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Body

ABSTRACT

Each year over 600 people die and more than 4000 are reported injured in recreational ***boating accidents***. As with most other ***accidents***, human error is the major contributor. U.S. Coast Guard reports of 3358 ***accidents*** were analyzed to identify errors in each of the ***boat*** types by which statistics are compiled: auxiliary (motor) sailboats, cabin motorboats, canoes and kayaks, house ***boats***, personal watercraft, open motorboats, pontoon ***boats***, row ***boats***, sail-only ***boats***. The individual errors were grouped into categories on the basis of similarities in the behavior involved. Those presented here are the categories accounting for at least 5% of all errors when summed across ***boat*** types. The most revealing and significant finding is the extent to which the errors vary across types. Since ***boating*** is carried out with one or two types of ***boats*** for long periods of time, effective ***accident*** prevention measures, including safety instruction, need to be geared to individual ***boat*** types.

FULL TEXT

1 Introduction

In a typical year, over 600 recreational boaters die, and more than 4000 are reported injured, in U.S. waters. The U.S. Coast Guard (USCG) collects reports of ***boating accidents*** and reports them annually in ″***boating*** statistics″. The various ***accidents*** are categorized by type, such as ″capsizing″ or ″collision with vessel″, and contributors such as ″weather″ or ″drug use″. Information as to the conditions and events contributing to ***boating accidents*** can be very useful in guiding preventive efforts. Most ***accidents*** on the water involve multiple causes. Probably one of the better-known examples is the sinking of Titanic. While the direct cause was collision with an iceberg, other contributing causes include a northerly route, limited visibility, and failure to limit speed accordingly. Insight into the causes of ***boating accidents*** can help in reducing the incidence of death and injury by allowing educational, enforcement, and other preventive efforts to focus upon those factors that play the largest role in bringing them about.

1.1 Identification of ***accident*** causes

Some analyses of ***accidents*** reserve the term ″cause″ to that which directly results in unintentional damage or injury, treating those events which lead up to the cause as ″contributors″. However, more common usage in ***accident*** analysis accepts as a cause any factor without which the ***accident***, or its consequences, would not have occurred, often referred to as the ″but for″ criterion. Although it was collision with an iceberg that caused the Titanic to sink, a more southerly route, better visibility *or* slower speed would have prevented the collision and the sinking. The series of events leading

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up to the ***accident*** is frequently referred to as a ″causal chain″. Since avoiding any one of the causes would have prevented the ***accident***, no distinction is made among them. In the case of catastrophic ***accidents***, such as those involving commercial airliners, passenger trains and ocean liners, analyses of individual ***accidents*** lead to measures that are largely successful in preventing recurrence of the same causative factors.

Accidents involving vehicles operated by the general public are far too numerous, and the array of causes far too varied to make analysis of individual events a useful source of preventive measures. Fortunately, there are processes under which information concerning the circumstances surrounding certain ***accidents*** are routinely collected and processed. In the case of traffic ***accidents*** above a specified cost, drivers of the vehicles involved are required to obtain and submit forms on which the circumstances surround the event are described. Where there is personal injury, police may be summoned and trained analysts record information related to causes. But a particularly informative source is research into ***accident*** causes, undertaken by specialists trained in ***accident*** analysis.

The identification of ***accident*** causes can take two different routes. One is a process in which investigators study the circumstances surrounding the ***accident*** and make inferences as to the causes, much in the same manner as single catastrophic ***accidents***. The most intensive investigative effort to identify causes of traffic ***accidents*** is that of [Treat et al., 1977] whose team analyzed 2258 ***accidents*** in Indiana. The results revealed the influence failure to properly recognize the danger due to inattention or inadequate visual search (56%), making the wrong decision (52%), and performance errors (11%). The driver's physical and mental condition played a relatively small role. Highway factors contributed to 21% of ***accidents*** and vehicle factors to 12%.

Though an investigative process is useful in learning the immediate causes of ***accidents***, many of the influences are too remote in the causative chain to be accurately identified through analysis of the ***accident*** itself and inferred through statistical analysis. The most thorough application of statistics employs ″case–control″ methodology, comparing the characteristics of drivers, vehicles, and environmental factors involved in ***accidents*** with those of a comparable sample drawn from the population at large. Extraneous differences between case and controls samples are controlled statistically. Perhaps the best recognized use of such analysis is where the blood alcohol levels of fatally injured drivers are compared with measures taken from drivers selected at random in roadside checks. This method was applied to operators and passengers in recreational ***boating*** by [Smith et al., 2001] and found the odds of death at various blood alcohol levels to be similar to that for automobiles. Beyond alcohol, the same approach has been used to compare injuries to belted- and unbelted-drivers. The separation of investigative and statistical approaches parallels the distinction between ″latent″ and ″active″ conditions leading to ***accidents*** put forth by [Reason, 1990].

1.2 Human error in ***accidents***

The results of the Treat et al. analyses referenced earlier point to the role of driver error in automobile ***accidents***. While there is a wealth of information on ″human factors″ in ***accident*** causation, very little of it has dealt specifically with human error. Since errors are particularly frequent among novices, [McKnight and McKnight, 2003] analyzed ***accidents*** of 2128 beginning drivers and found a similar pattern with lack of attention and visual search errors predominating. Of particular interest is that speed contributed to about the same percentage of ***accidents*** but that speeds too great for road and traffic conditions rather than high speeds that were primarily responsible. Although the analysis of 900 motorcycle

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[Treat et al., 1977] Treat et al., 1977. J.R. Treat, N.S. Tumbas, S.T. McDonald, D. Shinar, R.D. Hume, R.E. Mayer, R.L. Stansifer, N.J. Castellan; Tri-level Study of the Causes of Traffic ***Accidents***, vol. I: Causal Factor Tabulations and Assessments, vol. II: Special Analyses; Government Printing Office (Indiana University, Institute for Research in Public Safety), Washington, DC (1977), .

[Smith et al., 2001] Smith et al., 2001. G.S. Smith, P.M. Keyl, J.A. Hadley, C.I. Bartley, R.D. Foss, W.G. Tolbert, J. McKnight; Drinking and recreational ***boating*** fatalities: a population-based case-control study; JAMA; Vol. 286, No. 23; (2001), .

[Reason, 1990] Reason, 1990. J. Reason; Human Error; Cambridge University Press, New York (1990), .

[McKnight and McKnight, 2003] McKnight and McKnight, 2003. A.J. McKnight, A.S. McKnight; Young novice drivers: careless or clueless; ***Accident*** Anal. Prev.; Vol. 35, No. 6; (2003), pp. 921-926.

accidents by [Hurt et al., 1981] revealed many contributing factors, it did not address human error. In-depth review of the narratives by a research staff consisting of experienced riders was highly revealing of errors leading to the ***accidents*** ([McKnight et al., 1980]). Of particular interest was the effect of failure to use the front wheel brake in emergencies, even though it supplies three-quarters of the braking power in sudden stops. General aviation, unlike its commercial counterpart, has large enough numbers of crashes to permit meaningful analysis of human error. [Shappell and Wiegmann, 1997] developed a taxonomy of human errors in general aviation and applied it to 2291 fatal ***accidents***, finding poor planning to be the leading cause by far. In a study of 431 cases, [Baker et al., 2001] found errors in use of aircraft controls to be involved in 70% of crashes, far higher than that for automobiles. However, inattention played a similar role, about 27%. Identification of errors leading to ***accidents*** can play a prominent role of their prevention; since the Titanic, collisions with icebergs have been eliminated. In the air, disasters due to certain errors in navigation, de-icing, and traffic control have been eliminated. While ***accident***-producing errors in attention or visual search by the driving public would not be eliminated, focusing attention on the leading contributors can improve the effectiveness of preventive measures.

Where analysis has addressed recreational ***boating*** ***accidents***, it has largely focused upon a limited array of variables, as are presented annually in [United States Coast Guard, 2004]. These include some 18 ″contributing factors″ that are ″operator controllable″. Almost all involve errors of some type and reveal the role, played by such errors as inattention and lack of proper lookout, contributors to ***accidents*** in other forms of transportation as well. The implications of these factors for prevention of ***accidents*** are not as entirely clear. For example, ″excessive speed″ would benefit from clarification. Does it mean in general, making turns at too great a speed or operating at high speeds in rough water. Somewhat tighter specification of errors would be helpful in guiding preventive efforts. A second limitation of available statistics is the lack of delineation by ***boat*** type. The fact that open motorboats account for about half of all ***boating*** injury ***accidents*** tends to place their operator errors high on the list. Problems handling current, which contribute heavily to canoe and kayak ***accidents***, do not appear on the list. One reason is that they account for only 2% of all injury ***accidents*** (although they are second only to open motorboats in drownings). Given the prospect of differences across ***boat*** types in the errors leading to ***accidents***, any analysis of human error needs to be delineated by ***boat*** type to provide information that can be applied to preventive measures.

One clear obstacle to the identification of human error through investigative analysis of ***accidents*** is the lack of direct access to such information in ***accident*** investigations. While operator, vehicle, roadway and environmental characteristics are observable at the scene, the behavior of the drivers is not. It must be inferred from that which is observable at the scene and from interviews with drivers and witnesses. Some degree of inaccuracy enters the information that is collected, its interpretations by investigators, and inferences drawn by analysts. However, no form of ***accident*** analysis is free of error. Case–control methodology relies on the ability to match the two groups using available information, which rarely includes all possible confounding variables. Both methods can, and have succeeded in revealing effects large enough to make them appropriate targets of prevention efforts.

2 Methods

The identification of human error in recreational ***boating*** involved the analysis of some 3358 ***accident*** reports drawn the 1996–1998 BARD files. Initially, two members of the project staff analyzed 1000 ***accidents*** drawn from the 1997

[Hurt et al., 1981] Hurt et al., 1981. Hurt Jr., H.H., Ouellet, J.V., Thom, D.R., 1981. Motorcycle ***accident*** cause factors and identification of countermeasures, vol. I. Technical Report. Traffic Safety Center, University of Southern California, DOT-HS 805 862, National Highway Traffic Safety Administration.

[McKnight et al., 1980] McKnight et al., 1980. A.J. McKnight, K. McPherson, A.C. Knipper; Motorcycle rider advancement course development (DOT-HS-805-738); National Public Services Research Institute, (1980), .

[Shappell and Wiegmann, 1997] Shappell and Wiegmann, 1997. Shappell, S.A., Wiegmann, D.A., 1997. A human error approach to ***accident*** investigation: the taxonomy of unsafe operations. Int. J. Aviat. Psychol.

[Baker et al., 2001] Baker et al., 2001. S.P. Baker, M.W. Lamb, G. Grabowski, G. Rebok, G. Li; Characteristics of general aviation crashes involving mature male and female pilots; Aviat. Space Environ. Med.; Vol. 72, (2001), pp. 447-452.

[United States Coast Guard, 2004] United States Coast Guard, 2004. United States Coast Guard; ***Boating*** Statistics-2004; Office of ***Boating*** Safety, United States Coast Guard, Washington, D.C. (2004), .

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BARD file, fitting these data to what seemed a logical causal breakdown, based on their previous experience, to create an initial classification consisting of 300 error categories. The categories covered a range of ***boating*** activities including advanced preparation for the season, preparation for individual ***boating*** occasions, operating safely under normal conditions, accommodating rough weather and limited visibility, occupant protection, and several activities that take place on ***boats***. An ″error″ was defined as any act whose direct, unintentional contribution to an ***accident*** could be reliably determined from information provided in ***accident*** reports. Excluded were cases where causes were too remote from the ***accident*** in time and distance to be validly inferred from information collected at the ***accident*** scene (e.g. operator background, instruction, general health). As noted earlier, the role of such remote factors is better inferred statistically through comparisons of their involvement in ***accidents*** with their general presence in ***boating***.

Using a refinement of the initial classification based on the initial experience, an additional 3000 ***accidents*** from the 1996 and 1998 files were classified by six experienced ***boating*** safety specialists from outside the project staff. Each analyst was assigned 500 cases selected in a manner such that all reviewed what might be considered cross-section of ***boat*** types. In ***accident*** reports, as noted previously, ***boats*** are classified by the Coast Guard into nine categories: auxiliary (motor) sailboats, cabin motorboats, open motorboats, canoes and kayaks, house ***boats***, personal watercraft, pontoon ***boats***, row ***boats*** and sail-only ***boats***. Recognizing that open motorboats, cabin motorboats and personal watercraft (PWCs) account for approximately 90% of all ***accidents***, the sample was constructed so as to include all errors in the files for the remaining vessel categories. These made up but one third of the total sample, leaving two-thirds for the three major categories. From what remained, quotas were assigned the three major types in proportion to their share of all ***accidents*** reported. The final numbers appear later in the table of errors by ***boat*** type.

Up to four errors could be recorded for any ***accident***, no distinction being made as to relative contribution of the different errors to the ***accident*** (it either did or did not contribute to the ***accident***). The additional analysis yielded usable 2358 cases, raising the total sample 3358 ***accidents***. The shortfall involved cases in which either the causes were unknown or in which the information provided was insufficient to reveal errors. In analyses carried out under the BARD system, analysts would have the opportunity to follow up with investigators to gain additional information, an option not available in working with historical records. Of the entire sample, one third involved fatalities, all those for which causes could be reliably identified. The remainder were non-fatals. Consideration was given to separate analysis of the two sub-samples since most of the fatalities were drownings whereas the injuries were not. Yet, when the errors leading to the ***accidents*** were examined it was clear that they were highly similar.

The final step in the error classification process was to reduce the distribution of the original 300 error categories to a more manageable number using the following procedure. First, the error categories were consolidated by grouping together those errors that are similar enough to be treated in largely the same manner. While such a classification system is often referred to as a ″taxonomy″, the term connotes an inherent order of things, such as the classification of animal or plant life. Here the classification is used simply as a convenient way of organizing causes into relatively homogeneous categories. Following the initial classification, those errors occurring in less than 2% of ***accidents*** for any of the nine ***boat*** categories were excluded, thus limiting results to those errors that would be the most worthy targets of preventive efforts. The result of the classification process was 68 categories containing errors considered sufficiently homogeneous with respect to preventive measures to warrant being combined. However, although the frequencies of the full 68 error categories for each ***boat*** type are provided in the study final report ([McKnight et al., 2004]), this paper is limited to the 47 errors occurring at least 5% of the time across all ***boat*** categories.

One caution to be borne in mind is that the errors are inferences from the information supplied by state and local ***boating*** law enforcement officers investigating ***accidents***. The analysts identifying and coding errors were careful to limit their interpretations to that which could be reasonably well established from the information supplied. One form of error that must be viewed with caution concerns the involvement of alcohol, which is based upon the investigating officer's inference from observed behavior, which often conceals intoxication of a degree that can create risk.

[McKnight et al., 2004] McKnight et al., 2004. A.J. McKnight, W.W. Becker, A.J. Pettit, A.S. McKnight; Risk Management and Human Error in Recreational ***Boating***, vol. 2: Analysis of human error in recreational ***boating***; Marine Safety Foundation, Farmingdale, NJ (2004), .

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Estimates of involvement based upon the odds of death at various levels of blood alcohol for open and cabin motorboats have placed it at twice the level given in ***accident*** reports (Smith et al., 2001). However, one might expect alcohol involvement in fatalities to be greater than in a sample two-thirds of which are non-fatals.

3 Results

A tabular presentation of errors by ***boat*** type appears in Table 1. The total number of ***accidents*** analyzed for each type appears at the top. The most noteworthy result is the extent to which errors leading to ***accidents*** vary across ***boat*** categories. Even those errors that appear in more than one type of ***boat*** tend to take different forms for each type. This will become apparent in the following descriptions of errors in each of the ***boat*** types.

3.1 Auxiliary sail

Errors involving lack of adequate visual search are the leading causes of ***accidents*** involving auxiliaries, as is the case in most transportation ***accidents***. These include failure to keep an eye on ***boats*** ahead, primarily arising from diversion of attention to sail handling and other essential tasks, lack of general surveillance, and failing to overcome the vision obstructions caused by the sails and crew. Failure to keep sufficient distance from other ***boats*** or fixed structures is a problem often complicated by wind and wave action. ***Accidents*** are particularly frequent in crowded anchorages. Another contributor to ***accidents*** is cutting close to other ***boats***, often violating right-of-way in order to maintain a desired heading, particularly common in races. Given the wind and sea conditions under which sailboats operate, falls on board and overboard are frequent, particularly when handling sails or otherwise moving about the ***boat***. Falls frequently result from failure to adjust sails and steering for wind gusts, or to shorten sail when necessary. With their deep drafts, auxiliaries are prone to running aground when depth is not frequently checked with depth sounders or use of navigational aids. Auxiliaries are more difficult to maneuver under power than most other motorized vessels and tend to have difficulty docking in windy conditions, often when approaching too fast.

3.2 Cabin motorboats

Failure of cabin motorboat operators to notice things ahead include other ***boats***, anchored or moving, small floating objects or navigational markers. Many times operators are distracted by people or various tasks. The view ahead is often obstructed by passengers on the foredeck or by the foredeck itself when the bow is raised at increased speeds. Alcohol impaired operation of cabin motorboats is among the highest, often resulting in collisions with other ***boats*** or fixed objects, causing damage or injury when they occur at high speed. A third major ***accident*** contributor involves failing to keep sufficient distance from other ***boats***, including getting too close in normal travel or docking, not reacting properly to an unexpected maneuver, or trying to maneuver through a crowded anchorage. Failing to check water depth, visually or through navigational aids, is as common in motorboats as in sailboats, despite their relatively shallow drafts. Lack of a firm handhold is a common cause of falls overboard and injuries on board as ***boats*** traveling at relatively high speeds hit waves or wakes.

Cabin motorboats are heavily represented in ***accidents*** caused by excessive speed, including speeding near other ***boats***, creating large wakes near docks, in anchorages, or in narrow passages, and, in some cases, striking other ***boats***. Operating too fast to respond in time to such unlighted objects as anchored ***boats***, buoys, or piers, is also particularly frequent among cabin motorboats. Another speed-related error involves operating too fast in approaching waves and wakes, with the result that the ***boat*** is damaged, swamped or capsized, or occupants are bounced about or thrown into the water. Finally, as with other ***boats*** dependent on power, inadequate maintenance of engines and operating controls plays a role in ***accidents***.

3.3 Canoes and kayaks

The classification of ***boats*** employed in the BARD system at the time of the human error analysis, placed canoes and kayaks in the same category. Canoeing appears to be the more social and kayaks the more athletic of the activities, which shows up in the nature of their ***accidents***. For both ***boat*** types, failure to have PFDs, or to wear them in conditions creating a significant chance of immersion and drowning, are among the highest of all ***boat*** categories. Failure to wear them when cold water creates a risk of hypothermia is particularly characteristic of kayakers. Other frequent causes of ***accidents*** to both types of vessel are not checking the route ahead for strong currents, waterfalls, dams, or various other obstructions (e.g. logs and stumps), and generally failing to consider the vessel's design relative to its intended use. Neither vessel is designed for rough weather, and lacking the skill needed handle it, or failing to seek shelter when it is encountered, add up to a significant risk. Among canoeists, significant sources of ***accidents*** are standing up, playing games, jumping into water deeper than expected and having the canoe blown away, and failing to stay with the overturned canoe. Alcohol is also a major factor in the activities leading to capsizing, as well to getting out of a canoe in water too deep to touch bottom. Canoes and kayaks are particularly vulnerable to rough weather, lack of necessary skills, and failure to seek shelter. Kayakers are particularly inclined to venture out in very cold or rough conditions for which they are not properly clothed or equipped (e.g. helmets).

3.4 Houseboats

Low speed maneuvering alongside ***boats***, docks or other structures is a bigger problem for houseboats than for all others combined, largely a consequence of their beam and windage. The problem is further complicated by the frequent failure of inexperienced operators to recognize and develop the handling skills required. The difficulty in maneuvering frequently leads to approaching docks or other ***boats*** with too much speed, particularly when confronted by strong wind. The same ***boat*** design characteristics make weather a bigger factor for houseboats than for other types, and errors included failure to recognize conditions that call for certain precautions, to respond properly when they are recognized, and to seek shelter soon enough. Houseboats are used for social gathering as much as for transportation. The presence of other passengers often distracts from the operator's attention from the path ahead while position of the helm in most houseboats makes it difficult to see ***boats*** approaching from the side. All of these problems are complicated by the use of alcohol, which is a major factor in houseboat ***accidents***. Impairment coupled with the limited maneuverability of houseboats resulted in many collisions with docks and other ***boats***. However, many alcohol-related ***accidents*** also involve activities that lead to falls overboard. Houseboats appear to have more trouble anchoring than other ***boat*** types. Problems include not having an anchor ready to be dropped quickly when needed (e.g. engine quits) and being blown into other ***boats*** or the shore. A similar problem is not paying out enough scope on anchor lines in strong winds.

3.5 Open motorboats

Interest in the causes of open motorboat ***accidents*** is heightened by their sheer numbers over a third of all ***accidents*** reported. Excessive consumption of alcohol is a major contributor to ***accidents*** in open motorboats, leading to many of the problems that are to be described. The speed with which open motorboats travel places a premium on keeping a good lookout ahead and around the ***boat***, failure to do so making up the next most common ***accident*** contributor. High speed when negotiating waves and ***boat*** wakes creates conditions that invite such consequences as capsizing or swamping the ***boat***, losing passengers overboard, and causing injury to passengers inside the ***boat***. The latter two are often the result of occupants failing to have a firm grip or secure footing at all times. Finally, speeding in and around other ***boats***, close to land and various structures on or near land, and failing to reduce speed to the limits of night visibility or in tight quarters are also frequent ***accident*** causes, just as they are for cabin motorboats. Maneuvers that threaten stability, including excessively sharp turns, are problems for open motorboats.

Open motorboats share with canoes, kayaks and rowboats incidents that leave occupants in the water, and failure to have passengers wear PFDs where immersion is not an unlikely prospect are significant causes of drowning. Not having PFDs worn in cold weather, where hypothermia is a possibility, or by those who cannot swim is a problem exceeded by not even having them available. Open motorboats are the primary source of water-skiing ***accidents***, including those resulting from the way the ***boat*** is operated when towing skiers and or from unsafe recovery efforts, including running into the skiers. Like other ***boats*** dependent on power, poor maintenance of the engines or their controls leads to erratic operation and frequently to ***accidents***.

3.6 Personal watercraft

With the highest of all per-***boat*** ***accident*** rates, PWCs are a worthy object of attention in the search for ***accident*** causes. The inclination of operators to travel in close proximity to other vessels shows up in a large number of collisions. PWCs frequently travel in tight groups, with one making a sudden turn into another, attempting to pass as the one that is starting to turn, or traveling close behind when the one ahead stops suddenly. Under these conditions, operators spend considerable time looking at one another rather than ahead, increasing the chances of collisions with ***boats*** and objects in the path ahead. Many collisions in close quarters occurred in playing games, such as trying to spray one another or occupants of nearby ***boats***. About a fourth of PWC ***accidents*** took place while jumping waves or wakes, with injuries resulting from collisions with other ***boats*** or from hitting the water. Operating too close to land also leads to collisions with docks, piers, riprap, trees and branches.

PWCs are frequently operated by people having little or no experience with ***boats*** of any kind and who lack sufficient knowledge or skill to handle the vessel safely. Many are first time rentals. ***Accidents*** of inexperience involve making excessively sharp turns, cutting power and being unable to steer, or simply moving too fast in tight quarters. Ignorance of right-of-way regulations, and failing to yield in collision situations are significant ***accident*** contributors. Alcohol plays a very small role in PWC ***accidents***.

3.7 Pontoon ***boats***

Like houseboats and PWCs, pontoon ***boats*** are often operated by people with little previous experience with ***boats*** of any type. The designs of pontoon ***boats***, along with the environment in which they operate, have an obvious influence upon the nature of ***accidents*** and the errors contributing to them. Most are open platforms for fishing, swimming and social activities leading to falls onboard and overboard. Most could have been prevented by assuring a firm grip and good footing when standing or moving about, or simply by remaining seated in rough water. Falls overboard often come from bow riding (particularly with the gate open), playing games, leaving children unsupervised, and leaning over the side or bow (e.g. retrieving anchors). Failure of operators to look ahead and all around the ***boat***, or to the side before turns appears to result primarily from distraction, interacting with passengers or preparing for various activities, such as fishing. Instances of failure to keep enough distance from other ***boats*** tend to arise under two general conditions: (1) when traveling alongside or stopping in the company of other ***boat*** and (2) when having to maneuver in close quarters during docking. All of the preceding errors involve acts that can be affected by alcohol, the consumption of which occurs as part of the social activity that often takes place continuously.

Not leaving enough distance from land and structures such as docks tended to occur in low visibility and when distracting activities are taking place on board. Checking the depth of the water is particularly important given the shallow waters in which pontoon ***boats*** operate. Operators may have been lulled into thinking the shallow draft of pontoon ***boats*** exempt them from grounding. ***Accidents*** involving rough weather are relatively infrequent in a vessel intended primarily for use in quiet waters The risk of immersion and need for PFDs arises less from weather conditions than from on-board activities close to the water, such as doing repairs, or children playing near the edge of the ***boat***.

3.8 Rowboats

Rowboats exceed all other ***boat*** types in failure to have required numbers and types of PFDs aboard, and equal canoes in failure to put them on under risk of immersion. Such conditions include rough seas, the ***boat*** filling with water, danger of capsizing, swift current, particularly near rocks, ledges or low head dams, overloading, carrying out dangerous maneuvers, working over the side (e.g. pulling pots), passengers engaged in horseplay, and the inability to swim. Another problem is failure to wear PFDs when cold temperatures threaten survival in the water. For passengers in the water, attempting to swim ashore rather than remain with the floating ***boat*** leads to fatalities, as is the case in canoes. All told, failure to have or use flotation devices accounts for more than a third of fatalities. Acts leading directly to immersion include overloading the ***boat***, poor distribution of weight, particularly when stepping into the ***boat***, not remaining seated, and not having a good grip when leaning over the side or standing up, or when the ***boat*** was subject to severe roll. Attempting to use rowboats in strong currents, such as in rapids and near low head dams leads to capsizing and swamping. Setting out in rough weather is also a contributor to ***accidents*** typically resulting in immersion, a case of using a ***boat*** simply unsuitable for prevailing conditions.

Because of the low speed with which they generally travel, rowboats seldom have problems with seeing far enough ahead. However, a significant number of ***accidents*** do occur when the ***boat*** is under power (usually outboards), or when the rower is looking behind and moving in fast current or being rowed fast (e.g. racing shell). Making abrupt turns under power often result in capsizing. As a source of ***accidents*** due to drinking, rowboats are up with the leaders. Much of it occurs when the ***boat*** is being used for fishing or hunting and drinking goes on continuously. On other occasions the drinking takes place at a bar or on some other ***boat***, and the ***accident*** occurs when returning. As with canoes and pontoon ***boats***, the damage done by drinking is primarily to the drinkers themselves, who frequently fall off, capsize or swamp their ***boats***.

Inflatables were not included in the analysis of errors because of their relatively small number of ***accidents*** at the time the analysis took place. They are similar to rowboats in that about a third of ***accidents*** involve falls overboard, far exceeding the proportion for any other ***boat*** type. However, they differ in that rowboats have four times the number of fatalities but only about half the injuries. The higher fatality rate of rowboats is due to the greater tendency to capsize, whereas the higher injury rate of inflatables results from higher speeds and collisions with fixed objects.

3.9 Sailboats

It is not surprising that problems in sail handling would be a leading contributor to ***accidents*** for ***boats*** depending upon sails for propulsion. Such problems include failing to shorten or drop sail in excessive wind and not spilling the wind in gusts. Most of the time the result of such shortcomings was capsizing, although in some cases injury occurred from contact with some part of the ***boat***, such as the boom. There are also a few instances with smaller ***boats*** where sailors fail to recognize the severity of the weather and should avoid attempting to sail at all.

Accidents due to improper lookout are similar to those experienced with auxiliaries. Failure to look ahead involves not paying enough attention to what was going on and running into other ***boats*** or, in some cases, fixed objects such as buoys. Failure to exercise all-round surveillance becomes a problem mainly when ***boats*** are on intersecting paths, often where the approach of another ***boat*** is obscured by the sail. There are also some cases when the intersecting ***boat*** is seen, but the skipper on the port tack misjudges clearance. Related to these ***accidents*** are those in which the ***boat*** is sailed close to other ***boats*** or other structures (e.g. docks) without allowing for wind changes and momentary loss of control. Some of these situations occur at the start of races where space is at a premium and collisions are not uncommon. Failure to wear a PFD under recognized risk of immersion, primarily high winds, leads to many instances of drowning. Leaks most often occur in catamaran pontoons, but are also found in monohulls where holes in the hull are overlooked or the when the crew fails to insert plugs. Sailing is an activity that requires a relatively high degree of skill and knowledge, and the decision to tackle challenging conditions without having both is a significant cause of ***accidents***. Little drinking goes on under sail, but in a few instances the effects of alcohol appear to play a role in poor handling of conditions.

4 Discussion

The most significant finding in the analysis described is the extent to which the errors leading to recreational ***boating accidents*** vary from one category of ***boat*** to another. The differences in category of error, as shown in Table 1, are further varied by specific characteristics of ***boats***. For example, the descriptions given in Section 3 show that failure to ″look for obstructions in the path ahead″ for auxiliary sailboats arises from vision obstructions caused by crew while in cabin motorboats it is passengers on the foredeck and the raised bow itself. Few attempts to improve ***boating*** safety attempt to take account of the large differences across ***boat*** types in the errors that occur and the effect they have upon safety. Most present safety courses prescribe safety measures that apply across ***boating*** in general. A reasonable approach in preparing boaters to handle the specific problems they will encounter in the type of ***boat*** they will be operating would be to augment general ***boating*** safety courses with segments focusing upon the dominant errors of individual ***boat*** types. As noted earlier, inferences as to human error leading to ***accidents*** based upon the reports of investigators are themselves subject to error. However, this is true of any inferences as to cause drawn from other than controlled experimentation. The frequencies of errors described in this paper were those prevailing over the period in which they were recorded. They may change over time in responses to changes in the hazards presented to boaters and their ability to handle them. The U.S. Coast Guard has added the 68 errors targeted by the analysis to its ***boating accident*** report database, allowing changes in the frequency of various errors to be considered in various prevention measures.

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TABLES

Table 1

Activity in which error occurred	**Aux. sail (202)**	**Cabin motor (408)**	**Canoe kayak (291)**	**House *boat*** (132)	**Open motor (1176)**	**PWC (612)**	**Pont. *boat*** (161)	**Row *boat*** (128)	**Sail only (148)**
Assure ***boat*** suitability for conditions			5					6	
Maintain engine properly	3	4		6	2				
Maintain engine controls properly		4		4	3				
Check hull for leaks								2	5
Check fuel lines, handle fuel safely				6					
Check route for current/obstructions			10		2				
Possess skill for handling vessel			2	11		4	3		
Possess skill for conditions			7						3
Assure availability of PFDs			8		2			16	
PFD use under immersion risk			17		8		4	15	5
PFD use under hypothermia risk			6		2			5	
PFD use by non-swimmers			5		2			3	
Limit consumption of alcohol	3	11	15	10	15	5	12	15	3
Load vessel relative to capacity					3			11	
Occupants/load distributed safely								5	
Check/recognize weather conditions				5				4	4
Avoiding unsafe weather condition			8		2		3	5	8
Maneuver safely in tight quarters	3	2		18			4		
Safe speeds in tight quarters	3			9	2	2			
Maintain enough power for steering						5			
Avoid excessively					2	4		4	

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Activity in which error occurred	**Aux. sail (202)**	**Cabin motor (408)**	**Canoe kayak (291)**	**House *boat*** (132)	**Open motor (1176)**	**PWC (612)**	**Pont. *boat*** (161)	**Row *boat*** (128)	**Sail only (148)**
sharp turns									
Steer and trim sail for balance	6								
Operate safely in strong current			14					7	
Respond safely to rough conditions			5	4					4
Seek shelter in rough conditions			5	3					
Refrain from wave jumping						8			
Exercise all around surveillance	6	4		3	4	8			
Look for obstructions in path ahead	19	15		5	14	23	12	6	10
Look around before turning						10	3		
Visually check depth regularly	4	5			4		6		
Overcome vision obstructions	5					3			12
Limit speed in tight quarters									
Reduce speed at night/low visibility		5			3				
Reduce speed in waves/wakes		3			6	7			
Reduce speed near other ***boats***		5			3	16			
Keep distance from other ***boats***	11	10	2		7	35	8		5
Keep distance from land/structures	5	4		2	3	4	3	2	3
Avoid acts reducing vessel stability			9		4			12	
Use navigation aids to avoid danger	4	6							
Yield legal right-of-way	4					3			3
Give way in risk of collision						6			
Keep firm grip to avoid falls	6	6		2	8		16	8	3
Adjust sail/steering for wind gusts	3								7
Shorten sail when necessary	4								12
Stay in secure position on ***boat***							6		
Operate safely with skiers					7				
Recover skiers/					5		3		

Activity in which error occurred	**Aux. sail (202)**	**Cabin motor (408)**	**Canoe kayak (291)**	**House *boat*** (132)	**Open motor (1176)**	**PWC (612)**	**Pont. *boat*** (161)	**Row *boat*** (128)	**Sail only (148)**
swimmers safely									
Use proper anchor type and scope				6			3		
Safe action if capsized or swamped			4					6	

Percent error by ***boat*** type (for errors totaling 5% or more across types)

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