An empirical analysis of life jacket effectiveness in recreational boating

Ali Gungor
US Coast Guard

Christelle Viauroux*
University of Maryland - Baltimore County

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Abstract

This paper presents the results of an analysis on Life Lacket (LJ) effectiveness in U.S. recreational boating between 2008 and 2011. We use the US Coast Guard's Boating Accident Report Database (BARD) to fit a Poisson regression of number of fatalities on many different factors interacting at the time of the accident. We find that LJ wear is one of the most influential determinant of the number of fatalities on a vessel, together with the number of vessels involved, the type and engine of the vessel. We estimate that the expected number of deceased per vessel would decrease by about 80% if the operator wears his LJ. The number of deceased is also estimated 1.86 times higher when the vessel is a canoe or a kayak, but 80% lower as one more vessel is involved, and 34% lower when the operator has more than 100 hours of experience. Interestingly, we find LJ effectiveness decrease significantly with the length of the boat and slightly with increases in water temperature; it increases slightly with the age of the operator.

We simulate the impact of a LJ regulation that would impose all operators to wear their LJ, corresponding to a a minimum of 20% increase in wear rate (to about 40%). Between 2008 and 2011, we estimate that such a policy would have saved between 1,721 and 1,889 (out of 3047) boaters, i.e. 1,234 out of 2,185 drowning victims. A similar policy restricted to 16 to 30 feet length boats would have saved approximately 778 victims. Finally, an analysis of causes of death shows that a policy on LJ wear would reduce the share of drowning victims compared to other causes.

*Corresponding Author: Dr C. Viauroux. *Email: ckviauro@umbc.edu. Phone: 410-455-3117. Fax: 410-455-1054.* C. The authors are thankful to S. Farrow, all participants to US Coast seminars and all participants of the 2013 Society for Risk Analysis annual meeting for their very insightful comments. This project was funded by Rolling Bay, LLC.

1 Introduction

Although life jackets (also referred as Personal Flotation Devices, PFDs) are legally required to be carried on vessels in the US and most other countries, wear rates are very low for many types of recreational boats. The 2008-2011 US Coast Guard's Boating Accident Report Database (BARD) reports that of the 2,185 drowning victims (out of a total of 3,047 fatalities), only 15.1% were reported to wear a life jacket (the wear rate was only 19.8% for all fatalities). One of the reason for this low wear rate may simply be because it is unpopular. Quistberg et al. (2013) explore behavioral factors and strategies to encourage consistent life jacket use among adult recreational boaters. They find that most boaters report inconsistent use of life jackets, using them only when conditions were poor. Quistberg et al. also report resistance among older children. In particular, barriers to consistent life jacket use included discomfort and the belief that life jacket use indicates inexperience or poor swimming ability. Participants in their experiment suggest that designing more comfortable, better-fitting, more appealing life jackets would encourage consistent use. They also state that laws requiring life jacket use could change this behavior.

Attempts at raising risk awareness in recreational boating started in the early 1990s. In 1993, the National Transportation Safety Board released a study[1] examining 281 drowning cases from recreational boating accidents in which persons were not wearing life jackets. It is believed that 238 of them would have survived. In a 2012 US Coast Guard blog post[2] (based on a 7th Coast Guard District press release), it is mentioned "The Coast Guard estimates 80 percent of boating fatalities could have been prevented if boaters wore their life jackets." This statement is based on direct calculation of how many people drown each year, and of those, how many were not wearing life jackets. As such, these measures do not constitute robust measures of life jacket effectiveness, but they clearly call for further investigation.

A first measure of life jacket effectiveness was calculated in Traub (1989). In his analysis of boaters involved in fatal accidents observed between 1960 and 1965, Traub calculated the odds of dying and finds that they are 3.18 times greater for individuals not wearing their life jacket than the odds of dying while wearing his life jacket. He also concludes that if everyone who had fallen in the water and died had worn a life jacket, 60% of them would have survived. This study, however, is not limited to recreational boating but includes all types of boating.

Using BARD 1995-2004 data, Duda et al. (2007) analyzes factors associated to canoe and kayak fatalities. Their results are as follows: More people involved in the incident or longer canoe or kayak are associated with lower fatality rates. Males are more prone to death in canoe/kayak incidents than are females. Alcohol/drug use emerged as a factor positively associated with the fatality rate. They also find that the states of West Virginia, Maine, and the Pacific Division (consisting of Alaska, California, Hawaii, Oregon, and Washington) are more

[1] Safety Study: Recreational Boating Safety, PB93-917001, NTSB/SS-93/01.

[2] http://coastguard.dodlive.mil/2012/05/12-tips-for-12-weeks-of-summer

unsafe relative to the rest of the United States. Finally, they find life jacket accessibility is correlated to safer boating. Life jacket accessibility is a prerequisite for life jacket use but does not infer use and hence does not constitute a good measure of possible life savings in case of accidents.

In a case-control study on recreational boating, Yang et al. (2007) estimate that children 1-4 years who wore PFDs when playing near water were less likely to drown than other children with an adjusted risk ratio of 0.43. It is unknown, however,whether this estimate is relevant for adults or boaters. Cummings et al. (2010) use the 2000-2006 BARD and a matched-cohort design to compare accident outcomes of persons from the same boat who were involved in recreational incidents which resulted in being in the water or at risk of drowning. They find that wearing a PFD (i.e. a 100% wear rate) reduces the risk of drowning by 49%. However, the authors warn that substantial bias is possible because of the small number of vessels (201 vessels involving 497 boaters) that met their criteria. These criteria excluded vessels involved with less than one fatality, accidents where only one person ended up in the water and other vessels because of non matching records or missing data on gender or age. Using 2008 BARD data and the NTSB estimate above, Maxim (2010) calculates that a 43.6% reduction (drowning decrease from 250 to 141) would follow an increase in the wear rate from 17.9% to 70% (corresponding to 67.7% for a 100% wear rate). However, his calculation method based on probability theory assumes that life jacket wear is the only factor explaining the drowning rate and is limited to open-motorboards type vessels incidents in 2008.

The present paper provides a more comprehensive analysis of life jacket effectiveness for two reasons. First, we use the 2008-2011 BARD to explain the number of fatalities and its variation across vessels by many different factors that together influence the outcome of the accident. Our model allows us to measure the relative importance of life jacket wear compared to other influential factors and to identify the most significant environmental and individual factors explaining fatalities in recreational boating. Second, we investigate how much a policy on life jacket wear would impact the number of fatalities observed. Third, we take a closer look to drowning and explore the main factors explaining it compared to other causes of death. We end the analysis by showing how the distribution of causes of death would be affected by a regulation on life jacket wear.

Our results show that life jacket wear is one of the most influential determinant of the number of fatalities in recreational boating, together with the number of vessels involved, the type and engine of the vessel. We estimate that the expected number of deceased per vessel would decrease by about 80% if the operator wears his life jacket. We also find that life jacket effectiveness decreases significantly with the length of the boat and decreases slightly with increases in water temperature. Finally, it increases slightly with the age of the operator. Our simulation of a life jacket regulation imposing all operators to wear their life jacket show that between 2008 and 2011, we estimate that such a policy would have saved between 1,721 and 1,889 (out of 3,047) boaters, i.e. 1,234 out of 2,185 drowning victims. A similar policy restricted to 16 to 30 foot length boats would have saved approximately 778 victims. Finally, an analysis of causes of death shows that a policy on life jacket wear would reduce the share of drowning victims compared to other causes.

Section 2 presents the data and model used to measure the impact of many interacting factors with a significant effect on the fatality rate and draw conclusions on life jacket effectiveness, while section 3 analyzes the distribution of causes of death.

2 Data and Estimation Procedure

2.1 Data

Federal and state regulations require boat owners/operators to complete boat accident report forms and submit them to the state boating law administrators within 48 hours to 10 days of an accident, depending on the circumstances. The fifty states, five US territories, and the District of Columbia submit accident report data electronically to the US Coast Guard for inclusion in the annual Boating Statistics publication. These data are then compiled into Coast Guard's Boating Accident Report Database (BARD). The database stores the data in several layers: an overview table provides an overview of the accident and includes fields such as dates, time and location of the accident, a second table provides information about the vessels and operators involved in accidents, but also the number of deceased or injured on each boat. Finally, tables on dead, injured and casualty victims are available. For the purpose of this study and its focus on the number of fatalities rather than types of fatalities, we merged the overview and the vessel tables for the years 2008 to 2011. The merged file contains a total of 30,066 vessels (corresponding to 81,179 persons involved), each observation corresponding to a vessel involved in an accident. For each fatality, the data also includes whether a life jacket was worn by the victim, among characteristics. Table 1[3] below presents life jacket wear rates among recreational boating fatalities from 2008-2011. Drowning victims show the lowest wear rates among all causes of death, with about 85% of them without a life jacket. Life jacket wear is higher for trauma victims and other causes of death. The average over all causes of death shows a very low 19.8% wear rate for all fatalities. Also note that operators' wear rates are close to the overall wear rates except for the victims with a cause of death other than drowning or trauma.

[3] The category "Other" includes the following reported causes of death: "cardiac arrest" (Total: 83, N.W.: 59.7%), "hypothermia" (Total: 45, N.W.:44.2%), "carbon monoxide poisoning" (Total: 23, N.W.:100%), "unknown" (Total: 192, N.W.: 85.9%) and "other" (Total: 27, N.W.: 84.6%). Note that some columns or rows may not sum due to rounding.

Table 1 : Life Jacket Wear Rate by cause of death in 2008-2011 Recreational Boating Fatalities

Life Jacket	Not Worn (N.W.)	Worn (W)	Missing (m.d.)	Total	Total (w/o m.d.)
All	2,202	544	301	3,047	2,746
% of total w/o m.d.	**80.2%**	**19.8%**			
All-operators	1,196	296	159	1651	1492
% of total w/o m.d.	80.2%	19.8%			
Drowning	1,730	308	147	2,185	2,038
% of total w/o m.d.	**84.9%**	**15.1%**			
Drowning-operators	987	171	86	1244	1158
% of total w/o m.d.	85.2%	14.8%			
Trauma	264	162	66	492	426
% of total w/o m.d.	**62%**	**38%**			
Trauma-operators	96	76	19	191	172
% of total w/o m.d.	55.8%	44.2%			
Other	208	74	88	370	282
% of total w/o m.d.	**73.8%**	**26.2%**			
Other-operators	113	49	54	216	162
% of total w/o m.d.	69.8%	30.2%			

Source: Boating Accident Report Database (BARD), US Coast Guard

Table 2 (in Appendix) presents the summary statistics of many candidate variables that can explain the observed number of deceased on each boat involved in an accident.

Reported data show for example that we observed one fatality in ten vessels involved in accident, with a maximum of five deceased observed on a vessel and that in about 1% of the vessels there is a disappearance. While an average of 4.85 PFDs are observed per vessel, it is reported that 46% of vessels' operators are wearing their life jacket. This reported rate is high, probably due to owners'/operators' fear of incriminating themselves; this is however the only life jacket wear measure available. So, the impact of life jacket wear on the number of fatalities may be underestimated and our objective is to obtain a lower bound of this effect. In 80% of the accidents, the whether was clear and 85% of accidents happened during the day. The average air temperature was about 80 degrees Fahrenheit while the water temperature was 71 degrees Fahrenheit. Vessels involved in the accident are mostly open motorboats (46%), followed by cabin motorboat (15%). Most operators, of average age 40, are male (89%) with low boating experience (Only 25% have acquired more than 100 hours of experience). Additional statistics are available in Appendix.

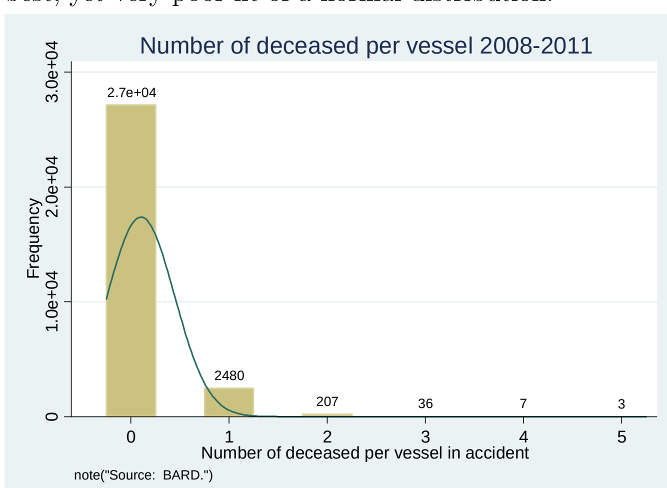
Unfortunately, Table 2 also shows a large number of missing values for most strategic variables such as life jacket wear of the operator or his blood alcohol concentration. For example, the data set reports life jacket wear in only 4,063 accident cases (out of 30,066 vessels). The number of PFDs available on a vessel (on average 4.85) is reported in only 1,550 cases. Blood alcohol concentration is reported in 3,856 of cases.

As a consequence, one may wonder whether the subsample of accident reports showing this strategic information gives a good representation of the entire set of vessels involved in accidents. To improve on the robustness of our results, we construct an additional data set where a weight is given to each vessel for which the operator's life jacket wear is collected. This weight is constructed in order for the final data set to match the share of vessel types found in the initial sample so that the weighted sample give a more accurate representation of boats types involved in accident. Although the power of weighting the observations remains limited by the presence of other variables with a large number of missing values, the robustness and possible generalization of our results is greatly improved.

In the following paragraph, we present the model used to measure life jacket effectiveness. Descriptive statistics of sub-samples of observations treated in those models will be presented in the Results section.

2.2 The Model

In this section, we investigate which factors explain best the number of deaths on each vessel involved in an accident. Figure 1 below shows its distribution between 2008 and 2011. The histogram shows a large number of accidents with no fatalities and only a very small number of positive values. The line represents the best, yet very poor fit of a normal distribution.



A more suitable distribution to represent a count variable such as the number of deceased is the Poisson distribution. In what follows, we model the number of fatalities. Let y_i represents the actual number deceased of vessel i, let μ be the average number of deceased per vessel involved in an accident, and let ϵ_i denote a random unobserved component. We assume that:

$$y_i = \mu + \epsilon_i$$

The unobserved term ϵ_i is added to account for the fact that the different variables reported may not be sufficient to fully explain the variation in fatalities observed across vessels. Based on Figure 1 above, it is assumed ϵ_i, although unobserved, follows a Poisson distribution. Its probability density function is:

$$\begin{aligned} f(\epsilon_i) &= f(y_i) \\ &= \frac{\mu^{y_i} \exp(-\mu)}{y_i!} \end{aligned}$$

where the first equality follows from the fact that μ is non-random.

We use the Poisson regression model, an extension of the Poisson distribution above, by allowing each accident to have a different value of μ. More specifically, the Poisson regression model assumes that each observed count of fatalities (for vessel i) is drawn from an independent and possibly different Poisson distribution with mean μ_i, where μ_i is estimated from various observed factors. These factors include environmental conditions at the time of the accident (weather, water temperature...), but also the vessel's intrinsic characteristics (engine type, length...) or some socioeconomic characteristics of the vessel's operator (age, experience...). More specifically,

$$\mu_i = \exp(\beta_0 + \beta x_i) \geq 0$$

where $x_i \equiv (1, x_{i1}, ...x_{ik})$ represents a vector of characteristics of the accident and $\beta \equiv (\beta_0, \beta_{i1}, ...\beta_{ik})$ is the associated vector of coefficients to be estimated. Note that the Poisson distribution requires accident events to be independent. It also has the major property that

$$Var(y_i|x_i) = E(y_i|x_i) = \mu_i = \exp(\beta_0 + \beta x_i), \tag{1}$$

which proves to be verified by our data set: Table 2 shows for example that $E(y_i)$ =.102 is close to $V(y_i)$ =.343^2 =0.117.

Note that as μ_i increases the conditional variance of y_i increases, the proportion of predicted zeros decreases, and the distribution around the expected value becomes approximately normal.

2.3 Estimation procedure

The first step to understanding which factor present at the time of the accident mattered most is to analyze their direct individual relationship with our dependent variable, i.e. the number of fatalities per vessel. Table 3 (in Appendix) reports the results of 54 one-variable Poisson regressions (corresponding to 54 candidate variables), one per factor, providing a univariate measure of correlation between the amount of fatalities per vessel and each available factor. We will henceforth refer to these as Models 1 (M1s). Interpretation of the effect of each factor on the number of deceased is as follows. Let $E(y|x, x_k)$ denote the expected number of deceased per vessel given factor x takes value x_k (of associated estimate β). Let $E(y|x, x_k + \delta)$ denote the expected number of deceased per vessel after increasing x_k by δ units. Then, using (1),

$$\frac{E(y|x, x_k + \delta)}{E(y|x, x_k)} = \exp(\beta\delta)$$

For a change of δ in x_k, the expected number of deceased per vessel increases by a factor of $\exp(\beta_k\delta)$, holding all other variable constant. This factor is also defined as the Incident Rate Ratio (I.R.R.). Note that if the change $\delta = 1$, then the I.R.R. is simply $\exp(\beta)$. For example in Table 3, an operator wearing his life jacket (i.e. variable "life jacket wear" going from no wear (0) to wear (1)) decreases the expected number of deceased per vessel by 68.3% (i.e. an increase by a factor of 0.317).

Among candidate variables for the models below, those that appear significantly negatively related to the number of fatalities (i.e. with I.R.R. <1) include life jacket wear, experience (although not significantly), increases in water temperature, increases in number of vessels involved in the accident and increases in length of the vessel. The number of fatalities seem to also be significantly lower when the accident occurs during the day or when the weather is clear at the time of the accident. On the other hand, fatalities seem to be significantly higher (i.e. with I.R.R. >1) when blood alcohol concentration increases, when the operator is older, when the accident occurs during a week day or when the vessel is an open-motorboard. Other results for possible candidate variables are all reported in Table 3. Note that each regression uses a different number of vessels. This is because each candidate variable has a different set of missing values.

These one-variable regression results, however, do not account for the complexity of the accident and hence, represent very poor predictors of the observed variation in number of fatalities across accidents. This is shown by the very small fit measure of the regression (Pseudo R^2) in Table 3.

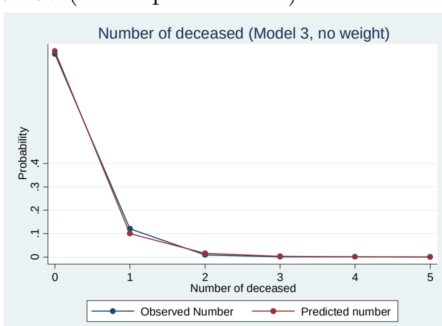
Indeed, during the accident, all of these factors are combined and it is their combination that results in a specific outcome, such as the number of fatalities. Consequently, it is possible for a factor to significantly affect the number of fatalities when it is seen as a unique explanation of the outcome and become insignificant when other factors are introduced because some of their effect is summarized by one or more other variables.

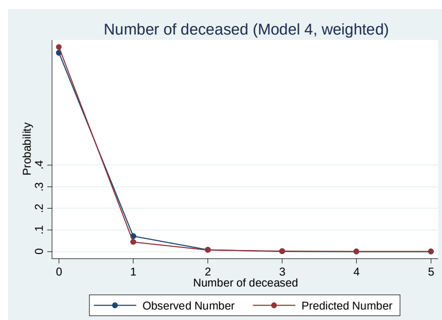
One such occurrence is illustrated in Table 4 (in Appendix). Table 4 reports Poisson estimation results of a model where blood alcohol concentration and life jacket wear are introduced simultaneously in the estimation (henceforth, model (M4)). As briefly mentioned in the data section, we consider two data sets: one unweighted data set and one weighted data set to represent the distribution of vessel types from the complete sample. Results of this model (in Table 3) show that taken separately, both wearing a life jacket and blood alcohol concentration are significant in explaining the number of deceased with intuitive signs: a decrease by 67% of the average number of fatalities on the vessel and a 28% increase in number of fatalities for every 10% increase in operator's blood alcohol concentration. However, combining both factors shows that the information on life jacket wear may summarize some of the behavior found in operators drinking alcohol, as the latter become insignificant. This is consistent with the result of Loeb et al. (2006) who find that there is no persuasive evidence of alcohol contributing substantially to operator fault in fatal accidents.

In the section below, we report the results of the best model specifications (i.e. in the sense of statistical fit) when introducing the significant factors (from Table 3) simultaneously.

3 Estimation Results

Tables 6 (Appendix) below reports the results of two models, one of which use unweighted data (M3) while the second model (M4) uses data weighted as described above. We control for the fact that an accident is reportable[4] by introducing the variable "Reportable Accident"[5]. The graphs below show that the Poisson distribution is a very good fit for both unweighted (M3) and weighted (M4) models, with a Deviance goodness-of-fit test showing a X^2= 1,226.437 (and a p-value of 1).





Note that the Pseudo-R^2 of these two models, respectively 0.268 and 0.330 cannot be compared as they do not use the same sample of vessels. All other variables held constant, estimation results show that the expected number of deceased per vessel decreases by about 80% (79.4% in (M3) and 80.8% in (M4)) when the operator wears his life jacket, as opposed to when he does not. This result is highly significant and makes this variable together with the number of

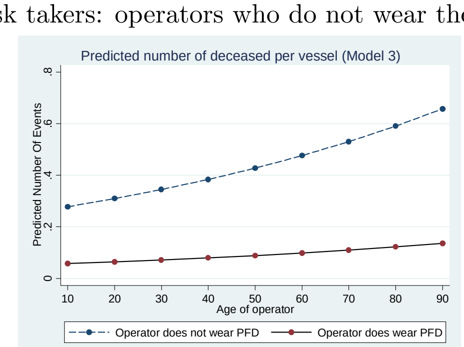
[4] See the 2012 annual statistics report for details pages 9-11 (http://www.uscgboating.org/assets/1/workflow_staging/Page/705.PDF).

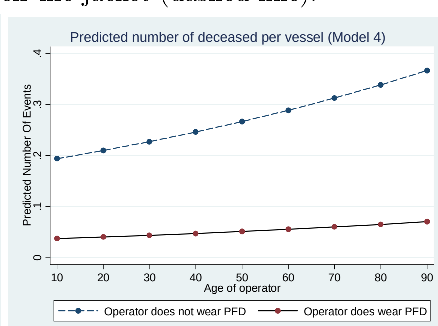
[5] Estimation of the sample selecting only reportable accidents removes an additional 235 observations in (M3) and 1333 in (M4). Estimation results are extremely similar to those of Table 8 and for this reason are not reported in Appendix.

vessels involved in the accident, one of the most important potential contributors of fatality reduction. Despite its significant impact, this result is lower than Traub's (1989) result. Several reasons may explain the lower magnitude of this result. First, life jacket wear may be correlated with some characteristics of the accident, such as the type of boat or weather conditions that we control for in our calculations. In our model, the effect of life jacket wear is the effect estimated, once the effects of other such characteristics have been controlled for. Second, boating may be safer today than it was in the 1960s. For example, the use of GPS to determine the location of the accident may be associated with faster rescue. Finally, the reported operator's wear rate in our sample seems high when compared to the wear rate of fatalities, which could lower the ratio of the odds of dying for life jacket non-users to the odds of dying for life jacket users.

Results also show that one more vessel involved in the accident reduces the amount of fatalities between 78% (M3) and 83% (M4). This result is consistent with Duda et al. (2007) who find that more people involved in accident is associated with lower fatalities. One could conjecture that more people involved means that more people may be able to perform rescues/first aid. Experience is also of great importance, with a 34% (M4) reduction of fatalities predicted when the operator has more than 100 hours of experience. Despite this, speed remains a significant determinant of the outcome: the average number of deceased increase about 57% (M3) if the vessel is not moving at the time of the accident and 65% lower if the vessel averages a speed of 10 to 20 miles per hour.

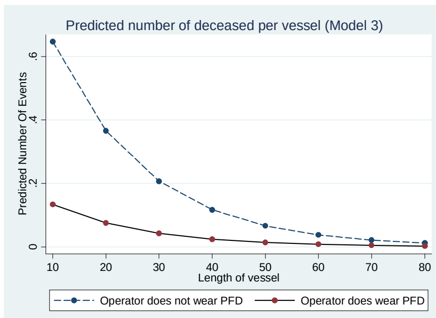
Age is found to be slightly positively correlated with the number of fatalities with an increase between 0.8% (M4) and 1.1% (M3) for every additional year of age. This result may capture some unobserved characteristics of the operator such as overconfidence or high risk taking, and is consistent with the result on rented boats (for which the number of fatalities is 22% lower) because the typical operator may be more risk averse, perhaps making mistakes overall less threatening. The graphs below illustrate these results. They show the predicted number of deceased for different operators' ages and distinguish between risk averse operators: those wearing their life jackets (black continuous line), from risk takers: operators who do not wear their life jacket (dashed line).

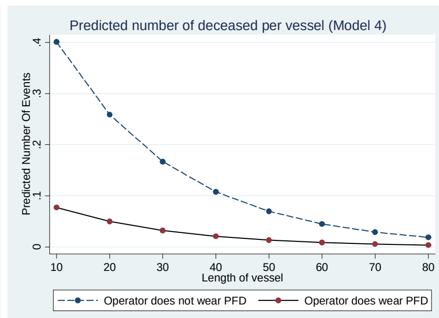




Both graphs show that the effectiveness of life jacket increases with age, as the operator feels more confident.

Table 6 estimation results also show that it is significantly safer to be on a longer vessel, with a number of fatalities estimated to be between 4.3% (M4) and 5.5% (M3) lower per additional foot length. The two graphs below report the predicted number of fatalities per length of vessel distinguishing between individuals wearing their life jacket and those who don't. Both models show that it is safer to be on longer boat and that the effectiveness of life jacket decreases with longer boats.

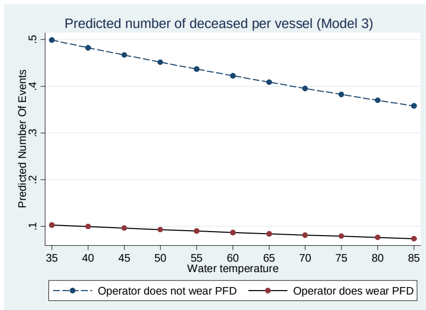


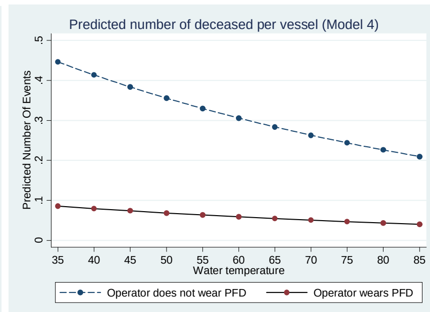


The number of fatalities on a vessel also seems to be closely related to its intrinsic characteristics. The average number of deceased is 1.86 times higher when the vessel is a canoe or a kayak. It is also more dangerous to be on a powerful boat with a 77% increase in fatalities for each additional engine. The result of open-motorboat seems at first counter intuitive, however one should be reminded of the simultaneous nature of our results. Indeed, the result cannot be separated from other intrinsic characteristics of the boat, such as the type of engine. In (M4), among open motorboats with outboard type engine, the average number of deceased is ((0.647-1)+(1.592-1))=23% higher than among other types of boats (excluding vessels with no engine).

Environmental conditions are also important predictors of the number of deceased on a vessel. All other variables being held constant, each additional degree Fahrenheit in water temperature decreases the average number of fatalities on a vessel between 0.7% (M3) and 1.5% (M4).

The graphs below show that the predicted number of deceased per vessel decreases as the water temperature increases and varies greatly depending on operators' willingness to wear their life jacket. Life jacket effectiveness is much higher in cold water, perhaps reflecting the inability of individuals without life jacket to swim in cold waters for a long time.





The average number of deceased is also 40% lower when the accident occurs during the day and is estimated between 24% (M4) and 29% (M3) higher when the accident occurs during a weekday as opposed to a weekend. Finally, once all the factors above have been controlled for, results show that the location of the accident still matters; in particular, it is more dangerous to boat in LA, IA, SC, IL, and FL (relative to other states).

The rest of this section focuses on the simulation of policies on life jacket wear and their potential impact on the number of fatalities. Table 7 gives the predicted average number of deceased conditional on operator's life jacket wear.

Table 7: Predicted number of deceased per vessel under life jacket regulation scenario

Number of Deceased/Vessel	(M3)	(M4)
1-*Predicted* Mean	**.0380**	**.0245**
St. Error	.0052	.0018
2- *All operators wear a LJ*		
Predicted Mean	**.0165**	**.0092**
St. Error	.0034	.0009
Confidence Interval	[.0099 .02317]	[.0074 .0112]
3- *No Operator wears LJ*		
Predicted Mean	**.0801**	**.0483**
Standard Error	.0114	.0036
Confidence Interval	[.0577 .1025]	[.0412 .0554]
% Change from 1- to 2-	**-56.5%**	**-62%**

Table 7 reports that the predicted number of deceased per vessel is estimated to 0.380 (M3) and 0.245 (M4). The table also reports how this estimated number would change if all operators were to wear their life jacket. It shows that the number of deceased would decrease between 56.5% (M3) and 62% (M4). This result is stronger than Maxim's (2010) who found that if at least 70% wear rates on open-motorboats would decrease drowning victims by 43.6% and much stronger than Cummings et al. (2010). One of the reasons may be that our results apply to a more recent data set, to all fatalities and all types of boats.

In order to infer how many lives could have been saved, one needs to know 1- the total number of people involved in accidents, 2-the current life jacket wear rate (since the data set only reports the wear rate of operators) and 3-how much a policy imposing all operators to wear their life jacket would increase the current wear rate.

Table 5a-b (in Appendix) report descriptive statistics for the data used in (M3) and (M4). The data in (M3) contain 2030 vessels, 2027 of which had an operator, hence 2027 operators, of which 959 wore their life jacket. From Table 5a, the average number of people on board is 2.845, which means that a total of 5766 people were involved in an accident. Using a wear rate of 19.8% reported in Table 1 among fatalities would mean that 182 non-operators (i.e. 4.9%) would have worn their life jacket ($0.198=\frac{959+x}{5766}$,i.e. x=182). Hence going from a wear rate of 19.8% to a wear rate such that all operators wear their life jacket, i.e. $\frac{2027+182}{5766} = 38.3\%$, representing an increase of 18.5% would decrease the average number of deaths by 56.5%. Equivalently, increasing the wear rate by 20% is estimated to decrease the average number of deceased per vessel by 61%.

Assuming the data used in (M3) is random, it is possible to generalize the results to the overall population of accidents observed between 2008 and 2011. In the overall sample, Table 2 reports that 8% of vessels have no operator. Hence, we count approximately 27,661 operators (i.e. 27,661 vessels with an operator), 46% of which wear their life jacket (i.e. a total of 12,724 operators). With an average number of people on board of 2.7, the total number of persons involved in accidents was 27661*2.7=74,685. Assuming an aggregate wear rate of 19.8% means that 2063 non-operators wore their life jacket ($0.198=\frac{12724+x}{74685}$). Hence, going from 19.8% to $\frac{27661+2063}{74685} = 39.8\%$ reduces the number of fatalities between 56.5% (M3) and 62% (M4). As a conclusion, between 2008 and 2011, we estimate that between 1,721 and 1,889 (out of 3047) fatalities could have been avoided, had a policy increased the wear rate to about 40%. About 1234 out of 2,185 drownings could have been saved. Even a more conservative policy achieving a 20% wear rate increase to boats between, say 16-30 feet, which counted 1,378 deceased between 2008 and 2011 would have saved a minimum of 778 victims.

Note that these last calculations implicitly assume that there is no correlation between life jacket wear of the operator and life jacket wear of other users. Hence, we assume that when the policy is implemented, the wear rate of non-operators stays the same. As a result, it is reasonable to assume that a policy should aim a higher increase in wear rate to achieve the 20% increase among operators.

4 Extension: Factors explaining causes of death

In this section, we refine our analysis to explore how differently factors interact for different causes of death. We use a standard Multinomial Logit Model (MNL) to address how some fatalities' characteristics such as life jacket wear, alcohol use and the victim's role on the boat (passenger/operator) explain causes of death such as drowning, trauma or other causes of death. We predict how the distribution of causes of death would be altered, would a policy similar to the one above be implemented.

4.1 The Model

Let d denote a random variable indicating the type of death observed taking on the indexes $j = 0, 1, 2$ for drowning, trauma and other causes respectively. Let $\mathbf{x}$ denote a vector of *victim-specific* characteristics. Our interest lies in understanding the main factors that can potentially explain the probability p of each type of death occurring. We choose to use the standard Multinomial Logit Model (henceforth, MNL), a "proxy" of the probit model with better computational properties.

For the ith victim, we assign a function U_{ij} characterizing the chances of death j occurring as follows:

$$U_{ij} = V\left(\mathbf{x}_i\right) + \epsilon_{ij}$$

where $V()$ is a function constructed from observed variables and ϵ_{ij} is an unobserved random component characterizing the accident ϵ_{ij}. ϵ_{ij} is assumed to be independent across victims and causes of death and distributed according to an Extreme Value Type I distribution.[6]

Using the distributional properties of ϵ_{ij}, the probability that a cause of death j occurs, i.e. $p(\mathbf{x})$, can be expressed as[7]:

$$\begin{aligned} p(\mathbf{x}_i) &= P(y_i = j|\mathbf{x}_i) \\ &= \frac{\exp(\mathbf{x}_i\boldsymbol{\beta}_j)}{\sum_{h=0}^{2}\exp(\mathbf{x}_i\boldsymbol{\beta}_h)}, \qquad j = 0, 1, 2 \end{aligned}$$

The parameters of the MNL are generally not directly interpretable and are complicated. In particular, a positive coefficient need not mean that an increase in the regressor leads to an increase in the probability of that outcome being selected. To see this, we can compute marginal effects, i.e., the effect of a change in the victim's characteristics on the probability of a cause of death occurring. For a continuous variable x_{ik} of associated coefficient β_{jk} belonging to the $N \times K$ set of variables $x_i := (x_{i1}, ...x_{ik}, ...x_{iK})$ with associated vector of coefficients $\beta_j := (\beta_{j1}, ...\beta_{jk}, ...\beta_{jK})$ $\forall\ j \in J_i$ the marginal effect of x_k on the

[6] The Extreme Value Type I distribution, also known as Gumbel distribution, has the probability density function $F(\epsilon)$=exp$(-\exp(-\mu(\epsilon - \eta)$ where η is the *location parameter* and μ is the *scale parameter*. The location parameter determines where the origin of the distribution will be located, while the scale parameter determines the statistical dispersion of the probability distribution.

[7] See McFadden (1974).

probability can be written as:

$$\begin{aligned}\frac{\partial P_{ij}}{\partial \mathbf{x}_{ik}} &= P_{ij}\left\{\beta_{jk}-\left[\sum_{h=1}^{J}\beta_{hk}\exp(\mathbf{x}_i\beta_h)\right]/g(\mathbf{x}_i,\beta)\right\}\\ \text{where } g(\mathbf{x}_i,\boldsymbol{\beta}) &= 1+\sum_{h=1}^{J}\exp(\mathbf{x}_i\boldsymbol{\beta}_h)\end{aligned}$$

Note that for any particular x_k, $\partial P_j/\partial x_k$ need not have the same sign as β_{jk}. Furthermore, the marginal effects vary with the value of $\mathbf{x}$.However, when the function U_{ij} is linear in x, one can show that

$$\ln\left[\frac{P_{ij}}{P_{il}}\right]=\ln\Omega(\mathbf{x})=\mathbf{x}_i'(\beta_j-\beta_l)$$

By taking the exponential of both sides of the above equation we create an equation that is multiplicative instead of linear and is more intuitive:

$$\Omega(\mathbf{x}) = e^{\mathbf{x}_i'(\beta_j-\beta_k)}$$

If we let x_{ik} change by 1, we have

$$\Omega(\mathbf{x}_i,x_{ik}+1)=e^{(\beta_{j1}-\beta_{l1})x_{i1}}...e^{(\beta_{jk}-\beta_{lk})x_{ik}}e^{(\beta_j-\beta_l)}...e^{(\beta_{jK}-\beta_{lK})x_{iK}}$$

This leads to the odds ratio:

$$\frac{\Omega(\mathbf{x},x_k+1)}{\Omega(\mathbf{x},x_k)}=\frac{e^{(\beta_{j1}-\beta_{l1})x_{i1}}...e^{(\beta_{jk}-\beta_{lk})x_{ik}}e^{(\beta_j-\beta_l)}...e^{(\beta_{jK}-\beta_{lK})x_{iK}}}{e^{(\beta_{j1}-\beta_{l1})x_{i1}}...e^{(\beta_{jk}-\beta_{lk})x_{ik}}...e^{(\beta_{jK}-\beta_{lK})x_{iK}}}=e^{(\beta_j-\beta_l)}$$

In conclusion, for a unit change in x_k, the odds of outcome j occurring versus outcome l are expected to change by a factor $e^{(\beta_j-\beta_l)}$, holding all other variables constant. For $e^{(\beta_j-\beta_l)}>1$, you could say that the odds are " $e^{(\beta_j-\beta_l)}$ times larger", or that the odds "increase by $e^{(\beta_j-\beta_l)}-1$"; for $e^{(\beta_j-\beta_l)}<1$, you could say that the odds are " $e^{(\beta_j-\beta_l)}$ times smaller", or that the odds "decrease by $1-e^{(\beta_j-\beta_l)}$".

4.2 Results

Table 8 (in Appendix) shows that the odds of dying by drowning versus trauma (respectively other causes) among deceased wearing their life jacket are 61% (respectively 58%) lower than the odds among deceased who did not wear it. We also find that the odds of dying of a trauma versus drowning are 58.4% higher (i.e. $\frac{1.365}{2.162}-1=0.584$) when the deceased used alcohol prior to the accident than if he did not.

The graphs below show how the predicted probability of drowning change with age depending on whether the deceased did or did not wear a PFD device and did or did not use alcohol.

We find that the probability of drowning increases with age (at a decreasing rate) and then decreases with age, reaching a maximum at about 60 years old. This could be explained by a higher number of individuals boating in that age range, but also more risk taken by experienced older individuals. Alcohol touches a much younger population, with a maximum probability of drowning obtained at age 30.

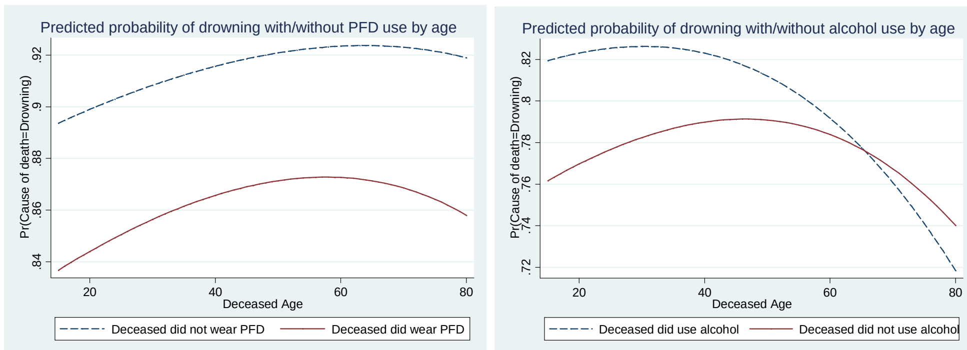
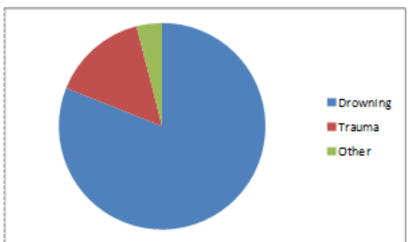


Table 9 below shows that our model slightly overestimates drownings as opposed to other causes although its predictive power is pretty good (95% confidence intervals are narrow).

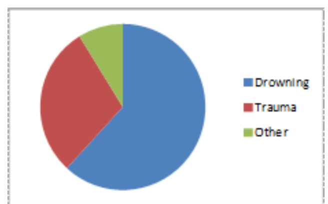
Table 9 : Predicted probability of dying by cause of death

Cause of death	Observed	Prediction	Std Err.	z	P-value	95% C.I.
Drowning	0.7653	0.79	0.01	81.56	0.00	[.77, .81]
Trauma	0.1723	0.16	0.01	18.37	0.00	[.14, .18]
Other	0.0623	0.05	0.01	9.08	0.00	[.04, .06]

Finally, the graphs below give an illustration of the predicted distribution of death before and after implementation of a policy on operators' life jacket wear (The size of the second graph is smaller to illustrate the smaller number of deaths after implementation of the policy). The policy is shown to significantly reduce both the total number of victims and the share of drowning victims compared to other causes.



Distribution before policy



Distribution after policy

5 Conclusion

In this paper, we use the recent US Coast Guard BARD database to investigate the different factors explaining the number of fatalities observed between 2008 and 2011 as well as the effectiveness of life jacket wear. Among many factors present at the time of the accident, we find that life jacket wear is one of the most influential at explaining the number of fatalities. We also find that during this period, between 1,721 and 1,889 (out of 3047) fatalities, or , drownings out of 2,185, could have been saved, had life jacket wear been increased to 40% (among individuals who had an accident) through regulatory policy.

One limitation of this study is the number of missing values encountered in the data set which may have compromised the randomness of the data. However, one of the major goals of the US Coast Guard is to achieve 100% boat accident report completeness by 2016. In this paper, we remedy this issue by weighting the reduced data set so it is representative of the entire sample of vessels' types and we find that our weighted results do not vary much from the unweighted one. This suggests our results are pretty robust to this issue.

Second, it would be useful to increase the overall quality/quantity of data reporting (for example, reporting life jacket usage on each vessel or life jacket wear of non-operators) and of its documentation of missing values. Indeed, it is difficult to extrapolate our finding to a higher percentage change in life jacket wear because the result is obtained by introducing a binary variable (operator life jacket wear). A quantitative, i.e. continuous, variable (number of life jacket wearers on the boat) would be required to estimate the functional form of the change in fatalities resulting from a change in life jacket usage rate, e.g. life jacket wear rate for all passengers on the boat. The relationship between the intensity of life jacket wear and the number of fatalities could be of logarithmic or polynomial form for example. In the case of a logarithmic relationship, for example, the biggest reduction in number of fatalities would be obtained for the first 20% increase in life jacket wear and this reduction would gradually decrease as the wear rate further increases. Further, our result only apply to boats involved in accidents and cannot be generalized to the entire population of vessels. Information about about all registered vessels activity would be required to perform this generalization.

Finally, life jacket wear among operators may have been over-reported, lowering the estimated effect of a policy on life jacket wear. However, one might argue that operators, on average, are more cautious than the average boater and that their life jacket wear attitude may be shared with other people on board the boat. Consequently, generalizing a policy based on operators to the entire population of boaters may slightly overestimate its impact, counteracting the previous effect.

6 Appendix

Table 2: Summary Statistics Overall Sample

Variables	count	mean	St Dev	min	max
Accident Characteristics					
Number of people on board	27,738	2.70	2.62	0.00	72.00
Number of deceased	29,863	.102	.343	0.00	5.00
Number of disappearance	14,620	0.01	0.08	0.00	3.00
Depth in Feet	2,042	3.84	5.11	0.00	71.00
Depth in Inches	1,446	6.66	7.61	0.00	84.00
Number of boating citations	346	0.63	1.26	0.00	17.00
Fire extinguishers on board (=1)	30,012	0.04	0.19	0.00	1.00
Number of PFDs on board	1,550	4.85	4.78	0.00	60.00
Dollar amount of vessel property damage	23,997	7845.85	88510.99	0.00	9000000
Operator Characteristics					
Gender (Male =1)	20,105	0.89	0.31	0.00	1.00
Age	22,716	40.43	15.86	0.00	95.00
Wore Personal Flotation Device (=2)	4,063	1.46	0.50	1.00	2.00
Blood Alcohol Concentration (*100)	3,856	2.03	6.57	0.00	160.00
Education: American Red Cross (=1)	30,012	0.00	0.07	0.00	1.00
Education: Informal (=1)	30,012	0.04	0.19	0.00	1.00
Education: None (=1)	30,012	0.42	0.49	0.00	1.00
Education: No Operator (=1)	30,012	0.08	0.27	0.00	1.00
Education: State Course (=1)	30,012	0.10	0.30	0.00	1.00
Education: U.S. Power Squadron (=1)	30,012	0.02	0.12	0.00	1.00
Education: USCG Auxiliary (=1)	30,012	0.04	0.20	0.00	1.00
Experience: 10 to 100 Hours (=1)	30,012	0.17	0.38	0.00	1.00
Experience: 100 to 500 Hours (=1)	30,012	0.25	0.44	0.00	1.00
Experience: No Operator (=1)	30,012	0.08	0.27	0.00	1.00
Experience: No Experience (=1)	30,012	0.01	0.09	0.00	1.00
Experience: Over 500 Hours (=1)	30,012	0.11	0.32	0.00	1.00
Weather Conditions					
Clear (=1)	29,401	0.79	0.41	0.00	1.00
Cloudy (=1)	29,401	0.15	0.36	0.00	1.00
Fog (=1)	29,401	0.01	0.10	0.00	1.00
Rain (=1)	29,401	0.04	0.19	0.00	1.00
Snow (=1)	29,401	0.00	0.05	0.00	1.00
Hazy (=1)	29,401	0.01	0.09	0.00	1.00
AirTemperature	25,393	79.53	13.98	0.00	125.00
Water temperature	24,674	71.10	11.36	29.00	108.00
Day (=1) / Night	29,917	0.85	0.36	0.00	1.00

Table 2: Summary Statistics Overall Sample (continued)

Variables	count	mean	St Dev	min	max
Vessel Characteristics					
Year vessel was built	26,411	1995.81	11.76	1899	2011
Number of engines	23,977	1.07	0.71	0.00	90.00
Length	28,125	21.48	16.59	3.00	734.00
Type: Airboat (=1)	29,359	0.01	0.07	0.00	1.00
Type: Auxiliary Sail (=1)	29,359	0.05	0.21	0.00	1.00
Type: Canoe (=1)	29,359	0.03	0.18	0.00	1.00
Type: Houseboat (=1)	29,359	0.02	0.12	0.00	1.00
Type: Inflatable (=1)	29,359	0.02	0.15	0.00	1.00
Type: Open Motorboat (=1)	29,359	0.46	0.50	0.00	1.00
Type: Other (=1)	29,359	0.01	0.11	0.00	1.00
Type: Personal Watercraft (=1)	29,359	0.20	0.40	0.00	1.00
Type: Pontoon (=1)	29,359	0.04	0.19	0.00	1.00
Type: Rowboat (=1)	29,359	0.01	0.10	0.00	1.00
Type: Sail (only) (=1)	29,359	0.01	0.11	0.00	1.00
Type: Sail (unknown)	29,359	0.00	0.02	0.00	1.00
Engine type: Inboard (=1)	28,142	0.41	0.49	0.00	1.00
Vessel has no engine	28,142	0.08	0.27	0.00	1.00
Engine type: Other (=1)	28,142	0.01	0.08	0.00	1.00
Engine type: Outboard (=1)	28,142	0.34	0.47	0.00	1.00
Engine type: Stern Drive (=1)	28,142	0.17	0.38	0.00	1.00
Number of horsepowers	21,441	224.30	346.81	0.00	7000.00
Propulsion: Manual (=1)	28,405	0.06	0.25	0.00	1.00
Propulsion: No Propulsion (=1)	28,405	0.00	0.02	0.00	1.00
Propulsion: Other (=1)	28,405	0.00	0.01	0.00	1.00
Propulsion: Propeller (=1)	28,405	0.69	0.46	0.00	1.00
Propulsion: Sail (=1)	28,405	0.02	0.13	0.00	1.00
Propulsion: Air Thrust (=1)	28,405	0.01	0.08	0.00	1.00
Propulsion: Water Jet (=1)	28,405	0.22	0.42	0.00	1.00
Fuel type: Diesel (=1)	26,924	0.07	0.25	0.00	1.00
Fuel type: Electric (=1)	26,924	0.01	0.09	0.00	1.00
Fuel type: Gasoline (=1)	26,924	0.84	0.36	0.00	1.00
Fuel type: No Fuel (=1)	26,924	0.08	0.27	0.00	1.00

Table 3: One Variable Poisson Regression (M1s)

Dep. var.: *Number of deceased per vessel*	Coeff.	I.R.R.	S.E.	N	ps.R^2
Operator's characteristics					
PFD wear (=1)	-1.150***	0.317***	0.101	4,063	0.045
PFD wear, weighted per vessel type (=1)	-1.112***	0.329***	0.047	30,250	0.034
Blood Alcohol Concentration (%)	0.027***	1.028***	0.002	3,855	0.027
Experience greater than 100 hours (=1)	-0.024	0.976	0.053	18,800	0.000
Vessel has no operator (=1)	-1.625***	0.197***	0.140	29,863	0.012
Gender: male (=1)	0.741***	2.099***	0.088	20,092	0.006
Age	0.017***	1.017***	0.001	22,710	0.011
Accident's Characteristics					
Water Temperature	-0.033***	0.968***	0.001	24,578	0.026
Day (=1)/Night	-0.612***	0.542***	0.042	29,772	0.009
Weekday (=1)	0.342***	1.408***	0.036	29,863	0.004
Air Temperature (=1)	-0.028***	0.972***	0.001	25,283	0.029
Weather: Clear (=1)	-0.395***	0.674***	0.041	29,257	0.004
Weather: Cloudy (=1)	0.254***	1.289***	0.047	29,257	0.001
Weather: Rain (=1)	0.362***	1.436***	0.081	29,257	0.001
Weather: Snow (=1)	1.083***	2.955***	0.197	29,257	0.001
Weather: Hazy (=1)	-0.501*	0.606*	0.259	29,257	0.000
Number of people on board	-0.008	0.992	0.007	27,725	0.000
Number of people towed	-0.533***	0.587***	0.070	21,150	0.006
Number of vessels involved	-1.879***	0.153***	0.057	29,852	0.091
Dollar amount of vessel property damage	-0.000***	1.000***	0.000	23,985	0.006

p<0.10, ** p<0.05, *** p<0.01

Table 3: One Variable Poisson (continued)

Dep. var.: *Number of deceased per vessel*	Coeff.	I.R.R.	S.E.	N	ps.R^2
Vessel's Characteristics					
Boat was rented (=1)	-0.522***	0.593***	0.082	24,999	0.003
Floatation device accessible (=1)	0.149*	1.161*	0.078	29,863	0.000
Fire extinguisher present (=1)	-0.487***	0.615***	0.123	29,863	0.001
Number of engines	-1.334***	0.263***	0.048	23,966	0.045
Number of horsepowers	-0.004***	0.996***	0.000	21,434	
Beam width	-0.006	0.994	0.006	2,797	
Depth in feet	-0.009	0.991	0.015	2,042	
Length	-0.042***	0.959***	0.002	28,107	0.021
Year vessel was built	-0.020***	0.981***	0.002	26,398	0.009
Type: Airboat (=1)	-0.873**	0.418**	0.378	29,311	0.000
Type: Auxiliary Sail (=1)	-0.894***	0.409***	0.131	29,311	0.003
Type: Cabin Motorboat (=1)	-0.831***	0.436***	0.071	29,311	0.009
Type: Canoe or Kayak (=1)	1.824***	6.198***	0.048	29,311	0.048
Type: Inflatable (=1)	0.748***	2.113***	0.089	29,311	0.003
Type: Open Motorboat (=1)	0.186***	1.204***	0.036	29,311	0.001
Type: Personal Watercraft (=1)	-1.411***	0.244***	0.079	29,311	0.024
Type: Rowboat (=1)	1.727***	5.625***	0.078	29,311	0.015
Type: Sail (only) (=1)	0.023	1.023	0.165	29,311	0.000
Type: Sail (unknown) (=1)	0.812	2.253	0.578	29,311	0.000
Engine: Inboard (=1)	-1.560***	0.210***	0.056	28,111	0.057
Engine: None (=1)	1.599***	4.948***	0.041	28,111	0.060
Engine: Outboard (=1)	0.640***	1.896***	0.037	28,111	0.015
Engine: Stern Drive (I/O) (=1)	-0.779***	0.459***	0.067	28,111	0.009
Fuel: Diesel (=1)	-1.408***	0.245***	0.143	26,900	0.009
Fuel: Electric (=1)	1.595***	4.928***	0.101	26,900	0.009
Fuel: Gasoline (=1)	-1.064***	0.345***	0.040	26,900	0.033
Fuel: No Fuel (=1)	1.582***	4.862***	0.042	26,900	0.060
Propulsion: Air Thrust (=1)	-0.945**	0.389**	0.378	28,373	0.000
Propulsion: Manual (=1)	1.737***	5.681***	0.042	28,373	0.067
Propulsion: Propeller (=1)	-0.249***	0.780***	0.039	28,373	0.002
Propulsion: Water Jet (=1)	-1.371***	0.254***	0.074	28,373	0.026
Speed: 10 to 20 mph (=1)	-0.973***	0.378***	0.081	22,104	0.014
Speed: 21 to 40 mph (=1)	-0.533***	0.587***	0.073	22,104	0.005
Speed: Not Moving (=1)	0.110**	1.117**	0.053	22,104	0.000

p<0.10, ** p<0.05, *** p<0.01

Table 4: Model 2 estimation results

	Unweighted	Sample	Weighted	Sample
Variables	Coef.	IRR	Coef.	IRR
Blood Alcohol Concentration (BAC) (%)	-0.013	0.987	-0.031***	0.970***
	(0.013)		(0.006)	
Operator wears life jacket	-2.629***	0.072***	-2.888***	0.056***
	(0.345)		(0.157)	
Constant	2.137***	8.478***	2.242***	9.415***
	(0.421)		(0.188)	
R-squared	0.221		0.219	
N	377		2670	

Table 5a: Descriptive Statistics for observations used in Model 3

Variables	Mean	Sd	min	max
Number of deceased	.1064	.346	0	4
Length of vessel	18.96	10.37	5	120
DayNight	0.87	0.34	0	1
Operator wears life jacket	1.47	0.50	1	2
USCGpol2	0.88	0.32	0	1
Age of operator	41.01	16.21	9	89
Nb of engines of vessel	1.08	0.35	0	3
Water temperature	72.80	11.35	29	108
Nb vessels involved in accident	1.44	0.54	1	5
Vessel type Open Motorboat	0.48	0.50	0	1
Vessel Engine type: outboard	0.33	0.47	0	1
Accident occured on a week day	0.41	0.49	0	1
Speed 10 to 20 miles per hour	0.20	0.40	0	1
Vessel not moving	0.18	0.38	0	1
state: AZ	0.05	0.21	0	1
state: FL	0.09	0.29	0	1
state: MO	0.07	0.26	0	1
state: NJ	0.06	0.24	0	1
state: NY	0.09	0.28	0	1
state: OH	0.06	0.23	0	1
N	2030			

Table 5b: Descriptive Statistics for observations used in Model 4

Variables	Mean	Sd	min	max
Number of deceased	.0881	.325	0	3
Operator wears life jacket (=2)	1.41	0.49	1	2
Age of operator	42.67	15.83	9	89
opexpermore100	0.63	0.48	0	1
Length of vessel	20.64	11.00	4	120
Vessel was rented	0.13	0.34	0	1
Nb vessels involved in accident	1.37	0.54	1	5
Vessel type Open Motorboat	0.50	0.50	0	1
Vessel Engine type: outboard	0.38	0.49	0	1
USCGpol2	0.88	0.33	0	1
DayNight	0.85	0.35	0	1
Accident occured on a week day	0.43	0.50	0	1
Water temperature	72.89	11.78	29	98
AirTemperature	80.86	13.83	25	113
Horsepower	223.83	305.25	0	5200
Canoe type	0.02	0.15	0	1
state: AZ	0.04	0.20	0	1
state: FL	0.12	0.33	0	1
state: IA	0.00	0.04	0	1
state: IL	0.00	0.02	0	1
state: LA	0.01	0.11	0	1
state: MD	0.06	0.24	0	1
state: MO	0.09	0.29	0	1
state: NJ	0.06	0.24	0	1
state: OH	0.08	0.27	0	1
state: PA	0.03	0.18	0	1
state: SC	0.00	0.05	0	1
state: UT	0.02	0.14	0	1
N	10849			

Table 6: Estimation Results

	Model 3	N=2,030	Model 4	N=10,849
Variables	Coeff.	I.R.R.	Coeff.	I.R.R.
Length of vessel	-0.057***	0.945***	-0.044***	0.957***
	(0.014)		(0.008)	
DayNight	-0.611***	0.543***	-0.501***	0.606***
	(0.158)		(0.089)	
Operator wears life jacket	-1.578***	0.206***	-1.650***	0.192***
	(0.216)		(0.101)	
Water temperature	-0.007	0.993	-0.015***	0.985***
	(0.005)		(0.004)	
Reportable accident	0.891***	2.438***	1.630***	5.104***
	(0.330)		(0.221)	
Number vessels involved	-1.546***	0.213***	-1.795***	0.166***
	(0.249)		(0.143)	
Boat Type: Open Motorboat	-0.309*	0.734*	-0.435***	0.647***
	(0.172)		(0.095)	
Engine type: outboard	0.487***	1.628***	0.465***	1.592***
	(0.173)		(0.101)	
Accident on a week day	0.153	1.166	0.216***	1.241***
	(0.140)		(0.068)	
Speed 10-20 miles per hour	-1.041***	0.353***		
	(0.317)			
Vessel not moving	0.453***	1.573***		
	(0.161)			
state: AZ	-1.215*	0.297*	-1.112***	0.329***
	(0.715)		(0.327)	
state: FL	0.525**	1.690**	0.980***	2.665***
	(0.233)		(0.099)	
state: MO	-0.678*	0.508*	-0.979***	0.376***
	(0.371)		(0.209)	
state: NJ	-0.741	0.476	-0.993***	0.371***
	(0.459)		(0.295)	
state: NY	-0.549**	0.578**		
	(0.265)			
state: OH	-0.483	0.617	-1.168***	0.311***
	(0.335)		(0.197)	

Table 6 (continued)

	Model 3		Model 4	
Variables	Coeff.	I.R.R.	Coeff.	I.R.R.
Age of operator	0.011**	1.011**	0.008***	1.008***
	(0.004)		(0.002)	
Vessel's number of engines	-0.412*	0.662*		
	(0.249)			
opexpermore100			-0.418***	0.658***
			(0.082)	
Vessel was rented			-0.256**	0.774**
			(0.125)	
AirTemperature			-0.003	0.997
			(0.004)	
Horsepower			-0.002***	0.998***
			(0.000)	
Canoe type			0.624***	1.867***
			(0.134)	
state: IA			1.280***	3.596***
			(0.467)	
state: IL			0.931**	2.538**
			(0.456)	
state: LA			1.745***	5.725***
			(0.117)	
state: MD			-0.672***	0.511***
			(0.178)	
state: PA			0.409***	1.506***
			(0.130)	
state: SC			1.112***	3.039***
			(0.236)	
state: UT			-0.787*	0.455*
			(0.453)	
Constant	2.815***	16.694***	2.708***	15.006***
	(0.683)		(0.402)	
R-squared	0.268		0.330	

p<0.10, ** p<0.05, *** p<0.01

Table 8: Determinants of cause of death

Dep. Variable: Cause of Death	Coeff.	Odds-Ratio	Marginal Effect
Drowning			
Deceased wore PFD	-0.773***	0.462***	-0.092***
	(0.191)		(0.018)
Deceased used Alcohol	0.311	1.365	-0.047**
	(0.285)		(0.021)
Deceased Age	-0.034***	0.967***	0.000
	(0.006)		(0.001)
deceased Role: operator	0.355	1.426	0.197***
	(0.491)		(0.037)
deceased Role: passenger	-0.014	0.986	0.085**
	(0.494)		(0.034)
Constant	5.334***	207.176***	–
	(0.825)		–
Other	Ref.	Ref.	Ref.
Trauma			
Deceased wore PFD	-0.278	0.757	0.061***
	(0.214)		(0.016)
Deceased used Alcohol	0.771**	2.162**	0.064***
	(0.304)		(0.018)
Deceased Age	-0.048***	0.953***	-0.002***
	(0.006)		(0.000)
deceased Role: operator	-1.023**	0.359**	-0.193***
	(0.506)		(0.032)
deceased Role: passenger	-0.722	0.486	-0.091***
	(0.507)		(0.026)
Constant	3.754***	42.688***	–
	(0.888)		–
R-squared	0.065		
N	2019		

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