Survival After Ditching in Motorized Aircraft, 1989–2022

Volker C. Schick; Douglas D. Boyd; Catherina Hippler; Jochen Hinkelbein

INTRODUCTION: Although an unintended aircraft landing on water (referred to as ditching) is a rare event, the potential for occupant injury/fatality increases immediately following the event due to adverse conditions. However, to date, few studies have addressed the subject. Herein, ditching events and post-ditching survival were investigated.

METHODS: Ditchings (1982–2022) in the United States were identified from the National Transportation Safety Board database. Occupant injury severity, aircraft type, pilot experience, flight conditions, and number of occupants were extracted. Poisson distribution, the Chi-squared test (2-tailed), Mann-Whitney U test, and Kruskal-Wallis one-way analysis of variance were employed.

RESULTS: A total of 96 ditchings were identified. A systematic survey was hampered by the lack of a standardized reporting matrix in the reports. In total, 77 reports were included in the analysis. Across all ditchings, 128 of 169 (76%) occupants survived ditching and were rescued. Importantly, the initial ditching event was survived by 95% of all occupants. However, 32 (19%) occupants died post-ditching by drowning (21/32 cases) or for undetermined reasons. Considering probability per ditching event, in 26 (34%) of all ditchings, one or more occupants was/were fatally injured.

DISCUSSION: Initial survival of the emergency ditching is high. Drowning was the leading cause of death after ditching and reduced the overall survival to 76%. Further investigation is needed to identify risk factors for fatal outcomes and/or improve probability of survival after ditching.

KEYWORDS: unintended water landing, fatal injury, drowning, National Transportation Safety Board (NTSB), survival probability, aviation.

Schick VC, Boyd DD, Hippler C, Hinkelbein J. *Survival after ditching in motorized aircraft, 1989–2022*. Aerosp Med Hum Perform. 2024; 95(5):254–258.

Civil aviation refers to all nonmilitary aviation, including commercial air transportation and general aviation. Commercial air transportation largely comprises scheduled airlines (also referred to as air carriers), while general aviation includes all other civil aviation activities, such as personal and recreational flying, public service missions, charter operations, and agriculture.[1] The majority of general aviation operations involve light (<12,501 lb) single-engine aircraft engaged for the purpose of personal flights.[2]

An unintended landing on a body of water (commonly referred to as ditching) is a rare event in aviation and may be caused by mechanical failure, fuel exhaustion, weather conditions, or human error. To the knowledge of the authors, there is a paucity of research on the subject and likewise few, if any, studies on occupant survivability post-ditching. When operating over an extended body of water, ditching is unavoidable if power is lost and the aircraft is beyond gliding range of land. One question posed in the current study relates to occupant survival surrounding the ditching event itself as well as post-ditching survival. The former is relevant since, upon

From the Department of Anesthesiology and Intensive Care Medicine, Faculty of Medicine and University Hospital of Cologne, University of Cologne, Germany; the College of Aeronautics, Embry Riddle Aeronautical University, Daytona Beach, FL, United States; University Department of Anaesthesiology, Intensive Care Medicine and Emergency Medicine, Johannes Wesling University Hospital and Ruhr University Bochum, Minden, Germany; and the German Association of Aerospace Medicine (DGLRM), Munich, Germany.

This manuscript was received for review in June 2023. It was accepted for publication in February 2024.

Address correspondence to: Volker C. Schick, M.D., Department of Anesthesiology and Intensive Care Medicine, Faculty of Medicine and University Hospital of Cologne, Kerpener Straße 62, Cologne NRW 50999, Germany; Volker.schick@uk-koeln.de.

DOI: https://doi.org/10.3357/AMHP.6332.2024

ditching, varying wave height can have considerable effect on aircraft structural integrity and the amount of time it takes for the occupants to exit the aircraft. After ditching, the aircraft might be floating or partially submerged with the risk for rapid sinking. There could be various challenges that occupants face when attempting to evacuate, such as water ingress, structural damage, disorientation, or the need to use emergency exits or procedures that are not used in normal operations, or compromising injury. Additionally, delayed rescue could adversely affect occupant survival, especially if the occupant does not have a flotation device.

The purpose of this retrospective study was to investigate general aviation ditching events (1982–2022) in an area under the jurisdiction of the United States and thus reported on by the corresponding National Transportation Safety Board (NTSB). Survival after ditching and possible influencing factors were investigated.

METHODS

Data were obtained from a retrospective search of the NTSB databases (February 2022 and 1982–2007 releases, available from: https://data.ntsb.gov/avdata). The databases were queried using Boolean search "OR" for events in which the following wildcarded terms included in the "Narr_cause" field were used: ditch, ocean, sea, sunk, sank. Data were exported to Excel and events involving a "ditch" as a synonym for an emergency landing in a ravine/canyon or a catch drain without an actual water landing on an extended body of water were deleted. Merged excel files for the NTSB databases 1982–2007 and 2008–2022 were checked for duplicates.

NTSB electronic reports were downloaded. The following data from the NTSB final reports were used for further analysis: aircraft (engine type, certified maximum gross weight, landing gear type, seats, damage, recovery); pilot (flight time, pilot certification, number of flight crew); environment (flight conditions, light conditions, daytime); occupants (total, injury severity, ditching survival, overall survival); accident location; and rescue and reason for ditching. Occupant injury severity definitions were per 49 CFR 830.2 as extracted from the final NTSB report.[3]

The first step was to investigate the effect of pilot flight experience, the presence of a copilot, and the number of passenger(s) on survival after ditching. In order to exclude scale effects, the flights were categorized with respect to no fatalities or at least one fatality and correlated with the aggregate passenger count (0, 1, or >1 passengers) and the flight experience of the pilots.

Ditching rates can be calculated using total fleet activity data (hours flown) as denominator. The total aviation activity for general aviation (Fleet activity) was derived from the U.S. General Aviation Survey (available from: https://www.faa.gov/data_research/aviation_data_statistics/general_aviation). It represents the sum of fixed-wing and rotary-wing activity (hours) for the periods specified. Rotary-wing fleet activity ranged from 7–15% of total aircraft times over the 1990–2020 period. Fleet activity was used to calculate the ditching rates over the period under review. Since fleet times were only available from 1990 forward, rate analyses could only be determined for that year onward. The current research did not constitute "human subjects research" by virtue of all data being in the public domain. Consequently, institutional review board approval was not required.

Descriptive statistics comprised frequencies for categorical data and median and quartile for metric and ordinal variables. Pearson Chi-squared/Fisher (2-tailed) tests were used to determine whether differences in proportions of categorical variables were, or were not, significant. Continuous variables were analyzed using the Mann-Whitney U test or the Kruskal-Wallis one-way analysis of variance.

Poisson distributions using the natural logarithm of annual fleet times were employed to determine temporal changes in ditching rates over the period specified. *P*-values less than 0.05 were considered statistically significant for all tests. All statistical analyses were performed using SPSS® version 27 (IBM®, Armonk, NY, United States).

RESULTS

Since the search field "narr cause" in the NTSB database was not commonly populated for accidents until 1989, our query period spanned 1989–2021. A total of 96 ditchings were identified over this timespan. All but one of the NTSB's final reports could be downloaded. Screening and exclusions, per **Fig. 1**, allowed for the final inclusion of 77 ditching events in the current study.

Of the aircraft included, 63 (82%) were single engine and 14 (18%) were twin engine. Of the aircraft, 38 (49%) were equipped with retractable landing gear; the median (Q1–Q3) number

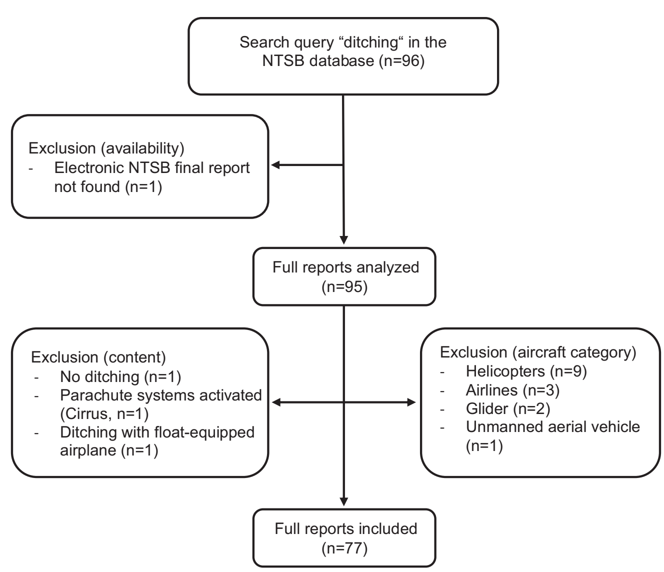

Fig. 1. Flow diagram of the search in the NTSB database and final inclusion of 77 ditching events.

of seats was 4 (3–6). The median (Q1–Q3) certified maximum gross weight of all aircrafts under review was 2925 (2300–3763) lb. Of the aforementioned ditching events, by far the majority were flights with a single pilot (*N* = 71; 92%). On the other flights, the flight crew included a pilot and copilot. Flight attendants were not listed. Approximately half (*N* = 39, 51%) of the ditchings involved flights without passengers, with *N* = 17 (22%) and *N* = 21 (27%) being with one and more than one passenger, respectively. Median (Q1–Q3) flight times of the pilots for all models was 2246 (641–5554) hours. Median (Q1–Q3) flight times for the specific make and model was 250 (91–636) hours.

There were 42 aircraft (55%) that were recovered and could be examined by the NTSB. Neither the passenger count ($P = 0.21$), the presence of a second pilot-in-command ($P = 0.41$), nor the pilot's license (private, commercial, or airline transport; $P = 0.78$) showed a significant effect on fatality rates.

By far the majority of ditching accidents (*N* = 56; 73%) occurred after an event (e.g., loss of power) in the cruise phase of flight. Conversely, ditchings associated with approach and takeoff/climb phases of flight were less frequent, accounting for 8 (10%) and 7 cases (9%) cases, respectively. No significant differences in fatal outcome were found with respect to a specific phase of flight from which the ditching was initiated ($P = 0.08$). During the evaluation period, a higher number of ditches were evident for the months of July (*N* = 11; 14%) and August (*N* = 10; 13%), although the absence of fleet activities precluded a rate analysis over a calendar year. Of the accidents, 37 (48%) occurred during daylight hours between 11:00 and 15:00 (local time). There were no significant differences in the number of fatalities by time of day ($P = 0.84$), light conditions ($P = 0.73$), or month of the year ($P = 0.89$).

The causes of the ditching events were based on the NTSB reports. There were 29 (38%) classified as mechanical and 23 (30%) had a nonmechanical cause. Due to the low aircraft recovery rate, the cause of the ditching event could not be determined in 25 (33%) flights. When considering ditchings due to nonmechanical causes, fuel exhaustion or starvation was the most prevalent cause in 13 (57%) cases. Carburetor icing, fuel contamination, temporary lack of fuel during maneuvering, and incorrect use of the fuel selector or the fuel shut-off switch represented less frequent causes (each *N* = 2, 9%). The causes of fuel exhaustion were deficient preflight planning or altered flight routes due to navigational difficulties with no refueling facilities or delayed decisions to reroute or request assistance.

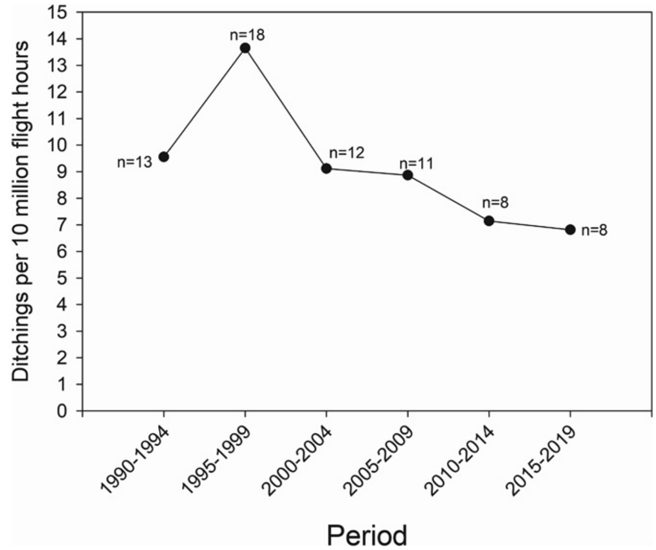

Fig. 2. Ditching rates represent the sum of the fixed-wing and rotary-wing activity over the periods specified. Statistical testing was with a Poisson distribution using the initial period 1990–1994 as referent. Ditching rates did not change significantly over time ($P = 0.45$).

To determine if ditching accident rates changed over time, a Poisson distribution was used. There were no significant changes in ditching rates over time ($P = 0.45$, 95% confidence intervals 0.296, 1.722, **Fig. 2**).

Overall, 26 (34%) of the ditchings in the current analysis had a fatal outcome in which one or more occupants perished (**Table I**). Passengers were involved in 16 out of 26 of these ditched flights with at least one fatality. In all of these cases, at least one passenger died (**Table II**). Regarding total occupant count, 128 of 169 (76%) survived the ditching and were rescued. A total of 25 (29%) passengers and 16 (19%) pilots were fatally injured.

The majority of occupants (95%) survived the initial ditching event. For five flights (nine occupants), no information on primary survival was available due to unobserved crash or lack of contact after ditching. However, in total 32 (19%) occupants subsequently succumbed as a result of drowning (21/32 cases) or undetermined causes. Details are shown in Table II.

Ditchings were placed in the context of all types of unintended flight terminations. Therefore, the NTSB database was queried for all aviation accidents between 1982 and 2022. The ratio of fatal accidents to nonfatal accidents for terrestrial accidents was 21% (13,568 fatal vs. 50,804 nonfatal). When

Table I. Survival After Ditching.

DITCHINGS, *N* (%)	≥ 1 FATALITY	OCCUPANTS, *N* [PILOTS/ PASSENGERS, *N*]	SURVIVAL AFTER DITCHING, *N* (%) [PILOTS/ PASSENGERS, *N* (%)]	OVERALL SURVIVAL, *N* (%) [PILOTS/ PASSENGERS, *N* (%)]	MISSING DATA, *N* (%) [PILOTS/ PASSENGERS, *N* (%)]
77 (100%)		169 [83/86]	160 (95%) [78 (94%)/82 (95%)]	128 (76%) [67 (81%)/61 (71%)]	9 (5%) [5 (6%)/4 (5%)]
26 (34%)	Yes	71 [27/44]	62 (87%) [22 (81%)/40 (91%)]	30 (42%) [11 (41%)/19 (43%)]	9 (5%) [5 (6%)/4 (5%)]
51 (66%)	No	98 [56/42]	98 (100%) [56 (100%)/ 42 (100%)]	98 (100%) [56 (100%)/ 42 (100%)]	0 (0%)

Table II. Fatally Injured Occupants by Aircraft Type.

N	AIRCRAFT	OCCUPANTS, *N*	PILOTS, *N*	PASSENGERS, *N*	FATALLY INJURED OCCUPANTS, *N*	FATALLY INJURED PILOTS, *N*	FATALLY INJURED PASSENGERS, *N*
1	Cessna 172	2	1	1	1	0	1
2	Cessna 172 M	1	1	0	1	1	N.A.
3	Cessna 172 P	4	1	3	2	1	1
4	Cessna 177 RG	2	1	1	2	1	1
5	Cessna 195	4	1	3	3	1	2
6	Cessna U206 B	5	1	4	1	0	1
7	Cessna 207 A	1	1	0	1	1	N.A.
8	Cessna 208 B	9	1	8	1	0	1
9	Cessna P210 N	1	1	0	1	1	N.A.
10	Cessna 310 Q	1	1	0	1	1	N.A.
11	Cessna 421 C	4	1	3	4	1	3
12	Chicco Miguel E Quicksilver	2	2	0	1	1	N.A.
13	Johnson Joel H S-6ES Coyote II	2	1	1	1	0	1
14	Maule M-5-235 C	3	1	2	2	0	2
15	Petzel 106 A	1	1	0	1	1	N.A.
16	Piper PA-28-181	1	1	0	1	1	N.A.
17	Piper PA-28-235	2	1	1	2	1	1
18	Piper PA-31-350	5	1	4	1	0	1
19	Piper PA-32	6	1	5	4	0	4
20	Piper PA-32-260	3	1	2	2	0	2
21	Piper PA-32R-301	5	1	4	2	0	2
22	Piper PA-32RT-300T	2	1	1	2	1	1
23	Republic P47 D	1	1	0	1	1	N.A.
24	Temco GC-1B	2	1	1	1	0	1
25	Universal Stinson 108	1	1	0	1	1	N.A.
26	Varga Aircraft 2150 A	1	1	0	1	1	N.A.

comparing ditching and terrestrial accidents, fatality rates were significantly higher after ditching (21% vs. 34%, $P = 0.009$).

Information on lifejackets or flotation devices (whether they were available in cabin, used or not used) was recorded for only 22 (29%) of the NTSB reports. A systematic survey of flotation devices did not exist. It is essential to take into account the potential reporting bias in this context. When reported, lifejackets were worn adequately in seven (32%) and inadequately in another seven (32%) cases. Lifejackets or flotation devices were not used at all in eight (36%). Reasons for inadequate or nonuse of lifejackets range from lack of such devices, inadequate preflight preparation as to their location/retrieval, to insufficient time between ditching and aircraft submersion.

Information on search and/or rescue was available for only 48 (62%) of all cases. Of these, 13 (27%) of all search and rescue attempts were unsuccessful. The occupants of 17 (35%) ditched airplanes were rescued by the U.S. Coast Guard with crew/passengers of 13 (27%) ditched airplanes rescued by other boats or bystanders. For the remainder (five cases, 10%), the occupants swam to shore independently.

DISCUSSION

We report herein that although ditching of general aviation aircraft is rare, when it occurs the probability of surviving the ditching itself is high. Unfortunately, the risk of fatality increases significantly after an initially successful ditching.

Overall, 95% of all occupants survived the primary ditching event. Drowning was described as the predominant cause of death after the ditching in the NTSB's reports and contributed to the overall survival rate of 76% in our study cohort. This is consistent with previous analyses of 40 ditched aircraft from the NTSB database and the International Civil Aviation Organization between 1979 and 1989.[4] The most common cause of injury after ditching (67%) was asphyxiation due to inhalation of water.[5]

After ditching, the aircraft may sink rapidly. Rapid flooding of the cabin and subsequent descent of the aircraft within minutes was reported in another study of 33 ditchings.[4] A preflight briefing, time to prepare for ditching, and a quick and effective evacuation are, therefore, necessary and could increase the chances of survival. After successful evacuation, passengers and crew have to deal with rescue equipment and environmental hazards. In the present survey, passengers were more likely to succumb after a successful primary ditching than pilots. The reasons for this are unclear and we can only speculate that seating position away from an egress point, the pilots' responsibility to ensure that passengers have departed the aircraft prior, unpredictable reactions to stress factors, lack of knowledge in the use of rescue equipment, etc., are all contributory.

Inadequate preflight preparation and flight planning were described in several cases. Areas of bad weather can lead to a change of route and fuel shortages. These factors may lead to critical situations, particularly in low performance aircraft with short glide ranges. Improving pilot training with focus on pre/in-flight planning to prepare for or avoid flying beyond the glide range of land could help prevent ditching events.

The overall fatality rate after ditching was significantly higher compared to terrestrial accidents; however, it is important to remember that ditching is a rare event and represents only a small fraction of all accidents. Overall survival after ditching depends on various factors, including water conditions, availability of survival equipment, and rescue personnel. It is therefore difficult to compare terrestrial and ditching accidents and to make general recommendations.

The descent angle during ditching may affect the impact and could certainly influence outcomes. Unfortunately, there is no information about the descent angle during ditching since there is no information in the NTSB database and many accidents occur without being seen.

Our study was not without limitations. First, the current study is retrospective and only reported and investigated accidents could be included. Second, data analysis was hampered by incomplete data sets. Data extraction was from the final NTSB reports. Achieving data completeness was challenging due to the difficult conditions (ditching offshore, lack of recovery, or absence of witnesses). Third, despite a significant number of presumed drowning accidents, there is no systematic survey of the use of lifejackets or flotation devices in the NTSB reports. A reporting bias must be taken into account and underlines the necessity of further (prospective) investigations. Fourth, the final cause of death could not be determined in all cases for a plethora of reasons, e.g., submerged aircraft, lack of eyewitness reports, or missing bodies. Fifth, fleet activity is the sum of fixed-wing and rotary-wing activity for the periods indicated. The rotorcraft fleet activity ranged from 7–15% of the total aircraft hours over the 1990–2020 period.

While ditching remains a rare event, the probability of a fatal outcome immediately following the event remains high. The main cause of death after ditching was drowning. This was probably facilitated by the difficulty of exiting the aircraft and the rapid descent. Based on our data, the provision and use of flotation devices and the causes of delayed egress from the sinking aircraft need to be studied in detail to reduce fatalities and develop safety recommendations. Further investigation is needed to identify risk factors for fatal outcomes and/or improve probability of survival after ditching.

ACKNOWLEDGMENTS

Financial Disclosure Statement: The authors have no competing interests to declare.

Authors and Affiliations: Volker C. Schick, M.D., and Catherina Hippler, M.D., Department of Anesthesiology and Intensive Care Medicine, Faculty of Medicine and University Hospital of Cologne, University of Cologne, Cologne, Germany; Douglas D. Boyd, Ph.D., College of Aeronautics, Embry Riddle Aeronautical University, Daytona Beach, FL, United States; and Jochen Hinkelbein, M.D., University Department of Anaesthesiology, Intensive Care Medicine and Emergency Medicine, Johannes Wesling University Hospital and Ruhr University Bochum, Minden, and the German Association of Aerospace Medicine (DGLRM), Munich, Germany.

REFERENCES

1. AOPA Air Safety Institute; Smith MA, Ryon C, editors. 27th Joseph T. Nall Report: general aviation accidents in 2015. Frederick (MD): AOPA Air Safety Institute; 2019:1–43.
2. Li G, Baker SP. Crash risk in general aviation. JAMA. 2007; 297(14): 1596–1598.
3. Electronic Code of Federal Regulation. Transportation: notification and reporting of aircraft accidents or incidents and overdue aircraft, and preservation of aircraft wreckage, mail, cargo and records. 49 CFR 830; 2010. [Accessed April 2023]. Available from: http://www.ecfr.gov/cgi-bin/text-idx?tpl=/ecfrbrowse/Title49/49cfr830_main_02.tpl.
4. Cosper DK, McLean GA. Analysis of ditching and water survival training programs of major airframe manufactures and airlines. Washington (DC): Office of Aviation Medicine; 1998. 20591. [Accessed 15 March 2024]. Available from https://www.faa.gov/sites/faa.gov/files/data_research/research/med_humanfacs/oamtechreports/AM98-19.pdf.
5. Chen CCT, Muller M. Commuter/air taxi ditchings and water-related impacts that occurred from 1979 to 1989. U.S. Department of Transportation. Federal Aviation Administration. [Accessed February 29, 2024]. Available from https://apps.dtic.mil/sti/pdfs/ADA285691.pdf.