Challenges of Sustainable Development in Nautical Tourism on Small and Medium-sized Islands

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This paper examines the challenges of sustainable development in nautical tourism on small and medium-sized islands, focusing on environmental limitations and the need for balanced development. It highlights the importance of adapting regulations to local conditions and promoting responsible resource management. The establishment of stricter environmental standards and the inclusion of local communities in planning processes are proposed.

KEYWORDS
~ Sustainable development
~ Nautical tourism
~ Small and medium-sized islands
~ Environmental standards
~ Local communities

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1. INTRODUCTION

When planning any interventions in the coastal and maritime areas of locations suitable for the development of new or the enhancement of existing nautical tourism facilities (NTFs) on islands, it is crucial to consider a wide range of factors that enable such development, as well as the arguments presented by the local island community. Indeed, each small or medium-sized island, with its area and/or number of residents, constitutes a unique ecosystem that can only partially be generalised across island groups (archipelagos), necessitating a separate approach that creators of sustainable development in nautical tourism should bear in mind.

Small and medium-sized islands face unique environmental challenges arising from their limited space, sensitive ecosystems, and increased resource pressure during peak tourist seasons. The primary goal of this paper is to examine the environmental aspects of sustainable development in nautical tourism on small and medium-sized Croatian islands. The study focuses on the impact of environmental constraints on marina capacities and infrastructure within sensitive marine and terrestrial ecosystems. While sustainability encompasses economic and social dimensions, this paper emphasises the environmental component due to its critical role in preserving natural heritage and ensuring the long-term sustainability of island tourist destinations.

These challenges necessitate a careful approach to sustainable development, particularly in the context of nautical tourism. While sustainable development encompasses economic, social, and environmental aspects, this study primarily focuses on the environmental component due to its critical role in preserving the natural heritage and ensuring the long-term sustainability of island tourist destinations.

The study specifically addresses sustainable development in nautical tourism on small and medium-sized Croatian islands, examining how environmental constraints shape capacity adaptation and infrastructure requirements in these fragile marine and terrestrial ecosystems.

The paper is structured as follows: it first discusses the regulatory frameworks and existing environmental standards, then analyses specific environmental challenges in island marinas, including resource pressures, biofouling, and invasive species management. The final sections provide recommendations for enhancing sustainability based on the findings.

The sustainable development of nautical tourism on small and medium-sized islands in Croatia requires adherence to several regulatory frameworks and consideration of various environmental factors. This paper examines the interplay between these regulations and the practicalities of developing nautical tourism facilities (NTFs) on these islands. The regulatory frameworks include the Maritime Code, the Law on Maritime Property and Sea Ports, and several sets of rules and regulations aimed at ensuring safety, order, and environmental protection in maritime activities.

Accordingly, the research in this paper should be viewed only as a fragment that is intended to contribute to a better understanding of all the challenges arising from the theme of sustainable development in nautical tourism on small and medium-sized islands. This research is limited to a general analysis of environmental challenges and marina capacities on Croatian islands and does not include an in-depth study of individual marinas or specific proposals for their restructuring. Such a detailed approach would require a significantly broader scope and extensive research. Instead, this paper provides a foundation for understanding common environmental challenges and offers guidelines for improving sustainability at the system-wide level. The limitations of this research relate to the sample of Adriatic islands and the analysed NTFs on them.

2. REGULATORY FRAMEWORKS

1. Maritime Code (Official Gazette 181/04, 76/07, 146/08, 61/11, 56/13, 26/15, 17/19):

- Establishes the legal framework for maritime activities in Croatia, including the development and operation of nautical tourism ports. This code sets out the rules for maritime safety, vessel registration, and the responsibilities of maritime authorities.

2. Law on Maritime Property and Sea Ports (Official Gazette 83/23):

- Governs the management and use of maritime property and the operation of sea ports, including those dedicated to nautical tourism. This law outlines the responsibilities of port authorities and the rights and obligations of users of maritime property.

3. Rules on the Categorisation of Nautical Tourism Ports and the Classification of other Facilities Providing Mooring Services and Accommodation for Vessels (Official Gazette 120/19):

- Provides guidelines for the categorisation of ports based on their facilities and services, ensuring standardised quality and safety. These rules classify ports into different categories based on the level of services they offer, such as mooring facilities, repair services, and amenities for tourists.

4. Rules on the Conditions and Methods of Maintaining Order in Ports and in other Parts of the Internal Marine Waters and Territorial Sea of the Republic of Croatia (Official Gazette 72/21):

- Establishes procedures for maintaining order in ports and other marine areas to ensure smooth and safe operations. This includes regulations on vessel traffic, docking procedures, and the responsibilities of port operators in maintaining order.

5. Rules on the Safety of Maritime Navigation in the Internal Marine Waters and Territorial Sea of the Republic of Croatia and the Method and Conditions of Supervision and Management of Maritime Traffic (Official Gazette 79/13, 140/14, 57/15):

- Sets out the conditions for safe navigation and the supervision of maritime traffic. These rules ensure that maritime traffic is managed safely and efficiently, with provisions for the monitoring and control of vessel movements.

6. Regulation on Amendments to the Regulation on Environmental Impact Assessment (Official Gazette 61/14, 3/17):

- Requires an environmental impact assessment (EIA) for all marinas, defining conditions for environmental protection. The EIA process evaluates the potential environmental impacts of proposed projects and establishes measures to mitigate adverse effects.

3. SPATIAL AND ECOLOGICAL LIMITATIONS TO THE DEVELOPMENT OF NTFS ON SMALL AND MEDIUM-SIZED ISLANDS

The existing symbiosis between island marinas and the local community is rooted in the islanders' mentality and their collective love for the sea and boats, which, over time, has evolved from romantic and existential needs into recreation and leisure activities. The local island community has welcomed boaters, initially in their small ports and later supported the construction of marinas and the arrival of nautical tourists, finding in them sources of economic benefit.

According to the 2021 population census (DZS, 2023), the Republic of Croatia has 52 inhabited islands with a total of 127,838 residents who annually host 3,079,000 tourists, accounting for 22.3% of the total tourist arrivals in the Republic of Croatia that year. Since the Croatian archipelago makes up only 5.8% of the total land area of the Republic of Croatia, it is evident that it is attractive to tourists with clear trends of increase, which inevitably reflects on the potential carrying capacity of the islands. Therefore, the development of tourism through the increase of NTF capacities should be viewed from the perspective of sustainable island development. Before that, it is important to understand that each island community is unique, with unique geographical features, unique history, culture, and socio-economic status (De Clercq, Proka, Jensen, & Montero Carrero, 2019, str. 5). Thus, any normative act that seeks to impose solutions in the field of sustainable development and the use of clean energy should be viewed as a framework to which the island community can adapt through its own efforts to participate in sustainable development.

The European Commission has adopted, on the initiative of the group of representatives "new pathways for European islands," which supports islands to become self-sufficient, more prosperous, and sustainable (2nd Smart Islands Forum, 2018).

Table 1 provides a summary of spatial and operational characteristics of selected Croatian island NTFs, essential for evaluating the environmental impact of marina utilisation and potential pressures on local ecosystems. These metrics offer baseline data for assessing the carrying capacity and planning sustainable development in these sensitive locations.

MARINA	Area in m²			Mooring Area m²	Capacity m²/day (m²*365 days)	Utilisation of Water Area m²/day	Berth utilisation m/day
	Territory	Water Area	Total				
Cres	35.052	100.876	135.928	46.313	16.904.175	0,40	0,62
S. Draga	15.228	54.345	69.573	26.030	9.500.951	0,33	0,55
Rab	2.609	14.694	17.303	6.856	1.371.188	0,24	0,13
Šimuni	14.027	21.169	35.196	9.738	3.554.213	0,75	0,74
Žut	12.652	31.038	43.690	14.823	2.964.683	0,14	0,13
Piškera	15.222	21.052	36.274	9.680	1.936.026	0,16	0,10
Jezera	15.628	32.460	48.088	15.417	5.627.377	0,64	0,78
Milna	9.222	24.006	33.228	10.948	4.009.151	0,55	0,61
Vrboska	3.583	14.169	17.752	6.517	2.378.737	0,75	0,60
Palmižana	16.127	28.626	44.753	13.378	2.675.644	0,42	0,20
Korčula	7.705	22.365	30.070	10.256	3.743.399	0,36	0,31
Ukupno	147.055	364.800	511.855	169.956	54.665.544	Sr.vr. 0,43	Sr.vr. 0,43

Table 1. General data on the analysed sample of Croatian island NTFs, 2022. (Source: Processed by the authors based on data collected from a survey questionnaire 2022).

The spatial and capacity data outlined in Table 1 are critical in understanding the environmental limits of each marina, particularly regarding water area utilisation and berth occupancy. By analysing these metrics, the study identifies ecological pressures that result from high occupancy rates and limited space, influencing decisions on sustainable marina management.

As the most important element of all development plans on islands, the acceptable value of the carrying capacity (CC) should be established. The carrying or acceptable capacity (potential), as Dulčić and Petrić point out (Upravljanje razvojem turizma, 2001, str. 330): "represents the maximum number of tourists in a destination (place), which will not cause unacceptable disturbances to the physical, economic, and socio-cultural environment, nor reduce the quality of visitor satisfaction."

The criteria for assessing the carrying capacity of an area are set by the World Tourism Organisation and relate to the following four elements (Črnjar & Črnjar, 2009, str. 43): 1) physical, 2) psychological-perceptual, 3) biological, and 4) sociological capacity.

The carrying capacity of a tourist destination is not an absolute value but is variable according to the effects of destination management. Likewise, the load on one observed element does not simultaneously mean the destination is unacceptable. Magaš (Magaš, 2000, str. 104) proposed the following formula for calculating the carrying capacity:

$$CC = f\,(Ecological, Physical, Economic)\,(Tourists, Development, Policy)$$

CC = tourist carrying capacity is a function of:

- the ecological system (Ecological),
- physical infrastructure and development of tourist facilities (Physical),
- economic characteristics (Economic),
- characteristics of tourists (Tourists),
- acceptability of tourism development to the local population (Development), and
- policy-making decisions (Policy).

From the given formula, it follows that in calculating the carrying capacity - CC, it is necessary to know the characteristics of tourists, their age, gender, economic power, travel motives, expectations, available time, etc., while simultaneously knowing the characteristics of the destination, economic structure, current developmental phase, and characteristics of the population.

4. SAFETY PARAMETERS OF NAUTICAL TOURISM PORTS

The 21st century is marked by a rapid increase in interest in nautical tourism, resulting in the need for the development or modernisation of nautical ports and marinas. The primary purpose of design is to determine the minimum port parameters to ensure the highest level of vessel safety. To determine the parameters of nautical tourism ports, it is necessary to define the maximum dimensions of vessels that can safely navigate within the designed water area. These dimensions relate to the overall length and width of the vessel, draught, and height above water level. When creating (redesigning) the spatial plan of a nautical tourism port, a series of data needs to be collected, which includes the position of breakwaters, berths, ramps, piers, mooring bollards, etc. Every intervention in space must be in accordance with spatial plans and professional rules, with special emphasis on the preservation of the natural environment.

From the perspective of nautical tourists and skippers, the concept of safety in a nautical tourism port is defined as a harbour that can be safely entered, where one can moor to the shore, replenish water, fuel, and provisions, and carry out necessary repairs if needed. The mooring must be protected from the effects of wind, waves, and tidal changes, have sufficient depth below the keel for safe manoeuvring, and be wide enough for the required manoeuvres. The term "sufficient" is not quantified numerically but implies that the vessel is operated by an averagely skilled sailor. The problem related to safety is a consequence of the fact that most nautical tourism ports were designed and built in the 20th century, making them outdated in terms of vessel accommodation capacity. Increasingly longer and wider vessels exceed the designed capacities, necessitating intervention in the safety system of vessels in marinas. Besides safety reasons, there are also economic reasons because the greater length and width of vessels decrease the number of safe berths, ultimately reducing the revenues of NTFs. From an ecological standpoint, larger vessels require more crew members and can accommodate more passengers, which may constitute an additional burden on the environment and thus higher waste management costs. Initially, it is important to highlight the basic features of NTFs.

Nautical tourism ports – hereinafter NTPs - are regulated by the Maritime Code (NN, Pomorski zakonik, 2015/26), the Maritime Domain and Seaports Act (NN, Zakon o pomorskom dobru i morskim lukama, 2016/56), as well as various subordinate legislation regulating the types and categories of ports, minimal requirements for such ports, as well as the categorisation of ports and vessels in nautical tourism. An NTP is primarily intended for berthing and accommodation of vessels of nautical tourism and it is properly equipped to provide services to customers and vessels. Pursuant to the Ordinance on Classification and Categorisation of the Nautical Tourism Ports (NN, Pravilnik o razvrstavanju i kategorizaciji luka nautičkog turizma, 2008/72), an NTP represents a business, construction and functional whole in which a legal or natural entity conducts its business and provides tourist services in nautical tourism, as well as other services serving tourist consumption (commerce, hospitality, etc.).

In NTPs, special attention is paid to safety of navigation, marine environment protection and security of the marina. The Ministry of the Sea, Transport and Infrastructure, via the directly competent Harbourmasters' Office, is authorised to supervise safety of sailing and environmental protection in marinas, being a part of maritime domain and internal waters. Security in most marinas is achieved through video surveillance and an organised mariner security service, and many marinas outsource to private security agencies.

The degree of safety of navigation, marine environment protection and security in a marina is also supported through a system of insurance against potential damage. The functioning of a marina can hardly be imagined without quality insurance of the marina against various risks, primarily liability insurance of the marina concessionnaire towards berth users or third parties (Padovan, 2013).

Marine NTFs, as well as dry marinas, consist of: water areas, port engineering structures, port surfaces, buildings, technical port facilities to ensure the safety of moored vessels, vessel maintenance works, recreational or tourist vessels, and floating equipment. To fulfil its tasks, an NTF must have appropriately designed water basins protected from winds, waves, currents, ice, as well as suitable land areas. All of the above, plus the appropriate equipment, provides professional service for vessels, their crew, and other users of the NTF, as specified by the spatial regulation for nautical tourism ports.

A marina is a yacht harbour that includes residential buildings, such as pavilions or other club and port facilities for hotel accommodation, shops, bars, cafes, and restaurants, and all functions required by temporary or permanent residents.

The fleet of nautical tourism vessels comprises: a) motorboats, sailboats, catamarans, and floating homes.

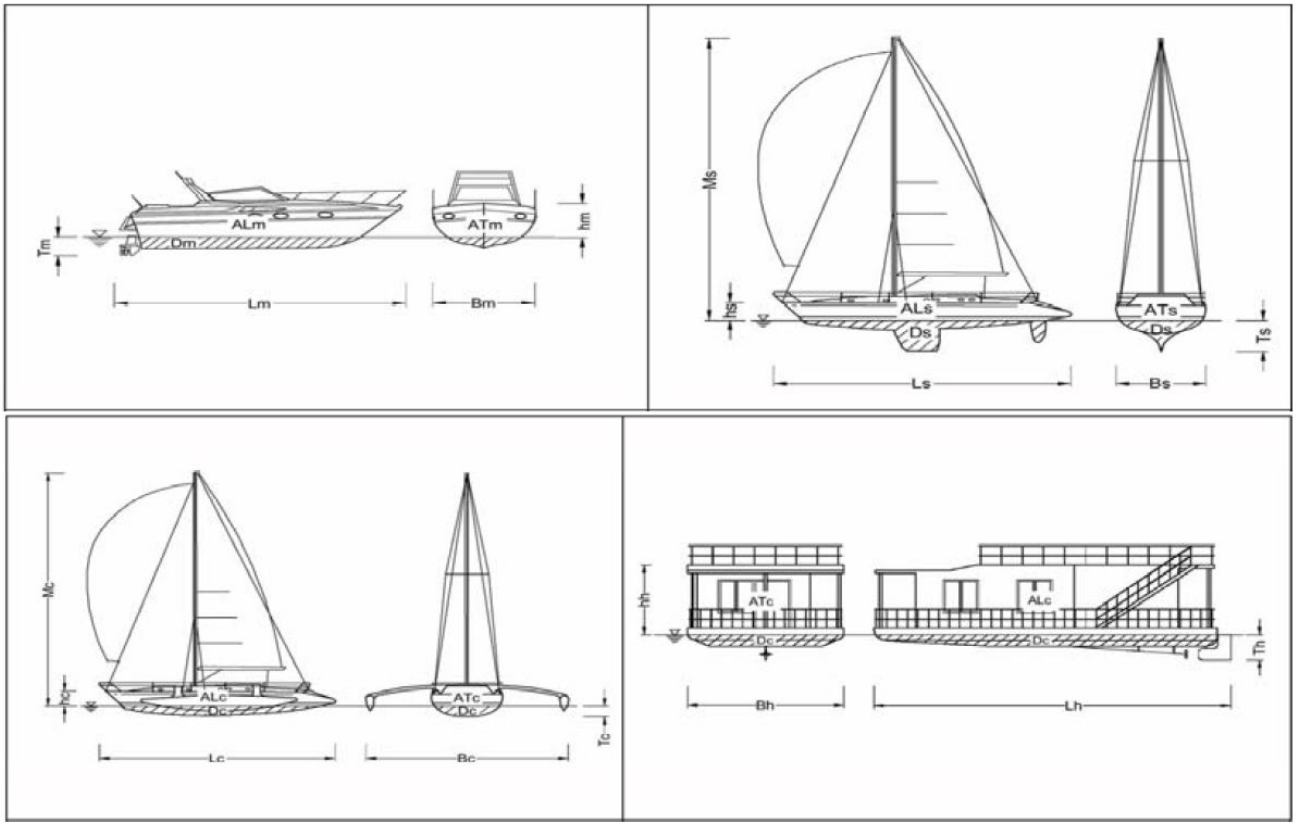

Figure 1. Nautical tourism vessel fleet (Source: Carević i Pršić; Yachts Parameters for Marina Design, 2005, str. 2)

T[m] - draught; h[m] - height above waterline; L[m] - length; B[m] - breadth; D[m³] - displacement; AL[m²] - cross-sectional area; AT[m²] - longitudinal sectional area; m - motor vessel; s - sailing vessel.

4.1. Designing and Sizing NTFs from the Vessel Safety Perspective

The process of designing marina projects is lengthy due to the scope and complexity of the projects. It also involves an iterative process for studying layout alternatives. There are international and national codes and guidelines that need to be considered during the design process to ensure safe navigation and mooring for ships, enable smooth operations, meet market and user expectations, and avoid design errors. (Balku, 2021).

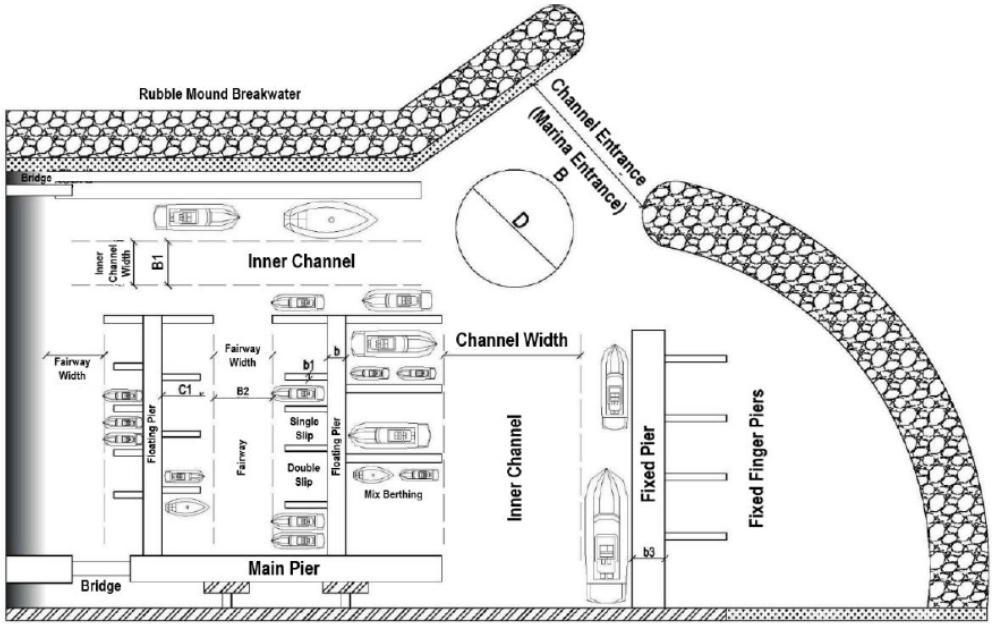

Figure 2. Typical Marina Layout (Source: Balku, C.: BIM-BASED marina design and semi-automated code checking process, 2021).

Nautical tourism ports differ in their method of accommodating vessels as:

1. Mediterranean type (med)
2. Finger piers type (f)

The choice of type depends on the tradition of construction, as well as on the technical and economic aspects of the project. Generally, the "finger" type is a more expensive configuration option because it requires more space but ensures safe manoeuvring and mooring of vessels. On the other hand, the Mediterranean type allows for better utilisation of space and enables the possibility of mooring larger boats longitudinally along the pier. The weakness of this type is the narrowness of the mooring space, which requires greater agility from the skipper.

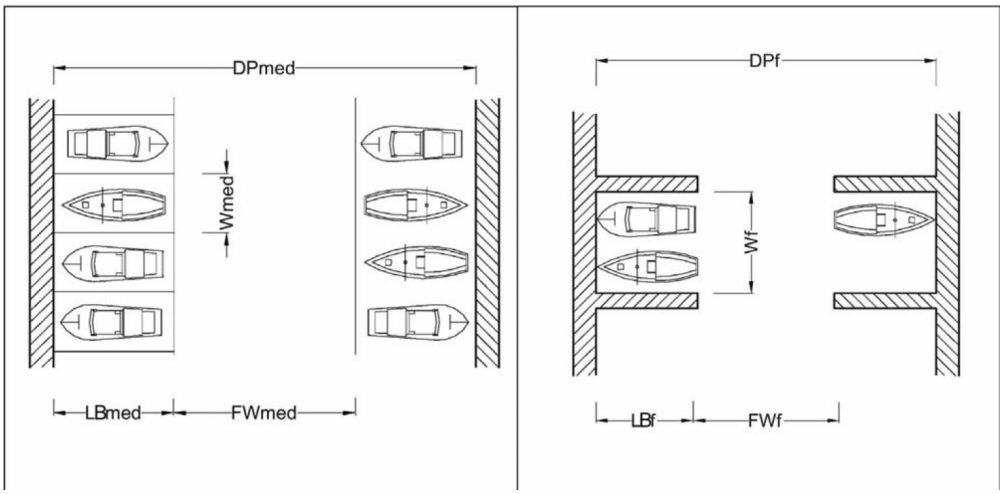

Figure 3. Basic types of NTFs according to mooring method: a) Mediterranean and b) Finger ((Source: Carević i Pršić; Yachts Parameters for Marina Design, 2005 pp. 5)

DP [m] - space between piers; W [m] - berth width; LB [m] - berth length; FW [m] - fairway between berths; d [m] - draught; mid-mediterranean type; f-finger type

An NTF (Nautical Tourism Facility) must ensure appropriate vessel capacity for the defined nautical fleet, secure adequate access from the sea, and enable safe manoeuvring within the marina. The basic elements of a marina include:

Breakwater: The primary function of a breakwater structure is to protect against waves and currents, consisting of devices and structures that effectively block 90% of wave action. There are various types, such as fixed, floating, solid, porous, etc. Generally, different sizes of natural rocks are used for constructing breakwaters. Artificial structures like X-blocks can also be utilised.

Docks (Piers) can be either fixed or floating. The choice depends on functionality and environmental conditions, such as water depth, water fluctuations, and soil conditions.

Finger Piers are a docking structure, typically used in North America. This arrangement facilitates separating vessels, safer mooring, and easier embarkation from the ship. It is preferred in areas that specifically have significant wave and boat action (Tobiasson & Kollmeyer, 1991).

Moorings: Anchors are one of the main structures in the arrangement of Mediterranean moorings. In a Mediterranean mooring, boats are moored side by side with the help of anchors. The stern of the boat is connected to the pier, and the bow of the boat is anchored. The Mediterranean mooring allows a large number of vessels to be moored in marinas, as shown in figure 4.

Adriatic marinas utilise the Mediterranean mooring system.

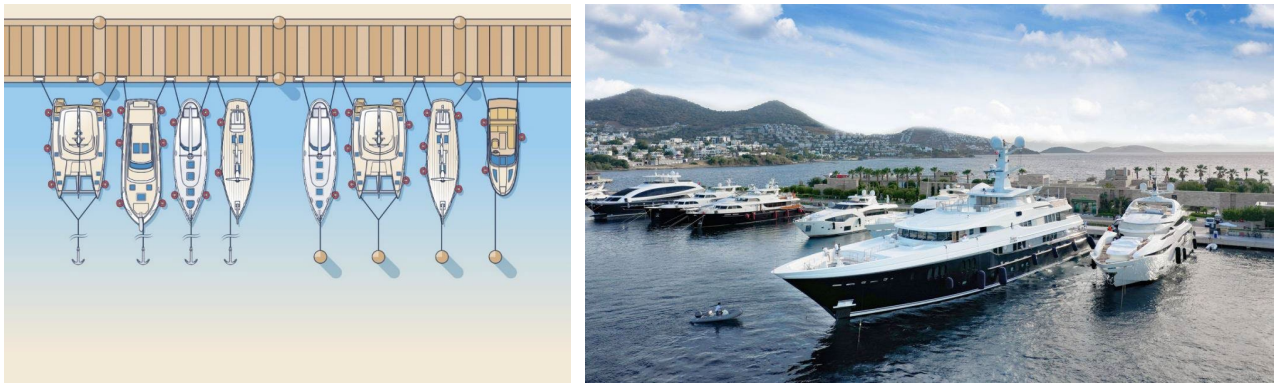

Figure 4. The Mediterranean mooring (Source: Carević i Pršić; Yachts Parameters for Marina Design, 2005 pp 6)

The distribution of elements is unique for each marina due to variations in physical, economic, environmental conditions, and customer demands. Therefore, there are no strict guidelines for marina design, but some guidelines do specify minimum planning requirements for the layout of a marina to ensure safe areas. These guidelines relate to (Balku, 2021): berth width, width of internal channels, width of navigation paths, minimum draught, length of vessels, etc.

These guidelines aim to:

Berth Width: Ensure each vessel has enough space to moor without risking damage to itself or adjacent vessels. This includes room for fenders and ease of access for boarding.

Width of Internal Channels: Provide sufficient space for vessels to navigate within the marina, allowing for safe passage in and out of berths.

Width of Navigation Paths: Ensure that navigation paths leading to and from the marina are wide enough to accommodate the traffic volume and types of vessels using the marina.

Minimum Draught: Guarantee that the water depth is adequate for the keels of the vessels expected to use the marina, preventing grounding at low tide.

Length of Vessels: Accommodate vessels of various lengths with appropriate berth sizes, ensuring that the marina can cater to a wide range of customers.

These planning requirements are designed to create a functional, efficient, and safe marina environment for all users, taking into account the specific site conditions and operational objectives of the marina. Proper planning and design are critical to the success of a marina, impacting everything from the safety and satisfaction of its users to its environmental footprint and economic viability.

4.2. Types and Dimensions of Vessels

In this section, the types and dimensions of vessels are briefly introduced. There are two main classifications of vessels according to propulsion: motorboats and sailboats. The general dimensional characteristics of recreational vessels are given in the following table. Table 2 summarises the typical design parameters of recreational vessels commonly using nautical tourism facilities. These specifications are essential for understanding the spatial and infrastructure requirements in marinas, impacting both environmental planning and sustainable marina management.

length (m)	draught (d) (m)		width (b) (m)	
	Motrorboats	Sailing boats	Motrorboats	Sailing boats
0-5	0.80	1.40	2.20	1.80
5-9	1.00	2.00	3.60	3.00
9-12	1.20	2.40	4.10	3.40
12-15	1.04	2.08	4.80	3.90
15-20	1.66	3.40	5.30	4.40

Table 2. Typical Design Parameters of The Boats (Source: Balku, C.: BIM-BASED marina design and semi-automated code checking process, 2021.)

These vessel dimensions help to estimate marina capacity and manoeuvring space, both of which are critical for minimising environmental impact. Properly designed facilities, based on vessel specifications, reduce the risk of physical damage to marine ecosystems and help in optimising marina layout for sustainable operations.

The lengths of ships are continuously increasing due to the development of shipbuilding. As a result, new terms are emerging, such as mega yachts and superyachts. Vessels ranging in length from 24 m to 36 m are referred to as mega yachts, and ships longer than 36 m fall into the category of superyachts. In designing berths for vessels up to 20 m in length, the formula is: W = Bmax + 0.6 m.

The water area of the marina designated for mooring vessels on a permanent or daily basis - Np, vessels under repair (service) – Nr, and vessels in transit – Nt. According to Mazurkiewiczu (Yacht Ports and Marinas, The designing (in Polish) 2nd ed, 2010) he basic area occupied by one vessel at berth and in manoeuvring amounts to 130 m², which represents a constant for calculating the water area from the perspective of vessel safety. From this follows (Gucma, Drwiega, & Butrymowiz, 2018):

$$Sw=130(N'p+N't+N'r)=130(\tfrac{2}{3}Np+\tfrac{1}{2}Nt+\tfrac{1}{5}Nr)=130(\tfrac{2}{3}Np+\tfrac{1}{6}Np+\tfrac{1}{50}Np), \quad (1)$$

or finally:

$$Sw\cong 111Np \text{ ili } 78\ Cj\ , \quad (2)$$

Where:

Np - number of vessels moored permanently,
Nr – umber of vessels under repairs,
Nt – number of vessels in transit,
Cj – maximum number of berths.

The relationship between Equation 1 and Equation 2 lies in the simplification of the total water area required for marina operations. Equation 1 calculates the necessary area per vessel (130 m²) based on safety considerations for mooring and manoeuvring. Equation 2 provides an approximate value by aggregating these requirements relative to the number of permanent berths (Cj) or moored vessels (Np), streamlining the calculation for practical application.

In determining the total size of the NTF area, the manoeuvring area $Sm.$ is also considered. It can be assumed that the manoeuvring area is approximately equal to the basic area Sw. A wind force of 3 on the Beaufort scale is assumed. The results presented in various ways (diameter or area) and in different units, after being brought to a common denominator, have proved almost identical. For design purposes, a minimum manoeuvring area radius of 1.5 to 2.0 Lc is assumed.

Similarly, the required area of the dry part of the marina and parking lot is calculated.

5. ENVIRONMENTAL PROTECTION PARAMETERS IN NTFS

Any boat entering and using a nautical tourism port is an actual polluter of marine environment. Its presence disrupts the original flora and fauna of the port's waters, even if it does not discharge as much as a drop of oil or sewage,

biodegradable or nondegradable waste, even if it does not use its motors, lights, or any electronic devices (radar, vhf, wi-fi..).

Every boat that enters and uses the nautical tourism port is a part of maritime traffic within the NTP. Therefore, it is subject to the rules and regulations on safety of navigation and manoeuvring in ports, and the concessionary operating the NTP is obliged to secure unrestricted access and safe berth for vessels.

Navigation in restricted areas, docking, anchoring and berthing manoeuvres carry an inherent risk of incidents. Especially so because during the season there are multiple manoeuvres happening at the same time in an NTP, so it is possible that several vessels are simultaneously entering or leaving the marina, observing the Regulations for Preventing Collisions at Sea. However, their frequency often requires the assistance of trained professionals employed by the NTP.

The greater the frequency of manoeuvring within an NTP, the greater the risk of an incident and, consequently, the greater the risk of pollution. The detected problem determines the subject-matter of the research: to explore the types and intensity of risk of an incident within an NTP and related environmental consequences.

The carrying capacity of an NTF is a term that encompasses the safety of vessels in the marina, the impact on the environment, the quality, and the sustainability of nautical tourism. For the purposes of this research, the carrying capacity of an NTF is considered to be the maximum number of vessels that can be in the marina at the same time without jeopardising the safety of other vessels and crews moored or manoeuvring, and without affecting environmental pollution.

All marinas must prepare an environmental impact assessment (EIA) to define conditions for environmental protection. This includes the evaluation of potential impacts on the marine environment and the implementation of measures to mitigate these impacts. Key aspects of environmental protection in NTFs include waste management, pollution control, and the preservation of marine biodiversity.

5.1. Pollution Risks in an NTP

Preservation of the environment with rational utilisation of natural resources represents one of the most relevant issues in further technological and economic growth of any country. Construction of NTPs and accompanying infrastructure lacking in control and vision often leads to total loss and depreciation of the aesthetic value of the landscape (Bukša, Jugović, Schiozzi, & Oblak, 2019).

SOURCES OF POLLUTION IN AN NTP	MEASURES FOR PREVENTING POLLUTION OF THE MARINE ECOSYSTEM IN AN NTP
• waste water originated during the washing of vessels; • paint used to paint vessels; • waste waters originated in the washing of the engine during repairs and waste waters from washing underwater surfaces; • oily rainwater from asphalt – covered handling zones, zones for vessel and vehicle storage and internal roads; • sewage and ballast water; • mineral oils from vessels; • polyester resin particles originating from works on plastic parts of the vessel; • biocides contained in anti – fouling paints, during the vessel's stay in the marina.	• sustainable use and management of marine resources; • increase of berthing capacities through restoration, reconstruction and revitalisation of existing nautical tourism ports to enable berthing of large yachts; • setting up a system for surveillance and management of navigation; • control and equipping of boats and yachts and nautical tourism ports with devices and equipment for protection of the sea from pollution; • application of new ecological standards.

Table 3. Nautical tourism impact on marine environment (Source: Author's processing according to Dogan & Mršić, 2013.)

As a rule, nautical tourism is not a great polluter if the infrastructure has been done according to appropriate technical standards (Dogan & Mršić, 2013). The solution lies in avoiding high concentrations of nautical tourism ports in the

coastal zone because the pollution of the sea is harder to control. It should be noted that in the construction of marinas, caution is required in the use of coastal space. Thus, in ecologically sensitive and extremely valuable zones commercial construction should be limited.

Therefore, coastal zones should be managed applying the principles of environmental ecology, as the cornerstone of the environment as a whole. This means that we must establish development priorities where marine environment protection comes first, while the development of nautical tourism ports and marinas must be in line with fundamental ecological criteria (Dogan & Mršić, 2013).

There are several approaches to resolving the environmental protection problem, from education to prevention and the like. As a rule, these approaches are effective, but practice shows they are insufficient. Namely, nautical tourists nowadays are not exclusively ecologically aware sea and environment enthusiasts. Any pollution poses a significant cost before the management of an NTP which will have an impact on business results. Therefore, the author will attempt to analyse the notion and approach to environmental costs as an additional contribution to environment preservation.

Environmental costs (eco costs) are conditional upon the nature of a business activity, the approach in creating the range of services, the selection of the technological process, and the equipment used to achieve the goal of sustainable development, taking into account the systemic reduction of negative impact on the environment, which has to be balanced with the goal of a profitable business (Peršić, 2005).

Using very strict design requirements for newbuilds without corresponding operational requirements for all ships could severely disadvantage new ships, as they are forced to use a much more expensive fuel. This could again lead to older and less efficient ships being kept in operation longer (Sopta, Bukša, Bukša, & Peronja, 2020).

5.2. Ecological Risks from Stationary Vessels in NTFs

The ecological risks from stationary vessels in marinas are related to the issues of antifouling coatings on the underwater part of the vessel.

The International Maritime Organisation (IMO) uses the term "anti-fouling system," which is defined as "a coating, paint, surface treatment, surface, or device that is used on a ship to control or prevent attachment of unwanted organisms." (OECD Environmental Health and Safety Publications, 2005)

The most commonly used protection method to prevent marine biological fouling on ships is antifouling paint. Biofouling has been recognised as a problem for over 2,000 years, and initially, lime and later arsenic were used to protect against fouling. Since the use of the first simple antifouling coatings, many types of antifouling methods have been explored. The early Phoenicians were the first to use lead and copper sheets to prevent biofouling on their wooden ships. By the late 18th and into the 19th century, coatings containing copper, arsenic, and mercury were applied to protect the underwater hull of the ship. Since the late 20th century, organotin compounds and their derivatives have been widely used as antifouling coatings due to their effectiveness (Ivče, Paparić, Zekić, & Škapul, 2020). Figure 7 provides a general overview of the types of anti-fouling systems that can be applied to protect the hull of a vessel.

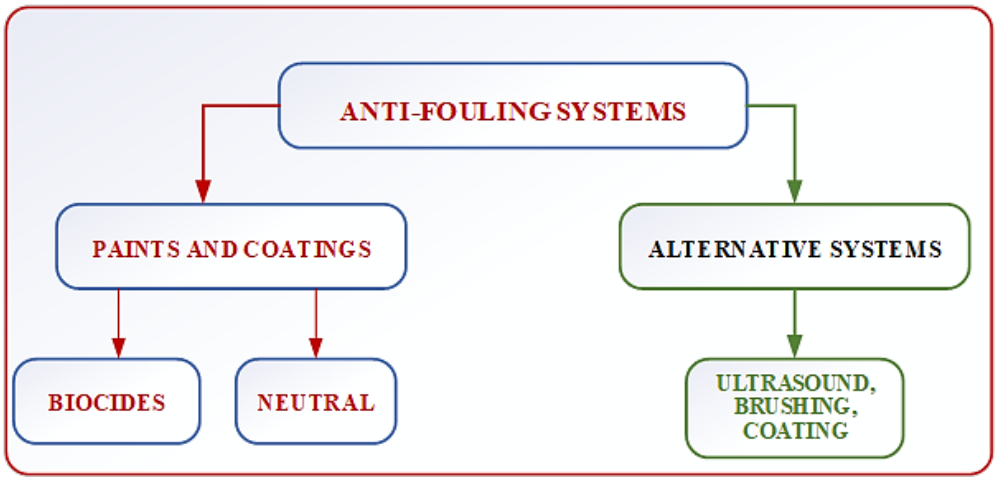

Figure 5. General Overview of Anti-Fouling Systems for Ship Hulls (Sourcer: Ivče, Paparić, Zekić, & Škapul, 2020)

This overview demonstrates that various alternative anti-fouling systems are available for leisure ships, some of which are expected to be safer than biocidal self-polishing paints. These include:

- Various types of hard release coatings
- Coatings that release foul substances
- Liquid surface technology
- Ultrasonic systems
- Other alternative anti-fouling systems.

Hard coatings are generally made of epoxy, polyester, vinyl ester, or ceramic-epoxy compounds, sometimes reinforced with glass flake. Generally, these coatings are intended for use in conjunction with routine cleaning, using high-pressure washing in dry dock or underwater cleaning while the ship is still afloat.

Routine and timely cleaning minimises fouling, and the hull performs optimally. These coatings are advertised as "extremely hard" and should have a much longer lifespan than conventional silicone coatings - possibly up to ten years.

Anti-fouling coatings do not contain biocides. They have a smooth surface that does not dissolve in water. The characteristic of this coating is that organisms simply fall off when the boat moves through the water at an appropriate speed and cannot adhere or are easily removed when the boat is lifted out of the water. Most foul-release coatings are based on silicone elastomer, fluoropolymers, or a combination of the two. Silicone coatings have an ultra-smooth surface that is slippery and hydrophobic (Karlsson, Ytreberg, & Eklund, 2010).

Liquid surface technology is the basis for a newly developed coating, based on nano-/micro-structured porous material imbued with a lubricating fluid. This creates a thin, slippery layer. Ultrasonic waves can be used for fouling control. A small transmitter is placed on the inside of the ship's hull and emits ultrasonic waves (≈23 kHz). These waves continuously pass through the hull and act as a soundboard, causing microscopic vibrations.

Other promising alternative anti-fouling systems are still being researched and developed, such as UV light and natural, easily degradable biocides that remain within the coating. Anti-fouling action occurs due to UV radiation and causes DNA damage to marine organisms, thereby preventing the continuation of biofilm growth on the hull of the vessel.

Ecosystems of enclosed and shallow seas are most exposed to pollution from antifouling paints. Toxic elements enter the water column and remain there for some time. Tides, wind, and local currents remove them from the water column and deposit them on the bottom. The problem significantly increases with the development of nautical tourism, which is one of the most profitable selective forms of tourist offerings and for which, considering the market, an increase in vessel mooring can be expected. Therefore, the importance of preventive measures should be emphasised, even in the case of smaller NTFs.

5.3. Environmental Risks Caused by Secondary Activities

The greatest potential risk of pollution in NTFs, which falls within the regular activities of NTF operations, comes from the domain of vessel maintenance and servicing within the ports. Therefore, a visual inspection was conducted in these ports, and the existing condition was evaluated.

Table 4 provides an evaluation of service facilities in various island marinas, based on visual inspections and interactions with marina managers. This evaluation helps assess the readiness of these facilities to meet modern nautical tourism demands, while also highlighting potential areas for environmental risk, particularly in facilities where maintenance work can pose pollution risks.

ACI MARINA	ANNUAL MOORING	SERVICE FACILITIES	RATING
Cres	333	crane, self-propelled crane, technical vessel service	10
Supetarska Draga	218	9t crane, slipway, technical vessel service	5
Rab	34	crane, slipway, technical vessel service	5
Šimuni	173	crane, slipway, technical vessel service	5
Žut	0	mooring 15 buoys	0
Piškera	4	-	0
Jezera	201	crane, technical vessel service	6
Milna	98	crane, technical vessel service	6
Vrboska	83	Crane	6
Palmižana	21	-	0
Korčula	49	crane, technical vessel service	7

Table 4. Evaluation of the condition of existing service facilities by marina (Source: author's processing)

The ratings presented in Table 4 are derived from visual inspections and discussions with marina managers, offering a practical yet qualitative assessment of service facility conditions. While subjective to some extent, these evaluations highlight key facilities, where maintenance activities have a heightened potential for pollution. This allows for targeted recommendations to improve environmental management practices in marinas with lower service scores.

The evaluations presented in Table 4 are derived from visual inspections and contacts with marina managers. The range of scores is from 0 to a maximum of 10. It is evident that only one NTF can fully meet the needs of contemporary boaters. Four other marinas (scores 6 and 7) are satisfactory for less demanding boaters, while the service offerings in the remaining marinas are modest or negligible. All of the mentioned NTFs comply with existing regulations on the protection of nature and the marine environment.

However, the mere presence of leisure boats, whether they are moored annually or entering the NTF in transit, just passing near islands, or using anchorages, represents a source of pollution. The rich biodiversity of marine life is one of many reasons why boaters come and value sailing and spending time in these areas. As recreational vessels move between areas, various marine lives accumulate as biofouling on the hull, in water intake niches, on anchors and chains, in bilge water, or on equipment, and even on the clothing of boaters. (IMO, 2022). While the transfer of numerous invasive species across oceans is likely facilitated by large commercial ships through biofouling or in ballast waters, biological fouling on smaller, recreational vessels poses a risk for spreading invasive species. In some areas, marinas have been shown to host a larger number of invasive aquatic species than commercial ports. This can be explained by the longer periods of inactivity of recreational vessels in a marina or port compared to a commercial ship. For sailboats and slower motorboats, the slower speed of travel through the water is another factor that creates more opportunities for non-native species to remain attached to the hull and successfully settle in order to colonise new areas with similar climatic conditions.

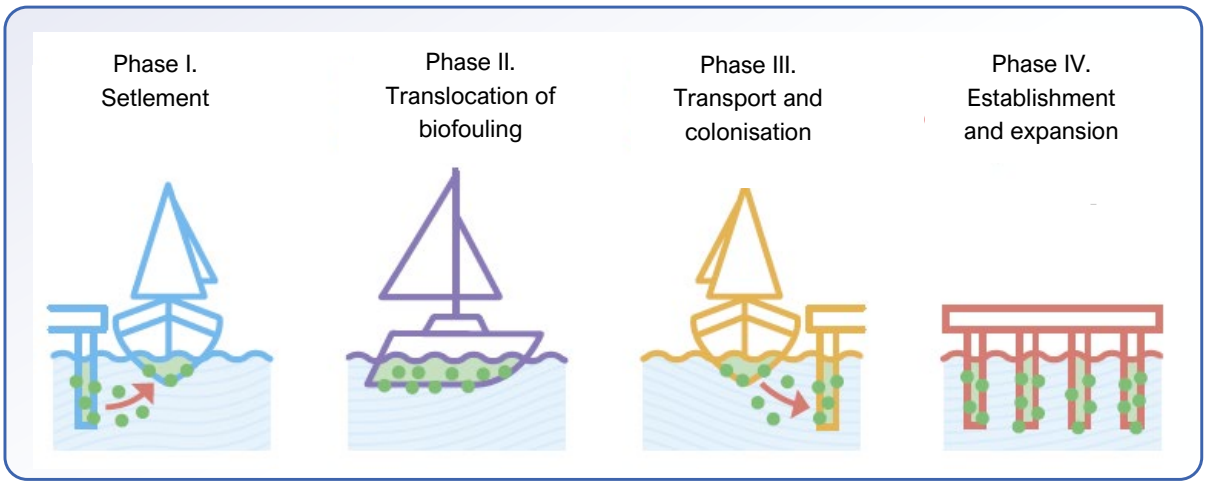

Figure 6. Ports and Marinas as "Hot Spots" for Invasive Species (Source: IMO 2002)

The great diversity of foreign invasive species can make their identification challenging, especially for non-experts. However, recreational boaters can and should play a crucial role in preventing the spread and transmission of invasive species through regular and proactive steps to prevent biofouling on and in their vessels and equipment. This underscores the importance of awareness and involvement in environmental protection efforts.

6. CONCLUSION

This research highlights the issues related to Nautical Tourism Facilities (NTFs) on islands, which are tied to the specificities of island destinations. Most medium-sized islands are, in a tourism sense, marginal islands with a solid tourism perspective but inadequate infrastructure. Small islands, where up to 100 inhabitants reside permanently, are tourism-wise inferior, attractive only for Robinson Crusoe-style tourism but without tourist infrastructure, weak connections to the mainland, and an uncertain tourism perspective. Existing marinas are located on inhabited islands (1,000 or more inhabitants) that have good connections to the mainland and developed tourist infrastructure. However, despite their tourist attractiveness and investor interest, there is not much room for expanding the capacities of existing or building new marinas on the islands. Supporting this assertion are arguments that the carrying capacity of island destinations during the tourist season has already reached its maximum, and all environmental protection parameters indicate that further increase in nautical traffic is unacceptable without more rigorous measures for the protection of the marine environment.

The development of nautical tourism on Croatian islands must be guided by a comprehensive regulatory framework and a strong commitment to environmental sustainability. By adhering to the relevant laws and regulations and implementing effective environmental protection measures, it is possible to achieve a balance between economic growth and the preservation of the unique natural and cultural heritage of these islands. The engagement of local communities in the planning process is also crucial to ensure that development meets their needs and respects their way of life.

By focusing on these aspects, Croatia can continue to be a leading destination for nautical tourism, while safeguarding its precious marine and coastal environments for future generations.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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