

MOTORBOAT PROPELLER INJURIES

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Executive Summary

The purpose of this report is to collect and summarize existing studies of the incidence and severity of motorboat propeller injuries, of the feasibility of propeller injury countermeasures, and of the effectiveness of manufacturer, regulatory and litigation efforts to reduce these injuries.

Injuries caused by motorboat propellers have been documented in medical literature worldwide for more than 20 years. These injuries are often characterized by massive trauma, including significant blood loss, amputation or death.

In the United States, the Coast Guard has jurisdiction over recreational boating, including the authority to promulgate rules for marine safety equipment and the responsibility for gathering and reporting data on recreational boating injuries. Between 1976 and 1990, the Coast Guard officially reported 175 fatalities and 1,438 non-fatal injuries in its *Boating Statistics* category "struck by boat or propeller," or an average of approximately 100 per year. For a number of reasons, primarily the non-reporting of many propeller injuries to the Coast Guard, these data represent substantial and systematic underreporting. Other estimates of the annual incidence of non-fatal propeller injuries have been much higher: 2,013 in a 1991 Red Cross boating survey and 3,420 in an unpublished 1979 Coast Guard study.

Since most recreational power boats remain propeller-driven, efforts to prevent propeller injuries have concentrated on the design and manufacture of propeller guards – devices in the shape

of rings or cages which surround the propeller and separate its spinning blades from people in the water. Propeller guards designed to protect people and marine mammals have been developed and patented by private entrepreneurs for more than 35 years.

No major marine engine manufacturer currently offers for sale any propeller guard intended to protect people in the water. Possible reasons for this position are explored.

Primarily in the context of litigation on behalf of people injured by unguarded boat propellers, a number of analyses of the hydrodynamic feasibility and protective effect of various propeller guards have been conducted. Although there is little consensus as to the hydrodynamic feasibility of guards, several engineering studies suggest that a cage-type guard would prevent most serious limb injuries at speeds at least up to about 10-12 mph. Additional well-designed and unbiased research is needed.

In 1988, a subcommittee of the Coast Guard's National Boating Safety Advisory Council was appointed to examine the issue of propeller injuries and to recommend appropriate regulatory action concerning propeller guards. Relying in part upon the Coast Guard's incomplete data set, in 1989 the subcommittee recommended that no regulatory action be taken to require propeller guards. The Coast Guard accepted the subcommittee's recommendation and no regulations were promulgated.

Given the Coast Guard's refusal to mandate guards and the manufacturers'

unwillingness to introduce them voluntarily, the primary remaining propeller injury forum has become tort litigation. A series of cases is discussed, reviewing arguments for and against manufacturer liability, including the legal reasoning and potential societal effect of preempting plaintiffs' case.

Finally, misconceptions about propeller injuries and their prevention are critically examined. Recommendations are made to improve propeller injury data collection and to encourage the development of feasible countermeasures to reduce the toll of these devastating injuries.

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CLINICAL ASPECTS AND EPIDEMIOLOGY OF PROPELLER INJURIES

Introduction

On September 4, 1989, Linda Katherine Hall¹, six months pregnant, was riding in a 16-foot fishing boat on Lake Tohopekaliga in Florida, when her sun visor blew off. While trying to retrieve it, she fell overboard and under the boat. The boat's propeller struck her in the head and sheared off a piece of her skull four inches in diameter. Her baby, delivered by Caesarean section at one pound ten ounces, survived 16 hours. Six days later, Ms. Hall died, one of a growing number of victims of motorboat propeller injuries. [Lebowitz, 1989]

Boating-related injuries occur to operators, passengers, and others in the water, most often in the course of recreation – skiing, boating or swimming – during the crowded summer boating season. [Red Cross, 1991; USCG *Boating Statistics*, 1990]. In recent years, as the result of more than a dozen lawsuits, attention has been focused on motorboat propellers as instruments of devastation that are injuring and killing large numbers of people. [Hogan, 1989; Bolden, 1987]

The motorboat propeller can be deadly. Spinning three to five times faster than the forward speed of the boat [Reed, 1987], its blades are hidden

under water, invisible to most victims. Among those struck in the head, few survive. When struck in the extremities, victims often face amputations and severe disfigurement. [Thibault, 1987; Gomez, 1991] These injuries have been described as “devastating,” “catastrophic,” and “the civilian equivalent of severe battlefield injuries.” [Banta, 1979; Mann, 1976; Romano, 1962] Like the hazard which causes them, however, propeller injuries are a hidden category of recreational injuries.

For at least two decades, propeller injuries have been documented in the medical literature as a dramatic but largely preventable class of injury. [Jackson, 1965; Paterson, 1971; Sleight, 1974] Monitoring the true number of propeller injuries, however, has been difficult, since they are substantially and systematically underreported in data published by the United States Coast Guard, the federal agency responsible for boating safety in the United States. In fact, many who have fallen overboard, like Linda Katherine Hall, have been included only in the Coast Guard's “fall overboard” category, even though their deaths or injuries were a direct result of a blow from the propeller.

These injuries have been described as “the civilian equivalent of severe battlefield injuries.”

*John V. Banta,
physician, 1979*

¹ Not her real name.

The Coast Guard has a difficult task in policing the nation's crowded recreational waterways with admittedly limited resources. Failure to report known boating injuries in a manner that would illuminate rather than obscure the role of motorboat propellers, however, results in little if any cost or manpower savings. More importantly, the Coast Guard's current data collection and reporting methods preclude sound government decision-making toward the prevention of propeller injuries.

In addition, marine propulsion manufacturers, whose products cause these injuries, have failed to step into the void created by inadequate Coast Guard data. They have not initiated active injury surveillance efforts to determine the true incidence of propeller injuries. Although the number of known cases

should have been more than sufficient to stimulate preventive action, manufacturers have not committed appropriate energy or resources to developing ways to reduce or eliminate these deaths and injuries.

Clinical Aspects

Surgeons attending patients with propeller injuries report especially severe and disabling wounds. Inertial force, drag and the added mass of the boat affect the dynamics of objects colliding in water so that the force of a collision in water is greater than that of an equivalent collision in air. [Purcell, 1987] The spinning propeller blades strike the human body with the force of both the forward velocity of the boat hull and with their own even greater rotational velocity. After the body is

TABLE 1.

Struck by Boat or Propeller

Injury and Fatality Totals
U.S. Coast Guard Boating Statistics Data, 1976 - 1990

Year	Fatalities	Injuries	Total
1976	12	112	124
1977	5	107	112
1978	16	95	111
1979	18	69	87
1980	12	88	100
1981	7	83	90
1982	11	66	77
1983	18	113	131
1984	8	79	87
1985	16	98	114
1986	16	133	149
1987	12	155	127
1988	11	40	51
1989	6	60	66
1990	7	180	187
TOTAL	175	1,438	1,613

TABLE 2.**Struck by Boat or Propeller**

Injury and Fatality Rates Per Million Boats
 U.S. Coast Guard Boating Statistics Data, 1976 - 1990

Year	Boats x Million	Fatality rate	Injury rate	Total rate
1976	12.8	0.9	8.7	9.7
1977	13.3	0.4	8.0	8.4
1978	13.6	1.2	7.0	8.2
1979	14.1	1.3	4.9	6.2
1980	14.6	0.8	6.0	6.8
1981	15.1	0.5	5.5	6.0
1982	15.5	0.7	4.3	5.0
1983	15.8	1.1	7.2	8.3
1984	16.3	0.5	4.8	5.3
1985	16.7	1.0	5.9	6.8
1986	17.3	0.9	7.7	8.6
1987	17.7	0.7	6.5	7.2
1988	18.4	0.6	2.2	2.8
1989	19.0	0.3	3.2	3.5
1990	19.5	0.4	9.2	9.6

struck by the propeller, the relative viscosity of water can limit the body's deflection, making it more likely to absorb the full energy of the impact. [Hargarten, 1992]

Propeller injuries frequently involve multiple wounds and are often characterized by a series of deep parallel cuts [Romano, 1962], which can lead to traumatic or surgical amputation and significant blood loss; wounds immersed in water tend to bleed more freely, as the body's coagulation time is increased. Long periods of recovery and rehabilitation may be required. [Hargarten, 1992] Water-borne organisms can infect the wounds, further

complicating recovery. [Price, 1987; Lineaweaver, 1988]

National costs for the treatment and rehabilitation of propeller injuries have never been estimated. However, in one case series of severe propeller injuries reported by Hargarten et al., the average cost for hospital and physician care alone exceeded \$100,000 per injury. [Hargarten, 1992]

Epidemiology

Between 1976 and 1990, the U.S. Coast Guard officially reported 175 fatalities and 1,438 non-fatal injuries in its annual *Boating Statistics* report category "struck by boat or propeller."²

² Analysis of the raw (uncompiled) Coast Guard data may reveal a different number of injuries. This report relies upon the aggregated statistics compiled and made available by the Coast Guard, to the public, and to those who formulate boating safety policies. See, for example, *Boating Statistics* data supplied to Congress [USCG, 1988] and to the media. [Williams, 1989]

During this 15-year period, the reported numbers of injuries and fatalities varied, with no discernible upward or downward trend. [See Tables 1 and 2; Figures 1 and 2] Annual fatalities ranged from a low of 5 in 1977 to a high of 18 in both 1979 and 1983 (average 11.7 per year), while non-fatal injuries ranged from a low of 40 in 1988 to a high of 180 in 1990 (average 95.9 per year). Based on Coast Guard estimates of the number of recreational boats in the United States, the fatality rate per million boats has varied from a low of 0.3 in 1989 to a high of 1.3 in 1979.³

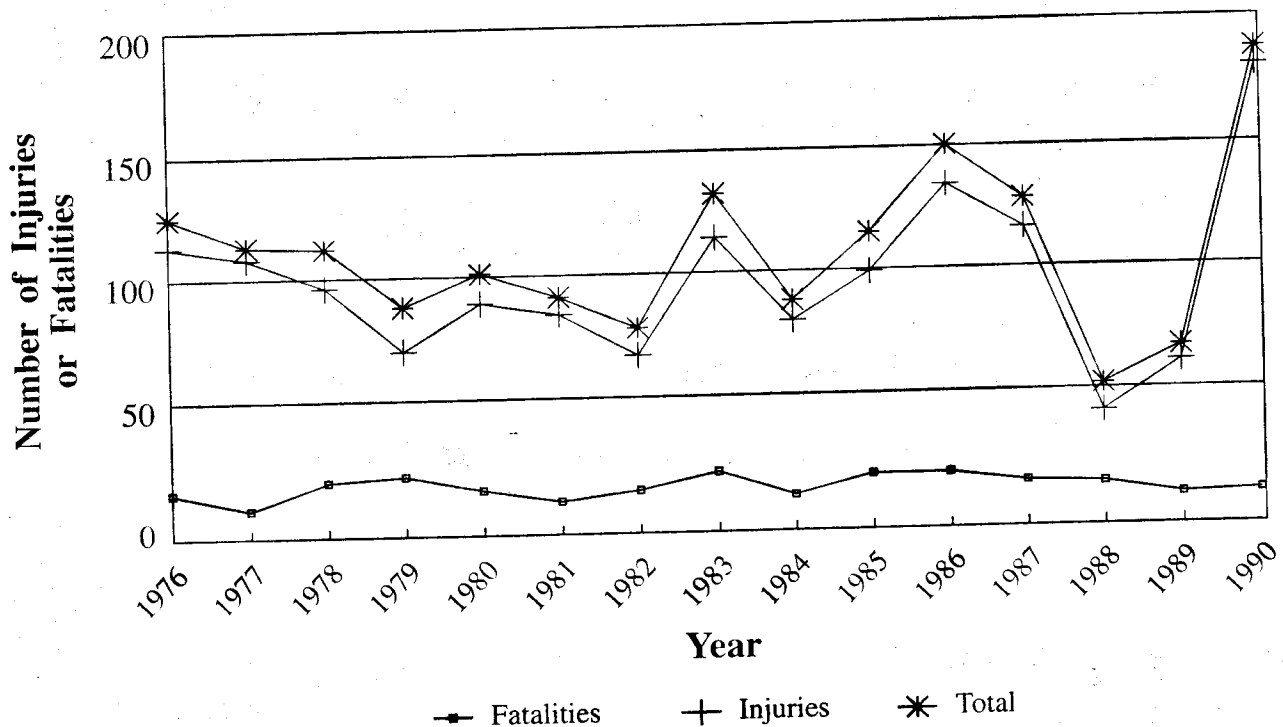
The non-fatal injury rate per million boats was at its lowest in 1988 at 2.2 and peaked during the 15-year period in 1990 at 9.2. [USCG *Boating Statistics*, 1976-1990]

For a number of reasons, Coast Guard data for propeller injuries represent substantial and systematic under-reporting.⁴ Estimates of the true annual incidence of propeller injuries have been as high as 3,420 in a Coast Guard analysis of its own 1978 data, for a rate of 251 per million boats. [Freund, 1979]

Reports in the medical and scientific literature as well as unpublished studies

Figure 1

Struck by Boat or Propeller
Injury and Fatalities - 1976 - 1990



U.S. Coast Guard Boating Statistics Data

³ It is important to recognize that a more accurate measure of exposure, to use as the denominator for a rate calculation, would be person-hours of propeller-driven boating activity, rather than raw numbers of boats. These more precise data are not readily available for each of the past 15 years.

⁴ See discussion beginning at page 8, *infra*.

performed by the Coast Guard provide much of our additional understanding of the epidemiology of propeller injuries. Propeller-related case fatality rates⁵ based on reported case studies vary from 15 percent (in a literature review of 77 cases) [Kutarski, 1989] to 23 percent (in an analysis of 223 cases in 1978). [Freund, 1979]

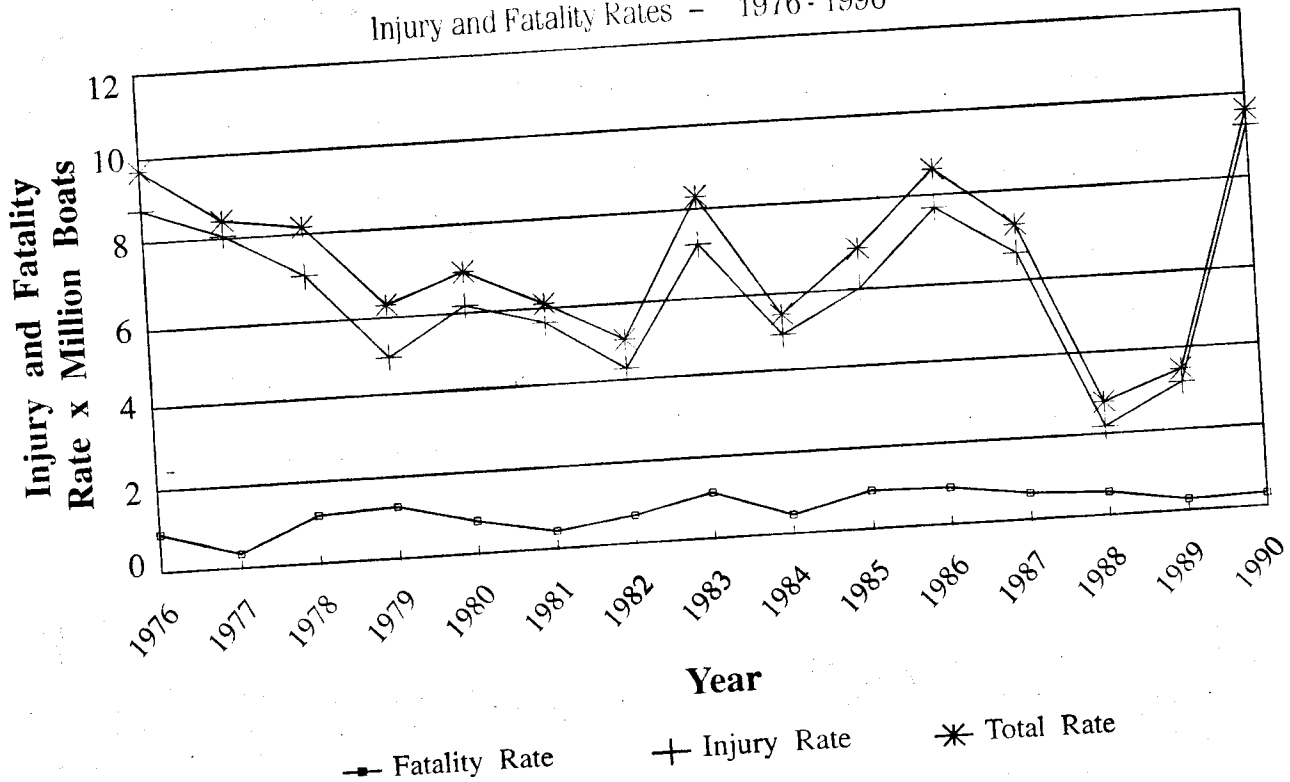
Propeller strikes to the head cause the largest number of deaths: a Coast Guard analysis of propeller injury data from 1978 showed that, where the location of impact was known, 39 percent of fatalities (16 of 41) involved solely a head injury. When multiple impacts which include the head are aggregated,

nearly two-thirds (27 of 41) of all fatalities involved a head injury. By comparison, only about 5 percent of non-fatal injuries (7 of 144), where impact location was known, involved solely a head injury, with about 15 percent (21 of 144) including a head impact when multiple locations are combined. [Freund, 1979]

Coast Guard annual boating data do not report age and sex breakdowns for the various injury scenarios. In the same 1979 Coast Guard analysis (of its 1978 data), however, 72 of 223 propeller injury victims (combining fatal and non-fatal injuries) were age 0-19 (32 percent); 92 were age 20-39 (41 per-

Figure 2

Struck by Boat or Propeller
Injury and Fatality Rates - 1976 - 1990



U.S. Coast Guard Boating Statistics Data

⁵ A case fatality rate compares the number of individuals who die from a particular injury or disease to the total number affected within a specified time. Therefore, if a case series reported 20 propeller injuries, 5 of which result in a fatality, then the case fatality rate (over the time frame of the case series) would be 25 percent. [Lilienfeld, 1977]

cent); and 27 were age 40 or older (12 percent), with another 32 of unknown age (14 percent). More than one-quarter of all victims, where age was known, were between 16 and 19 years old (49 of 191). [Freund, 1979] In 1984, the Coast Guard completed a similar analysis of its limited data with comparable results: of 58 "struck by boat or propeller" injury victims⁶, 19 were age 0-19 (33 percent); 27 were age 20-39 (47 percent); and 2 were age 40 or older (3 percent), with another 10 of unknown age (17 percent). Among the 48 victims whose age was known, 16- to 19-year-olds again represented a significant proportion of the total, with 11 of those 48 (23 percent) falling in that range. [Traub, 1984] Similarly, one 1987 Florida study, conducted by Price and Moorefield, found that of 195 propeller injuries identified from 1979 to 1983 through a survey of the members of the local orthopedic society, 89 were to victims age 0-19 (46 percent); 65 were age 20-39 (33 percent); 16 were age 40 or older (8 percent); the ages of 25 victims (13 percent) were not reported. [Price, 1987]

When data on victim and operator sex are available, males predominate in both categories, probably reflecting the large proportion of young males among participants in motorized water sports. The Coast Guard's 1979 study found that 171 of 222 victims (77 percent) and 197 of 211 operators (93 percent), where sex was known, were male. [Freund, 1979] In the 1984 study, 42 of 58 "struck by boat or propeller" victims (72 percent) were male (operator information was not reported). [Traub, 1984]

Waterskiing is the activity most often associated with propeller injuries. A review of medical and technical literature on water-skiing-related injury reveals that, in a sport fraught with hazards, propeller strikes inflict the most damage. [Paterson, 1971] "Accidents involving propellers remain the chief cause of devastating and mutilating injuries," Banta reported in 1979.⁷

Waterskiers themselves are the victims in about one-third of propeller injury incidents (27 percent in the 1979 Coast Guard analysis and 35 percent in the 1984 analysis). [Freund, 1979; Traub, 1984] Usually a skier is struck by the towing boat or by another boat whose driver fails to notice the downed skier. Price and Moorefield found that 48 percent of their cases involved waterskiing, with another 36 percent resulting from falls overboard. Just over 10 percent occurred to people already in the water, swimming or diving. [Price, 1987] The 1979 and 1984 Coast Guard studies reported that 48 to 61 percent of all victims were boat operators or passengers; 44 to 57 percent were the operator or passenger of the very boat which struck them. [Traub, 1984; Freund, 1979]

Waterskiing injury scenarios often involve a passenger or operator of a ski boat thrown overboard during sharp turns and rapid acceleration or deceleration, followed by contact with the boat's propeller. Alternatively, the boat may collide with another boat or object while the operator's attention is diverted. The collision then causes a fall overboard and a propeller strike. Some details from a 1987 Coast Guard report

⁶ The 1984 study analyzed only a 25 percent sample of the more than 240 "struck by boat or propeller injuries" contained in the Coast Guard's 1983 data. Of the 58 analyzed, 47 were struck by the propeller, 8 by the boat only, with 3 unknown. Because the study does not separately analyze boat and victim characteristics for struck by boat versus struck by propeller injuries, these data have been aggregated to determine the distribution of this injury scenario.

⁷ Some physicians have attributed these injuries to operator negligence or the lack of a vigilant observer in the tow boat. [Grace, 1974; Hummel, 1982]

illustrate the variety of waterskiing-related accident scenarios:

State	Date	Description
MA	07.14.84	Ski, passenger thrown out and hit by prop.
NM	08.08.84	Teen, ski, backed up to pick up skier, prop cut person on head.
NY	09.01.84	Teen, skier in water awaiting tow, hit by other ski boat, probably killed by prop.
OR	08.07.84	Teen, ski, passenger on bow, rapid deceleration, falls forward overboard, hit by boat and prop.
TN	07.21.84	Teen, ski, hit a log, passenger on bow thrown out, severe cuts to abdomen, probably prop.

All of these injuries were fatal.
[Purcell, 1987]

Waterskiing coupled with today's very powerful marine engines creates an especially dangerous combination. "It is obvious that with the increasing popularity of waterskiing, and with the burgeoning number of boats powered by high speed outboard propellers..., we can expect correspondingly large numbers of dramatic accidents to water skiers and passengers in the boats." [Jackson, 1965] This comment was published in 1965, when the number of pleasure boats in the U.S. was about six million. Today, there are more than 19 million. [Red Cross, 1991] Further-

more, the "high speed" propellers Jackson described are slow by today's standards. He described two separate, disabling brain injuries each inflicted by a 25 horsepower motor. More recently, according to Coast Guard analyses, nearly all reported propeller injuries have involved motors of greater than 25 horsepower. For reported injuries and fatalities where horsepower was known, well over half (55-62 percent) of the motors involved were greater than 75 horsepower. [Freund, 1979; Traub, 1984] Many pleasure boats today are powered by engines rated at several hundred horsepower. Information about the speed of boats involved in propeller injuries is

Distribution of Propeller Injuries - 1979 and 1984 Coast Guard Studies

1. More than one-quarter of victims were between 16 and 19 years of age.
2. Approximately three-quarters of victims and more than 90 percent of boat operators involved in propeller injuries were male.
3. About one-third of propeller injury victims were water skiers.
4. Most propeller-related fatalities involved a head impact. Fewer than one-fifth of non-fatal injuries involved a head impact.
5. More than half of the boats involved in propeller injury incidents were powered by engines greater than 75 hp.
6. Where precise boat speed was known, approximately 20 percent of fatalities and more than two-thirds of non-fatal injuries occurred at speeds of 10 mph or less.

"It is obvious that with the increasing popularity of waterskiing, and with the burgeoning number of boats powered by high speed outboard propellers..., we can expect correspondingly large numbers of dramatic accidents to water skiers and passengers in the boats."

*Commander Frederick Jackson,
U.S. Naval Hospital, 1965*

Next to the non-reporting of many incidents, classification of "accident type" by the first event leading to the injury is perhaps the most serious factor in the Coast Guard's official underreporting of propeller injuries and serves to disguise the true number of deaths and injuries caused by propellers.

also incomplete.⁸ In the Coast Guard's 1979 study, boat speed in miles-per-hour was known for only 21 of 52 fatalities and 38 of 171 non-fatal injuries. Of the fatalities where boat speed was known, four (19 percent) occurred at speeds between 0-10 mph; 5 (24 percent) at 11-20 mph; 6 at 21-30 mph (29 percent); and 6 (29 percent) at speeds greater than 30 mph. For non-fatal injuries, the distribution is somewhat different, with a greater proportion of incidents at slower boat speeds. Of the 38 injuries where boat speed was known, more than two-thirds occurred at boat speeds of 10 mph or less (26 injuries or 68 percent); 5 at 11-20 mph (13 percent); 5 at 21-30 mph (13 percent); and 2 at speeds greater than 30 mph (5 percent). [Freund, 1979]

Vessels involved in propeller injuries are typically in the 15 to 20 foot range – the same range in which most powered boating injuries occur. [Freund, 1978; Traub 1984; USCG propeller guard subcommittee, 1989] Riders of the much smaller, increasingly popular "personal watercraft" or "jetskis" (powered by water jet engines) have also been killed by propellers of other boats following a collision or fall. [Hummel, 1982; Scott, 1989]

No study we located described the temporal or weather-related variations associated with propeller injuries, but it is reasonable to assume that they occur most frequently under the same conditions as other boating injuries – on summer weekends, in good visibility, and in good to fair wind and weather conditions – when boating activity is at its

peak. [USCG *Boating Statistics*, 1990; Red Cross, 1991; Baker et al., 1992]

Underreporting

Propeller injuries are an internationally recognized problem. Case reports from the medical literature of Australia, Great Britain, Yugoslavia, the former Soviet Union, Israel, Canada, and most extensively the United States, document the hazards of unguarded propellers. [Paterson, 1971; Sleight, 1974; Kutarski, 1989; Sustic, 1970; Batinica, 1973; Budrin, 1976; Levy, 1979; Grace, 1974; Mann, 1976; Price, 1987; Lineaweaver, 1988] There is little consensus regarding the actual incidence of propeller injuries, however, because data collection is inadequate and reporting methods unreliable or misleading.

In the United States, the Coast Guard has federal jurisdiction over recreational boating and is required to collect and publish boating accident statistics. [Federal Boat Safety Act, 46 U.S.C. § 4301 *et seq.* (1991)] The Coast Guard collects data on boating-related casualties through a system which requires that the operator of any vessel used for recreational purposes file a report if that vessel is involved in an accident resulting in:

1. Loss of life; or
2. Personal injury which required medical treatment beyond first aid; or
3. Damage to the vessel and other property exceeding \$500 (\$200 before 1989); or
4. Complete loss of the vessel. [USCG *Boating Statistics*, 1990]

⁸ The National Boating Safety Advisory Council's 1989 report of its propeller guard subcommittee (see Part Three) claims that "approximately 80 percent of all accidents occur when a boat is operating at speeds in excess of 10 miles per hour..." No data or specific citation supporting this assertion were presented. According to the same report, casualties occurring at lower speeds "typically appear to happen when the operator is in the process of picking up a fallen water skier, moving in the vicinity of swimmers, or inadvertently putting an engine in gear when swimmers are using a boarding ladder or platform." [NBSAC propeller guard subcommittee, 1989]

The reports are filed with the authorities of the state in which the incident occurred (or directly to the Coast Guard if in Alaska) and the states provide copies of the accident reports to the Coast Guard. All incidents which meet the federal reporting requirements (above) are included in the Coast Guard's annual *Boating Statistics* compilation.

This system misrepresents the true number of propeller injuries in at least three ways:

(1) The Coast Guard's "type of accident" categories do not distinguish between impacts with propellers and those with the hull of the boat or other underwater appendages. Instead, all such incidents are grouped together as "struck by boat or propeller" in the Coast Guard's annual report.

(2) The "type of accident" tables, which include the category "struck by boat or propeller," refer only to the first event leading to the injury. A fall overboard which was followed by a fatal propeller strike, for example, appears only in the "fall overboard" category, even if it was the propeller strike that led directly to the fatality. In fact, no propeller injury which was preceded by another event for which the Coast Guard has established a separate category (such as capsizing, sinking, or collision with another vessel) would be classified as a "struck by boat or propeller" incident in the annual *Boating Statistics* report.

(3) The Coast Guard estimates that it receives reports for only five to ten percent of non-fatal reportable injuries⁹ (reporting on fatal injuries is believed to be fairly complete). [USCG, *Boating*

Inadequacy of Coast Guard Propeller Injury Data

1. The Coast Guard estimates that it receives reports for less than ten percent of non-fatal injuries.
2. The Coast Guard's annual *Boating Statistics* compilation categorizes injuries only by the first event in any injury scenario.
3. *Boating Statistics* aggregates propeller injuries and those caused by contact with the boat hull in a single category, "struck by boat or propeller."

Statistics, 1979-90] While the agency is to be commended for its candor in admitting the reporting rate for non-fatal injuries, it should not be satisfied with this low level of reporting, nor can it formulate reliable injury prevention policy without more complete data. In fact, in order to improve the completeness of its non-fatal propeller injury data, the agency's own 1987 study recommended that the Coast Guard should begin active random sampling of hospital emergency rooms "rather than the passive voluntary collection of reports that is presently used." To date, it has not done so.¹⁰ In addition, according to the same study, the quality of individual case reports "varies from an official Coast Guard inquiry to the scribblings of an inebriated teenager." [Purcell, 1987]

Next to the non-reporting of many incidents, classification of "accident type" by the first event leading to the injury is perhaps the most serious factor

While the Coast Guard is to be commended for its candor in admitting the reporting rate for non-fatal injuries, it should not be satisfied with this low level of reporting, nor can it formulate reliable injury prevention policy without more complete data.

⁹ It has been suggested, however, that the likelihood of reporting for non-fatal injuries is correlated to the severity of injury, so that the Coast Guard data may include more of the most severe propeller injuries. No data supporting this suggestion were located. Furthermore, even lesser (though still serious) injuries are worthy of enumeration and prevention.

¹⁰ A study which does utilize more active data collection is currently being conducted by the Centers for Disease Control with Coast Guard funding. See pages 29-30, *infra*.

The Red Cross study estimated that 2,013 reportable and 4,022 unreportable (not meeting Coast Guard reporting criteria) deaths and injuries associated with propeller contact were sustained during the one-year study period.

in the Coast Guard's official underreporting of propeller injuries and serves to disguise the true number of deaths and injuries caused by propellers. An analysis of Coast Guard data for 1983-1987 found that less than half (45 percent) of 1,304 casualties which involved "struck by boat or propeller" were classified as such in the published statistics for those years. Another one-third of these underwater impact cases were coded as "falls overboard" because that was the first event in the injury scenario. More than one-tenth began with a "collision with another vessel or fixed object." [Kerlin, 1988] The Coast Guard's unpublished 1978 analysis of its own accident reports discovered 52 fatalities and 171 injuries caused in whole or in part by propeller strikes; the Coast Guard's *Boating Statistics* report for that year, however, lists just 16 fatalities and 95 injuries as "struck by boat or propeller." Therefore, coding by "first event" caused even known propeller strikes to be underreported by about two-thirds for fatalities, and by about half for non-fatal injuries. In fact, the actual number of non-fatal propeller injuries may have been as high as 3,420, the report states. This assumes that the 171 reported to the Coast Guard¹¹ represent as few as 5 percent (due to non-reporting) of all non-fatal injuries. [Freund, 1979]

In 1984, the Coast Guard repeated this analysis with similar results. Although it analyzed only a 25 percent sample of the 246 "struck by boat or propeller" deaths and injuries for 1983, this study found 11 propeller-related fatalities and 35 non-fatal injuries, for an estimated reported total of 184. However, the Coast Guard's *Boating Statistics* report for 1983 lists just 131

(18 fatal and 113 non-fatal) injuries in the "struck by boat or propeller" category. [Traub, 1984; USCG *Boating Statistics*, 1983]

A 1991 Red Cross "National Boating Survey," supported by a Coast Guard grant, further illustrates the magnitude of the Coast Guard's official underreporting of propeller injuries. The Red Cross study employed a telephone survey of a statistically representative group of boating and non-boating households. A total of 3,700 boating households answered the survey questions, and from this group national estimates were extrapolated. Survey respondents were asked to report their involvement in any "critical incidents or accidents" from October 1, 1988 to September 30, 1989. A "critical incident or accident" could range from an accident involving personal injury or property damage to a scenario in which the respondent "thought a dangerous situation might develop but didn't." Finally, respondents were asked to provide additional information about the most severe critical incident or accident in which their household was involved during the study period.

The Red Cross survey estimated that 236,599 reportable incidents (according to the Coast Guard's reporting criteria) occurred during the one-year study period. During the same period, the Coast Guard received reports for only 6,060 reportable incidents. Assuming, as the Coast Guard asserts, that Coast Guard statistics for fatal injuries are fairly complete (even though some propeller fatalities are "hidden" due to first event coding) then the Coast Guard actually receives reports for only about 2.5 percent of all non-fatal incidents. [Red Cross, 1991]

¹¹ This figure includes those propeller injuries that were retrieved from other Coast Guard categories but which were initially coded by some other "first event."

Noting that "the most devastating types of injuries result from propeller contact and high speed impact," the Red Cross study separated "struck by boat" and "struck by propeller" injuries, and estimated that 2,013 reportable and 4,022 unreportable (not meeting Coast Guard reporting criteria) deaths and injuries associated with propeller contact were sustained during the one-year study period.¹² The Red Cross estimates, although based on a small sample of propeller injuries, correspond to an annual rate that is at least 34 times the 117 deaths and injuries in the category "struck by boat or propeller" reported by the Coast Guard for *all* of 1988 and 1989.

Two independent studies also demonstrate that the Coast Guard has not accurately monitored and reported the true incidence of propeller injuries. Price and Moorefield surveyed members of the Florida Orthopedic Society and, with a 50 percent response rate, discovered 195 propeller injuries from 1979 to 1983 – nearly six times the number of vessels involved in "struck by boat or propeller" incidents reported to the Coast Guard during the same five-year period in Florida. (The Coast Guard annual report provides type of accident breakdowns for each state only by the number of vessels involved.) [Price, 1987; USCG *Boating Statistics*, 1979-1983]

Hargarten et al. examined data from four different sources to determine the number of fatalities and injuries due to propeller strikes in Wisconsin from 1987 through 1989. They used death certificates, the Wisconsin Department of Natural Resources (DNR) boating accident files, the U.S. Coast Guard boating statistics for Wisconsin, and a

Propeller Injury Data and Estimates

1. Based on Coast Guard reports of 171 non-fatal propeller injuries, and the assumption that these reports may represent only 5-20 percent of non-fatal injuries, Freund estimated between 855 and 3,420 such injuries for 1978. The Coast Guard officially reported 95 "struck by boat or propeller injuries" in 1978.

2. Based on a nationwide representative survey, the Red Cross estimated 2,013 propeller deaths and injuries occurring in the one-year period between October 1, 1988 and September 30, 1989. The Coast Guard officially reported just 66 "struck by boat or propeller" deaths and injuries for 1989.

3. Based on a survey of the members of the Florida Orthopedic Society, Price identified 195 propeller injuries in Florida alone between 1979 and 1983. The Coast Guard officially reported just 34 "vessels involved" in "struck by boat or propeller" injuries in Florida for those years.

survey of emergency department medical directors at 126 acute care hospitals within the state. The U.S. Coast Guard reported only five "vessels involved" in a "struck by boat or propeller" incident in Wisconsin during the study period, by comparison with 23 deaths and injuries identified through DNR records and 14 non-fatal injuries discovered by the state emergency department survey.

¹² The Red Cross study does not report confidence intervals for its national injury estimates. Given the small number of propeller injuries actually identified through the survey (less than 10), the confidence intervals may be quite broad.

Data from a number of sources, including special Coast Guard reports, indicate that the true number of propeller injuries and fatalities may be closer to the 2,000-3,000 per year estimated by the Red Cross and Freund than to the approximately 100 per year officially reported by the Coast Guard.

The number of vessels involved in propeller injuries reported by the Coast Guard was, therefore, less than 25 percent of the deaths and injuries reported by the Department of Natural Resources and 36 percent of those from the survey of emergency departments. [Hargarten, 1992]

Based on these studies, the number of people injured and killed by motorboat propellers could range from 4.6 [Hargarten, 1992] to 34 [Red Cross, 1991] times the number listed as "struck by boat or propeller" in *Boating Statistics* for any year.¹³ Using the factor of six determined by Price and Moorefield (with only a 50 percent response rate), estimates for fatal and non-fatal propeller injuries combined would range in the last decade from a low of about 300 in 1988 to a high of 900 in 1986. Even more dramatically, using the factor of 34 derived from the Red Cross survey, there would be an estimated 54,842¹⁴ fatal and non-fatal propeller injuries for the years 1976 to 1990, or an average of more than 3,600 per year. This figure is consistent with Freund's 1978 estimate of as many as 3,420 injuries per year, although it is unlikely that the level of underreporting would remain constant from year to year.

Conclusion

Propeller injuries present an often devastating and costly clinical picture, demanding a clear understanding of their incidence, distribution and risk factors. The Coast Guard substantially and systematically underreports the number of propeller injuries in the United States. Data from a number of sources, including special Coast Guard reports, indicate that the true number of propeller injuries and fatalities may be closer to the 2,000-3,000 per year estimated by the Red Cross and Freund than to the approximately 100 per year officially reported by the Coast Guard.

The Coast Guard generally points to the steady decline in the overall boating fatality rate (for all accident scenarios, expressed as deaths per 100,000 boats) as evidence of the increased safety of recreational boating and the effectiveness of its safety programs. Even as underreported in Coast Guard data, however, no downward trend is evident for propeller-related deaths and injuries. [See figures 1,2] Even if some downward trend were discernible, however, the personal and social costs associated with propeller injuries are unacceptable, given the strong prospects for their prevention.

¹³ There are limitations associated with comparing injuries (from the state studies) with "vessels involved" (from the Coast Guard *Boating Statistics* state data), but the general magnitude of Coast Guard underreporting is still evident.

¹⁴ This figure is derived by multiplying the Coast Guard's officially reported 15-year total of 1,438 propeller injuries by 34.