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Iulia Manole and Arnab Majumdar *

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Article

When Maritime Meets Aviation: The Safety of Seaplanes on the Water

Iulia Manole and Arnab Majumdar *

Imperial College London

* Correspondence: a.majumdar@imperial.ac.uk

Abstract: The water environment is a dynamic domain critical to global transportation and commerce, where seaplanes operate during take-offs, landings and ground operations, often near maritime traffic. Canada's vast remote regions and unique geography increase reliance on seaplanes, especially for private and recreational purposes. This article examines the intersection of aviation and maritime operations through a mixed-methods approach, analyzing seaplane safety on waterways using quantitative and qualitative methods. First, data from 1,005 General Aviation (GA) seaplane accidents in Canada (1990–2022) is analyzed, revealing 179 fatalities, 401 injuries and 118 destroyed aircraft - significant given seaplanes comprise under 5% of GA aircraft. Of these, 50.35% occurred while the seaplane was not airborne. Second, insights from interviews, focus groups, and questionnaires involving 136 participants are explored through thematic and content analysis. These capture pilot concerns not evident in accident data, such as hazards from jet ski interactions and disruptive boat wakes. The findings highlight risks like limited visibility and maneuverability during waterborne take-offs, worsened by seaplanes' lack of priority over maritime vessels in shared spaces. This article concludes with recommendations for both the seaplane and maritime communities, including increasing awareness among boaters about the presence and operations of seaplanes and regulatory adjustments particularly considering the right of way.

Keywords: seaplane; safety; take-off; landing; collision; water operations; maritime safety; aviation safety

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1. Introduction

Hazards, whether natural or human-made, present potential threats to individuals, equipment, and operations [1]. Reducing these and mitigating associated risks are essential objectives in transportation safety to protect lives, goods, and the environment. However, systematic hazard analysis is often constrained by reporting limitations, as incidents that do not result in significant damage or harm may go unreported. Public accident databases frequently lack critical contextual details, such as environmental factors or pilot decision-making processes, leading to incomplete insights. A comprehensive safety analysis must, therefore, go beyond traditional accident data to incorporate both qualitative and quantitative methods.

The maritime industry is considered the most complex and dangerous worldwide [2,3]. Canada is a nation that boasts a rich maritime heritage and vast coastal regions, with major ports such as Vancouver, Halifax, and Montreal playing critical roles in international trade and commerce. Maritime safety is crucial due to its role in providing a protective refuge for vessels, facilitating the transfer of people and goods, promoting trade and economic growth, and serving as significant sources of employment. In particular, ports represent dynamic environments with a complex set of safety challenges.

Canada is also a global leader in seaplane operations. These operate at the intersection of aviation and maritime environments, requiring pilots to navigate risks associated with both sectors. Canada, with its vast and rugged geography, is a global leader in seaplane operations, supporting

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both commercial and recreational activities. While commercial seaplane operations are subject to stringent regulatory oversight, private and recreational seaplane pilots often operate under more relaxed regulatory frameworks, increasing exposure to safety risks. Unlike land-based aircraft, seaplanes must contend with additional hazards, such as water conditions, limited maneuverability and interactions with maritime traffic. The dual nature of seaplane operations further complicates safety management, as regulatory distinctions exist between aircraft and vessels.

Seaplanes are generally defined as aircraft that can take off and land on water. The International Civil Aviation Organization (ICAO) defines a seaplane as "An airplane on floats (amphibious or non-amphibious) or a flying boat (water-only or amphibious)" [4]. There are two main categories of seaplanes in use in Canada:

i) floatplanes – these have floats but no wheels, and
ii) Amphibious - which are planes that have floats and retractable wheels, so they have the capability to land and take-off from both the land and the water.

In addition, according to the 1972 International Regulations for Preventing Collisions at Sea (COLREGs), a seaplane is regarded as a vessel when it is on the water, whether it is landing, anchored, or being launched from a water slide. However, when the seaplane is out of the water, it is treated as an aircraft [5].

Research relating to the safety of ships and seaplanes sharing the water environment is scarce, but there are a few studies that mention both. These have revealed several key areas of concern and methodological approaches. Gao [6] conducted an extensive risk analysis of seaplane operations in Sanya Port in China, comparing the maritime traffic environment of seaplanes to that of other vessels, and emphasizing unique safety challenges. Similarly, Vidan et al. [7] explored the operational and environmental safety of seaplane traffic in Croatia, noting differences in waste management between seaplanes and traditional vessels. These studies emphasize the need for customized safety protocols that consider the specific dynamics of seaplanes on water.

In complex socio-technical systems, the safety issues of smaller communities within a transport sector can often be overlooked. General safety measures designed for larger communities or transport sectors, outlined in safety management systems (SMS), may be ineffective for those which are smaller, requiring tailored safety strategies to address their unique challenges. For example, seaplane operations are part of both the aviation and maritime sectors and require specific safety measures due to their dual operational environments. Additionally, safety in commercial operations is more thoroughly addressed due to greater scrutiny and regulations needed to protect larger passenger and cargo volumes. In contrast, private operations often fall under less rigorous regulatory frameworks, with fewer mandatory safety measures and oversight, leading to gaps in comprehensive safety standards. Consequently, private pilots may be indirectly affected by factors less prevalent in commercial aviation, such as less rigorous training and infrequent flying. Given the unique risks associated with recreational seaplane flying, such as varying pilot experience and diverse operating environments, a thorough sector-specific analysis is imperative. Analysing subsets of occurrences is crucial to understand and address specific challenges for underrepresented communities in a transport sector. This approach aids in identifying specific safety issues and formulating targeted recommendations to enhance overall safety in complex transport systems.

In summary, the water environment is a complex and dynamic place where two transport sectors intersect. Even though the literature including both seaplanes and vessels is very limited, it remains important to study the interactions of these sectors and mitigate their specific risks. Both the maritime and aviation sectors benefit from tailored SMSs that incorporate both human factors and risk assessment methodologies. Therefore, this paper aims to address the above limitations by employing a mixed-method approach of qualitative and quantitative analysis of seaplane safety on water. A holistic understanding of seaplane safety is sought not only through data collection and analysis, but also through understanding the importance of minor incidents or near-misses and their reporting, the knowledge and expertise of different stakeholders and industry professionals, and finally assessing how organizational aspects come into play and share safety knowledge.

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2. Materials and Methods

This section outlines the methodology used to analyze the safety of private, recreational seaplane operations in Canada, as shown in Figure 1. It includes details of the occurrence (accident/incident) database (Section 2.1), data categorization (Section 2.2), data analysis (Section 2.3) and survey proposal (Section 2.4).

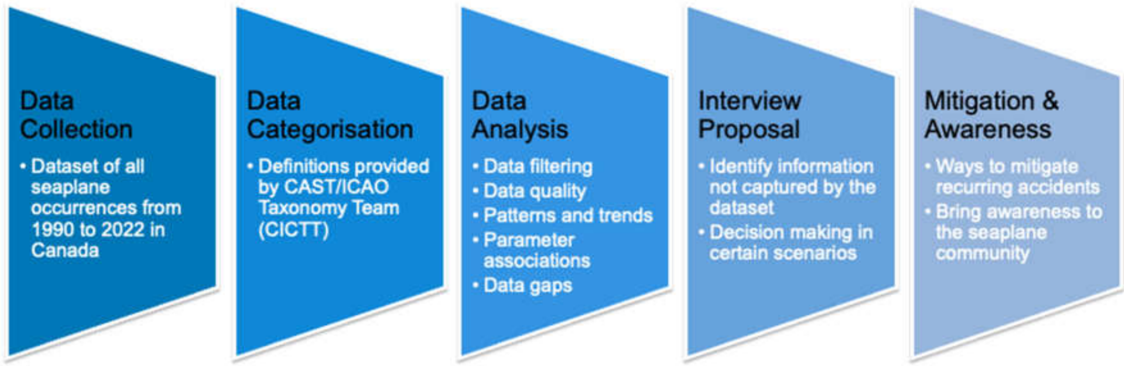

Figure 1. Methodology used for the study of seaplane safety on Canadian waters.

Firstly, as this paper considers only occurrences of seaplanes on the water, it is important to correctly categorize the phase of flight when an accident or incident occurs. For this purpose, Goblet et al. [8] provide a comprehensive list of possible safety events during each phase of flight and develop an algorithm to detect the phase of flight. However, these phases of flight are for commercial operations and we make changes below to reflect the phases of flight for General Aviation (GA) operations. It should be noted that, for seaplanes, a runway can also be on a body of water.

The phases of flight where an occurrence can happen for GA seaplane operations have been separated into 14 categories, presented in Table 1. This is based on adaptation of the CAST/ICAO Common Taxonomy Team (CICTT) [9] definitions of phases of flight, so as to reflect the phase categories used by the regulator, Transport Canada, for its occurrence reports and for GA.

Table 1. Definitions for phases of flight during seaplane operations by adapting CICTT [9] definitions of phases of flight.

Phase of flight	Definition
Standing	Stationary aircraft at dock before taxi.
Taxi	Aircraft unassisted in moving before take-off or after landing.
Take-off	Starts when take-off power is applied, until either being airborne above 35 feet from the runway/water elevation, or when the gear is up. This includes rejected take-offs.
Climb	
Initial Climb	After take-off, until the aircraft either reduces prescribed power for the first time or reaches 1,000 feet above the runway/water elevation.
Cruise Climb	Subcategory added to account for the period after the initial climb and prior to level off at cruise altitude.
Cruise	Level flight segment between the end of climb and the beginning of descent for landing.
Maneuvering	Intentional altitude changes during low altitude (not associated with take-off and landing).

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Descent	Descent between level flight and 1,000-2,000 feet above the runway/water elevation. It includes emergency and uncontrolled descent.
Approach	Constant altitude decrease in preparation for landing, from 1,000-2,000 feet above the runway/water elevation until the beginning of the landing flare. It includes Missed Approaches and Go-Arounds for up to 200 feet above the runway/water elevation.
Landing	The phase that immediately follows the approach, where the aircraft transitions to the landing attitude enabling the airplane to touch down on the landing surface at the slowest speed possible commensurate with safety. This transition is known as the flare. The flare is normally executed at 50 feet or less above the runway/water elevation. For touch-and-go's, this phase ends the moment power is applied for take-off. Landing includes flare, touchdown, and aborted landings after touchdown.
Landing Run	The phase that immediately follows the water landing, when the aircraft slows down to taxi speed (normally with the engine at idle), until reaching the end of the landing runway or coming to a stop on the runway.
Docking	The transition from idle taxi to the safe securing of the seaplane to a permanent structure fixed to the shore. Docking is normally executed with the engine stopped.
Other	
En Route	After initial climb, through cruise and controlled descent, until the initial approach. Often used when it is not clear in which of the airborne phases of flight the occurrence took place.
Post-Impact	Considers the segment of flight after impacting terrain, obstacles, people or objects.
Unknown	For accident and incident data, when the phase of flight of the occurrence could not be determined.

Figure 2 has been created to account for 10 out of the 14 phases of flight. It does not include Maneuvering, En Route, Post-Impact and Unknown.

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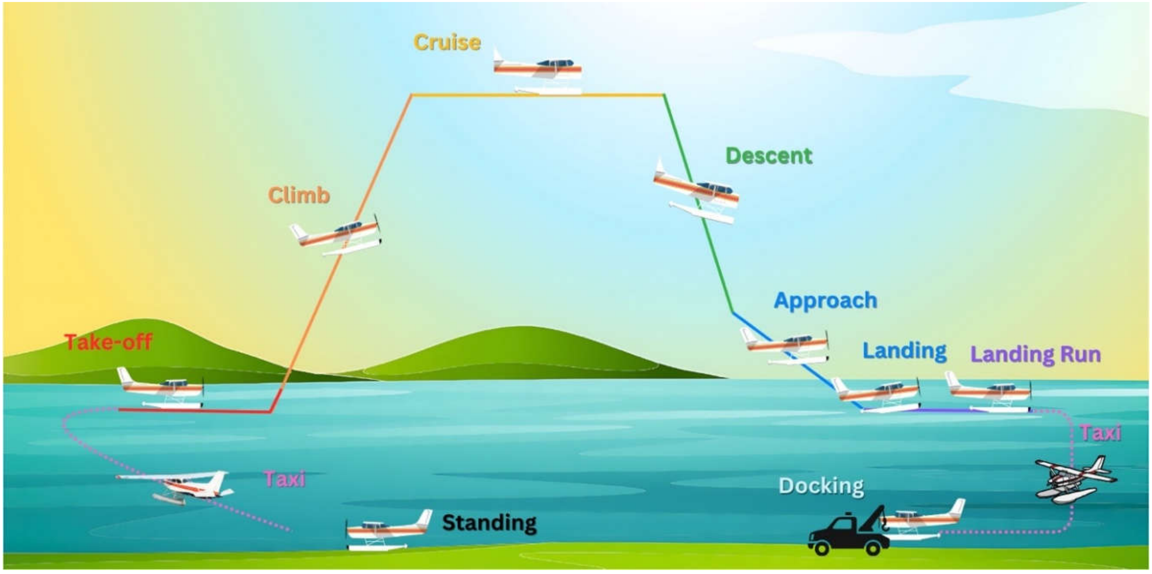

Figure 2. Illustration of the typical phases of flight of a seaplane, excluding Maneuvering, En Route, Post-Impact and Unknown.

2.1. Description of the Database of Seaplane Occurrences in Canada

Transport Canada (TC), the safety regulator, has collated a database that consists of 1,771 seaplane occurrences (accidents and incidents) in Canada, from 1990 to 2022. In this database, there are 466 occurrences on water involving private, recreational operations, during the following phases of flight: standing, taxi, take-off, landing, landing run (roll out) and docking (including parked).

While TC provided a comprehensive data set, certain data fields had to be derived from the narratives, such as the cause of the occurrence (categorization), number of injuries and fatalities and route. The data fields include general information (e.g., date, time, phase of flight), details of the surrounding environment (e.g., route, location), aircraft specifications (e.g., damage level, tonnage, landing gear) and environmental conditions (e.g., weather).

Details of individuals affected (e.g., gender, age, injuries) were unavailable, as well as any details about the pilot's performance. Complementary data collection methods such as interviews, focus groups, and decision-making studies e.g. those by Irwi et al. [10] are considered in this paper. The underreporting of incidents either due to minimal reporting requirements or fear of repercussions further limits dataset accuracy, potentially skewing risk assessments. Comprehensive reporting and interdisciplinary approaches are essential therefore to address these limitations, ensuring a holistic understanding of seaplane safety and enabling meaningful recommendations for mitigating risks in shared waterways.

2.2. Categorisation of Seaplane Occurrences

Hazards which can lead to an occurrence are categorized using the Hazards Common taxonomy [11], according to their type as: Human, Technical, Environmental and Organizational. Aviation occurrences are categorized using the Aviation Occurrence Categories from the Commercial Aviation Safety Team (CAST) and the International Civil Aviation Organization (ICAO), as of May 2021 [12], according to their contributory factor(s). These categories are grouped into the following: Take-off and landing, Airborne, Ground operations, Aircraft, Non-aircraft-related, Weather and Miscellaneous [12]. The categorization is not part of the recorded data fields of reported accidents or incidents, and it is determined separately only for the few occurrences that require deeper investigation and have a published Canadian Transport Safety Board (TSB) report.

2.3. Analysis of Past Seaplane Occurrences on Canadian Waters

Descriptive statistics, frequency analysis and distributions were used to analyze trends of seaplane occurrences on Canadian waters. The TC dataset contains the following types of data:

- Continuous (e.g. number of injured people);
- Categorical (e.g. phase of flight);
- Textual (e.g. accident description).

Both continuous and categorical data were tested for normality using the Kolmogorov-Smirnov (sample>50) and the Shapiro-Wilk tests (sample<50) [13]. Non-parametric statistical tests, such as Pearson's Chi Square test (χ^2), were applied for non-normally distributed data. For categorical variables, the Pearson's Chi Square test (χ^2) was used to compare the actual frequencies with the corresponding expected frequencies in the categories of the variables [13]. The χ^2 statistic is calculated using Equation (1):

$$\chi^2 = \sum \frac{(observed\ frequency - expected\ frequency)^2}{expected\ frequency} \qquad (1)$$

where the expected frequency refers to the expected count if there was no association between parameters, while the observed frequency is obtained from the dataset. Moreover, the data fields are adjusted such that the expected frequencies less than five are under 20% [14]. Otherwise, it is considered that there is not enough data to test the association.

The p-value indicates the statistical significance of the association, with lower p-values, meaning stronger evidence against the null hypothesis, for statistically significant relationships. The significance was set at $p<0.05$ for the statistical test, meaning a 95% confidence level. Consequently, the phi-value was used as a measure of the strength of the association, with higher phi-values indicating stronger relationships. Based on this, the strength of the relationship is determined (weak, moderate or strong). Table 2 shows the interpretation of the phi-values.

Table 2. Interpretation of Phi value [15].

Phi value	**Strength of relationship**
-1.0 to -0.5 and 0.5 to 1.0	Strong
-0.5 to -0.3 and 0.3 to 0.5	Moderate
-0.3 to -0.1 and 0.1 to 0.3	Weak
-0.1 to 0.1	None or very weak

2.4. Survey

While the analysis of accident and incident data is crucial for improving safety and ensuring accident prevention in the future, there are though certain limitations that hinder a comprehensive understanding of all underlying safety factors. There are gaps in the available data which have been mentioned previously, especially related to the people involved in the occurrence, such as decision-making, concerns, and other contributory factors that can influence safety outcomes. Hence, additional data was collected to complement the insights from accident and incident data analysis, by means of a survey, that engaged with pilots and other safety professionals in the field.

This survey encompassed a wide range of scenarios that encourage pilots to consider critically their actions in different conditions, while bringing awareness regarding current safety issues. These scenarios are around the most frequent occurrence categories and phases of flight when accidents occur. The methods used to gather qualitative data from recreational, private GA pilots in Canada are: semi-structured interviews, phenomenological focus groups and a phenomenological questionnaire. Thematic and content analysis are employed to identify key safety issues and develop an in-depth understanding of the processes and interactions affecting GA seaplane safety. The data is coded and analyzed iteratively, enabling themes to emerge naturally from the data. This approach ensures a comprehensive understanding of the participants' perspectives and experiences.

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The confidentiality of participants taking part in the study has been preserved, and the transparency requirements under the General Data Protection Regulation for health and care research were fulfilled. Additionally, approval from the Research Governance and Integrity Team (RGIT) has been obtained for this survey. The documents approved by the Imperial College ethics committee are attached in Appendix A. This study has been conducted in compliance with the protocol, Data Protection Act 2018 and General Data Protection Regulations (Europe) and other regulatory requirements as appropriate.

Multiple choice or open-ended questions have been used, which have been structured into six parts. These are a subset of the questions asked that relate to seaplane operations on waters only:

1. Participant information & Consent
2. General details
3. Information gathering – Safety training and concerns
4. Scenario discussion – Take-off
5. Scenario discussion – Landing
6. Ending questions

The questionnaire, focus groups and interviews are based on the same questions and begin with a short description of its purpose, then the participants are assured of confidentiality and explained their freedom to withdraw without giving a reason (Part 1). Informed consent is obtained from all participants, prior to proceeding with the questions. Parts 2 and 6 contain questions about participants' age group, experience, seaplane ratings, safety training and methods of safety awareness preferred. Sections 4 and 5 consist of scenarios which include the questions "What have you done to mitigate this?" and "What would you do to mitigate this?", regarding different hazardous situations that may happen during take-off and landing.

This survey aims to gain information related to pilot decision making during different scenarios, as well as other details about safety training and practices, and ways in which pilots stay current and proficient. Pilots can express current safety concerns and propose ways for safety prevention and awareness. All answers are anonymous, increasing the chance pilots answer truthfully.

3. Results

Mixed methods of quantitative and qualitative analysis have been used to analyze the safety of seaplanes on Canadian waters, as previously presented in Section 2. This section presents and interprets the results of the accident/incident data analysis (Section 3.1), as well as the responses obtained through the survey (Section 3.2). Table 3 summarizes the accident/incident dataset and the methods of analysis used.

Table 3. Summary of the accident/incident dataset and the reasons of employing different methods of analysis.

Dataset Description	Method of Analysis	Reason
- Canada - 1990 to 2022 - 466 private, recreational GA on-water seaplane occurrences - source: Transport Canada	Narrative analysis	To extract further information and improve the quality of the analysis. It includes the occurrence categorization.
	Trend analysis	Calculate trends and determine patterns.
	Contingency analysis	To detect potential associations and relationships between two and three variables.
	Three-way associations	

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	Interviews	Engagement with industry professionals to discuss the data analysis results and assess mitigation methods.
	Focus groups	Engagement with seaplane pilots and industry professionals to determine potential factors not included in the database and bring awareness on current areas of concern.
	Questionnaire	

3.1. Analysis of Previous Accidents and Incidents

This section provides the quantitative analysis of the accident/incident dataset of past seaplane occurrences on Canadian waters. It includes an assessment of the narratives (Section 3.1.1), trend analysis (Section 3.1.2), contingency analysis and three-way associations (Section 3.1.3) and a summary of the results in Section 3.1.4.

3.1.1. Narrative Analysis

The occurrence narratives have been used to identify their root causes from the following categories: airborne, ground operations, take-off and landing, aircraft-related, non-aircraft-related, weather conditions and miscellaneous. Within these categories, factors such as visibility, wind, loss of control, mechanical errors, human errors in making decisions or in operating the plane, the reason for pilots making certain decisions (such as abrupt maneuvers), missing emergency etc. have been considered. This particularly timely task revealed that loss of control and abnormal runway contact led to the majority (59.23%) of seaplane occurrences on the water (Table 4).

Table 4. Five most recurrent types of seaplane accidents and incidents on the water.

Category Name	Category ID	Count	Percentage
Loss of Control – Ground & Inflight	LOC-G & LOC-I	152	32.62%
Abnormal Runway Contact	ARC	124	26.61%
System/Component Failure or Malfunction (Non-Powerplant)	SCF-NP	42	9.01%
Collision with Obstacle(s) During Take-off and Landing	CTOL	29	6.22%
Unintended Flight in IMC	UIMC	20	4.29%
System/Component Failure or Malfunction (Powerplant)	SCF-PP	18	3.86%
Abrupt Maneuver	AMAN	15	3.22%
Unknown	UNK	15	3.22%
Ground Handling	RAMP	10	2.15%
Other	OTHR	9	1.93%

3.1.2. Trend Analysis

The dataset of seaplane occurrences was analyzed around the following variables:

- Year
- Landing Gear
- Phase of Flight
- Aircraft Damage Level
- Injuries and Fatalities

In Canada, the number of seaplane occurrences has gradually decreased over the years (Figure 3). However, considering private, recreational seaplane operations on the water in particular, the number of occurrences is showing an increase over the years (Figure 4). This indicates that, while general seaplane safety may be improving, especially in the commercial world, there are unique challenges and risks associated with private, recreational, on-water seaplane operations that need to be addressed. This subset of data is used for the subsequent analysis in this article. It should also be noted that Covid restrictions impacted the number of flights in 2020-2021.

The accurate calculation of occurrence rates for seaplanes presented a significant challenge due to the deficiency of data on seaplane movements, or on the yearly number of hours flown by seaplane pilots. This issue is particularly relevant in the context of private recreational seaplanes in Canada, where specific data is not available. One of the primary issues highlighted by Ison [16] is the lack of detailed data on the seaplane fleet and the cadre of seaplane pilots in the US, which makes it difficult to calculate accurate accident rates because comprehensive records of flight hours, pilot experience and operational contexts are often incomplete or unavailable. This is also the case for Canada.

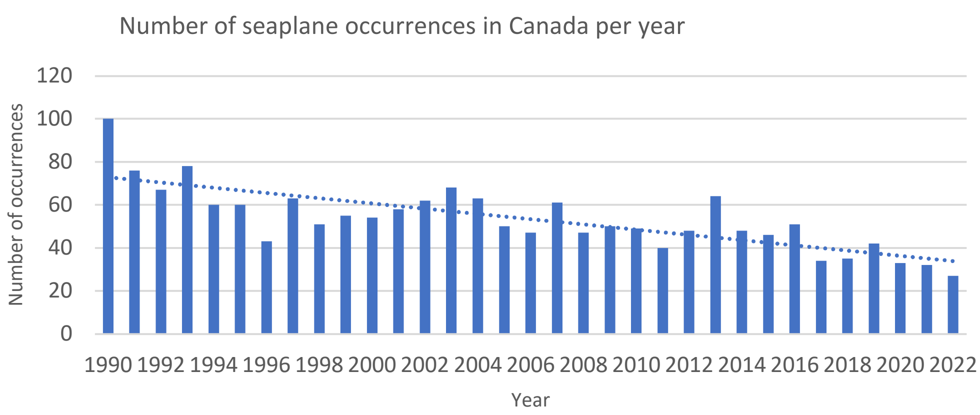

Figure 3. Distribution of the yearly number of seaplane occurrences in Canada.

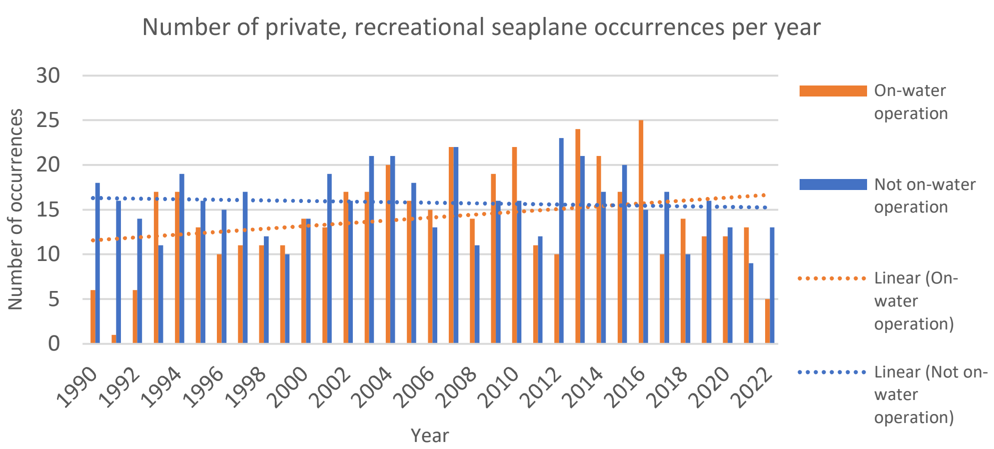

Figure 4. Distribution of the yearly number of seaplane occurrences in Canada for private, recreational on-water operations.

Figure 5. shows how the number of injuries and fatalities fluctuates over the period, with the trendline ascending for the number of injuries and constant for the number of fatalities. The probable impact of Covid restrictions on the number of flights in 2020-2021 should be noted. Also, it was not possible to determine the number of injuries and fatalities between 1990-1992 for a large number of narratives, so these three years have been removed.

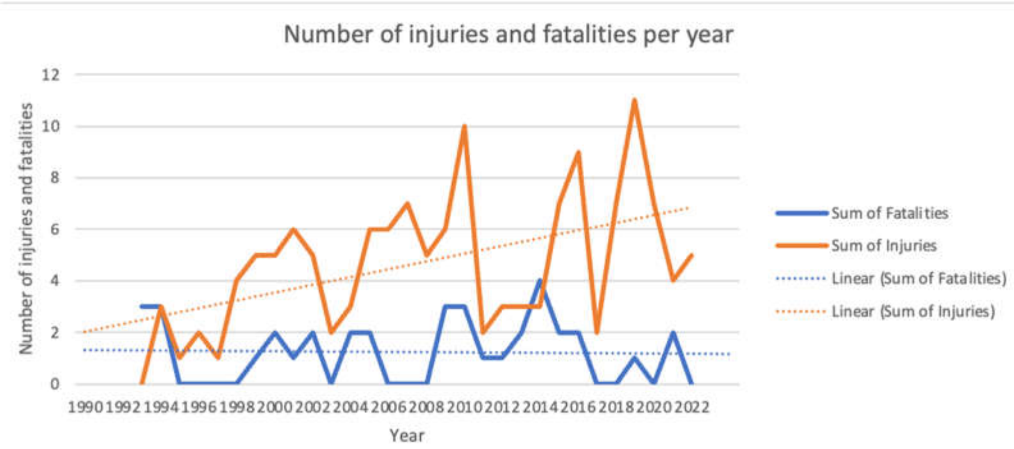

Figure 5. Number of injuries and fatalities per year, for private, recreational, on-water seaplane operations in Canada.

The number of occurrences annually for private, recreational seaplane operations on water involving amateur built aircraft shows an increasing trend over the period, as shown in Figure 6, with the first amateur built occurrence in 1998. From 2003, the numbers stabilize around a consistent average, which can be attributed to improved safety and a more experienced and knowledgeable community, along with regulatory enhancements. However, in recent years, a considerable percentage of occurrences involve amateur built aircraft. This highlights the importance of maintaining improvements so that, in the future, amateur built aircraft become safer to ensure a decreasing trend int heir occurrences.

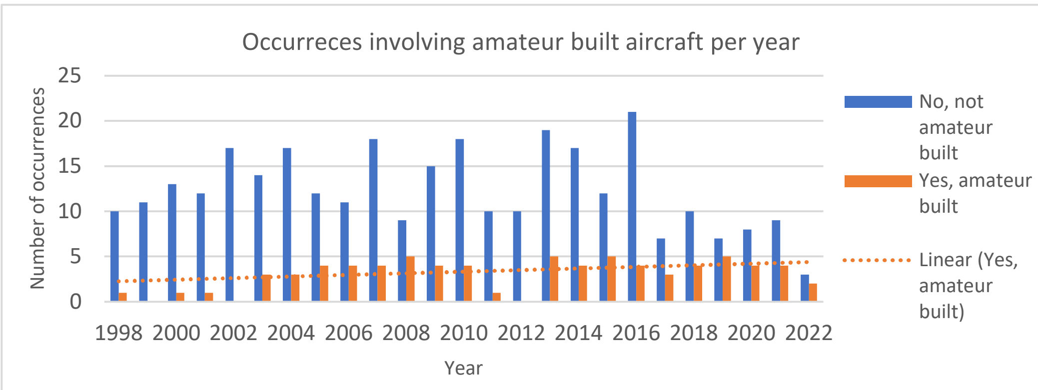

Figure 6. Number of occurrences per year for private, recreational on-water seaplane operations using amateur built aircraft, in Canada.

Exploring the relationship between different accident causes and the level of damage of the aircraft reveals whether there are significant differences in the degree of damage suffered by seaplanes under different accident causes, thereby providing information for safety management and flight operations.

Figure 7 illustrates the severity of aircraft damage resulting from the occurrences with 94.62% leading to substantial aircraft damage, while 3.44% resulted in the aircraft being destroyed. These figures show that irrespective of accident cause, serious serious damage or even destruction of the seaplane is the likely result. The most notable trend is the fluctuation in the number of substantially damaged aircraft, which, in the past six years, while showing a gradual decline, nonetheless has an increasing trendline over the period. Since occurrences with less than major structural problems with the aircraft are not required to be reported, unless there has been a death, injury, missing aircraft or

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collision [17], which is reflected in the low numbers of occurrences where the aircraft had minor or no damage.

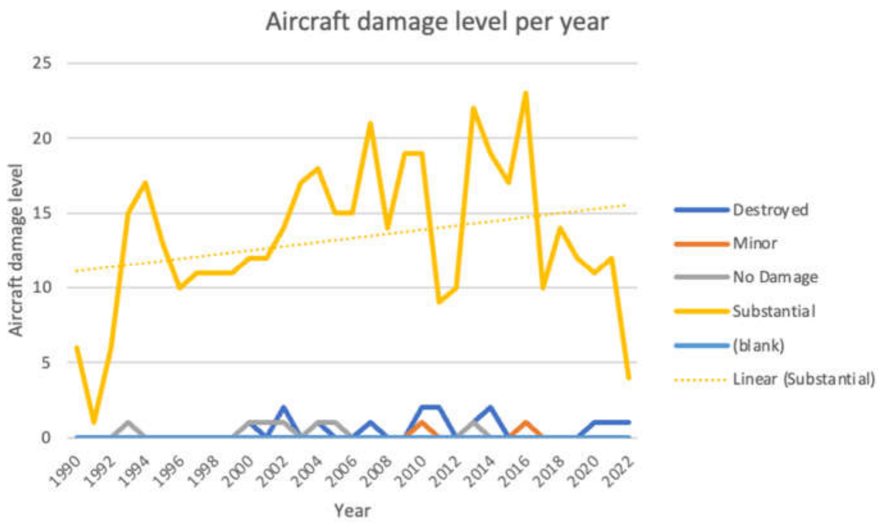

Figure 7. Aircraft damage level per year, for private, recreational, on-water seaplane operations in Canada.

Figure 8 indicates that the landing phase is the most hazardous for private, recreational seaplane operations on water in Canada, accounting for 51.5% of occurrences. It has an increasing trend, with an average increase in the past decade, following a peak period between 2013 and 2019. The trendline for take-off (accounting for 22.75% of the occurrences) is slightly decreasing, with an increase in 2020-2021.

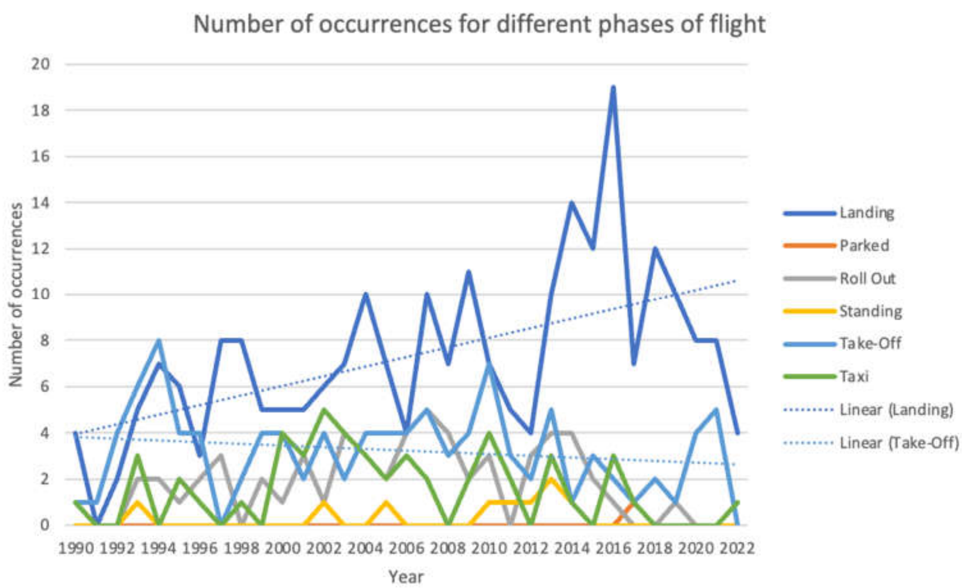

Figure 8. Number of occurrences during the top 5 phases of flight, for private, recreational seaplane operations in Canada.

Figure 9 shows the number of occurrences during take-off for the studied period. It shows several peaks, indicating intermittent periods of increased risk. Despite a low profile for take-off in 2014-2019, the years 2020 and 2021 show the highest number of occurrences in the past decade years, despite restrictions on the general population due to the Covid-19 pandemic in those years. The data for landing shows an increasing trend in occurrences from around 2013 onwards, peaking notably in

2016. This indicates a possible shift in the underlying factors contributing to landing incidents, such as changes in operational procedures, increased seaplane activity, or variations in reporting practices.

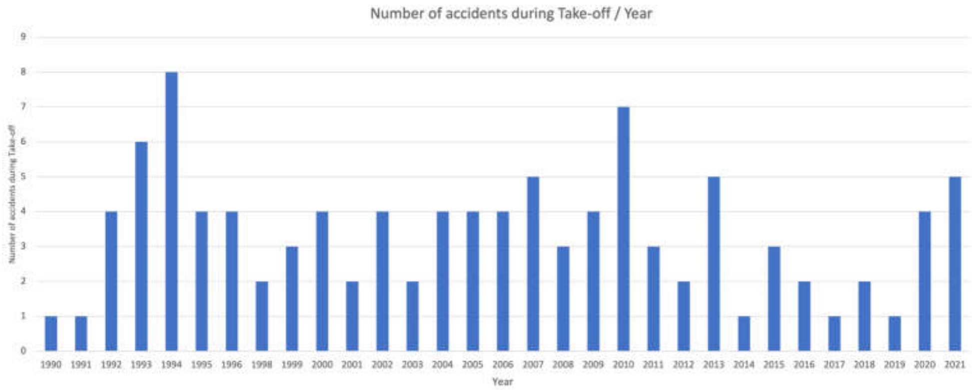

Figure 9. Number of occurrences during take-off per year, for private, recreational seaplane operations in Canada.

The distribution of the type of landing gear of the seaplanes involved in occurrences is 62.23% float and 32.83% amphibious (float-wheel and hull-wheel). The number of float seaplanes in Canada is expected to be higher than amphibious aircraft, though exact numbers could not be obtained, hence the difference in the number of occurrences for these categories. Figure 10 illustrates the number of occurrences for different occurrence categories, per different landing gear. It shows that float-equipped seaplanes have the highest number of occurrences across all categories, particularly in "LOC-G" (Loss of Control on Ground) with 28.62% of float occurrences. Amphibious float-wheel and hull-wheel configurations also show significant numbers of occurrences, albeit to a lesser extent. The most frequent types of occurrences for amphibious aircraft are: “ARC” (Abnormal Runway Contact) with 37.25% of amphibious occurrences.

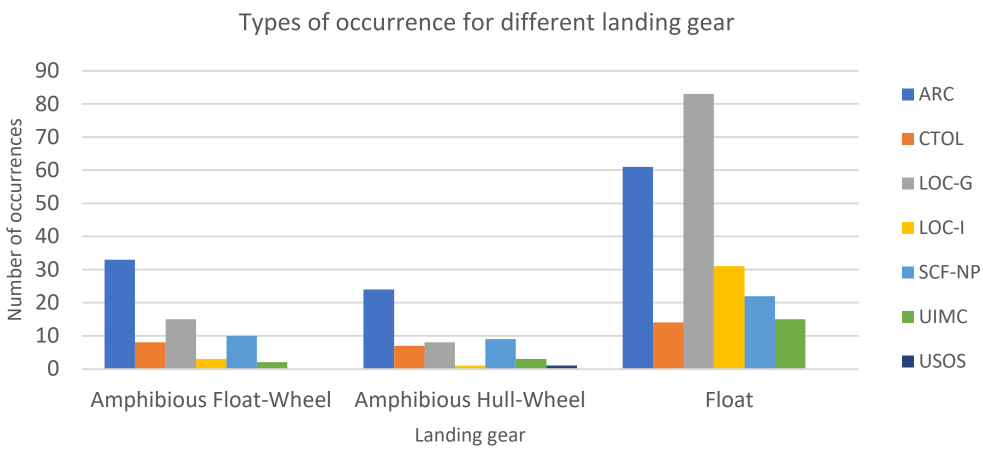

Figure 10. Number of occurrences for different categorization, per different landing gear, for private, recreational, on-water seaplane operations in Canada.

Between 1993 and 2022, private, recreational seaplane occurrences in Canada led to 179 fatalities and 401 injuries, out of which the on-water occurrences led to 37 fatalities and 140 injuries. Most injuries occurred after abnormal runway contact (31.43%), followed by loss of control on ground (15.71%) and engine failures (10%). When considering the number of fatalities, the majority occurred during unknown circumstances (35.14%), followed by abnormal runway contact and loss of control in flight (13.51% each).

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The landing phase shows the highest number of injuries (62.14%) and fatalities (64.86%), followed by the take-off phase (23.57% of injuries and 16.22% of fatalities).

Figure 11 outlines the changes in the number of injuries and fatalities over the studied period, showing an increasing trendline in the number of injuries and a constant one for fatalities. Despite low numbers in 2021-2022, this figure indicates peak values every decade, each higher than the time period before, which is concerning for the safety of seaplanes on the water.

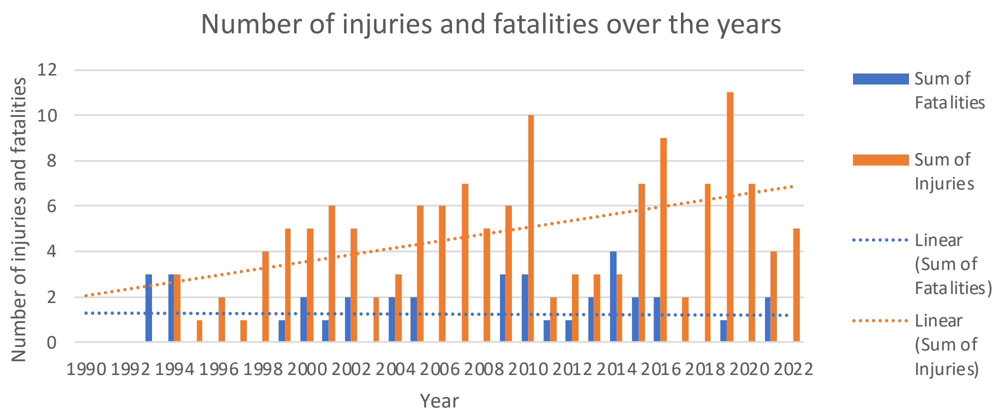

Figure 11. Number of injuries and fatalities per year, for private, recreational seaplane operations on water in Canada.

3.1.3. Contingency Analysis and Three-Way Associations

Results are obtained for 95% confidence level, for permutations of two or three of the parameters in Table 5. These have been recoded and converted into binary variables, as shown in Table 7.5-B, to help understand the meaning of the associations. In some cases, such as for the "Time" parameter which had many possible outcomes, these were grouped to reflect the part of the day (morning & evening, daytime and night-time) and therefore have only 3 possible outcomes. In other cases, such as for the "Phase of Flight" parameter, some possible outcomes were grouped into a "Other" binary variable, so that the focus can be on the phases of flight deemed of interest during the trend analysis. This was done in general for the least frequent outcomes, to avoid binary parameters with a low expected count, as those would not provide accurate results.

Table 5. Parameters used for the contingency analysis and three-way associations.

Parameter	Binary variables	Count	Description / Reasoning
Year	1990-2000	117	Separated the years into 3 groups of equal number of years.
	2001-2011	186	
	2012-2022	163	
Month	May-October	432	Grouped into flying season (May-October) and outside flying season (November-April).
	November-April	34	
Time	Daytime (11:00-17:59)	277	Grouped to reflect the part of the day.
	Morning & Evening (05:46-10:59 & 18:00-21:59)	168	
	Night-time (10pm-05:45am)	21	
	Yes Amateur Built	75	Unchanged.

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Aircraft Amateur Built Flag	Not Amateur Built	391	
Aircraft Landing Gear	Amphibious	153	"Amphibious Float-Wheel" and "Amphibious Hull-Wheel" were grouped into "Amphibious". Categories grouped into the "Other" category: "Hull" and "Water Landing Aircraft".
	Float	290	
	Other (landing) gear	23	
Aircraft Damage Level	Substantial	440	Categories grouped into the "Other" category: "Minor", "No Damage", "Missing Aircraft".
	Destroyed	16	
	Other damage (level)	10	
Phase of Flight	Landing	240	Categories grouped into the "Other" category: "Parked", "Standing".
	Roll-Out	59	
	Take-Off	106	
	Taxi	51	
	Other Phase (of Flight)	10	
Type of Occurrence (Occurrence Category)	ARC	124	Categories grouped into the "Other" category: "AMAN", "ATM", "BIRD", "CFIT", "FUEL", "GCOL", "LALT", "MAC", "MED", "OTHR", "RAMP", "RE", "TURB", "UNK", "USOS", "WSTRW".
	CTOL	29	
	LOC-G	113	
	LOC-I	39	
	SCF-NP	42	
	SCF-PP	18	
	UIMC	20	
	Other (1^{st} Occurrence) Category	81	

The results of this analysis are presented in Figure 12, which represents a heatmap of the relevant associations with 95% confidence level. The blue shades indicate moderate relationships, while the red shades indicate strong relationships.

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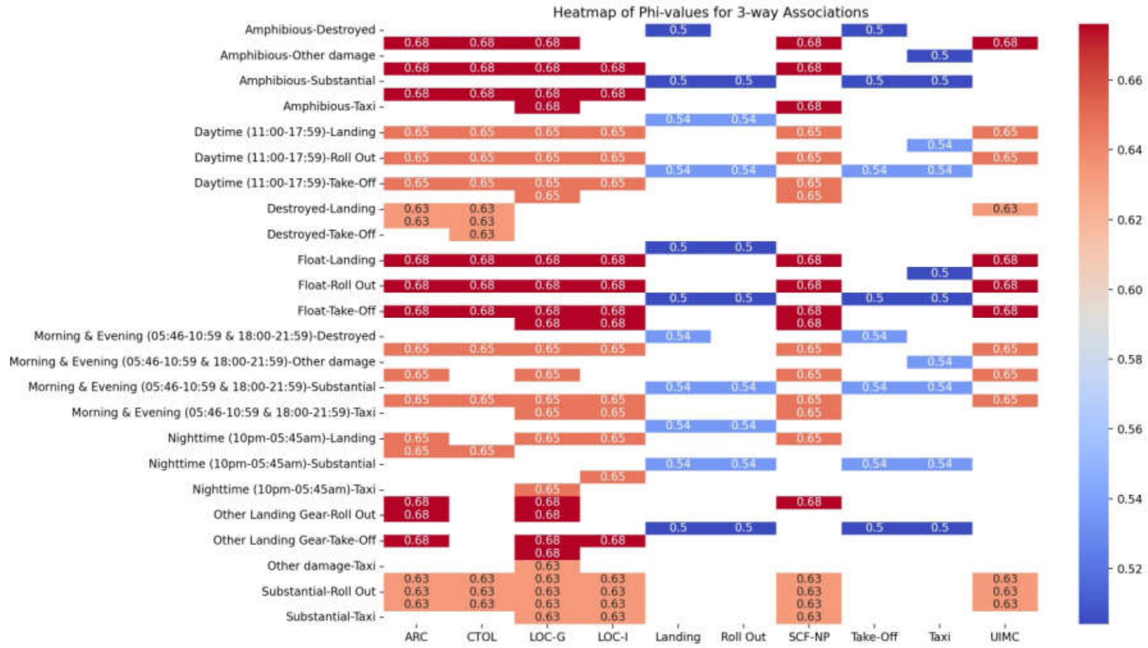

Figure 12. Three-way associations between 9 parameters for on-water occurrences of private, recreational seaplanes on the water.

Some findings that are similar to the findings already presented in the previous sections are excluded. Moreover, the associations where one of the parameters was daytime, May-October or non-amateur built were excluded, as it was previously determined that the majority of accidents and incidents happen then. Moreover, the "Other" categories have also been removed as they include combinations of less frequent variables.

Taking these into account, the main findings for strong relationships with a 95% confidence level are shown in Figure 12. As an example, there is a strong associations between amphibious aircraft being destroyed after occurrences during take-off or landing, or having substantial damage. However, occurrences of amphibian seaplanes during taxi are likely to not cause serious damage to the aircraft.

3.1.4. Summary of Quantitative Analysis

This section presented the analysis of private, recreational seaplane occurrences on water in Canada, based upon the methods outlined in Table 3. The dataset and its limitations have been defined, and data quality checks employed. For example, such limitations include the correlation between the number of occurrences and pilot experience, the inability to calculate accident rates, or factors such as pilot experience, decision making and critical thinking in adverse scenarios which are not captured by the dataset.

Despite these insights from safety data analysis, it is still insufficient if we wish to understand why such accidents happen in order to enhance the safety of this sector. The following section (Section 3.2) expands on this analysis and uses the results as the basis for collecting additional qualitative data from GA pilots.

3.2. Analysis of the Survey Responses

To supplement the quantitative analysis of the previous section, a mixed-methods approach based on qualitative data from interviews, focus groups and a questionnaire is analyzed in this section.

This study recruited 80 recreational seaplane pilots with varying degrees of experience (both in terms of years and hours flown). They range from under 20 to over 70 years in age, with the majority

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below the 50+ age range. A possible explanation for this could be that the population of seaplane pilots is decreasing, while at the same time they are currently likely to be working and thus unable to attend the interviews or focus groups. Moreover, their experience in flying seaplanes is not directly proportional to their age and has a better distribution: 32% of participants have over 30 years of experience flying seaplanes, indicating a highly experienced group. Other categories of seaplane flying experience include: 20% of participants with 6–10 years, 18% with under 2 years, 12% with 21–30 years, and smaller groups with 2–5 years (9%) and 11–20 years of experience (9%). This reflects a broad range of experience levels among participants, with a notable concentration of experienced pilots.

Data collection methods included online questionnaires, interviews, and focus groups, both in-person (22 participants) and online (29 participants). The study also engaged representatives from Canadian seaplane associations and Transport Canada, ensuring diverse stakeholder representation. Ethical considerations excluded minors and vulnerable populations to prioritize participant safety and consent.

This qualitative data was analyzed using thematic analysis [18,19]. This method was employed to identify safety concerns by refining and analyzing codes and themes (patterns) within the data, with the themes redefined to be consistent for all three methods of data collection used. By identifying and analyzing these themes, the concerns and experiences of seaplane pilots can be better understood and specific recurring issues can be addressed [20].

Before the start of the scenarios, the participants of the questionnaire were asked about personal safety concerns. The notable responses include concern over too many aircraft crashing and people killed, amphibious safety including landing gear configuration on landing, and concerns about pilot attitudes in general. The identified themes related to seaplane safety on the water are:

i) training issues;
ii) overreliance on technology;
iii) hazards from boats and jet skis;
iv) misuse of radios during private, recreational operations;
v) environmental and fauna awareness;
vi) mechanical reliability and safety.

Pilots emphasized the importance of real-world experience, citing it as a critical complement to theoretical knowledge in preparing them for unexpected situations. However, concerns were raised about overreliance on advanced systems like the G1000 avionics system, which was perceived to erode fundamental flying skills. Participants highlighted the need for training programs to strike a balance between teaching traditional piloting techniques and incorporating modern technologies, as excessive dependence on technology could lead to problems if it fails. The interplay of these themes points to a decline in basic flying skills, with a call to adapt training methods to address this challenge effectively.

Regarding the hazards imposed by boats and jet skis, seaplane pilots expressed significant concerns about their unpredictable movements, with jet skis and boats towing tubes often changing direction erratically, creating dangerous situations during take-off and landing. Pilots recounted near collisions and emphasized that many boat operators are unaware of the risks they pose to seaplanes, particularly during critical flight phases. To mitigate these hazards, pilots often delay landings or choose less congested areas, though these strategies are not always feasible. The presence of boats and jet skis adds considerable stress and anxiety to seaplane operations, leading to calls for regulatory adjustments to prioritize aircraft during take-off and landing. Additionally, pilots highlighted the importance of understanding maritime regulations to navigate busy waterways safely.

For seaplane operations on water, the lack of consistent radio use among pilots poses significant risks. Pilots often fail to announce their intentions and positions, leading to missed communications and increasing the likelihood of misunderstandings and accidents. This issue is exacerbated by a culture of "silent operations," particularly among older pilots unaccustomed to relying on radios. The absence of proper radio communication heightens the risk of collisions, especially in areas with mixed traffic, as it becomes difficult to coordinate with other seaplanes and watercraft. Furthermore, the lack of radio use reduces situational awareness, with pilots recounting incidents where unannounced aircraft suddenly appeared during critical flight phases, endangering operations.

Environmental awareness also plays a critical role in ensuring safety of seaplanes on the water. Unpredictable weather conditions pose significant challenges, requiring pilots to have strong forecasting skills and the ability to adapt to sudden changes. Wildlife hazards, including birds and marine animals, are another notable concern during take-off and landing, as wildlife strikes can be dangerous and demand constant vigilance. Additionally, glassy water conditions present unique difficulties, such as misjudging distances and visual references, which can lead to errors during landing. These environmental factors emphasize the need for heightened awareness, thorough training, and careful planning to mitigate risks in seaplane operations.

Finally, for mechanical reliability and safety, pilots highlighted that engine failures, especially during take-off, represent a significant hazard, emphasizing the importance of dependable engines. Maintenance lapses exacerbate safety risks, underscoring the need for diligent upkeep. Reliable equipment is essential, as failures can lead to severe consequences. To ensure safety and instill pilot confidence, the participants emphasized that operators must prioritize regular maintenance and invest in high-quality, dependable equipment.

4. Discussion

The findings of this study highlight critical safety challenges associated with private, recreational seaplane operations on Canadian waters, incorporating both quantitative data analysis and qualitative survey responses. By employing this mixed-methods approach, a nuanced understanding of the risks and contributing factors associated with seaplane occurrences has been provided. The implications of these findings are discussed in the context of previous studies and broader safety management systems (SMSs), emphasizing the need for targeted safety interventions and future research.

4.1. Interpretation of Results in Context of Previous Studies

The analysis revealed that loss of control and abnormal runway contact are the predominant causes of seaplane occurrences on Canadian waters, accounting for over half of the recorded occurrences. This aligns with findings from Gao [6] and Vidan et al. [7], which emphasized operational and environmental challenges unique to seaplanes. Unlike commercial seaplane operations, which benefit from rigorous regulatory oversight and advanced training protocols, private recreational activities often operate in less controlled environments with diverse pilot experience levels, increasing the risk of such incidents.

The data also indicate that landing remains the most hazardous phase of on-water seaplane operations, accounting for over half of all accidents and incidents. This corroborates international studies, including those focusing on Croatian seaplane operations, which identified landing as a critical phase due to its reliance on both waterway conditions and pilot proficiency [7]. However, this paper uniquely highlights an increasing trend in landing-related incidents in recent years, suggesting that additional factors such as operational changes or reporting practices may play a role.

The persistent challenge of obtaining detailed data, particularly for private recreational seaplanes, is consistent with Ison's [16] observations regarding the lack of comprehensive records on flight hours, pilot experience, and seaplane operations. This gap underscores the need for enhanced data collection mechanisms to support more accurate risk assessments and safety interventions.

4.2. Broader Implications

From a broader perspective, the study highlights the intersection of maritime and aviation safety, where dual operational environments create unique challenges for seaplane operations. The increasing trend in private recreational occurrences, particularly involving amateur-built aircraft, raises concerns about regulatory oversight and safety education in this sector. Addressing these gaps requires collaboration between aviation and maritime authorities to establish integrated safety management systems (SMS) that consider the dual nature of seaplanes. The findings also underscore the importance of reporting near-misses and minor incidents, which often go unreported but provide valuable insights into potential hazards. Enhanced reporting frameworks could significantly improve the understanding of seaplane safety and inform the development of targeted interventions.

Mitigating risks from boats and jet skis requires raising boater awareness about seaplane operations through community outreach and collaboration with maritime authorities. Regulatory adjustments giving aircraft priority during take-off and landing, along with clear right-of-way rules communicated to both pilots and boaters, can reduce conflicts. Education on maritime regulations is essential for safer shared waterways. Thus, pilots should be trained to recognize high-traffic water areas and apply effective avoidance tactics using standardized protocols.

To address the issue of insufficient training quality, the minimum mandatory course durations could be extended, and mandatory proficiency checks could be implemented, as well as using detailed checklists to ensure pilots meet required standards before flying solo. To combat any decline in skills due to over-reliance on technology, training programs should balance advanced system use with manual flying techniques, emphasizing hands-on experience. Updating the Seaplane Rating document to cover unsafe scenarios and spreading training over diverse conditions will better prepare pilots. Incorporating real-world flying exercises, simulated emergencies, and theoretical-practical integration should be mandatory as they can further enhance pilot readiness. Additionally, offering insurance discounts for pilots completing extra safety-related courses can incentivize further training and improve overall safety standards.

4.3. Future Research Directions

While this study provides critical insights, several areas warrant further exploration. Future research on seaplane safety should prioritize comprehensive data collection, focusing on seaplane movements, pilot experience and operational contexts, particularly in private, recreational activities. Incorporating GPS tracking and automated reporting systems could enhance data accuracy.

Studies relating to amateur-built aircraft are also essential, exploring design, construction, and operational practices through collaborations with manufacturers and pilot associations. Furthermore, expanding this research to other countries could provide a comparative analysis across different regions with established seaplane industries. Additionally, deeper exploration of human factors, including pilot decision-making, cognitive biases, and stress management is crucial to address the role of human error in seaplane occurrences.

5. Conclusions

This study has emphasized the unique safety challenges associated with seaplane operations on Canadian waters, particularly in the private and recreational sectors. Unlike their commercial counterparts, private seaplane pilots operate in less regulated environments, increasing exposure to risks related to pilot experience, water conditions, and interactions with maritime traffic. The findings underscore the need for a holistic approach to safety management that integrates both aviation and maritime principles.

Raising safety awareness within the seaplane community requires active engagement through in-person events like seminars, workshops, and focus groups, which have proven effective based on positive participant feedback. Encouraging community involvement in safety initiatives fosters a strong safety culture, supported by awareness programs sharing practical tips through social media, newsletters, and seasonal emails. Additionally, collaboration with industry stakeholders, including regulatory bodies, training organizations, and seaplane operators, is essential for developing standardized safety protocols and sharing resources to enhance safety education.

Ultimately, addressing seaplane safety on water requires ongoing research, policy adjustments, and proactive engagement with all stakeholders. By implementing targeted safety interventions and

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fostering a culture of awareness and preparedness, future efforts can contribute to safer waterways for seaplane pilots, passengers, and the broader maritime community.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of Imperial College London.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The seaplane accident/incident data has been made available by the collaborators in Transport Canada.

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Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Appendix A

Figures, Tables, etc. should be labeled starting with "A"—e.g., Figure A1, Figure A2, etc.

This appendix presents the documents approved by the Imperial College ethics committee through the Research Governance and Integrity Team (RGIT). It includes:

- Research protocol
- Participant information sheets (for interviews and survey)
- Consent forms (for interviews and survey)
- Booklets (one to provide information related to data analysis which is kept by the participant and another with multiple choice questions kept by the investigator)
- Online questionnaire.

1. Research protocol

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Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges

Study Management Group

Principal Investigator: Iulia Manole

Co-investigators / Collaborators: Prof. Arnab Majumdar, Simon Garrett

Sponsor

Imperial College London is the main research Sponsor for this study. For further information regarding the sponsorship conditions, please contact the Head of Research Governance and Integrity.

This protocol describes the " Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges" study and provides information about procedures for entering participants for the survey and interviews. Every care was taken in its drafting, but corrections or amendments may be necessary. These will be circulated to investigators in the study. Problems relating to this study should be referred, in the first instance, to the Principal Investigator.

This study will be conducted in compliance with the protocol, Data Protection Act 2018 and General Data Protection Regulations (Europe) and other regulatory requirements as appropriate.

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TABLE OF CONTENTS

Contents

 doi:10.20944/preprints202503.1767.v1

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1. INTRODUCTION

1.1 Background

General Aviation (GA) encompasses all civil aviation operations other than scheduled air services and non-scheduled air transport operations for remuneration or hire. It is a vital component of the global aviation ecosystem as it is crucial for various purposes, including flight training, agriculture, law enforcement, recreational flying, and emergency medical services. Given its diverse applications, the safety of GA operations is of paramount importance. Most GA accidents and serious incidents involve pleasure flights or flight training, so studying these is of paramount importance for improving the safety of GA operations. [1]

In Canada, GA plays a significant role in connecting remote communities and supporting various economic activities. The safety of GA in Canada is crucial given the large geographical expanse and the reliance on aviation for transportation and logistics [2]. A significant problem contributing to GA accidents is related to seaplane operations. Seaplanes are uniquely suited for a variety of operations but carry additional risks due to the environments in which they operate. From 1990 through 2022, there were 1005 accidents involving privately registered seaplanes, with a considerable number (118) ending in the aircraft being destroyed. In the past 30 years (between 1993 and 2022), seaplane accidents in Canada led to 179 fatalities and 401 injuries. This is significant considering that seaplanes make up less than five percent of all GA aircraft. The analysis of these accidents reveals that understanding and addressing the specific challenges of seaplane operations are crucial for the safety of this sector within GA.

A relevant study is the paper by Irwi, Sedlar and Hamlet (2019), which aims to understand how pilots evaluate risks relevant to flight, by looking at their assessment and management strategies across various risk types. The study used an online vignette method, presenting pilots with 12 go/no-go take-off decision scenarios across four risk categories. Pilots' responses varied based on the risk depicted [3]. This type of analysis, focusing on pilots' decision-making processes, adds a crucial dimension to accident data analysis. It provides insights into the subjective nature of risk perception and decision-making, offering a deeper understanding of the factors influencing pilots' choices in different scenarios. This approach is vital as it complements traditional accident data analysis, highlighting areas for targeted training and safety awareness campaigns.

It can be concluded that the safety of General Aviation is of great importance, requiring continuous attention and improvement. Seaplane operations present specific challenges that contribute significantly to GA accidents. This highlights the need for comprehensive safety strategies, including regular surveys and interviews with pilots and operators. Such proactive measures are vital because analysing accident data alone has proven insufficient in recent years. A more holistic approach that includes feedback from those directly involved in seaplane operations can provide deeper insights into safety deficiencies and lead to more effective preventive measures.

1.2 Study Rationale

This study aims to diminish the number of seaplane accidents in Canada by enhancing safety awareness within the Seaplane General Aviation (GA) community in Canada, and by determining further details that had not been captured by the previously analysed databases,

 doi:10.20944/preprints202503.1767.v1

such as pilot concerns and decision making during pre-determined scenarios (answer "What would you do in this scenario?").
The survey and interviews will cover a wide range of scenarios during take-off, climb, cruise, approach and landing, based on the most recurring accident types seen after analysing data between 1990 and 2022 of privately registered seaplanes in Canada. This format encourages pilots and other seaplane safety professionals to think critically about what could happen in different conditions, and flag any potential current issues that should be addressed. This study will significantly contribute to safety awareness and training improvements.

2. STUDY OBJECTIVES

This study has the following objectives:

Determine factors contributing to accidents and incidents that had not been captured by the previously analysed databases, such as pilot concerns and decision making, by asking pilots and other seaplane safety professionals to think critically about what could happen in different conditions, and flag any potential current issues that should be addressed.
Determine whether the actions pilots take in certain scenarios differ among age groups and level of experience with flying seaplanes.
Bring awareness on the main factors contributing to past seaplane accidents, and their implications.
Determine which methods of safety promotion are preferred, which will be used in the future to maximise the outreach and visibility of safety issues and recommendations.

3. STUDY DESIGN

The study will begin with a short description of its purpose and participants are assured of confidentiality.

- Type of study: anonymous online survey (on Qualtrics) and interviews (online on Microsoft Teams, recorded with the consent of the participant).
- Recruitment methods: Participants will be recruited from different General Aviation (GA) communities, during meetings of the Seaplane Working Group (SPWG) of Transport Canada, and then via email, based on their expressed willingness to take part in the study. Participants will also be recruited from COPA by the collaborator of this study, Simon Garrett.
- Duration of study from advertising and recruitment to end of data collection: 2 months.
- Number of participants:
    - Survey: aiming to have minimum 30 participants of different experience (minimum 10 people from each of the 3 groups of experience in flying seaplanes: 10 - 100, 101 - 500 and over 501 hours flown in a seaplane). If this number is not met, there will be no pressure on any other participants to take part in the study.
    - Interviews: aiming to have minimum 5 participants, so at least one participant from the following GA communities: Canadian Owners and Pilots Association (COPA), Aviateurs Quebec, Ontario Seaplane Association, Northwest Territories Flying Association, and Transport Canada's General Aviation

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Safety Program's Seaplane Working Group. If this number is not met, there will be no pressure on any other participants to take part in the study.

- Data processing: the results will be analysed using statistical and thematic analysis by the principal investigator.

The study is aimed for recreational and experienced seaplane pilots and other safety professionals, representatives of other GA communities, such as the Canadian Owners and Pilots Association (COPA), Aviateurs Quebec, Ontario Seaplane Association, Northwest Territories Flying Association, and members of Transport Canada's General Aviation Safety Program's Seaplane Working Group, who have expressed their interest in taking part in this study that will complement the current quantitative work of the working group. The participants for the survey will be sent a link to complete the survey online. The interviews will follow the same structure and questions of the survey, but the interviewed participants will have an opportunity to give more detailed answers and flag concerns that have not been included in the survey. Every participant will be emailed the participant information sheets and consent forms prior to the start of their interview. Consent will also be asked for at the beginning of the survey and interviews.

4. PARTICIPANT RECRUITMENT

4.1 Pre-recruitment evaluations

There are no requirements that a participant must fulfil. The survey will be circulated amongst seaplane pilots in Canada, and this requirement is also tested in the first section of the survey. The participants for the interviews will be selected by the investigators based on their experience in the field.

4.2 Inclusion Criteria

The participants must have experience in flying seaplanes or other experience in seaplane safety. People that are contacted must have expressed willingness to take part in the study, during the SPWG meetings or via email, to the investigators and collaborator of this study. The survey will be circulated amongst seaplane pilots in Canada by the collaborator Simon Garrett and other members of the SPWG, and this requirement is also tested in the first section of the survey.

4.3 Exclusion Criteria

Minors and people considered vulnerable. People without any experience in flying seaplanes or seaplane safety will also be excluded. Any level of experience in these is welcome. The participants for the interviews will be carefully selected by the investigators based on their experience in the field.

4.4 Withdrawal Criteria

The participants can withdraw anytime, before, during or after the interviews and questionnaires. Even if the data has already been collected and anonymised, it can be removed from the study at the request of the participant.

Participants can contact Iulia Manole at iuliamanole97@gmail.com about withdrawing from the study.

 doi:10.20944/preprints202503.1767.v1

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5. ASSESMENT AND FOLLOW UP

The final results will be presented online at the meetings of the Seaplane Working Group (SPWG) of Transport Canada for the participants that are part of these working groups, followed by another presentation at the annual meeting. The interviewed participants will be emailed a copy of their transcribed answers and have the opportunity to alter any information.

6. REGULATORY ISSUES

6.1 Ethics approval

The Principal Investigator has obtained approval from the Head of Department and favourable opinion from the Research Governance and Integrity Team (RGIT).

6.2 Consent

Consent to enter the study must be sought from each participant only after a full explanation has been given, and time allowed for consideration. Participant consent should be obtained at the beginning of the survey and interviews, which will be recorded, or via email if the participant refuses to have their interview recorded. The right of the participant to refuse to participate without giving reasons must be respected. All participants are free to withdraw at any time.

6.3 Confidentiality

The Principal Investigator will preserve the confidentiality of participants taking part in the study and fulfil transparency requirements under the General Data Protection Regulation for health and care research. Data and all appropriate documentation will be stored for a minimum of 10 years after the completion of the study, including the follow-up period.

6.4 Indemnity

Imperial College London holds negligent harm insurance policies which apply to this study.

6.5 Sponsor

Imperial College London will act as the main sponsor for this study.

6.6 Funding

This study is not funded.

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6.7 Audits

The study may be subject to inspection and audit by Imperial College London under their remit as sponsor.

7. PUBLICATION POLICY

The results of this study will be published by Imperial College as main authors.

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2. Participant Information Sheet – Interviews

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Participant Information Sheet

Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges - INTERVIEW

Principal investigator: Iulia Manole
Coinvestigator: Prof. Arnab Majumdar
Collaborator: Simon Garrett

- **Invitation paragraph**

We invite you, a valued member of the seaplane pilot community in Canada, to take part in a research study aimed at enhancing the safety of Seaplane General Aviation (GA). This will be in the form of an interview. Your insights and experiences are crucial to our understanding and improvement of safety measures within the community.

Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.

The purpose of this study is to bring awareness on Seaplane General Aviation (GA) safety concerns in Canada that resulted from an in-depth analysis of Seaplane GA past accident and incident data, as well as to determine further details in areas previously overlooked by existing data, such as pilot concerns and decision making during pre-determined scenarios (answer “What would you do in this scenario?”).

If you decide to take part, your contribution will consist of completing an online survey or interview divided into 3 parts:

- Part 1: General details - Share general information about yourself, including your age group, flying experience, and any relevant training.
- Part 2a: Scenarios - Engage with hypothetical scenarios to reveal your decision-making processes, by providing your own answers and flag any areas of concern.
- Part 2b: Review and reflect on statistics and trends from past GA seaplane accidents in Canada, which are linked to the scenarios in Part 2a.
- Part 3: Ending questions - Help us understand the factors influencing the reporting of minor incidents and near misses, since these can often signal that something is amiss and analysing these could help prevent more serious

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events. This will also help us understand how accurate the analysis of past accidents and incidents actually is.

Your participation is entirely voluntary, but immensely valuable. We encourage you to take the time you need to consider this invitation. Should you have any questions or need further information, please do not hesitate to contact us.

We appreciate your consideration of this invitation and hope you will decide to contribute to our shared goal of improving seaplane safety in Canada.

- **What is the purpose of the study?**

This study aims to enhance safety awareness within the Seaplane General Aviation (GA) community in Canada using the results from an in-depth analysis of Seaplane GA past accident and incident data, as well as to determine further details that had not been captured by the previously analysed databases, such as pilot concerns and decision making during pre-determined scenarios (answer “What would you do in this scenario?”).

The interview covers a wide range of scenarios during take-off, climb, cruise, approach and landing, based on the most recurring accident types seen after analysing data between 1990 and 2022 of privately registered seaplanes in Canada. This format encourages pilots to think critically about their actions in different conditions, while bringing awareness on current safety issues. The interviewed participant will be able to answer freely and flag any points of concern. This study will significantly contribute to safety awareness and training improvements.

This study is conducted for a student research project, as part of the PhD research of the main investigator (Iulia Manole), under the supervision of Prof. Arnab Majumdar.

- **Why have I been invited?**

You have been invited as you are a GA Seaplane pilot, or you have other relevant experience in seaplane operations and safety.

- **Do I have to take part?**

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

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- **What do I have to do?**

You will be invited to take part in an online interview.

- **What will happen to me if I take part?**

Within two months of receipt, you will be asked to take part in an online interview when you are available. This interview has been designed to take under 60 minutes.

- **What are the possible disadvantages and risks of taking part?**

There are no risks or disadvantages associated with taking part in this study.

- **What if something goes wrong?**

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been treated during the course of this study then you should immediately inform the Investigator (Iulia Manole at iuliamanole97@gmail.com). If you are still not satisfied with the response, you may contact the Imperial College Research Governance Integrity Team (rgitcoordinator@imperial.ac.uk).

- **What will happen to the results of the research study?**

The results will be analysed and studied together with the findings from the analysis of past seaplane accidents/incidents. This will provide a comprehensive understanding of what is amiss, so that recommendations can be made on ways to improve seaplane safety. The aim is to publish the results this year, so that the findings are not outdated. You will not be identified in any publication as grouped study data will be used and not individual data.

- **Who has reviewed the study?**

This study was given favourable opinion by the Research Governance and Integrity Team (RGIT) and approval by Prof. Washington Ochieng, Head of Department of Civil and Environmental Engineering.

Contact for Further Information

A copy of the written information and signed Informed Consent form will be given to the participant to keep.

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For further information, please contact Iulia Manole at iuliamanole97@gmail.com or +447936696372, or Prof. Arnab Majumdar at a.majumdar@imperial.ac.uk .

Thank you for taking part in this study!

Imperial College London

Transparency Notice

How will we use information about you?

Research Study Title: Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges

Imperial College London is the sponsor for this study and will act as the data Controller for this study. This means that we are responsible for looking after your information and using it appropriately Imperial College London will keep your personal data for:

- 10 years after the study has finished in relation to data subject consent forms.
- 10 years after the study has completed in relation to primary research data.

The study is expected to finish in July / 2024

For more information / confirmation regarding the end date please contact the study team, see '**WHERE CAN YOU FIND OUT MORE ABOUT HOW YOUR INFORMATION IS USED'** for contact information.

We will need to use information (including personal data and data created as part of the study) from you for this research project.
This information will include your email address. People within Imperial College London and study team (see section 'Sharing your information with others') will use this information to do the research or to check your records (see information to be collected) to make sure that the research is being done properly and the information held (such as contact details) is accurate. If you wish to provide your email address, people who do not need to know who you are will not be able to see your contact details. Your data will have a unique study number instead.
We will keep all information about you safe and secure.
Once we have finished the study, we will keep some of the data so we can check the results. We will write our reports in a way that no-one can work out that you took part in the study.

LEGAL BASIS

As a university we use personal information to conduct research that will either be in the public interest, or the 'legitimate interests' of Imperial College whose interests are to conduct world leading research and innovation aiming to deliver transformative impact for society. Our legal basis for using your information under the General Data Protection Regulation (GDPR) and the Data Protection Act 2018, is as follows:

• Imperial College London - "performance of a task carried out in the public interest";
Where special category personal information is involved (most commonly health data, biometric data and genetic data, racial and ethnic data etc.), Imperial College London relies on "scientific or historical research purposes or statistical purposes

We will conduct scientific research in compliance with the law and the recommendations and guidance published by the UK Information Commissioners Office (ICO). This will follow similar rules to health and social care research but may not meet the definition of the College's public interest task or requirement. In such cases we will be holding and using

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your data for what are called our "legitimate interests" where, as previously stated, the College aims to conduct world leading research and innovation aiming to deliver transformative impact for society. Scientific research should serve the public interest, which means that we have to demonstrate that our research has societal impact serving the interests of society as a whole.

INTERNATIONAL TRANSFERS

There may be a requirement to transfer information to countries outside the United Kingdom for example, to a research partner, either within the European Economic Area (EEA) or to other countries outside the EEA. Where this information contains your personal information, Imperial College London will ensure that it is transferred in accordance with data protection legislation. If the data is transferred to a country which is not subject to a UK adequacy decision in respect of its data protection standards, Imperial College London will enter into a data sharing agreement with the recipient organisation that incorporates UK approved standard contractual clauses or use another transfer mechanism that safeguards how your personal data is processed.

SHARING YOUR INFORMATION WITH OTHERS

We will only share your personal data with certain third parties for the purposes referred to in this participant information sheet and by relying on the legal basis for processing your data as set out above.

- Other Imperial College London employees (including staff involved directly with the research study or as part of defined secondary activities which may include support functions, internal audits, ensuring accuracy of contact details etc.), College agents, contractors and service providers (for example, suppliers of printing and mailing services, email communication services or web services, or suppliers who help us carry out any of the activities described above). Our third party service providers are required to enter into data processing agreements with us. We only permit them to process your personal data for specified purposes and in accordance with our policies.
- the following Research Collaborators / Partners in the study:
    - Transport Canada – Only the survey data, not personal data (i.e., Participant Information Sheet), will be shared with Simon Garrett, Lead of the General Aviation Safety Program and Seaplane Working Group, for the purposes of further research and analysis to improve seaplane safety in Canada. Mr. Garrett is listed as a Collaborator on this project.

POTENTIAL USE OF STUDY DATA FOR FUTURE RESEARCH

When you agree to take part in a research study, the information collected either as part of the study or in preparation (such as contact details) may, with your consent, be provided to researchers running other research studies in this organisation and in other organisations. These organisations may be universities or organisations involved in research in this country or abroad. Your information will only be used by organisations and researchers to conduct research in accordance with all relevant legislation including the GDPR (UK GDPR and EU GDPR 2016/679), the Data Protection Act 2018.

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This information will not identify you and will not be combined with other information in a way that could identify you, used against you or used to make decisions about you.

COMMERCIALISATION

Samples / data from the study may also be provided to organisations not named in this participant information sheet, e.g. commercial organisations or non-commercial organisations for the purposes of undertaking the current study, future research studies or commercial purposes such as development by a company of a new test, product, service or treatment. We will ensure your name and any identifying details will NOT be given to these third parties, instead you will be identified by a unique study number with any sample analysis having the potential to generate 'personal data'.

Aggregated (combined) or anonymised data sets (all identifying information is removed) may also be created using your data (in a way which does not identify you individually) and be used for such research or commercial purposes where the purposes align to relevant legislation (including the GDPR) and wider aims of the study. Your data will not be shared with a commercial organisation for marketing purposes.

WHAT ARE YOUR CHOICES ABOUT HOW YOUR INFORMATION IS USED?

You can stop being part of the study at any time, without giving a reason, but we will keep information about you that we already have because some research using your data may have already taken place and this cannot be undone

- **OPTION if follow up data will be collected after withdrawal:** If you choose to stop taking part in the study (also known as opting out), we will stop collecting information about you.
- We need to manage your records in specific ways for the research to be reliable. This means that we may not be able to let you see or change the data we hold about you if this could affect the wider study or the accuracy of data collected.
- If you agree to take part in this study, you will have the option to take part in future research using your data saved from this study.

WHERE CAN YOU FIND OUT MORE ABOUT HOW YOUR INFORMATION IS USED

You can find out more about how we use your information:

- by asking one of the research team
- by sending an email to Iulia Manole at iuliamanole97@gmail.com or to Prof. Arnab Majumdar at a.majumdar@imperial.ac.uk, or
- by ringing Iulia Manole on +447936696372 (time zone UTC+1 / BST).

COMPLAINT

If you wish to raise a complaint about how we have handled your personal data, please contact the research team first by sending an email to Iulia Manole at iuliamanole97@gmail.com, Prof. Arnab Majumdar at a.majumdar@imperial.ac.uk , or by ringing us on +447936696372.

Following our response, if you are not satisfied please contact Imperial College London's Data Protection Officer via email at dpo@imperial.ac.uk, via telephone on 020 7594 3502 and/or

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via post at Imperial College London, Data Protection Officer, Faculty Building Level 4, London SW7 2AZ.

If you remain unsatisfied with our response or believe we are processing your personal data in a way that is not lawful you can complain to the Information Commissioner's Office (ICO) via www.ico.org.uk. The ICO does recommend that you seek to resolve matters with the data controller (us) first before involving them.

3. Participant Information Sheet – Survey

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Participant Information Sheet

Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges - SURVEY

Principal investigator: Iulia Manole
Coinvestigator: Prof. Arnab Majumdar
Collaborator: Simon Garrett

- **Invitation paragraph**

We invite you, a valued member of the seaplane pilot community in Canada, to take part in a research study aimed at enhancing the safety of Seaplane General Aviation (GA). This will be in the form of a survey. Your insights and experiences are crucial to our understanding and improvement of safety measures within the community.

Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish.

The purpose of this study is to bring awareness on Seaplane General Aviation (GA) safety concerns in Canada that resulted from an in-depth analysis of Seaplane GA past accident and incident data, as well as to determine further details in areas previously overlooked by existing data, such as pilot concerns and decision making during pre-determined scenarios (answer "What would you do in this scenario?", by choosing from a set of pre-defined answers).

If you decide to take part, your contribution will consist of completing an online survey or interview divided into 3 parts:

- Part 1: General details - Share general information about yourself, including your age group, flying experience, and any relevant training.
- Part 2a: Scenarios - Engage with hypothetical scenarios to reveal your decision-making processes, selecting from predefined responses or providing your own.
- Part 2b: Review and reflect on statistics and trends from past GA seaplane accidents in Canada, which are linked to the scenarios in Part 2a.
- Part 3: Ending questions - Help us understand the factors influencing the reporting of minor incidents and near misses, since these can often signal that

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something is amiss and analysing these could help prevent more serious events. This will also help us understand how accurate the analysis of past accidents and incidents actually is.

Your participation is entirely voluntary, but immensely valuable. We encourage you to take the time you need to consider this invitation. Should you have any questions or need further information, please do not hesitate to contact us.

We appreciate your consideration of this invitation and hope you will decide to contribute to our shared goal of improving seaplane safety in Canada.

- **What is the purpose of the study?**

This study aims to enhance safety awareness within the Seaplane General Aviation (GA) community in Canada using the results from an in-depth analysis of Seaplane GA past accident and incident data, as well as to determine further details that had not been captured by the previously analysed databases, such as pilot concerns and decision making during pre-determined scenarios (answer “What would you do in this scenario?”, by choosing from a set of pre-defined answers).

The survey covers a wide range of scenarios during take-off, climb, cruise, approach and landing, based on the most recurring accident types seen after analysing data between 1990 and 2022 of privately registered seaplanes in Canada. This format encourages pilots to think critically about their actions in different conditions, while bringing awareness on current safety issues. This study will significantly contribute to safety awareness and training improvements.

This study is conducted for a student research project, as part of the PhD research of the main investigator (Iulia Manole), under the supervision of Prof. Arnab Majumdar.

- **Why have I been invited?**

You have been invited as you are a GA Seaplane pilot that could have experienced scenarios similar to those presented in the survey.

- **Do I have to take part?**

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

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- **What do I have to do?**

You will be asked to answer an online survey.

- **What will happen to me if I take part?**

Within one month of receipt, you will be asked to answer an online survey in your own time. This survey has been designed to take 30 minutes.

- **What are the possible disadvantages and risks of taking part?**

There are no risks or disadvantages associated with taking part in this study.

- **What if something goes wrong?**

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence, then you may have grounds for a legal action. Regardless of this, if you wish to complain, or have any concerns about any aspect of the way you have been treated during the course of this study then you should immediately inform the Investigator (Iulia Manole at iuliamanole97@gmail.com). If you are still not satisfied with the response, you may contact the Imperial College Research Governance Integrity Team (rgitcoordinator@imperial.ac.uk).

- **What will happen to the results of the research study?**

The results will be analysed and studied together with the findings from the analysis of past seaplane accidents/incidents. This will provide a comprehensive understanding of what is amiss, so that recommendations can be made on ways to improve seaplane safety. The aim is to publish the results this year, so that the findings are not outdated. You will not be identified in any publication as grouped study data will be used and not individual data.

- **Who has reviewed the study?**

This study was given favourable opinion by the Research Governance and Integrity Team (RGIT) and approval by Prof. Washington Ochieng, Head of Department of Civil and Environmental Engineering.

Contact for Further Information

A copy of the written information and signed Informed Consent form will be given to the participant to keep.

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Thank you for taking part in this study!

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We will keep all information about you safe and secure.
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- the following Research Collaborators / Partners in the study:
    - Transport Canada – Only the survey data, not personal data (i.e., Participant Information Sheet), will be shared with Simon Garrett, Lead of the General Aviation Safety Program and Seaplane Working Group, for the purposes of further research and analysis to improve seaplane safety in Canada. Mr. Garrett is listed as a Collaborator on this project.

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- by sending an email to Iulia Manole at iuliamanole97@gmail.com or to Prof. Arnab Majumdar at a.majumdar@imperial.ac.uk, or
- by ringing Iulia Manole on +447936696372 (time zone UTC+1 / BST).

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Imperial College London

via post at Imperial College London, Data Protection Officer, Faculty Building Level 4, London SW7 2AZ.

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4. Consent Form – Interviews

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Consent Form for Participants Able to Give Consent

Full Title of Project: Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges - INTERVIEW

Name of Principal Investigator: Iulia Manole

	Please write your initials in the box
1. I confirm that I have read and understand the participant information sheet version .... dated .... for "Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges" and have had the opportunity to ask questions which have been answered fully.	
2. I consent to take part in "Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges".	
3. I understand that my participation is voluntary, and I am free to withdraw at any time, without giving any reason and without my legal rights being affected.	
4. I give / do not give (delete/mark as applicable) consent to being contacted about the possibility to take part in other research studies.	
5. I understand that data collected from me are a gift donated to Imperial College and that I will not personally benefit financially if this research leads to an invention and/or the successful development of a new test, medication treatment, product or service.	
6. I give/do not give (delete/mark as applicable) consent for information collected about me to be used to support other research or in the development of a new test, medication, medical device or treatment (delete as applicable) by an academic institution or commercial company in the future, including those outside of the United Kingdom (which Imperial has ensured will keep this information secure).	
7. I give/do not give (delete/mark as applicable) consent for my interview to be recorded and transcribed. The recordings will be deleted after the transcription is complete, and only accessible by the investigators of the study during that time.	

______________________	______________	______________
Name of participant	Signature	Date
___IULIA MANOLE_______	______________	______________
Principal Investigator	Signature	Date

Template Ref: RGIT_TEMP_078
Template V3.0 09Apr2024

 doi:10.20944/preprints202503.1767.v1

Imperial College London

1 copy for participant; 1 copy for Principal Investigator

To ensure confidence in the process and minimise risk of loss, all consent forms must be printed, presented and stored in double sided format

5. Consent Form – Survey

Imperial College London

Consent Form for Participants Able to Give Consent

Full Title of Project: Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges - SURVEY

Name of Principal Investigator: Iulia Manole

	Please write your initials in the box
1. I confirm that I have read and understand the participant information sheet version .... dated .... for "Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges" and have had the opportunity to ask questions which have been answered fully.	
2. I consent to take part in "Safety In The Skies And Waters: Understanding Seaplane Pilot Decision Making In Critical Situations While Bringing Safety Awareness On Current Challenges".	
3. I understand that my participation is voluntary, and I am free to withdraw at any time, without giving any reason and without my legal rights being affected.	
4. I give / do not give (delete/mark as applicable) consent to being contacted about the possibility to take part in other research studies.	
5. I understand that data collected from me are a gift donated to Imperial College and that I will not personally benefit financially if this research leads to an invention and/or the successful development of a new test, medication treatment, product or service.	
6. I give/do not give (delete/mark as applicable) consent for information collected about me to be used to support other research or in the development of a new test, medication, medical device or treatment (delete as applicable) by an academic institution or commercial company in the future, including those outside of the United Kingdom (which Imperial has ensured will keep this information secure).	

______________________	________________	________________
Name of participant	Signature	Date
___IULIA MANOLE_______	________________	________________
Principal Investigator	Signature	Date

1 copy for participant; 1 copy for Principal Investigator

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6. Booklet 1 (to provide information related to data analysis which is kept by the participant)

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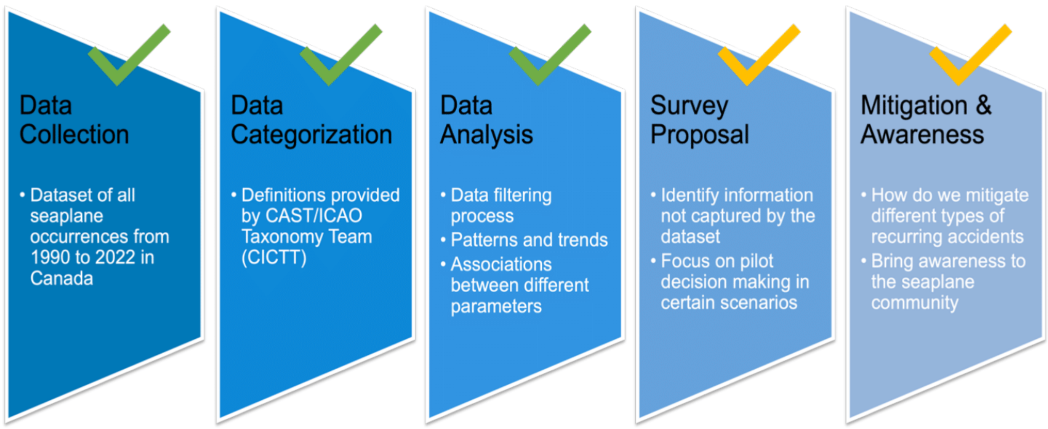
IMPERIAL

Analysis of Seaplane Accidents in Canada

1,005 private seaplane occurrences in Canada - 1990 to 2022

* Occurrences = Accidents + Incidents

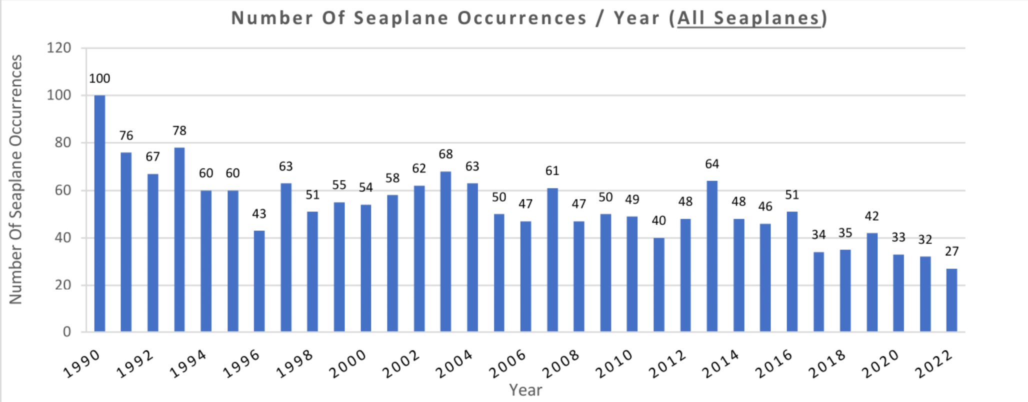
- General Aviation Safety Program
- Seaplane Working Group
- Imperial College London

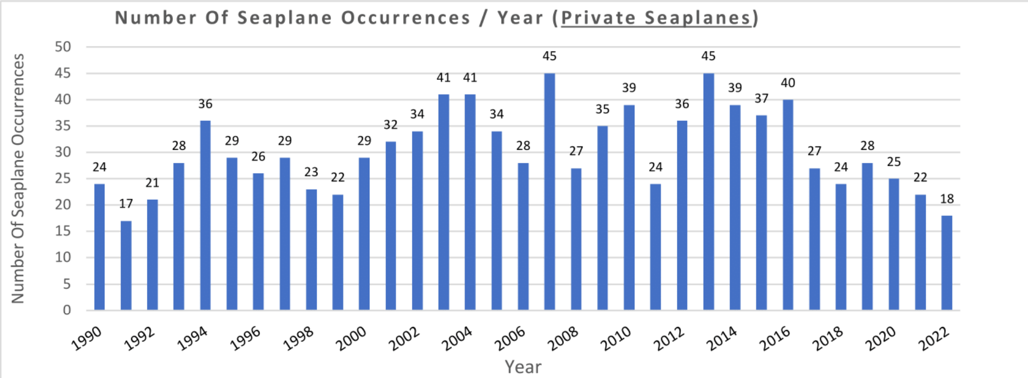


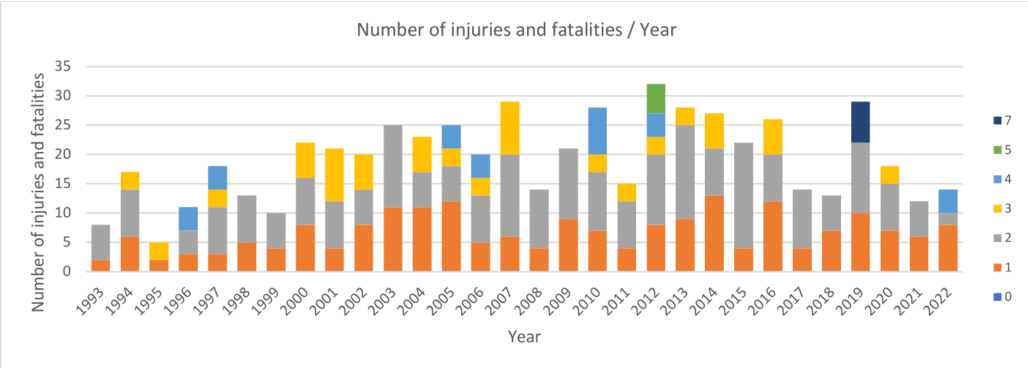
Data analyzed around specific variables:

- Year
- Landing Gear
- Phase of Flight
  - Take-off
  - Climb
  - Landing
- Aircraft Damage Level (Destroyed Aircraft / Number of fatalities and injuries)
- Other

Statistics / **Year** of occurrence:







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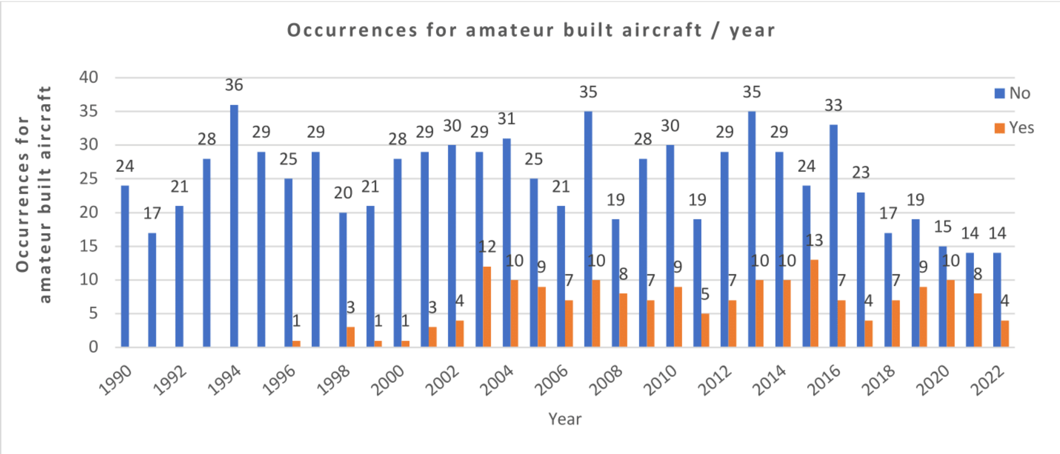

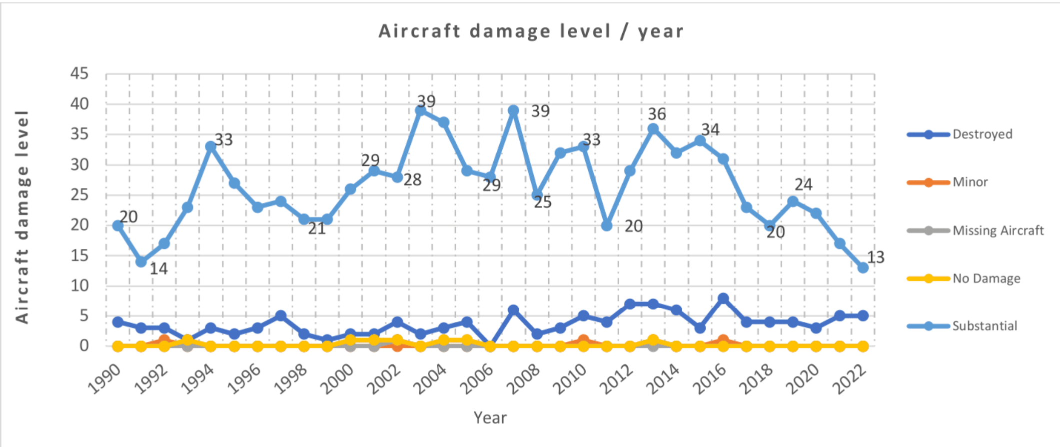

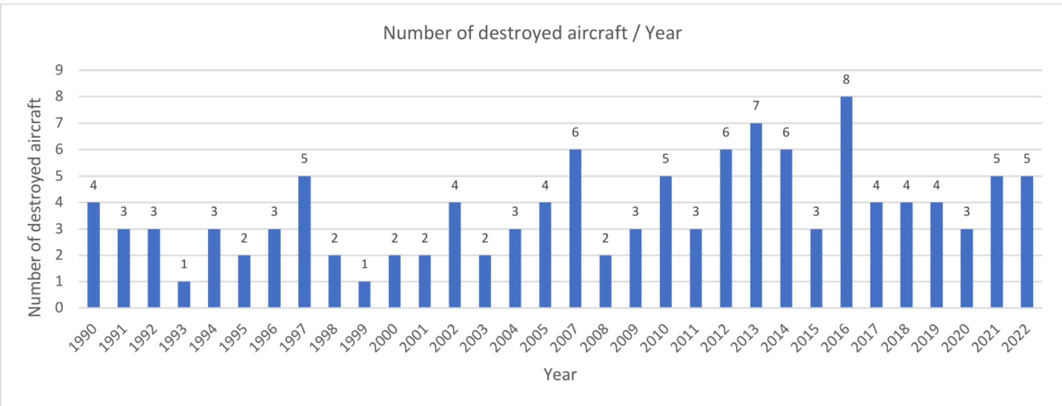

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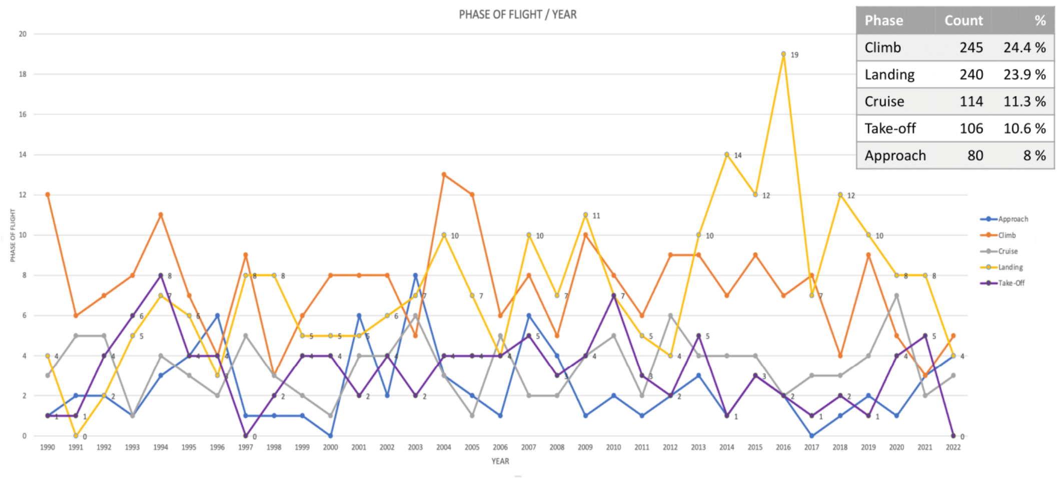

Categorization	Description	Count	%
LOC-I	**LOSS OF CONTROL–INFLIGHT**	**165**	**16.4%**
SCF-PP	**SYSTEM/COMPONENT FAILURE OR MALFUNCTION (POWERPLANT)**	**141**	**14.0%**
ARC	**ABNORMAL RUNWAY CONTACT**	**139**	**13.8%**
LOC-G	**LOSS OF CONTROL–GROUND**	**122**	**12.1%**
SCF-NP	SYSTEM/COMPONENT FAILURE OR MALFUNCTION (NON-POWERPLANT)	77	7.7%
CTOL	COLLISION WITH OBSTACLE(S) DURING TAKEOFF AND LANDING	71	7.1%
UNK	UNKNOWN OR UNDETERMINED	65	6.5%
FUEL	FUEL RELATED	48	4.8%
UIMC	UNINTENDED FLIGHT IN IMC	32	3.2%
LALT	LOW ALTITUDE OPERATIONS	25	2.5%
AMAN	ABRUPT MANEUVER	24	2.4%
OTHR	OTHER	24	2.4%
CFIT	CONTROLLED FLIGHT INTO/TOWARD TERRAIN	12	1.2%
RAMP	GROUND HANDLING	11	1.1%
GCOL	GROUND COLLISION	8	0.8%
RE	RUNWAY EXCURSION	7	0.7%
TURB	TURBULENCE ENCOUNTER	7	0.7%
WSTRW	WIND SHEAR OR THUNDERSTORM	7	0.7%
MAC	AIRPROX/TCAS ALERT/LOSS OF SEPARATION/NEAR MIDAIR COLLISIONS/MIDAIR COLLISIONS	6	0.6%
USOS	UNDERSHOOT/OVERSHOOT	4	0.4%
ICE	ICING	3	0.3%
F-NI	FIRE/SMOKE (NON-IMPACT)	2	0.2%
ATM	ATM/CNS	1	0.1%
ADRM	AERODROME	1	0.1%
BIRD	BIRD	1	0.1%
EXTL	EXTERNAL LOAD RELATED OCCURRENCES	1	0.1%
MED	MEDICAL	1	0.1%

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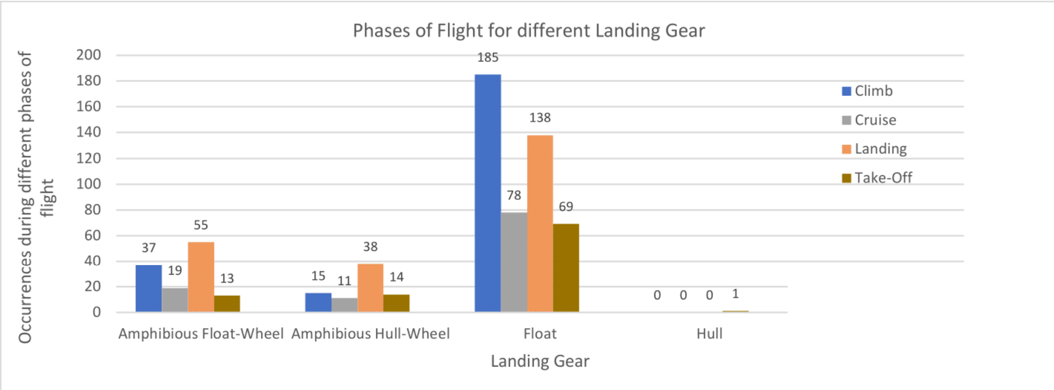
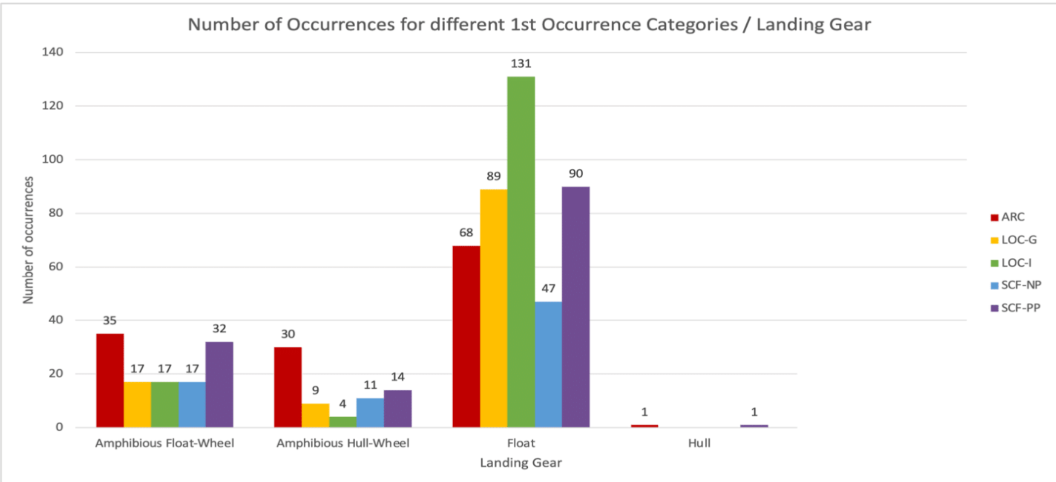
Statistics / **Landing Gear:**





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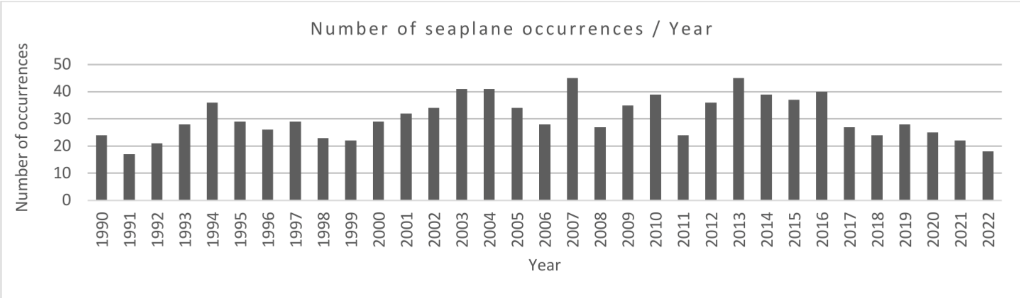
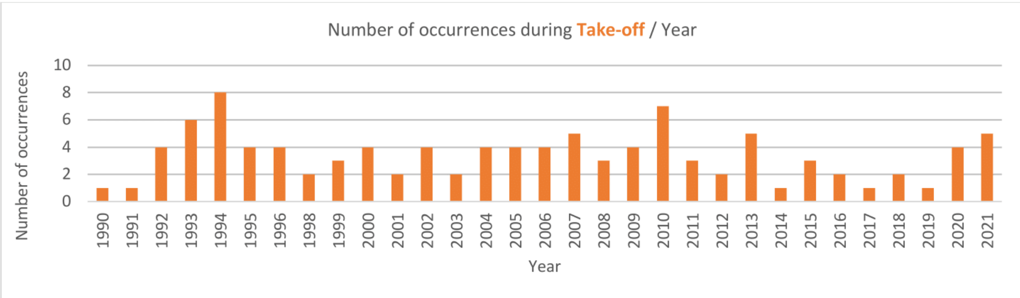
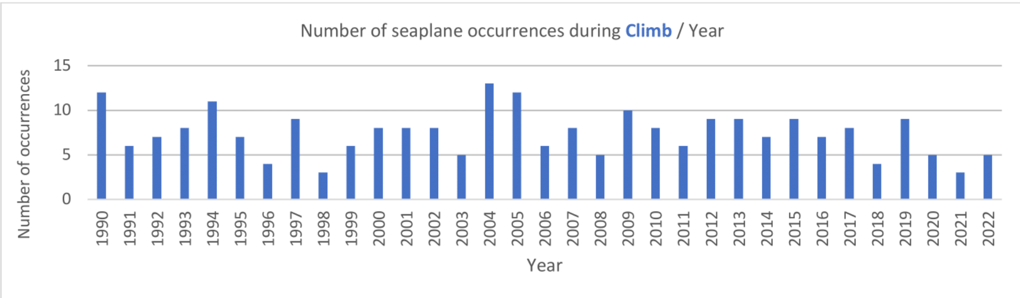
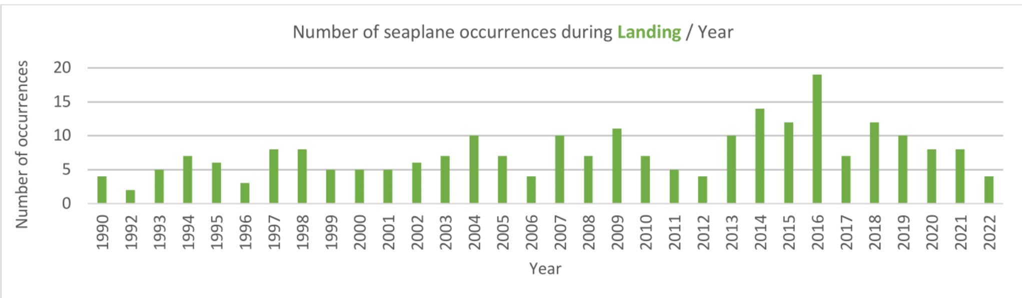
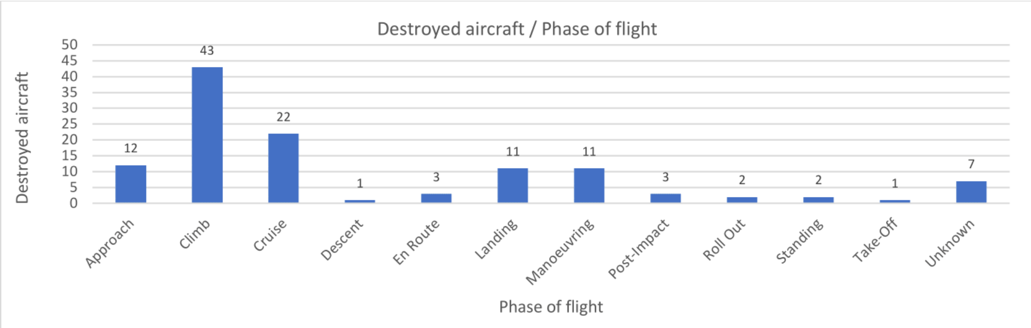
Statistics / **Phase of Flight:**

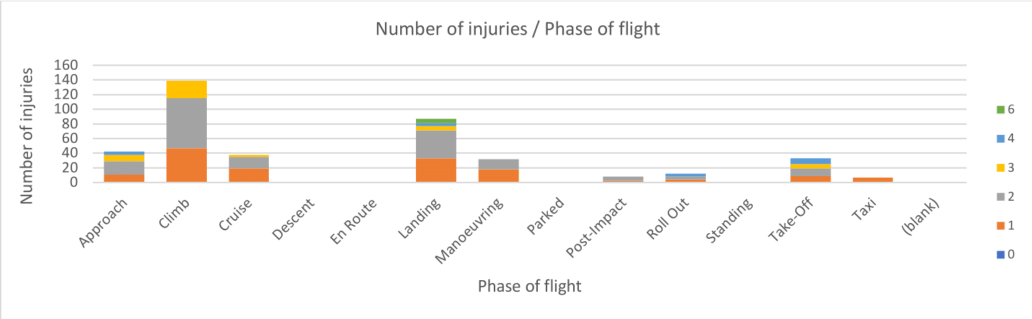


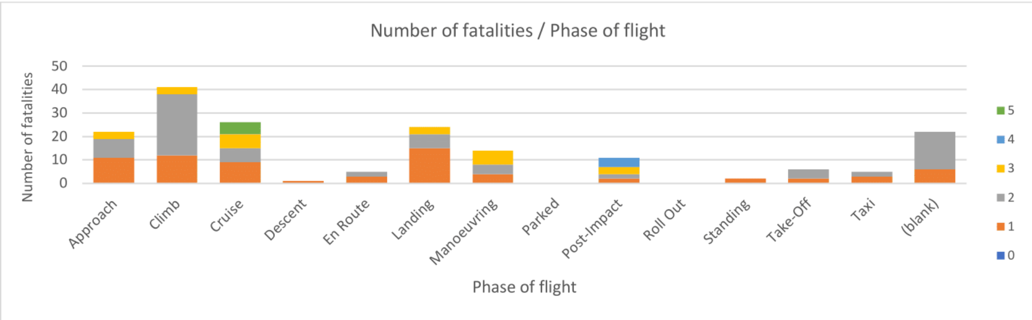


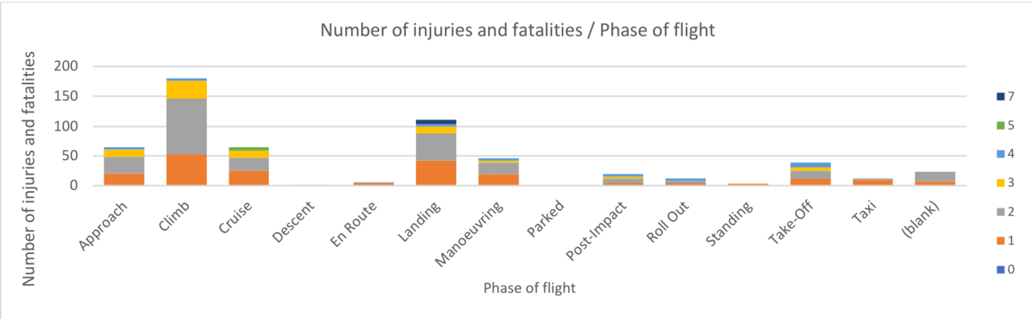




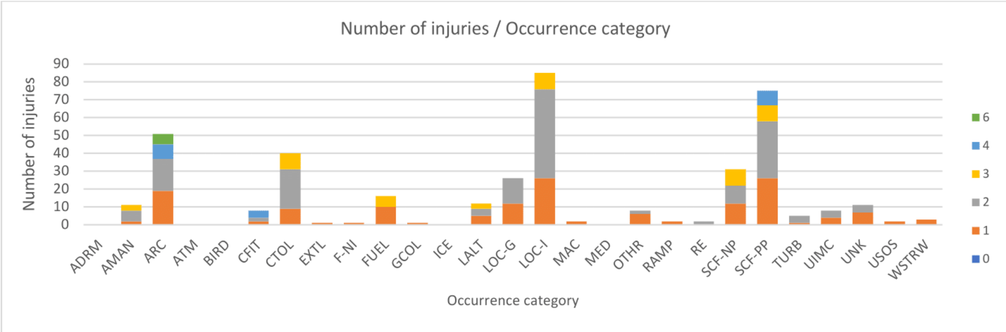

Destroyed aircraft / Phase of flight
Destroyed aircraft
Phase of flight
Approach
Climb
Cruise
Descent
En Route
Landing
Manoeuvring
Post-Impact
Roll Out
Standing
Take-Off
Unknown
12
43
22
1
3
11
11
3
2
2
1
7

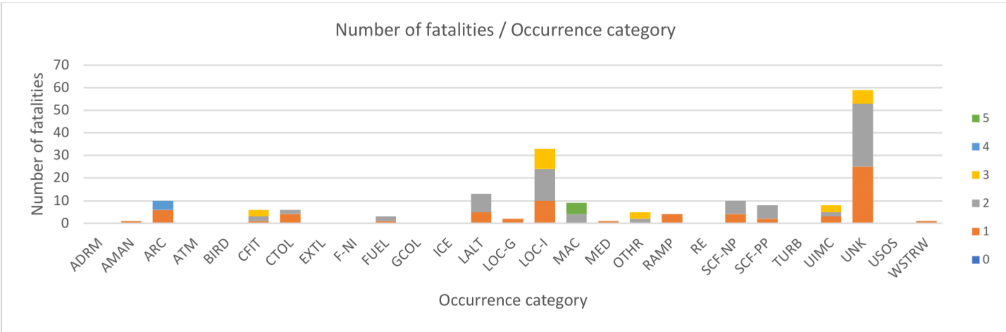

Number of injuries / Phase of flight
Number of injuries
Phase of flight
Approach
Climb
Cruise
Descent
En Route
Landing
Manoeuvring
Parked
Post-Impact
Roll Out
Standing
Take-Off
Taxi
(blank)
6
4
3
2
1
0

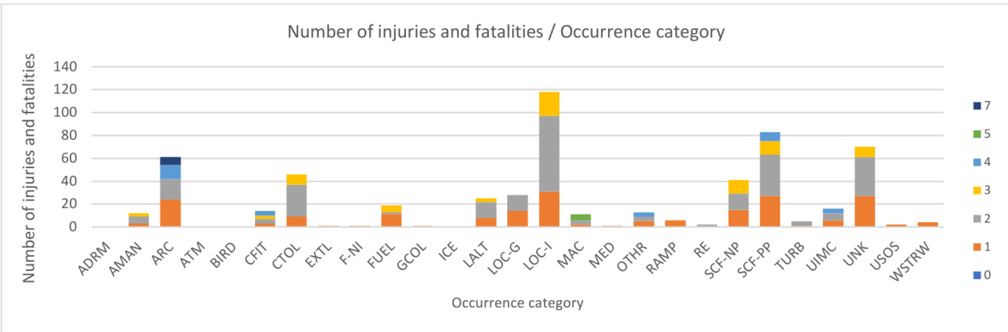

Number of fatalities / Phase of flight
Number of fatalities
Phase of flight
Approach
Climb
Cruise
Descent
En Route
Landing
Manoeuvring
Parked
Post-Impact
Roll Out
Standing
Take-Off
Taxi
(blank)
5
4
3
2
1
0


Number of injuries and fatalities / Phase of flight
Number of injuries and fatalities
Phase of flight
Approach
Climb
Cruise
Descent
En Route
Landing
Manoeuvring
Parked
Post-Impact
Roll Out
Standing
Take-Off
Taxi
(blank)
7
5
4
3
2
1
0

Statistics / **Occurrence Category:**







Iulia Manole: iuliamanole97@gmail.com

7. Booklet 2 (multiple choice questions kept by the investigator)

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General details:

a) Age:
   i) Under 20
   ii) 21-30
   iii) 31-40
   iv) 41-50
   v) 51-60
   vi) 61-70
   vii) 70+

b) Years of experience flying (not only seaplanes):
   i) Under 2
   ii) 2-5
   iii) 6-10
   iv) 11-20
   v) 21-30
   vi) Over 30

c) Years of experience flying (only seaplanes):
   i) Under 2
   ii) 2-5
   iii) 6-10
   iv) 11-20
   v) 21-30
   vi) Over 30

d) Experience in flying seaplanes (in hours flown):
   i) Under 10
   ii) 10 - 100
   iii) 101 – 300
   iv) 301-500
   v) 501 - 1,000
   vi) Over 1,000

e) Seaplane training
   i) Seaplane Rating only
   ii) Insurance Checkout(s) on Type
   iii) 25 Hour Bush Pilot Course
   iv) 50 Hour Bush Pilot Course
   v) Underwater Egress Training
   vi) Other:

f) Last time a safety course/training related to seaplane operations or safety was completed:

Ending questions

a) What do you think the best methods of promoting safety and bringing awareness on current seaplane safety issues are?

i) Annual questionnaires (such as this one)
ii) Annual focus groups
iii) Weekly newsletters / bulletins
iv) Monthly newsletters / bulletins
v) Weekly emails
vi) Monthly emails
vii) Seasonal emails
viii) Designated website
ix) Social media (Facebook, Instagram, Twitter, etc.)
x) Other:

b) Are you willing to be contacted via email about taking part in future research? (e.g., surveys, interviews, seminars, workshops)

i) Yes, I wish to be contacted for future research, and it will be my decision whether to take part or not.
ii) No, I do not wish to be contacted.
iii) **If yes**, please provide your email address:

c) Are you willing to be contacted via email for clarifications regarding your answers to this survey questions?

i) Yes
ii) No
iii) If yes, please provide your email address:

8. Online questionnaire

Analysis of Seaplane Accidents in Canada - Questionnaire

Start of Block: Participant information & Consent

Q001 We invite you, a valued member of the seaplane pilot community in Canada, to take part in a research study aimed at enhancing the safety of Seaplane General Aviation (GA). Your insights and experiences are crucial to our understanding and improvement of safety measures within the community.

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Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully.

The purpose of this study is to bring awareness on Seaplane GA safety concerns in Canada that resulted from an in-depth analysis of past accident and incident data, as well as to determine further details in areas previously overlooked by existing data, such as pilot concerns and decision making during pre-determined scenarios (answer "What would you do in this scenario?").

If you decide to take part, your contribution will consist of completing 3 sections:
Section 1: General details - Share general information about yourself, including your age group, flying experience, and any relevant training.
Section 2a: Review and reflect on statistics and trends from past GA seaplane accidents and incidents in Canada, which are linked to the scenarios in Part 2b.
Section 2b: Scenarios - Engage with hypothetical scenarios to reveal your decision-making processes and flag any areas of concern.
Section 3: Ending questions

The results will be analysed and studied together with the findings from the analysis of past seaplane accidents/incidents. This will provide a comprehensive understanding of what is amiss, so that recommendations can be made on ways to improve seaplane safety.

The aim is to publish the results this year, so that the findings are not outdated. You will not be identified in any publication as grouped study data will be used and not individual data.

I confirm that I have read and understood the above information.

- Yes (1)
- No (2)

Q002 I understand what will be expected of me and I had the opportunity to ask questions that have been answered satisfactorily.

- Yes (1)
- No (2)

Q003 I understand that my data gathered in this study will be stored anonymously and securely by Imperial College London. Identifying me in any outputs, including publications, will not be possible.

- Yes (1)
- No (2)

Q004 I understand that my participation is voluntary and that I am free to withdraw at any time without giving a reason.

- Yes (1)
- No (2)

Q005 I consent to voluntarily participate in this study and understand how my responses will be used.

- Yes (1)
- No (2)

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End of Block: Participant information & Consent

Start of Block: General details

Q1 What is your age group?

- o Under 21 (1)
- o 21-30 (2)
- o 31-40 (3)
- o 41-50 (4)
- o 51-60 (5)
- o 61-70 (6)
- o 70+ (7)

Q2 How many years of flying experience do you have? (not only seaplanes)

- o Under 2 (1)
- o 2-5 (2)
- o 6-10 (3)
- o 11-20 (4)
- o 21-30 (5)
- o Over 30 (6)

Q42 How many years of flying experience do you have? (only seaplanes)

- o Under 2 (1)
- o 2-5 (2)
- o 6-10 (3)
- o 11-20 (4)
- o 21-30 (5)
- o Over 30 (6)

Q3 Number of seaplane flying hours

- o <10 (1)
- o 10-100 (2)
- o 101-300 (3)
- o 301-500 (4)
- o 501-1000 (5)
- o Over 1000 (6)

Q4 Seaplane training

- ☐ Seaplane Rating only (1)
- ☐ Insurance Checkout(s) on Type (2)
- ☐ 25 Hour Bush Pilot Course (3)
- ☐ 50 Hour Bush Pilot Course (4)
- ☐ Underwater Egress Training (5)
- ☐ Other (6) ____

Q11 Last time a safety course/training related to seaplane operations was completed

____

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End of Block: General details

Start of Block: Information gathering

Q5 What safety issues or concerns do you have?

____

Q6 How do you stay current?

____

Q7 How do you stay proficient?

____

Q8 How often do you practice emergency procedures?

____

Q9 How often do you practice engine failures?

____

Q10 What do you think we need to do to reduce the number of seaplane accidents?

____

End of Block: Information gathering

Start of Block: Scenario discussion - Take off

Q12 Striking obstacles - what have you done to mitigate this?

____

Q13 Striking obstacles - what would you do to mitigate this?

____

Q14 Floats digging in - what have you done to mitigate this?

____

Q15 Floats digging in - what would you do to mitigate this?

____

End of Block: Scenario discussion - Take off

Start of Block: Scenario discussion - Climb

Q16 Crosswind - what have you done to mitigate this?

____

Q17 Crosswind - what would you do to mitigate this?

____

Q18 Low or no airspeed indication - what have you done to mitigate this?

____

Q19 Low or no airspeed indication - what would you do to mitigate this?

____

Q20 Poor climb performance - what have you done to mitigate this?

____

Q21 Poor climb performance - what would you do to mitigate this?

____

Q22 Engine power loss - what have you done to mitigate this?

____

Q23 Engine power loss - what would you do to mitigate this?

____

End of Block: Scenario discussion - Climb

Start of Block: Scenario discussion - Approach

Q24 Unstable approach - what have you done to mitigate this?

____

Q25 Unstable approach - what would you do to mitigate this?

____

Q26 Entanglement/striking obstacles - what have you done to mitigate this?

____

Q27 Entanglement/striking obstacles - what would you do to mitigate this?

____

End of Block: Scenario discussion - Approach

Start of Block: Scenario discussion - Landing

Q28 Not able to clear terrain ahead - what have you done to mitigate this?

____

Q29 Not able to clear terrain ahead - what would you do to mitigate this?

____

Q30 Bounce / Floats digging in - what have you done to mitigate this?

____

Q31 Bounce / Floats digging in - what would you do to mitigate this?

____

Q32 Aborted landing - what have you done to mitigate this?

____

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Q33 Aborted landing - what would you do to mitigate this?

____

End of Block: Scenario discussion - Landing

Start of Block: Ending questions

Q34 What do you think the best methods of promoting safety and bringing awareness on current seaplane safety issues are?

- ☐ Annual questionnaires (such as this one) (1)
- ☐ Annual focus groups (2)
- ☐ Weekly newsletters / bulletins (3)
- ☐ Monthly newsletters / bulletins (4)
- ☐ Weekly emails (5)
- ☐ Monthly emails (6)
- ☐ Seasonal emails (7)
- ☐ Designated website (8)
- ☐ Social media (Facebook, Instagram, Twitter, etc.) (9)
- ☐ Other (10) ________________________________

Q35 Are you willing to be contacted via email about taking part in future research? (e.g., surveys, interviews, seminars, workshops)

- o No (1)
- o Yes, I wish to be contacted for future research, and it will be my decision whether to take part or not. (Please provide your EMAIL address) (2) ________________________________

Q36 Are you willing to be contacted via email regarding the results of this study?

- o No (1)
- o Yes, I wish to be contacted for future research, and it will be my decision whether to take part or not. (Please provide your EMAIL address, if you have not done so in the previous question) (2) ________________________________

Q43 Is there anything else you wish to tell us?

____

End of Block: Ending questions

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