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A Quantitative Analysis of Seaplane Accidents from 1982-2021

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Seaplanes, a class of aircraft that can float, land, and take off on water, have been a part of aviation since the industry's inception. Seaplanes combine two modes of transportation (i.e., air and sea) and the requisite skills to conduct such operations. Thus, seaplane flying can be one of the more challenging endeavors in aviation. As noted in chapter 7-5-8 of the *AIM*,

> acquiring a seaplane class rating affords access to many areas not available to landplane pilots. Adding a seaplane class rating to your pilot certificate can be relatively uncomplicated and inexpensive. However, more effort is required to become a safe, efficient, competent “bush” pilot. The natural hazards of the backwoods have given way to modern man-made hazards. Except for the far north, the available bodies of water are no longer the exclusive domain of the airman. Seaplane pilots must be vigilant for hazards such as electric power lines, power, sail and rowboats, rafts, mooring lines, water skiers, swimmers, etc. (Federal Aviation Administration [FAA], 2022a)

Further explanation about the complexity of seaplane flying is provided by Xiao et al. (2020), with the authors noting that the

> seaplane operation process starts and ends in water aerodromes… seaplanes have no brakes, once a seaplane casts off or is untied, wind will keep the seaplane in constant motion…furthermore, wind has a significant impact on the direction of the seaplane. (p. 888)

especially because there is no “traction” provided by wheels on pavement. Another complicating issue for seaplane pilots is the requirement to comply with many of the right-of-way rules applicable to boats while the seaplane is operating on the water. Amphibian pilots must regularly make the mental shift from conducting land to sea operations or vice versa. The versatile proficiency as both aircraft and “boat” operator required of a seaplane operator demands “a higher pilot standard” (Seaplane Pilots Association [SPA], p. 11). This is because

> seaplanes operate largely outside the structured framework of our air transportation system. It is thus very versatility, this freedom of choice, that must provide the basis for holding seaplane pilots to an unusually high standard, for along with increased freedom comes heightened responsibility. For instance, a pilot departing a land airport often has the benefit of a weather-condition report including winds, temperature and even comments from other pilots. Departing, however, from a remote waterway leaves the seaplane on his own to observe and make judgments about water, wind and weather conditions and about his personal ability and that of his aircraft relative to them. (SPA, 1996, p. 11)

Beyond the aforementioned generalization concerning the requisite skills of seaplane pilots, these pilots must exhibit exemplary judgment:

> Operating a seaplane requires a unique combination of mechanical skills and judgment… The judgment necessary to safely operate a seaplane, considering the wide-ranging conditions seaplane pilots are likely to encounter, cannot be over emphasized. (SPA, 1996, p. 11)

Seaplane operations are especially challenging for several other reasons, such as the typically remote nature of its flying, the lack of air traffic control and weather services, harsh operating environments (both for the pilots and the aircraft), limited available facilities as seaplane bases and services, the scarcity of modern seaplanes and innovative technologies, and the highly seasonal nature of operations. While this list is not exhaustive, it highlights some additional challenges seaplane operators face in day-to-day operations (Gobbi et al., 2011).

Just as seaplane flying differs from landplanes, one might expect that seaplane operations have certain distinctive variations in levels of safety, accident causality, and lethality. Unfortunately, little operational and safety data, specifically on seaplane operations, exist. Few studies have been conducted over 25 years old, with the majority of research originating in Canada. From the limited available research, it appears that seaplanes have a higher rate of accidents than land planes. According to the Transportation Safety Board of Canada (TSB) (1993), 17% of seaplane accidents were fatal versus 10% among land planes of the same or similar type. At least part of the reasoning behind the difference was described in the TSB study on the survivability of seaplane accidents, in which almost 50% of accidents terminated in the water. Among these in-water accidents, only 10% of individuals were able to escape from the aircraft “unhampered,” while 26% were only able to escape “with difficulty,” and 44% did not escape (TSB, 1994).

Considering the distinctive nature of seaplane operations and the safety implications thereof, coupled with the lack of recent and comprehensive seaplane safety data, the need for an in-depth inquiry into seaplane safety was evident. This study sought to provide a comprehensive analysis of historical seaplane accident data.

Literature Review

A review of the available literature is provided to provide adequate context and potential for comparisons within safety data. This review includes an overview of general aviation accident data. Although there historically have been limited inquiries into seaplane safety, available studies are described. Also, existing models of accident and incident analysis are outlined to provide the background and basis for adoption for use in this study.

General Aviation Accidents

Since 1997, the most prominent general aviation accident report is the Joseph T. Nall Report generated by the Aircraft Owners and Pilots Association (AOPA) Aviation Safety Institute (ASI). This report provides an up-to-date analysis of general aviation accident data on a 30-day rolling cycle. According to the report’s preamble, it covers 99%

of general aviation flight activity in the United States. Accident rates outlined in the report are calculated per 100,000 flight hours as measured by the FAA's General Aviation and Part 135 Activity Survey. Although the FAA survey provides detailed data on flight operations based on category, class, purpose of flight, and other factors, there is no breakout provided for seaplane or amphibious operations. A primary takeaway from the report is the analysis of trends in the data and factors of prominent concern to overall flight safety (AOPA, n.d.).

The number of overall general aviation accidents has remained relatively stable over the period between 2015-2019, as has the overall rate of general aviation accidents. While there have been some small fluctuations in the numbers and rates of fatal accidents, these did not vary statistically significantly during this period.

In 2019, 1,169 general aviation accidents were fatal, of which 18.1% were fatal. In 2019, the overall accident rate per 100,000 hours was 4.88, and the overall fatal accident rate was 0.88. The report subdivides accident data further, showing the information specific to non-commercial and commercial fixed-wing general aviation operations. During the 2015-2019 period, the number of non-commercial accidents (988), fatal accidents (179 or 18.1%), accident rates (5.62), and fatal accident rates (1.02) did not significantly vary. During the same period, the number of commercial accidents (57), fatal accidents (10 or 17.5%), accident rates (1.68), and fatal accident rates (0.3) did not vary at a statistically significant level.

Combining commercial and non-commercial accidents into a comprehensive fixed-wing group, there were 1,045 accidents, of which 189 (18.1%) were fatal. The majority (61.9%) of the accidents in fixed-wing operations were attributed to the pilot. Most fixed-wing accidents (69.5%) occurred in single-engine fixed-gear aircraft. Among fatal accidents, pilots were faulted in 48.1% of cases, and 56% occurred in single-engine fixed-gear aircraft. Another highly prevalent factor among accidents was that they were most likely (82.8%) to occur during day VMC conditions. Fatal accidents were also most likely (61.4%) to occur during day VMC. Among non-commercial accidents, the pilot was most likely to have a private pilot certificate (44.1%), including fatal events (41.4%). Among commercial accidents, the pilot was most likely to have a commercial pilot certificate (73.6%); the same was true for fatal events (60%) (AOPA, n.d.).

Because the primary type of seaplane operations involves fixed-wing aircraft, these data will be the focus of discussion and used for comparison purposes in the results section of this report.

Seaplanes and Seaplane Accidents

Although there has been regular reporting of general and commercial aviation safety, minimal detail is available specifically for seaplane operations. The Seaplane Pilots Association produced the last comprehensive analysis conducted in the U.S. in May 1996. The report included data from a review of NTSB records about seaplane accidents from 1983 through 1995. Over this 13-year period, 338 accidents involved "aircraft that, *due to their configuration at the time,* were capable of water operations" (SPA, 1996, p. 4) and occurred within the United States, its territories, or possessions. Among these events, 195 were relevant to seaplane operations in the water environment. The accidents involved 438 persons, with 54 total fatalities (SPA, 1996).

Unfortunately, there were several deficiencies in the data available from the SPA (1996) report. One is that while the total number of fatalities for seaplane accidents was provided, the number of fatal accidents were not. Thus, the comparison with general aviation fatality values is not possible. Further complicating the utility of seaplane accident information is that "determining the exact number of seaplanes and seaplane pilots in the United States and their levels of activity is a challenge" (SPA, 1996, p. 3). The reasons for this are threefold: 1) some aircraft are not permanently seaplanes, with configuration changes being made over the lifetime of the aircraft or even seasonally, 2) the number of seaplane-rated pilots does not equate to the number that are active seaplane operators, and 3) recreational and non-scheduled commercial seaplane activity is not required to be tracked or recorded. As a result of these factors, meaningful comparison between seaplane accident data and general aviation as a whole is questionable.

The SPA (1996) report determined the most common contributing factors among the studied seaplane accidents. The top six factors were:

1. Improper technique or procedures
2. Water landing with wheels extended
3. Poor weather/gusty winds
4. Glassy water
5. Striking a submerged object
6. Rough water

It was also determined that pilot technique or judgment were factors in the accidents in 138 (72%) of the 195 accidents. Over half (52.8%) of seaplane accidents were concentrated within three states: Alaska, Florida, and Washington (in order of prevalence). The top five aircraft most involved in accidents were found to be:

1. Lake Amphibian
2. Cessna 185
3. Cessna 206
4. De Havilland Beaver
5. Cessna 180 (SPA, 1996).

A number of conclusions were offered in the report. One was that seaplane flying "requires a higher pilot standard" (SPA, 1996, p. 11). Because of the various conditions and environments in which seaplanes must operate, a specialized skill set is needed beyond that required among landplane-only pilots. Personal freedoms inherent to the remote nature of much of seaplane flying possibly contributed to breakdowns in cockpit discipline. Instances of improper procedures or the omission of checklists were found to be more common in the “freedom’ environment” (SPA, 1996, p. 11) associated with remote or bush flying (Mondor, 2021).

The Transportation Safety Board of Canada (TSB) is the only significant source of seaplane-specific accidents. Even in light of the comprehensive nature of the data, it is rather outdated. The *Aviation Safety Study SSA9301: A Safety Study of Piloting Skills, Abilities, and Knowledge in Seaplane Operations* published in 1993 provided an assessment of seaplane accidents, contributing factors, pilot attributes, and details of the seaplane operating and regulatory environment. A significant limitation to the findings of this report, much like that of the SPA, is the lack of reporting requirements. The number of hours flown by seaplanes and current seaplane pilots is essentially unknown. These limitations prevent meaningful comparisons with other types of flight operations using statistics such as accident rates per 100,000 flight hours (TSB, 1993).

This study examined 1,432 seaplane accidents from 1976 to 1990. The TSB (1993; 1994) found that seaplanes make up approximately 19% of the Canadian aircraft fleet and are involved in 18% of aircraft accidents. This statistic seems to align with expectations based on equity among operational types and conditions. However, it was noted that seaplane operations are concentrated within a six-month (or less) period when the weather is favorable. Thus, the monthly accidents would theoretically be more serious (i.e., more frequent). Seaplane accidents were evenly split between approach/landing (34%) and takeoff (35%). Enroute accidents accounted for 23% of events, while standing/taxiing made up the rest. The TSB also noted that just over 20% of enroute accidents were classified as VFR into IMC accidents. The most frequent types of seaplane accidents (excluding enroute) were:

1. Loss of control (air or on the surface)
2. Engine failure
3. Collision with object
4. Dragging wing
5. Nose down/nose over
6. Hard landing

Besides identifying the general type of accident, contributing factors were also determined. The most frequently occurring contributing factors were:

1. Failure to obtain/maintain speed
2. Unsuitable area for takeoff, landing, or taxi
3. Unfavorable wind
4. Improper wind compensation
5. Improper landing flare
6. Inadequate preflight preparation
7. Failure to follow procedures/guidance
8. Operation beyond ability
9. Obstructions/objects

10. Glassy water conditions

Each combination of the phase of flight, accident type, and contributing factors were found to have commonalities. Among loss of control accidents on takeoff, those occurring on the water were most likely related to the wind (improper reaction to wind or unfavorable wind), while those in-flight during takeoff were related to "lack of skill or knowledge." Examples included failure to maintain speed and improper operation of controls. For accidents during approach and landing, blame mostly fell on failure to take proper action by stalling, misjudging the flare, or erroneously responding to wind conditions (TSB, 1993).

Pilot attributes were examined as well. Most accident pilots (54%) held a private pilot certificate, while 43% held a commercial. Most accidents occurred when the pilot has less than 100 hours in seaplanes. The number of accidents decreased as seaplane hours increased over 100 hours, with incidence leveling off at and above 500 hours. Among low-time pilots (100 hours in the same configuration), these individuals were involved in 17% of landplane accidents while being involved in 21% of seaplane accidents (TSB, 1993).

The TSB report analyzes the deeper nuances inherent to seaplane and bush operations. This exploration provides compelling insights into potential human factors issues among seaplane pilots outside Canada. It was clear that the TSB felt that "by their nature, seaplane operations require a high degree of independence of problem-solving" (TSB, 1993, sec. 7.0), and therefore, it was not surprising that breakdowns in judgment and procedural compliance lead to problems. The remote nature of seaplane operations – in Canada in particular – has led to "a distinct operating culture" that is not "always consistent with safe flight operations" (TSB, 1993, sec. 7.1). Examples of disregard for rules and operating procedures were outlined in the report with the conclusion that "tips from friends, hearsay, local recipes, and tricks are sometimes being followed by some seaplane pilots… learning from the experience of other pilots may also lead to the propagation of unsafe practices" (TSB, 1993, sec. 7.1).

The TSB noted that Canadian training and experience requirements are questionable because there was a high "frequency and severity of seaplane accidents involving pilot knowledge, skills, and techniques, as well as judgment and decision making" (TSB, 1993, sec 7.2-7.3). Transport Canada acknowledged that enhancements to seaplane flight training materials and recommendations for mentoring training during the early stages of experience were warranted. Proficiency issues were reviewed as potentially weighing on safety as "seaplane operations are conducted during the months of May to October…Consequently, the maintenance of currency in techniques for taking off from and landing on water surfaces suffers…traits which can erode with the passage of time" (TSB, 1993, sec. 7.4-7.5). Transport Canada recommended improved training, specific recency of experience for seaplane operations, and additional seaplane endorsements (TSB, 1993).

In a separate analysis of the same 1,432 accidents during the 1976-1990 period, the TSB (1994) released *Report Number SA9401: A Safety Study of Survivability in Seaplane Accidents.* There were 234 (16.3%) fatal accidents in which 452 people died. It was evident that the survivability of seaplane accidents that terminate in the water is somewhat concerning. Only about 8% of individuals were able to escape from an aircraft post-accident unhampered. Among those who perished, 70% of passengers and 78% of pilots were trapped inside the aircraft. The cause of death of those in the aircraft was drowning in 67% of cases for both passengers and pilots. Most of those who perished after escaping the wreckage died of drowning (86%). Contributory issues related to the large volume of drownings were the lack of use of shoulder restraints, especially among pilots, and the improper briefing of passengers (TSB, 1994).

Passengers were not educated on ways to escape the aircraft in case of an accident, nor were they often instructed on using personal floatation devices. Cabin loading issues were also noted to be an issue in some cases. With loads within the cabin, there was an increased risk that cargo may shift in a crash injuring passengers or inhibiting their ability to escape. Recommendations of the TSB highlighted the need for increased use of seatbelts, more stringent enforcement of regulations, and improvements to passenger briefings (TSB, 1994). The FAA (1999) outlines similar best practices in *Advisory Circular AC91-69A.*

FUESTRA, a European Union-funded project on the future of seaplane traffic, produced a SWOT analysis of the future of seaplane transportation globally with an emphasis on Europe. While most of this report covers subjects beyond this project's scope, there were some relevant issues raised on the weaknesses of seaplanes. It was noted that almost all aircraft in use are land-based aircraft converted to seaplane or amphibian configurations. The bulk of aircraft in use was designed 40 to 50 years ago. Seaplanes often operate in harsh environments with water and salt contributing to corrosion and other types of damage. Furthermore,

> existing float planes are not competitive comparing to state-of-the-art aircraft designs – neither in its performance nor its cost effectiveness . The seat layout and the available space for luggage is not really passenger-friendly. The maintenance cost is high and spare parts have sometimes long lead-times. (Gobbi et al., 2011, p. 32)

The primary threat to the development of replacement aircraft is that the market is extremely limited: “this niche market is not large enough to compensate the investment for development and certification of new products” (Gobbi et al., 2011, p. 37). Therefore, in the near term, at least, there are unlikely to be any changes to seaplane operational paradigms.

AIN reported a problematic safety issue concerning commercial seaplane oversight in Alaska in 2021. The article summarizes the FAA’s actions as full of “disfunction and neglect” (Mondor, 2021, sec. 5). The NTSB faulted FAA oversight practices in recent accidents involving several commercial operators in Alaska. In more than one instance, the FAA assigned a Principal Operations Inspector based in South Carolina to oversee companies in Alaska. POIs were also found to be overtasked, responsible for overseeing 25 to 40 operators scattered over broad geographic areas.

In some cases, inspectors only visited an operator once. Exacerbating the issues highlighted by the NTSB was that one large seaplane operator's director of flight operations had multiple jobs and was mostly absent from duty. Again, this slipped through the cracks of FAA oversight, all of which was deemed to be contributory to more than one accident. These revelations reinforce that increased oversight is a recommendation by Canadian and American safety officials. It further underscores the existence of operational cultures of remote operators that may not always align with safety best practices (Mondor, 2021).

Considering the unique nature of seaplane operations, it should be no surprise that insurance for these aircraft comes at a premium. Unfortunately, for seaplane operators, this means higher insurance costs. There is a range of reasons why such rates are so high (and going higher); however, this is in part due to the complexity of operating a seaplane as well as the typical operational environments in which seaplanes operate. This reiterates the fact that seaplane safety may differ from general aviation as a whole. Thus a study focused on the safety of this niche would benefit the seaplane and research communities (SPA, 2021).

As evidenced in the above review, the data on seaplane safety is limited and outdated. Even considering this, there are notable commonalities within available records. There is little doubt that seaplane operations are uniquely different from their land-based counterparts. For instance, accidents involving seaplanes consistently involve water damage or complete loss. Seaplanes also tend to operate in more remote locations or those away services common to airports, all of which bring different challenges. The data outlined here provides some basis for comparison and discussion with broader data sets. Moreover, common causal factors noted in historical reports guide the qualitative analysis conducted within the current study.

Method

This report aimed to provide a comprehensive analysis of seaplane safety. A brief overview of the procedures used under each methodology is provided here.

Data Collection

Quantitative data from NTSB and FAA resources were collected for analysis. Quantitative data included numerical data such as pilot age and flight time. Also, count data was utilized to classify accidents and incidents into relevant categories. Data cleaning was conducted via Excel data queries. XLSTAT 2022 was used for all statistical analyses in this study.

NTSB

The aviation accident database was accessed to collect three downloadable datasets to ensure complete coverage of available date ranges. The downloaded datasets were avall.zip, PRE1982.zip, and Pre2008.zip (NTSB, n.d.). Data were available in Microsoft Access format.

FAA

The FAA Airman Inquiry was used to determine the number of individuals that hold a seaplane rating in the U.S. (FAA, n.d.a). Three databases were accessed from the FAA Aviation Safety Information Analysis and Sharing (ASIAS). Accident and incident data was harvested from FAA Accident and Incident Data Systems (AIDS). Aircraft registry data was accessed via the Air Registry (AR) to determine the numbers of seaplanes registered in the U.S. The NASA Aviation Safety Reporting System (ASRS) was used to access ASRS reports (FAA, n.d.b).

Procedure

Descriptive statistics on relevant data sources were calculated, providing a broad overview of the seaplane accident landscape. Data trends over time were analyzed to provide meaningful conclusions as to the significance of variations. While several statistical methods are available to evaluate trends, correlation is an intuitive measure. Correlation provides a positive or negative trend scale. For example, a positive correlation would be associated with increased accidents over time. The correlation scale ranges from 0 to 1, where zero equals no relationship or correlation exists, to the value of one, where a perfect correlation exists. The guidelines for the strength of correlations are as follows:

- 0-0.19 very weak,
- 0.2-0.39 weak,
- 0.40-0.59 moderate,
- 0.6-0.79 strong and,
- 0.8-1 very strong correlation (BMJ Publishing Group, 2022).

When statistically sound, comparisons were made between seaplane and other data. Whenever means or variance were unavailable for analysis, counts or proportions were used following apposite statistical techniques, i.e., non-parametric techniques were used instead of parametric options when appropriate. Effect sizes were calculated and converted into Cohen’s *d* as these are more readily used and interpretable in the statistical literature (Psychometrica, 2022). The interpretation of Cohen d is:

- d = 0.2 (small)
- d = 0.5 (medium)
- d = 0.8 (large) (Lakens, 2013).

Results

In an effort to provide data for meaningful comparison with other types of safety and operational data, an effort was made to quantify the number of seaplanes and seaplane pilots in the United States. While there was a significant amount of information about general aviation and air carrier operations collected via the FAA's survey programs, the utility of this data to the current study was limited. As has been noted as a limitation in other studies, since 2015, no entity in the U.S. reports the number of seaplanes, seaplane pilots, or the number of hours flown explicitly by seaplanes (note: the FAA still collects these metrics but suppresses its publication due to high estimates of error within the data). However, every effort was made to use other data sources to assist in discovering as much detail about seaplane operations as was feasible. This included evaluating the historical size of the U.S. seaplane fleet and estimated seaplane operating hours previously collected by the FAA's survey program.

Seaplane Pilots in the US

The airman registry was queried for pilot rating types. This was mined for individuals with a single-engine or multi-engine sea rating. Out of 675,356 pilots in the registry as of June 2022, 24,955 or 3.7% had such a rating. This closely matches the estimated 22,809 (3.4%) seaplane pilots provided by the SPA. Although the number of rated pilots is not an indicator of how actively they use their ratings, the percentage of seaplane pilots can be used for a rough comparison with other types of operators. At the very least, these values could serve as index points for further study.

Seaplanes in the US

The calculation of the number of seaplanes in the US is challenging for several reasons. One is that most aircraft used as seaplanes in the US are derivatives of makes and models of landplanes. For example, in several cases, a Piper J-3 Cub was originally designed as a landplane but has been converted for use as a floatplane. It is not uncommon for an aircraft to be registered as a landplane, yet it is configured as a seaplane (float or amphibian). It is also possible that an aircraft can be configured in various landing gear formats depending upon the season. For example, an aircraft may be on skis or wheels in colder months but on floats in the summer. The landing gear configuration in the aircraft registration database may not match what we currently installed on the aircraft. As of June 2022, the U.S. aircraft registry had 287,769 aircraft. A search of the aircraft registry indicated a total of 3,456 potential seaplane make and models. However, the total number of aircraft registered as seaplane or amphibian was 2,986, or 1% of the registered aircraft. This is slightly less than the FAA historical average of 3,609 or approximately 1.7% of the total aircraft fleet and 3,096 or 1.9% of fixed-wing aircraft.

This value underestimates the number of seaplanes available from alternative sources, albeit anecdotal in most cases. For example, the SPA estimates that there are approximately 8,000 seaplanes in the US. The aviation insurance industry estimated that there are between 5,000 and 10,000 seaplanes. Even in light of this estimate, one insurer noted that less than 1% of insured units were seaplanes. Looking to Canada for guidance, recall that 19% of their aircraft were seaplanes in the outdated report cited in the literature review. However, there is no evidence that seaplanes have been or currently are at such plentiful levels in the U.S. (FAA, 2022b).

Seaplane Hours Flown in the US

Since 2015, as previously noted, there is no available reporting of the number of hours flown by seaplanes in the US. Seaplane activity has historically averaged 1.5% of total reported hours, or 350,796 hours and, for fixed-wing only, 1.6% or 297,740 hours. When reviewing the 2019 FAA general aviation and charter operations estimates, there were 25,566,000 total hours flown. The number of estimated hours flown by single-engine piston fixed-wing aircraft was 12,700,000 hours. Using the estimates for seaplanes and seaplane pilots, a plausible range for operational hours would likely fall between the total (383,490) and fixed-wing values (203,200). See Figure 1, which shows the percentage of seaplanes and seaplane hours flown versus total reported aircraft in the U.S. over the most recent five years (FAA, 2022b).

Analysis of Data from Most Recent 10 Years (2012-2021)

The total number of accidents for the last 10 years (2012-2021) was analyzed next. A graph of the number of accidents for each year is provided in Figure 2. The trend is shown as a dashed line. Kendall *tau* rank correlation was calculated for this period and found to be negligibly negative ($\tau_\beta = -0.094$). A Dixon *Q* test for outliers was conducted to ensure that this value falls well outside expectations. No values were determined to be outliers ($p = 0.709$, see Figure 3 for *z*-scores of values).

The number of fatal seaplane accidents is displayed in Figure 4. The linear trend was moderately negative ($\tau_\beta = -0.414$), and no outliers were noted (see Figure 5). Figures 6 and 7 show the annual fatal accidents and the annual fatalities.

Comparisons were made among three pilot samples extracted for the years 2012-2021:

1. Seaplane accident pilots
2. Non-Seaplane accident pilots
3. Non-accident pilots

Differences in total flight time, age, and gender were analyzed across groups. Because the data did not meet assumptions for parametric analysis, non-parametric assessments were utilized. A Kruskal-Wallis test with Dunn procedure for pairwise analysis was conducted. There were significant differences in total flight time among the pilot groups, $H(2) = 43.878$, $p < 0.0001$, $d_{Cohen} = 0.098$. The mean flight time for each group is provided in Table 1. Specific groups that were significantly different are shown in Table 2.

There were also significant differences among the ages of pilots, $H(2) = 25.365$, $p < 0.0001$, $d_{Cohen} = 0.073$. The mean age of pilots in each group is provided in Table 3. Specific groups that were significantly different are shown in Table 4.

A Chi-square Test of Independence was conducted on the basis of gender for all three pilot groups. The variables of gender and group are independent, $\chi^2(2) = 0.027$, $p = 0.987$, $d_{Cohen} = 0.002$.

There were no significant differences found between seaplane accident pilots and non-seaplane accident pilots when examining the number of hours in Make and Model of aircraft, $U = 7683081$, $p = 0.077$, $d_{Cohen} = 0.565$. Table 5 shows the mean Make and Model flight time for each group.

The five seaplane makes and models with the highest incidence of accidents from 2012-2021 were:

1. De Havilland DH-2
2. Cessna A185
3. Cessna 180
4. Piper PA-18
5. Maule M-7

The event sequences that occurred most frequently from 2012-2021 (ties are noted with *) for seaplanes and non-seaplanes are shown in Table 6. The most frequent causes from 2012-2021 (ties are noted with *) for seaplanes and non-seaplanes are shown in Table 7.

Next, a comparison of accident rates per 100,000 hours was made between non-commercial fixed-wing non-seaplanes versus non-commercial fixed-wing seaplanes. A Mann-Whitney *U* test was conducted on the rates from 2012-2019. There was no significant difference noted, $U = 47$, $p = 0.130$, $d_{Cohen} = 0.546$. A graph juxtaposing the rates is shown in Figure 8.

Analysis of Data from Most Recent 40 Years (1982-2021)

The total number of accidents for the 40-year period from 1982 to 2021 was analyzed next. At the time of data collection, 2021 was the last year with complete, verified accident data. A graph of the number of accidents for each year is provided in Figure 9. The trend is shown as a dashed line. Kendall *tau* rank correlation was calculated for this period and found to be very strongly negative ($\tau_\beta = -0.700$). A Dixon *Q* test for outliers was conducted to ensure that this value falls well outside expectations. Only the counts from 1987 and 1988 were determined to be outliers (see Figure 10 for *z*-scores of values).

The number of fatal seaplane accidents is displayed in Figure 11. The linear trend was strongly negative ($\tau_\beta = -0.795$), and no outliers were noted. The annual numbers of fatalities are shown in Figure 12.

Comparisons were made among three pilot samples extracted for the years -2021:

1. Seaplane accident pilots
2. Non-Seaplane accident pilots
3. Non-accident pilots

Differences in total flight time, age, and gender were analyzed across groups. Because the data did not meet assumptions for parametric analysis, non-parametric assessments were utilized. A Kruskal-Wallis test with Dunn procedure for pair-wise analysis was conducted. There were significant differences in total flight time among the pilot groups, $H(2) = 244.715$, $p < 0.0001$, $d_{Cohen} = 0.207$. The mean flight time for each group is provided in Table 8. Specific groups that were significantly different are shown in Table 9.

There were also significant differences among the ages of pilots, $H(2) = 64.499$, $p < 0.0001$, $d_{Cohen} = 0.293$. The mean age of pilots in each group is provided in Table 5. Specific groups that were significantly different are shown in Table 10.

A Chi-square Test of Independence was conducted on the basis of gender for all three pilot groups. The variables of gender and group are independent, $\chi^2(2) = 0.860$, $p = 0.634$, $d_{Cohen} = 0.021$.

There were significant differences found between seaplane accident pilots and non-seaplane accident pilots when examining the number of hours in Make and Model of aircraft, $U = 5519578$, $p = 0.012$, $d_{Cohen} = 1.958$. Table 11 shows the mean Make and Model flight time for each group.

The five seaplane makes and models with the highest incidence of accidents from 1982-2021 were:

1. De Havilland DH-2
2. Cessna A185
3. Cessna 180
4. Piper PA-18
5. Lake LA-4

The top accident event sequences and causes for 1982-2021 are displayed in Tables 12 and 13. The geographic distributions of accidents for this period are mapped in Figure 14.

Discussion

During the most recent five years, there was a moderately negative decline in all accident types. Specifically, fatal, serious, and no injury accidents had negative linear trend slopes, while minor injury accidents showed a positive slope.

A statistical test was conducted that identifies if the actual percentage of occurrences matches the expected percentages. The test (Chi-square Goodness-of-Fit) determines if the percentage of seaplane accidents that occurred aligns with the expected percentage of 1.7% (calculated as described previously). In 2019, the percentage of actual accidents was statistically significantly larger than expected for both total and fatal accidents. There was no difference for 2017, 2018, 2020, and 2021.

This data indicates that, for the most part, anecdotal discussion about increasing seaplane accidents or disproportionate accident counts is not well-founded in the data. Over the past five years, the evidence clearly shows the contrary: decreasing numbers of accidents that align with historical expectations.

Next, comparisons were made among seaplane accidents, non-seaplane accidents, and non-accident pilots. The first two metrics were extracted from the NTSB database, while the non-accident pilot data was derived from the dataset from a previous study (Ison, 2015). There were statistically significant differences in flight time and age. From

2017-2021, seaplane pilots had higher total time than non-seaplane and non-accident pilots. Further, seaplane pilots were older than both groups (although the seaplane-non-seaplane comparison was not statistically significant [*p* = 0.06], it was practically so since it was so close to *p* = 0.05) (Kline, 2013). Total time in type was statistically lower for seaplane vs. non-seaplane accident pilots. Gender did not appear to be a significant factor.

The top five aircraft makes involved in accidents were Cessna (A-185 and 180), de Havilland (DH-2), and Piper (PA-12 and PA-18). There was some overlap between a seaplane and non-seaplane accident event sequences, with landing-roll issues and controlled flight into terrain (CFIT) appearing in both lists, although the context of each was slightly different (see Table 8). The top accident causes were similar between these groups as well. The number one cause for both groups was aircraft control issues at the hands of pilots. Second place was also shared with directional control not being maintained. The third spot also had some intersections, with pilot judgment errors being the source of trouble.

Discussion for 2012-2021

The linear trend for all seaplane accidents from 2012-2021 was negative but less convincingly than during 2017-2021. During this period, the trend for fatal seaplane accidents was downward. Again, comparisons were conducted among seaplane accidents, non-seaplane accidents, and non-accident pilots. Broader significant differences were noted. Seaplane accident pilots had statistically significantly more total flight time than non-seaplane and non-accident pilots. Seaplane pilots were also older than the pilots in the other two groups. When comparing seaplane to non-seaplane pilots, there was no statistical significance. In contrast, it can be argued that the difference may have practical significance, considering *p* = 0.077.

From 2017-2021, the top five makes of aircraft involved in accidents were de Havilland (DH-2), Cessna (A185 and 180), Piper (PA-18), and Maule (M-7). Most of the top aircraft listed in this range match that during the most recent five years, yielding more solid conclusions. Considering that these are fairly commonly used makes and models, it would be helpful to know how many of each are operated as seaplanes to put these hierarchies into a holistic perspective.

There were two overtly similar accident event sequences within the top five lists for seaplane and non-seaplane events: CFIT and loss of control during landing. Interestingly, the top seaplane accident event sequences were almost exclusively during landing or takeoff. In contrast, takeoff sequences were not even within the top five in non-seaplane accidents. Remarkably, the top four accident causes were shared, in sequential order, between aircraft groups. The number one cause in both groups was erroneous task performance-aircraft control by the pilot. Also shared between the two groups were judgment blunders. The compelling aspect of these particular findings is that in terms of causes, seaplane and non-seaplane accidents were quite similar.

Because of the availability and distribution of data, estimated accident rates per 100,000 hours were calculated (per the 1.7% assumption) for seaplanes and compared to those of non-seaplanes between 2012 and 2019. No statistically significant differences existed. This finding contradicts anecdotal theories that seaplanes are more dangerous than non-seaplanes.

Discussion for 1982-2021

Over the past 40 years, seaplane accidents, just like accidents in general aviation, have declined significantly. Statistically, the trend was distinctly downward. Of note is that two years, 1987 and 1988, were determined to be outliers with accident counts above what would fall within a normal (expected) distribution. The reasoning for these discrepancies was not evident from the available data thus, it may warrant future investigation. Encouragingly, the trend for fatal seaplane accidents was also markedly downward. The number of fatalities per year varied greatly, oddly displaying a 10 to 12-year cycle.

Comparisons among seaplane accidents, non-seaplane accidents, and non-accident pilots were performed. Seaplane pilots were found to have significantly higher total flight time and older than their non-seaplane counterparts. When examining the distributions of pilot genders, there was no difference discovered. Within this time period, seaplane accident pilots were found to have significantly lower time in aircraft type.

The top five seaplanes shared all but one makes with other timeframes, with de Havilland, Cessna, and Piper populating the list. The only difference was position five, with Lake LA-4 being substituted for the Piper PA-12 and Maule M-7 in other ranges. The aircraft that do appear on all the lists are not necessarily indicative of a problem with the aircraft. Instead, they are the most popularly utilized types of seaplanes. The seaplanes that *do not* appear on all the lists may warrant additional investigation to see how the accident prevalence of that make and model stack up against the overall use of the aircraft.

Upon examination, the top accident event sequences were conspicuously dissimilar. The non-seaplane accidents primarily were incurred during landing and in the fifth position was a loss of engine power during cruise. Seaplane accidents were concentrated within takeoff and climb operations, with loss of control being a common thread that was not shared with the non-seaplane group. The number two spot was landing with the landing gear not appropriately configured. Accidental water landings with the gear down were unmistakably occurring far too frequently. Most troubling is the catastrophic nature of gear down water landing accidents as they almost always result in aircraft hull loss and, as a result, loss of life.

The top accident cause for both groups was problematic pilot task performance-aircraft control. The remaining causes were somewhat similar, although, in some cases, they appeared in different positions within each list. One thought-provoking difference in the lists is that seaplane pilots appear to have a loss of control and deficient airspeed management more frequently. Not surprisingly, along with the aforementioned, seaplane pilots also incurred more frequent attention/monitoring errors.

The geographic distribution of accidents showed a concentration of events along the Atlantic, Pacific, Gulf of Mexico, and Great Lakes coasts. Additional locations were, not surprisingly, located on rivers, large lakes, and large urban areas (due to large numbers of aircraft operations, in general). Also surprising was the large number of accidents in Alaska, as the state is a hot spot for seaplane operations.

Because of the prevalence of gear-down water landings, trends in this type of accident were assessed for both the 2017-2021 and 2012-2021 periods. In the most recent 5 years, gear-down water landings decreased significantly, but looking at the broader period, there was a trivial decrease. These findings contrast anecdotal assumptions that these events are occurring more frequently in recent years.

Conclusion

The purposes of this report were to review all historical NTSB reports for seaplane accidents, determine primary, secondary, and any other notable factors and causes from the reports, review data from insurance underwriters with the same objective as above, and review of ASRS data to identify issues, causes, and trends, review of trends in accidents per category and themes, and make a comparison with non-seaplane data. Except under the circumstances where data was unavailable or distorted (described below), this report met the goals mentioned earlier in the project.

It should be noted that insufficient data was made available by insurers. The limited findings presented in this report almost exclusively were extracted from a presentation by an insurer endorsed by the Seaplane Pilots Association.

All historical NTSB accident reports since 1982 were extracted for analysis. The pre-1982 database was essentially unusable due to its organization and presentation. Attempts to meaningful data from these particular files caused numerous software crashes. Analysis was abandoned before potentially corrupting other software or files on the research computer. For analysis, reports were bisected into seaplane (float, amphibian, and hull) and non-seaplane groups. All ASRS reports mentioning seaplane, amphibian, or floatplane keywords were extracted for analysis. Primary and potential peripheral causes were identified from the data's quantitative and qualitative aspects. Trends in accidents were identified and presented. In relevant cases, seaplane data were compared to equivalent non-seaplane data.

Quantitative findings showed that there is a deficiency in the level of available detail on the seaplane fleet and cadre of seaplane pilots in the U.S. It is unclear as to how this could be rapidly corrected, but considering that the FAA continues to suppress seaplane details from its annual survey results, it is likely due to lack of response to the survey. Thus it would benefit the seaplane and research communities if a campaign by the Seaplane Pilots Association and similar local organizations would provide communication and outreach to promote the completion of the survey each year. It would also be beneficial if some amendments were made to the survey or the aircraft registration process to identify better the number of aircraft actively being utilized as a seaplane or the percentage of time it is being operated in that capacity. Leadership at the Seaplane Pilots Association communicated that they would be surveying their members to improve information about the numbers of pilots and their activity. This endeavor would help expand the findings of this study.

In the most recent five years (2017-2021), statistical analysis indicated a moderate decline in seaplane accidents of all severity levels. During the same timeframe, the number of seaplane accidents occurred at values aligned with expected quantities that were based on historical averages for all years except 2019. In 2019, the number of fatal accidents was higher than expected. More research is needed to determine why this may have been the case.

Next, data on seaplanes, non-seaplane accidents, and non-accident pilots were analyzed. Seaplane accident pilots had higher total flight time than the other groups and were older than non-seaplane accident pilots and, for practical purposes, older than non-accident pilots. Both attributes may speak to the demographics of the average seaplane pilot. It may be interesting to explore how much of this flight time was in seaplanes, as it is surmised that seaplane pilots are simply more experienced overall, i.e., with a significant amount of flight time in non-seaplanes. Seaplane accident pilots had a significantly lower total time in type than non-seaplane accident pilots. Possible explanations for this are that seaplane pilots only fly part of the year, fly seaplanes as a part-time or side job, tend to vary the aircraft type flown, or the pilot shortage could have led to lower time seaplane pilots in recent years. More research is needed to determine the reasoning behind this difference.

When comparing accident event sequences, it was noted that seaplane accidents tended to occur more frequently during takeoff but also shared some sequences during landings with non-seaplanes. It is hypothesized that the challenging nature of seaplane operations and their environment increase the complexity and risks associated with takeoff, thus the higher number of incidences during this phase of flight. Moreover, seaplane operations often occur in waterways constrained by shorelines, trees, and rising terrain.

The most recent 10 years of data showed a negative trend in all accidents and fatal accidents, although only the latter being statistically convincing. During this timeframe, seaplane accident pilots had significantly higher total time and age than other groups (non-seaplane accident and non-accident). Although *practically* (not statistically) significant, seaplane accident pilots had significantly more flight time in type than non-seaplane accident pilots. In both periods, the top accidents were de Havilland, Cessna, and Piper. This was not surprising considering the ubiquitous use of these makes as seaplanes. The view of accident event sequences delineated seaplanes and non-seaplanes further, with definitely higher numbers of accidents during takeoff among seaplanes.

An examination of the estimated seaplane accident rate per 100,000 hours vs. that of non-seaplanes was not significantly different. This provides further evidence that the assumption that seaplanes are involved in more accidents is simply anecdotal, although more research is required for a conclusive answer.

The 40 years spanning from 1982 to 2021 showed clear gains in seaplane safety, with all fatal accidents decreasing at pace. This appears to coincide with the overall improvements in aviation safety. Interestingly, the long-term difference between a seaplane and a non-seaplane accident pilot time in type shows that seaplane pilots have significantly lower hours. This could be partly because seaplane pilots are only flying part of the year, or the seaplane portion of their flying is a peripheral part of their flying. The top aircraft makes virtually unchanged across timeframes, with the top slots still going to de Havilland, Cessna, and Piper. This seems logical as the seaplane fleet has not seen a major upgrade during this period – new seaplanes are rarely introduced, and when they are, they are not purchased in large numbers. This is reflected by the fact that the fifth-place spot was a Lake amphibian. Recently, aircraft that have been fitted as seaplanes have joined the list, like the Maule amphibian.

The accident event sequences over this broader period reinforce the notion that seaplanes encounter more airborne loss of control events, especially during takeoff, climb, and landing. In particular, takeoff accidents were more prevalent. It is believed that the nature of seaplane operations is likely the reason for this, but it is also likely related to pilot experience issues. Interestingly, the top accident causes were similar, with the top spot in both groups being task performance-use of equipment/information-aircraft control by the pilot.

Assumptions

It was assumed that the data sources were valid and reliable. This is a typical assumption when using government databases as there is a range of quality assurance and auditing policies. In fact, the suppression of specific data by the FAA indicates that when data quality is deemed to be substandard, the information is redacted instead of being used in a way that could result in misleading or erroneous conclusions.

It was assumed that the research methodologies and designs were appropriate for the desired outcomes. The decisions to use these options were guided by exigent literature and research guidance commonly used by scholarly researchers.

It was also assumed that data extraction, cleaning, and sorting by the software were accurately executed, resulting in the data being presented in the expected formats. Data science best practices were utilized as a guide during this process and were assumed to be valid counsel.

Lastly, when assumptions for parametric statistical analysis could not be met, non-parametric alternatives were used per guidance from the research literature.

Limitations and Delimitations

This research had limitations that must be identified. One limitation was a problem with the pre-1982 portion of the NTSB database. This subset was highly disorganized and did not conform to the formatting of later data sets. Moreover, a different set of coding schema was used in the early database than in more recent sets. Another issue was that there were problems accessing some of the FAA survey findings. It is unclear as to why these issues were incurred or if they were temporary outages. The computational capabilities of the computer used in the study also limited the study. Unfortunately, there were several instances in which quantitative data analysis requests caused computer crashes or software issues that caused delays in data processing. The lack of FAA data on seaplanes, seaplane pilots, and seaplane operational hours made it difficult to compare with non-seaplane counterparts.

The goals of the study set the bounds of the study delimitations. These included the restriction of data to operations in the U.S. Also, upon noticing problems associated with the pre-1982 NTSB database, it was decided to exclude this subset. Only variables from the NTSB database were used for quantitative analysis. Data points that were not uniformly provided for omitted. For example, the variable BFR representing the pilot's flight review status was not widely notated, thus minimizing any utility from its collection and inclusion in the study. Therefore, similar types of data were omitted. Statistical analysis techniques used in this study were selected due to their use in similar studies or under similar circumstances within the scholarly literature. Qualitative analysis was restricted to the accident and incident narratives. The study was time-constrained due to the contract for the project. If more time was allowed, further quantitative and qualitative aspects could have been explored.

Author's Note

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Recommendations

The results of this study indicated recommendations for future research that include:

- Continued quantitative analysis of datasets used in this study
- The conduct of a broader study to explore similar aspects of another subpart of general aviation
- The use of a computer with higher processing capabilities to evaluate all datasets

Other recommendations include:

- Use of the findings from this study to improve seaplane education and training
- Prompting the FAA to help rectify the reasons that seaplane data is no longer presented

- Create a central repository for user-friendly accident and incident data that uses standardized coding and does not require data extraction, cleaning, and analysis for utilization.

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Appendix

Figure 1

Percentage of Aircraft and Hours Flown: Seaplanes

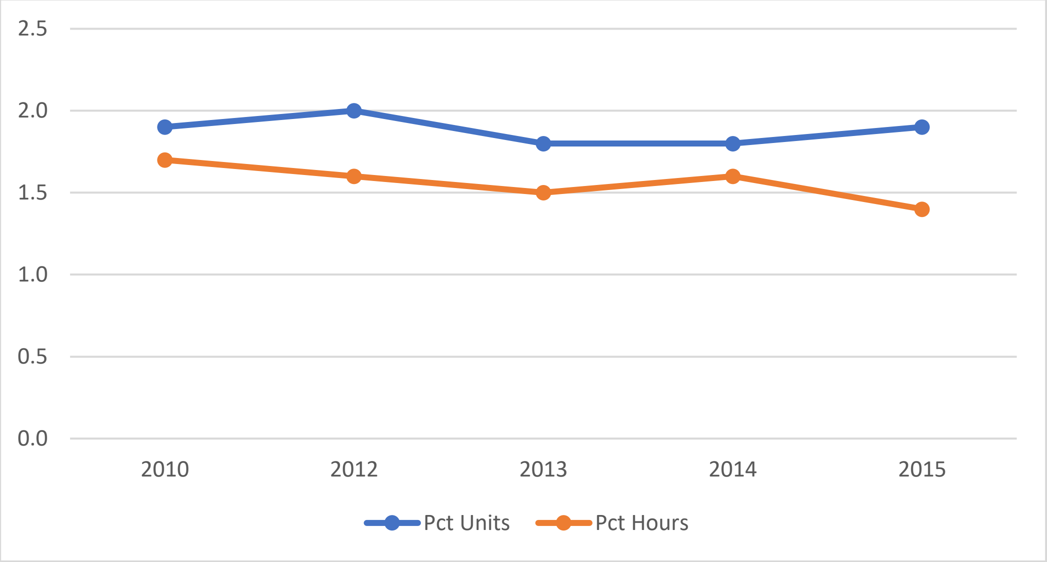


Figure 2

Total Number of Seaplane Accidents Per Year 2012-2021

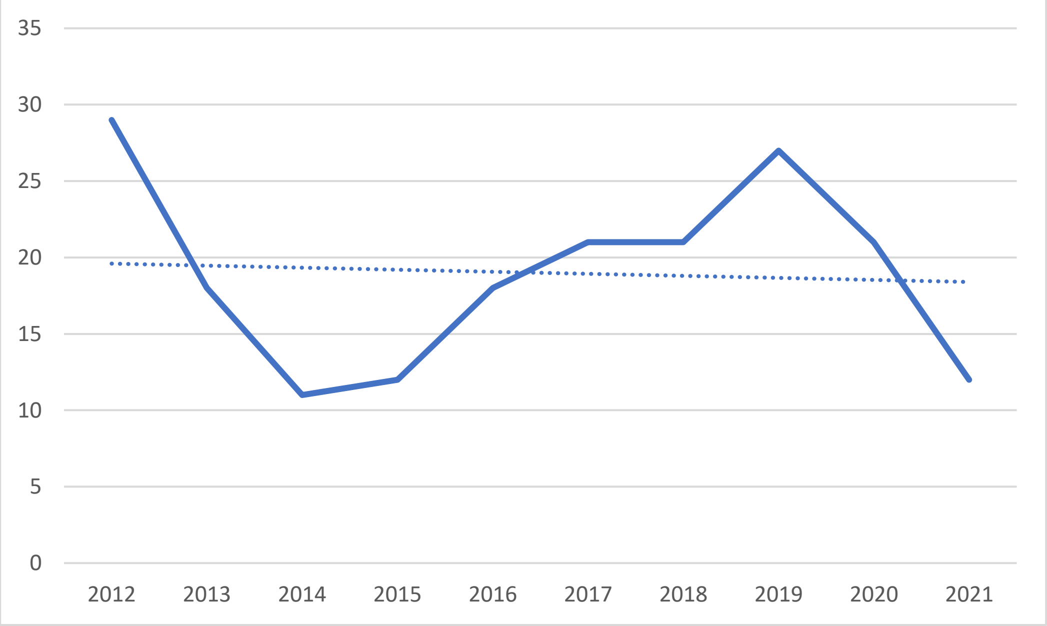
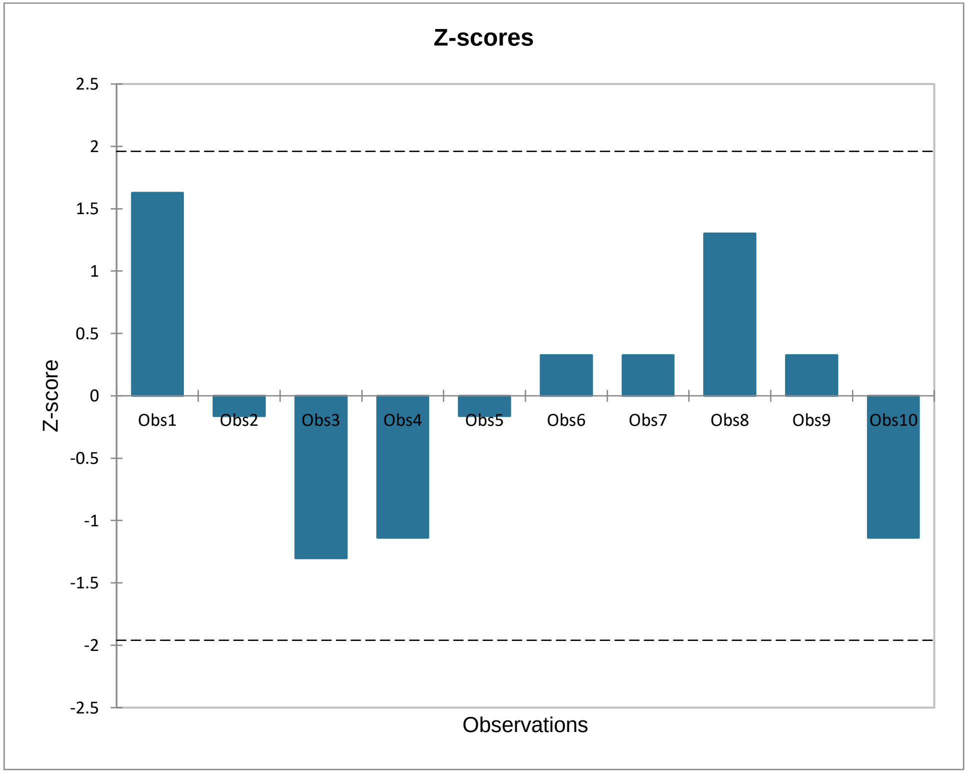


Figure 3

Z-scores of Accident Counts (Dixon Q)



Note. Z-score for significance $p = 0.05$ is $Z = +/-1.96$

Figure 4

Total Number of Fatal Seaplane Accidents Per Year 2012-2021

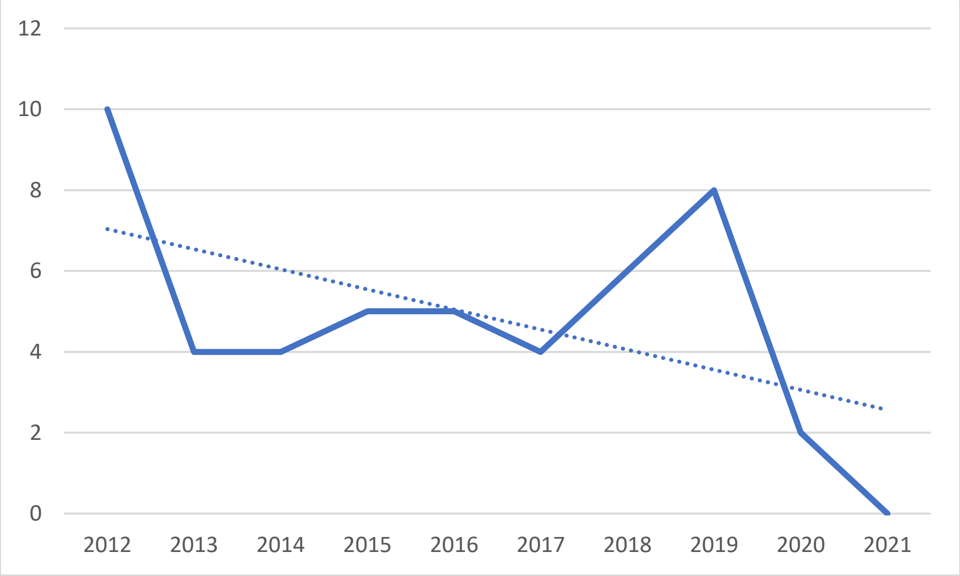


Figure 5

Total Number of Seaplane Fatalities Per Year 2012-2021

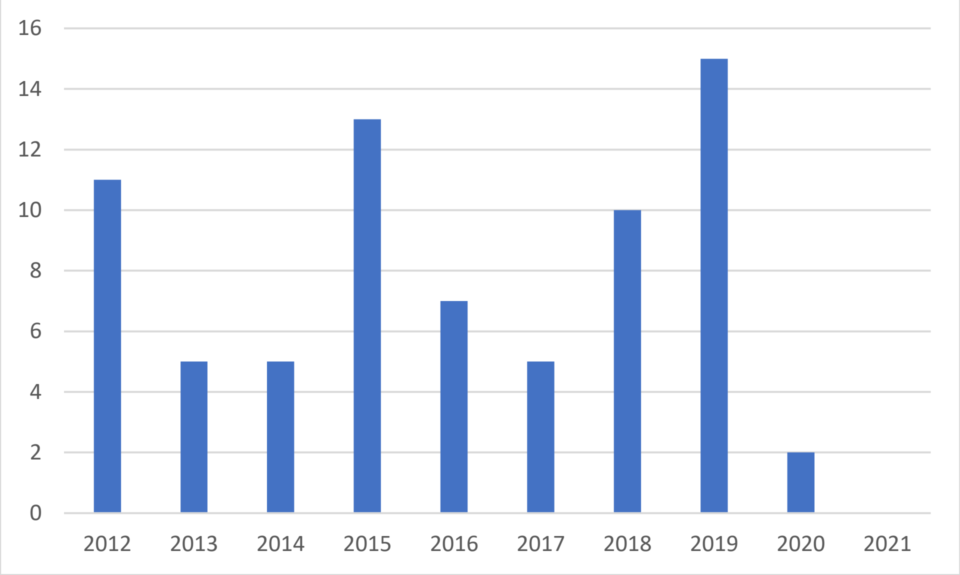
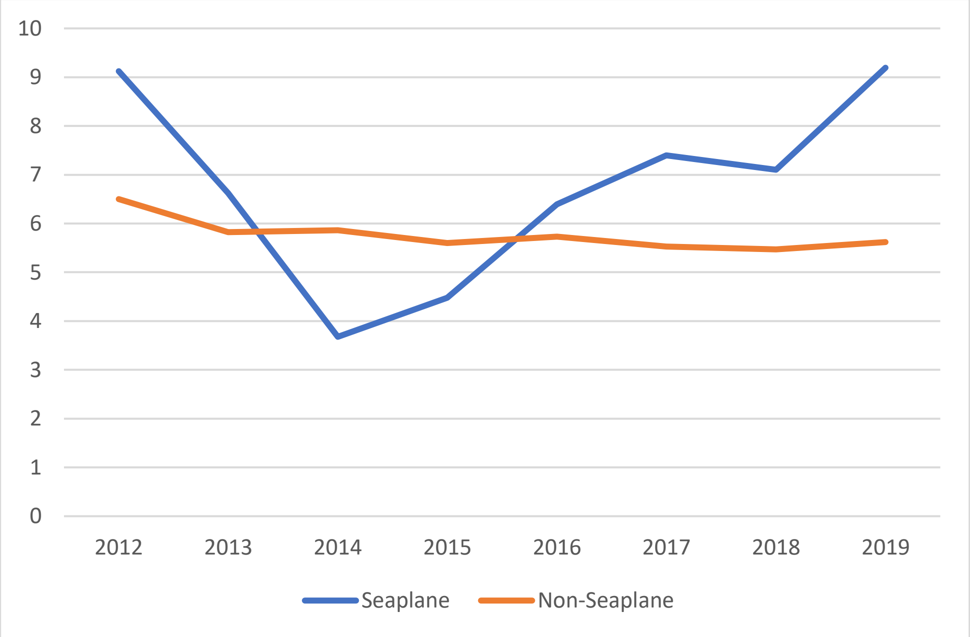


Figure 6

Accident Rates: Non-Seaplane vs. Seaplane 2012-2019



Note. No rate was published for non-seaplanes in 2020-2021. Years 2016-2020, seaplane rate was estimated based on the historical percentage of total hours flown by fixed-wing aircraft per the FAA data. Seaplane hours for 2012-2015 were extracted directly from FAA data.

Figure 7

Total Number of Seaplane Accidents Per Year 1982-2021

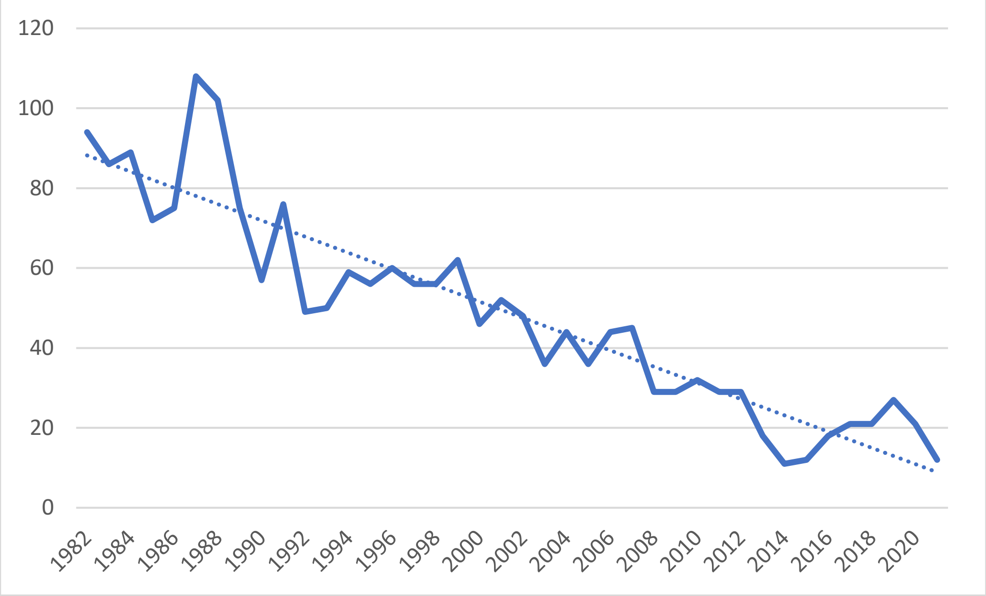


Figure 8

Z-scores of Accident Counts (Dixon Q)

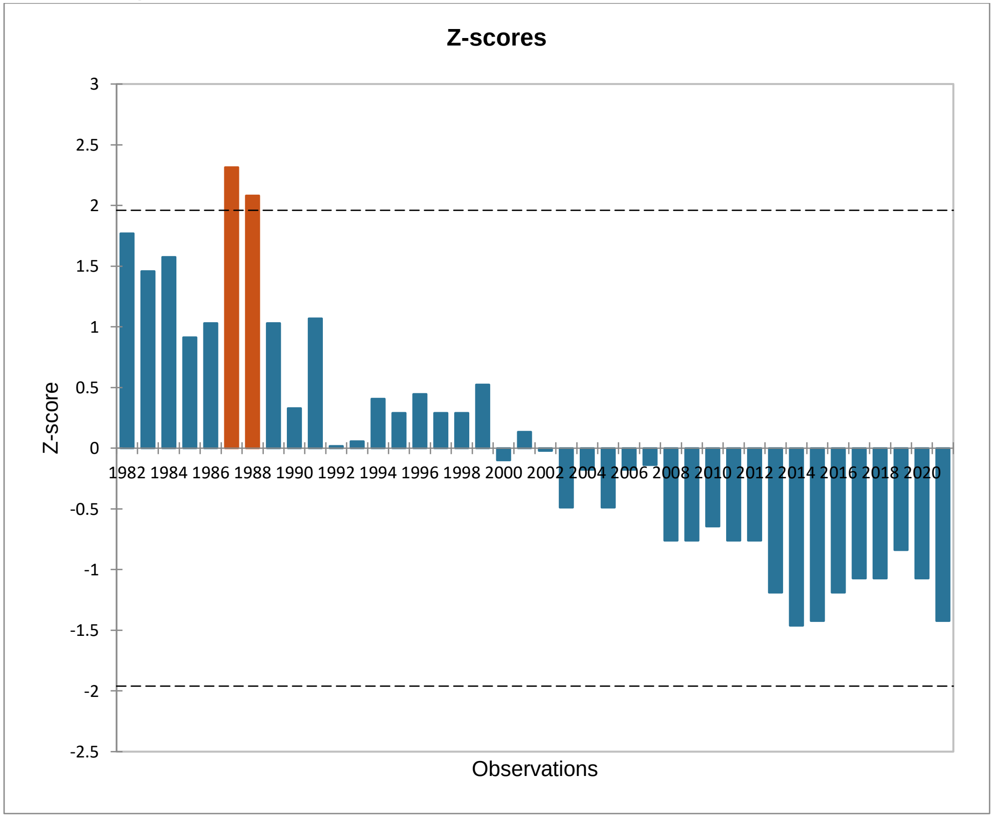


Figure 9

Total Number of Fatal Seaplane Accidents Per Year 1982-2021

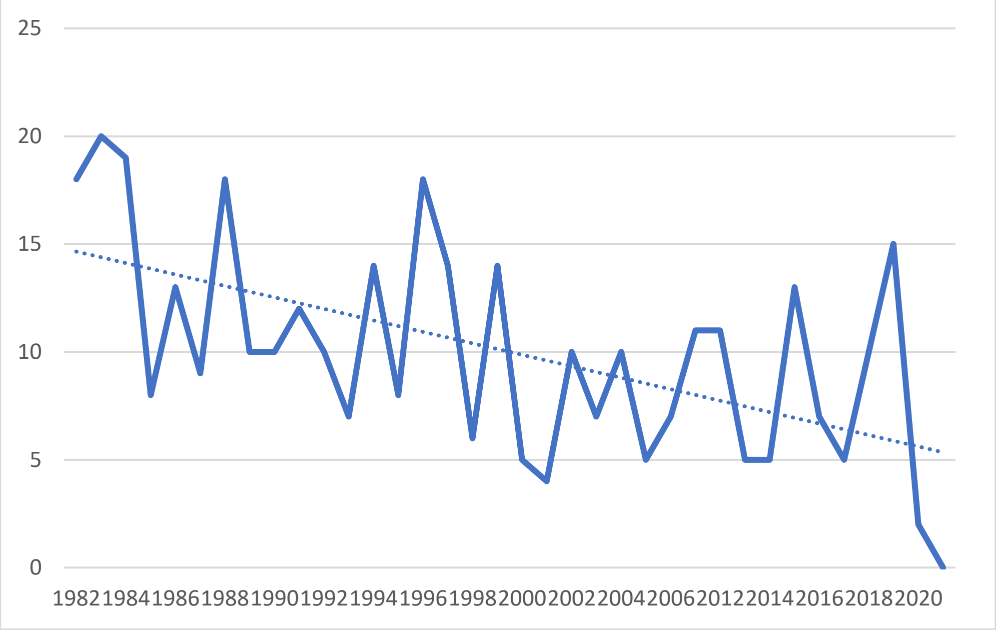


Figure 10

Total Number of Seaplane Fatalities Per Year 1982-2021

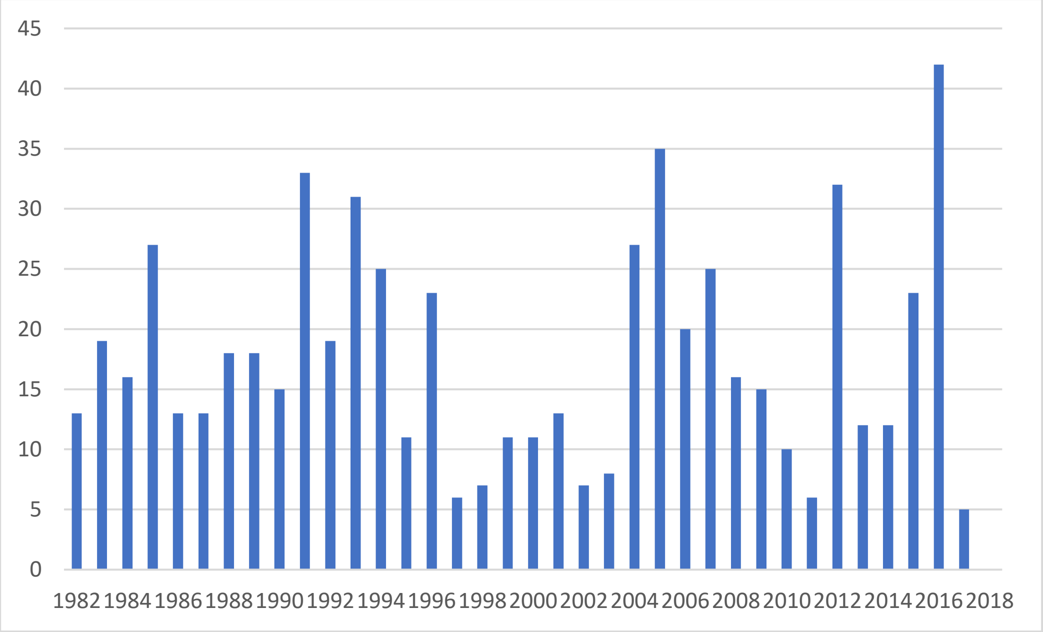


Figure 11

Geographic Distribution of Seaplane Accidents 1982-2022

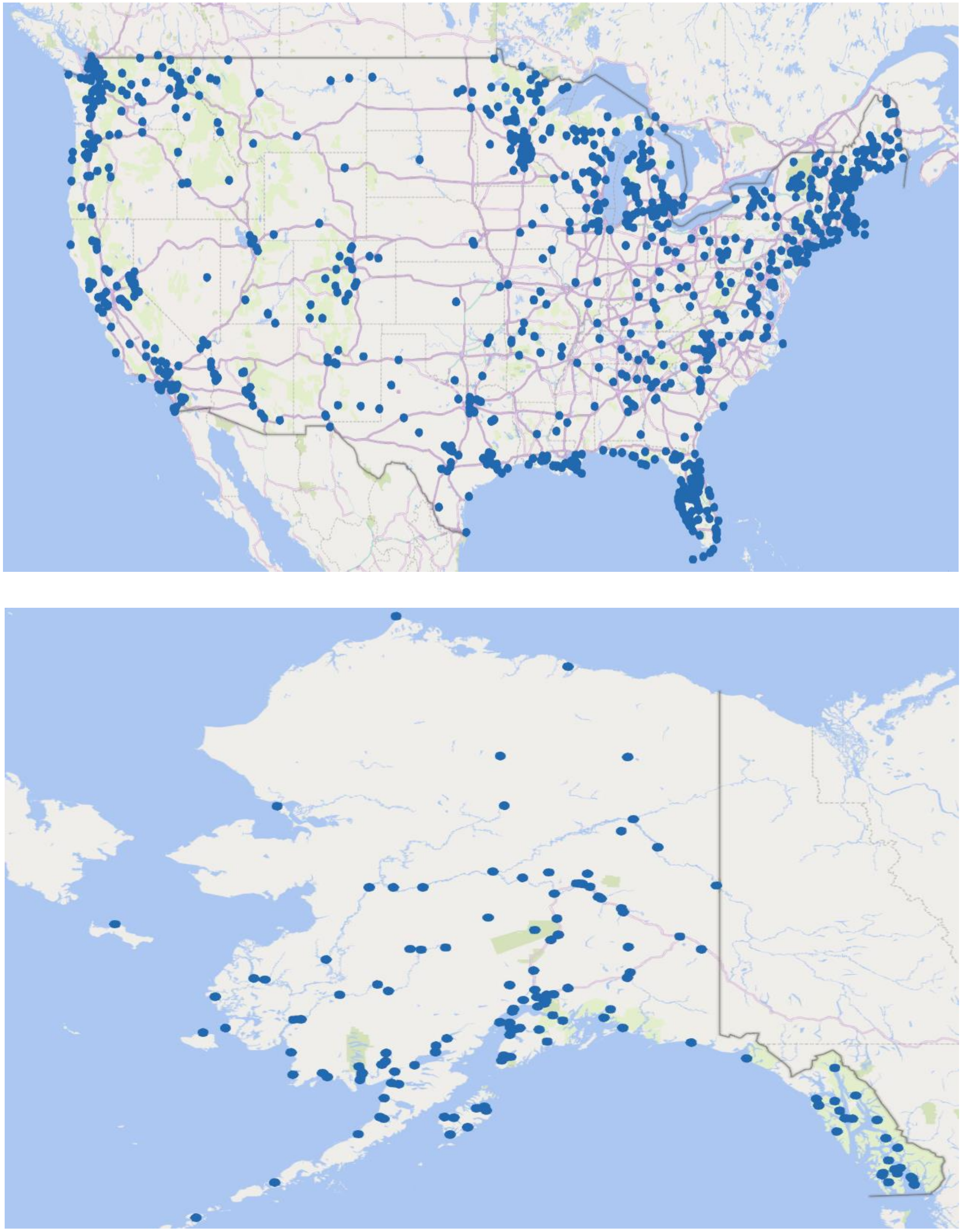


Table 1

Mean Flight Time 2012-2021

	Mean
Seaplane	6069.035
Non-Accident	4063.515
Non-Seaplane	3999.055

Table 2

Differences Among Pilot Groups: Total Flight Time 2012-2021

	Seaplane	Non-Accident	Non-Seaplane
Seaplane	1	**<0.0001**	**<0.0001**
Non-Accident	**<0.0001**	1	**0.005**
Non-Seaplane	**<0.0001**	**0.005**	1

Bonferroni corrected significance level: 0.0167

Table 3

Mean Age 2012-2021

	Mean
Seaplane	57.015
Non-Accident	55.094
Non-Seaplane	53.275

Table 4

Differences Among Pilot Groups: Age 2012-2021

	Seaplane	Non-Accident	Non-Seaplane
Seaplane	1	**0.000**	**0.002**
Non-Accident	**0.002**	**0.000**	1
Non-Seaplane	**0.000**	1	**0.000**

Bonferroni corrected significance level: 0.0167

Table 5

Mean Flight Time 2012-2021: Make and Model

	Mean
Seaplane	904.490
Non-Seaplane	699.366

Table 6

Top Accident Event Sequences

Rank	Seaplane	Non-Seaplane
1	Landing-flare/touchdown Nose over/nose down	Uncontrolled descent Collision with terr/obj (non-CFIT)
2	Landing-landing roll Nose over/nose down Uncontrolled descent Collision with terr/obj (non-CFIT)*	Landing-landing roll Loss of control on ground
3	Takeoff Loss of control in flight Landing Collision with terr/obj (non-CFIT)* Initial climb Loss of control in flight*	Landing-landing roll Runway excursion
4	Takeoff Collision with terr/obj (non-CFIT) Landing-landing roll Loss of control on ground* Landing-flare/touchdown Hard landing*	Emergency descent Off-field or emergency landing
5	Landing Nose over/nose down Landing Hard landing*	Landing-landing roll Collision with terr/obj (non-CFIT)

Table 7

Top Accident Causes

Rank	Seaplane	Non-Seaplane
1	Personnel issues-Task performance-Use of equip/info-Aircraft control-Pilot	Personnel issues-Task performance-Use of equip/info-Aircraft control-Pilot
2	Not determined-Not determined-(general)-(general)-Unknown/Not determined	Not determined-Not determined-(general)-(general)-Unknown/Not determined
3	Aircraft-Aircraft oper/perf/capability-Performance/control parameters-Directional control-Not attained/maintained	Aircraft-Aircraft oper/perf/capability-Performance/control parameters-Directional control-Not attained/maintained
4	Personnel issues-Action/decision-Info processing/decision-Decision making/judgment-Pilot	Personnel issues-Action/decision-Info processing/decision-Decision making/judgment-Pilot
5	Aircraft-Aircraft oper/perf/capability-Performance/control parameters-Airspeed-Not attained/maintained	Personnel issues-Task performance-Use of equip/info-Aircraft control-Pilot

Table 8

Mean Flight Time 1982-2021

	Mean
Seaplane	4783.455
Non-Accident	4311.284
Non-Seaplane	3546.870

Table 9

Differences Among Pilot Groups: Total Flight Time 1982-2021

	Seaplane	Non-Accident	Non-Seaplane
Seaplane	1	**<0.0001**	**<0.0001**
Non-Accident	**<0.0001**	1	**<0.0001**
Non-Seaplane	**<0.0001**	**<0.0001**	1

Bonferroni corrected significance level: 0.0167

Table 10

Mean Age 1982-2021

	Mean
Seaplane	57.261
Non-Accident	55.094
Non-Seaplane	52.691

Table 11

Differences Among Pilot Groups: Age 1982-2021

	Seaplane	Non-Accident	Non-Seaplane
Seaplane	1	**0.000**	**0.002**
Non-Accident	**0.002**	**0.000**	1
Non-Seaplane	**0.000**	1	**0.000**

Bonferroni corrected significance level: 0.0167

Table 12

Mean Flight Time 1982-2021: Make and Model

	Mean
Seaplane	624.727
Non-Seaplane	638.243

Table 13

Top Accident Event Sequences

Rank	Seaplane	Non-Seaplane
1	Initial climb Loss of control in flight	Landing-landing roll Loss of control on ground
2	Landing Landing gear not configured	Landing-flare/touchdown Hard landing
3	Takeoff Other weather encounter	Takeoff Loss of control on ground
4	Landing-flare/touchdown Loss of control on ground	Landing-flare/touchdown Abnormal runway contact
5	Initial climb Aerodynamic stall/spin Takeoff Loss of control in flight* Takeoff Loss of control on ground*	Enroute-cruise Loss of engine power (total)

Table 14

Top Accident Causes

Rank	Seaplane	Non-Seaplane
1	Personnel issues-Task performance-Use of equip/info-Aircraft control-Pilot	Personnel issues-Task performance-Use of equip/info-Aircraft control-Pilot
2	Personnel issues-Action/decision-Info processing/decision-Decision making/judgment-Pilot	Aircraft-Aircraft oper/perf/capability-Performance/control parameters-Directional control-Not attained/maintained
3	Not determined-Not determined-(general)-(general)-Unknown/Not determined	Not determined-Not determined-(general)-(general)-Unknown/Not determined
4	Aircraft-Aircraft oper/perf/capability-Performance/control parameters-Directional control-Not attained/maintained Aircraft-Aircraft oper/perf/capability-Performance/control parameters-Airspeed-Not attained/maintained*	Personnel issues-Action/decision-Info processing/decision-Decision making/judgment-Pilot
5	Personnel issues-Psychological-Attention/monitoring-Monitoring environment-Pilot	Aircraft-Aircraft oper/perf/capability-Performance/control parameters-Airspeed-Not attained/maintained