice conditions associated with snowmobile immersion deaths (Figure 15), with open holes most frequent in Ontario and thin ice in Quebec, the Prairies, and the northern territories.

Figure 14 **SNOWMOBILE IMMERSION DEATHS* BY ICE CONDITIONS, CANADA 1991-2000 (n=246)**



* *Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 15 **SNOWMOBILE IMMERSION DEATHS* BY ICE CONDITIONS BY REGION, CANADA 1991-2000 (n=246)**

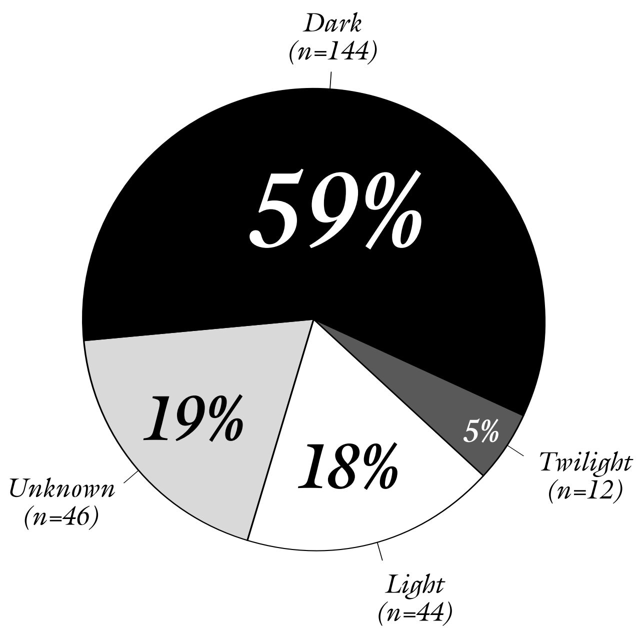


* *Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

VISIBILITY: LIGHT CONDITIONS, TIME OF DAY, WEATHER At least 64% of incidents occurred in the dark or during twilight; only 18% occurred during known daylight (Figure 16). Where time of the incident was known, 66% occurred between 18:00 and 05:59 hours (Figure 17). In many northern locations where snowmobile use is frequent, it can be dark even by 14:00. Hence low visibility due to darkness was a factor in the great majority of incidents. Weather was reported for only 30% (74/246) of deaths; among these, snowing was reported for 27% and fog for 8%.

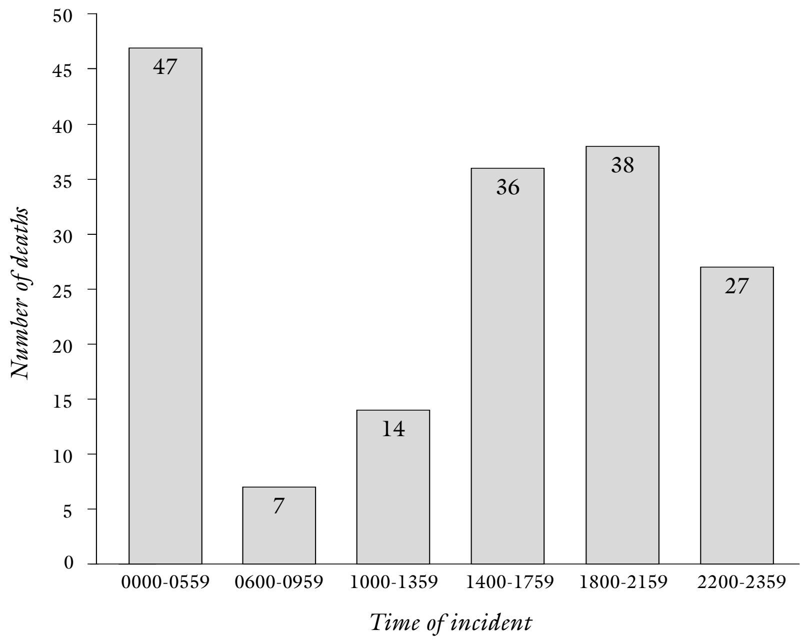
SEASON, DAY OF WEEK Snowmobile immersions occurred mainly between November and April, with the peak in January (Figure 18). A few cases occurred during late spring-summer, since ice persists until then in the far north. There was a shift of incidents to later in the season between the two periods 1991-1995 and 1996-2000. Although snowmobile immersions occurred throughout the week, 47% of deaths took place on Saturdays and Sundays (Figure 19).

Figure 16 **SNOWMOBILE IMMERSION DEATHS* BY LIGHT CONDITIONS, CANADA 1991-2000 (n=246)**



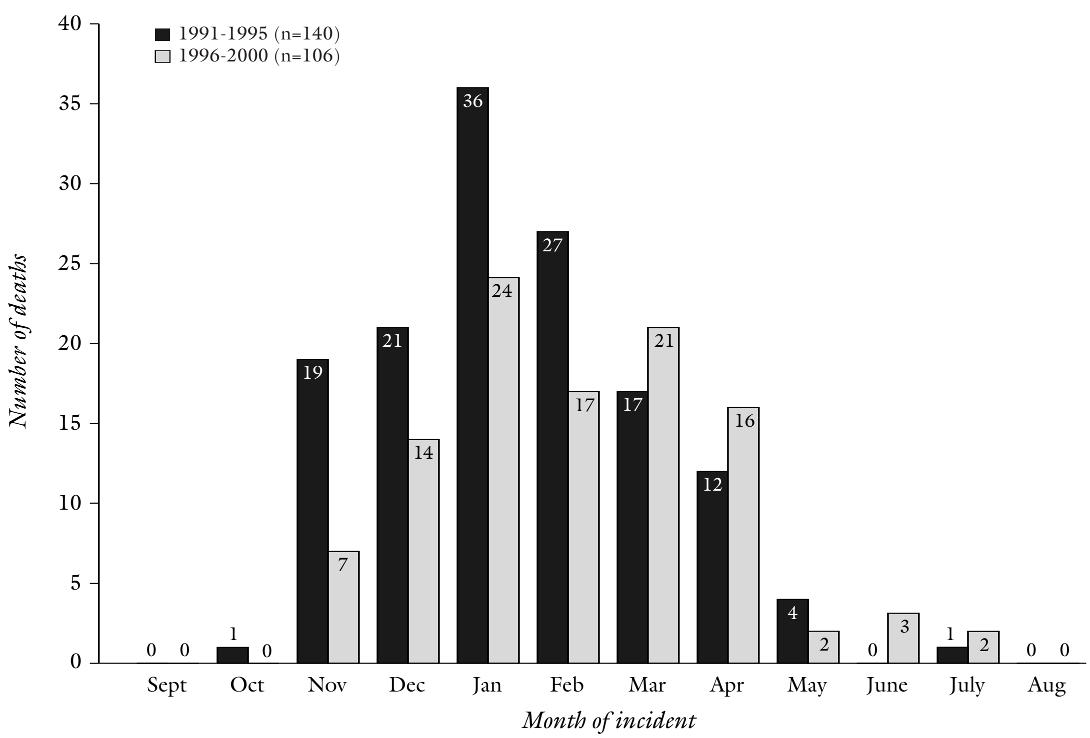
** Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 17 **SNOWMOBILE IMMERSION DEATHS* BY TIME OF INCIDENT, CANADA 1991-2000 (n=246)†**



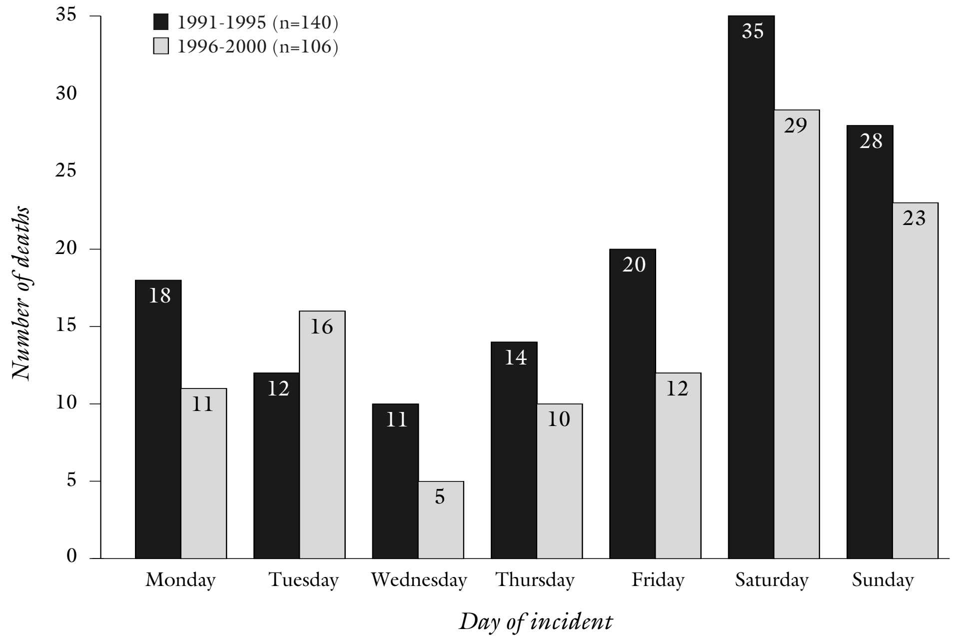
** Includes drowning with or without hypothermia and hypothermia without drowning † Time unspecified for 77 deaths*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 18 **SNOWMOBILE IMMERSION DEATHS* BY MONTH OF INCIDENT, CANADA 1991-2000 (n=246)†**



** Includes drowning with or without hypothermia and hypothermia without drowning † Month unspecified for 2 deaths (2, 0)*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 19 **SNOWMOBILE IMMERSION DEATHS* BY DAY OF INCIDENT, CANADA 1991-2000 (n=246)†**



** Includes drowning with or without hypothermia and hypothermia without drowning † Day unspecified for 2 deaths (2, 0)*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

AIR TEMPERATURE Air temperature was extremely cold (<-5°C) in 37% of deaths, very cold (-5-+5°C) in 7%, cold (6-15°C) in 2%, moderate (16-27°C) in 0.4%, and unknown in 52%.

URBAN/RURAL RESIDENCE AND LOCATION Rural areas were the site of incident for 80% of snowmobile immersion deaths, urban for 19%, and unknown 1%. 197 deaths occurred in rural areas; of these 66% of victims were rural residents, 33% urban residents, and for 1% residence was unknown. 46 deaths occurred in urban areas, of which 91% victims were urban residents, 2% rural residents, and for 7% residence was unknown.

NATURE OF LOCATION 7% of deaths were reported on aboriginal reserves, 3% at cottages, and 2% at parks or conservation areas. Many were unspecified.

DEPTH OF WATER Depth of water was known for 44% of deaths (108/246). Of these, 73% took place in water >2.5 metres deep, 25% 1.1-2.5 m., and 2% <1 m.

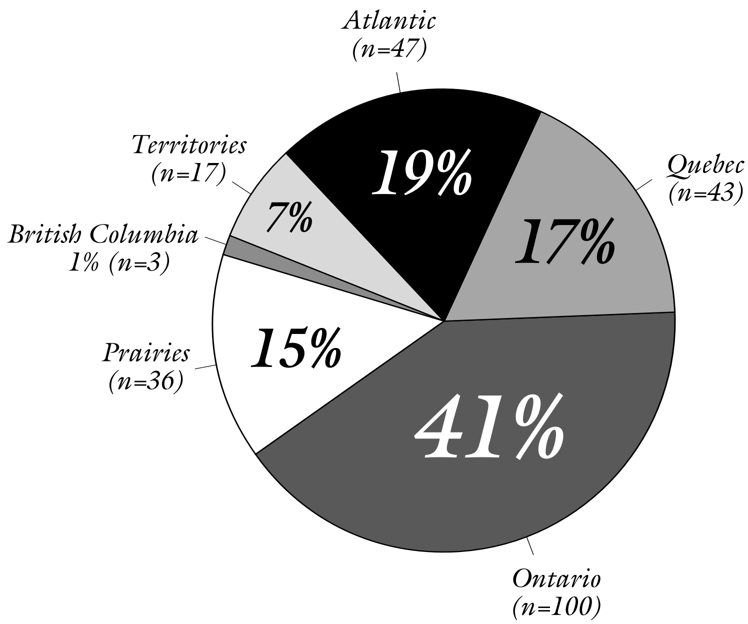
DISTANCE FROM SHORE Distance from shore was known for 43% of deaths (105/246). Of these, 44% occurred >50 metres from shore, 24% 16-50 m., 29% 2-15 m., and 4% <2m.

REGIONAL INCIDENCE & TRENDS The largest number of snowmobile immersion deaths occurred in Ontario, and the smallest in British Columbia (Figure 20). However, the highest rates were seen in the three northern territories, followed by the Atlantic region, mainly Newfoundland (Figure 21). There was an improvement in all regions except Quebec between 1991-1995 and 1996-2000. On the other hand, because of the shift of incidents to later months of the season, it is unclear if the favourable trend in reduction of deaths was due to preventive interventions or to climate change with less exposure during a shorter season.

ACCOMPANIMENT/SUPERVISION Whether the victim was accompanied by another person was known for 95% of deaths. Of these, 67% were with an adult, 2% were with a minor, and 31% were alone.

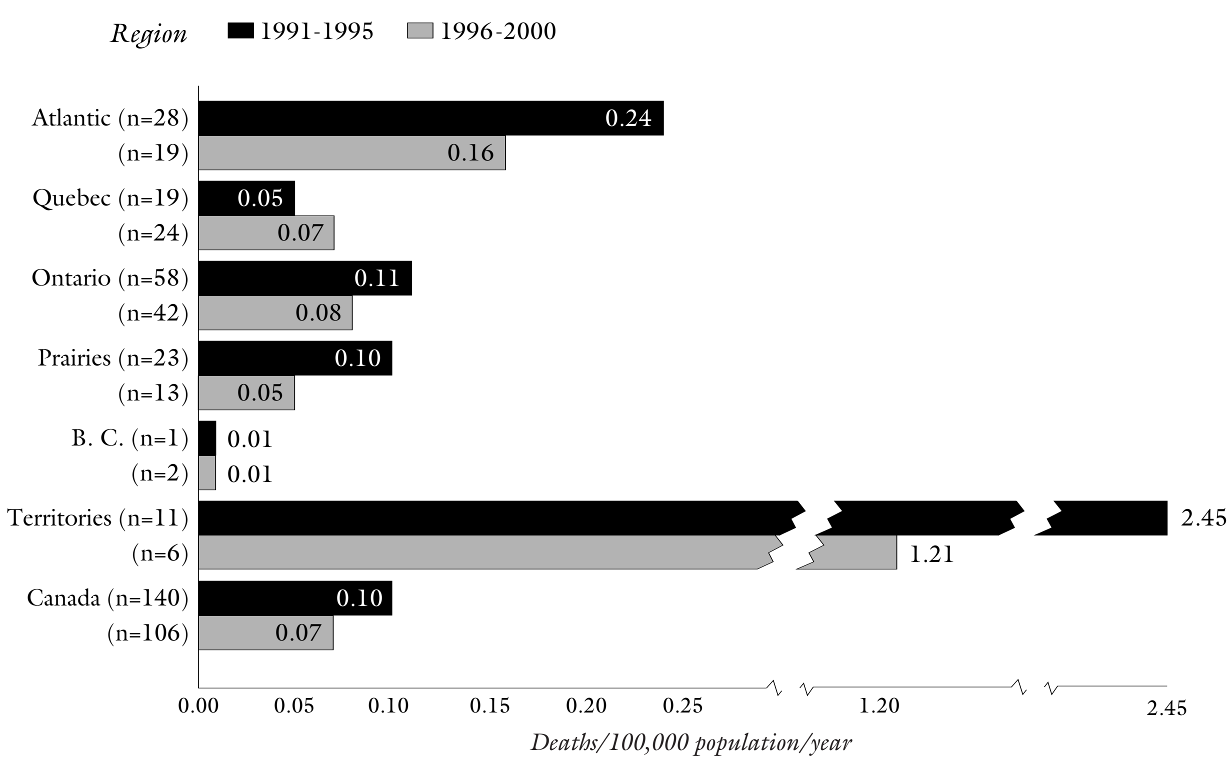
RESCUE/CPR Acute rescue for a potentially survivable victim was carried out for only 25% (62/246) of cases, and CPR was attempted for 12% (30/246).

Figure 20 **SNOWMOBILE IMMERSION DEATHS* BY REGION, CANADA 1991-2000 (n=246)**



* *Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 21 **RATE AND NUMBER OF SNOWMOBILE IMMERSION DEATHS* BY REGION, CANADA 1991-2000 (n=246)**



* *Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

SNOWMOBILE IMMERSION DEATHS AS A PROPORTION OF ALL SNOWMOBILE DEATHS

According to vital statistics, there were a total of 360 snowmobile deaths from all causes — collision trauma and immersion — during 1991-1995, an average of 72 deaths per year. Our coroner-based surveillance database includes 140 snowmobile immersion deaths for the same period, an average of 28 per year, or 39% of the total.

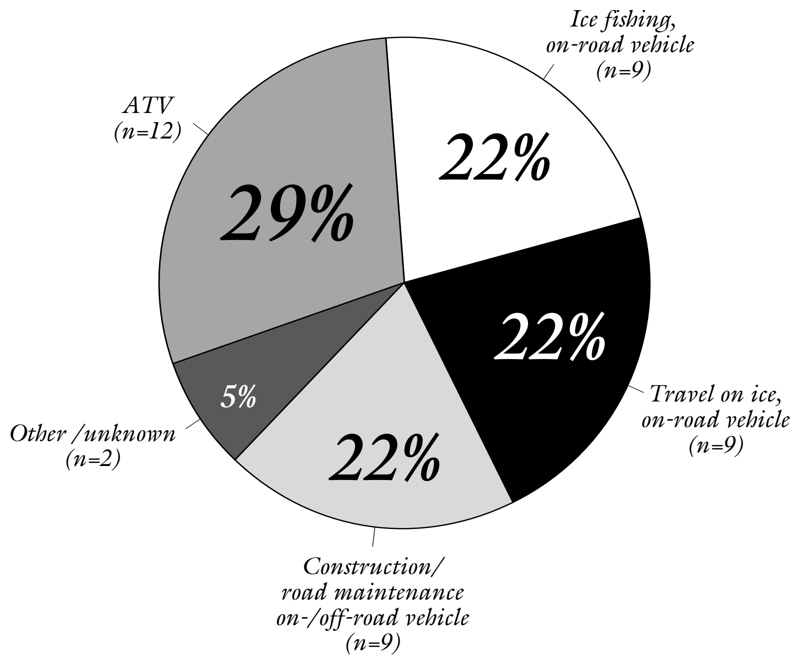
During 1996-1999 there were 313 snowmobile deaths reported by vital statistics, an average of 78 per year. Our surveillance database includes 106 snowmobile immersion deaths during 1996-2000, an average of 21 per year. Hence it appears that for this period about 27% of snowmobile deaths resulted from drowning or immersion hypothermia.

Thus while the average number of snowmobile deaths increased between the two periods, the average number of snowmobile immersion deaths decreased.

O T H E R M O T O R V E H I C L E S O N I C E

Immersion deaths involving other motor vehicles on ice were relatively infrequent, with only 41 deaths during the 8-year period from 1993-2000, as compared with 180 snowmobile deaths during the same period. Vehicles included on-road vehicles such as cars or trucks used for ice fishing or travel on ice, all-terrain vehicles, and vehicles used for clearing snow, road maintenance, and other activities on ice (Figure 22).

Figure 22 **IMMERSION DEATHS* INVOLVING MOTOR VEHICLES† ON ICE BY TYPE OF VEHICLE AND ACTIVITY, CANADA 1993-2000‡ (n=41)**



** Includes drowning with or without hypothermia and hypothermia without drowning † Excludes snowmobiles*
‡ Information not available for 1991-1992

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

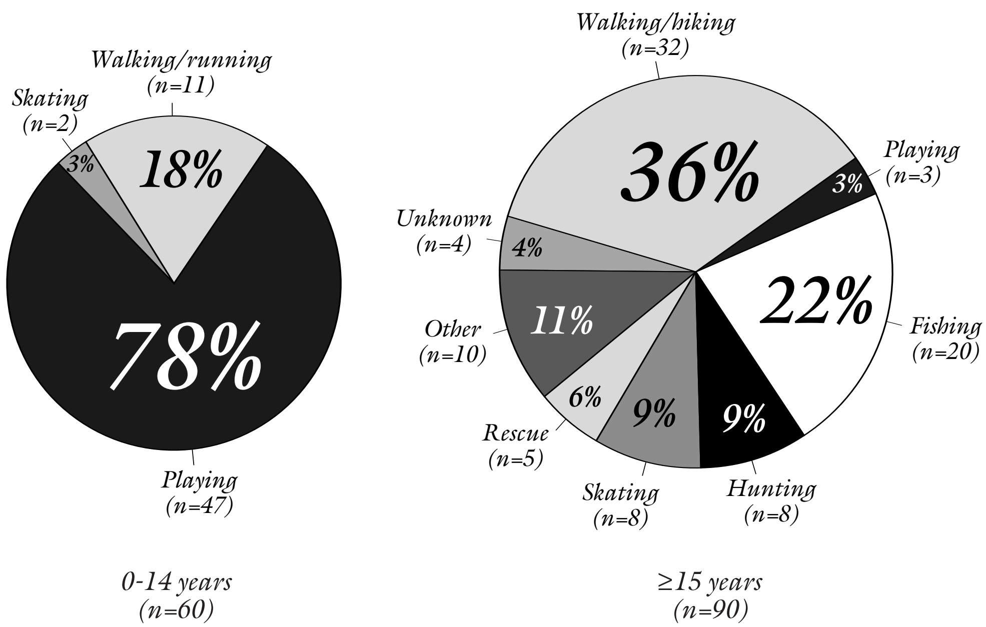
WALKING, PLAYING, FISHING, SKATING, AND OTHER ACTIVITIES ON ICE

During 1991-2000 there were 150 ice immersion deaths from falling through ice during non-motorized activities on ice, including 144 drownings with or without hypothermia and 6 deaths from hypothermia without drowning.

ACTIVITY AND PURPOSE Activity varied greatly by age. For children 0-14 years old, incidents resulted mainly from playing on ice, followed by walking or running and skating. For persons 15 and older, walking or running was followed by ice fishing, skating, and hunting (Figure 23). Recreational activities accounted for 75% (113/150) of deaths, daily living 15%, occupation 3%, rescue of dogs 3%, fleeing police 2%, and unknown 4%.

MULTIPLE-VICTIM INCIDENTS Based on data from 1993-2000, 28% of victims (33/120) died in multiple-victim incidents. These data were not available for 1991-1992.

Figure 23 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY AGE & ACTIVITY, CANADA 1991-2000 (n=150)**



** Includes drowning with or without hypothermia and hypothermia without drowning*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

INCIDENCE & PERSONAL FACTORS

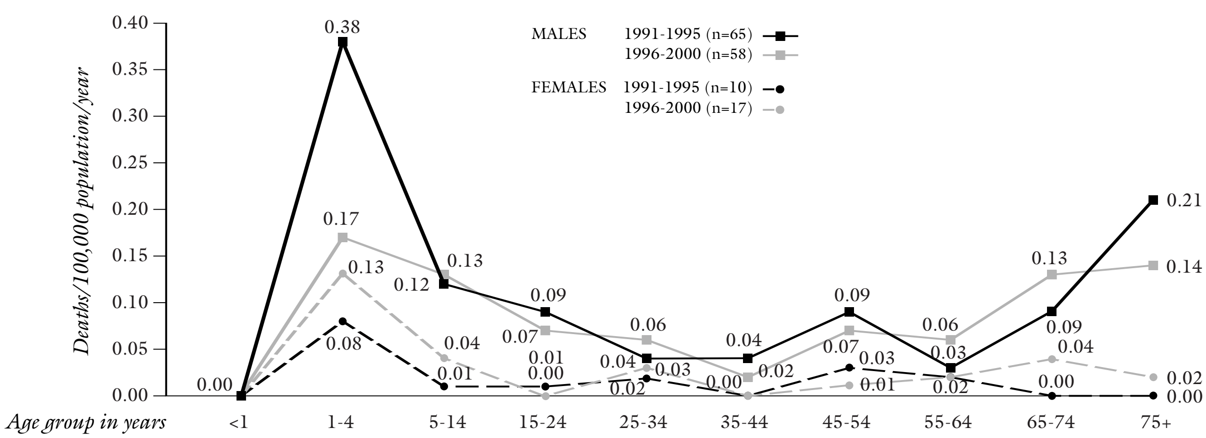
The average incidence rate was 0.54 non-motorized ice immersion deaths per million population per year. The incidence fell from 0.54 per million during 1991-1995 to 0.51 during 1996-2000, a slight decrease of 6%. This decrease was mainly apparent in male toddlers 1-4 years old, where the number of deaths decreased by 53% (Figure 24).

AGE AND SEX The major risk groups for ice immersion deaths were male and female toddlers, followed by 5-14 year old males and by males 15 to 75 and older. 82% of all victims were male, while toddlers and 5-14 year olds each accounted for 20% of victims. Thus children under 15 represented 40% of victims, in contrast with snowmobile immersion, where they represented only 4% of victims.

ALCOHOL & OTHER DRUGS Alcohol was consumed or suspected for 30% of victims ≥15 years of age, (Figure 25); this may be an underestimate, since alcohol was unknown for 38%. Illegal drugs were consumed or suspected in 7% of cases; similarly, drugs were unknown for 56%.

ETHNICITY Aboriginals were over-represented among the victims. While accounting for about 4% of the population, they accounted for 19% of victims (27 definite and 1 probable aboriginals). This may be an underestimate, since if ethnicity was not specified in the file, it had to be left unknown *(*Figure 26*)*.

Figure 24 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY AGE & SEX, CANADA 1991-2000 (n=150)†**



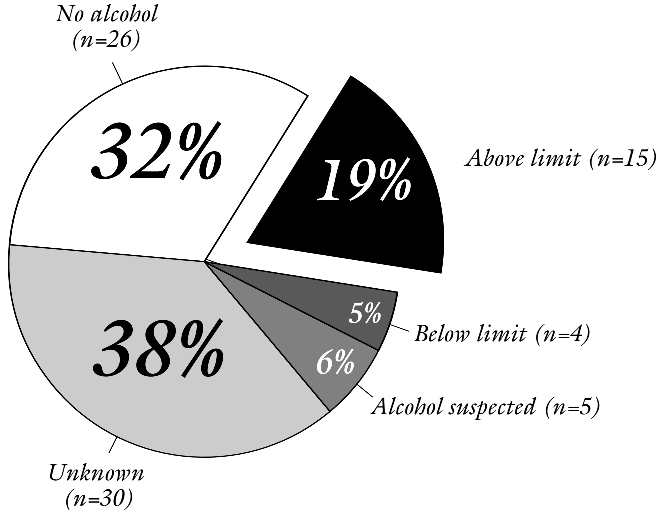
Number of deaths in age group

		<1	1-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	75+
MALES	1991-1995	0	15	12	9	5	4	7	2	4	5
	1996-2000	0	7	13	7	7	3	7	4	6	4
FEMALES	1991-1995	0	3	1	1	2	0	2	1	0	0
	1996-2000	0	5	4	0	3	0	1	1	2	1

** Includes drowning with or without hypothermia and hypothermia without drowning*
† Age unknown for 2 male victims (2, 0)

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

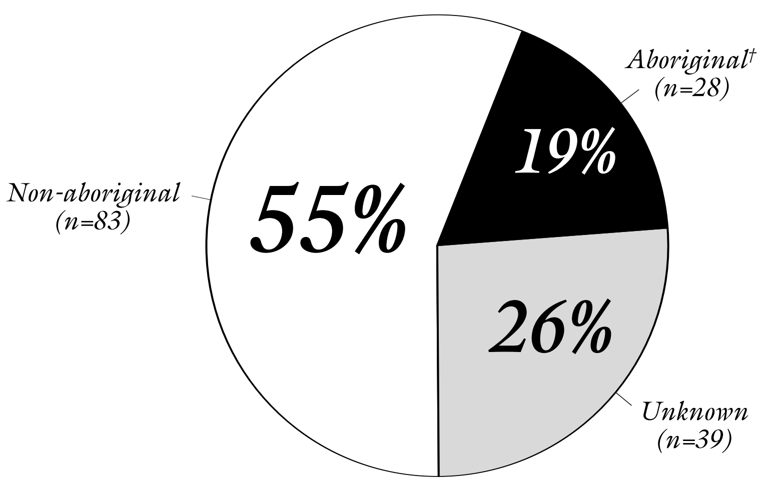
Figure 25 **BLOOD ALCOHOL LEVELS* FOR IMMERSION DEATHS† DURING NON-MOTORIZED ACTIVITIES ON ICE, CANADA 1991-2000 (VICTIMS ≥15 YEARS OF AGE; n=90)‡**



* Legal limit is 80 mg % † Includes drowning with or without hypothermia and hypothermia without drowning
‡ This figure excludes 10 victims; decomposition rendered blood alcohol unreliable

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

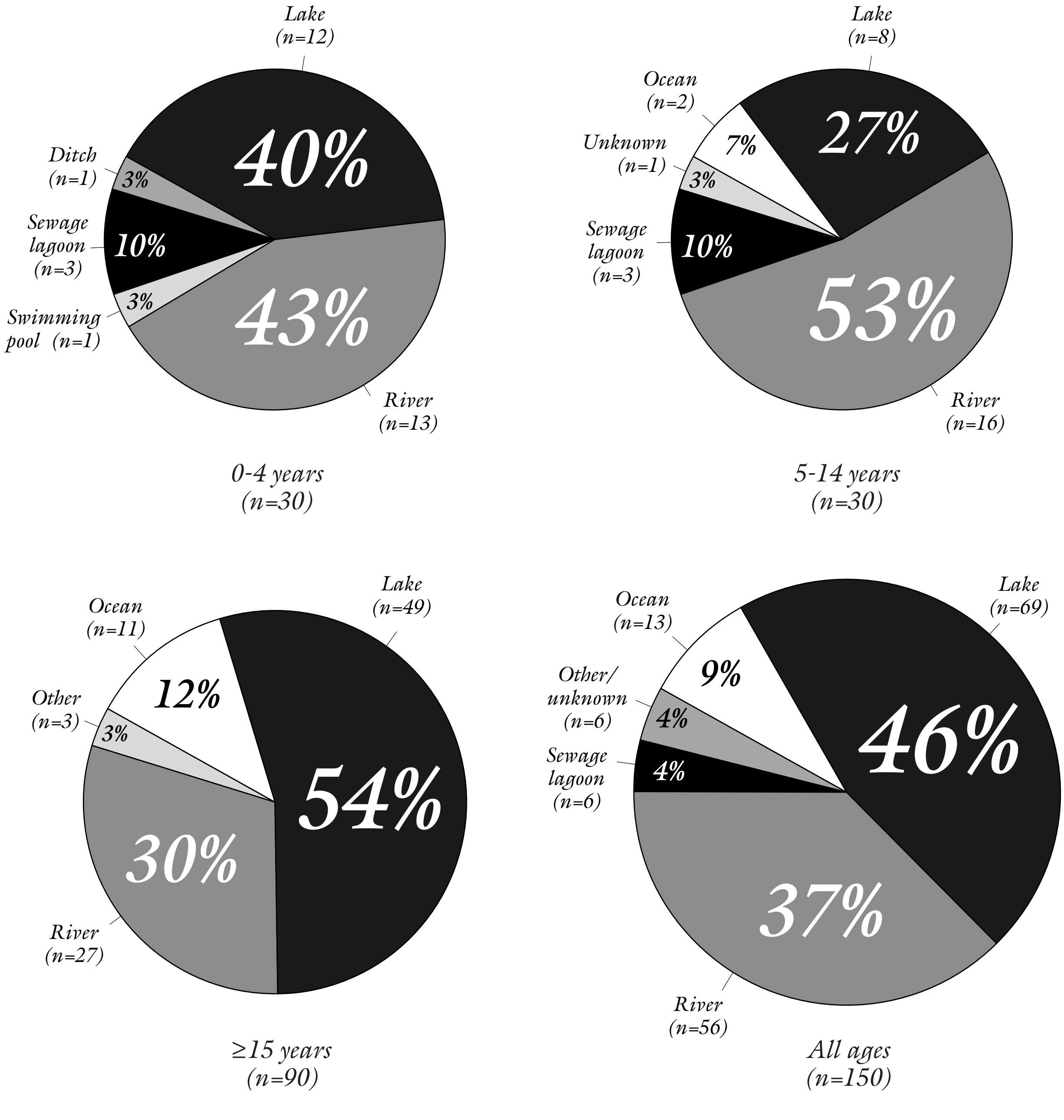
Figure 26 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY ETHNICITY, CANADA 1991-2000 (n=150)**



* Includes drowning with or without hypothermia and hypothermia without drowning
† Includes definite & probable aboriginals (First Nations, Inuit & Metis)

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 27 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY AGE & BODY OF WATER,† CANADA 1991-2000 (n=150)**



* *Includes drowning with or without hypothermia and hypothermia without drowning* † *Lake includes pond & reservoir*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

EQUIPMENT FACTORS

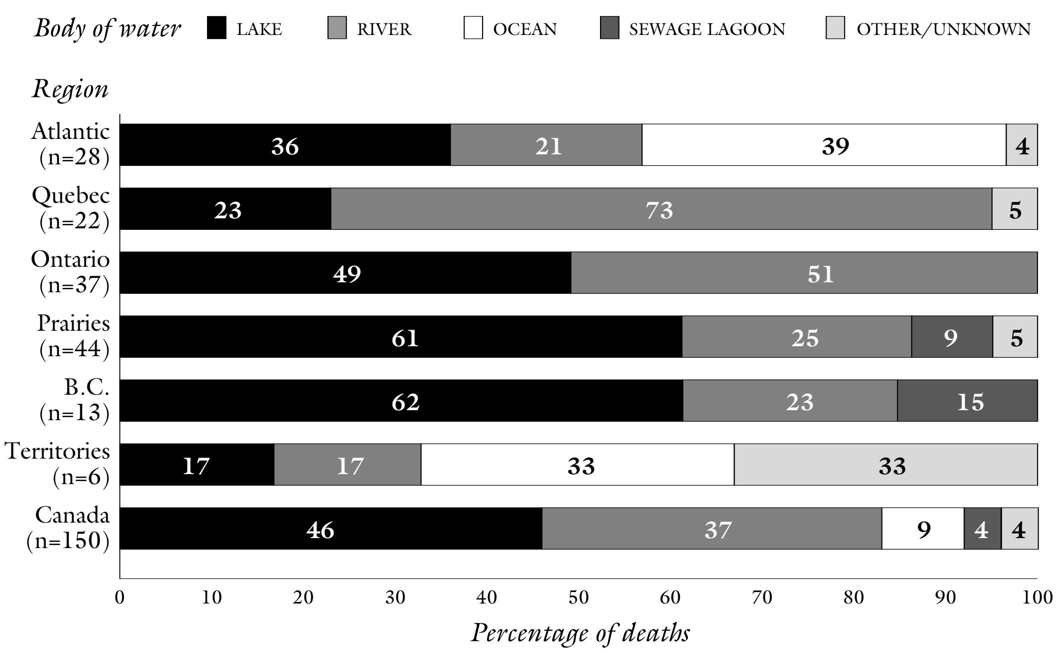
FLOTATION DEVICES Although rarely used for ice walking, a simple boating PFD could be helpful for survival, but there was no record of such safety equipment in coroners' reports.

Seldom if ever recorded by coroners is use of flotation-hypothermia suits, rescue throw bags with rope, or ice picks for crawling out of water onto ice.

ENVIRONMENT FACTORS

BODY OF WATER Lakes were the most frequent body of water for non-motorized ice immersion deaths, followed by rivers and the ocean (Figure 27). There were significant differences by age. The most frequent body of water for children 0-14 was rivers, whereas for adults lakes were much more frequent. The predominant type of body of water varied by region, with lakes most frequent in central and western Canada, rivers in Quebec, and the ocean in the Atlantic region (Figure 28). While the number of sewage lagoon incidents was not very large, all of these incidents involved children under 15 in the Prairies or B.C. Such sites should normally be fenced to protect children.

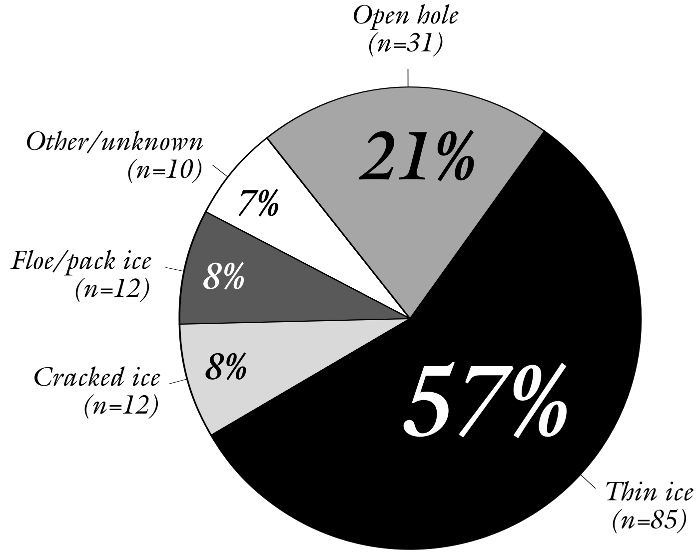
Figure 28 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY BODY OF WATER† BY REGION, CANADA 1991-2000 (n=150)**



** Includes drowning with or without hypothermia and hypothermia without drowning † Lake includes pond & reservoir*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

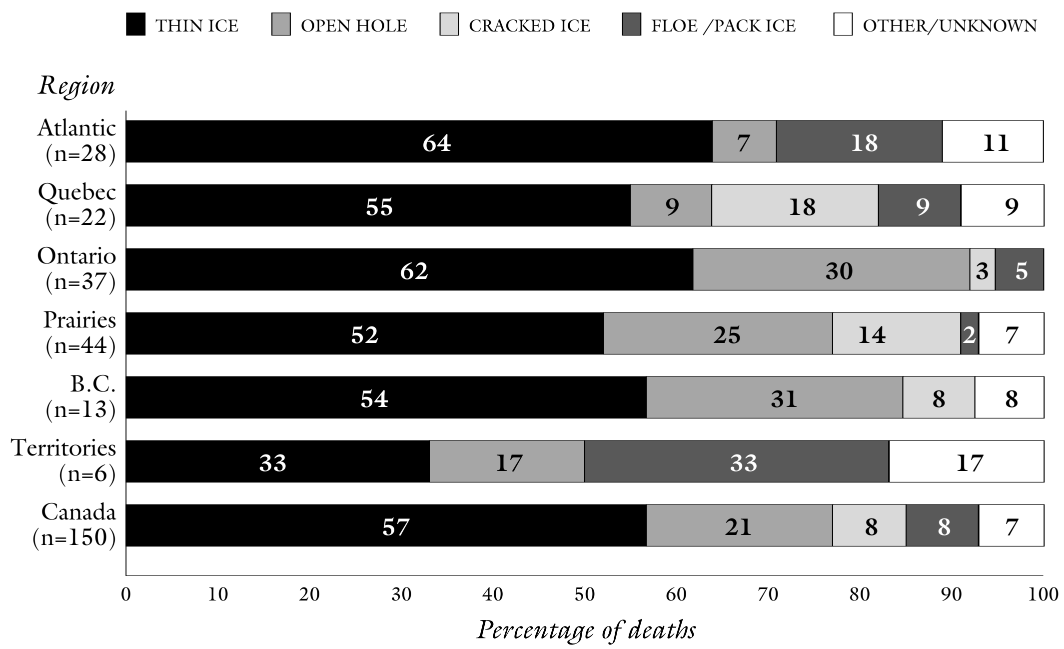
ICE CONDITIONS The most common ice condition was thin ice at 57%, followed by an open hole in the ice at 21%, cracked ice 8%, and ice floe 8% (Figure 29). This contrasted with snowmobile incidents, where an open hole accounted for 41% and thin ice for 40% of deaths. There were regional differences in ice conditions (Figure 30), but these variations were minor compared with snowmobiles.

Figure 29 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY ICE CONDITIONS, CANADA 1991-2000 (n=150)**



* *Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 30 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY ICE CONDITIONS BY REGION, CANADA 1991-2000 (n=150)**



* *Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

AIR TEMPERATURE Air temperature was unspecified for 62% of deaths. Where this factor was known, the air was extremely cold in 32% of cases, very cold in 42% and cold in 26%.

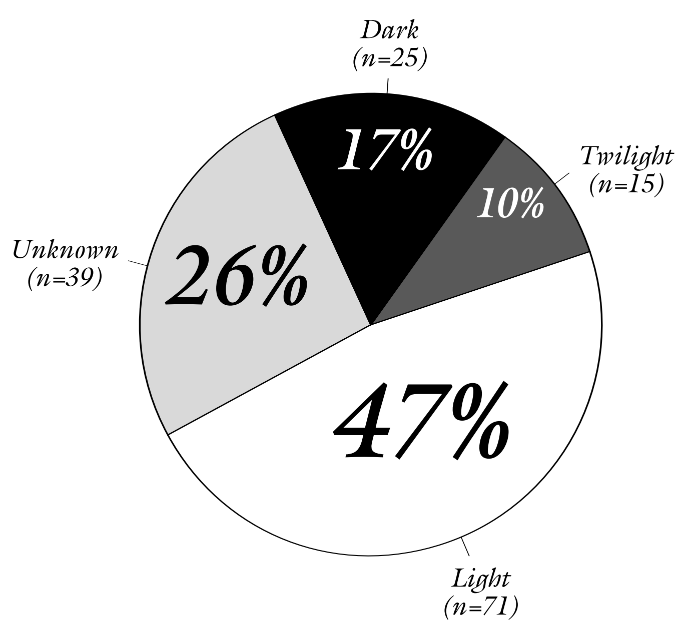
DEPTH OF WATER Depth of water was known for 24% of deaths (36/150). Of these, 50% took place in water >2.5 metres deep, and 50% in water 1.1-2.5 metres deep.

VISIBILITY: LIGHT CONDITIONS, TIME OF DAY, WEATHER At least 48% of ice immersion deaths occurred during daylight (Figure 31), compared with only 18% of snowmobiling deaths. Where the time of the incident was known, 79% had occurred between 10:00 and 17:59 (Figure 32). This contrasted with snowmobiling, where 66% of incidents occurred between 18:00 and 05:59 hours. Low visibility due to darkness was a factor in about 30% of deaths, whereas it was a factor in the great majority of snowmobiling deaths. Weather was reported for only 15% (22/150) of deaths; among these, snowing was reported for 7%, rain for 9%, it was cloudy for 32% and clear for 55%.

SEASON Non-motorized ice immersions occurred mainly between November and April (Figure 33). During 1991-1995, incidents occurred at a fairly steady rate in November, December, February, March, and April, with a dip in January. During 1996-2000 there were fewer incidents in November, April, May and June, with an increase in February.

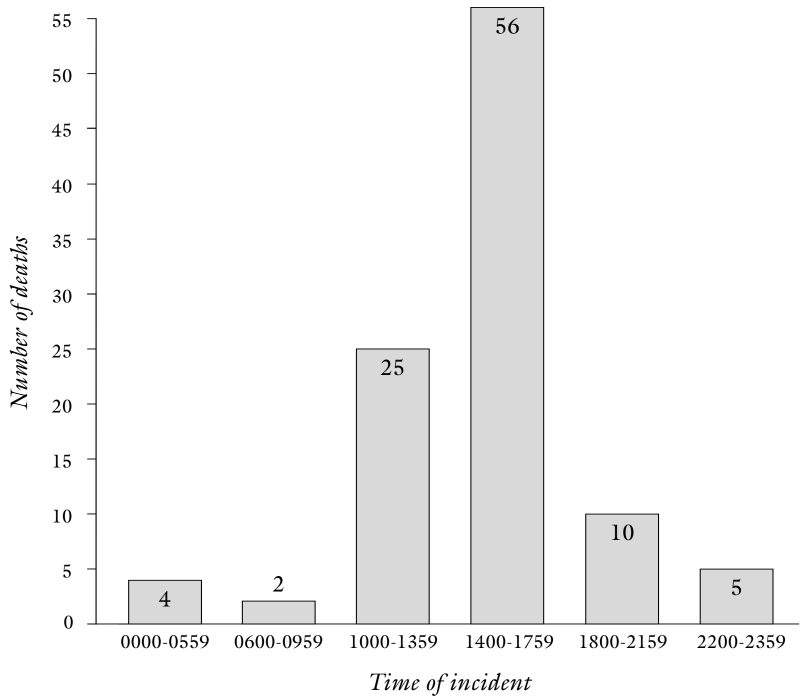
DAY OF WEEK Ice immersions occurred throughout the week (Figure 34). There was a substantial shift of incidents from Sundays and Mondays to Wednesday between the two periods 1991-1995 and 1996-2000. Reasons for this change are unclear.

Figure 31 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY LIGHT CONDITIONS, CANADA 1991-2000 (n=150)**



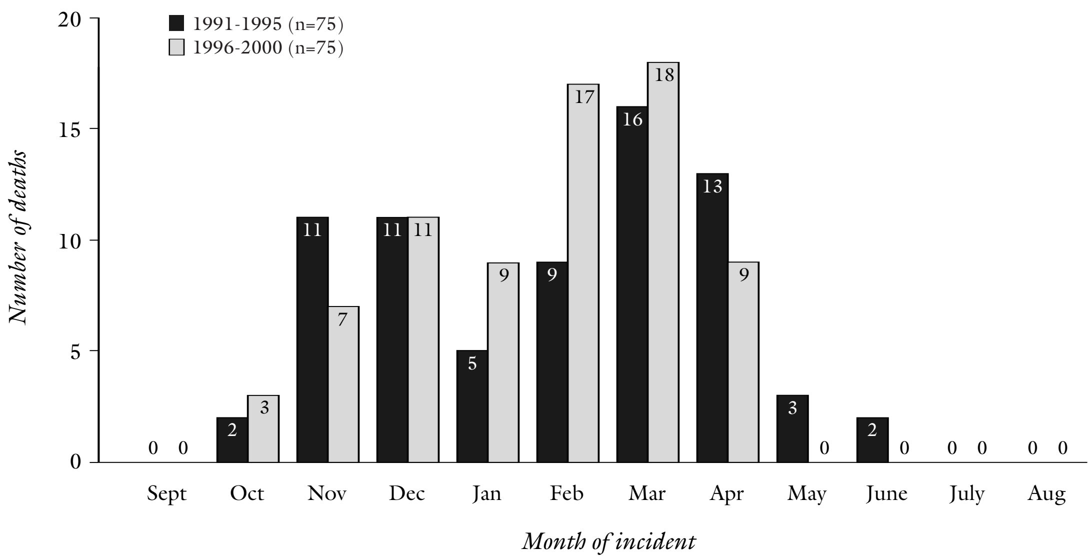
** Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 32 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY TIME OF INCIDENT, CANADA 1991-2000 (n=150)†**



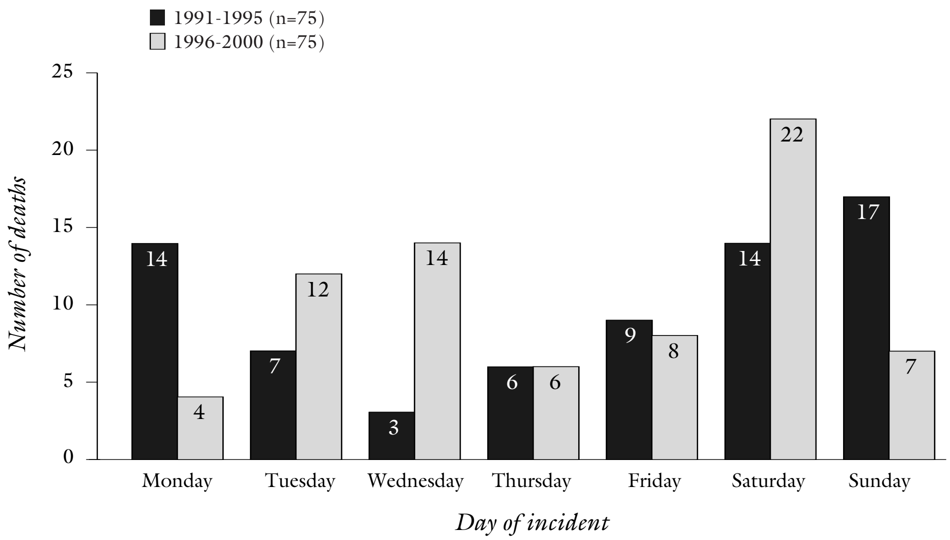
** Includes drowning with or without hypothermia and hypothermia without drowning † Time unknown for 48 deaths*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 33 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY MONTH OF INCIDENT, CANADA 1991-2000 (n=150)†**



** Includes drowning with or without hypothermia and hypothermia without drowning † Month unknown for 4 deaths (3, 1)*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 34 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY DAY OF INCIDENT, CANADA 1991-2000 (n=150)†**



** Includes drowning with or without hypothermia and hypothermia without drowning † Day unknown for 7 deaths (5, 2)*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

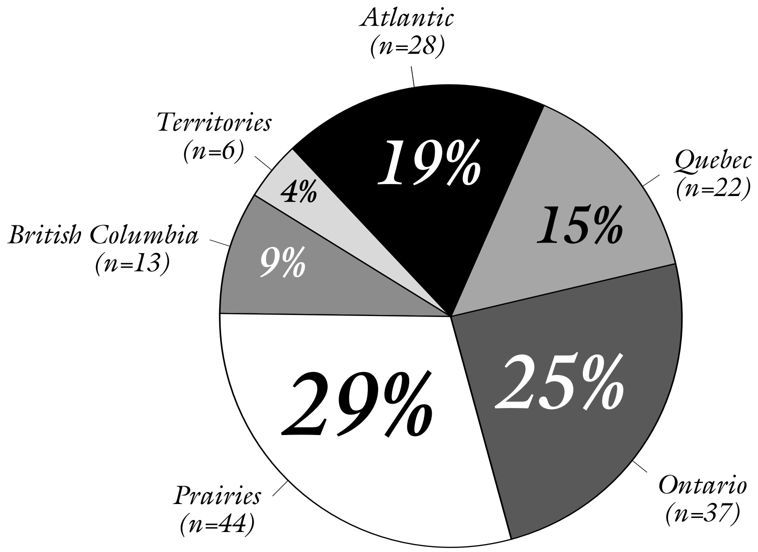
URBAN/RURAL RESIDENCE AND LOCATION 64% of ice immersion deaths (96/150) took place in rural areas; of these 81% of victims were rural residents, 18% urban residents, and for 1% residence was unknown. 36% of deaths (54/150) occurred in urban areas; 96% of victims were urban residents, 2% rural residents, and for 2% residence was unknown.

NATURE OF LOCATION 7% of deaths were reported on aboriginal reserves, 5% at cottages, and 8% at parks or conservation areas. Many were unspecified.

REGIONAL INCIDENCE & TRENDS The largest number of ice immersion deaths occurred in the Prairies, followed by Ontario and the Atlantic region (Figure 35). The highest rates were seen in the Atlantic and Prairie regions and in the northern territories. Although Quebec had the lowest average rate in Canada for 1991-2000, twice as many deaths occurred in 1996-2000 as in 1991-1995 (Figure 36).

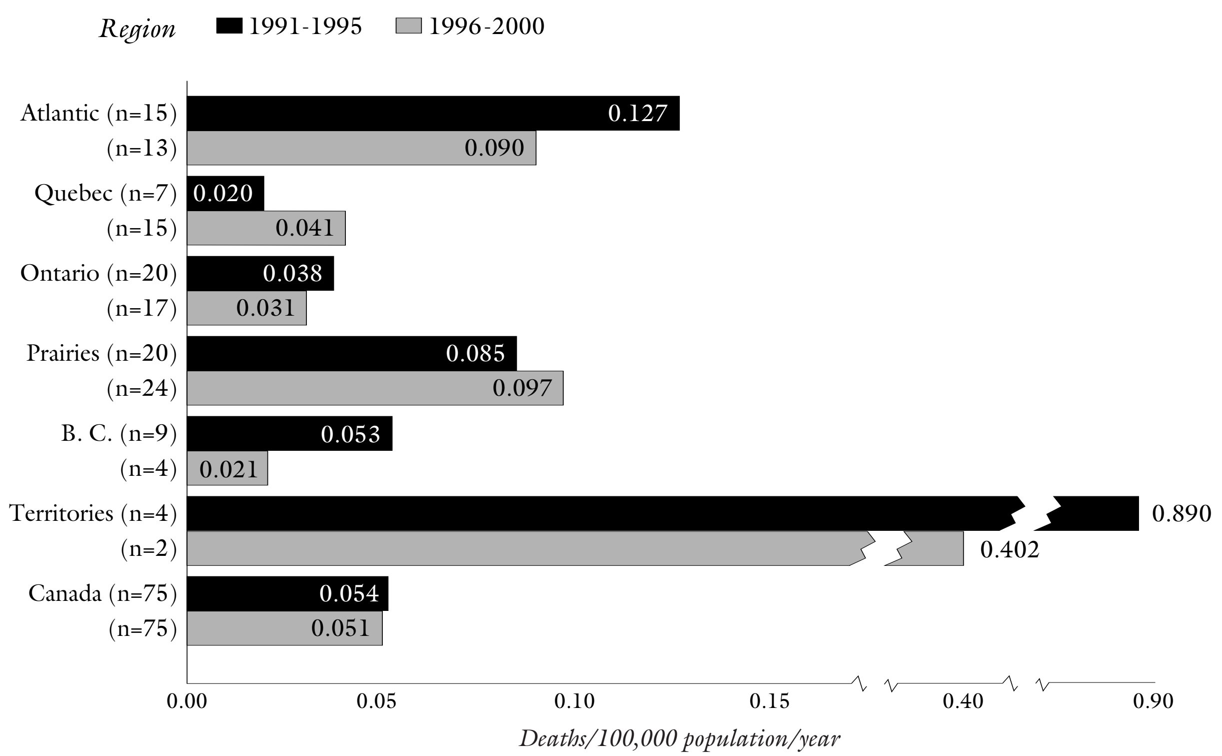
Overall, there was no significant improvement between 1991-1995 and 1996-2000. Due to the shift of incidents to later months of the season, possibly due to climatic changes, the relative ice safety between the two periods may even have deteriorated.

Figure 35 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY REGION, CANADA 1991-2000 (n=150)**



** Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 36 **RATE AND NUMBER OF IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY REGION, CANADA 1991-2000 (n=150)**

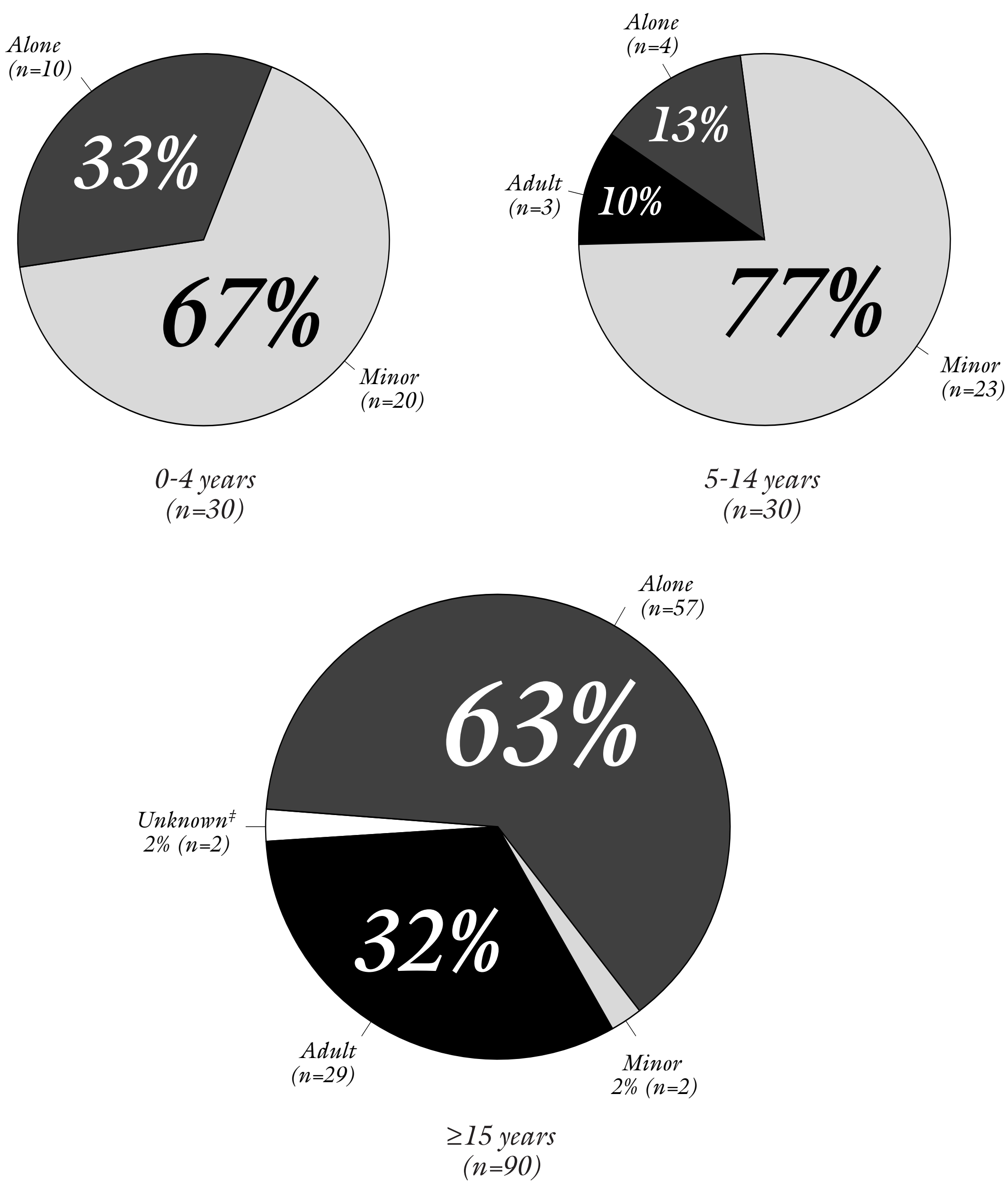


** Includes drowning with or without hypothermia and hypothermia without drowning*
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

ACCOMPANIMENT/SUPERVISION None of the toddlers and only 10% of 5-14 year-olds who drowned during activities on ice were accompanied by an adult (Figure 37). Most children were accompanied only by a minor, while most adults were alone.

RESCUE/CPR Acute rescue for a potentially survivable victim was carried out for 42% of victims, and CPR for 22% (Figure 38). The proportion of victims who underwent acute rescue was much higher for children, youths and young adults, while CPR was most frequent for children.

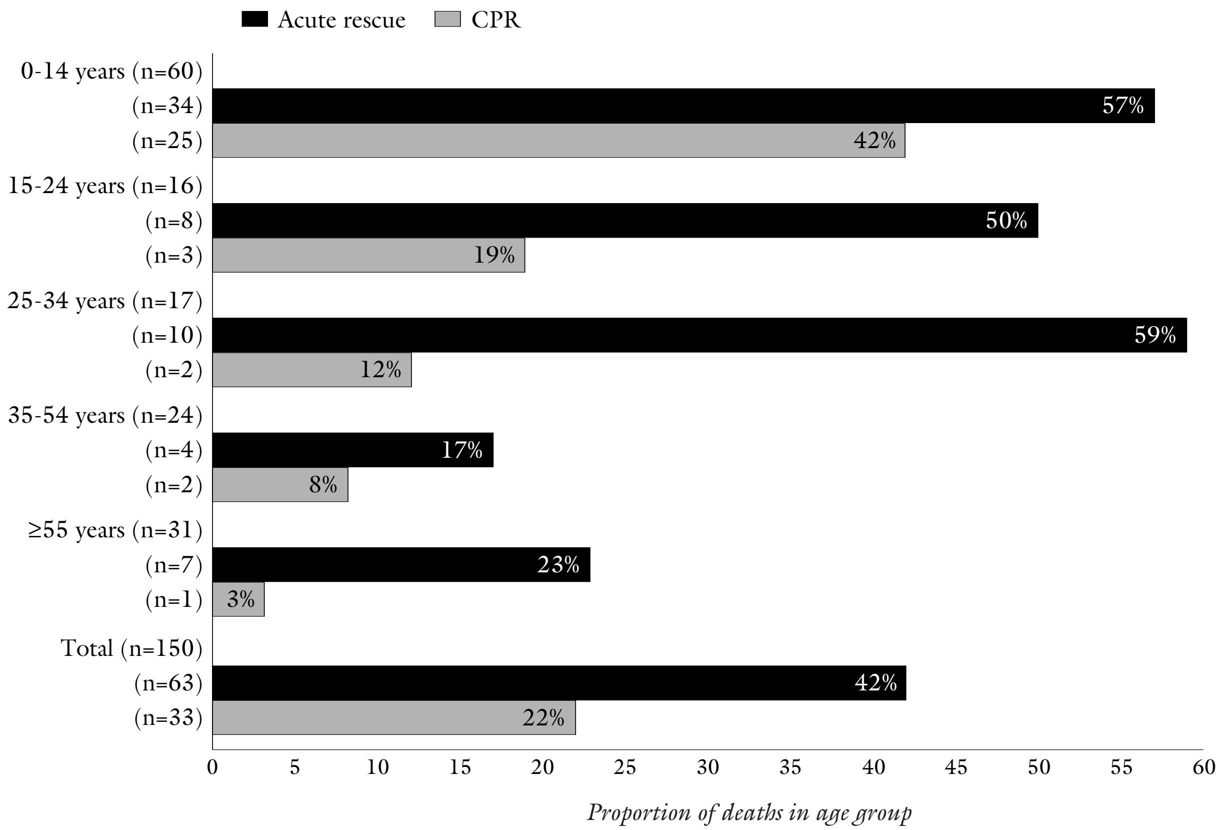
Figure 37 **IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE BY AGE OF VICTIMS & ACCOMPANYING PERSONS,† CANADA 1991-2000 (n=150)**



** Includes drowning with or without hypothermia and hypothermia without drowning*
† "Adult" indicates presence of adult(s) but does not exclude presence of minors (<18 years); "minor" indicates presence of minor(s) only
‡ Accompaniment unknown, or age of companion(s) unspecified

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 38 **PERCENT OF IMMERSION DEATHS* DURING NON-MOTORIZED ACTIVITIES ON ICE WITH ACUTE RESCUE & CPR† BY AGE, CANADA 1991-2000 (n=150)‡**



** Includes drowning with or without hypothermia and hypothermia without drowning*
† Cardiopulmonary resuscitation ‡ Age unknown for 2 victims (both without acute rescue or CPR)

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

ACTIVITIES IN, ON, OR AROUND COLD WATER

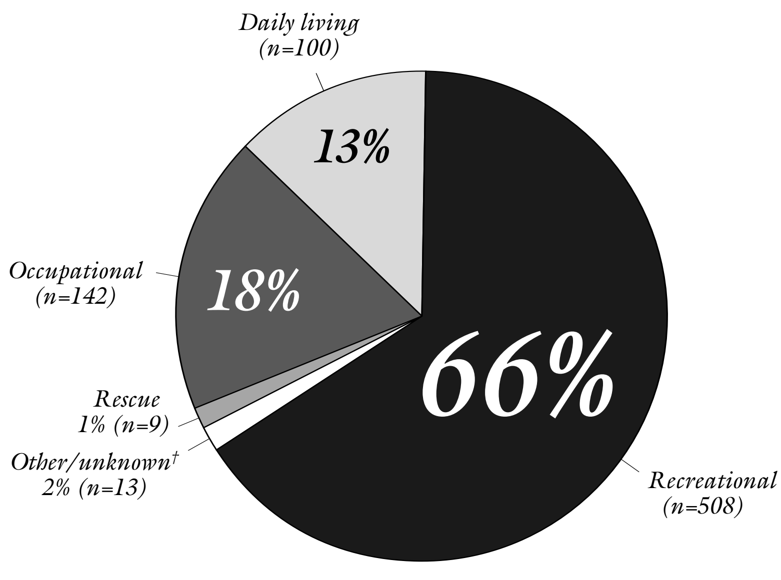
BOATING

During 1991-2000, boating accounted for 39% of drownings, excluding land and air transport (1,803/4,671); 33% of all drownings, including land and air transport (1,803/5,535); and for 55% (51/92) of all cases of hypothermia without drowning. Hence it is not surprising that boating accounted for 38% of all cold water immersion deaths (772/2,007), as previously noted in Figure 1.

There were 13 deaths involving boating where causes other than immersion were considered primary and extremely cold water secondary. These included 6 trauma of boating collision, 3 falls, 1 carbon monoxide poisoning and trauma of collision, 1 strangled hauling nets, 1 cardiac failure, and 1 vehicle collision.

PURPOSE OF ACTIVITY Recreational boating accounted for 66% of cold water boating immersion deaths, followed by occupational 18%, and daily living 13% (Figure 39). This compares with the following proportions for all boating immersion deaths: recreational 75%, occupational 12% and daily living 10%.

Figure 39 **COLD WATER BOATING IMMERSION DEATHS* BY PURPOSE OF ACTIVITY, CANADA 1991-2000 (n=772)**



** Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April) † Other 2, unknown 11*

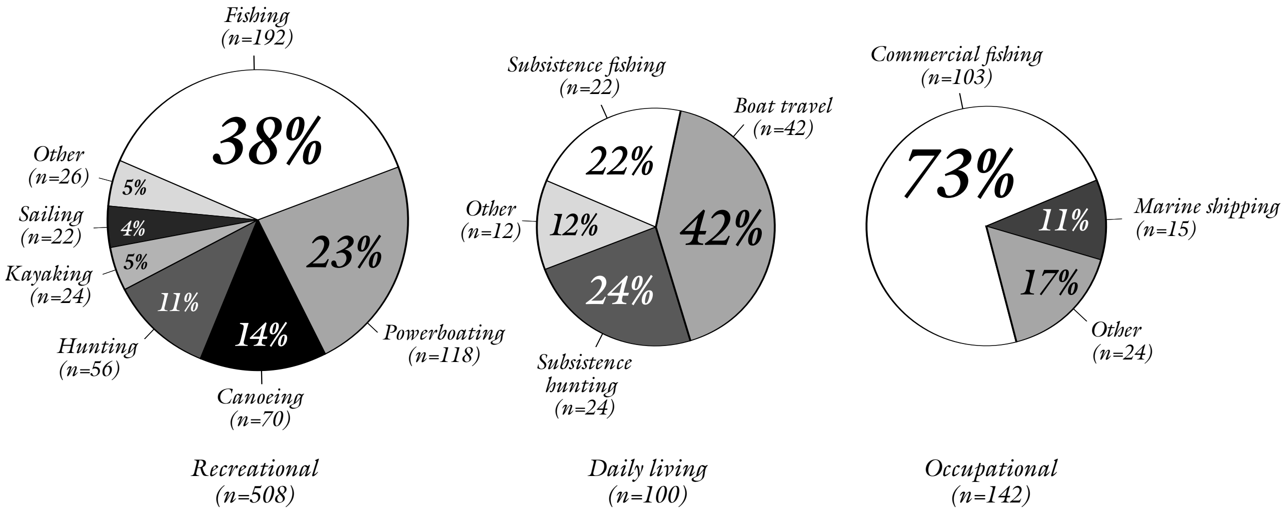
Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

ACTIVITY Fishing was the most frequent recreational and occupational activity associated with cold water boating immersion deaths (Figure 40). For daily living, boat travel was the most frequent activity, followed by subsistence hunting and fishing.

PERSONAL RISK FACTORS

AGE AND SEX AND TRENDS Males made up 92% of victims (Figure 41). Children under 15 accounted for only 4% of victims. The main high-risk group was males 15 and older. There was little improvement overall, with a slight decline in rates for the younger adult males offset by an increase for males 55-74 years of age.

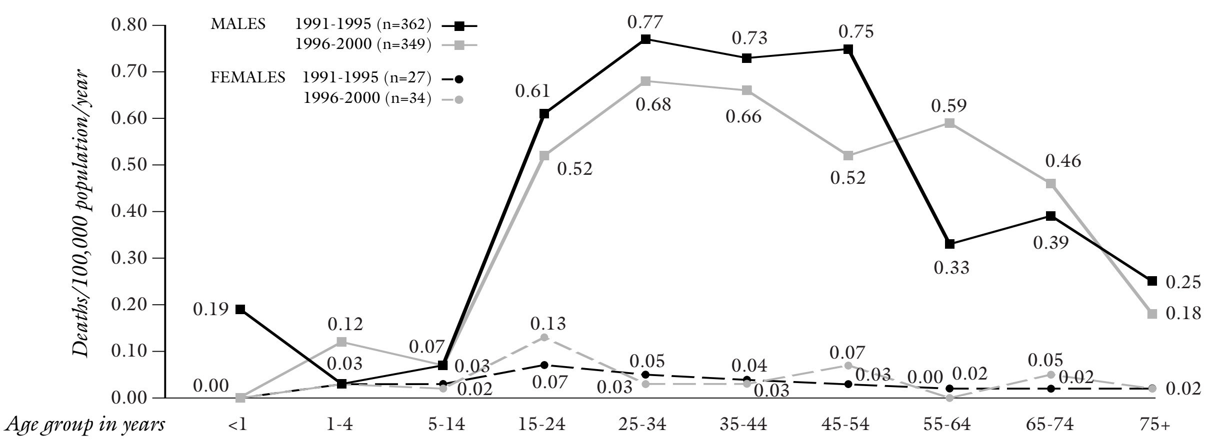
Figure 40 **COLD WATER BOATING IMMERSION DEATHS* BY PURPOSE & ACTIVITY, CANADA 1991-2000 (n=772)†**



** Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April)*
† This figure excludes 22 victims whose purpose was rescue 9, other 2, & unknown 11

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 41 **RATE AND NUMBER OF COLD WATER BOATING IMMERSION DEATHS* BY AGE AND SEX, CANADA 1991-2000 (n=772)†**



Number of deaths in age group

		<1	1-4	5-14	15-24	25-34	35-44	45-54	55-64	65-74	75+
MALES	1991-1995	2	1	7	63	99	82	57	20	17	6
	1996-2000	0	5	7	54	82	82	49	37	22	5
FEMALES	1991-1995	0	1	3	7	6	5	2	1	1	1
	1996-2000	0	1	2	13	3	4	7	0	3	1

** Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April)   † Age unknown for 14 male victims (8, 6)*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

ALCOHOL Alcohol was associated with 33% of deaths of victims ≥15 years of age (Figure 42). This is an underestimate, since alcohol was unknown for 30%.

ETHNICITY Aboriginals accounted for 16% of cold water boating immersion deaths (Figure 43), which is an underestimate since ethnicity was unknown for 25% of cases.

EQUIPMENT RISK FACTORS

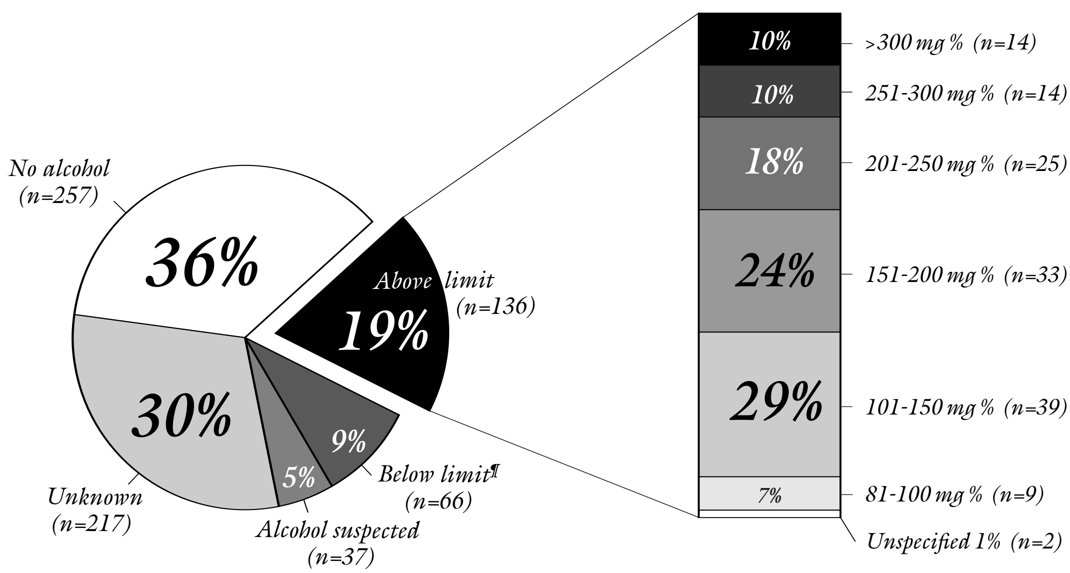
TYPE OF BOAT At least 60% of incidents occurred in small boats (≤ 5.5 m) (Figure 44). Most recreational and daily living incidents involved small boats, most occupational incidents large boats (> 5.5 m).

FLOTATION DEVICE Only 19% (143/772) of all victims were properly wearing a flotation device (Figure 45).

ENVIRONMENTAL RISK FACTORS

TYPE OF BODY OF WATER Overall, lakes and oceans were the two main bodies of water for deaths (Figure 46). Most recreational and daily living incidents took place in lakes and rivers, most occupational incidents in the ocean.

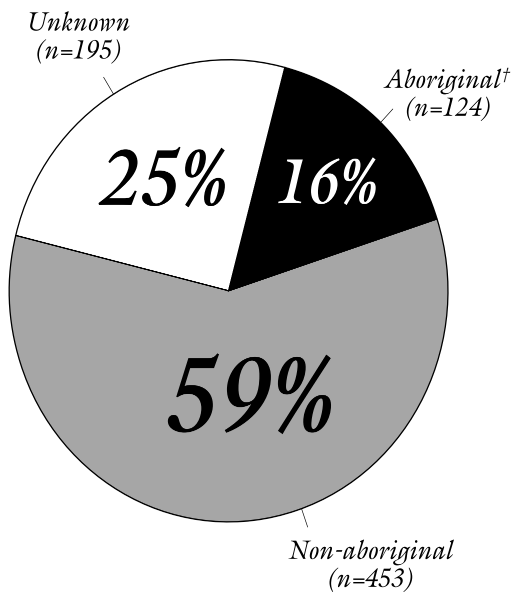
Figure 42 **BLOOD ALCOHOL LEVELS* FOR COLD WATER BOATING IMMERSION DEATHS,† CANADA 1991-2000 (VICTIMS ≥ 15 YEARS OF AGE; n=743)‡§**



** Legal limit is 80 mg % † Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April)*
‡ Age unknown for 14 victims, presumed adult § This figure excludes 30 victims; decomposition rendered blood alcohol unreliable
¶ 35 at 1-49 mg %, 23 at 50-80 mg %, 8 unspecified

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

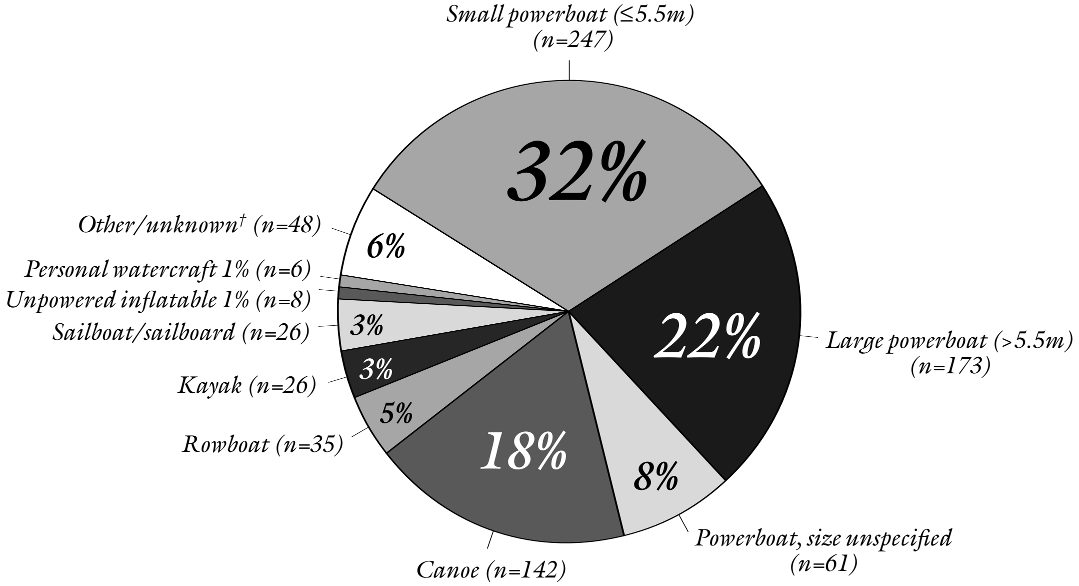
Figure 43 **COLD WATER BOATING IMMERSION DEATHS* BY ETHNICITY, CANADA 1991-2000 (n=772)**



* *Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April)* † *Includes definite & probable aboriginals (Firt Nations, Innuit & Métis)*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

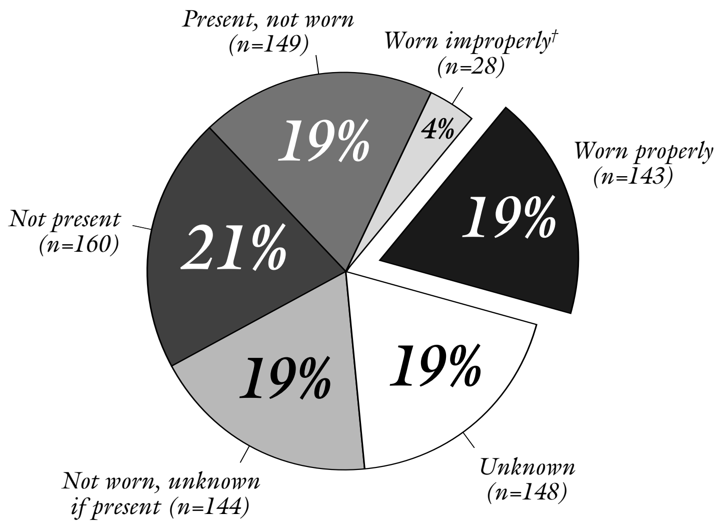
Figure 44 **COLD WATER BOATING IMMERSION DEATHS* BY TYPE OF BOAT, CANADA 1991-2000 (n=772)**



* *Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April)* † *Other 17, unknown 31*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

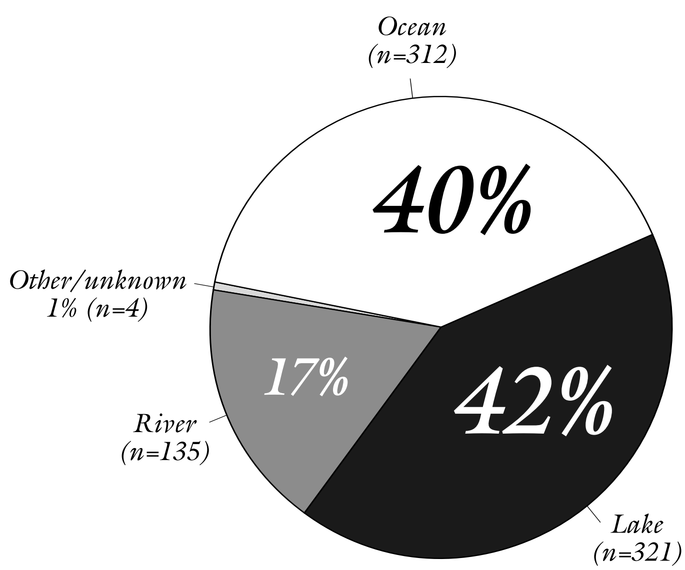
Figure 45 **COLD WATER BOATING IMMERSION DEATHS* BY USE OF A FLOTATION DEVICE,† CANADA 1991-2000 (n=772)**



* Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April) † Personal flotation device or lifejacket
‡ Not fastened or inappropriate size

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 46 **COLD WATER BOATING IMMERSION DEATHS* BY BODY OF WATER,† CANADA 1991-2000 (n=772)**



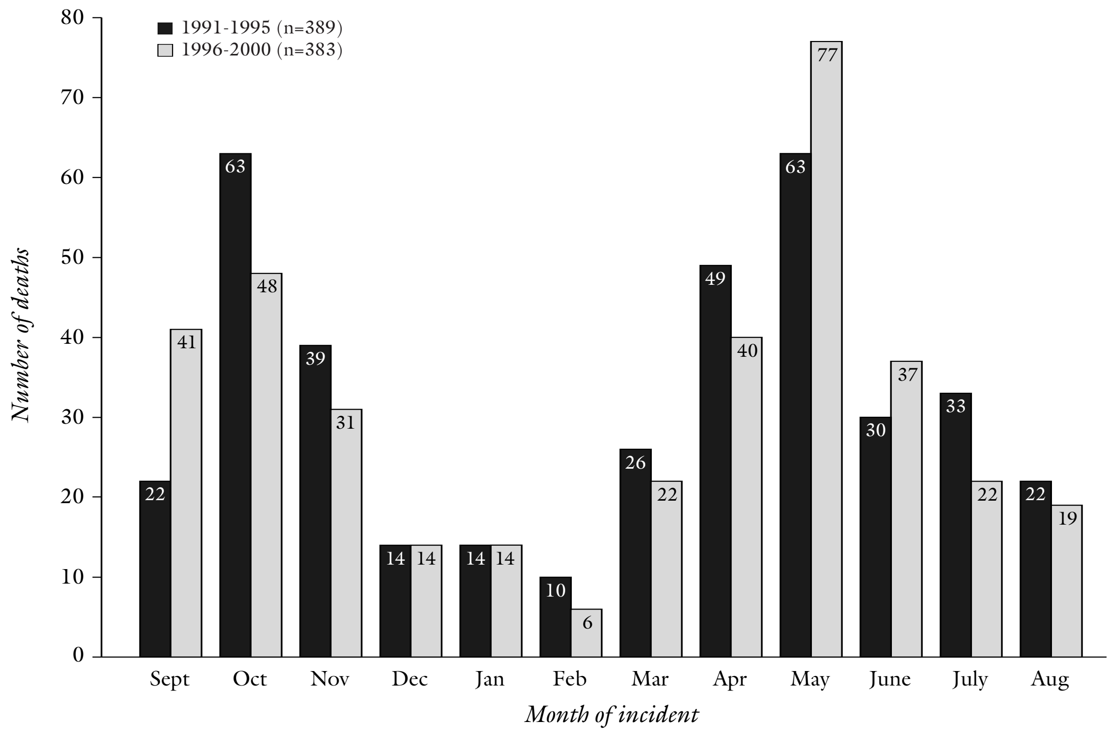
* Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April) † "Lake" includes pond & reservoir

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

MONTH Peaks of cold water immersion deaths during boating are evident in the spring months of April and May, and in the autumn months of September, October, and November. Comparing 1991-1995 and 1996-2000, in the spring months there was a slight decrease in incidents during March-April with a shift to May-June. Similarly, in the autumn there was a shift from October and November to September (Figure 47).

RATES AND TRENDS BY REGION The coastal provinces had rates about 5 times higher than the other provinces (Figure 48). Overall, there was little change for Canada. There was a large drop in the rate for the northern territories, and a fairly large decrease in the Prairies. There was a moderate increase in Quebec.

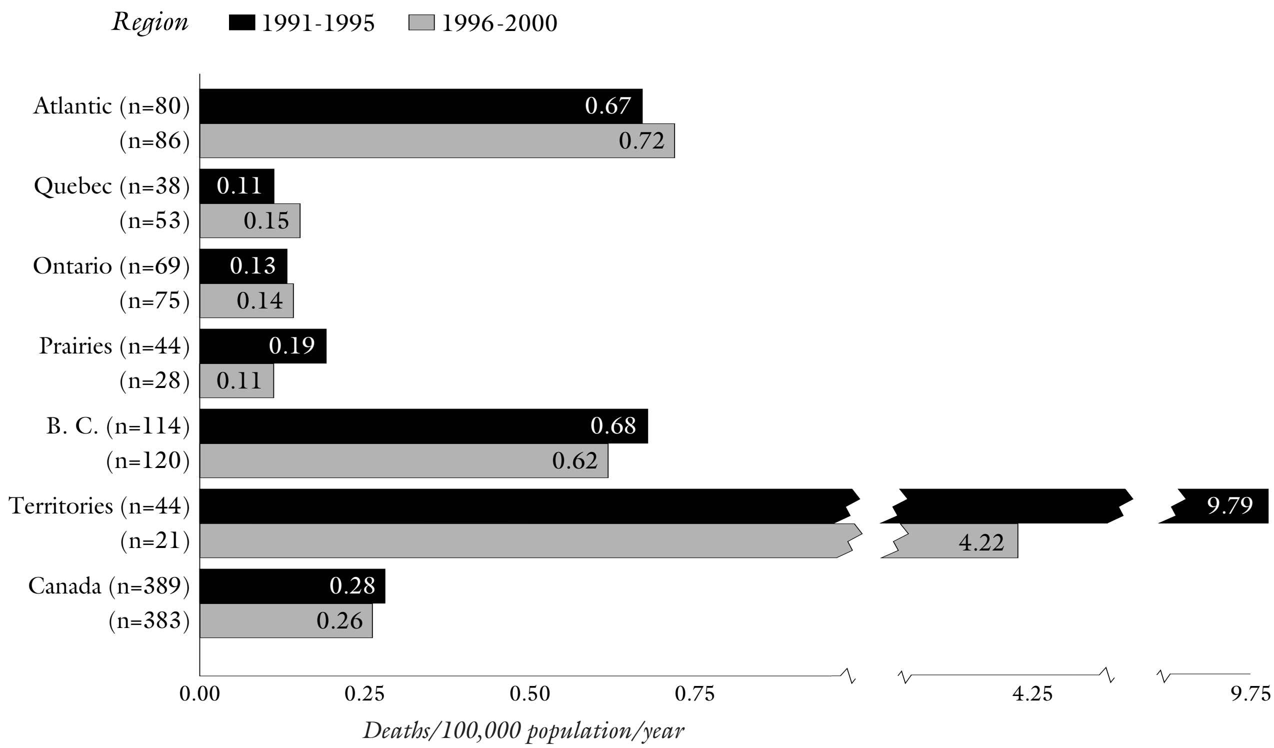
Figure 47 **COLD WATER BOATING IMMERSION DEATHS* BY MONTH, CANADA 1991-2000 (n=772)†**



* *Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April)* † *Month unknown for 16 deaths*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Figure 48 **RATE OF COLD WATER BOATING IMMERSION DEATHS* BY REGION, CANADA 1991-2000 (n=772)**



* *Includes victims for whom one or more of these factors were reported: hypothermia (with or without drowning), ice or extremely cold water, or cold weather month (November through April)*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

VICTIM & SURVIVOR RESPONSES TO IMMERSION The behaviour of victims and survivors of cold water boating immersions due to capsizing and swamping was similar. Similar proportions swam for shore immediately, after a delay, or stayed with the boat.

36% of victims (82/230) had a choice of whether to stay with the boat or swim for shore (i.e. the boat didn't sink or get swept away by current or wind). Of these, 27% (22/82) stayed with the boat, 33% (27/82) swam for shore immediately, 28% (23/82) swam for shore after a delay, and 12% (10/82) did other things.

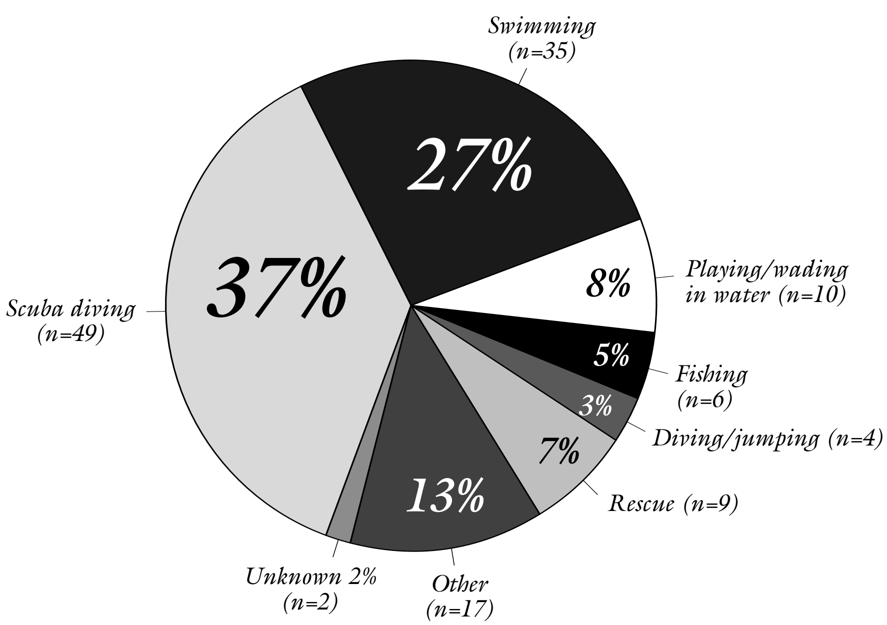
73% of survivors (91/125) had a choice of whether to stay with the boat or swim for shore. Of these, 30% (27/91) stayed with the boat, 31% (28/91) swam for shore immediately, 29% (26/91) swam for shore after a delay, and 11% (10/91) did other things.

Aquatic activities — where the person intended to be in the water — accounted for only 7% of cold water immersion deaths, as compared with 25% of all drownings. There were 20 deaths involving aquatic activities where causes other than immersion were considered primary and extremely cold water secondary. These included: air embolism 14, nitrogen narcosis 1, asphyxia 1, trapped in intake pipe 1, trauma of diving into water 2, and unknown 1.

ACTIVITY, PURPOSE Scuba diving was the most frequent aquatic activity leading to cold water immersion death (Figure 49), accounting for 37% of deaths, whereas scuba diving accounted for only 3% of all aquatic drownings. While only 5% (35/752) of swimming deaths were associated with cold water immersion, 61% (49/80) of scuba diving deaths were associated with cold conditions. For all deaths from aquatic activities associated with cold, 73% occurred during recreational activities, 19% occupational, 5% attempted rescues, and 1% daily living.

BODY OF WATER 40% of cold water aquatic deaths took place in the ocean, followed by rivers, 29%, and lakes, 23%.

Figure 49 **COLD IMMERSION DEATHS DURING AQUATIC ACTIVITIES BY ACTIVITY, CANADA 1991-2000 (n=132)**



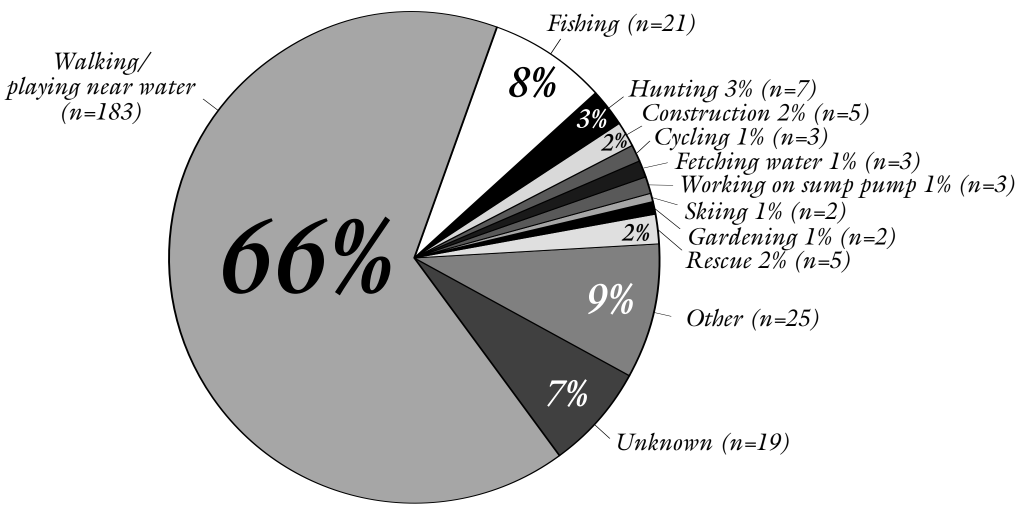
** Includes victims for whom one or more of these factors were reported: drowning with hypothermia, hypothermia without drowning, the presence of ice or extremely cold water (<10° C), cold weather month (November through April)*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

Falls into cold water (not through ice) during non-motorized activities represented 14% (278/2,007) of all cold water immersion deaths (see Figure 1). There were 12 deaths involving falls into water where trauma of a fall was considered a significant factor in the death, and 1 incident where the victim was swept away by a large wave; in all these incidents, extremely cold water was also a factor.

ACTIVITY, PURPOSE The most frequent activity was walking or playing near water, followed by fishing from shore (Figure 50). In a majority of cases, the purpose of the activity was recreational, 61%, followed by daily living, 26%, and occupational, 5%.

Figure 50 **COLD WATER IMMERSION DEATHS* FROM FALLS INTO WATER BY ACTIVITY, CANADA 1991-2000 (n=278)**



* *Includes victims for whom one or more of these factors were reported: hypothermia with or without drowning, extremely cold water (<10° C), or cold weather month (November through April)*

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

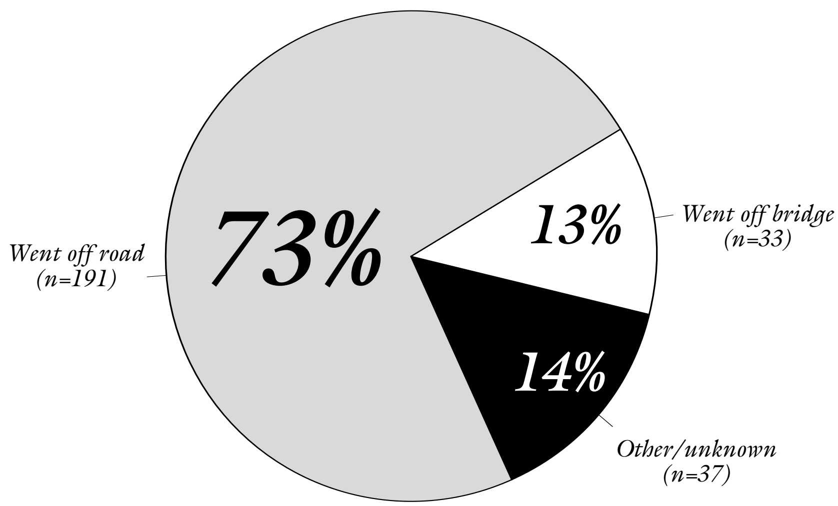
There were about 293 deaths associated with cold-water immersion during land transport in Canada during 1991-2000, excluding the incidents during activities on ice described in the first section of the results; these deaths accounted for about 15% of all cold-water immersion deaths (See Figure 1). Most incidents involved daily living travel.

There were 10 deaths involving motor vehicles, 1 of an ATV, 1 of a snowmobile and 1 of an airplane where trauma of collision or crash was considered a significant factor in the death, along with extremely cold water temperature.

TYPE OF INCIDENT, VEHICLE During 1993-2000, vehicles that left the road into water or through ice accounted for 73% of incidents, those that went off a bridge for 13% (Figure 51). On-road vehicles such as cars and trucks accounted for about 90% of deaths. There were a few incidents involving off-road vehicles such as ATVs and heavy occupational vehicles.

There were also 28 cold-water immersion deaths involving aircraft during 1991-2000.

Figure 51 **COLD WATER IMMERSION DEATHS* DURING LAND TRANSPORT† BY TYPE OF INCIDENT, CANADA 1993-2000‡ (n=261)**



** Includes victims for whom one or more of these factors were reported: hypothermia with or without drowning, the presence of ice or extremely cold water (<10° C), or cold weather month (November through April)*
† Excludes snowmobiles and vehicles on ice ‡ Information not available for 1991-1992

Source: The Canadian Red Cross Society & the Canadian Surveillance System for Water-Related Fatalities, 2005

In the weeks that followed their loss, the sun shone brightly and the currents were strong, and the ice turned black beneath its own whiteness, as if eaten by a hidden cancer which only now began to make itself visible.

– Alistair MacLeod, *No Great Mischief*, 1999

THE IMPORTANCE OF COLD WATER IMMERSION DEATHS IN CANADA

The tragic impact of cold-water immersion and ice drownings was vividly portrayed by Alistair MacLeod of Nova Scotia, Ontario and Saskatchewan in his Canadian novel *No Great Mischief*. The impact of injury on a Cape Breton family spanned two generations. The first paragraph of the quotation at the beginning of the report is a typical description of the causality of injury by the multiplicative interaction of several risk factors. Current, tides, and the sun overrode a man's experience with ice. The various interpretations of the causality of the incident described in the second paragraph were typical of the period, when views of causality were fatalistic. Unfortunately, such views are prevalent even today in many communities, and are a significant barrier to development of positive attitudes necessary to successfully implement injury prevention programs.

While the enormous scale of the tragedy of cold-water immersion for the Canadian population has yet to be portrayed so vividly as the loss of a single family by MacLeod, there is no doubt that prevention of cold-water immersion fatalities is a major public health issue for Canada. Cold-water immersion, often sudden and unexpected, was associated with at least 35% of all cases of drowning and fatal immersion hypothermia in Canada during 1991-2000, accounting for at least 2007 deaths. If we exclude deaths in artificial environments including swimming pools, hot tubs and bathtubs, the proportion of immersion deaths associated with cold water rises to 40%. If we consider only ice-related drowning and immersion hypothermia due to motorized and non-motorized activities on ice, these represented 8% of all immersion deaths (437/5617), or 9% if incidents in pools, hot tubs and bathtubs are excluded.

The costs associated with cold water drowning in Canada are enormous. If we assign a conservative figure of an average $2 million in direct and human capital costs per life lost, the cost savings of more effective prevention of all cold-water immersion deaths could have been on the order of $4 billion.

PRIORITIES FOR PREVENTION

Key activities that led to cold water immersion fatalities included boating, 38%, snowmobiling, 12%, and non-motorized activities on ice, 7%. This section of the report includes a discussion of the epidemiologic approach to prevention, general issues of cold water immersions, cold water, and ice. This is followed by consideration of the epidemiologic approach to prevention for specific factors in cold-water immersions for snowmobiling, non-motorized activities on ice, and briefly, for other motorized activities on ice, boating, non-aquatic, and aquatic activities.

THE EPIDEMIOLOGIC APPROACH TO PREVENTION

What are some key messages for prevention? It is helpful to use a structured epidemiologic approach, considering in turn personal, equipment, and environment risk factors (Barss et al., 1998). The classic epidemiologic triad for prevention incorporates host, agent, and environment. The vector is an additional element; examples include a mosquito transmitting a pathogen such as a malaria parasite, or a snowmobile delivering the agent of energy, kinetic energy. Cold water or ice drain away body energy in the form of heat. The classic epidemiologic triad, for the purposes of injury prevention, was modified to include the element of vehicle or equipment factors. To the three main types of risk factors, we can also incorporate the pre-event, event, and post-event time phases of the injury incident. This combination of risk factors and time phases for injury incidents is the Haddon matrix, well known to injury epidemiologists, but still not as well known as it should be to all with responsibility for water and ice safety.

For non-aquatic ice immersions, an example of modifying a pre-event equipment factor would be the intervention of installing a fence around the play area for toddlers of a home facing a frozen river. For snowmobile immersions, an event phase intervention could be a requirement for all snowmobile users traveling on ice to wear a hypothermia-flotation immersion suit, or at least a simple flotation device to prevent immediate death during stage one of immersion. For all ice immersions, a post-event phase intervention could be cold-water management first aid training as a requirement for a licence to operate a vehicle on ice, waterproof communication devices, and rapid response time.

In considering event and post-event phase interventions, consideration should be given to modification of different stages in the physiologic response to a cold immersion, including in stage one the prevention of inhalation of water during gasping/cold shock of immersion. In stage two a key issue is prevention of loss of use of extremities from cooling of skin and muscles, as well as mental performance. In stage three, the issue is prevention of generalized hypothermia with declining body temperature, and finally, in stage four, prevention of peri-rescue and post-rescue collapse (*Ducharme 2006, Ducharme et al 2006, Brooks et al 2005, Brooks/Transport Canada 2003, Giesbrecht 2000, Tipton et al 1999)*.

COLD WATER IMMERSION: OVERVIEW

Some key issues for all cold-water immersions include how to prevent incidents from ever occurring, how to survive or minimize damage if an incident occurs, and how to arrest or reverse damage after the incident.

Many urban Canadians are unfamiliar with preventive measures for cold and ice. New Canadians often come from tropical countries where they are familiar with strategies to deal with extremes of heat, but not of cold. When the ambient temperature exceeds the normal body temperature of 37°C, ground temperature could exceed 60 or 70°C. Once the body's normal temperature control mechanisms are overwhelmed, collapse onto hot ground, leads to rapid heat transfer to the body, overheating of the brain, loss of consciousness, and death. In Nordic countries such as Canada we need basic knowledge about the reverse process, including the body's reaction to sudden cold exposure, including gasping and deep breathing, rapid heat transfers away from the body with loss of muscle strength, impaired cognition, loss of control of core temperature, and eventual hypothermia.

Considering the pre-event phase, every Canadian needs knowledge about risk factors and consequences of exposure to cold on land, ice, and in the water. Hence basic training in cold water and ice safety, including the dangers and consequences of sudden and unexpected immersion in cold water, should be taught in schools, along with essential water safety skills such as swimming.

Next, let's consider features pertinent for injury prevention of cold water and then of ice.

COLD WATER

The definition of cold water must be considered with respect to normal body temperature, duration of exposure, and degree of protection by insulation. Since water is very efficient at conducting heat away from the body, prolonged exposure of the unprotected body to water at even relatively comfortable levels, but below body temperature, will lead to transfer of heat from the body to the water. Thermal neutrality in water is 35°C. Below that temperature, the body is losing more heat than it produces. During immersion at 30°C, the skin is fully vasoconstricted. If immersion continues for a long period of time in water at <30°C, as a protective response to cold, shivering will begin. People have died of cold-water immersion even in subtropical waters after prolonged immersion.

Significant is the effect of reverse temperature stratification observed as water approaches the freezing point (Canadian Red Cross, 1994). Colder water becomes less dense and floats on the surface, like ice. Hence immersion in ice water or other water just above freezing, such as seen in large lakes in spring, is particularly hazardous since at the surface one is immersed in the coldest water rather than the warmest. This phenomenon is particularly relevant for fishers in boats.

Since temperature transfer from the body to water becomes much more rapid in water ≤15°C, and because the impact of such temperatures on stages one and two of cold immersion is much more severe than at warmer levels, some experts in cold immersion consider sudden unprotected immersion in water of ≤15°C to be a potentially life-threatening emergency. It has been suggested that above 15°C the hazard of immersion is much less and survival is greatly prolonged as water temperature increases above this level (Brooks et al., 2005). Nevertheless, considering stage three of cold immersion, laboratory research showed the onset of hypothermia within two hours in water of 20°C (Thelma, 2002). Other research predicts survival times of about two hours at 5°C, four hours at 10°C, and seven hours at 15°C for unprotected males, and about one hour less for females. This assumes survival of the initial two stages of a cold immersion (Tikuisis and Daanen, 2006).

For the purposes of this report, very cold water has been classified as less than 10°C. Coroners and police seldom measured exact temperatures at the scene of a death during the period of this study, so data were missing for many victims. The categories used in the surveillance questionnaires were <10°C, 10-20°C, and >20°C.

COLD WATER SURVIVAL

As noted in the introduction, it is generally agreed that there are *four stages of death* from cold immersion (Brooks/Transport Canada, 2003; Golden & Hervey, 1984), including:

STAGE 1. Gasping and cold shock
STAGE 2. Swimming failure
STAGE 3. Hypothermia
STAGE 4. Post-rescue collapse

It is believed that the majority of cold-water immersion deaths occur during the first two stages, rather than from generalized hypothermia. Knowledge of the effects of the stages is essential for prevention and should be well understood by all who venture in, on or around cold water and ice. Because immersion in cold water at ≤15°C can kill almost immediately without the presence and wearing of flotation equipment, any immersion is potentially fatal and should be avoided if at all possible. For this reason, life rafts are strongly recommended for all boats where it is feasible (Brooks/Transport Canada 2003). Prevention of stage 3 is necessary mainly where immersion is prolonged far from shore, as in commercial fishing incidents; many such vessels now carry specialized survival suits. Prevention of post-rescue collapse after prolonged immersion involves appropriate handling of a victim during and after rescue.

Since they are least understood and most important for the general public, consider details of stages 1 and 2 of the event phase of cold immersions:

STAGE 1. GASPING/COLD SHOCK Death from cold immersion can occur very rapidly during the first few minutes of immersion from so called cold shock. *Aspiration of water* occurs because the sudden cold initiates involuntary rapid deep breathing and gasping in the initial moments. Such deaths could result from aspiration and rapid drowning. In some cases, deaths may also occur from cardiac arrhythmias. The use of the term shock for this stage could mislead the uninformed, since in most types of clinical shock the blood pressure drops to dangerously low levels, whereas in response to cold it can rise to very high levels. It is helpful to remember that the “shock” or stress of sudden immersion in cold water leads to various responses by the body, the most serious of which is huge gasping respirations, which can lead to immediate death by drowning if the airways are below the surface of the water or in waves when this response occurs.

STAGE 2. LOSS OF MANUAL PERFORMANCE Next in the time sequence is *loss of strength of muscles of the limbs* due to cooling of muscles and nerves. Nerves may fail to signal muscle to contract, and the muscle itself may be unable to contract even if it receives a signal (Tipton and Golden, 2006). First to go may be fine muscles of the hands. Ability to hang on to an overturned boat is lost, the individual is unable to perform activities such as putting on or fastening a flotation device, and, more gradually, loses the ability to swim effectively. Limb strength is also necessary for a person floating in water to help keep the face turned away from wind and waves so that water is not aspirated into the lungs. The effects of stage two may result from both local cooling and from the shutdown of blood to the limbs in response to cold. Death may result from drowning due to inability to keep the airways above the surface or away from waves.

Although the results cannot apply to an injury incident in storm conditions and/or darkness, on a positive note, it was found in experiments in Sweden and the UK that volunteers were able to swim for at least an hour in water at 10°C, and most swam for 90 minutes (Tipton et al, 1999). Even among volunteers who swam for 90 minutes in water at 10°C, the problem leading to swim failure was not hypothermia, which by definition is generalized and affects the core of the body, but rather local muscle cooling of the limbs. Other experiments with swimmers wearing a personal flotation device showed that they were able to swim an average of 889 metres in water at 14°C and 650 metres at 10°C before swim failure (Wallingford et al, 2000, Kenny et al, 2000). During another study in Canada of both novice and expert swimmers, it was observed that both groups could swim for about 45 minutes in 10°C water before incapacitation. The expert swimmers could swim faster and were able to swim an average 1.4 km, compared with 820 m for the novices. The average distance for both groups combined was 1.1 km (Lounsbury 2004, Lounsbury and Ducharme 2005).

Now consider some practical implications of the four stages of death from immersion.

First, for people who fall into very cold water, *protection of the airway* from gasping associated with sudden exposure to cold is very important. Otherwise, water can be inhaled and drowning initiated rapidly. Hence from a practical perspective, this stage is a phase of *gasping/acute drowning* and also of sudden cardiovascular effects. For prevention of sudden drowning, use of appropriate flotation helps keep the body higher and the mouth and nose out of the water to minimize inhalation. Specialized flotation devices are now available to boost the body high out of the water during this stage of immersion. Other protection of airways such as splashguards has been recommended. Whatever the equipment that happens to be available, the victim of a sudden cold immersion should concentrate on protecting their airway from cold water inhalation until their breathing stabilizes and gasping stops (Ducharme, 2006). This would include avoiding swimming for a few minutes during the cold shock period, until the massive gasping, rapid breathing, high blood pressure, and rapid heart rate have a chance to subside.

Practical implications of the sequence of progression and rapidity of loss of strength of hands and later limbs, known as the *incapacitation phase*, include the fact that hanging on to an overturned boat is a reasonable survival strategy only if rescue will be rapid. If rescue is delayed the immersed person will lose the ability to hang on within as few as 10-15 minutes, or even to keep the face away from wind and waves, and drown. Unfortunately, with both nerve conduction and muscle contraction blocked, and with no blood flowing to the limbs, mind cannot control matter.

Hence if one is immersed in cold water, unable to climb out of the water onto a stable object, drifting away from shore, and rapid rescue is unlikely, it may be preferable to swim to safety, especially if the distance is not too great, one is a good swimmer, and wearing a flotation device, i.e., immediate self-rescue. Indeed, in a detailed analysis of Red Cross national surveillance data, it was observed that more survivors of boating capsizes and swampings swam for shore than stayed with the boat (Sawyer and Barss, 1998); current routine data are less conclusive in that they show similar responses between survivors and victims, with about a third in each group swimming for shore immediately, a third swimming for shore after a delay, and a third staying with the boat.

As noted above, it may be feasible to swim up to about one kilometre in cold water. Hence upon immersion in cold water, it would be advisable to allow 2 to 3 minutes to concentrate on keeping the airways clear of water until gasping and other immediate effects of cold immersion subside before deciding upon a course of action. The effort during this brief period should be spent on avoiding aspiration of water by keeping one's head above the water and shielded from waves. Once breathing becomes near normal, decide then on whether to stay on site or swim to shore.

On the other hand, if the distance is great and/or rapid rescue by others is known or probable, the victim should immediately make every effort to get as much of the body as possible out of the water as quickly as possible if there is something to climb onto; although it may feel colder out of the water than in, it is always better to be out of the water (Tipton and Golden, 2006). If this cannot be achieved in the first 10 to 20 minutes or so, it may rapidly become impossible due to loss of hand and arm strength. Other options include raising the probability of detection and rescue by immediate use of flares and other measures (Ducharme, 2006). This must be done right away, as the ability to open and deploy flares is also rapidly lost in cold water.

As noted by Ducharme, *the goal or ultimate objective is not to preserve body heat, but to move out of the water as quickly as possible*. If every Nordic skier who felt cold lay down on the cold snow immobile to conserve body heat whenever she/he felt cold, awaiting rescue, it is likely that many would perish. Quite the contrary, one moves on rapidly to generate core energy and heat, which helps warm the extremities so that one is capable of skiing on to the destination. Furthermore, one can help keep blood flowing to the extremities warmer by protecting from cold the head and core, where heat loss can be rapid.

While a snowmobile suit may protect against the third stage of immersion, i.e., hypothermia, if the victim is unable to immediately access ice picks to get out onto the ice, rapid loss of fine movements of hands and arms during the second stage may result in the inability to self-rescue. Similarly, if a boater fails to wear a flotation device prior to immersion, she/he will be unable to find it and put it on in the water. As known to Nordic skiers, vigorous exercise generates internal heat and combats cold hands and feet and hypothermia on the trail. If one simply hangs on to a boat, internal heat generation from exercise would be minimal, and development of cold in the extremities would be expected to rapidly accelerate, and be soon followed by loss of grip. Survival clothing that maintains dryness and core temperature may not be enough to ensure that warmer blood reaches the limb muscles and extremities. Humans evolved in a hot climate where extremities including fingers were designed to lose heat. Extremities may also be allowed to cool when it might be better for immediate survival if they did not. Blood vessels can shut down rapidly resulting in essentially bloodless nerves and muscle that cannot respond.

As for *prolonged immersions* where hypothermia may eventually result in death in stage three of immersion, wearing of a survival suit would be very helpful in maintaining core temperature until rescue occurs. This is particularly the case for commercial ocean fishing where boats may swamp or capsize far from shore, where it is clearly impossible to swim for safety, and where rescue may be delayed for many hours. Such suits would protect head, brain, and core from cooling. Unfortunately, a key issue, they may not help with the limbs as much as one might expect, due to shutdown of blood to the periphery. Hence the victim may not be able to use their limbs for long to orient their body so as to protect their head and airway from waves that could cause drowning by aspiration, so that the flotation should if possible keep the airway clear. Furthermore, survival actions should be done as soon as possible before muscle and nerve cooling cause them to lose tactility. Suitable waterproof gloves that do not prevent dexterity, together with ice picks, may be needed to crawl out onto the ice. Nevertheless, even if so equipped, a snowmobiler may be unable to access his/her ice picks when immersed and struggling in the dark, perhaps wearing a helmet filled with icy water.

Use of an immersion suit might not protect a snowmobiler from ice immersion if the victim's head were exposed and they aspirated water during the shock of sudden cold immersion and rapid breathing. This could be exacerbated if the victim were intoxicated by alcohol and disoriented by darkness, in which case he might fail to keep his face out of water and aspirate. Nonetheless, the gasping and other effects of cold shock are initiated by the rapid decrease of skin temperature during sudden immersion in cold water. It is dependent on the surface areas of the skin in contact with the water and the water temperature. When someone is wearing a suit, contact with the cold water is not as sudden and the cold shock not as intense as if the body is nude or minimally protected.

The demands of wearing a helmet to protect against head injury and the need to protect the head from cold water would need to be given coordinated attention by manufacturers of the survival suits and helmets. Field testing by immersion under conditions of cold and darkness, not to mention fatigue and alcohol intoxication, would be needed to assess whether a victim wearing the suit and helmet would be able to survive the initial immersion without aspiration and then be capable of finding and using ice picks to crawl out onto the ice. Otherwise, the use of a survival suit might give a false sense of security. Perhaps a supplementary source of flotation may be needed, such as an inflatable or other type of flotation device that would help to keep the body oriented with the face out of the cold water. Since ice travel should take place at not more than about 15km/hr, it needs to be verified whether snowmobilers should be advised to remove the helmet when travelling across ice and replace with other headgear to improve visual and auditory acuity. It is unclear whether the potential benefit of thermal protection from a helmet in the water would be offset by the adverse effects on respiration and vision of a helmet full of ice-cold water, not to mention the effect of additional weight on the depth of submersion. Further research is needed on all of these points.

As for *post-rescue collapse* in stage four of immersion this is a key post-event phase issue for anyone involved in rescuing a victim of prolonged cold immersion, since about 20% of cold immersion deaths occur just before, during, or after rescue. It has been suggested that victims should be removed gently from the cold water in a horizontal position to minimize fall in blood pressure that results from a number of mechanisms, including dehydration (Tipton and Ducharme, 2006). If shivering is prominent, the patient should be dried and provided with insulating clothes or blankets (Ducharme et al., 2006; Giesbrecht, 2000).

Rather than focussing on providing external heat during transport, which can even inhibit internal heat generation, provision of appropriate fuel for generating internal heat is believed to be more effective. Such fuel includes warm high-energy drinks and food. Naturally, the victim should be conscious if anything is given by mouth, or aspiration could occur.

Anyone who travels on ice or water in situations where cold immersion is a possibility should carry extra dry clothing in a waterproof flotation bag, and this practice should be followed by all members of a party so that wet clothing can be rapidly exchanged for dry, even if one individual loses their dry bag. Otherwise, victims can die of hypothermia on the land even after a successful rescue, if evacuation is delayed. For details of field management of more severe cases of hypothermia where shivering has stopped or cardiac arrest has occurred, see the excellent summaries by Ducharme et al. (2006), Tipton and Ducharme (2006), and Walpoth and Daanen (2006).

ICE

Change without sound, yet change nonetheless, and change that was important, although sometimes invisible as well as silent. As quiet as the cancer cells which multiply within the body or the teeth within the imperfect jaw which "drift" towards the spaces vacated by their fellows. As quiet as the ice which wears and rots beneath its white deceptive surface or the sperm which journeys toward the womb and reaches its destination without a single sound…

– Alistair MacLeod, *No Great Mischief,* 1999

Anyone who ventures onto ice should consider the relevant personal, equipment, and environment factors for prevention and survival. The most important ***personal factor*** for prevention during the *pre-event phase* is probably an attitude of respect for the potentially lethal hazards of ice. This should predispose the individual to make the necessary efforts to acquire and maintain the knowledge of ice and safety procedures, and caution, which are essential for any activity on ice.

Full mental alertness is needed to exercise the vigilance that is necessary to assess ice conditions and to constantly monitor and reassess appearance, consistency, sounds, and reaction of ice as travel proceeds. Visual and auditory senses must be on full alert. Since alcohol and fatigue adversely affect alertness, both are contraindications to travel on ice.

For *event and post-event phases* of ice immersion incidents, factors that can make a difference for survival include sufficient fitness level and swimming ability to be able to exert the sustained physical activity needed to stay afloat and get out of freezing water onto the ice, or to help rescue others. Hence prudence dictates that unfit individuals and non-swimmers avoid ice travel. Knowledge of the effects of stages 1 and 2 of cold immersion as discussed above must be acquired prior to ice travel, and could be a key personal factor for survival during stages one and two of the event phase.

In addition to these general factors, detailed knowledge of the properties of ice under different conditions and safety practices for various activities on ice is essential. Excellent information is available in the Canadian Government document "Safety Guide for Operations Over Ice" and the following section of this report draws heavily upon that document (Treasury Board of Canada Secretariat, 1993).

Safety equipment for activities on ice includes a personal flotation device, which could be inflatable or otherwise. The choice of a personal flotation device is a serious decision, and will depend upon the type that is most suitable for the degree of physical exertion and the potential hazard of the activity. Hypothermia protective clothing that protects in water as well as in air is also required. Ice picks and a throw bag with rope that floats are other essential equipment; these must be attached to the body and immediately accessible under the adverse conditions of an actual immersion. Good ice picks are available commercially. For individuals on foot, a long heavy ice chisel can be used to probe the ice ahead. If the chisel goes through, ice travel should be abandoned (Cold Regions Research & Engineering Laboratory, 2004). Manual or powered ice drills or augers are also available; they are probably most practical for people responsible for assessing ice bridges on snowmobile or other vehicle trails.

As for ***environment factors***, *visibility* is a key issue for safety. Constant visual assessment of ice is essential during activities on ice; therefore activities on ice after dark or in the presence of heavy blowing snow are contraindicated. If all snowmobilers in Canada had stayed off the ice during such conditions, at least 65% of snowmobile immersion deaths would have been avoided. This included about 160 deaths during 1991-2000, with potential cost savings of nearly 500 million dollars.

Auditory assessment is also essential. Loud cracks or booms on a large lake may simply result from expansion or contraction, but on a river may mean danger, a warning that ice could be about to break up or move (Cold Regions Research & Engineering Laboratory, 2004). Operation of motorized vehicles at high speeds that would mask cracking sounds should be avoided for this and other reasons to be discussed. Quiet operation of engines should be a priority for manufacturers.

The *properties of ice* should be considered in developing safety practices for activities on ice. Factors to consider in assessing ice include the fact that the underside of ice floating on water will be close to the melting point, and the upper surface of exposed ice will be closer to air temperature. Snow acts as an insulator and also imposes a load on ice. Hence if ice is covered by snow early in the season, it may never form a thick solid layer and could remain dangerous for the entire season, no matter how much snow cover there is. If there are large variations in the depth of snow on the ice layer, there may be corresponding large variations in ice strength. On the other hand, a thin layer of about 10 cm of snow can be protective for ice by absorbing energy of vehicles and also by protecting ice from solar radiation; such a layer is recommended for ice crossings.

Clear ice formed by the freezing of water is about twice as strong as snow ice that forms when wet snow freezes on ice. Visual inspection is essential and *colour* is helpful in assessing ice quality, with blue or clear ice being strongest. White opaque snow ice is weaker since it contains a lot of air, and grey ice is unsafe because it includes water from melting. Other considerations in visual inspection include cracks. Dry cracks of less than 0.3 cm depth are not considered hazardous. A single crack of 2.5 cm reduces load capacity by one-third and intersecting cracks by one-half. Wet cracks penetrate the ice and reduce load bearing by half for a single crack and down to one-quarter for two intersecting cracks. Travel over wet ice should generally be avoided. Furthermore, if wet ice becomes dry it could indicate impending immediate failure due to honeycombing.

Temperature fluctuations can reduce ice strength. A sudden drop, such as a very cold night after a warm day, can weaken ice by 50% for 24 hours, and to a lesser extent for some days. A similar weakening is observed when clearing snow from ice, which under cold conditions lowers surface temperature by removing the insulating layer.

Currents and springs affect the flow and temperature of water and can result in thin ice that is deceptive since on the surface it appears the same as adjacent ice. Before crossing ice, currents and springs need to be identified; typically they could occur at inflows and outflows of lakes and at bends, shallows, and tributaries in rivers. A detailed knowledge of the qualities of the bodies of water concerned, especially rivers, is necessary prior to considering any activity on the ice.

Other factors can significantly impact ice strength. For example, a vehicle travelling over ice depresses the ice, which creates a *dynamic wave* in the underlying water, i.e., a hydrodynamic wave. The properties of the wave can combine with the energy of the vehicle to cause a break through. It has been recommended that when the ice is less than 75cm (30 in) thick, vehicle speeds should be restricted to less than 15km/hr (10mph), and that this speed maximum should be generally respected. Hyper-performance snowmobiles would be expected to generate high energy levels and could be unsafe for ice travel under many circumstances. The impact of such waves is greater closer to shore or over shallow water. Sudden braking at high speeds would result in high-energy transfer to ice and could also lead to ice failure. Each vehicle that passes over the ice will re-stress the area by load and dynamic waves, so the fact that a single vehicle passed successfully is no guarantee for others.

Another factor that affects ice strength is *static load*, such as a stationary vehicle or fishing hut, which can reduce load-bearing capacity by 50%. Ice that will safely support a slow moving vehicle could give way under a vehicle that is stopped, so it is recommended that vehicles be parked at least five lengths apart. Static load also needs to be considered for activities such as ice fishing if huts are used. Radial cracks, sagging, continuous cracking or appearance of surface water are visible signs of impending ice failure; such signs could be masked by snow on the ice.

Measuring ice strength by its thickness is a useful – though not infallible – way to assess ice strength. The main issue that affects interpretation of such measurements is variability in thickness, so that they must be considered only in conjunction with other factors. It has been recommended that test holes be made about 15 m (50ft) apart on rivers and 30m (100ft) on lakes, and that no activity be carried out on ice less than 15 cm (6 in) thick since due to variability in thickness ice in nearby locations might be only 5 cm (2 in) (Treasury Board of Canada Secretariat, 1993). In the presence of snow ice, the minimum thickness would need to be doubled to 30cm, while in the presence of a single dry crack, to about 40 cm, and for a single wet crack, 60 cm. Intersecting wet cracks on snow ice could raise minimum thickness for travel to 120 cm. Practical recommendations for ice are available at government sites for Alberta and Northwest Territories (Alberta Human Resources and Development, 2003; Northwest Territories Resources, Wildlife, and Economic Development Department, no date). Recommendations differ and the evidence base is not provided in these sources. Users of tables must be cautious since many are based upon ideal ice conditions; less favourable conditions can greatly reduce load-bearing capacity.

Prudence would dictate assessment of ice thickness as a general precaution, but unfortunately measurements in locations with no current may have no generalizability to other locations where current is present. Simple tables on minimum thickness requirements understandable to casual ice users do not take account of the key issues discussed above, and furthermore, recommendations would not be valid for high-powered snowmobiles travelling at great speed, nor for the impact of energy transfers during sudden braking, nor for stationary loads such as occur when a vehicle stops for more than a few seconds.

The data on ice in this report show that for most Canadian snowmobilers, a key issue for prevention of immersion when travelling on ice is avoiding open holes in lakes and rivers, and in Newfoundland and the northern territories, open ocean water. Undertaking all of the standard recommended precautions, such as measuring ice thickness and assessing the most appropriate ice thickness, will not resolve the frequent presence of open water or of fragile ice in areas where current or tides are present. Every snowmobiler must be aware that travel on ice is dangerous, and that precise knowledge of currents is essential. One cannot trust any location where tides and currents are present, including rivers, inflows and outflows of lakes, and the ocean.

In summary for motorized travel on ice, essentials include good lighting, preferably daylight, slow and cautious speed, and avoidance of anything that impairs alertness, including alcohol and fatigue. Furthermore, full protection with safety equipment is essential. Travel at night should be avoided unless the return route has already been verified on foot during daylight and carefully marked.

Some of the issues for children and adults who play or walk on ice differ. Most incidents involve thin ice rather than open holes, and occur during the daytime. The issue of current makes measurements problematic since they cannot be generalized to other areas. Small children are not able to assess ice conditions. For children, barrier fencing around yards or other play areas provides constant automatic "passive" protection and is to be preferred when it is feasible and affordable. In the absence of automatic protection, careful and constant supervision by adults is essential when children play or walk anywhere near ice or water. Walkers and skaters should be informed about the hazards of current, and need survival protection including flotation and ice picks. Skiers are probably at much lower risk due to spread of the load by skis.

For boaters, ice is not often an issue, except for fishers in the spring. Nevertheless, it is surprising to note how many death reports describe non-swimmers and other boaters who ventured forth in small open boats without any flotation device or survival clothing, even with ice still present. It is clear that many boaters, especially fishers and hunters who use boats in spring and fall, are unaware of the hazards of cold-water immersion.

SNOWMOBILE IMMERSION

HIGH PREVENTABILITY It is clear from a review of the risk factors that nearly all of the 246 fatal snowmobile immersions in Canada during the 1990's could have been prevented. If we assign a conservative figure of an average $2 million in direct and human capital costs per life lost, the cost savings of better prevention could have been on the order of $500 million.

ENCOURAGING TREND There was an encouraging trend in the snowmobile immersion fatality rate in all regions of Canada except for Quebec during 1991-2000. Whether this trend was due to improved safety or to decreased exposure due to global warming and shorter seasons is open to question. The increase in Quebec could reflect better reporting of incidents, or increased exposure to risk, such as from snowmobile tourism or greater use of high-speed machines. In any case, much remains to be done for snowmobile safety in Canada.

EPIDEMIOLOGIC APPROACH TO PREVENTION

Most of the recommendations that follow are based upon the data presented in this paper. Others are based upon the published literature, or follow logically from obvious considerations.

PERSONAL RISK FACTORS

AGE, SEX, ETHNICITY A key target population for prevention is males between 15 and 74, with emphasis on younger males 15-34. A second key target for prevention includes First Nations and Inuit peoples, who have a much higher average exposure to the hazards of snowmobile travel, and accounted for at least a third of all victims.

ALCOHOL Since alcohol was involved in at least half of all incidents, penalties and enforcement for consumption of alcohol should be at least as severe as for on-road vehicles. Police will need to be innovative in their enforcement tactics and active in appropriate locations, months, and times of day. Furthermore, no one should serve alcohol to persons who must travel by snowmobile, especially late in the day when intoxication is compounded by low visibility. Other research from Manitoba, Ontario, Alaska, and Sweden has confirmed the importance of alcohol as a risk factor in 64-70% of all snowmobile injury deaths (Ostrom & Eriksson 2002, Stewart & Black 2004, Rowe et al 1994). The Ontario research was a case-control study that showed alcohol to be associated with a four times greater proportion of snowmobile deaths than for automobile or motorcycle. In the few occupational incidents, alcohol is probably less frequent, as reported among Antarctic researchers where only 5% of incidents involved alcohol (Cattermole 1997).

FATIGUE Although not recorded in most reports of immersion deaths, fatigue is probably a significant factor since many incidents occur at night. Fatigue would slow perception of hazards and reaction to them, and would be magnified by alcohol. The poor ergonomic design of many snowmobiles (Tostrup 1994) would also contribute to fatigue.

PRE-IMMERSION HEAT LOSS Driving a snowmobile at high speeds leads to rapid transfer of body heat by convection to the cold air surrounding the driver and by direct contact and conduction to the machine. In a study in mild winter conditions, local cooling on the face and peripheral area of extremities led to temperature decreases exceeding the limit for performance degradation (Virokannas 1996, Virokannas & Antonnen 1994); wind and colder air would accelerate cooling. The impact of local cooling of the limbs could affect muscular response to hazard in the pre-event phase, such as rapid braking. Once in the water, event-phase responses would be impaired, including swimming, keeping nose and mouth clear of the water, gripping a rescue rope, and use of limbs and ice picks to crawl out onto the ice.

TRAINING Snowmobile operators need rigorous training, testing, and licensing, as required for other hazardous vehicles where the operator is exposed and vulnerable to injury, such as motorcycles. Since snowmobiles are mainly off-road vehicles, drivers are not as well regulated as on-road vehicle drivers, and hence poorly protected. As discussed below, modern snowmobiles are high-speed, high-energy vehicles that travel in hazardous environments. Training requirements for licensing may be lagging behind the increases in engine power and hence the degree of risk.

In addition to training for collision hazards of on and off-road travel on land, snowmobilers need practical training and examination in evaluation of ice conditions, on effects of cold immersion, particularly stages one and two, and in self-rescue and rescue of others. They should understand pertinent aspects of the Haddon injury matrix, including personal, equipment, and environment factors for each time phase of common snowmobile injury incidents. Thus the operator should be familiar with the main strategies to avoid an immersion, to escape an immersion, and for post-immersion first aid and survival. Safety information on cold immersion should be evidence-based and regularly updated in materials and websites of Organizations responsible for safety of snowmobilers. These include snowmobile sites of Transport Canada and the Canadian Council of Snowmobile Organizations.

EQUIPMENT/VEHICLE RISK FACTORS FOR SNOWMOBILE IMMERSIONS

The user of a snowmobile can be considered as analogous to a "vulnerable road user". This term incorporates all types of road users where human flesh is unprotected since not enclosed by the metal cage of a closed vehicle such as car or bus (Barss et al, 1998). On the roads, such individuals include mainly motorcyclists, bicyclists, and pedestrians. In the case of snowmobiles, the terminology would be "vulnerable off-road user", except when the machine is used on the road, in which case the rider is a vulnerable road user. Modern snowmobiles can travel at extreme speeds that would be highly dangerous for the vulnerable exposed rider even on a good highway, let alone a hazardous natural environment. High-powered snowmobiles are also heavy. Kinetic energy is the agent of injury, and increases as the square of the velocity multiplied by weight, so clearly many modern snowmobiles are extremely high-energy vehicles. Furthermore, high noise levels could mask auditory warnings of unstable ice.

VEHICLE SPEED Snowmobiles are classified as low performance, moderate, high, and hyperperformance (Canadian Council of Snowmobile Organizations 2005). This classification reflects a change from low to moderate speed vehicles, such as less than 340 cc, in the pre-1980s, to high speed in the 1980's. Hyper-performance includes >500cc and >160km/hr; some machines can allegedly attain speeds of 200 kph.

Since it is considered dangerous, in fact illegal, to drive a car on a divided highway at 90 mph or 150 kph, how could we then consider it to be safe and legal to drive a snowmobile at 90 mph or 150 kph off road on ice or in the woods? A speed of 90 mph is equivalent to 132 feet/sec. If reaction time to a hazard such as thin ice, an open hole, rock, fence wire, or tree is 1.5 sec, at such speed the snowmobile will have traveled 198 feet before the brakes are even applied. To this 198 feet needs to be added the stopping distance on ice and/or snow.

Because of the size of the machines and the high land and ice speeds attainable, the closest analogy to a snowmobile could be a high-performance motorcycle, a device that is strictly regulated in many countries due to the high degree of hazard for the user and death rates. Perhaps it is time for government bodies to re-examine how snowmobiles are regulated in Canada? It could be useful to investigate the average speeds of snowmobiles on ice and snow in different locations, especially at night, and compare this to the recommended speed for vehicles travelling on ice not to exceed about 15 kph. In other research excessive speed, in combination with poor lighting, has been described as an important risk factor for snowmobile trauma in Manitoba. (Stewart and Black 2004, Beilman et al, 1999).

It is beyond the competence of the author to determine the permissible maximum speed of snowmobiles sold for standard recreational outings, but it is clear that rigorous standards are needed. Furthermore, as discussed special licensing should be required, as for other hazardous vehicles such as motorcycles. In Sweden, the speed limit for snowmobiles was limited to 70km/h (44mph) in 1998 (Ostrom and Eriksson, 2002). Even this speed is very high for ice travel due to considerations discussed above. In Sweden, insurance companies were reported to be raising premiums for high-speed machines to encourage purchase of low speed snowmobiles. Finally it was suggested that a more drastic solution such as reducing the speed capability of machines could be indicated.

WEIGHT & ENERGY Other factors to be considered are snowmobile weight, kinetic energy, and braking, and their combined impact on ice strength. Presumably faster machines require heavier engines and other associated structural parts, and snowmobiles are reported to weigh 600 pounds (Pierz, 2003). Heavier and more energetic machines would increase the risk of breaking through thin ice. Purchasers who need or wish to travel on ice should be fully informed by vendors about weight and energy differences and resulting differences in ice-thickness requirements. Some snowmobile groups rely upon recommendations based on Minnesota data, which state that 4 inches are adequate for walking or skiing, 5 inches for a snowmobile, and 8 to 12 inches for a car (Canadian Council of Snowmobile Organizations, 2005). The difference of one inch in ice requirements for a person walking compared with a snowmobile, including a 600-pound hyper-performance machine with two riders, seems insufficient. As discussed above, these minimal recommendations based upon ideal conditions are not supported by other more detailed scientific documents (Treasury Board Secretariat 1993, Cold Regions Research & Engineering Laboratory, 2004).

PERSONAL SAFETY EQUIPMENT All snowmobile operators and passengers who travel on ice should be required to wear flotation and hypothermia protective apparel. This could be a single garment that supplies both flotation and protection against immersion hypothermia, and facilitates self-rescue. Flotation is probably the most important of these two protective factors and should be sufficient to keep the mouth and face out of water to minimize gasping and aspiration into the airways during the first few minutes of immersion, stage one. Otherwise any effects on prolonging survival from the slower onset of hypothermia would be only theoretical. Suits, gloves, sleeves, and boots need to be waterproof to minimize cold exposure of arms and hands when immersed and to maintain core temperature. Waterproof clothing of this nature has been recommended by Injury Prevention Committees of both the Canadian and American Pediatric Societies (Injury Prevention Committee 2004, Committee on Injury & Poison Prevention 2000). Such a garment should also incorporate attached ice picks such that a victim could use them for self-rescue by pulling themselves out of a hole onto firm ice. A compact high-strength bundled floating throw rope attached to the victim that could be tossed to a rescuer would also be useful, since the victim might not be able to grip a rope thrown to them. A supplementary flotation device such as a boating PFD could help provide additional flotation to protect face and airways.

Thermal flotation suits may be helpful in survival, but prudence should not be abandoned since at least a few adults die with them. If the suit provides sufficient flotation to keep the face well out of the water — and this needs to be proven under adverse conditions — it should help to protect against stage one of an immersion, but consideration needs to be given as to how to maintain muscle strength in arms and hands long enough for the victim to crawl out onto the ice. Appropriate types of gloves to maintain hand strength in the water and easily accessible ice picks would probably help. Suits and accessory equipment such as gloves, ice picks, and helmets should be field-tested under typical conditions in the dark, then rated and certified appropriately for ice travel. It is interesting to note that injury committees dedicated to snowmobile safety consist mainly of paediatric doctors interested in protecting children, while most snowmobile victims are adult males. Greater priority and interest in protecting adult males, who comprise the vast majority of victims, is needed.

VEHICLE SAFETY EQUIPMENT If we consider the hazard of driving a snowmobile at high speed in unregulated natural environments, safety standards should be more rigorous than for cars, at least for high-speed snowmobiles. Certain safety devices, if mandatory, would be built into the snowmobile to provide so called passive or automatic protection in the event of an immersion. A flotation device incorporated into the seat of the snowmobile that would automatically inflate and float to the surface as soon as the machine started to sink would provide riders with a means of flotation even if they did not happen to be wearing it. A device analogous to an automobile air bag could be incorporated into handlebars to help protect against head or neck injury in the event of frontal collision, with ice or other objects. This could help a victim avoid head injury, remain conscious and be better able to self-rescue, and could be designed to float to the surface at the end of a sturdy rope to provide supplementary flotation, and facilitate later retrieval of the machine.

If we move to other safety equipment to be incorporated into the snowmobile, the strength of lighting, braking capacity on ice or ice/snow combination, and the maximum speed of the vehicle should be considered jointly. In no case should a snowmobile be licensed for sale or registration for use on ice where the speed of the machine would allow it to outrun the lights and braking capability for a reasonable reaction time on ice. Effective silencing of engine noise is also essential so that the operator can monitor for auditory signs of unstable ice. Any machine not meeting such requirements should not be licensed for use on ice, including prominent warning labels and strict penalties for misuse. With respect to use and licensing of snowmobiles for use on land, in view of the hazard of striking rocks, trees, or fences off road similar considerations might apply, and the flotation air bag might be useful, but this topic is beyond the scope of this paper. It has been recommended to manufacturers that improving headlight luminance and braking are priorities (Committee on Injury & Poisoning, 2000).

ENVIRONMENT RISK FACTORS

The ice environment must be considered a cold-water environment where immersion is possible at any time. Visibility was a key factor in many snowmobile immersion fatalities in Canada, since most occurred late in the day or during the night; a 25-year review of snowmobile fatalities in Sweden had similar findings (Ostrom & Eriksson, 2002). Current was another factor; rivers and lake outflows can result in open holes or thin ice, and are never really safe for walking, let alone travelling at high speeds on a machine that could weigh half a ton with two riders. While trailside monitoring has been shown to be effective in reducing snowmobile injuries and deaths in one region of Ontario, another study indicated that this would be relatively ineffective overall since most incidents did not occur on designated trails (Rowe et al 1994, Stewart & Black 2004).

INTERACTION OF RISK FACTORS Considering that injury incidents tend to be multi-factorial, to the above considerations must be added the fact that alcohol, fatigue, and exposure to wind and cold all combine to slow mental and physical perception of and reaction to environmental hazards. Furthermore, perception at a distance of open holes or thin ice would be expected to be difficult late in the day during twilight and darkness, and further reduced in the presence of adverse weather such as snow or fog. Indeed, fog can result from open water and is a warning sign for it. Riders need to be fully informed about the hazard of traveling on ice under conditions of reduced visibility, and be completely aware of the braking and lighting capacities of their machine on ice.

Snowmobiles are high-speed, high-energy vehicles that operate in a hazardous natural environment, and riders are exposed "vulnerable" off-road users. Safety features and regulations should therefore exceed those for occupants of on-road vehicles. Active informed vigilance and passive automatic protection are needed for riders and machines, in order to avoid but also withstand both cold-water immersion and collision.

COLD-WATER IMMERSIONS DURING OTHER MOTORIZED ICE ACTIVITIES

Some considerations for snowmobiles also apply for other vehicles used on ice. The most frequent vehicles involved were cars and trucks used for ice fishing. In such incidents, the weight of the vehicle, distributed on four small points, was probably a more important issue than speed. Nevertheless, such vehicles can initiate depression of the ice and pressure waves in the underlying ice that can result in ice failure. Speeds should not exceed 15 kph, especially in shallow water such as near shore where the impact of pressure waves is much greater and the ice is thinner.

Another important consideration is the presence of static loads on the ice during activities such as ice fishing, which greatly reduce the load-carrying capacity of the ice. Stationary vehicles and huts should be spaced as far apart as possible, and such decisions taken in view of ice thickness and quality.

For closed vehicles, it is recommended that doors and windows be open or lashed open and seat belts not be worn so that rapid escape is feasible. Wearing of a flotation survival suit is advisable. If no flotation suit is available, at least an inflatable or other flotation device should be worn. Rapid access to ice picks could be the only way to escape from water onto ice.

It is beyond the scope of this report to go deeply into the issue of such incidents, but it is clear that ice requirements are great for such travel and extreme caution should be taken at all times. Since there are many factors that affect minimal ice thickness requirements for different activities and types of bodies of water, participants in activities on ice are urged to consult the Treasury Board Secretariat's excellent detailed guide.

COLD-WATER IMMERSIONS DURING NON-MOTORIZED ICE ACTIVITIES

They say that beneath the ice there is always a layer of air between it and the actual water. And that if you are swept under, the thing to do is to try to turn on your back until you can almost press your mouth and nostrils against the underside of the ice which will, at least, allow you to breathe. And then you must keep your eyes open so that you can see the hole that you came through, and try to work yourself back towards it. If you close your eyes in the freezing salt, you may become disoriented, and therefore doomed, because you do not have much time. And if the currents are running strongly, they may take you under such a distance, and so quickly, that your most rapid reaction may prove, in the end, to be too slow.

I have often thought of my parents as upside down beneath the ice. Almost the way you see potato bugs on the underside of the leaf. Their hands and knees pushing upwards in something resembling a macabre fetal position, trying to press their mouths against the underside of the top which kept them down. Trying to breathe in order that they might somehow stay alive.

– Alistair MacLeod, *No Great Mischief,* 1999

IMPORTANCE There were 150 deaths during non-motorized activities on ice during 1991-2000. If we assign a conservative figure of an average $2 million in direct and human capital costs per life lost, the cost savings of better prevention of all deaths during non-motorized activities on ice could have been on the order of $300 million.

ACTIVITIES Non-motorized activities on ice leading to cold-water immersion fall into two major activity groups by age, those involving children 0-14 years of age, and youth and adults 15 to 75 plus years. For children, most incidents occurred during playing or walking on ice. For older victims, the main activities included walking, ice fishing, hunting, and skating.

EPIDEMIOLOGIC APPROACH TO PREVENTION

PERSONAL FACTORS: AGE, SEX, ETHNICITY Key target populations for prevention by age and sex include 1-4 year old toddlers of both sexes, and 5-14 year old males, and by ethnicity, aboriginal peoples. Victims are probably either too young or have not been educated to be aware of the hazards of walking on ice over current, such as is present in most rivers and the ocean. In order to protect children, parents who live near rivers or lakes need to be targeted and well informed.

"Water competence" is a recommended term for general swimming and water safety knowledge, skills, and attitude (Brenner et al., 2006). In Canada and other northern countries, schools and other pertinent organizations should provide education and/or training in both water and ice competence, including not only swimming, but also awareness of hazards of ice and cold along with other aspects of water safety, including appropriate active and passive safety measures for ice.

EQUIPMENT Data showed that victims of ice immersion rarely were protected by appropriate safety equipment. For pre-event phase automatic protection, people who live along rivers or lakes should consider installing barrier fencing around the home yard and/or play area to protect small children. As for event phase protection, anyone who ventures onto ice should be equipped for survival, wearing a flotation device and hypothermia protective clothing that provide a barrier against water and cold, or a combination garment to provide flotation and thermal protection. Inflatable flotation devices are light and comfortable. Other recommended safety equipment includes ice picks and a throw rope, as well as waterproof boots and gloves. For individuals who are testing or otherwise verifying the condition of ice, ice chisels and long poles for self rescue have been recommended. Issues of equipment are discussed in greater detail in earlier sections of the discussion.

ENVIRONMENT Most victims fell through thin ice rather than open holes. Rivers followed by lakes were the most frequent body of water for child victims, while the reverse was the case for older victims. There were large regional differences in the types of bodies of water involved. In the Atlantic area and the northern territories, many incidents occurred on the ocean. In Quebec, incidents were mainly on rivers, while in Ontario there was an even split between rivers and lakes. In western Canada, most incidents were on lakes.

Most incidents occurred between November and April. Health promotion should begin in late October and early November and continue through April. Although significantly fewer incidents occurred at night than for snowmobiles, activities on ice after dark should be considered high-risk and avoided. After clearing of ice for skating, the ice will not attain full strength for at least 24 hours or more, so skating should be delayed for an appropriate interval. To reduce the risk of static load on ice, ice-fishing huts should be spaced far apart, and also placed only on areas where the ice has been assessed and found to be of suitable thickness and quality.

ACTIVITIES IN, ON OR AROUND COLD WATER

BOATING IMMERSIONS

Boating immersions are discussed in other modules of this series. Nonetheless, since boating accounted for 38% of cold-water immersion deaths, with 772 victims, a few key points should be mentioned. While recreation was the most frequent purpose of activity for cold-water boating fatalities, 66%, occupational incidents were also numerous, 18%, followed by daily living, 13%. Fishing, including recreational, commercial, and subsistence, was the most frequent activity for cold-water boating incidents. If we assign a conservative figure of an average $2 million in direct and human capital costs per life lost, the cost savings of better prevention of all cold-water boating deaths for the decade could have been as much as $1.5 billion.

EPIDEMIOLOGIC APPROACH TO PREVENTION

AGE, SEX, ETHNICITY A focus for prevention is all males 15 years and older, who had high rates of mortality in all age groups; aboriginal peoples were also over-represented among the victims.

EQUIPMENT Small powerboats, 32%, large powerboats, 22%, and canoes, 18%, were the most frequent types of boats; the proportion of large powerboats involved in cold water immersion deaths is higher than for other boating immersion deaths. 19% of victims were reported to be properly wearing a flotation device, which is about double that for all boating immersions, but still highly unsatisfactory. Hence a key issue for prevention is legislation to require wearing of a flotation device, and during cold weather, a hypothermia-protective garment. While modern inflatable flotation devices can and should be worn comfortably at all times, for boat travel on water at ≤15°C, it is even more compelling that wearing of flotation should be mandatory (Brooks/Transport Canada, 2003; Brooks et al, 2006). Since entry into an automatic life raft prevents the hazards of immediate death in stages one and two of cold immersion, rafts of appropriate size should be carried on all but the smallest boats (Brooks/Transport Canada, 2003).

ENVIRONMENT As compared with other boating immersions, a high proportion of cold-water incidents occurred in oceans, 40%, while lakes accounted for 42% and rivers 17%. The peak numbers of incidents were in April-May and September-November. Hence health promotion should begin in March and early September. Rates in coastal provinces were about 4 times higher than inland provinces, and rates in the northern territories about 40 times higher.

DISCOURAGING TREND, BUT HIGH POTENTIAL FOR IMPROVEMENT The overall trend for Canada in cold-water boating immersions was discouraging, with a rate of 0.28 deaths per 100,000 population per year in 1991-1995 and 0.26 during 1996-2000. The greatest improvement during the 1990's was seen in the northern territories, where the rate was halved. It is probable that the only highly effective means of bringing about a major reduction in the overall cold-water boating immersion death rate is legislation and enforcement to ensure wearing of appropriate personal protective equipment. Education alone has proven relatively ineffective, as for other injury prevention measures such as safety belts in cars. Since many fishers and hunters use boats mainly as a platform for their sport, and during hazardous cold seasons, they warrant special attention for education, training, and legislation on safety equipment and practices.

AQUATIC ACTIVITIES

Aquatic activities involve intentional immersion in water. Scuba diving was the most frequent aquatic activity associated with cold-water immersion deaths. In addition to drowning, many deaths also occurred from air embolism. Although diving is not a major focus of this report, divers need to be aware of the effects of cold described above on their limbs, cognition, and air requirements. Swimming efficiency could deteriorate fairly quickly during a dive at low temperatures, but much more rapid would be loss of fine motor movements of hands that might be needed for self-rescue in various situations. Clearly dives at water temperatures ≤15°C should be limited and only undertaken when necessary, and under ideal conditions. Difficult deep dives and dives where manual dexterity may be required should be avoided in cold water. Divers should be aware that they may have insufficient manual strength and dexterity to use knives or rescue equipment if they become entrapped or otherwise endangered. The reasons why there were many deaths from air embolism in cold water needs further research. It could be multi-factorial due to excessive air requirements, hyperventilation, impaired cognition, and perhaps other reasons.

Individuals without thermal protection should not jump into or enter water ≤15°C. This includes so-called polar swims in winter. Even young healthy good swimmers have died in a few moments from gasping and inhalation (Brooks, Transport Canada, 2003).

Older individuals can die from massive increases in blood pressure and cardiac arrhythmias that may result from cold immersion. It could be the case that individuals who are experienced in polar swims are better able to protect themselves from the sudden effects of stage 1 immersion, but further research should be undertaken prior to endorsing such events.

FALLS INTO WATER

Non-aquatic incidents result from non-aquatic activities where the individual had not intended to be in the water but fell in. Falls into cold water most frequently involved walkers or hikers, as well as people fishing from shore. Training in water competence and a more general public awareness of the specific hazards of cold-water immersion, including that sudden death can result in stages one and two, might help individuals who engage in such activities to exercise greater caution and to be better prepared if they should happen to fall in.

CONCLUSION

A majority of immersion deaths could be prevented, with health care cost savings in the billions during each decade. The ideal would be to avoid all immersions in water ≤15°C, and to ensure that all individuals who venture onto cold water or ice are ***wearing*** appropriate flotation and cold protection. All who venture onto cold water or ice must remember that flotation and hypothermia protection have to be worn before immersion occurs. Activities on ice at night should be considered extremely high risk and should be avoided. Use of alcohol during ice activities or boating is absolutely contraindicated since they require full alertness, good judgement, and continual assessment of risk.

For snowmobilers there are several key priorities, starting with vehicle and equipment factors. Most authorities recommend limiting vehicle speeds on ice to 15 kph, with excellent reason, as explained above. Legislation to bring snowmobile speeds, lighting and braking systems into conformity with reasonable stopping distances on ice is key to prevention. It would also be wise for us to research the success of snowmobile regulations in other countries such as Norway, where snowmobile safety patrols are a regular feature.

A requirement for wearing of appropriate flotation and hypothermia immersion protection, and carrying rapidly accessible ice picks, would also be key elements in a comprehensive prevention program. Approved flotation and hypothermia immersion protection would meet stringent testing conditions that reflect conditions seen in the typical night time scenario. Nevertheless, the use of such equipment could result in a false sense of security and lead to risk-taking such as travel at night. Such equipment may not protect against stages one and two of immersion and death can still result, especially in darkness if the individual gasps and inhales water or cannot extricate himself from immersion before losing manual dexterity.

In order to discourage this false sense of security, snowmobile users must be convinced that travel on ice at night is a high-risk activity that should be avoided unless a life-threatening emergency justifies it. The only exception might be a clearly identified route, under ideal conditions where the ice has been inspected on foot with full visibility on the same day. To reinforce these key messages, leaders of snowmobile outings that will cross any ice should insist on appropriate safety equipment and practices for all members of the group.

Organizations responsible for snowmobiling safety should also do more to ensure their recommendations for avoiding and managing immersion are sufficiently detailed and strongly communicated to their members. They should also lobby for safer machines and well-tested safety equipment.

For children who drown while playing or walking on ice, periodic education of parents is essential. Physical barriers for homes adjacent to rivers or lakes, should also seriously be considered. For youth and adults, high schools might be a suitable location for targeting of ice education, which should be taught as a component of water and ice competence. As a minimal safety requirement, all persons who venture onto ice should be wearing a flotation device and carrying rapidly accessible ice picks.

For boaters, mandatory wearing of flotation and hypothermia protection appropriate for the water temperature and season would save many lives. Nonetheless, the ideal is entry straight into a life raft to eliminate sudden death from immersion. Attempts to don flotation in the water will be too late to avert immediate death from stage one of a cold immersion, and loss of hand and arm strength will make it difficult or impossible to don flotation for those who manage to survive stage one. Legislators should bear this in mind and implement *wearing* requirements, and *not carrying* requirements, for flotation and thermal protection, as a matter of the greatest urgency to avert further unnecessary loss of life.

For all Canadians, greater awareness of the specific hazards of cold immersion and the practical implications of the four stages of cold immersion, particularly the first two, is needed. Such education could be given in high schools, in general swimming and water safety training, in safety education for new immigrants, and in regular media publicity each fall and spring season.

LIMITATIONS OF THIS REPORT

Water temperature measurements are frequently missing from police and coroners' reports, so we may have failed to include many cold-water incidents in this report, underestimating the true total. The fact that we were obliged by the data form to use 10°C rather than 15°C as our cut-off for cold water would also result in underreporting. It is probable that at least a few snowmobile immersion deaths were missed during data collection, i.e., not supplied to data collectors by coroners' statistical staff, so that the incidence rates and numbers may underestimate at least slightly the true values. Data on ethnicity are incomplete for First Nations and Inuit peoples, with underestimation of their true risk. Immersion deaths are seldom reported with sufficient details to describe in which of the four stages they occurred, so we were unable to examine this aspect of the topic. Such information would be helpful in planning prevention. An improved reporting form has been proposed for cold-water deaths (Brooks et al 2005).

FURTHER RESEARCH

It would be helpful if coroners and other investigating doctors would routinely record for all injury deaths pertinent personal, equipment, and environment factors. For snowmobile incidents, equipment factors include power, speed, lighting, and braking of machines. This would require enforcement of regulations to require that these be specified for all machines. Other personal safety equipment of interest for reporting includes waterproof flotation/hypothermia suits, gloves, and boots, as well as throw bags and ice picks.

Further research would be helpful to test the most practical strategies for changing knowledge, attitudes, and behaviour for prevention of cold immersions. Laboratory and field research would also be helpful to assess the actual performance of safety equipment such as flotation suits, ice picks, and throw ropes in typical real life situations, such as a snowmobiler in the dark, impaired by alcohol and fatigue, and wearing a helmet. As noted above, snowmobile suits need testing under typical field conditions to verify if they protect against stages one and two of cold immersion, and if not, the utility of extra flotation to protect against sudden death by keeping the airways well out of the water. Since not all snowmobilers are willing or able to purchase flotation suits for all family members and friends, it would helpful to test inexpensive ordinary boating PFDs or inflatables worn with snowmobile clothing to verify whether than can protect against stage one. Helmets need to be assessed to determine whether they are helpful or harmful during an immersion. Other research is needed on braking and lighting systems of high performance snowmobiles, and stopping distances on ice. Products that cannot be considered safe for ice travel should carry prominent warning labels.

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