



## Impacts of recreational boating on the marine environment of Cap de Creus (Mediterranean Sea)

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### ABSTRACT

A study was set up in summer 2004 in the marine reserve of Cape Creus (Mediterranean Sea) to estimate the environmental impacts of this activity. The large numbers of recreational boats (most of which are motor powered) that can be found affect the marine environment. In particular, results show that *Posidonia oceanica* meadows, which constitute an ecologically and vulnerable habitat, are suffering from mechanical damage caused by anchors. Anchoring was the largest threat on the marine environment of the area; the activities conducted by boaters such as sunbathing, swimming, snorkelling and scuba diving had little or negligible environmental impact. Overall, our results indicate that a primary element for coastal management in busy boating areas must be the anchoring of recreational boats and the specific impacts associated with motor craft, such as speed and the discharge of bilge waters.

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### 1. Introduction

Coastal and marine environments are increasingly important in the provision of opportunities for leisure, contemplation and physical activity [17]. In the context of conservation and sustainable development of the coastal zone, tourism and recreation are key factors and thus marine tourism has surfaced as a pressing topic in the field of ocean and coastal management [10,25]. Recreational boating has become a popular marine activity in most of the developed coastal countries. The rapid growth in recreational boat numbers has brought a high demand for moorings and launching sites and is causing stresses to the marine environment including pollution [23], increased turbidity [2] and physical damage to the bottoms from anchoring [6,9,25].

Even though shallow water ecosystems in the Mediterranean Sea, especially in marine protected areas (MPAs), are stressed because of the mechanical action of chains and anchors, dumping of trash and hydrocarbon spills from recreational boats [24], most of the research dealing with the impact of human recreational activities in MPAs has been conducted in tropical and in non-Mediterranean temperate seas [16]. The scarcity of data on human impacts in Mediterranean MPAs makes necessary the development of new investigations on the effects of visitor frequentation that

help to designate specific plans for managing tourism use in each MPA. Actually, there is a growing need for Mediterranean MPA managers to receive detailed information from research to plan conservation strategies [1]. Because marine protected areas exist both to maintain ecological integrity and facilitate recreational activity, a better understanding of the relationship between park boaters and these habitats are critical to fulfilling these goals.

In particular, the increasing number of recreational boats is raising the incidence of anchoring and consequent risk of damage in sensitive Mediterranean seagrass communities such as *Posidonia oceanica* beds [3,5–7,19]. *P. oceanica* is a long-lived, slow-growing species endemic to the Mediterranean and constitutes the most widespread seagrass in this sea, playing an important role in sediment stabilization, primary productivity and providing physical habitat for fish and invertebrates [15]. Nowadays, *P. oceanica* meadows are experiencing a widespread decline throughout the Mediterranean Sea [4,14,21].

The purpose of this study is to provide baseline data on recreational boating in the marine reserve of Cap de Creus (north-western Mediterranean) in order to estimate the environmental impacts of this activity and to contribute to anchoring management in that area. Firstly, an evaluation of boat numbers and distribution in Cap de Creus is done, and the factors affecting the frequentation are studied. Secondly, an assessment of the craft type and the bottom type where anchor is deployed is conducted. Thirdly, a user profile is devised and some aspects of boater habits regarding sea-outings are evaluated. Finally, to respond to the management needs

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of the MPA of Cap de Creus, this paper discusses the environmental management issues raised by increasing numbers of boats and proposes some basic management measures.

## 2. Methodology

### 2.1. Boat numbers and characteristics

The study sites were located within the Natural Park of Cap de Creus (north-western Mediterranean), which encompasses 3056 ha of sea around the peninsula of Cap de Creus. This Natural Park is divided into different zones with different levels of protection: three partial reserves, an integral reserve and a park zone (Fig. 1). Shallow bottoms of the Park are mostly rocky even though in many creeks the existence of sandy bottoms allows the development of *P. oceanica* meadows. Trawling and purse-seining are not allowed in any zone of the Park whilst artisanal and recreational fisheries are allowed in the park zone and the partial reserves with the exception of spear fishing, which is not allowed in the partial reserves. In the integral reserve, only scientific research is permitted. With ca. 8500 boats distributed in five neighbouring harbours, recreational boating is a popular activity in the waters of Cape Creus. During the summer, many pleasure boats sail to the waters of Cape Creus from these nearby ports. At present, anchoring is possible in the whole Park with the exception of the integral reserve. In some few creeks there is a number of mooring buoys deployed by the municipalities of the Park.

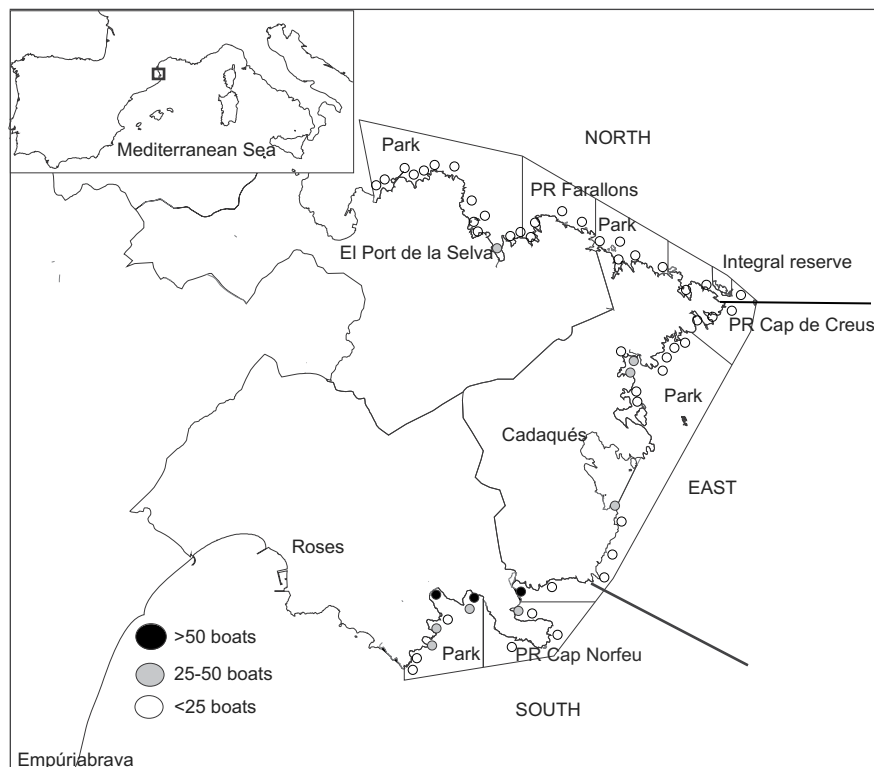
The coast of Cape Creus (less than 1 mile from the shoreline), was divided into 56 sites (creeks or coastal sections) that comprised of three sectors (north, east and south) and four zones (partial reserves of Farallons, Cap de Creus, Cap Norfeu, and a park zone; Fig. 1). The integral reserve was not surveyed since mooring and navigation are prohibited there. In the sites, surveys were

conducted in 2004 during 23 days comprising Fridays, Saturdays and Sundays of July and August, between 11:00 AM and 3:00 PM (i.e. the busiest boating hours, days and months). Surveys involved two vessels and 4 observers and were conducted in sunny days. Overall, two to 14 counts were carried out at each site according to the area of the site (measured in ha). Furthermore, wind speeds at 1:00 PM (average value for the northern coast of Catalonia) were gathered from the Catalan Meteorological Office. With all these information, we evaluated the effect of site's area (ha), zone (partial reserves or park), sector (north, east, south), day (Friday, Saturday or Sunday), month (July or August), and wind speed on the number of boats counted at each site.

Apart from counting the number of boats, craft was classified in one of the following categories of craft: runabouts (includes day-cruisers, day-boats, walkarounds and consoles; ca. 3–7 m in length), inflatable boats (ca. 3–7 m), yachts (ca. 8–12 m), traditional Mediterranean motorboats (ca. 2–6 m), sailboats (ca. 6–12 m), jet-skis (<2 m) and kayaks (<2 m). Runabouts, inflatable boats, yachts, traditional Mediterranean boats and jet-skis are motor powered whilst sailboats and kayaks are non-motor powered. Motor craft, with the exception of traditional Mediterranean boats, can be classified as high-speed craft whilst these traditional boats, together with sailboats and kayaks, can be classified as slow-speed craft. Overall, we classified 1946 crafts.

### 2.2. Bottom type where anchors were deployed

Underwater surveys (free diving or using a bottom glass apparatus) were conducted in each site below 875 anchored boats selected by random in order to record the bottom type where the anchor was deployed. Jet-skis and kayaks were not considered here since they did not anchor. Four bottom categories were used: high cover or dense *P. oceanica* beds (when meadows were compact, i.e.



**Fig. 1.** Map of the MPA of Cap de Creus showing the 56 coastal sites where boats were surveyed in summer 2004. The maximum number of recreational boats counted at each site during the surveys is displayed according to three intervals: less than 25 boats, between 25 and 50 boats and more than 50 boats. The sectors (north, east and south) and zones (park and partial reserves of Farallons, Cap de Creus and Cap Norfeu) in which the MPA is divided are also indicated.

without patches), sparse *P. oceanica* beds (when meadows were patchy), rocky substrate (with or without algae) and soft (sandy or muddy) bottoms.

### 2.3. Boater's habits and profile

In addition, in order to gather data on boater's habits (in order to estimate indirect environmental impacts related to these habits), we evaluated during the surveys the purpose of sea-outings by observing the behaviour (activity at sea) of 7991 boaters. The term "boaters" includes here all people on board and also those observed at sea at the vicinity of the boat. The following activities were considered: sunbathing/swimming, recreational fishing, scuba diving and snorkelling. Furthermore, 107 boaters were interviewed in the southern sector of the Park, which is the most frequented one. Questions were made to ascertain boater profile regarding the number of outings per month and year, the base port and their nationality, as well as to determine whether they know the bottom type where they deployed the anchor.

### 2.4. Statistical analyses

Analysis of covariance (ANCOVA) models were used to compare the number of boats at each site among days, months, zones and sectors (categorical factors) and to assess whether the area of the site and the wind speed (covariates) accounted for the change in the number of boats. We could not include all independent factors in a single multiple ANCOVA model because we had no data from all sectors and zones in all days and months. Thus, we conducted first an analysis of covariance taking into account the day, the month, the wind speed and the site's area and second we conducted additional ANCOVAs to test the differences between Park zones and sectors (data were limited to Saturdays and Sundays in a given month in order to keep them balanced). The assumptions of normality and homogeneity of variances were tested with the Kolmogorov–Smirnov and the Cochran's tests, respectively. If these assumptions were not met, data were log-transformed. We furthermore tested the homogeneity of regressions (or slopes) among groups with the test of parallelism and Fisher's post-hoc (LSD) test was used for comparisons of significant effects after ANCOVA. A *p*-value of 0.05 or less was considered statistically significant.

### 3. Boat numbers

The number of boats counted in a given day is highly variable among sites. Thus for example, in Montjoi, which is one of the largest creeks (20 ha), boat numbers can range between 9 and 90 whilst in Prona, which is one of the smallest creeks (1.5 ha), the number of boats fluctuates between 1 and 11. Consequently, the number of boats per hectare can vary largely too, from less than one to a maximum of 20. The maximum number of boats counted at

**Table 1**

Summary of results from analysis of covariance (ANCOVA) and post-hoc Fisher LSD test evaluating the effect of day (Friday, Saturday, Sunday), month (July, August), area of the site (ha), and wind speed (m/s) on the number of boats counted at each site

Effect (groups)	df	F	p	LSD
Intercept	1	33.720	<0.001	
Area of the site (ha)	1	140.629	<0.001	
Wind speed (m/s)	1	27.160	<0.001	
Month	1	13.082	<0.001	August > July
Day	2	5.629	0.004	Saturday = Sunday > Friday
Month × day	2	1.227	0.295	
Error term	239			

each site in summer 2004 is shown in Fig. 1 as a measure of the total boat capacity of each site. If these maximum values are summed up, this would give an estimation of ca. 800 recreational boats in the whole MPA in the busiest summer day.

The number of boats is significantly higher in the weekends (Saturdays and Sundays) than in Fridays, and increase from July to August (Table 1). Furthermore, the number of boats at each site is positively correlated with the area of the site and negatively with the wind speed (Table 1). The model including all these factors (day, month, area and wind speed) explains 49% of the variability of the number of boats by site.

In contrast to this, the analyses of covariance revealed that the differences in the number of boats neither between zones nor between sectors are not statistically significant (*p* > 0.05) once the other effects (i.e. site's area, wind speed, day and month) are considered.

### 4. Craft categories

Altogether, motor craft (runabouts, inflatable boats, yachts, traditional Mediterranean boats and jet-skis) made up 83.71% of the recreational craft surveyed, whilst sailboats and kayaks comprised the 16.29% left (Table 2). Runabouts were the most frequent representing 47% of the total. The percentage of larger craft such as yachts, runabouts and sailboats is relatively higher in the eastern and southern sectors compared to the northern sector, whilst the opposite is found in the case of smaller craft such as traditional boats, inflatable boats and kayaks (Table 2). There are also differences in craft categories between zones (Table 2). In particular, the partial reserve of Cap Norfeu has the maximum percentages of high-speed craft (i.e. yachts and ski-jets) and the minimum percentages of slow-speed craft (i.e. traditional boats and kayaks).

### 5. Boat anchoring

Overall, the percentages of moored and anchored boats were 7.54% and 92.46%, respectively. If only anchored boats are considered (Table 3), it was observed that 49.81% boats were anchoring on

**Table 2**

Typology of the recreational craft in the Natural Park of Cap de Creus, by sector and zone (in %)

Craft type	Sector			Zone			Total	
	North	East	South	Park	PR Farallons	PR Cap de Creus		PR Cap Norfeu
Inflatable boat	32.69	13.75	9.59	12.81	14.58	15.49	7.69	13.00
Runabout	38.46	36.30	61.99	48.38	55.56	28.87	48.08	47.48
Traditional	20.19	25.52	3.72	16.29	13.89	14.79	7.69	15.78
Yacht	0.00	5.54	6.95	5.22	4.86	11.27	13.46	5.86
Jet-ski	5.77	0.40	2.52	1.24	0.00	2.82	13.46	1.59
Sailboat	0.96	14.05	14.27	13.99	6.25	16.20	9.62	13.46
Kayak	1.92	4.45	0.96	2.05	4.86	10.56	<0.01	2.83

PR: partial reserve.

**Table 3**  
Bottom type where boats anchored in the Natural Park of Cap de Creus, by sector and zone (in %)

Bottom type	Sector			Zone				Total
	North	East	South	Park	PR Farallons	PR Cap de Creus	PR Cap Norfeu	
Dense meadows	26.28	46.23	53.85	34.12	12.94	64.06	34.12	34.61
Sparse meadows	14.43	16.51	16.48	16.82	7.06	7.81	16.82	15.20
Sandy/muddy	36.76	29.72	13.19	25.79	50.59	7.81	25.79	32.26
Rocky/stony	22.53	7.55	16.48	23.27	29.41	20.31	23.27	17.92
Dense meadows	26.28	46.23	53.85	34.12	12.94	64.06	34.12	34.61

PR: partial reserve.

seagrass beds of *P. oceanica* (34.61% on dense meadows and 15.20% on sparse ones), 32.26% on soft (sandy/muddy) bottoms and 17.92% on hard (rocky/stony) bottoms. The percentage of boats anchoring on *P. oceanica* meadows is higher in the eastern and southern sectors (62.74% and 70.33%, respectively), than in the northern sector, where 40.71% of the total anchored boats deployed the anchor on these meadows (Table 3). Regarding the zones (Table 3), the highest percentages of anchored boats on *P. oceanica* were found at the partial reserves of Cap de Creus (71.88%) and Cap Norfeu (66.67%).

## 6. Boater's habits and profile

Going out to sea for sunbathing and swimming was the main activity of boaters (91.8% of observations). Snorkelling is the second most common objective for craft-users, making up 3.7% of the total, whilst fishing for sport makes up 2.8% and scuba diving makes up the 1.7% left (Table 4). Differentiating between sectors zones, it is observed that sport activities such as snorkelling, fishing and scuba diving are more practised, compared to swimming/sunbathing, in the partial reserves than in the park zone (Table 4). Furthermore, the percentages of boaters that practise these sport activities are higher in the northern sector than in the eastern and southern sectors (particularly in the south), where relatively more people sunbath or swim.

The interviews conducted in the southern sector of the Park revealed that most (64.6%) of boaters were non-residents (mainly French and Germans representing 40.2% and 16.8% of the total, respectively), whilst the 36.4% left were Spanish citizens (from which 25.2% coming from the Catalonia region). Most (86.0%) of the crafts found in that sector came from the neighbouring ports of Empúriabrava, Roses and Cadaqués (located within less than 2 miles from the Park), and the rest came from more distant ports. The majority (76%) of boaters affirmed they didn't know the bottom type where they deployed the anchor. The interviews also revealed that boaters go out at sea on an average of 3.67 months per year. Most of the boaters (72%) go out at sea less than three months per year (typically in summer, between June and September), whilst 17% do it between three and six months per year (typically in spring, summer and autumn, between March and October) and only 11% go out at sea more than six months per year (typically all year-round; Fig. 2).

**Table 4**  
Recreational maritime activities practised by boaters in the Natural Park of Cap de Creus, by sector and zone (in %)

Activity	Sector			Zone				Total
	North	East	South	Park	PR Farallons	PR Cap de Creus	PR Cap Norfeu	
Sunbathing/swimming	87.78	92.06	94.87	93.49	85.24	80.03	86.12	91.8
Snorkelling	3.93	5.02	2.86	3.49	4.07	5.43	3.35	3.7
Recreational fishing	4.61	2.29	1.55	1.95	6.36	8.79	4.31	2.8
Scuba diving	3.68	0.62	0.72	1.06	4.33	5.75	6.22	1.7

PR: partial reserve.

## 7. Discussion

The large numbers of recreational boats that can be found in the MPA of Cap de Creus during summer have a number of effects on its coastal marine environment. In a single creek of just 20 ha there can be up to 90 boats in a day. The boats distribute according to the area of each creek and the only environmental factor that can effectively limit the number of boats in summer in a given site is the wind.

The increasing recreational anchoring in Cap de Creus can bring increasing levels of impairment to the ecologically important seagrass meadows of *P. oceanica*. The majority of boaters in Cape Creus affirmed they don't care about the bottom type where they deploy the anchor and consequently don't avoid anchoring on seagrass meadows. Even though we cannot assess the loss of these meadows due to anchoring because we have not evaluated how many shoots are being destroyed during an anchoring cycle and shoot density is unknown, our results indicate that *P. oceanica* meadows of Cap de Creus are suffering from mechanical damage caused by anchors because half of the recreational boats are deploying their anchors on them.

Results elsewhere support that, among the various types of human activities, the mechanical damages resulting from uncontrolled pleasure boats anchoring in shallow coastal waters would appear to be responsible for localized regressions of *P. oceanica* meadows [3,5–7,15,19]. Experiments conducted in other Mediterranean MPAs such as Port-Cros (France) and Ustica Island (Italy) revealed that, on average, between six and 34 shoots were destroyed during an anchoring cycle (lock-in and retrieval), depending on the anchor size [6,15]. Heavier anchors, which are used by larger boats, sunk deeper into the seagrass mat during lock-in and inflict more damage to *P. oceanica* meadows [6,15].

Apart from anchor size, the levels of damage inflicted by anchors on *P. oceanica* meadows differ depending on the anchor type, the anchoring process and the seagrass mat compactness [6,15]. Recolonisation of *P. oceanica* is bound to occur very slowly and meadows lost are, therefore, likely never to become re-established. Furthermore, if *P. oceanica* beds are destroyed, bottoms occupied by this plant will become sandy or muddy and sediment resuspension in shallow parts of the creeks by motorboats will soon probably start, increasing turbidity levels and degrading water quality. Further research has to incorporate study on the specific effects of



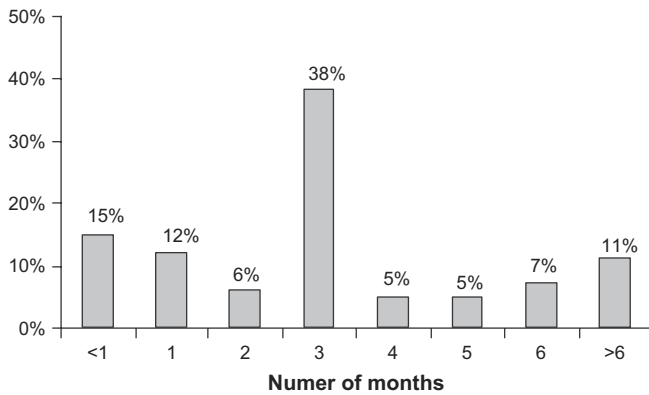


Fig. 2. Number of months per year in which boaters go out at sea.

anchoring, motor noise, sediment suspension and pollution of recreational boats on the marine animals and plants.

Findings also indicate that specific environmental impacts associated to motorboats must be common since these boats make up the majority of the recreational craft, particularly in the southern sector where many high speed and large motorboats are found. Thus for example, the discharge of bilge water, which can contain gasoline and oil that are toxic for many organisms, and motor noise, which disturbs fish and other wildlife such as seabirds and marine mammals, may threaten the marine environment of Cap de Creus. In addition to this, pollutants from vessels such as sewage, toxic antifouling and grey waters can adversely affect water quality and health of organisms. We do not expect, however, an erosion of the rocky shoreline of Cap de Creus like it has been observed in the sandy shorelines of the Mississippi River exposed to significant recreational motorboat traffic [18].

Apart from anchoring, nearly all boaters were conducting activities that have little or negligible environmental impact such as sunbathing, swimming, snorkelling and scuba diving. Special attention should be given, however, to boaters that fish for sport, although they represent less than 5% of the total. This is because recreational fishing is known to impact on Mediterranean littoral fishes, particularly in Cap de Creus [11,20], where it could threaten the effectiveness of such MPA as a fisheries conservation tool for coastal species [12,13]. In addition to this, recreational fishermen, who compete with professional ones, seem to be in part responsible of the decline of the artisanal fisheries in this area [8]. The recreational fishing activity in Cap de Creus, however, seems to be lower compared to other areas such as the Cantabrian Sea (North Atlantic), where fishing for sport is the main purpose of most sea-outgoings of boaters [22].

Our results indicate that a primary element for coastal management in busy boating areas like Cap de Creus must be the anchoring of recreational boats and the specific impacts associated with motor craft, such as speed control and the discharge of bilge waters. Specific plans for managing recreational boating in the Mediterranean MPAs are urgently needed that consider management strategies through education and informing recreational boaters on the environmental threats caused by discharging wastewater and sewage and anchoring on seagrass beds, training boaters about the anchoring process, changes in legislation, the use of certain anchor types such as “Hall” anchors that minimise their impact on the seagrass beds, deployment of ecological mooring buoys in areas with *P. oceanica* meadows where anchoring is to be restricted or forbidden (particularly in vulnerable areas with sparse meadows, i.e. where mat compactness is weak and rhizome baring high) and supporting or promoting the use of small vessels (using light anchors) and non-motor craft (e.g. sailboats and kayaks).

Albeit we could not find any significant ( $p < 0.05$ ) relationship between boater’s activity and anchoring pattern because nearly all

(92%) boaters were sunbathing and very few (less than 7%) were snorkelling or diving, we may expect that boaters practising underwater activities, having seen the seabed in person, would avoid anchoring in sensitive seagrass areas. Thus, education efforts shall promote underwater activities (particularly snorkelling), which will not only rise the awareness of boaters on the ecological value of *P. oceanica* meadows but will make boaters more likely to avoid anchoring on them. Because more than half of the boaters come from overseas, some of which are from non-Mediterranean EU countries, the design of education programs should take into account to these particularities. For example, the edition of leaflets in several languages to inform boaters about existent boating and anchoring regulations and about the ecological value of *P. oceanica* meadows is recommended.

The efficiency of environmental education as a management measure versus restrictions on anchoring or deploying mooring buoys will depend on the boats characteristics. Recent studies conducted in Mediterranean MPAs suggest that whilst environmental education seems to be preferable in sites frequented by small boats (<5.5 m in length) using light anchors [15], restrictions on anchoring or deploying mooring buoys is still recommended in the case of anchorage frequented by bigger vessels using heavier anchors and chains [6]. Our results also show that small-scale geographic differences in the boating activity should be taken into account when management measures are to be implemented in a particular coastal area since the boating activity at different sectors, zones and sites can be different with respect to number and characteristics of boats, anchoring pattern and boater’s activities.

The environmental management of the marine leisure industries such as the recreational boating is a key area world-wide [25]. Marine conservation, particularly in Mediterranean countries like Spain where marine tourism is economically very important, has to be a top priority in the recreational boating business to sustain the attractiveness of the coastal environment upon which it depends. Recreational boaters and industry, regulatory authorities and marine scientists must work cooperatively to ensure the long-term health and sustainability of the coastal areas and recreational opportunities for future generations. Overall, results like the ones here presented may represent an important tool to influence the outcome of decision-making in coastal zone management.

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