

From DEPARTMENT OF PUBLIC HEALTH SCIENCES,
DIVISION OF SOCIAL MEDICINE
Karolinska Institutet, Stockholm, Sweden

**IMMERSION- AND RECREATIONAL-
BOATING RELATED INJURIES IN
ALASKA**

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It is a good morning exercise for a research scientist to
discard a pet hypothesis every day before breakfast.
It keeps him young.

Konrad Lorenz (1903–1989).

On Aggression, ch. 2 (1963, trans. 1966).

ABSTRACT

Immersion and Recreational Boating-related Injuries in Alaska

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Background: Cold water is an ever-present hazard in Alaska, and when water-related injuries occur, they often take place in remote environments, where the nearest trained emergency response teams are several hours away. Alaska's crude drowning death rate in 2002 was 4.21 per 100,000 population, a rate nearly three times higher than the US average. Immersion and recreational boating-related injuries occur frequently in Alaska, and such events present special challenges to researchers. Boaters and swimmers are subject to the normal risks of land-based activities, including falls, burns, and cuts. They also incur additional risks for asphyxia from submersions, and are exposed to hypothermic water.

Materials and methods: This research analyzed data from the Alaska Occupational Injury Surveillance System (Study One), the Alaska Trauma Registry (Studies Two and Three), and the Boating Accident Report Data System (Study Four) to compare fatalities and injuries occurring in commercial fishermen (Study One), injuries occurring during immersions related to recreational events (Study Two), injuries occurring to passengers while on board recreational vessels (Study Three), and differences in factors associated with fatalities and survivors who had been together during recreational boating-related immersions (Study Four). Descriptive statistics, t-tests, odds ratios, and logistic regression were used to elucidate differences in risk factors and injury outcomes in comparison groups.

Findings: Our research found that permanent flotation device (PFD) use provided strong protection from hypothermia and/or cold water drowning (Study One). The research also found that half of hospitalizations due to immersion involved other traumatic injuries (Study Two). Another research finding demonstrated that injuries on board recreational vessels frequently resulted in fractures, and often occurred to nonresidents who were traveling aboard cruise ships (Study Three). Our research also showed that cold-water immersion events in Alaska are survivable (Study Four).

Conclusion: Immersion and recreational boating-related injuries in Alaska are associated with predictable risk factors, and thus, can be prevented. The prevention of drowning and recreational-immersion related injuries requires a combination of education, enforcement, and engineering approaches to address multiple risk factors.

Key words: Alaska, injuries, drowning, cold water, immersion, submersion, hypothermia, survival

LIST OF PUBLICATIONS

This dissertation is based on four publications, which are referred to within the text by their respective numbers, i.e., Study One, Study Two, Study Three, and Study Four.

- I. Hudson DS, Conway GA. The role of hypothermia and drowning in commercial fishing deaths in Alaska, 1990-2002. *Journal of Circumpolar Health*. 2004;63 S 2:357-60.
- II. Hudson DS, Nilsen P, Johnson JS, Mode NA, Moore MA, Bensyl DM, Ekman RS. Hospitalizations for immersion-related injuries in Alaska, 1991-2000. *Safety Science*. Forthcoming 2005.
- III. Hudson DS, Nilsen P, Dahl E, Mode NA, Ekman RS. Factors associated with injuries occurring aboard vessels in Alaska: differences between residents and nonresidents. *Journal of Travel Medicine*. Forthcoming, Winter 2006.
- IV. Hudson DS, Ekman RS, Svanström L. Survival of immersions during recreational boating events in Alaska, 1999-2004. *Accident Analysis and Prevention* (Accepted).

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LIST OF ABBREVIATIONS

AIS	Abbreviated Injury Score. AIS scores range from one, to six, in order of injury severity.
AOISS	Alaska Occupational Injury Surveillance System. AOISS compiles information on all work-related fatalities occurring within Alaska.
ATR	Alaska Trauma Registry. The ATR is a surveillance system that captures information on all injury-related hospitalizations occurring in Alaska.
BARDS	Boating Accident Reporting System Database. BARDS is maintained by the US Coast Guard, and captures information on all fatalities occurring as a result of recreational boating events.
CDC	The Centers for Disease Control and Prevention, part of the US Department of Health and Human Services. CDC is the supervising agency for NIOSH, and maintains WISQRS.
CFIVSA	Commercial Fishing Industry Vessel Safety Act. CFIVSA is a federal act, regulating safety for commercial fishermen working in US water.
CPR	Cardiopulmonary Resuscitation, used to treat victims of drowning.
ICD-9-CM	International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM), used in Alaska by the ATR to catalogue hospitalizations from injuries.
NIOSH	National Institute for Occupational Safety Health. Part of the CDC, NIOSH administers AOISS.
OBS	The Office of Boating Safety. Part of the State of Alaska's Department of Parks and Recreation, OBS is responsible for administering federal and state boating laws in Alaska.
OR	Odds ratio. ORs compare whether the probability of a certain event is the same for two groups. An OR of 1 implies that the event is equally likely in both groups. An OR greater than one implies that the event is more likely in the first group.
PAR	Population Attributable Risk. PAR is defined as the proportion of the injuries in a population that would be prevented if an exposure were eliminated, assuming the exposure to be causal (Rockhill et al 1998).
PFD	Personal Flotation Device. PFDs, also called life jackets. Some PFDs, called immersion suits, cover the entire body, and offer protection against cold.
USCG	The United States Coast Guard. The USCG has primary oversight for boating safety in the USA, including Alaska.
WISQRS	Web-based Injury Statistics Query and Reporting System; WISQRS collects information from all areas of the US.

1 INTRODUCTION

Water, while essential for human life, also carries with it a threat to human safety. Tales of floods, shipwrecks, and misadventures on oceans and lakes are as old as humanity, and serve as reminders that waters kills, as well as preserves. The threat is not restricted to natural bodies of water: drowning can occur when people are submersed in as little as a few millimeters of liquid, if airways become blocked. In many countries, bathtub and swimming pool drowning are common, as are immersion-related injuries to babies and young children, who may fall into buckets of water or other small containers of liquid. However, it is in natural bodies of water that large scale threats to human safety emerge. In the first years of the 21st century, we have witnessed the impact of natural disasters as causal events associated with drowning. Consider, for just one example, the deaths of hundreds of thousands throughout South Asia after tsunamis hit the region.

Human beings have few biological defenses against drowning. Drowning fatalities occur after victims become submerged, with their noses and mouths blocked by water. Submersions can occur as victims enter water, or may result after victims have experienced a period of immersion. Cold water, ≤ 15 °C, presents special risks for submersion hypothermia and/or drowning in immersion victims, who must contend with challenges to body temperature regulation, while they also struggle to maintain open airways. Deaths occurring during an initial submersion stage are often ascribed to cold shock drowning. These events are characterized by an initial gasp reflex and hyperventilation, which can result in inhalation of water. In a small percentage of cases involving cold shock drowning, post-mortem examinations have revealed that deaths occurred without water inhalation. Submersion in so-called “dry drowning” may be due to peripheral vasoconstriction or tachycardia (Auerbach 2001; Brooks et al. 2005). However, most, if not all, pathways leading to cold shock deaths are precipitated by submersion; a prolonged period of submersion has been consistently linked with cold water drowning deaths.

If victims survive their initial immersions and/or submersions, they are still at high risk for cold water drowning, if they remain in water. Continued hyperventilation and peripheral vasoconstriction can lead to submersion deaths due to swimming failure, after 3-15 minutes of immersion. Prolonged immersion in cold water, for periods greater than half an hour, increases the likelihood of hypothermia, and eventual drowning (Auerbach 2001).

The studies in this framework describe risk factors associated with drowning and nonfatal immersion injuries that took place in Alaska during the 1990s and first half of the 2000s. Alaska is an especially appropriate natural laboratory in which to study these injuries. Almost all natural bodies of water in Alaska, barring hot springs, are considered cold water. Alaska’s shoreline waters seldom, if ever exceed 15 °C (National Oceanic Data Center 2001). A 31-day surface water temperature sample from 22 monitoring stations located around the state revealed that for the period 03 July-03 August 2005, surface water temperatures for rivers and lakes around Alaska ranged from 0.5 °C to 22 °C, with all but two waterways having average temperatures below 15 °C during the warmest summer months. Even the location with the highest surface water temperature for the period only maintained that temperature for half an

hour. It is reasonable to assume that people who participate in activities on natural bodies of water in Alaska will be at risk for cold water drowning or related nonfatal injuries, if they become immersed without protective equipment.

Indeed, Alaska's drowning rates indicate that drowning comprises a serious injury risk for people there. Alaska's crude drowning death rate in 2002 was 4.21 per 100,000 population, a rate that was nearly 3 times higher than the national average of 1.44 per 100,000 population (Centers for Disease Control and Prevention 2005). Boating and other immersion injuries happen frequently in Alaska and present special challenges to researchers. Boaters and swimmers are subject to the normal risks of land-based activities, including falls, burns, and cuts. They also incur additional risks for asphyxia from submersions; asphyxia is a condition caused by tissue oxygen deprivation, and is caused by drowning, hanging, strangulation, and other events where breathing is prevented (Ibsen and Koch 2002). Cold water is an ever-present hazard in Alaska, and when water-related injuries occur, they often take place in remote environments, where the nearest trained emergency response teams are several hours away.

This document contains findings from four studies that were conducted from 2003 through 2005, to describe factors associated with fatalities and injuries related to boating and/or recreational activities in Alaska. The framework includes a general overview of the studies, and background information on Alaska and immersion injuries. To date, these studies are the first known by authors to address risk factors specific to Alaska. The studies were conducted under the general supervision of the Department of Public Health Sciences, Division of Social Medicine, Karolinska Institutet, and under the tutelage of Robert Ekman, PhD, who served as the primary supervisor, with assistance from supervisor Dr. Leif Svanström. Our research benefited from the participation of more than a dozen scientists, either as co-investigators, or as valued peer reviewers. The studies aimed not only to identify specific factors associated with cold water drowning and injuries, but also to identify injury prevention strategies, to improve the well-being of visitors and residents who engage in boating or water-related activities. (Readers should be encouraged to note that many of the study's recommendations have already been endorsed or acted upon by regulatory agencies and/or injury prevention programs in Alaska.) In the next decade, many of the studies' authors hope to contribute to the growing body of work related to cold water hazards, through cooperation with other scientists in circumpolar areas.

2 BACKGROUND

2.1 INJURIES AS A GLOBAL EPIDEMIC

Deaths and disabilities from injuries have a tremendous impact on quality of life around the world. In 2000, approximately 5.1 million people died from trauma, with a much larger number requiring hospitalization or other medical care as a result of injuries (World Health Organization 2002). The relationship of injury-related mortalities to injury-related morbidities and disabilities is part of a phenomenon known as the injury pyramid. In the United States, a recent study comparing fatal injuries against hospitalizations and emergency room visits for injuries in two states with universal hospital-based injury surveillance showed a ratio of approximately 1:10:142 (Wadman et al. 2003). Because many injuries occur in younger people, injuries are the most important cause of years of potential life lost (YPPL), with losses from injuries running approximately 20% to 25% higher than those YPPLs attributable to cancer and cardiovascular disease, for example (Segui-Gomez and Baker 2003).

Until the middle of the last century, public health scientists paid little attention to the study of injuries, as these events were assumed to be unavoidable “acts of God.” However, systematic analysis of injury events has demonstrated that injuries, like diseases, affect identifiable groups, and are associated with specific markers, or risk factors, and therefore, can be prevented. Two separate, but very closely linked research and practice areas have emerged. “Injury control” addresses methods to manage injuries, and minimize damage from injuries, once they have occurred. “Injury prevention” aims to stop injuries, before they have occurred. Injury control and injury prevention draw upon many disciplines, including epidemiology, health promotion, risk analysis, policy analysis, acute care, and rehabilitation. The science behind both injury control and injury prevention lies in the use of the traditional public health model, based on the following four principles: 1.) define the problem; 2.) identify causes and risk factors; 3.) develop and test interventions; and 4.) implement interventions and evaluate their impact (Razzak et al. 2005).

2.2 EFFECTIVE INJURY PREVENTION AND SAFETY PROMOTION STRATEGIES

While injury control research has grown at a rapid rate in the past sixty years to incorporate hundreds of studies that describe risk factors for specific injury problems and treatment protocols for injured victims, less has been written about injury prevention, that is, the science of implementing programs and policies that allow vulnerable members of society to avoid harm in the first place. Safety promotion is a strongly related concept to injury prevention that focuses on developing and maintaining optimal quality of life. It is defined as “a process that aims to ensure the presence, and maintain the conditions, that are necessary to reach and sustain an optimal level of safety” (Welander et al. 2004). As such, safety promotion relies on a multiplicity of activities, including regulatory processes, community-based programming, and ongoing surveillance.

Researchers, policy makers, public safety officials, and other interested parties have relied on a simple formula, called the “3 Es,” to identify and develop effective prevention programs and policies. Enforcement of safety regulations, Education and training for at-risk groups, and Engineering (sometimes partnered with Environmental controls) are all considered effective components of injury prevention. The literature assessing the relative importance of education, enforcement, and engineering on injury prevention programs stresses, however, that no single approach can be considered effective to prevent injuries (Carlson-Gielen and Girasek 2001; Nichols 1994; Segui-Gomez and Baker 2003). Effective prevention must consider all three Es (and their cousin, Evaluation). One has only to look at the motor vehicle and bicycle safety programs that were first implemented in the 1980s in Scandinavia and North America, while changes in highway, motor vehicle and bike helmet design were being implemented, to see how the interplay between enforcement, education, and engineering combined to sharply reduce the number deaths from vehicle and bicycle crashes (Ekman et al. 2001; Evans et al. 2001; Schelp and Ekman 1990; Svanström et al. 2002).

Perhaps the biggest challenge that injury prevention faces, as a discipline, is the strongly held belief that injuries are things that “just happen” and that little can be done to prevent them. A recent telephone survey of randomly selected American adults asked them to consider a series of injury scenarios that resulted in fatalities, and describe which deaths they felt could have been preventable. Respondents felt that, as a whole, only 56% of the injuries presented to them could have been prevented. Responses to injury fatality scenarios varied; it was encouraging to note that, within this study, respondents indicated that they felt that 62% of drowning deaths could have been prevented (Girasek 2001).

2.3 DROWNING AS A GLOBAL INJURY PROBLEM

The World Health Organization (WHO) estimates that 409,000 people drowned in 2000, making drowning the second leading cause of unintentional injury death globally (World Health Organization 2001). Because victims are often not declared dead at hospitals, but rather, at the scenes of the events, there may be a tendency by local health care providers to under-estimate the number of deaths caused by drowning (Chochinov 1998). Indeed, within the scientific community, there still exists some confusion over the best manner to identify the causes of drowning deaths, and over how best to report these deaths in a manner that leads to better prevention efforts (Idris et al. 2003; Szpilman 1997). World-wide, victims under the age of five comprise an important segment of the populations most at risk for drowning. According to WHO, victims under the age of 15 make up more than one half of the drowning fatalities documented in 2000. Although young children are at highest risk for drowning globally, older children and younger adults also face increased risks of drowning. In Canada, drowning was the second leading cause of unintentional injury mortality in people ages 0-24 in 1997, and the third leading cause of unintentional injury mortality in people ages 25-44 (Barss 2001). In the United States, the National Center for Injury Prevention and Control (NCIPC) reported that drowning was the second leading cause of unintentional injury-related death for Americans ages 1-14, and among the top ten causes of unintentional injury-related deaths for Americans ages 15-44. Nationally, the age-adjusted drowning rate in the US was 1.42 per 100,000 population per year for the

years 1999-2001 (National Center for Injury Prevention and Control 2004). (See Table, International rates for Drowning, page 11.)

To date, very little data on nonfatal submersion injuries have been collected in the US. In the one study available, the author analyzed Centers for Disease Control and Prevention (CDC) reports of 6913 cases of nonfatal submersions in the US in 2000, with 4706 (68%) of these cases requiring emergency transport and/or hospitalization (Ibsen and Koch 2002). In another regional investigation about the impact of nonfatal submersions, an economic analysis of expenses associated with 865 hospitalizations for nonfatal submersion injuries in California in 1991 found that such injuries resulted in costs of more than \$11 million. The biggest expenses, exceeding \$100,000 per case, were incurred by 19 victims, many of them children, who suffered neurological damage as a result of delayed rescues (Ellis and Trent 1995).

Region	Year	Crude Drowning Rate per 100,000 Population	Source
Africa: LMI	2000	13.1	WHO 2002
Americas: HIC	2000	1.3	WHO 2002
Americas: LMIC	2000	4.3	WHO 2002
Southeast Asia: India	2000	7.6	WHO 2002
Southeast Asia: Other LMIC	2000	3.8	WHO 2002
Europe: HIC	2000	1.0	WHO 2002
Europe: LMIC	2000	9.2	WHO 2002
Eastern Mediterranean HIC	2000	1.8	WHO 2002
Eastern Mediterranean: LMIC	2000	4.2	WHO 2002
Western Pacific: HIC	2000	4.0	WHO 2002
Western Pacific: China	2000	12.3	WHO 2002
Western Pacific: Other LMIC	2000	4.9	WHO 2002
Canada: National	2000	1.54	Canadian Red Cross 2003
Canada: Territories	1996-2000	8.24	Canadian Red Cross 2003
United States: National	2002	1.44	CDC 2005
United States: Alaska only	2002	4.21	CDC 2005

2.3.1.1 Table: Comparison of Selected Drowning Rates per 100,000 Population

LMIC: Low and Middle Income Countries

HIC: High Income Countries

Canada Territories include Yukon Territory, Northwest Territory, and Nunavut

2.3.2 Defining the Injury Problem

Immersion-related injuries have multiple causes and outcomes. Up until the last decade, the commonly accepted term for an immersion-related injury was “drowning” and discussions centered on fatalities. Research on survivors of such events described injuries associated with “near-drowning”, and indeed, this term is still in use. However, new guidelines and case definitions for immersions and submersions, called the Utstein Guidelines, have been enacted by many of the organizations with interests in drowning research, including the European Resuscitation Council, American Heart Association, and the Resuscitation Council of South Africa, among others. The case definitions recommended by the Utstein Guidelines were used by the principal investigator of the studies documented in this paper, to develop case definitions for research (Idris et al. 2003).

The papers contained in this document primarily use the terms “immersion” and “submersion” to describe, respectively, conditions where any portion of a victim’s body is in water, or where a victim’s head or face is in the water. While immersion events are sometimes described as accidents, readers should not infer that such events were unavoidable. Similarly, descriptions of vessels associated with watercraft accidents or events frequently employ the generic term “boats,” which also refer to canoes, kayaks, rafts and other vessels.

2.3.3 Risk Factors for Immersion-related Injuries

Immersion-related injuries often go unnoticed by bystanders. Drowning can occur with no sign of distress from the victim, who is struggling to breathe. Victims are often in upright positions, with arms thrashing or slapping the water, and bystanders may mistake this activity for play (Orlowski and Szpilman 2001).

Known risk factors associated with drowning deaths include non-use of Personal Floatation Devices by victims (PFDs, also known as life jackets,) and alcohol use by victims (Lippincott Health Promotion Letters 1997; Cass et al. 1991). Other global risk factors associated with drowning include age, with children under the age of five at highest risk (Cass et al. 1991). Gender is also a known risk factor--in many areas, especially where fishing is a primary means of gathering food, males are far more likely to drown than females (World Health Organization 2002).

One of the most significant risk factors associated with immersion-related injuries is alcohol use. Several studies have estimated that alcohol use is involved in about 25% to 50% of adolescent and adult deaths associated with water recreation in the United States (Copeland 1986; Howland et al. 1990, 1996). Drinking history is strongly associated with the risk of drowning. In a study published by Chen et al. (2005) the odds ratio (OR) of dying from drowning was 3.48 higher for current drinkers, than it was for the general population in the United States. Driscoll et al. (2004) conducted a meta-analysis to assess the role of alcohol in drowning during recreational events and found that consumption of alcohol significantly increased the risk of drowning. The relevant studies indicated that people with blood alcohol levels of 0.10g/100ml had

approximately 10 times the risk of drowning after a recreational boat accident than people who had not been consuming alcohol. The population attributable risk (PAR) for alcohol association as a contributing factor for recreational boating events was estimated by Driscoll et al. (2004) to be between 10 and 30 percent. A report published in 2001 on non-commercial boating deaths in two states found that drinking increased the relative risks for victim deaths; even low levels of blood alcohol were associated with increased mortality risks, both in boat operators and their passengers (Smith et al. 2001). While field sobriety tests have been developed to assess alcohol use in boating operators and passengers in the US, these populations still appear to be mixing alcohol and boating at an alarming rate (McKnight et al. 1999). A national survey of motor boat operators in the US, analyzed by Logan et al. (1999) indicated that 31% had operated a boat after consuming alcohol. Another study published reported that boat passengers who imbibed alcoholic beverages while onboard had an increased risk of falling overboard and drowning, even when the boat was operated correctly (Howland et al. 1993).

Other factors associated with submersion-related injuries include:

- Inability to swim;
- Hyperventilation;
- Hypothermia;
- Illicit drugs;
- Cerebrovascular accidents;
- Seizures;
- Myocardial infarctions;
- Trauma; and,
- Child abuse or neglect (Olshaker 2004).

There is significantly less information available on the prevalence of, and risk factors associated with, nonfatal immersion-related injuries. Traumatic injuries occur when people come into contact with moving machinery, or when falls occur aboard watercraft. A study of US boating injuries in 1996 indicated that 171 people were injured by boating propellers (MMWR 1998). A New Zealand meta-analysis of non-submersion injuries related to water recreation described amputations of limbs when water skiers, swimmers, and divers come into contact with propellers, and spinal cord injuries from diving into too-shallow water (Chalmers and Morrison 2003).

2.3.4 Factors that Help Prevent Drowning

PFD use by victims has been shown to be significantly related to survival from submersion (Lincoln and Conway 1999; Lincoln et al. 1996; Smith et al. 2001). PFDs allow users to keep their heads above water, minimizing the risk for hypoxia. Some PFDs, designed for use in colder waters, provide full body coverage, and help users maintain body heat, minimizing the risk for hypothermia. However, PFD use varies by country and by group. A study of watercraft-related drowning among New York State residents for the years 1988-1994 indicated that only 9% of the 883 non-bathtub related drowning victims were wearing PFDs (Browne et al. 2003). According to a US Coast Guard (USCG) analysis (2003) of 750 drowning deaths in the US in 2002, 85% of drowning victims were not wearing PFDs. Although people engaged in water activities may feel that their swimming ability offers them some protection absent the use of

PFDs, this advantage has not been adequately demonstrated in large-scale studies. In a report on swimming ability and the risk of drowning published in 2003, the authors state that to date, a clear protective relationship between increased swimming ability and the risk of drowning has not been satisfactorily demonstrated in adults, although such ability may confer a small advantage to older children (Brenner et al. 2004).

2.3.5 Predictors of Outcome after a Submersion Injury

After a submersion injury has occurred, it can be difficult to predict survival. The single most important determinant of submersion injury outcome is hypoxia. Immediate resuscitation is required, in order to minimize neurological damage and increase survival. Mouth-to-mouth ventilation should be started as soon as the victim's mouth can be lifted above the water's surface. Every submersion victim, even those who have appeared to recover and begin breathing on their own, should be transported to the nearest appropriate medical facility for follow-up care (European Resuscitation Council 2000).

A study of 61 submersion survivors in Helsinki showed that patient age, water temperature and rectal temperatures at hospitalization were not significant predictors of survival. Exposure, that is, submersion time, even though it was usually just an estimate, was the best predictor of outcome (Suominen et al. 2002). However, there are reports of victims, particularly children, who have been submersed in cold water, and who have been revived. Children who are successfully revived using CPR after submersions may demonstrate survival outcomes. One study found that about 40% of children who had been submersed and then treated with CPR were revived (Pearn 2000). Another study found, however, that the effect of cold water as a precursor to beneficial outcomes of 47 nearly drowned children could not be proved (Suominen et al. 1997) There are few studies that address post-submersion neurological functioning of survivors in the years following their recoveries (Ibsen and Koch 2002).

2.4 COLD-WATER IMMERSIONS

The material contained in this document addresses injuries taking place in cold water. All water-related activity in Alaska takes place in potentially deadly settings. Average surface water temperatures for oceanic waters in Alaska rarely, if ever, exceed 15 °C (National Oceanic Data Center 2001). The first survival prediction curves for cold-water submersions were developed in 1946 by Molnar, who found that survival rose steadily for water temperatures above 15.5 °C (Molnar 1946). In 1969, Keatinge produced the first book on cold water survival (Keatinge 1969), and in 1976, Smith's work on survival at sea postulated that hypothermia was a primary factor in drowning (Smith FE 1976). In the early 1980s, Golden and Hervey described four stages of cold water drowning, any of which could lead to death. These include: 1) an initial immersion stage, with death occurring within two to three minutes; 2) a short term immersion stage, which results in death after 3-15 minutes of immersion; 3) a long-term immersion stage, which results in death after 30 minutes of immersion; and, 4) a post-immersion stage, where death occurs during or after rescue (Golden and Hervey 1984). Brooks et al. (2005) analyzed records describing the drowning deaths of 130 commercial fishermen in British Columbia and found that 95% of these events

occurred in water temperatures at or below 15 °C. There was sufficient information to classify 36 deaths using the criteria described by Golden and Hervey; of these deaths, seven were attributed to cold shock (stage one), seven were attributed to swimming failure (stage two), seven were attributed to hypothermia (stage three), and one was attributed to post-rescue collapse (stage four).

Submersion injuries often follow a scenario where victims panic, followed by breath-holding, and then swallowing large amounts of water. In cold water, a variation of this scenario may occur, where laryngeal spasms occur, without victims ingesting water (Brooks et al. 2005). Prolonged submersion results in hypoxia and organ failure. Victims who survive an immersion event may still experience Acute Respiratory Distress Syndrome (Edwards et al. 1990) or post-event pneumonia. While cold shock is a life-threatening condition, a small percentage (perhaps 15%) of the population may exhibit the mammalian diving response to cold water (Gooden 1992). This response, which begins upon submersion, prevents aspiration of water, redistributes oxygen stores to the brain and heart, slows cardiac oxygen use, and initiates a hypo-metabolic state. As with other submersion events, early rescue and resuscitation are vital if victims are to recover. Along with resuscitation efforts, great care must be taken to re-warm hypothermic victims without damaging affected body parts.

Some findings have suggested that younger people may be less susceptible to cold water hypothermia (stage three). However, a controlled experiment in cold water immersion demonstrated no significant differences in thermo-sensitivity between younger adults (average age 22.7 ± 2.7 years) and older adults (average age 41.7 ± 2.7 years) (Glickman et al. 2002). Although some modern folklore insists that alcohol confers an advantage against cold water injuries, Franks et al. found that moderate consumption of alcohol is not protective of cold shock responses, and is unlikely to reduce the risk of drowning (Franks et al. 1997).

2.4.1 Populations at Risk for Drowning and Immersion-Related Injuries in Alaska

This section will describe some characteristics of populations known to be at risk for drowning or immersion related injuries in Alaska.

2.4.1.1 Commercial Fishermen in Alaska

Commercial fishermen in Alaska have some of the highest occupational fatality rates in the US. The National Institute for Occupational Safety and Health (NIOSH) estimated that between 1991-1999, commercial fishermen in Alaska had a fatality rate of 124/100,000 workers/year, roughly 28 times higher than the overall US occupational fatality rate of 4.4/100,000/year for the same time period. The vast majority of these deaths are attributed to drowning. NIOSH described several risk factors that were associated with occupational fatality in this group, including: cold water, fatigue and stress in crew, poor use of emergency equipment, unstable vessels and work platforms, and icing conditions (Conway et al. 2002).

2.4.1.2 Recreational Participants in Water-related Activities in Alaska

Recreational activities also contribute to the high drowning rate in Alaska. Boat registration rates in Alaska amount to about one per 12 inhabitants, a rate far surpassing the US average of one boat per 22 inhabitants (United States Coast Guard 2004). Boating and fishing are popular activities with both residents and visitors. In 2001, more than 48,000 powered boats were licensed for use by the State of Alaska (State of Alaska Department of Administration 2004). From 1994 through 2000, there were 814,500 recreational fishing licenses sold to Alaska residents, a number that equates to one license per year per every five residents.

2.4.1.3 Subsistence Boaters

Subsistence boaters comprise a large user group that is at-risk for immersion-related injuries. Subsistence users are defined by the State of Alaska as people whose diet depends on “the customary and traditional uses of fish and game in all of Alaska’s rural areas. If a person moves into a rural area and adopts that way of living for their own, then that person, whether Alaska Native or non-Native, may legally fish and hunt for subsistence.” In 1999, there were approximately 124,000 people (about 20% of the state’s population) who qualified as subsistence users. Subsistence diets consist primarily of fish, most of which is caught using boats, usually in locations that are quite remote from medical facilities (State of Alaska Department of Fish and Game 2000).

2.4.2 Regulatory Environments for Boating Safety

Commercial fishing safety in Alaska is addressed by federal regulations, primarily mandated through the Commercial Fishing Industry Vessel Safety Act (CFIVSA), which was enacted through a series of laws in the 1990s. CFIVSA regulations call for most commercial fishing vessels to be equipped with survival suits, electronic position-indicating radio beacons, life rafts, and fire-fighting equipment that is in operating condition and easily available to crew. Crew members must conduct frequent safety drills that address evacuations from vessels and cold water immersions. Since the implementation of CFIVSA, NIOSH analysis has demonstrated that deaths to commercial fishermen have declined by 67% (1990-1992 average compared to 1997-1999 average) (Conway et al. 2002).

Unlike commercial fishermen, recreational boaters in Alaska are not required to complete safety courses per se, although they are strongly encouraged to do so by the state’s Office of Boating Safety (Tikusis et al. 2000). Youth may operate Personal Watercraft, also known as jet skis, at the age of 12. There are no age minimums for operation of other watercraft, including canoes or rafts. State and federal regulations call for boats and canoes to have PFDs for all passengers. However the state only requires PFD use for children 12 and under while they travel in open boats, while on deck, or when waterskiing. Depending on size and equipment, boats must also carry fire extinguishers, visual distress signals, sound producing devices, and navigation lights (State of Alaska Department of Natural Resources Division of Parks and Outdoor Recreation Office of Boating Safety 2003). Enforcement of the minimal existing recreational boating regulations is rare.

3 AIMS AND OBJECTIVES

3.1 THE OVERALL AIM OF THIS RESEARCH

1. Describe factors associated with immersion-related injuries and recreational boating-related injuries in Alaska, with an overall objective to identify safety promotion approaches to reduce injuries and fatalities from immersions and recreational boating.

3.2 INDIVIDUAL STUDY OBJECTIVES

1. Analyze risk factors associated with hypothermia and drowning in commercial fishermen working in Alaska (Study One);
2. Analyze the risk factors associated with nonfatal severe injuries caused by boating or other water-based non-commercial activities in Alaska (Studies Two and Four);
3. Analyze risk factors associated with nonfatal severe injuries occurring aboard water transportation vehicles (Study Three);
4. Analyze and compare the risk factors associated with fatalities to non-commercial boating operators and passengers in Alaska against survivors of similar events, in order to identify protective factors for survival, and discuss potential safety promotion efforts to enhance survivability in vulnerable groups (Study Four).

4 MATERIALS AND METHODS

4.1 STUDY AREA

Alaska has about 640,000 residents occupying 1,477,261 square kilometers (570,374 square miles). Alaska's coastline stretches 10,686 kilometers (6,640 miles) point to point; including islands, Alaska has 54,563 kilometers (33,904 miles) of shoreline (State of Alaska 2004).

The median age for Alaska's population in 2000, the year for which the most recent national census data is available, was 32.4 years. Males comprised 51.7% of the population, with Whites comprising the largest ethnic group (about 68%) followed by Alaska Natives/American Indians (about 16%) (State of Alaska Department of Labor and Workforce Development 2005a).

Residents and visitors to Alaska frequently engage in water-related activities. Alaska's commercial fishing industry is the largest on the continent, and in 2002, employed approximately 6500 jobs per month (State of Alaska Department of Labor 2004). Because only a small portion of the state is served by the road system, watercraft, ranging in size from paddle canoes to huge barges, provides an effective means by which to transport people and goods throughout Alaska. The state's lakes, rivers and oceans serve not only as highways, but as working and recreational sites for many people. As discussed in section 2.4.1.2, boat ownership rates in Alaska far exceed those of the rest of the US, and personal and subsistence fishing is one of the most popular activities in the state: one out of five residents has a fishing license.

Alaska has become one of the most popular US ports of call for cruise ships, and ranks among the top five states in the nation in terms of economic benefits generated from cruise industry activity. A recent study by the International Council of Cruise Lines (2004) found that Alaska accounted for 5.4 percent of the entire North American cruise industry's direct spending and nearly 6.3 percent of all U.S. cruise-related jobs. Passenger traffic to Alaska via cruise ships increased 7 % from summer 2002 to summer 2003, with about 621,000 passengers arriving to the state via cruise ships. An additional 161,000 passengers arrived to the state via other transportation methods, embarking on cruises ships from port within the state (Northern Economics Inc. 2004).

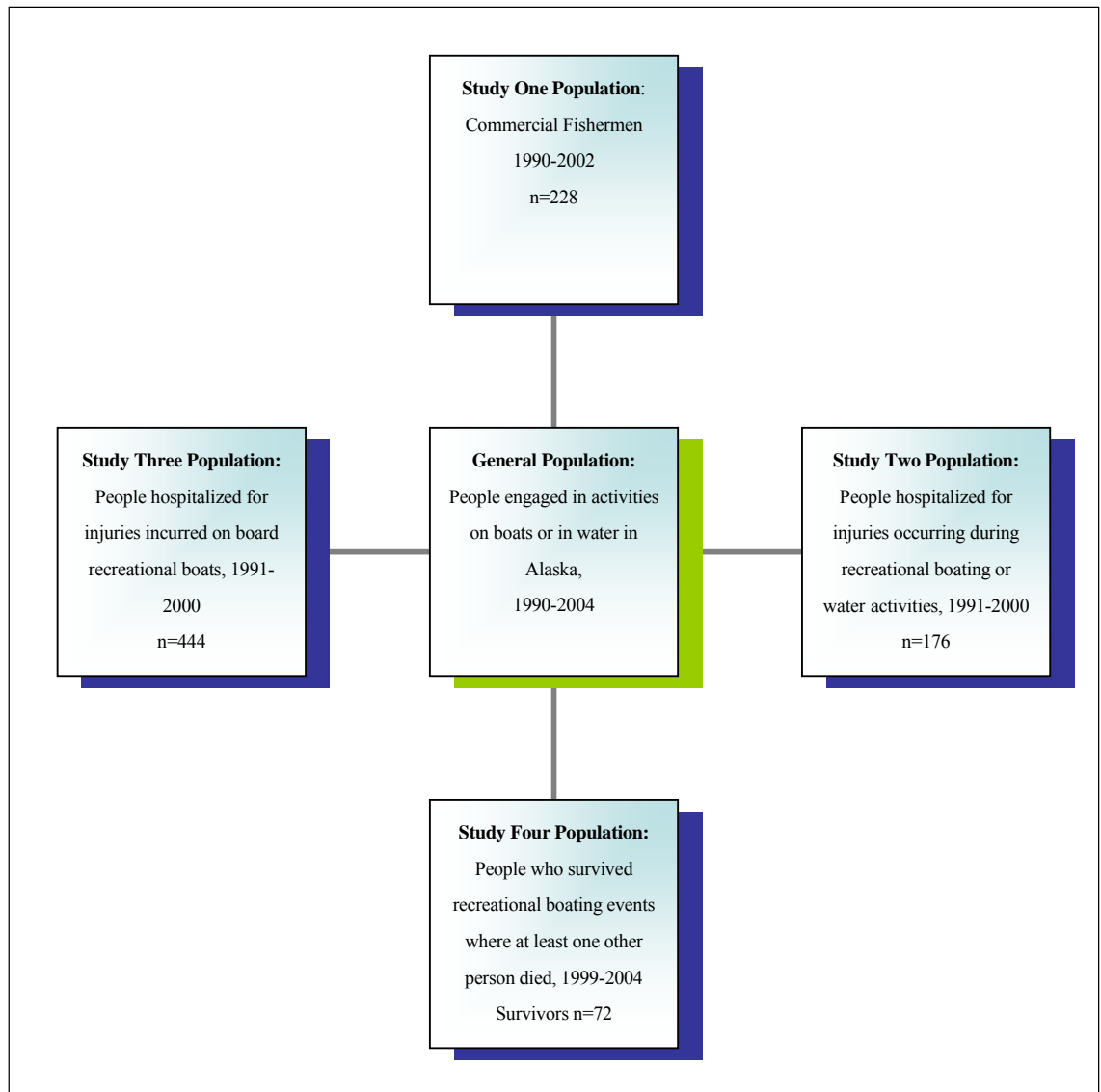
While visiting the state, nonresidents have enjoyed a growing number of recreational opportunities aboard Alaska water-transport vehicles of all sizes. More than 2 million nonresident recreational fishing licenses were sold to visitors to Alaska from 1994 through 2000 (State of Alaska Department of Fish and Game 2004). Nonresidents fishing for saltwater salmon and bottom fish accounted for over 300,000 boat-hours aboard chartered vessels in 1999 in Alaska (Dean 2001). In 2004, the US National Parks Service oversaw more than 125 concessionaires offering rentals of, and/or guided trips using canoes, rafts, kayaks and other small, non-powered water transport vehicles throughout federal parks in Alaska (Coleman 2004). It appears as if water-based activities are just as enjoyable, and enticing, to many tourists in Alaska, as they are to residents of the state.

4.2 STUDY POPULATIONS AND PERIODS

Study Populations and periods for research in this document consisted of:

- Commercial Fishermen working in Alaska, 1990-2002 (Study One);
- Individuals hospitalized for immersion-related events occurring in Alaska, 1991-2000 (Study Two);
- Individuals hospitalized for traumatic injuries taking place on board boats in Alaska, 1991-2000 (Study Three); and
- Individuals and groups in Alaska who were immersed in water after recreational boating events where at least one other member of their group drowned, 1999-2004 (Study Four).

Please refer to Chart, Study Populations, on following page.



4.2.1.1 Chart One: Study Populations

4.3 DATA SOURCES FOR STUDIES

The data sources used in this study consisted of all drowning-related surveillance material that is gathered within the state. These sources include federal data, from the CDC and US Coast Guard, and data gathered by the State of Alaska through a universal injury-related hospitalization registration system.

4.3.1 CDC Data

All studies used national data from the CDC, to provide comparison statistics that highlight the relative risk of drowning in Alaska. The US Centers for Disease Control and Prevention (CDC) is charged with gathering information on injuries to the US population, through two agencies: the National Institute for Occupational Safety and Health (NIOSH) and the National Center for Injury Prevention and Control (NCIPC). NIOSH conducts surveillance on work-related injuries, while the NCIPC conducts surveillance on non-commercial injuries. (Injuries from consumer products are monitored by the US Consumer Product Safety Commission.) Information on nonfatal non-commercial injuries is collected by the NCIPC from state public health agencies and is available for analysis on the Internet via the Web-based Injury Statistics Query and Reporting System (WISQRS). Information on drowning fatalities is available from all 50 US states, beginning in 1981, through 2002. Information on nonfatal injuries is collected into the WISQRS system through a sample of emergency rooms throughout the US; Alaska is not part of this sample, and no data from WISQRS regarding non-fatal injuries was used in the studies contained in this document.

4.3.2 Alaska Trauma Registry

Studies Two and Three relied extensively on data from the Alaska Trauma Registry. The ATR collects injury information from all 24 hospitals around the state, and is one of just a few population-based injury surveillance systems operating in North America. To be included in the ATR, a person must be admitted to a hospital for a stay of 24 hours or more, due to traumatic injuries. Traumatic injuries are described as those events classified under the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnoses codes of 800.00-995.89. Injury cases that are included in the ATR include those patients who are originally seen at the reporting hospital, transferred to a hospital with a higher level of care, or declared dead in a hospital emergency room. Cases are excluded if they are a result of injuries more than 30 days old, if individuals are admitted to a hospital for observation only, or if the admission is the result of a pre-existing injury that has already been entered into the ATR (Husberg et al.1998). From 1991 through 1999, the registry captured 39,168 injuries, with an average of 500 additional injuries being added annually during the past three years.

4.3.3 Boating Accident Reporting Database Systems

Study Four focused on analysis of data from the US Coast Guard. Data on recreational boating drowning events in Alaska and other boating related events that cause other injuries or significant property damage are collected by the USCG 17th District,

headquartered in Juneau, for eventual input into the national Boating Accident Reporting Database Systems (BARDS). Events involving watercraft that result in one or more fatalities are documented through official reports from responding public safety agencies. Records are also augmented by news reports.

4.3.4 Alaska Occupational Injury Surveillance System (AOISS)

Study One used data from a CDC agency-developed surveillance system. The Alaska Occupational Injury Surveillance System is maintained by the Alaska Field Station, National Institute for Occupational Safety and Health, Centers for Disease Control and Promotion. AOISS receives records of work-related injury from multiple sources including: USCG, National Transportation Safety Board, State Medical Examiner, Alaska Vital Statistics, and municipal and local public safety officials (Conway et al. 2002). Surveillance is ongoing, with work-related deaths usually entered into the system within a month after occurrence.

4.3.5 Validity and Reliability of Data Sources, and Data Limitations

In order to produce accurate injury risk profiles, researchers must use data sources that are valid, and reliable. Valid data is data that measures what it claims to measure, and reliable data is data that produces the same results, no matter who uses the data source (Page et al. 1995). Validity and reliability issues for the four data sources used in research are addressed here.

The CDC database is a universal surveillance system, with mandated reporting from all areas of the US. Definitions are strictly defined for each variable. The databases used in research were pre-defined, and thus, reliable.

The ATR is also a universal surveillance system; all hospitals in the state report injury hospitalizations to this system and thus can be presumed to be valid. There are some injury cases requiring hospitalization that may not be captured; in particular, injuries occurring in some areas of Alaska that are near the Canadian border may result in patients being admitted to Canadian hospitals. The areas of the state where this is most likely to occur are near Haines, Alaska, which is inaccessible by road from the rest of the state, and where emergency treatment sometimes involves a trip across the border. It would be extremely difficult to estimate how many cases might be overlooked, but given the small population of Haines, 2245 in 2002, the relative effect of missing cases would quite low (State of Alaska Department of Labor and Workforce Development Research and Analysis 2005b). ATR data is reliable in that case definitions are provided to every user, and injuries are documented using ICD-9-CM guidelines. However, it is quite probable that there are variances in coding by the personnel employed at the state's hospitals. We note also the differences in the quality of information that is recorded in the ATR's 250-space free text field by the different coders. To address issues of reliability, information was only coded as positive if there was a written reference to it within the ATR text; for example, we only coded people as submersed in Study Two, if they were described as either being submersed, or having their faces or heads covered by water, as verified by the ATR text. If people were said to have been hospitalized for hypothermia, but were not documented as having had their heads or faces under water, then we did not code them positive for being

submersed, although, in all likelihood, many of these cases most likely involved submersion.

BARDS is a universal surveillance system, collecting information on all recreational boating accidents that involve fatalities, and/or injuries requiring treatment beyond first aid, damage to vessels in excess of \$2000, or the disappearance of a person who is presumed to have drowned. The USCG states that many boaters do not report incidents that do not involve fatalities; however, they state that they have captured almost every instance of recreational boating fatality (United States Coast Guard 2004). Study Four was limited to events involving such fatalities in Alaska, and thus, the data in Study Four was valid. The data was collected using a collection instrument, and was checked by two people, one of whom was the principal researcher, and the other a certified medical records specialist. We developed an electronic data bases for use in this study, populated by data from BARDS records, which were sent in hard form from Juneau. Data was collected using a collection instrument, and then entered into the data base. Electronic records were checked against collection instruments, and source records, multiple times. Thus, the data in Study Four is reliable. However, we note that many times, information on specific factors associated with injuries in BARDS-reportable events was missing. To our dismay, information on PFD use was missing in more than half of the BARDS records. We also lacked information on ethnicity, in some cases. This hit or miss record keeping may be the result of multiple converging factors. The USCG, during this period of study, was reorganized under a new federal department, and recreational boating was de-emphasized as a safety initiative. Key personnel who were employed in the Juneau office were transferred, and a lack of funding and program support prevented other USCG BARDS specialists from conducting personal interviews with survivors of events. The USCG is not tasked with epidemiological analysis of its records, and the focus of its efforts is on enforcement, rather than prevention.

A final note on data limitations should be stated here. Alaska is the second newest of the United States, having only gained statehood in 1959. For much of its history as a US territory, and later, as a state, it has lacked the manpower, the expertise, or the resources to conduct injury surveillance on a scale comparable to other areas of North America or Europe. Given its small population, Alaska is seldom selected for observational studies to measure safety behaviors or attitudes. Researchers working with Alaska data sometimes lack information on PFD use as demonstrated by Alaska boaters. Researchers will encounter missing information on ethnicity, and at times, even on gender, of victims as they are entered into databases. One hopes that the appropriate response to missing data is to use what is available to highlight problems, while at the same time, creating a stronger awareness of the need for improved surveillance. As awareness of Alaska's injury problems are shared with others, it is possible that studies based on data with missing information, can be replaced by studies that are based on complete surveillance reports.

4.4 ETHICS

Researchers working with records that involve small populations must be careful to report findings in such a way that individuals are not identified. In a location with a

population as small as Alaska's, information such as village, waterway, or year could easily identify particular injury events and/or victims. The findings in the studies contained in this document are generally reported in aggregate form, and, in the case of Study Four, are not broken down by year, due to small study numbers.

Permissions to use databases were granted by the appropriate agencies. The ATR Use Committee required review of any material using ATR data for accuracy before publication of same. BARDS records, while considered public information, do contain data that could be used to identify victims, especially those from less populous areas. The first author of these studies obtained permission from USCG to use these records under the condition that no personal identifiers would be used. When hard copies of files were used, data was transferred into an electronic data base, and hard copies were then kept in a locked file cabinet, in a separate building. No personal identifiers were transferred from hard records into electronic format.

Karolinska Institutet Ethical Committee reviewed all research designs, and found no hindrances to completing the studies. (See: Decision Bilaga 2004/5:10, Diarienummer 04-855/5)

4.5 STUDY DESIGNS

Study One: The purpose of this study was to describe the patterns associated with cold-water immersion and drowning in *commercial fishermen* in Alaska from 1990 through 2002. Research was conducted using a retrospective study design, incorporating data from the Alaska Occupational Surveillance System (AOISS). Researchers extracted and analyzed all records describing deaths from drowning or hypothermia to commercial fishermen in Alaska from 1990 through 2002 (n=228) that were registered within AOISS. Researchers also analyzed a subset of records from AOISS to compare use of PFD use between the target population and survivors of fatal events. We used odds ratios to compare the two groups. The main outcome measure investigated was fatalities versus survivors.

Study Two: The purpose of this study was to describe the risk factors associated with *nonfatal* severe injuries caused by boating or other water-based non-commercial activities in Alaska from 1991 through 2000 (n=176). Researchers used logistic regression to analyze risk factors associated with nonfatal severe immersion-related events, and built models to explain differences between subject groups. Subjects were divided into two groups: the *Immersion Only* (IO) group had no additional injuries associated with their immersion-related events, while subjects in the *Associated Injury* (AI) group incurred additional trauma during injury events. The main outcome measures investigated were number and type of injuries.

Study Three: The purpose of this study was to describe the risk factors associated with nonfatal injuries aboard water-transport vehicles that required hospitalization in Alaska, 1991-2000. Researchers analyzed 444 ATR records to determine risk factors associated with injuries to *Nonresidents* (N group) and *Residents* of Alaska (A group) occurring aboard water-transport vehicles. Researchers conducted tests of proportion to measure differences between groups, then constructed odds ratios to describe risk factor and injury outcome factors associated with injuries to the N group. The main outcome measure investigated was type of injury.

Study Four: The purpose of this study was to compare and analyze differences between victims who died and survivors of events involving at least one drowning fatality in Alaska, 1995-2002. Researchers conducted analysis of all boating-related fatalities reported by the USCG's BARDS taking place in Alaska 1999-2004, to identify and further analyze those events where *Survivors* (S group) and *Fatalities* (F group) either shared the same craft, or collided in separate craft but then shared the same environment. Tests of proportion and other t-test methods and odds ratios were used to analyze inter-group variances/differences and to elucidate protective factors, i.e., those differences that may have promoted survivability of potentially fatal events. The main outcome measure investigated was survival of an immersion event.

4.6 OUTCOME MEASURES AND INDEPENDENT VARIABLES

4.6.1 Outcome Measures

Outcome measures for these studies included survival of immersion-related events where fatalities occurred (Studies One and Four), hospitalizations of 24 or more hours for serious injuries taking place in water (Study Two), and hospitalizations of 24 or more hours for serious injuries taking place on boats (Study Three).

4.6.2 Independent Variables

4.6.2.1 Type of Activity

Study Two differentiated between injuries occurring as a result of immersion, and injuries that occurred as a result of trauma from other sources. The classification of activities was derived from analysis of e-codes and narrative reports accompanying individual ATR records. Study Four limited the study population to those individuals who were participating in recreational boating, but who left their craft and were immersed in water. The classification of these individuals was accomplished through analysis of narratives in each BARDS report.

4.6.2.2 Type of Watercraft

Study Two included analysis of watercraft type used by seriously injured individuals. Study Three restricted the study population to those whose injuries occurred while they were on board watercraft. E-codes and ATR narratives were used to identify watercraft type. Only positive identifications were used. If watercraft was unknown, then it was listed as such.

4.6.2.3 Type of Injury

Studies Two and Three analyzed distribution of injuries in study populations. E- and n-codes were used to identify injuries. ATR records contained information on up to ten injuries per individual.

4.6.2.4 Use of protective equipment

Study One focused specifically on the use of PFDs as protective factors against occupational fatalities to commercial fishermen.

4.6.2.5 Demographic Factors

Analysis of demographic factors was included in all studies. Of specific interest to the researchers were: age, gender, residency, and race.

- *Age* was captured by all data sources. Age groups were used as the unit of measurement for Studies Two and Three.
- *Gender (sex)* was captured by all data sources. ATR and BARDS records captured the sex of all but one victim each.
- *Residency status* was derived from ATR records, through analysis of home towns for each study subject.
- *Race* was a variable of interest for studies two and three. Distribution of injuries in the United States does not follow an equal pattern when viewed through the lens of

race. In Alaska, Alaska Natives experience a disproportionate number of injuries, compared to non-Native populations. Race was documented in ATR records.

4.7 STATISTICAL METHODS

Descriptive statistics used in these studies included mean averages and proportions (all studies). Differences between groups were analyzed using t-tests and odds ratios; significance levels of .05 were assigned for all studies.

Logistic regression was used in Study Two to analyze risk factors associated with nonfatal severe immersion-related events, and build models to explain differences between subject groups.

Odds ratios were used in Studies One, Three and Four to elucidate differences in pre-injury risk factors and post-injury outcomes and to describe risk factor and injury outcome factors associated with injuries to different groups.

Population Studied	Data Sources	Exposure	Outcomes	Statistical methods
Study One Commercial fishermen working in Alaska	AOISS	Immersion	Fatalities PFD Use	Descriptive statistics, case fatality rates, odds ratios
Study Two Recreational participants in water-related activities	ATR	Immersion Submersion	Hospitalizations Watercraft user	Descriptive statistics, t-tests of differences between groups, logistic regression
Study Three Patients hospitalized for traumatic injuries occurring on board watercraft in Alaska waters	ATR	On board watercraft	Hospitalizations Residency versus visitor status Fractures	Descriptive statistics, t-tests of differences between groups, odds ratios
Study Four Survivors and Fatalities of events involving immersions	BARDS	Immersion Submersion	Fatalities Survivors Emergency responses	Descriptive statistics, t-tests of differences between groups, case fatality and survival rates, odds ratios

4.7.1.1 *Table Materials and Methods*

5 RESULTS

5.1 STUDY ONE

What role does hypothermia play as a contributing factor in drowning deaths of commercial fishermen in Alaska?

There were 228 deaths resulting from cold-water immersion and subsequent drowning in the target population between 1990 and 2002. Victims were far less likely to have used PFDs than were survivors of events where cold-water drowning occurred. The strong protective association seen with the use of PFDs, particularly immersion suits, in surviving cold-water events indicates that many of the events that led to deaths in the target population could have been survivable.

Findings from this study provide additional evidence of the utility of CFIVSA, especially in the legislative mandate for commercial fishing vessels to have properly fitting, appropriate PFDs on board for every crew member. These findings call for continued enforcement of CFIVSA, and continued education for crew. This study, while just one of many that replicate the oft-repeated findings that PFDs save lives, was important for the specific population of commercial fishermen in Alaska, as state and federal political support for continued enforcement of safety regulations is often based on Alaska-specific findings.

5.2 STUDY TWO

What factors are associated with nonfatal severe injuries associated with immersion-related events in Alaska?

Researchers used logistic regression to analyze risk factors associated with nonfatal severe immersion-related events, and built models to explain differences between subject groups. Subjects were divided into two groups: the “Immersion Only” (IO) group had no additional injuries associated with their immersion-related events, while subjects in the “Associated Injury” (AI) group incurred additional trauma during injury events between 1991 and 2000. There were 176 ATR records that met the inclusion criteria. In 87 (49.5%) cases, hospitalizations were due to the effects of immersion only (IO group). In 89 (50.5%) cases, hospitalizations were due not only to the effects of immersion, but also due to additional injuries suffered by victims, immediately before or while immersion took place (AI group). The final model revealed statistically significant risk factors for AI injuries including age greater than 12 years, female gender, white ethnicity, and operation of water transport.

Findings from this study will lead to increased knowledge on risk factors associated with boating or other water-based injuries in non-commercial and subsistence groups, leading to more effective education and safety programs for these groups. Findings will be incorporated into safety training programs by OBS, and have been shared with policy makers who have an interest in promoting boating safety in Alaska.

5.3 STUDY THREE

What factors are associated with nonfatal severe injury fatalities occurring aboard water-transport vehicles in Alaska?

Researchers analyzed 444 ATR records to determine risk factors associated with injuries to non-residents (N group) and residents of Alaska (A group) occurring aboard water-transport vehicles between 1991 and 2000. Tests of proportions elucidated significant differences in both risk factors and outcome factors between the groups. Significant differences in race, gender, age, cruise ship status, fall involvement, fractures, AIS scores >2, and hospital discharges existed between the two groups. Non-residents were more likely to be female, over age 65, passengers aboard cruise ships, and experience falls. Odds ratios for injury outcomes identified fractures, AIS >2, post-injury disabilities, and discharges to sites other than home as significantly higher for N group members, than for A group members.

Findings from this study will lead to increased knowledge of risk factors associated with severe injuries to non-residents aboard water-transport vehicles in Alaska, leading to more effective education and safety programs for at-risk groups. While the significant injury problem that emerged was falls, the 'take-home' message from this study was that falls in a particular group, that is, nonresidents of Alaska, resulted in more impact to the state's health care system, than had been previously known. The population of interest, cruise ship passengers, often was subject to additional stressors as a result of their injuries, including prolonged rehabilitations, and the need to be transferred out of the state back to hospitals in their own areas of residence. Findings were shared with the State of Alaska's Injury Prevention Program, and a falls prevention program is currently underway, targeting cruise ship passengers. This may have a spill over effect for other passengers, as in North America, cruise ship seldom restrict themselves to passengers of a 'certain age,' but target all age groups. Findings may also be interpreted as a call to promote environmental controls to prevent falls aboard larger boats.

5.4 STUDY FOUR

What factors promoted survival of subjects who were involved in an immersion event where at least one fatality occurred?

There were 32 immersion events that were included in this study, involving 36 fatalities (F-group members) and 72 immersed survivors (S-group) between 1991 and 2004. Boaters were involved in a variety of vessel operations, activities and accident scenarios. There were few statistically significant differences between the S and F-groups. The relative efficacy of various rescue methods was analyzed, using survivors and fatalities of each method as denominators. Rescue attempts by fellow members of one's own traveling party were the most successful, followed by self-rescue attempts. Post-immersion responses were catalogued against recommended actions for emergencies developed by the USCG and a leading textbook on wilderness medicine (Auerbach 2001), using the boater groups as the denominator data. Most groups (59%) had members who got to land, or other sheltered places (including ice floes) and out of the water as quickly as they could. Other responses to emergencies varied

considerably--none of the other recommended reactions were selected by a majority of the groups. However, all but two groups demonstrated at least one response to emergencies.

This study is the first known to address protective actions by survivors of fatal recreational boating accidents in the US. Findings from this study will be incorporated into the OBS Water Wise courses, and shared with Boating Law Administrators from other areas of the US. Findings point out the need for education of boaters, enforcement of safety policies, and the utility of properly engineered safety devices, particularly emergency notification equipment.

6 DISCUSSION

The main focus of the studies contained in this document was to describe factors associated with immersion-related injuries and recreational boating-related injuries in Alaska, from 1990 through 2004, and identify safety promotion approaches to reduce injuries and fatalities from immersions and recreational boating.

The results of these studies indicate that multiple factors are associated with immersion-related injuries and recreational boating-related injuries in Alaska, and that such factors are predictable, and thus, preventable. The studies described factors associated with fatalities among commercial fishermen, serious injuries occurring in water and on recreational boats, and factors that were associated with survival of fatal submersion events. The studies lent support for a multi-faceted approach to commercial and recreational boating safety in Alaska, by demonstrating that many of the risk factors described in these studies could be addressed through enforcement of safety regulations, engineering and use of appropriate safety technology, and training and education of user groups.

6.1 GENERAL CONSIDERATIONS

The analysis of injuries in these studies was limited to those taking place in Alaska, begging the question, can these results be generalized? The answer, when viewed through the lens of previously published studies, is, maybe. The impact of cold water submersions is identical for humans around the globe; physiologically, we are all the same. Cold water at a temperature of ≤ 15 °C in Norway will feel just like cold water at the same temperature in Alaska, or for that matter, off the coast of New Zealand. However, the regulatory environments, and the cultures in which commercial fishermen, swimmers, and boaters operate are very different in these three places and elsewhere where cold water is a problem. The impact of strong, enforced safety regulations and safety-promoting behavioral norms as they affect injury problems cannot be overestimated. A short example: in the 1980s, it became apparent that Alaska had the highest occupational fatality rate in the US, at 35/100,000/year for the period 1980-1989, a rate that was five times higher than the US average (and due in no small part to the number of commercial fishing deaths.) The accepted explanation for this was that somehow, the northern climes of Alaska resulted in inherently unsafe working conditions. However, when occupational fatality rates for Nordic nations were compared to Alaska's for the same time period, investigators found rates that were even lower than the US average. Interestingly, Norway had been undergoing an economic boom based on oil, at the same time as Alaska, and yet, its occupational fatality rate for the same period was 3.8/100,000/year, with Sweden's rate even lower, at approximately 3/100,000/year (Conway et al. 2002). The differences in occupational fatality rates are more than likely due to the differences in the safety environment. The studies that are described here took place in a particular milieu, where safety behaviors, and safety enforcement, are not consistently promoted. The Alaska social environment is dramatically different from, for example, Sweden, and thus, some of the findings here may very well be self evident to researchers who have lived with more cohesive social safety networks, where safety is viewed as a communal responsibility, rather than an individual option. But, the findings here can be used to promote a more

cohesive safety network where one is desperately needed, and thus, may be of great service to Alaskans, and our neighbors to the south in Yukon Territory and other regions of Canada that exhibit similar injury profiles. They also serve as useful baselines for prospective studies, and to provide comparison data for other cold-water drowning and cold-water immersion research. Thus, they provide some usefulness for global applications.

The use of Alaska as a study setting results in other issues, when considering generalization. Boating use in Alaska differs than that of the rest of the United States in several aspects. First, boats are used for transportation far more often in remote areas of Alaska, than they are in land-locked, high density areas of the US. Injuries in Alaska, at least those described in this study, were as likely to occur in remote areas of the state, as they were to occur in areas with rapid emergency response systems. In many cases, victims in our studies had to be transferred multiple times before they arrived at appropriate medical facilities; it is quite possible that injuries were exacerbated by delays in care.

Finally, at the risk of sounding repetitive, immersions taking place in Alaska take place in hypothermic water. Cold water injuries follow a different pattern than do those occurring in warmer water. It is probable that many of the findings from this body of studies, as they related to survival of cold water immersions, can be generalized only to other areas where cold water, remote locations and boating transportation patterns are similar. Such comparison areas might include Yukon Territory, Nunavut, and British Columbia, Canada; Greenland; Iceland; and areas of northern Finland and Norway.

Replication of study methodology is essential, if knowledge is to be verified, and built upon. The methodologies of Studies One and Two were adapted from previously conducted studies. Study One built upon methodology that has been published by other researchers from the Alaska Field Station, National Institute for Occupational Safety and Health (Conway et al. 1998). Study Two was adapted from an analysis of fatalities and survivals of commercial aircraft crashes in Alaska, conducted by researchers at the Alaska Field Station (Bensyl et al. 2001). Studies Three and Four required the development of original methodologies; in the case of Study Four, rescue behavior categories had to be adapted from a wilderness medicine text and a boating safety organization text. It is quite possible that other responses can prove just as helpful for survival of immersion events, and it is our hope that new studies will identify these responses, and test the methodologies of Studies Three and Four.

When conducting studies using data from injury surveillance systems, the accuracy of the systems themselves must always be addressed. The surveillance systems used in these studies are based on reports that are documented not only through public safety agencies, but also are supplemented by newspaper clippings. In many cases, the information was discrepant between official and unofficial sources. The researchers ranked sources on a hierarchy, relying on official reports, when differences existed.

Surveillance system records often featured missing information. In particular, ATR records usually lacked information on PFD use, and on length of hospital stay. BARDS records also lacked information on PFD use for many of the survivors of fatal

immersion events, as described in Study Four. The statistical significance of PFD use in Study Four, between Fatalities and Survivors of fatal immersion events was .0529, resulting in a (very) borderline finding. It is entirely likely that significant differences DID exist between the groups, but the information available from the BARDS records could not prove this. It must also be mentioned that electronic BARDS records, available via the Internet, had many information fields missing; it was only through analysis of hard copies of official BARDS paper records that Study Four could be completed.

Neither ATR nor BARDS records contained fields that would allow researchers to differentiate between subsistence and recreational boating use. This is extremely unfortunate, as the purposes of such activities are very different; it is quite possible that analysis by purpose of activity would elucidate strong differences in injury patterns between the two user groups.

All analysis using surveillance system reports entails a risk that those systems have not completely captured information on the populations of interest, resulting in under-reporting. In the case of research described here, there would be no ATR information on people who were injured, but did not require admissions to hospitals. Thus, ATR analysis is restricted only to the most seriously injured. BARDS records contain only basic information on non-injured parties. The research described in Study Four was not unduly affected by these BARDS limitations, but additional studies comparing risk factors of fatalities, immersed survivors, and survivors who did not leave boats, will not be possible until more complete information is captured for all parties involved in events.

Confounding factors must also be considered. The impact of confounders on studies can be minimized if models are adjusted for their presence, for example, if using regression models, researchers can compare findings from unadjusted and adjusted models. We used precisely this methodology in Study Two, with good results, and demonstrable changes in models that offered the most parsimonious explanations for injury problems.

Finally, we note the impossibility of obtaining baseline information on the relative frequency of immersion- and submersion-related injuries, due to lack of data. The USCG, by its own admission, does not usually capture information on nonfatal injuries, if victims do not make reports, or if the events are not accompanied by a drowning fatality. The actual frequency of immersion- and submersion-related injuries in the general US population may be quite high, compared to amount of exposure this population has to recreational boating. However, there is no way to know this, until better records are kept.

6.2 FACTORS ASSOCIATED WITH DROWNING FATALITIES

Limitations having been discussed and considered, what have we learned from these studies? To begin with, the single most important factor associated with prevention of cold water drowning, as documented by Study One, was the use of PFDs. The protective role seen in the use of PFDs, particularly immersion suits, in surviving cold-water events indicates that many of the events that led to death in the target population

could well have been survivable. Although the Coast Guard requires that most commercial fishing vessels in Alaska waters have proper-sized immersion suits for each crew member, and for crews to receive survival training, this study provides evidence that some crew members may have been wearing other types of PFDs, or they may have not been able to access and/or properly put on immersion suits before cold water immersions occurred. In order to improve survivability for crew members, two critical issues must be addressed: first, there must be adequate PFD gear to equip each crew member aboard a fishing vessel working in Alaska waters, and second, there must be adequate training for each crew member on how to properly suit up with survival gear. Adequate PFD gear should be viewed as that type of PFD that not only helps immersed crew members remain afloat, but that also helps crew members avoid hypothermia. Only full-body immersion suits are able to provide this type of thermal protection. Study One demonstrates that enforcement of safety policies and education and training of high-risk populations can have a strong protective effect, even when these populations are engaged in high risk work, in dangerous circumstances. The study, while perhaps repetitive of many similar findings associated with PFD use, also points out that even with a fairly strict safety environment, other changes and environmental cues must be considered, if policies calling for universal access and use of PFDs are to move from a theoretical possibility, to reality.

6.3 FACTORS ASSOCIATED WITH NONFATAL RECREATIONAL IMMERSION INJURIES

The results of our research, especially Studies Two, Three and Four, demonstrate that recreational cold-water injuries and fatalities, and injuries taking place on board watercraft in Alaska, have identifiable risk factors, and, thus, can be prevented.

Study Two highlights the (nearly) equal risks of being harmed through submersion or external sources, when recreational boating accidents occur, and points out the dangers of operating Personal Watercraft (PWCs.) This study found that females in Alaska who were hospitalized for immersion-related events were at higher risk for associated injuries, than their male counterparts. Study Two also demonstrated that watercraft use, either as operators or passengers, was a factor that was significantly associated with victims receiving additional injuries. Ethnicity was also strongly associated with non-immersion injuries, with whites being far more likely to experience injuries than other groups. This finding has implications for education outreach to promote safer behavior on and near water, in that the vast majority of Alaska's white population resides in urban locations, and are, by law, not eligible to participate in subsistence activities. In Study Two non-immersion injuries were also associated with age, with victims ages 13 and above far more likely to experience associated injuries than younger victims. This relationship raises questions: Are older victims more likely to engage in risky behavior? It seems probable that expansion of Alaska law to require PFD use by all boaters and water-skiers of all ages would have a beneficial effect to help lower Alaska's fatal drowning rates. In the final model developed in Study Three, occupational status emerged as a protective factor against associated injuries. Again, in light of CFIVSA, this provides very strong evidence of the effect that enforcement of safety regulations has on cold water injuries.

Study Three demonstrates non-residents injured aboard boats were much more likely to experience fractures than a comparison group composed of Alaskans. Non-residents were also more likely than Alaskans to experience discharges to interim care facilities or other health care facilities. This result may be partially attributed to non-residents wishing to be transferred to facilities located in their own home areas as soon as they were able to be air-transported. However, when considered against the other factors associated with non-residents, including advanced age, falls and fractures, it seems likely that many of the non-residents might have required ongoing care well past the initial hospitalization period. This has implications not only for local health care facilities, but for family members of travelers who may be injured far from home. Post-injury disability was more likely to occur within the non-resident group, compared to the Alaskan group. The non-resident group was also more likely to have AIS scores >2. Both of these injury outcomes further document the particular vulnerability of non-residents aboard watercraft in Alaska, to experience more serious injuries, than residents of the state.

6.4 SURVIVAL OF FATAL RECREATIONAL IMMERSION EVENTS

Study Four demonstrated that survivors of fatal submersion events were able to avoid exposure of faces and/or heads to cold water, which may have allowed them to avoid cold shock, and to conserve body heat, providing them the energy and mental faculties necessary to assist themselves and other group members. The responses of the survivors to immersion emergencies catalogued a number of behaviors. There were only two records of events where no responses to emergencies by survivors were recorded; in both these cases survivors were rescued by passers-by. Other survivors functioned effectively as groups, staying together and finding shelter. The relative efficacy of various rescue methods points out the need for recreational boaters to be prepared to not only handle their own emergencies, but also to assist when other boaters encounter problems. Study Four again points out the lack of universal PFD use in the boating population in Alaska. Although Alaska boaters are required to have PFDs on board for each passenger, only children ages 12 and younger are required to wear PFDs. It is apparent, from this study, that simply mandating the presence of PFDs aboard boats will not result in recreational boaters using PFDs.

6.5 IMPLICATIONS FOR PREVENTION

Studies of risk factors are useful, only in so far as they help drive prevention efforts that successfully reduce injuries. While the stated aims of each of the four studies have been shared this introductory section, and are featured in the four articles comprising the majority of text in this document, the overarching aim of this body of work was to help reduce drowning and immersion-related injuries in Alaska, and elsewhere where cold water is a feature of the environment. We refer readers to the earlier discussion on preventative strategies: the Three Es of Enforcement, Engineering, and Education. How can the findings of this research be used to enhance preventative strategies, using this model? The remainder of this section will focus on just that question, with a view to identifying specific actions that can be taken to improve safety in Alaska.

6.6 THE ROLE OF ENFORCEMENT IN DROWNING PREVENTION

The studies in this document outline the importance of enforcement of safety regulations, in order to prevent drowning. Nothing can be done to make Alaska's water warmer, short of hoping for continued global warming. However, all recreational and commercial boaters can mitigate the effects of cold water, by wearing appropriate PFDs. At the risk of sounding repetitious, we refer readers back to sections in this document that describe the effect that enforcement of CFIVSA regulations have had on survival of commercial fishermen. There is no equivalent safety enforcement approach for recreational users in Alaska. It is extremely likely that an initial campaign to develop an enforcement policy for universal use of PFDs aboard recreational vessel would be initially unpopular with the Alaska boating public. However, such laws have been implemented in many other areas of the United States, and in many other regions of the world, to good effect. Social change and acceptance of a universal PFD law in Alaska might require several decades, but then again, maybe not: CFIVSA has been consistently enforced only since the mid-1990s. The lifesaving effects of PFDs have been proven, time and again; the challenge in Alaska now is to put this knowledge into action, through enactment and strong enforcement of appropriate regulations mandating universal PFD use.

6.7 THE ROLE OF ENGINEERING AND/OR ENVIRONMENTAL ADAPTATION

All of the studies described here document the importance of engineering, and the availability of appropriate technology, to survival of boating events.

Study One demonstrates the protective effects of appropriate PFD and immersion suit use, both of which must be engineered to withstand freezing temperatures.

Study Two shows that engineering modifications may be in order to create safer watercraft. The study documented the association between PWC operation and serious injuries. PWCs are steered by directing the water jet, while powering forward. Unlike a motorcycle or snow machine throttle, releasing the throttle of a PWC affects its steering ability; inexperienced operators who attempt to avoid a collision with another person or watercraft by releasing the throttle in hopes of powering down may instead be on a direct collision course with the object they hoped to avoid. Clearly, an engineering modification would help operators maintain better control over their craft. Study Two also points out the need for other watercraft to be modified to provide safer transportation and to reduce the risk of injuries to operators and passengers. Falls on the deck of watercraft can easily lead to falls overboard; deck surfaces can be modified in most watercraft to install more slip-proof flooring on watercraft and ramps.

Study Three describes, in part, the risks of hip fractures in older passengers aboard cruise ships. This study was sometimes referred to, tongue-in-cheek, by its authors as "Cruisers and Bruisers." However, there is nothing humorous about a lengthy hospital stay, when one expected to go on a carefree vacation. Study Three, like Study Two, clearly points out the need for environmental and engineering changes to prevent falls. Slip-proof footwear, and hand railings can both have beneficial effects on passenger balance and orientation.

Study Four highlights the use of proper emergency notification equipment to get timely assistance.

6.8 THE ROLE OF EDUCATION IN DROWNING PREVENTION

All of the studies included in this document demonstrate that appropriate training can help prevent injuries. Study One demonstrates the survival of a group of people who had been trained in PFD use. Studies Two and Three demonstrated education gaps, and explained the role that training programs could play, in reducing recreational boating injuries. Study Four shows us that "accidents" are survivable, with the proper training and knowledge of effective emergency responses. Survivors in Study Four demonstrated a number of behaviors that indicated that they had been trained for emergencies: at least eight of the survivors were able to do CPR on victims of submersion. After statistical analysis, we found that the majority of rescue attempts were successful, whether they were attempts by the victim him- or herself, by members of a traveling party, or by people who were in the area. This study demonstrates both the incredible willingness of strangers to help out in dangerous situations and the role that education plays in injury prevention efforts.

6.9 FUTURE RESEARCH

Much remains to be done, both to identify risk factors associated with watercraft and immersion related injuries, and to identify effective injury prevention strategies that for watercraft operators and passengers, and other people who enjoy recreation on or nearby Alaska's waterways. Three future studies are suggested here.

1. Comparison studies identifying factors associated with injuries to recreational boaters in Northern Canada, Finland and Alaska can help identify the roles that environment and enforcement each play in promoting boating safety.
2. Studies addressing length of submersion in victims of cold water drowning in Alaska can help prove or disprove the cold water immersion model described in this document. In order to conduct these studies, more reliable information about submersion fatalities will be necessary.
3. Replication of Study Four would not only provide additional information on the usefulness of the study design, but more importantly, would shed additional light on effective survival tactics, which in turn can lead to more effective boating safety training programs.

7 CONCLUSIONS

The studies described in this document have identified multiple factors associated with cold water drowning, immersion-related injuries, and injuries occurring on board vessels in Alaska.

- PFDs, particularly immersion suits, save lives. Strong enforcement of safety regulations has resulted in increased use of PFDs in commercial fishermen, which in turn has led to increased survival in this group, following immersions in cold water.
- Nonfatal immersion injuries resulting in hospitalizations appear to follow two distinct patterns: in one group, injuries are related to complications from submersion. In the other group, traumatic injuries are the primary cause for hospitalization. Prevention activities targeting nonfatal immersions must address two separate etiologies.
- Injuries that occur on board watercraft in Alaska also follow two distinct patterns. In the first group, injuries occur on smaller vessels and are more variable in the types of injuries incurred. In the second group, injuries occur primarily in tourists aboard cruise ships, and are more likely to result in hip fractures. Prevention activities targeting nonfatal injuries taking place on board watercraft in Alaska must address two separate etiologies.
- Recreational boating immersions in Alaska are survivable. Even when other members of a boating party have drowned, survival is still probable, if people respond quickly and appropriately to emergencies.
- The prevention of drowning and recreational-immersion related injuries requires a combination of education, enforcement, and engineering approaches to address multiple risk factors.

The authors of these studies hope that their findings will be useful to others, and will help stimulate new research. Ongoing investigations into the problems of cold water drowning, immersion injuries, and injuries occurring aboard watercraft, coupled with solid enforcement, innovative engineering, and user-appropriate education, will help save lives, not only in Alaska, but in other areas where cold water drowning is prevalent.

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