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# A MULTI-DIMENSIONAL ANALYSIS OF CASUALTY DYNAMICS AND SAFETY-RELATED PATTERNS IN RECREATIONAL CRAFT

**MÜGE BÜBER**[1]

***ABSTRACT***

*This study examines casualty dynamics in recreational craft through a multi-dimensional analytical perspective focused on occurrence patterns, contributory safety factors, and consequence profiles. The analysis is based on data derived from the European Marine Casualty Information Platform (EMCIP) and covers recreational craft casualties recorded between 17 June 2011 and 12 April 2026. Methodologically, the study applies a structured descriptive approach based on three complementary components: multi-dimensional descriptive analysis, descriptive examination of contributory factor categories, and severity-based consequence assessment. The findings reveal that ship-related casualties are dominated by collision events, which account for 595 of 909 recorded ship-related casualty events (65.5%), followed by grounding/stranding (11.7%), loss of control (6.8%), and contact (6.4%). Person-related casualties are strongly concentrated in slipping, stumbling, and falling events (59.4%), indicating the prominence of onboard movement-related safety vulnerabilities. Human consequences are dominated by injuries, with 242 injured persons compared with 26 fatalities and no missing persons. Contributory factors are concentrated primarily in shipboard operation (57.6%) and shore management (33.7%), while personnel and manning, design, and crew resource management emerge as the most visible second-level contributory dimensions. Spatially, casualties are most visible in internal waters (48.8%) and the territorial sea (33.4%), emphasizing the importance of near-shore operational safety in recreational craft activities. Overall, the study provides a structured interpretation of casualty patterns in recreational craft and offers an analytical basis for more targeted maritime safety interventions.*

***Keywords:*** *Casualty Analysis, Human Factors, Maritime Safety, Marine Accident, Recreational Craft.*

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# REKREASYONEL DENİZ ARAÇLARINDA KAZA DİNAMİKLERİ VE EMNİYETLE İLİŞKİLİ ÖRÜNTÜLER ÜZERİNE ÇOK BOYUTLU BİR ANALİZ

***ÖZ***

*Bu çalışma, rekreasyonel deniz araçlarında meydana gelen kazaların dinamiklerini; olay örüntüleri, emniyete etki eden faktörler ve sonuç profilleri ekseninde çok boyutlu bir analitik perspektifle incelemektedir. Analiz, Avrupa Deniz Kazaları Bilgi Platformu'ndan (European Marine Casualty Information Platform, EMCIP) elde edilen verilere dayanmaktadır ve 17 Haziran 2011 ile 12 Nisan 2026 tarihleri arasında kaydedilen rekreasyonel deniz aracı kazalarını kapsamaktadır. Yöntemsel olarak çalışma, çok boyutlu betimsel analiz, katkıda bulunan faktör kategorilerinin tanımlayıcı incelenmesi ve şiddet temelli sonuç değerlendirmesi yaklaşımlarını kullanmaktadır. Bulgular, deniz araçları ile ilişkili kazaların ağırlıklı olarak çatışma olayları tarafından belirlendiğini; bu olayların 909 tekneyle ilişkili kaza olayının 595'ini, başka bir ifadeyle %65,5'ini oluşturduğunu göstermektedir. Bunu karaya oturma/sürüklenme (%11,7), kontrol kaybı (%6,8) ve çatma (%6,4) izlemektedir. İnsan temelli kazalar ise büyük ölçüde kayma, sendeleme ve düşme olaylarında yoğunlaşmakta (%59,4) ve bu durum, tekne üzerindeki hareket kaynaklı emniyet kırılganlıklarının belirginliğine işaret etmektedir. Kaza sonuçları bakımından yaralanmalar baskın sonucu oluşturmakta; 26 ölüm vakasına ve kayıp kişiye rastlanmamasına karşılık 242 yaralanma vakası kaydedilmektedir. Katkı faktörleri esas olarak tekne üzeri operasyonlarda (%57,6) ve kıyı yönetiminde (%33,7) yoğunlaşırken; personel ve vardiya yapısı, tasarım ve ekip kaynak yönetimi ikinci düzeyde en görünür katkı boyutları olarak öne çıkmaktadır. Mekânsal açıdan kazalar en fazla iç sularda (%48,8) ve karasularında (%33,4) görülmekte, bu da rekreasyonel deniz aracı faaliyetlerinde kıyıya yakın operasyonel güvenliğin önemini vurgulamaktadır. Genel olarak çalışma, rekreasyonel deniz araçlarındaki kaza örüntülerine ilişkin yapılandırılmış bir yorum sunmakta ve daha hedefe yönelik deniz emniyeti müdahaleleri için analitik bir zemin oluşturmaktadır.*

***Anahtar Kelimeler:*** *Kaza Analizi, İnsan Faktörü, Deniz Emniyeti, Deniz Kazası, Rekreasyonel Deniz Aracı.*

## 1. INTRODUCTION

Recreational craft operations have become an increasingly important component of contemporary maritime activity as marine leisure, private boating, yachting, and small-scale passenger mobility have expanded across coastal and inland waters worldwide (Lenorovitz et al., 2020; Ehrhardt Jr et al., 2022; Hsu et al., 2025). This growth has widened the scope of maritime safety research beyond conventional commercial shipping and has brought motorboats, personal watercraft, sailboats, and

other small craft into sharper focus as distinct safety domains with their own operational and regulatory challenges (McKnight et al., 2007; Torralbo and Castells i Sanabra, 2014; Toman and Zec, 2020). Recreational boating also contributes substantially to tourism, local economies, and coastal mobility, yet it simultaneously generates significant injury, fatality, and near-shore safety burdens that require closer scholarly and policy attention (Willcox-Pidgeon et al., 2019; Ehrhardt Jr et al., 2022).

Recent statistics further demonstrate the scale and safety relevance of this sector. In 2024, the U.S. Coast Guard recorded 3,887 incidents, 556 deaths, 2,170 injuries, and approximately 88 million dollars in property damage in recreational boating incidents. The leading contributing factors were operator inattention, improper lookout, and operator inexperience, while 87% of drowning victims were not wearing a personal flotation device where wear status was known. Open motorboats were the most common vessels involved in incidents and accounted for the highest share of deaths, indicating the continued importance of operator behavior, attention, experience, and lifejacket use in casualty prevention (U.S. Coast Guard, 2025). Canada presents a similarly important picture, with up to 12.4 million people participating in recreational boating annually and an average of 111 recreational boating fatalities recorded each year (Transport of Canada, 2024). Taken together, these figures show that recreational craft casualties should be treated as a major maritime safety issue rather than as a peripheral subset of general boating incidents (Wordsworth et al., 2023).

Unlike commercial shipping, this segment is often characterized by more variable operational conditions, heterogeneous user profiles, uneven levels of training and experience, and relatively limited organizational oversight, all of which create a distinct and highly vulnerable safety environment (McKnight et al., 2007; Willcox-Pidgeon et al., 2019; Wordsworth et al., 2023). Existing research consistently indicates that accidents in recreational craft are closely associated with human and operational vulnerabilities, including operator error, alcohol use, inadequate training, weak compliance with safety equipment, and insufficient situational awareness, while broader shortcomings in governance and enforcement further weaken preventive capacity (O'Connor and O'Connor, 2005; Torralbo and Castells i Sanabra, 2014; Peden et al., 2023; Hsu et al., 2025). The literature similarly emphasizes that operator error, inadequate safety measures, and environmental conditions remain among the most recurrent themes across the international evidence base, reinforcing the central role of safety in this

field (McKnight et al., 2007; Thieme et al., 2023; Yoshida et al., 2025; Komać et al., 2025).

For this reason, safety in recreational craft should not be viewed as a secondary extension of general maritime safety, but as a distinct research and policy domain requiring more focused analytical attention (Choi and Cho, 2021; Ehrhardt Jr et al., 2022; Peden et al., 2023). The literature increasingly suggests that effective safety improvement in this segment depends not only on onboard conduct, but also on the broader interaction between regulatory coherence, operator competence, enforcement capacity, safety awareness, and intervention design (Otamendi and de Vega, 2014; Torralbo and Castells i Sanabra, 2014; Hsu et al., 2025). In this respect, improving safety in recreational craft is essential not only for reducing casualties and strengthening user protection, but also for supporting the sustainable development of marine leisure activities through more targeted, risk-informed, and operationally grounded preventive strategies (Antão and Soares, 2019; Strabić et al., 2023).

Despite the growing body of research on recreational craft safety, the literature is still not sufficiently integrated in explaining how casualties emerge across different analytical dimensions (Antão and Soares, 2019; Ehrhardt Jr et al., 2022; Thieme et al., 2023; Hsu et al., 2025). Many studies examine isolated issues such as operator behavior, specific injury mechanisms, regulatory shortcomings, or vessel types, rather than addressing casualty formation as a broader and interconnected safety process (Peden et al., 2023; Wordsworth et al., 2023). This limits a more comprehensive understanding of how occurrence types, contributing mechanisms, and consequence profiles interact in recreational craft operations (Hsu et al., 2025). Research also underlines that fragmented governance, weak harmonization, and limited policy coherence continue to undermine accident prevention efforts across jurisdictions and craft categories, further demonstrating why safety remains a foundational issue in recreational craft operations (Torralbo and Castells i Sanabra, 2014; Peden et al., 2023; Komać et al., 2025).

Although recreational craft safety has received growing scholarly attention, it remains considerably less developed than accident research on commercial shipping. Existing studies have provided valuable insights into specific dimensions of recreational boating safety, including drowning and injury mechanisms, operator behavior, alcohol involvement, lifejacket use, regulatory weaknesses, and intervention strategies (Torralbo and Castells i Sanabra, 2014; Peden et al., 2023; Wordsworth et al., 2023; Komać et al., 2025). However, these studies often examine individual risk factors or

isolated accident outcomes rather than interpreting recreational craft casualties as a multi-layered safety problem in which occurrence types, operational conditions, contributory factors, and human consequences are interconnected. The analysis is based on data obtained from the European Marine Casualty Information Platform (EMCIP), operated by the European Maritime Safety Agency (EMSA) that brings together ship-related and person-related casualty categories, contributory factor classifications, temporal patterns, spatial/operational contexts, and severity outcomes. This contribution is particularly relevant because comparative and empirically grounded studies that systematically connect accident causes, event categories, and consequence profiles in recreational craft casualties remain limited.

Against this background, the present study investigates casualty dynamics in recreational craft through a structured descriptive perspective that integrates occurrence patterns, contributory factor categories, operational contexts, and consequence severity. By approaching these dimensions as interconnected elements of the recorded casualty profile, the study aims to develop a more comprehensive understanding of visible safety-critical patterns in recreational craft operations. The scientific contribution of this study is not the development of a new statistical method, but the provision of an integrated empirical interpretation of recreational craft casualty dynamics by linking dimensions that have largely been examined separately in previous recreational boating safety research. In doing so, it offers a clearer basis for identifying priority safety vulnerabilities and for informing more targeted preventive strategies, stronger operational awareness, and more focused safety management efforts in the recreational craft sector.

The remainder of the paper is organized as follows. The next section reviews the relevant literature on recreational craft safety and casualty patterns. This is followed by the methodology section, which outlines the analytical framework and data interpretation approach adopted in the study. The subsequent section presents the main findings, which are then discussed in relation to safety vulnerabilities and operational implications in recreational craft. The final section concludes the paper by summarizing the main insights and offering recommendations for future research and safety practice.

## 2. LITERATURE REVIEW

Recreational craft are described in EU Directive 2013/53/EU as watercraft designed for sport and leisure activities, with a hull length

ranging from 2.5 to 24 meters, irrespective of propulsion type. Their classification is based on intended recreational use, together with the safety, construction, and design standards applicable to such vessels. In this study, recreational craft refers to small motorized and non-motorized vessels used primarily for leisure, sport, tourism, or private non-commercial navigation, including motorboats, personal watercraft, sailboats, paddle craft, and similar privately operated craft (European Parliament and Council of the European Union, 2013). Figure 1 illustrates the principal types of recreational craft and summarizes their main operational and functional characteristics within the context of leisure-oriented, non-commercial maritime activity.

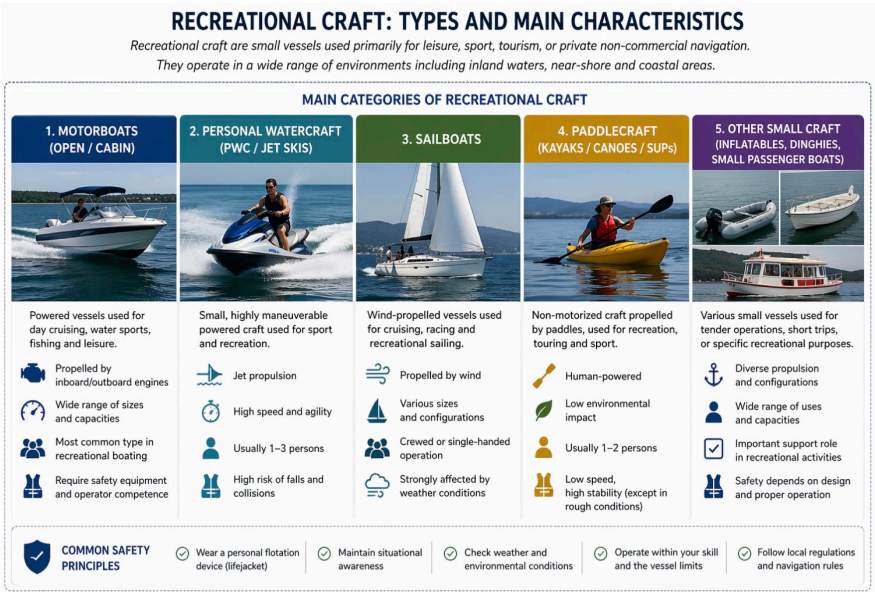



**Figure 1:** Main Categories and Defining Characteristics of Recreational Craft

Given the growing operational diversity and safety relevance of recreational craft, the literature has increasingly examined this segment through the lenses of accident causation, regulatory challenges, and preventive safety interventions (Ehrhardt Jr et al., 2022; Hsu et al., 2025). Earlier studies in this field largely focused on injury mechanisms, drowning, and operator-related accident causes, whereas more recent work has moved toward broader discussions of policy development, safety intervention design, harmonization challenges, and data-driven prevention strategies (Ryan et al., 2016; Peden et al., 2023; Hsu et al., 2025). This evolution indicates that recreational craft safety is no longer treated merely as an extension of general boating research, but increasingly as a multi-

dimensional field shaped by human, operational, regulatory, technical, and environmental factors (Willcox-Pidgeon et al., 2019; Antão and Soares, 2019; Thieme et al., 2023).

A consistent finding across the literature is that casualty formation in recreational craft is closely associated with human and operational factors. Operator error, inattention, poor situational awareness, alcohol use, and insufficient experience are repeatedly identified as major contributors to accidents and fatalities in recreational boating contexts (McKnight et al., 2007; O'Connor and O'Connor, 2005; Ehrhardt Jr et al., 2022). Similar patterns are also reported in more recent studies, which emphasize that non-compliance with safety measures, inadequate training, and weak behavioral integration remain central risk factors across different types of recreational craft (Yoshida et al., 2025). In this respect, the literature broadly supports the view that recreational craft casualties are shaped more strongly by unsafe actions and operational vulnerabilities than by technical deficiencies alone (McKnight et al., 2007; Lenorovitz et al., 2020; Hsu et al., 2025).

The literature also shows that casualty patterns are not evenly distributed across accident types. Drowning, collision, capsizing, falling overboard, and blunt trauma consistently emerge as the most visible forms of injury and fatality across recreational boating studies (Ryan et al., 2016; Willcox-Pidgeon et al., 2019; Peden et al., 2023). Motorboats and personal watercraft are frequently identified as higher-risk categories, while some studies further point to the importance of specific injury mechanisms such as propeller strikes, head trauma, and vessel movement-related passenger injuries (Lenorovitz et al., 2020; Scalia et al., 2023; Alunni et al., 2025; Zakaib et al., 2025). In addition, regional and seasonal variability has been emphasized in the literature, particularly in tourism-intensive waters where traffic density, user diversity, and environmental exposure increase accident likelihood (Strabić et al., 2023; Komać et al., 2025). These findings suggest that recreational craft safety cannot be reduced to a single dominant event type but must be interpreted through recurring and context-sensitive casualty patterns.

A second major strand of the literature concerns policy frameworks and regulatory coherence. Many studies report that recreational craft safety continues to be constrained by uneven legal structures, fragmented enforcement, inconsistent licensing systems, and limited harmonization across jurisdictions (Torralbo and Castells i Sanabra, 2014; Choi and Cho, 2021). This challenge becomes more pronounced when vessel diversity, emerging craft types, and region-specific operating conditions are

considered, since regulatory systems often fail to keep pace with changes in recreational use, technology, and user behavior (Hsu et al., 2025). Comparative and policy-oriented studies therefore underline the need for more harmonized definitions, inspections, safety equipment rules, and enforcement mechanisms if safety improvement is to be pursued systematically across the recreational craft sector (Torralbo and Castells i Sanabra, 2014; Antão and Soares, 2019).

Safety intervention design and training constitute another prominent area in the literature. A substantial body of research suggests that targeted interventions such as lifejacket promotion, skipper education, licensing requirements, awareness campaigns, and behavioral training can reduce accident rates and improve safety outcomes when they are effectively implemented (Peden et al., 2023; Komać et al., 2025). At the same time, several authors note that intervention effectiveness is often weakened by limited enforcement, low compliance, insufficient accessibility, and a lack of long-term evaluation (Otamendi and de Vega, 2014; Ehrhardt Jr et al., 2022; Scalia et al., 2023). Thus, literature does not simply advocate more interventions, but calls for interventions that are context-sensitive, evidence-based, and better aligned with real-world boating practices.

More recent studies have increasingly adopted analytical and decision-support approaches to recreational craft safety. Bayesian analysis, fuzzy multi-criteria decision-making, formal safety assessment, and risk-ranking models have been used to identify priority hazards, compare intervention options, and support more structured safety decision-making under uncertainty (Otamendi and de Vega, 2014; Antão and Soares, 2019; Lee et al., 2023). Other emerging work has explored the role of digitalization, operator gaze behavior, coordinated traffic systems, and new design solutions in improving situational awareness and accident prevention (Yoshida et al., 2025). Although these approaches strengthen the analytical depth of the field, the literature still notes persistent limitations related to data quality, underreporting, inconsistent definitions, and limited comparability across national systems (Peden et al., 2023). As a result, methodological progress has not yet fully resolved the structural weaknesses that continue to affect the interpretation of recreational craft safety.

## 3. RESEARCH METHODOLOGY

This section outlines the methodological design adopted to examine recreational craft casualties through a structured and multi-dimensional analytical framework. The study is based on the European

Marine Casualty Information Platform (EMCIP) derived casualty records and combines descriptive, interpretive, and consequence-oriented analytical components to capture occurrence patterns, contributory safety vulnerabilities, and outcome severity in an integrated manner.

## 3.1.Data Source

This study adopts a quantitative descriptive research design based on aggregated visual summary data obtained from the EMCIP database. The analysis focuses on recreational craft casualties recorded between 17 June 2011 and 12 April 2026 and includes 905 reported occurrences and 1,011 casualty events (EMCIP, 2026). It should be noted that these values refer to different analytical layers in the EMCIP reporting structure rather than to a single uniform denominator. In this context, reported occurrences represent the number of accident occurrence records, whereas casualty events refer to event-level records associated with these occurrences. Within this broader event-level dataset, 909 records correspond to ship-related casualty events. The occurrence-with-person subset includes 99 reported occurrences and 101 person-related casualty events. In addition, the consequence-to-people dimension consists of 26 fatalities, 0 missing persons, and 242 injured persons. Therefore, the numerical values used in the manuscript are not directly interchangeable but reflect different EMCIP classification and reporting layers. Accordingly, each figure in the findings section is interpreted according to its own analytical base and relevant denominator.

## 3.2.Methodological Approaches

The methodological design of the present study is organized around three complementary analytical components, namely multi-dimensional descriptive analysis, descriptive examination of contributory factor categories, and severity-based consequence assessment. This structure is consistent with the analytical logic of EMCIP-based safety evaluation, which enables the interpretation of recreational craft casualties through occurrence patterns, contributing factors, and human consequences within a unified reporting framework. Figure 2 presents the methodological framework of the study, illustrating how EMCIP-based casualty records are examined through multi-dimensional descriptive analysis, descriptive examination of contributory factor categories, and severity-based consequence assessment.

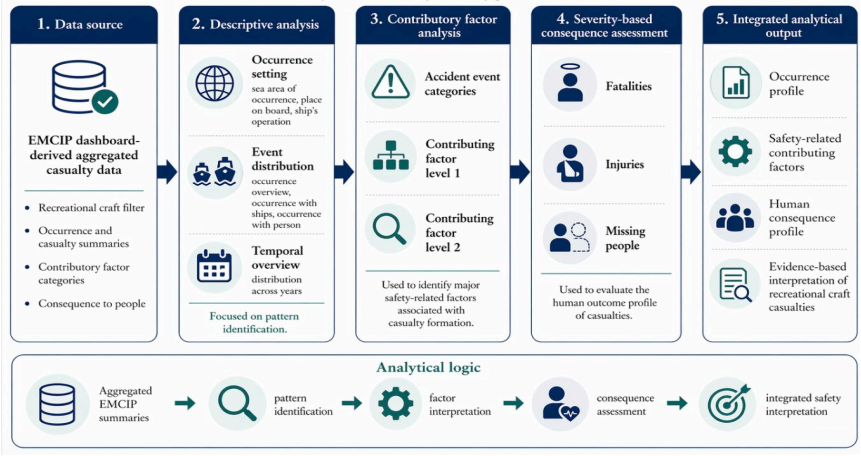



**Figure 2:** Methodological Framework for the Multi-Dimensional Analysis of Recreational Craft Casualties

As shown in Figure 2, the analytical approach of this study is structured around three complementary components. First, multi-dimensional descriptive analysis is used to identify the overall pattern of recreational craft casualties across occurrence settings, event categories, and operational conditions (Pilatis et al., 2024). In marine accident research, descriptive statistical analysis is widely used to reveal dominant accident profiles, distributional tendencies, and exposure-related clustering, thereby providing the empirical basis for subsequent interpretation (Kilic and Akdamar, 2020; Zhou et al., 2023; Pilatis et al., 2024). Second, the descriptive examination of contributory factor categories is used to identify the most visible human, operational, and organizational dimensions recorded in the EMCIP dataset. This component does not establish causality but supports the structured interpretation of safety-related patterns within the available classification fields (Chauvin et al., 2013; Yildiz et al., 2021). Third, severity-based consequence assessment is employed to distinguish more frequent but less severe outcomes from rarer and more critical consequences, especially regarding fatalities, injuries, and missing persons. This type of severity-oriented analysis strengthens the interpretive value of accident datasets by clarifying the consequence profile of observed events (Wang et al., 2022).

## 3.3.Analytical Scope of the Study

Taken together, these three components provide a structured descriptive basis for interpreting recreational craft casualty patterns through EMCIP dashboard data. The analytical scope of the study is

limited to the categories and aggregation logic provided by the EMCIP public dashboard. Therefore, the study should not be read as a causal accident investigation or as a predictive risk model. Multi-dimensional descriptive analysis identifies the observable distribution of casualty occurrences, the examination of contributory factor categories highlights the most visible safety-related dimensions recorded in the dataset, and severity-based consequence assessment clarifies the human outcome profile of the reported cases. In this respect, the study provides an empirically grounded overview of recreational craft casualty patterns and supports the identification of priority areas for more detailed future research and safety interventions.

## 3.4.Research Limitations

This study has several limitations that should be acknowledged. First, the analysis relies on pre-structured EMCIP dashboard categories, which confines the analytical scope to the classification logic embedded in the interface and prevents alternative regrouping of variables. Second, the counts reported for accident event, contributing factor level 1, and contributing factor level 2 are not directly equivalent, since these variables reflect different layers of accident coding rather than a single comparable analytical unit. Third, the use of aggregated visual summaries restricts the interpretation of temporal fluctuations, as short-term peaks may reflect reporting concentration as much as underlying variation in risk exposure. Finally, although the study identifies visible patterns in recreational craft casualties, it cannot fully reconstruct the operational sequence, behavioral context, or investigation-specific detail underlying individual cases.

# 4. FINDINGS

Consistent with the methodological framework of the study, the findings are presented in accordance with the three analytical components adopted in the research. In this respect, casualty occurrences were evaluated through multi-dimensional descriptive analysis, contributing conditions were examined through contributory factor analysis, and human outcomes were assessed through severity-based consequence assessment. Since the EMCIP dashboard reports recreational craft casualty data through different classification layers, the figures presented in this section are based on different denominators depending on the relevant variable and reporting category. For this reason, each figure should be interpreted with reference to its own analytical base rather than as a direct subset of a single uniform total.

## 4.1.Findings From Multi-Dimensional Descriptive Analysis

This subsection presents the descriptive structure of recreational craft casualties across operational context, onboard location, temporal distribution, and dominant occurrence categories. Figure 3 illustrates the distribution of ship operation categories in descending order, presenting each category with its corresponding frequency and percentage share within the total dataset. Figure 3 should be interpreted as a distribution of recorded operational contexts rather than as a strict normal service/special service comparison. The prominence of normal service categories, together with sailing and other routine-use categories, suggests that many recorded recreational craft casualties were associated with ordinary operational contexts. However, categories such as fishing, unknown, and other/unknown fall outside a strict binary classification and should therefore be interpreted cautiously.

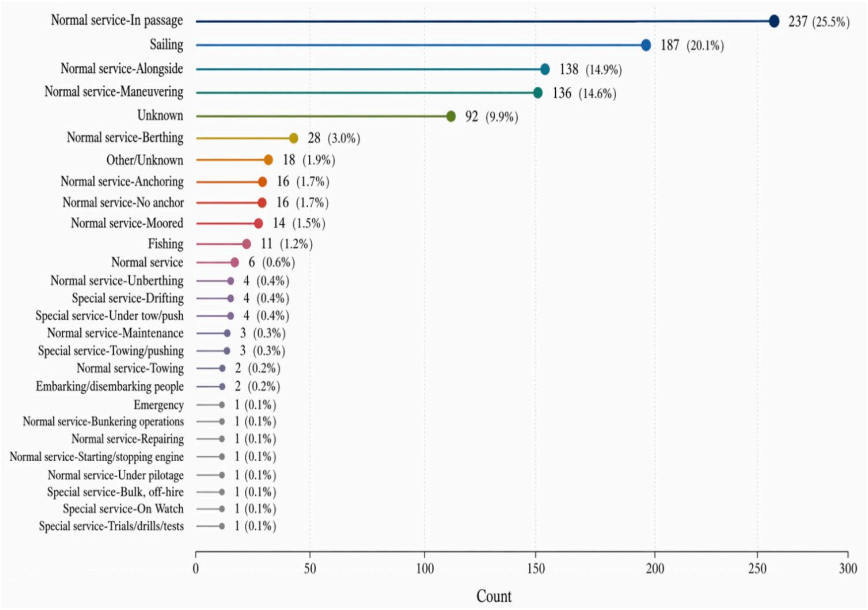



**Figure 3:** Distribution of Ship Operation Categories by Count and Percentage Share (N = 909 ship-related casualty events)

According to Figure 3, Normal service–In passage (25.5%), Sailing (20.1%), Normal service–Alongside (14.9%), and Normal service–Manoeuvring (14.6%) constitute the most prominent ship operation categories associated with recorded recreational craft casualties. These

categories suggest that many recorded events occurred during navigation, sailing, manoeuvring, or port-interface activities. However, because categories such as fishing, unknown, and other/unknown are also present in the EMCIP classification, this pattern should be interpreted cautiously as an indication of the operational contexts in which casualties were recorded, rather than as evidence of a strict distinction between ordinary and exceptional service conditions. Figure 4 represents the distribution of recreational craft casualty occurrences by place on board.

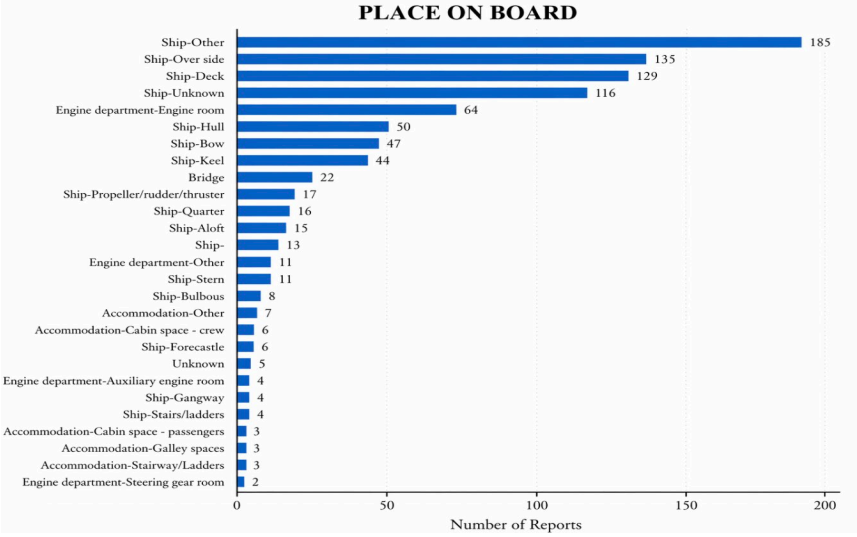



**Figure 4:** Distribution of Recreational Craft Casualty Occurrences by Place on Board (N = 947)

Figure 4 indicates that casualty occurrences are concentrated in open and operationally exposed onboard areas, particularly ship-other, ship-over side, and ship-deck. The largest category, "Ship-Other" (n = 185), should be interpreted as a residual ship-related location category rather than as a precise onboard area. It refers to records associated with the vessel but not assignable to the more specific predefined categories in the dashboard, possibly due to mixed onboard contexts, insufficient spatial detail, or less clearly specified shipboard locations. "Ship-Unknown" (n = 116), by contrast, indicates that the place on board was not specified or could not be determined from the available record. Figure 5 shows timeline of recreational craft casualty events from 2011 to April 12, 2026.

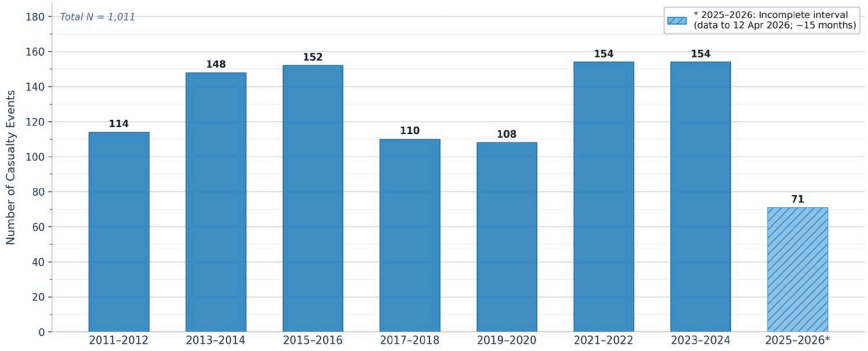



**Figure 5:** Timeline of Recreational Craft Casualty Events by 2-Year Interval (N = 1,011)

Figure 5 presents the temporal distribution of recreational craft casualty events by two-year intervals based on the overall event-level dataset (N = 1,011). The use of two-year intervals reduces short-term visual fluctuations and provides a clearer overview of temporal variation across the study period. However, the final interval, 2025–2026, should be interpreted cautiously because the dataset ends on 12 April 2026 and therefore does not represent a complete two-year observation period. Figure 6 presents the distribution of ship-related occurrence categories in recreational craft casualties. This distribution indicates that recorded ship-related recreational craft casualties are strongly associated with interaction-based navigational events rather than with stability failure, hull failure, or fire-related mechanisms. In descriptive terms, traffic interaction, manoeuvring judgement, and situational awareness appear as visible safety-relevant dimensions in the available casualty records.

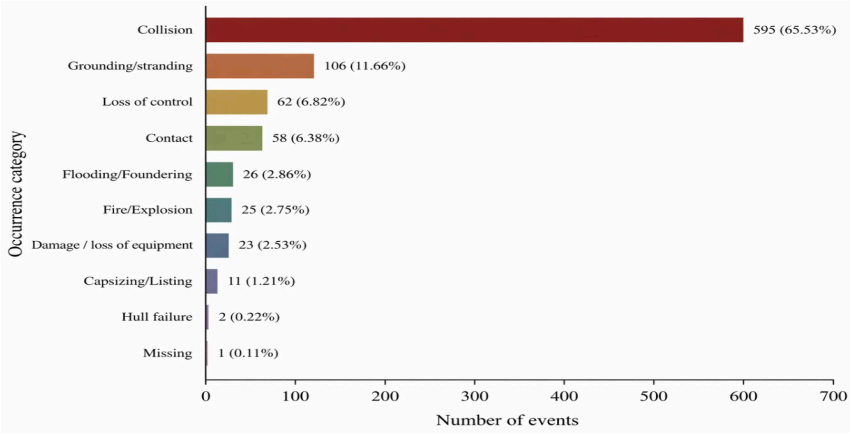
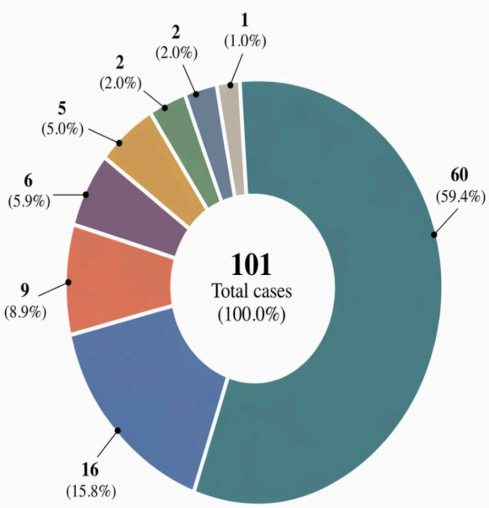



**Figure 6:** Distribution of Ship-Related Occurrence Categories in Recreational Craft Casualties (N = 909)

Figure 6 illustrates that ship-related recreational craft casualties are overwhelmingly dominated by collision accidents (n = 595, 65.53%), followed at a considerable distance by grounding/stranding (n = 106, 11.66%), loss of control (n = 62, 6.82%), and contact (n = 58, 6.38%). Figure 7 illustrates the breakdown of deviation categories in person-related recreational craft casualty events, with slipping, stumbling, and falling as the leading category.




| Outcome | Cases | Percentage (%) |
|---|---|---|
| Slipping, stumbling and falling – fall of persons | 60 | 59.4 |
| Body movement without any physical stress (generally leading to an external injury) | 16 | 15.8 |
| Body movement under or with physical stress (generally leading to an internal injury) | 9 | 8.9 |
| Loss of control (total or partial) of machine, means of transport or handling equipment, handheld tool, object, animal | 6 | 5.9 |
| Breakage, bursting, splitting, slipping, fall, collapse of material agent | 5 | 5.0 |
| Deviation by overflow, overturn, leak, flow, vaporisation, emission | 2 | 2.0 |
| Other | 2 | 2.0 |
| No information | 1 | 1.0 |
| **Total** | **101** | **100.0** |

**Figure 7:** Distribution of Deviation Categories in Person-Related Recreational Craft Casualty Events (N = 101)

Figure 7 shows a strong concentration of person-related casualty events in movement-related deviation categories, particularly slipping, stumbling, and falling, followed by body movement without physical stress. This pattern suggests that the human-risk profile in recreational craft operations is shaped primarily by onboard mobility, balance instability, and routine physical interaction with the vessel environment rather than by complex technical failure alone**.** Figure 8 presents the temporal distribution of person-related recreational craft casualty events across 2-year intervals since April 12, 2026.

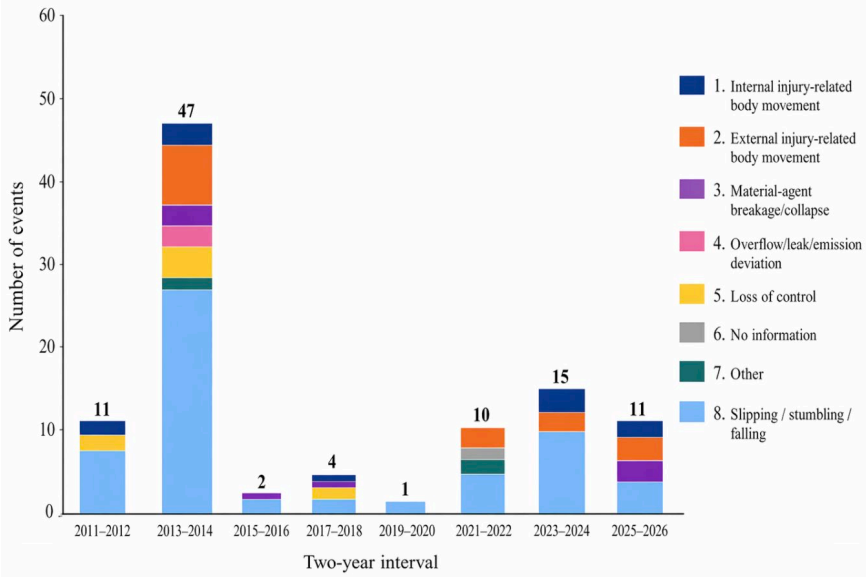



**Figure 8:** Person-Related Recreational Craft Casualty Events by 2-Year Interval (N = 101)

The figure indicates that person-related casualty events in recreational craft operations were strongly concentrated in the early period of the dataset, particularly in 2013–2014, when onboard fall-related events reached their highest level. This pattern suggests that injury formation in recreational craft activities is primarily associated with onboard physical exposure and movement-related vulnerabilities rather than with mechanically complex or rare deviation mechanisms. Although the overall number of person-related events declined after the peak period, the continued visibility of slipping, stumbling, and falling in later intervals indicates that this category represents a persistent safety weakness in recreational craft operations.

## 4.2. Findings from the Descriptive Examination of Contributory Factor Categories

This subsection examines the contributory structure of recreational craft casualties through accident event categories and contributing factor levels 1 and 2. The distribution of accident event categories in recreational craft casualties is presented in Figure 9.

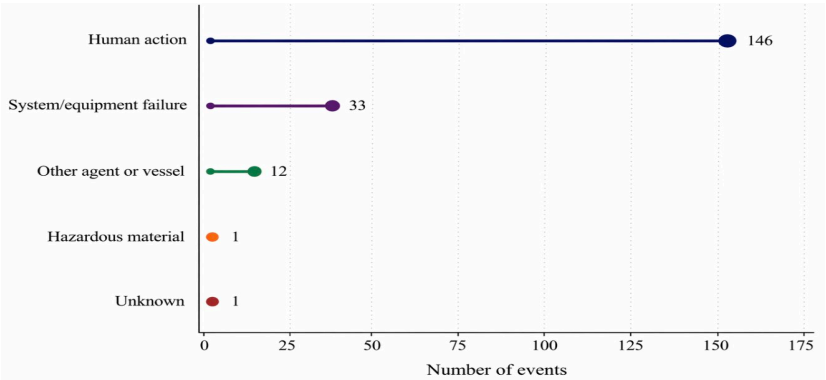



**Figure 9:** Distribution of Accident Event Categories in Recreational Craft Casualties (EMCIP contributory factor module, N = 193 coded events)

Figure 9 demonstrates that the accident-event category most frequently recorded in the relevant EMCIP subset is "human action" (146 cases), followed by system/equipment failure (33 cases) and other agent or vessel (12 cases), whereas hazardous material and unknown categories remain limited. However, "human action" should be interpreted as a broad EMCIP category rather than as direct evidence of individual human error. This category may include operational actions, procedural actions, intentional acts, and other human-related event mechanisms. Therefore, the results indicate that human-related event mechanisms are highly visible in the recorded accident-event subset, but they should not be reduced solely to human error. The Level 1 contributory factor structure of recreational craft casualties is shown in Figure 10.

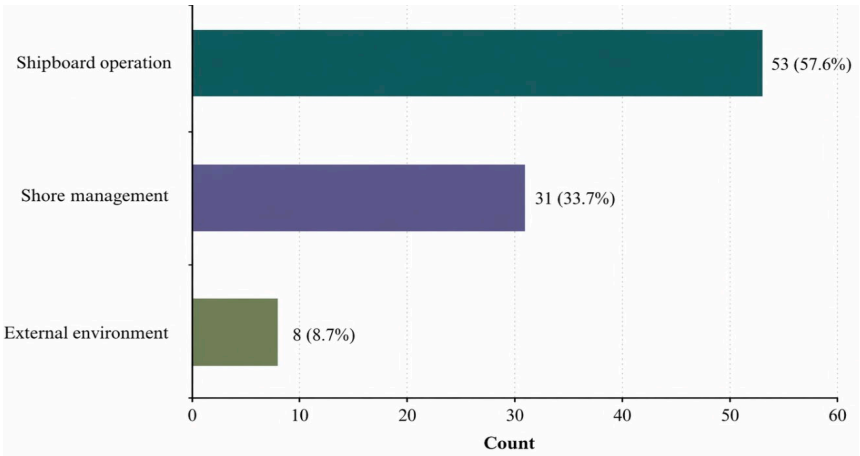
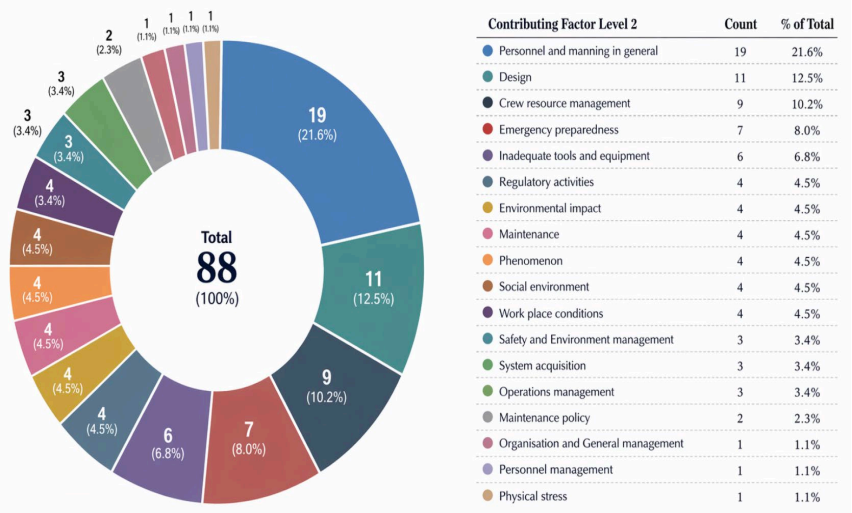



**Figure 10:** Level 1 Contributory Factors in Recreational Craft Casualties (N = 92 coded factors)

Figure 10 shows that Level 1 contributory factors in recreational craft casualties are concentrated predominantly in shipboard operation (53 cases; 57.6%), followed by shore management (31 cases; 33.7%) and, to a much lesser extent, the external environment (8 cases; 8.7%). This distribution indicates that the recorded Level 1 contributory-factor categories are concentrated mainly in operational and management-related dimensions rather than in external environmental conditions alone. Figure 11 shows the second-level contributing factor categories associated with recreational craft casualties.




| Contributing Factor Level 2 | Count | % of Total |
|---|---|---|
| Personnel and manning in general | 19 | 21.6% |
| Design | 11 | 12.5% |
| Crew resource management | 9 | 10.2% |
| Emergency preparedness | 7 | 8.0% |
| Inadequate tools and equipment | 6 | 6.8% |
| Regulatory activities | 4 | 4.5% |
| Environmental impact | 4 | 4.5% |
| Maintenance | 4 | 4.5% |
| Phenomenon | 4 | 4.5% |
| Social environment | 4 | 4.5% |
| Work place conditions | 4 | 4.5% |
| Safety and Environment management | 3 | 3.4% |
| System acquisition | 3 | 3.4% |
| Operations management | 3 | 3.4% |
| Maintenance policy | 2 | 2.3% |
| Organisation and General management | 1 | 1.1% |
| Personnel management | 1 | 1.1% |
| Physical stress | 1 | 1.1% |

**Figure 11:** Level 2 Contributing Factors in Recreational Craft Casualties (N = 88 coded factors)

The results show that "human action" is the most frequently recorded accident-event category within the available EMCIP accident-event coding layer. At the contributory-factor level, the available records are mainly concentrated in shipboard operation at Level 1 and in personnel and manning, design, and crew resource management at Level 2. Taken together, these findings suggest that recreational craft casualties are associated with visible human-related, operational, and organizational dimensions within the available EMCIP coding layers. However, because these categories are derived from aggregated and pre-coded dashboard records, they should not be interpreted as direct causal evidence of individual error or organizational failure.

## 4.3.Findings From Severity-Based Consequence Assessment

This subsection evaluates the human outcome profile of recreational craft casualties with reference to injuries, fatalities, and their temporal distribution across person categories. Figure 12 presents the temporal pattern of injuries and fatalities in recreational craft casualties by person category over the 2011–2026 period.

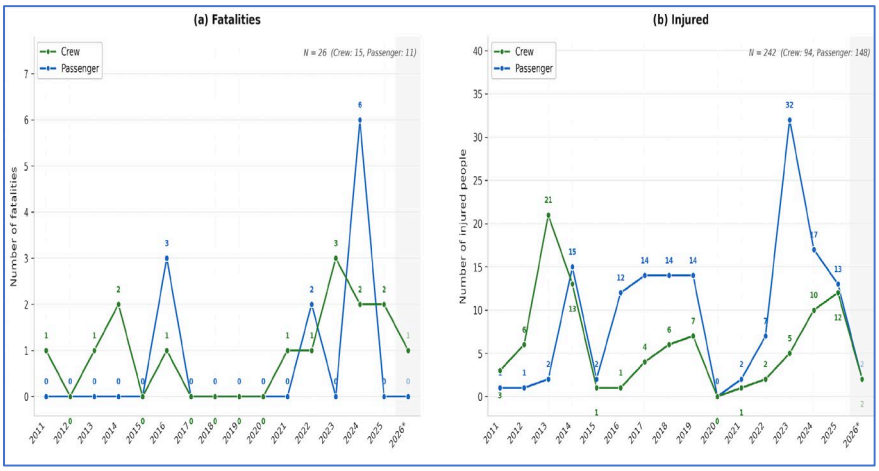



**Figure 12:** Temporal Distribution of Fatalities and Injured Persons in Recreational Craft Casualties by Person Category from 2011 to April 12, 2026.

Figure 12 presents the temporal distribution of fatalities and injured persons in recreational craft casualties by person category between 2011 and 2026. The corrected figure distinguishes between fatalities and injured persons by presenting fatalities in Panel (a) and injured persons in Panel (b). Among fatalities, crew members accounted for 15 cases (57.7%) and passengers for 11 (42.3%). The most pronounced single-year concentration was observed in 2016 (n = 4: crew = 1, passenger = 3) and 2024 (n = 8: crew = 2, passenger = 6), suggesting episodic rather than consistently distributed fatality patterns across the observation window. Among injured persons, passengers constituted the majority (n = 148; 61.2%) compared to crew (n = 94; 38.8%). The highest injury concentration was recorded in 2023 (n = 37: crew = 5, passenger = 32), followed by 2014 (n = 28: crew = 13, passenger = 15) and 2025 (n = 25: crew = 12, passenger = 13). A notable absence of casualties in 2020 across both categories is consistent with the reduction in recreational boating activity associated with pandemic-related restrictions. Overall, the consequence profile indicates

that while fatalities remain relatively rare and episodically distributed, injury risk — particularly among passengers — is persistent and concentrated in recent years, pointing to an intensifying safety burden in the post-2020 period.

## 5. DISCUSSION

The findings of this study are broadly consistent with the literature showing that recreational craft safety is shaped primarily by human and operational vulnerabilities rather than by technical failures alone. In the present dataset, accident events were dominated by human action, whereas contributing factors were concentrated in shipboard operation and shore management. This pattern is in line with maritime accident studies showing that visible unsafe acts are often embedded within wider human and organizational conditions rather than arising as isolated individual failures (Chauvin et al., 2013; Yildiz et al., 2021).

From a practical safety perspective, the prominence of collision-related events indicates that recreational craft safety interventions should place greater emphasis on operator-level navigational competence. Training and awareness programmes should address basic collision-avoidance rules, lookout practices, speed adjustment in congested or near-shore waters, safe passing distances, traffic interaction, and early risk recognition. These elements may be integrated into short recreational craft operator courses, licensing procedures, marina-based safety briefings, and user-oriented digital guidance materials. Such targeted measures would make the descriptive findings more directly relevant to collision-prevention practice. Research on recreational boating has similarly shown that collision-prone scenarios are closely linked to inattention, inexperience, and failures in situational judgement. McKnight et al. (2007) identified human error as a major contributor to recreational boating accidents, whereas Ryan et al. (2016) found that sailboat injuries and fatalities were frequently associated with preventable contributing factors such as operator inattention, inexperience, and alcohol use. Taken together, these studies suggest that the collision-heavy structure observed here is more plausibly related to traffic interaction, manoeuvring complexity, and judgement-based performance limitations than to isolated technical malfunction alone (McKnight et al., 2007; Ryan et al., 2016).

A second important contribution of the study concerns the person-related casualty profile. The strong concentration of slipping, stumbling, and falling events shows that recreational craft casualties are not limited to navigation-related mechanisms but are also shaped by onboard physical

exposure and routine movement within the vessel environment. This interpretation is supported by the broader injury literature. Ehrhardt Jr et al. (2022) emphasized the substantial burden of non-fatal trauma in watercraft-related incidents, whereas Hayes et al. (2023) reported that injuries during offshore recreational sailing were more frequent on smaller boats and among individuals with less experience on the current vessel. Earlier sailing epidemiology research also showed that injuries in novice and recreational sailing are predominantly acute and often result from physical interaction with the craft environment. Accordingly, the prominence of slipping, stumbling, and falling in the present study is likely to reflect the combined influence of vessel motion, exposed deck areas, surface interaction, and experience-related limitations in adapting to dynamic onboard conditions rather than random isolated missteps (Neville and Folland, 2009; Ehrhardt Jr et al., 2022; Hayes et al., 2023). The concentration of slipping, stumbling, and falling events also points to a need for more explicit onboard injury-prevention measures. These may include non-slip deck surfaces, adequate handholds, safer boarding and disembarkation arrangements, clear walkways, improved lighting, warning signs in wet or unstable areas, and passenger guidance during manoeuvring, anchoring, berthing, and adverse weather conditions. Therefore, recreational craft safety should be approached not only as a navigational issue, but also as an onboard movement and design-related safety problem.

The consequence profile identified in this study partly converges with, but also partly differs from, earlier recreational boating research. In the EMCIP-based dataset, injuries were substantially more frequent than fatalities, indicating that the recorded casualty burden is dominated by non-fatal human harm. This result is compatible with clinical and injury-focused studies emphasizing the importance of non-fatal trauma in recreational watercraft incidents. Fatality-focused studies, however, tend to place greater emphasis on drowning, falling overboard, and capsizing. Ryan et al., (2016), for example, reported that falls overboard and capsizing were the most common fatal accidents in sailboat incidents, whereas the present study captures a broader casualty structure in which injury-producing onboard events are more visible. This difference is therefore not contradictory; rather, it reflects the fact that the present analysis includes multiple casualty outcomes and not fatal events alone (Ryan et al., 2016; Ehrhardt Jr et al., 2022).

The contributory coding structure further strengthens the interpretive value of the study. The numerical differences between accident event, contributing factor level 1, and contributing factor level 2 should not

be treated as inconsistencies, because these variables represent different layers of accident coding rather than directly comparable frequencies. This layered reading is consistent with Human Factors Analysis and Classification System (HFACS)-based maritime research, which distinguishes between proximate unsafe acts and deeper preconditions, supervisory influences, and organizational weaknesses. Chauvin et al. (2013) demonstrated the usefulness of HFACS in collision analysis, whereas more recent work has shown that combining HFACS with Bayesian modelling can reveal more detailed human and organizational pathways in collision accidents. In this respect, the present findings suggest that the prominence of human action in recreational craft should not be interpreted as a sufficient causal explanation, but rather as a visible outcome category that points toward deeper contributory conditions (Chauvin et al., 2013; Yildiz et al., 2021; Wang et al., 2024).

An important implication of these results concerns the direction of future research. If collision events and fall-related person casualties dominate the observed structure, then the next analytical step should not simply repeat descriptive frequency analysis. Instead, future studies should examine why human action becomes dominant in the coding architecture of recreational craft casualties. Layered human factors frameworks such as HFACS would be particularly valuable for this purpose, because they allow researchers to move beyond surface attribution and examine unsafe acts together with their preconditions, supervisory influences, and organizational context. Such an approach would help clarify whether the collision dominance observed in recreational craft is driven primarily by perceptual failures, decision errors, inadequate training, weak compliance with navigation rules, or latent organizational conditions, whereas the predominance of slip and fall-type casualties could be examined in relation to onboard design, environmental exposure, operational routine, and user adaptation to vessel motion.

Overall, the study contributes to the recreational craft safety literature by integrating occurrence structure, contributory factor coding, and consequence severity within a single empirical reading. Much of the existing literature addresses specific issues such as operator error, fatality risk, or injury management in relative isolation, whereas the present study offers a more layered overview of how recreational craft casualties are distributed across operational settings, onboard exposure zones, contributing factors, and human outcomes. Its contribution therefore lies not in case-level causal reconstruction, but in providing a structured analytical interpretation of where the most visible safety burdens are concentrated in the available casualty record.

## 6. CONCLUSION

This study examined recreational craft casualties recorded in the EMCIP database between 17 June 2011 and 12 April 2026 through a structured descriptive perspective. By integrating occurrence categories, operational contexts, contributory factor classifications, and human consequence profiles, the study provides an empirically grounded overview of the most visible casualty patterns in recreational craft operations. The findings indicate that collision events constitute the most prominent ship-related occurrence category, whereas person-related casualty events are mainly concentrated in slipping, stumbling, and falling. The contributory-factor records further suggest that shipboard operation, shore management, personnel and manning, design, and crew resource management represent visible safety-related dimensions within the recorded casualty profile.

The findings have several practical implications for recreational craft safety management. First, the prominence of collision-related events indicates the need to strengthen preventive measures related to lookout practices, situational awareness, speed management, traffic interaction, and collision-avoidance training. Second, the visibility of slipping, stumbling, and falling events suggests that recreational craft safety should not be limited to navigational risks but should also address onboard movement-related hazards through improved deck layout, non-slip surfaces, handholds, boarding arrangements, passenger movement guidance, and safety awareness. Third, the concentration of contributory factors in operational and management-related categories underlines the importance of operator competence, pre-departure checks, emergency preparedness, safety culture, and clearer guidance for recreational craft users.

From a policy and safety-management perspective, the results suggest that recreational craft safety interventions should be more targeted and evidence-informed. General awareness campaigns may be strengthened by aligning them with the most visible casualty patterns identified in the data, particularly collision prevention and onboard movement-related injuries. Training inspection priorities, design guidance, and user-oriented safety materials may therefore benefit from explicitly addressing these recurring vulnerability areas.

The study is subject to certain limitations. Since the analysis is based on aggregated EMCIP dashboard data, it does not reconstruct individual accident sequences, identify causal mechanisms, or measure exposure-adjusted risk. Accordingly, the findings should be interpreted as descriptive indicators of recorded casualty patterns rather than as causal explanations.

Future research should move beyond aggregate descriptive analysis by combining EMCIP-based records with case-level accident investigation reports, operator surveys, exposure data, and comparative cross-regional datasets. Such research could examine why collision-related events are so prominent in recreational craft, how operator experience, traffic density, visibility, vessel type, speed, and local regulatory conditions shape accident occurrence, and which design or behavioral interventions are most effective in reducing slip/fall injuries. More advanced approaches, including Bayesian networks, sequence analysis, mixed-method accident reconstruction, or exposure-adjusted risk modelling, may also help clarify the interaction between human, operational, environmental, and design-related factors.

## AUTHOR CONTRIBUTION

All stages of this research were conducted by the author.

## Conflict of Interest

No potential conflict of interest was reported by the authors.

## Financial Support

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this research.

## Declaration of Generative AI and AI-Assisted Technologies

During the preparation of this manuscript, AI-assisted tools were used only for limited supportive purposes, including language refinement, improvement of sentence clarity, and visual formatting assistance for author-developed conceptual figures. These tools were not used to generate original research data, conduct database searches, determine study

eligibility, perform thematic analysis, interpret findings, or formulate the scientific conclusions of the study. All database searches, screening decisions, eligibility assessments, thematic synthesis, critical interpretations, and final academic judgments were carried out by the author. The author reviewed, verified, and take full responsibility for the accuracy, originality, integrity, and ethical appropriateness of all content included in the manuscript.

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