Analysis of Recreational Crafts Accidents – Precondition for Improvement of Safety of Navigation in the Adriatic Sea

Analiza nesreća rekreacijskih plovila – preduvjet za unaprjeđenje sigurnosti plovidbe na Jadranskom moru

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Abstract

The number of marine accidents involving recreational crafts on the Adriatic Sea has been increasing in recent years, especially during high season. In this paper, research on marine accidents of recreational crafts in the Croatian part of the Adriatic Sea was conducted. The aim of the research was to identify the main types of recreational crafts that are most frequently involved in different categories of accidents in the Adriatic Sea by presenting trends and patterns such as geographical distributions, type of recreational crafts, seasonality, time of occurrence and distribution of fatalities according to vessel type, upon which recommendations are proposed according to findings. The research is based on a retrospective review and analysis of data from a total of 2.654 archived files of marine accidents involving recreational crafts, which includes a detailed review of the chronology of individual accidents, weather reports, attached photographic evidence, port authority's reports, and a review of correspondence between Rescue Coordination Centers, sub-centers and competent ministries. The results of the analysis for the observed period are presented according to different categories, i.e., types of accidents, with the calculated values of statistical tests, for which the statistical program SPSS and the software STATISTICA 12 were used. The findings show that the majority of overall interventions are involved with recreational crafts and that the majority of rescued persons are caused by nautical tourism activities. Based on the conducted research, recommendations were made to increase safety in the domain of nautical tourism on the Adriatic Sea in terms of better training and education, especially for boat and sailing boat skippers.

KEY WORDS

accidents of recreational crafts
search and rescue
nautical tourism
Adriatic Sea

Sažetak

Broj pomorskih nesreća u kojima sudjeluju rekreacijska plovila na Jadranskom moru posljednjih je godina u porastu, osobito tijekom glave sezone. U ovom radu provedeno je istraživanje pomorskih nesreća rekreacijskih plovila na hrvatskom dijelu Jadranskog mora. Cilj istraživanja bio je identificirati glavne vrste rekreacijskih plovila koje su najčešće uključene u različite kategorije nesreća na Jadranu, prikazujući pritom trendove i obrasce kao što su geografska rasprostranjenost, vrste rekreacijskih plovila, sezonalnost, vrijeme nastanka nesreće i raspodjela smrtnih slučajeva prema vrsti plovila, na temelju čega su predložene preporuke. Istraživanje se temelji na retrospektivnom pregledu i analizi podataka iz ukupno 2654 arhiviranih datoteka pomorskih nesreća u kojima su sudjelovala rekreacijska plovila, što uključuje detaljan pregled kronologije pojedinačnih nesreća, meteoroloških izvješća, priloženih fotografskih dokaza, izvješća lučkih uprava te pregled korespondencije između Centara za koordinaciju spašavanja, podcentara i nadležnih ministarstava. Rezultati analize za promatrano razdoblje prikazani su prema različitim kategorijama, odnosno vrstama nesreća, uz izračunate vrijednosti statističkih testova, za što su korišteni statistički programi SPSS i STATISTICA 12. Nalazi pokazuju da je većina ukupnih intervencija povezana s rekreacijskim plovilima te da je većina spašenih osoba povezana s aktivnostima nautičkog turizma. Na temelju provedenog istraživanja dane su preporuke za povećanje sigurnosti u području nautičkog turizma na Jadranu u smislu boljeg osposobljavanja i edukacije, osobito za voditelje brodica i jedrilica.

KLJUČNE RIJEČI

nesreće rekreacijskih plovila
traganje i spašavanje
nautički turizam
Jadransko more

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1. INTRODUCTION / *Uvod*

It is a well-known fact that a significant number of marine accidents occur on the Adriatic Sea, which is directly related to recreational crafts, as shown in previous studies [1,2,3,4]. Generally, the brief annual reports of the Maritime Rescue and Coordination Center in Rijeka show a significant percentage of recreational craft accidents compared to the overall number of accidents. The possibility of improving safety is impossible without a detailed analysis of events, in other words, accidents at sea, and associated causes. In addition to the aforementioned, this paper aims to obtain an overview of the safety of navigation related to recreational crafts by processing data on accidents, defining existing trends and patterns to identify most common contributing factors related to accidents of recreational crafts, but at the same time to analyze data on marine accidents following the previous researches in the area of Adriatic Sea and create a broad picture. Based on this, it is necessary to make justified recommendations that will contribute to safer sailing in nautical tourism. These suggestions will point out the most important categories of the accident's analysis, as well as targeted further research in the field, e.g., determine which recreational crafts cause the most accidents in Croatia and then compare the data with similar ecosystems to highlight potentially most probable primary causes of such accidents.

More recent studies show that there is an increasing trend of recreational boating accidents on the Adriatic Sea, especially when it comes to grounding [5]. One of the studies has shown that there was a long-lasting trend of frequently occurring accidents that fall under the "Not under command" [6] category. When it comes to relevant research on accidents that occurred in marinas, some authors conclude that safety standards in Croatian ports of nautical tourism are satisfactory [7]. Some studies show that errors leading to recreational boating accidents in the US vary across boat categories, and that alcohol consumption, observation during navigation and unsafe distance from other vessels are the most common causes of accidents [8]. Similar conclusions were made in research where 60% of the accidents were caused by human error in some parts of the Mediterranean Sea [9]. For that reason, some authors suggest improvement of education and training for seafarers in the Adriatic Sea [10]. Their research demonstrates that prevention and enhancing awareness significantly influence the reduction in the number of accidents compared to repressive measures of supervision and inspection.

In the Croatian part of the Adriatic Sea, official data on marine accidents are collected by the Maritime Rescue and Coordination Center (MRCC) with headquarters in Rijeka. For this purpose, the Croatian part of the Adriatic Sea is divided by jurisdiction into sub-centers (harbour master offices of Pula, Rijeka, Senj, Zadar, Šibenik, Split), each of them is located in its county, and the sub-centers of Ploče and Dubrovnik, which are located in the same county. Each sub-center corresponds to a competent harbor master office. The remaining part is covered by the Rescue Coordination Center, which is responsible for the PEFZ area (Protected Ecological and Fishing Zone) and the area outside the jurisdiction.

A marine accident is an event or sequence of events at sea that is related to the navigation, exploitation, performance, or operation of a navigable or other vessel. Marine accident has one or more of the following consequences: death or serious physical injury of a person; loss of a person; presumed loss or loss of a navigable or other vessel or abandonment; grounding or incapacity for further navigation, exploitation, performance or work; participation in a collision; substantial damage to vessels; substantial damage to marine infrastructure facilities; and/or sea pollution [11]. Major loss or damage to property is defined as any marine accident that exceeds the damage of €8,000 [11]. The master or owner of a vessel involved in a marine accident is obliged to report the accident without delay on the prescribed form, which he submits to the competent harbor master office, no later than 3 days from the date of the accident. The harbor master initiates an administrative investigation if there is a well-founded suspicion of a maritime violation, to discover the specific culprit of the accident. Every initiated administrative investigation is recorded in a register, based on which proposed measures for improving the safety of navigation are brought to the competent ministry twice a year.

Independent of the administrative investigation, a safety investigation is being conducted to determine the cause of the accident and to improve the safety of navigation, regardless of the misdemeanor or criminal liability of the persons involved in the accident. The safety investigation is conducted by the Air, Maritime, and Railway Casualty Investigation Agency [12]. The agency records data on accidents in the National database (CMCIP - Croatian Marine Casualty Information Platform) and European database (EMCIP – European Marine Casualty Information Platform). In addition to some other vessels, accidents, and incidents involving only yachts and boats for personal use are exempted. Therefore, the research question is: What are the trends and patterns in marine accidents involving recreational crafts in the Croatian part of the Adriatic Sea, and how do different types of recreational craft accidents vary across geographical areas?

After the introductory part of this research, Chapter 2 presents the Methodology of this paper. It is followed by Chapter 3, where the results of the statistical analysis are presented in detail. The discussion of the results of the analysis can be found in Chapter 4, where the recommendations based on the processed data and recommendations for further research are given. Chapter 5 presents the conclusions of the research.

2. METHODOLOGY / *Metodologija rada*

MRCC Rijeka archives marine accidents as well as all extraordinary events that SAR has been initiated in the Croatian part of the Adriatic Sea by individual files and simultaneously records them into a digital database. From the total number of 4.147 files of marine accidents that occurred in the observed ten-year period (01/2010 - 12/2019), only accidents involving recreational craft were selected. More precisely, 2.288 files from which the necessary data for analysis were extracted individually. Following that period, from 2020 until 2023, there were significant restrictions in force due to the COVID-19 pandemic caused by the new coronavirus. Therefore, this period was not included in the research as it would represent a reflection of severe government restrictions on nautical tourism rather than a clear image of recreational craft accident trends and patterns. An additional 366 files/interventions on recreational crafts from the post-pandemic period (01/2023 until 12/2024) were included in the research.

The files contain certain attached documents such as chronological records of individual accidents, weather reports, misdemeanor and port authority reports, photographic

evidence, and correspondence between Rescue Coordination Centers, sub-centers, and competent ministries. Data from all archived accident files were compared with the data of the MRCC Rijeka digital database. The analysis also includes accidents that are geographically not under the jurisdiction of the Republic of Croatia alone, but in which Croatia also participates with joint forces in cooperation with neighboring countries. Such interventions occur rarely and account for less than 1% of the total number during the observed period. This research follows previous researches on the subject [6], however, additional areas of jurisdiction are being considered, as well as additional types of recreational crafts which are frequent subjects of intervention.

Recreational craft is a vessel of any type intended for sport and leisure with a hull length of 2.5 to 24 meters measured according to the agreed norm, regardless of the type of propulsion. Recreational crafts included in the data sample of this research are divided into the following categories [13]:

- Yacht – craft for sports and recreation, regardless of whether it is used for personal needs or business, exceeding 15 m in length and intended for longer stay at sea and which is authorized to carry no more than 12 passengers in addition to the crew,
- boat - craft intended for sea navigation that is authorized to transport a maximum of 12 passengers, whose hull length is greater than 2.5 meters and less than or equal to 15 meters, or the total power of propulsion units is greater than 5 kW,
- sailing vessel - boat or yacht that, as a propulsion device, has sails of a sufficient surface by which it can move on the sea or inland waters,
- rigid inflatable boat – recreational craft (boat or a yacht) that has a hull fully or partially made of pneumatic tubes and has up to 12 passengers,
- other – jet-ski, dinghy, surfboard, pedal boat and similar recreational crafts that are not included in the previous categories.

Statistical tests were made from the total collected sample of necessary data. Data has been grouped to get the insight of accidents distribution by the month, area of occurrence, day of the week and specific time of occurrence (day/night). Data on casualties (fatalities, injured and missing) were grouped according to aforementioned types of recreational crafts throughout the years and compared to all other non-recreational accidents. The obtained percentages are presented, 95% CIs for proportions were determined as a measure of precision in order to present a range of plausible values, and significances were calculated using the Chi-square test for geographical locations of accidents in order to compare the observed number of accidents at specific locations against the number of accidents that would be expected if accidents were distributed randomly. Statistical program SPSS was used (version 26.0, SPSS Inc., Chicago, IL, SAD) for the purpose of these calculations. Presentations of the results are shown according to different categories with calculated values for each year, and the test examined statistically significant seasonality. Seasonally adjusted variables were created after series decomposition using the Census 2 statistical method for monthly data, based on which the tendency of the number of interventions is graphically displayed. This way, seasonally adjusted data makes it easier to identify long term patterns and changes with improved trend analysis and better comparisons by removing seasonal noise. The analysis was made in the STATISTICA 12 software (TIBCO Software Inc., Palo Alto, California). The recommendations made and the entire discussion chapter of this research paper is supported by the semi-structured interview carried out with RCC center operators, aiming to discover and highlight the most important issues they face during their work. In addition to the above, official data from the Croatian Bureau of Statistics were also used. The fact that statistical data of the observed period was not affected by the global pandemic of the new coronavirus could be considered a limitation, however, a realistic review was created this way. Other limitations of the research are directly connected to the lack of available data: primary causes of accidents, precise geographical positions and accident circumstances.

Within the data sample, accidents are classified as collision, allision, sinking, flooding, grounding, fire, unable to maneuver (not under command), dangerous list, medico, and "other". The term "Unable to maneuver" (Not under command)" for the purpose of this analysis involves any recreational craft which through some exceptional circumstance is unable to maneuver (loss of propulsion or similar), however it also includes numerous recreational crafts without any means of propulsion. This term was previously used in similar scientific researches; therefore, it is adopted in this analysis as well. The term "Intervention" implies starting a search and rescue procedure, i.e., helping the injured persons, using all available resources and personnel. There is a disparity between the number of interventions and the number of accidents, which often happens when multiple accidents are solved with one intervention, or when an intervention is started without a real accident, so an intervention without an accident is recorded.

Finally, it is important to emphasize that in 2010, there were 98 nautical tourism ports on the Croatian coast, including 60 marinas (of which 10 are dry marinas) and 38 other nautical tourism ports with a total of 16,913 berths. Towards the end of 2024, 226 ports of nautical tourism were statistically included, namely, 65 marinas, 20 dry marinas, 81 anchorages, 16 moorings and 44 disposal sites for recreational crafts, with a total of 19,073 berths [14]. Lika-Senj County has access to the sea, but statistically, not a single marina has been recorded on its territory. However, since it covers a large area, Rescue Coordination Sub-centers are included in the statistical analysis of accidents.

3. RESULTS OF DATA ANALYSIS / *Rezultati analize podataka*

The analysis of collected data for the observed period includes a presentation of:

- The relation between the total number of recreational crafts and the number of interventions,
- Total number of interventions per month,
- Trend of interventions for the observed period,
- Number of individual accidents by area,
- Total number of crafts classified by type of vessel and type of accident,
- Share of rescued persons from recreational crafts in relation to the total number of rescued persons,
- The relation between the number of victims on each type of craft in relation to the total number of victims,
- Distribution of interventions by day of the week, and
- Distribution of the number of day and night collisions, allisions, and groundings.

Since the beginning of the observed period, the total number of crafts reported in the area has been decreasing on average,

and after 2014 it started to increase again, so that by the end of 2019 it almost reached the initial value of 220.000 recreational crafts (Figure 1). Similar value is reported for the years 2023 and 2024. From 2014 there is an increasing trend of overall interventions that follows the increase of total number of crafts. A more constant increase in the number of crafts throughout the mentioned period was recorded in Split-Dalmatia County. The total number of recreational crafts was analyzed according to the length. The most numerous categories were 12-15 m (the number of crafts varied between 60k and 80k annually).

Since the lowest average number of interventions is in January and gradually increases until August, after which there is a tendency for it to decrease until the end of the year, the presence of cycles can be assumed (Table 1). The existence of statistically significant seasonality was examined using the *F ratio*. A high value of *F* indicates a continuous seasonality that repeats itself during the observed period, and seasonal trends are recognizable. The empirical value $p < 0.001$ indicates the existence of seasonality in the number of recreational craft accidents. Since seasonality is present, the series was decomposed and deseasonalized variables were created (Figure 2). From the graphic display, the presence of a slight tendency to increase the number of interventions can be determined, but the growth is not statistically significant (P=0,492).

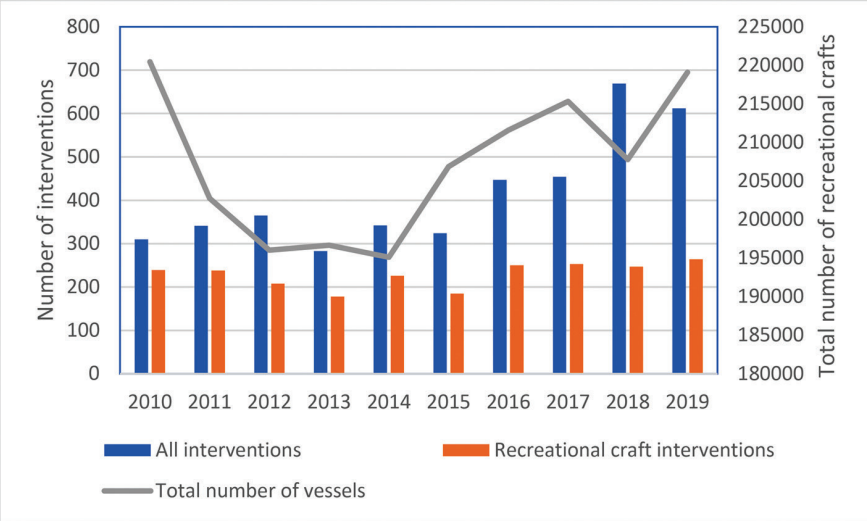

Figure 1 Relation between the total number of recreational crafts and the number of interventions
Slika 1. Odnos između ukupnog broja rekreacijskih plovila i broja intervencija

Table 1 Total number of interventions by recreational craft by month for the period from 2010 to 2019.
Tablica 1. Ukupan broj intervencija po rekreacijskim plovilima prema mjesecima za razdoblje od 2010. do 2019.

Original series: Table total: 2288,00 Mean: 19,0667 Std.Dev.: 22,05060 Interventions													
Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
2010	7	0	6	2	7	24	70	83	27	8	5	0	239
2011	2	2	6	12	14	41	61	63	23	8	4	2	238
2012	0	4	3	7	9	21	55	67	25	10	3	4	208
2013	1	3	7	9	11	22	46	46	22	7	0	4	178
2014	4	2	4	7	12	33	64	45	33	9	5	8	226
2015	5	3	7	9	14	25	37	50	21	7	6	1	185
2016	1	3	2	5	18	24	62	90	29	14	2	0	250
2017	1	0	4	5	8	35	64	89	25	13	6	3	253
2018	3	2	8	4	21	34	50	54	39	17	7	8	247
2019	3	9	8	13	17	30	79	65	25	5	5	5	264
Average	2,7	2,8	5,5	7,3	13,1	28,9	58,8	6 5,2	26,9	9,8	4,3	3,5	

Table 2 Seasonality test
Tablica 2. Test sezonalnosti

Effect	Stable seasonality test Stable seasonality present at the 1 percent level Interventions				
	Sum of	Degrs. of	Mean	F	p
Between months	1495935	11	135994,08	179,20	<0,001
Residual	81963	108	758,92		
Total	1577898	119			

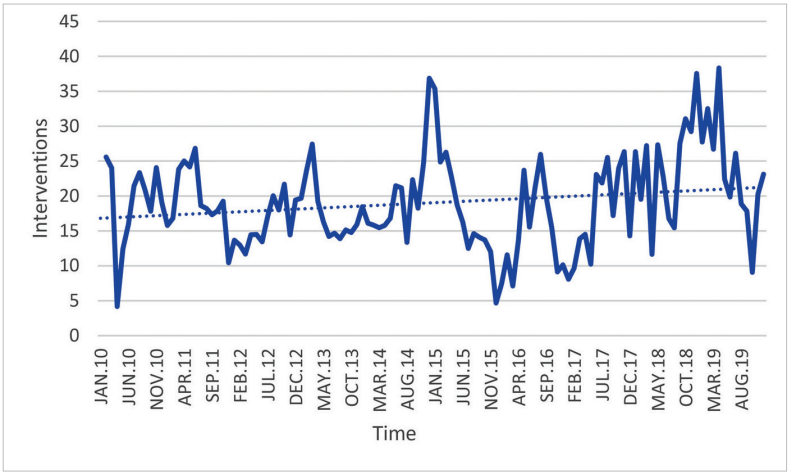

Figure 2 Deseasonalized values of recreational craft interventions and trends (2010-2019)
Slika 2. Desezonalizirane vrijednosti intervencija rekreacijskih plovila i trendovi (2010. – 2019.)

In the period from 01/2010 to 12/2019, throughout 2.288 interventions, 2.362 accidents were processed (Table 3). The most numerous accidents fall into the category of "Unable to maneuver" (N=721; 30.52%; CI 95%, 28.67-32.38), which is mostly correlated with the type of recreational craft "Boat" (N=318) and "Sailing vessel" (N=254). A relatively high number of "Groundings" (N=459; CI 95%, 19.43-21.03) is mostly caused by "Sailing vessels" (N= 263) and "Boats" (N=143). "Boat" is also the category that caused the largest number of collisions throughout the uninterrupted observed 10-year period. When geographical locations are being considered, it is evident that the largest number of accidents occurred in Split-Dalmatia County, however, Primorje-Gorski Kotar County and Zadar County also have considerable number of accidents in their area. Furthermore, after the pandemic period, altogether in 2023 and 2024 there were 366 interventions on recreational crafts with slightly changed trends where the most numerous accidents fall into the category of "Grounding" (N=64, 17,49%), which, in 2023 is mostly correlated with boats (N=24), and in 2024 with sailing boats (N=14).

The total number of recreational crafts, including other recreational means (pedal boats, inflatable mattresses, jet skis, boards, etc.) that were involved in marine accidents during the observed period 2010-2019 is 2.492. Boats participated in the most accidents (N=998, i.e. 40.05%; CI 95%, 38.12-41.97), followed by accidents of sailing vessels (N=806, i.e. 32.34%; CI 95%, 30.51-34.18). Yachts account for N=280, (11.24%; CI 95%, 10.00-12.48), and rigid inflatable boats N=148 (5.94%; CI 95%, 5.01-6.87). The group of other means for recreation includes N=260 (10.43%; CI 95%; 9.23-11.63). The "Allision" category data were not recorded in 2010. After the pandemic period, altogether in 2023 and 2024, 402 recreational crafts participated in accidents, where "Boats" participated in most accidents (N=181, 45,02%), followed by "Sailing boats" (N=70, 17,4%).

Generally speaking, noticeable more than half of the overall interventions (55.17%) fall under the domain of recreational crafts, i.e. nautical tourism (Table 4). The average daily values show that 1,14 interventions/day are being conducted, while 0,68 recreational crafts/day are involved in those interventions. Furthermore, the majority number of rescued persons (65.73%) fall under the domain of recreational crafts. 2,4 persons/day were saved by SAR service, of which 1,58 persons/day were using recreational crafts. The highest percentage of people rescued from recreational crafts was recorded in 2011 when it amounted to 82.42% (N=722; 95% CI, 79.9-84.9) compared to

Table 3 Recreational craft accidents by specific areas (2010-2024; pandemic period is not included)
Tablica 3. Nesreće rekreacijskih plovila po pojedinim područjima (2010. – 2024.; bez pandemijskog razdoblja)

	1	2	3	4	5	6	7 + 8	9	10	Σ
Collision	9	39	1	34	20	24	10	0	0	137
Allision	2	15	1	23	3	7	3	1	0	55
Sinking	2	14	4	28	21	21	9	1	1	113
Flooding	22	20	2	21	16	28	13	0	1	117
Grounding	57	85	7	134	102	88	47	3	0	497
Fire	10	19	0	26	18	30	9	3	0	115
Unable to manoeuvre	87	169	54	115	93	181	61	23	4	781
Dangerous inclination	10	10	1	7	8	4	7	0	0	47
Medico	15	32	2	32	19	52	22	11	1	230
Other	12	136	62	157	58	113	63	9	6	671
Total	268	486	95	459	321	497	184	40	12	2763

1 – Port authority Pula (Istria County)
2 – Port authority Rijeka (Primorje-Gorski Kotar County)
3 – Port authority Senj (Lika-Senj County)
4 – Port authority Zadar (Zadar County)
5 – Port authority Šibenik (Šibenik-Knin County)
6 – Port authority Split (Split-Dalmatia County)
7 – Port authority Ploče (Dubrovnik-Neretva County)
8 – Port authority Dubrovnik (Dubrovnik-Neretva County)
9 – MRCC Rijeka – PEFZ
10 – Out of Jurisdiction

Table 4 Number of rescued persons and interventions – overall interventions in relation to nautical tourism accidents
Tablica 4. Broj spašenih osoba i broj intervencija – ukupne intervencije u odnosu na nesreće u nautičkom turizmu

	NUMBER OF INTERVENTIONS				p	NUMBER OF RESCUED PERSONS				p
	TOTAL		RECREATIONAL CRAFTS			TOTAL		RECREATIONAL CRAFTS		
2010	310	7,48%	239	10,45%	p<0,001	944	10,79%	536	9,32%	p<0,001
2011	341	8,22%	238	10,40%		876	10,01%	722	12,55%	
2012	365	8,80%	208	9,09%		825	9,43%	651	11,32%	
2013	283	6,82%	178	7,78%		646	7,38%	478	8,31%	
2014	342	8,25%	226	9,88%		774	8,84%	599	10,41%	
2015	324	7,81%	185	8,09%		611	6,98%	491	8,54%	
2016	447	10,78%	250	10,93%		1075	12,28%	652	11,34%	
2017	454	10,95%	253	11,06%		765	8,74%	528	9,18%	
2018	669	16,13%	247	10,80%		1080	12,34%	566	9,84%	
2019	612	14,76%	264	11,54%		1155	13,20%	529	9,20%	
∑	4147	100,00%	2288	100,00%		8751	100,00%	5752	100,00%	

the total number of people rescued in the same year (N=876) (Table 4). On the other hand, the total number of interventions in the last year of the observed period (2019) is almost twice as high as the first year of the observed period (2010), but at the same time, recreational craft accidents do not follow the same trend of overall interventions and are evenly distributed annually. This might have happened for multiple reasons: better statistical reporting in the last years of the observation period, lack of reporting for category "allision" in 2010, and more "false alarm" accidents towards the year 2019.

In addition, the data for 2023 and 2024 shows a notable shift compared to previous years. In 2023, there were 451 total interventions (8.55% of the total), with 209 related to recreational crafts (7.87%). The number of rescued persons in 2023 was 677 overalls (6.57%), with 334 (5.27%) linked to recreational crafts. In 2024, total interventions increased to 674 (12.78%), yet recreational craft interventions dropped to 157 (5.92%). Similarly, the number of rescued persons rose to 879 (8.53%) overall, but those related to recreational crafts fell significantly to 251 (3.96%). This suggests a growing volume of total accidents and rescues in 2024, while the proportion and absolute numbers related to recreational crafts decreased, indicating possible changes in accident patterns or rescue resource allocation.

Table 5 presents the yearly totals of casualties, deceased, injured, and missing on recreational crafts from 2010 to 2024, categorized by vessel type. The data reveal that injuries consistently account for the highest number of casualties each year, peaking at 39 in 2017 and remaining substantial in recent years, such as 25 in 2023. Deceased totals vary, with notable highs of 19 in 2017 and 13 in 2014 and 2015, while missing persons remain comparatively low throughout the period, never exceeding 3 in a given year. The fluctuations in these figures reflect changes in accident severity and frequency across years and vessel types. The findings directly address the research question by highlighting how accident outcomes vary over time and by craft type, underscoring the importance of targeted safety measures and efficient rescue interventions to reduce injuries and fatalities in recreational boating. In addition, from Table 5, it can be depicted that the high number of casualties were injuries. The number of reported persons is relatively low across all the years. As far as the number of fatalities, injured and missing persons on recreational crafts are concerned, it is worth noting that the majority of these cases are directly correlated to the category "Boat" (Table 5) throughout the entire observed period.

Table 5 Number of casualties by individual type of recreational craft in the period from 2010 to 2024 (pandemic period excluded)
Tablica 5. Broj stradalih osoba prema vrsti rekreacijskog plovila u razdoblju od 2010. do 2024. (bez pandemijskog razdoblja)

	2010						2011						2012						2013					
	A	B	C	D	E	∑	A	B	C	D	E	∑	A	B	C	D	E	∑	A	B	C	D	E	∑
Deceased	0	0	0	3	6	9	0	2	0	2	1	5	0	1	0	2	1	4	1	1	0	7	2	11
Injured	3	4	2	4	8	21	4	1	1	8	8	22	1	10	1	8	5	25	4	7	1	8	1	21
Missing	0	0	0	2	0	2	0	0	0	0	1	1	1	0	1	0	0	2	0	0	0	0	0	0
	2014						2015						2016						2017					
	A	B	C	D	E	∑	A	B	C	D	E	∑	A	B	C	D	E	∑	A	B	C	D	E	∑
Deceased	1	1	1	8	2	13	0	1	1	1	1	4	0	1	0	2	0	3	2	3	6	7	1	19
Injured	1	7	1	5	6	20	0	1	4	15	3	23	0	5	6	8	0	19	1	8	2	22	6	39
Missing	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	3
	2018						2019						2023						2024					
	A	B	C	D	E	∑	A	B	C	D	E	∑	A	B	C	D	E	∑	A	B	C	D	E	∑
Deceased	0	3	0	2	1	6	0	0	1	5	1	7	1	2	0	5	1	9	1	0	2	3	2	8
Injured	0	1	2	4	2	9	5	6	0	9	0	20	0	5	2	16	2	25	0	4	3	5	4	16
Missing	0	0	0	0	0	0	0	0	0	2	0	2	0	0	0	0	2	2	0	0	0	0	0	0

A – yacht
B – sailing vessel
C – rigid inflatable boat
D – boat
E – other

Out of the total number of injuries (including all types of crafts), more than 55% of them happened on boats (Table 6), while median value of total fatalities is 29,5 for the observed period. Total missing persons amount to exactly 2 persons/year, of which one is related to recreational crafts. Total number of rescued persons trend is equally following the trend of total number of rescued persons from recreational crafts until 2017, after which total number of reported accidents increases significantly, as shown on Figure 3 which, for that purpose uses two forms of data representation and displays number of casualties and rescued persons both for overall number of accidents and recreational craft accidents.

Even though recreational craft accidents account for a significant portion of injuries and fatalities, medical emergencies involving recreational crafts represent a smaller proportion of overall maritime medical interventions, yet these cases often require complex coordination due to their remote nature. The number of recreational crafts in medical distress (N=147) compared to the total number of all medical interventions, which over a ten-year period amounted to 944 interventions, appears to be relatively low, it is important to note that the latter includes many emergency medical evacuations from remote islands to the nearest cities. In these cases, MRCC not only receives calls for medical assistance from the vessel but also facilitates the organization and coordination of emergency medical transport by sea. The overall number of emergency medical interventions recorded a significant growth, especially in recent years, when in 2019 it reached the highest number of 223 interventions, which presents a significant growth compared to 2014 (N=33 interventions). In 2024, medical evacuation interventions from remote islands reached a new high (N=513), where Šibenik-Knin County, Zadar County and Split-Dalmatia County had around 25% each, while Dubrovnik-Neretva and Primorje-Gorski Kotar County had around 10% of the cases.

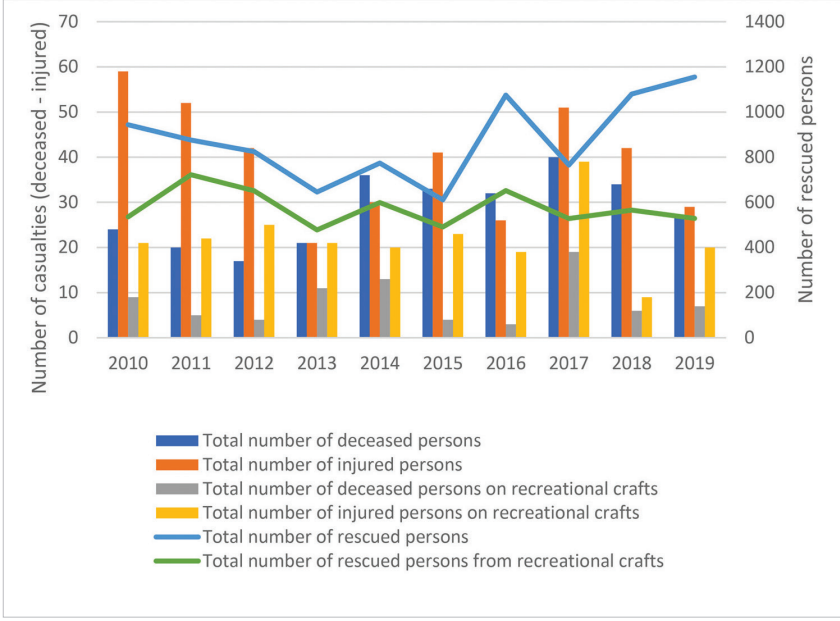

Figure 3 Displays of the total number of decreased, injured, and rescued persons in relation to recreational craft accidents for the period from 2010 to 2019.

Slika 3. Prikaz ukupnog broja smrtno stradalih, ozlijeđenih i spašenih osoba u nesrećama rekreacijskih plovila za razdoblje od 2010. do 2019.

Table 6 The total number of fatalities, injured, and missing persons in all interventions in relation to recreational craft accidents for the period from 2010 to 2019.

Tablica 6. Ukupan broj smrtno stradalih, ozlijeđenih i nestalih osoba u svim intervencijama vezanim uz nesreće rekreacijskih plovila za razdoblje od 2010. do 2019.

	Fatality		Injured		Missing		Fatalities recreationally		Injured recreationally		Missing recreationally		p
	N	%	N	%	N	%	N	%	N	%	N	%	
2010	24	8,45%	59	15,01%	3	12,50%	9	11,11%	21	9,59%	2	18,18%	0,002
2011	20	7,04%	52	13,23%	3	12,50%	5	6,17%	22	10,05%	1	9,09%	
2012	17	5,99%	42	10,69%	4	16,67%	4	4,94%	25	11,42%	2	18,18%	
2013	21	7,39%	21	5,34%	1	4,17%	11	13,58%	21	9,59%	0	0,00%	
2014	36	12,68%	30	7,63%	2	8,33%	13	16,05%	20	9,13%	1	9,09%	
2015	33	11,62%	41	10,43%	1	4,17%	4	4,94%	23	10,50%	0	0,00%	
2016	32	11,27%	26	6,62%	1	4,17%	3	3,70%	19	8,68%	0	0,00%	
2017	40	14,08%	51	12,98%	6	25,00%	19	23,46%	39	17,81%	3	27,27%	
2018	34	11,97%	42	10,69%	1	4,17%	6	7,41%	9	4,11%	0	0,00%	
2019	27	9,51%	29	7,38%	2	8,33%	7	8,64%	20	9,13%	2	18,18%	
Total	284	100,00%	393	100,00%	24	100,00%	81	100,00%	219	100,00%	11	100,00%	

While medical evacuations from remote islands highlighted critical healthcare challenges in coastal regions, another pressing concern for maritime safety emerged in recreational boating. Analysis of recreational craft accidents revealed distinct temporal patterns, underscoring risks tied to leisure activities along the same coastlines. Recreational craft accidents according to the time of occurrence were analyzed in relation to the day and time of the event, month and year. According to reported accidents by day of the week, a relatively equal distribution is present, with the highest number of recreational craft accident interventions on Sundays (N=392, i.e. 17.13%, CI 95%, 15.6–18.7), and the lowest on Fridays (N=285, i.e. 12.46%; CI 95%, 11.1-13.8). The analysis of data on the time when the accidents occurred, indicates the fact that most collisions, allisions and groundings occurred during the day, i.e., between sunrise and sunset [15]. Between 2010 and 2024, a total of 126 collisions, 53 allisions, and 482 groundings involving recreational crafts were recorded during either day or night. Collisions were more frequent during the day (87 cases) than at night (39), while allisions also occurred predominantly during daylight (41 day vs. 12 night). Similarly, groundings showed a nearly balanced distribution, with 247 accidents by day and 235 by night, indicating that groundings happen consistently regardless of lighting conditions. Notably, groundings consistently represented the highest number of accidents each year. Peaks in night groundings were observed in 2011 (23 cases) and 2014 (35 cases), while daytime groundings peaked in 2012 (34 cases) and 2016 (29 cases). The overall trend suggests that while most collisions and allisions occur during the day, groundings are a significant risk at any time, emphasizing the need for better navigational safety measures both during the day and at night.

Whereas navigational safety measures appear critical across all times of day, the spatial distribution of accidents reveals no significant geographical patterns. The Pearson Chi-square *p*-values were calculated for all locations (counties) and the values range from 0.23 to 0.31, all above the 0.05 significance level, indicating no statistically significant association between accident types and geographical areas. The statistically insignificant values suggest that recreational craft accidents are similarly distributed across the locations studied. However, low expected counts in many cells may limit the reliability of these results, and further analysis with larger data or combined categories could provide clearer insights.

Although the distribution of accidents shows no strong geographical patterns, the way these incidents are reported reveals important trends in emergency communication. Analyzing the method of reporting, i.e. calls for help, 85.5% (N=1.957 calls) were made via mobile phone and fixed telephone lines, followed by 10.4% of calls (N=237) made via GMDSS ("Global Maritime Distress and Safety System"). Only 0.8% (N=20 reports) belong to other reporting methods, and 3.2% (N=74 reports) were not recorded either in the written archive or in digital records. In 2010 and 2011, data on the statistics of calls for help were kept only under the categories "GMDSS" and "Mobile phone/Telephone". The report of an accident of a small recreational craft is most often sent via the GMDSS system if it is done by another vessel that is nearby and equipped with such a system.

4. DISCUSSION / *Rasprava*

The results of a research analysis of maritime accident files show that majority of the interventions fall under recreational craft accidents. With this research, the analysis of recreational craft accidents includes an overview of:

- Distribution of accidents by geographical area about the type of accident and type of craft,
- Distribution of accidents by month and day of the week, i.e., time of event,
- The number of rescued persons in relation to the number of victims on recreational crafts,
- Ways to report or call for help.

The largest number of recreational craft accidents falls under the category "Unable to maneuver", followed by "Grounding". This applies to the period from 01/1998 to 12/2019 if previous researches are compared [3]. In 2023 and 2024, this trend started to change slightly by making these categories almost the same. It can be seen that the leading county in terms of the number of accidents is Split-Dalmatia County, followed by Primorje-Gorski Kotar County. The first three counties with the highest number of accidents have almost an equal percentage of accidents throughout the observed period (around 20%). In terms of geographical location of the accidents, once available, allocation of additional search and rescue crafts should be considered within the counties with the highest number of reported recreational craft accidents to facilitate numerous interventions, as these counties also count most numerous medical interventions which have been significantly increasing within the last couple of years of the observed period.

The largest number of recreational crafts involved in an accident belongs to the "Boat" category, followed by "Sailing vessel". These categories are responsible for most ''Groundings" and ''Unable to maneuver" accidents. The biggest number of injured persons (41.55%; CI 95%, 35.0 – 48.1) and fatalities (48.15%; CI 95%, 37.3 – 59.0) are related to ''Boats". Therefore, since most recreational crafts have a length of 12-15 m, it is obvious that in the mentioned categories (''Boat" and ''Sailing vessel"), it is necessary to investigate the reasons why such accidents mostly occur. Initial boat skipper license issued in Croatia (Category A) does not involve any formal requirement to attend the course. Practical training followed by exam conducted on a boat is also not required for such a license [16]. Some studies show that most of the accidents are caused by human error in the Mediterranean Sea, but a lack of data makes it difficult to determine the primary causes in the Adriatic Sea. Knowing the primary causes of accidents would contribute to accident probability calculations. As a basis for recommending future research, it is also worth noting the large number of accidents that fall under the category of recreational means ''Other" (jet-ski, seabob, boards, pedal boats, inflatable mattresses, etc.). Since the types of recreational crafts are quite different, it is necessary to make individual recommendations concerning the type of craft and attention should be paid to the education and practice of recreational craft users, which is already being implemented in some countries [17]. The need to introduce additional information programs on the safety of users (especially within the category ''Other") of recreational crafts/means should be investigated and introduced to boaters, which would certainly have a positive impact on safety.

To further enhance safety measures, particularly within the category ''Other", targeted educational programs could help mitigate common risks, such as those observed in marinas. For instance, the most numerous accidents in marinas are ''Allisions"

which accounted for a median of 41 incidents over a five-year period (2011–2016) [7]. While no fatalities were reported, these collisions highlight the need for continued vigilance. Encouragingly, the rise in marina employment in Croatia, especially seasonal jobs, suggests growing activity, making proactive safety education even more critical.

Comparing this analysis with a similar ecosystem, such as the United States for instance, major differences are obvious. US reports are much more organized with lots of data. 77% of deaths occurred on boats where the operator did not receive boating safety instruction. Alcohol use is the leading known contributing factor in fatal boating accidents. Eight out of every ten boaters who drowned were using crafts less than 6,5 m in length. Operator inattention and inexperience, improper lookout, excessive speed, and machinery failure rank as the top five primary contributing factors in accidents [18].

While these contributing factors significantly increase drowning risks, the consequences are exacerbated when search and rescue efforts face logistical and operational hurdles, particularly in vast or hard-to-reach areas. One common scenario is an emergency call for help from private concession beaches and campsites that span over a large area when a search and rescue vessel cannot approach due to a psychological swimming barrier in place and often cannot be successful in a rescue. At the same time, the marine rescue unit could be more useful in another location, therefore, it is recommended to introduce mandatory organized rescue services within such areas. Therefore, a seasonal increase in search and rescue service personnel is also recommended (June-September), as it would increase efficiency both in the field and in the Rescue Coordination Center.

It has been brought to attention that among the search and rescue reports, there is no data on the potential alcoholic state of the users of recreational crafts. To collect a larger amount of more accurate data on accidents, further research is recommended in the context of adapting the marine accident database maintained at the MRCC, as well as a detailed expansion of the official marine accident reporting form. The information that needs to be expanded in the form refers to a more detailed description of the circumstances of the accident (including an assessment of the damage and the primary cause and type of the accident, geographical position and method of reporting), extended specifications of the craft that participated in the accident with detailed information of the persons on board (and activities on the craft at the time of the accident - recreation, fishing, water skiing, towing, sailing, anchoring...), data on weather conditions during the accident, and potential contributing factors (alcohol, drugs, excessive speed, insufficient observation, inexperience, sudden turn, overloaded craft, night navigation without navigation lights, sudden medical condition...), data on possible failure of equipment, data on persons (and specific injuries) who require further medical care in addition to the provided first aid, i.e. data on deceased and missing persons with a description of specific circumstances, data on the skipper's qualification (type of qualification, experience) and safety measures taken (life jacket, safety switch bracelet, helmet...) and potential information about other key persons (witnesses, passengers, owner of damaged property, skipper...). It is recommended to significantly expand the annual reports of MRCC Rijeka, which need to be based on more precise and extended data. Thorough reports that use simple language are recommended by some authors [19]. With the aim of easier data collection for a larger region, it is recommended to standardize reports between national Rescue Coordination Centers.

On the other hand, a valuable source of data are marine accident reports. The lack of reporting of marine accidents has been identified as a factor that significantly affects the general statistical analysis [20]. The lack of data in the accident report in the search and rescue intervention file also has a big impact. It is more logical to fill out the log with the necessary information about accidents at the scene of the event, if possible, and before contamination of evidence occurs. This log would be attached to the archive of an individual intervention or if the accident report was submitted on an official form by the master, i.e., owner of the craft *ex lege,* within the stipulated period, which would subsequently be attached to the archive. To increase the number of real and valid data, as a recommendation, it is necessary to ensure that even smaller recreational crafts/means must report an accident.

5. CONCLUSION / *Zaključak*

The research based on analysis of recreational craft accidents in the Croatian part of the Adriatic Sea covers the period from 01/2010 to 12/2024. Accidents are characterized by a seasonality pattern throughout the observed period, and when recreational accidents are compared to total number of overall accidents, it is clear that more than half of the overall interventions refer to recreational crafts. The largest number of recreational accidents falls under the category "Unable to maneuver", followed closely by "Grounding". Most recreational craft accidents were caused by the category "Boat", followed by "Sailing vessel ". It can be concluded that such a trend is constant from 01/1998 to 12/2024. More than half of the rescued persons on the Adriatic Sea fell under the domain of recreational crafts over ten years. The number of injuries is also mostly reported from recreational crafts. Most of these accidents happened in Split-Dalmatia County. Analyzing the time of occurrence of collisions, allisions and groundings, it is noticed that all these accidents mostly happen during the day when the traffic of recreational crafts is more active. Recommendations are made in terms of the introduction of additional seasonal personnel within the MRCC services, vessels and air forces, more accurate documentation management, introduce standardized MRCC annual reports and additional recreational craft safety education programs, especially in terms of the quality of collected and presented data in the accident reports, which is mainly related to necessary basic information on accident. Due to a large number of accidents on recreational crafts for which a boat leader and sailing skipper license is required, it is recommended to re-examine the theoretical and include additional mandatory practical training for such licenses, especially those issued in Croatia, e.g., navigation training during night or restricted visibility.

Further research is proposed for the specific purpose of expanding the database and reports of marine accidents involving recreational crafts. Based on these more detailed reports, further research is recommended to be made on the specific circumstances and causes of a large number of accidents involving smaller leisure crafts/equipment, such as jet-skis, seabobs, eFoils, boards, pedal boats, etc. Research on this specific group of recreational craft accidents on the Adriatic Sea hasn't been conducted yet. Surveys in this field will certainly contribute

to the improved safety of navigation by introducing new, adapted regulations and training standards in nautical tourism.

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