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Methodology for applying the Limits of Acceptable Change process to the management of recreational boating in the Balearic Islands, Spain (Western Mediterranean)

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ABSTRACT

The objective of this study is to propose a simple methodological approach, based on the Limits of Acceptable Change process, to support the formulation of management measures for recreational boating in bays. Management measures have been determined using statistical and geospatial analyses of data of biophysical characteristics, use, and user perceptions in a bay on the island of Mallorca. The results suggest that the optimal use level of the study site is being surpassed and a range of potential management options is provided. This methodology is applicable to additional management scenarios where balancing social and environmental needs is necessary and should be implemented as part of a broader Integrated Coastal Zone Management framework.

1. Introduction

The Limits of Acceptable Change (LAC) process was developed to support the management of sustainable recreational use of protected wilderness areas in the USA. As opposed to focusing directly on visitor numbers, the process requires the definition of acceptable social and environmental conditions in the management area and the prescription of measures to monitor and protect these conditions (Frissel, 1963; Cole and Stankey, 1998; Stankey et al., 1985). Essentially, LAC is designed to achieve a sustainable balance between environmental and social needs. The objective of this study is to demonstrate a simple methodological approach, based on the LAC process, to support the formulation of management measures for recreational boating in bays (the Spanish word for bay is *Cala*). The methodology is applied in the Cala Xinxell in the Illetas zone of Mallorca, Balearic Islands, Spain (Fig. 1).

The LAC process was developed to address emerging debates about how to manage recreational carrying capacity. The term *carrying capacity* was first used in the academic literature by Hadwen and Palmer (1922) in a study related to rangeland management. Early studies such as this tended to approach the concept as a fixed number and were primarily linked to ecological and biological variables. However, when attempts were made to apply the concept in the social science disciplines, the complexity and uncertainty resulting from the introduction of human systems (i.e. institutions, economy, society, culture) into the equation led to doubts about whether or not it could be determined as a fixed value. Nowadays, the idea that carrying capacity is a normative value as opposed to a fixed limit is widely accepted by many authors (Arrow et al., 1995; Clarke, 2002; Cohen, 1995; Daily and Ehrlich, 1996; McCool and Lime, 2001; Price, 1999; Seidl and Tisdell, 1999; Wagar, 1964).

Wagar (1964) provoked some of the first major discussions about whether or not recreational carrying capacity could be defined as an inherent, quantifiable number of visitors. Central to this discussion was the idea that defining recreational carrying capacity depends on the needs, values and concerns of visitors and managers and therefore can only be identified in terms of specific management objectives, which vary on a case by case basis (Clarke, 2002; McCool and Lime, 2001; Seidl and Tisdell, 1999; Cole, 2003; Lime, 1970; Lindberg et al., 1996). There are a number of management options for recreation besides simply limiting visitor use which include, among others, environmental education, zoning, enforcement, and technological innovation. Taking these options into consideration shifts the focus of recreational carrying capacity from asking how many boats are too many to defining how much change is acceptable. In this context, more recent definitions of recreational carrying capacity relate to the amount and type of visitor use that can be accommodated within a recreation area

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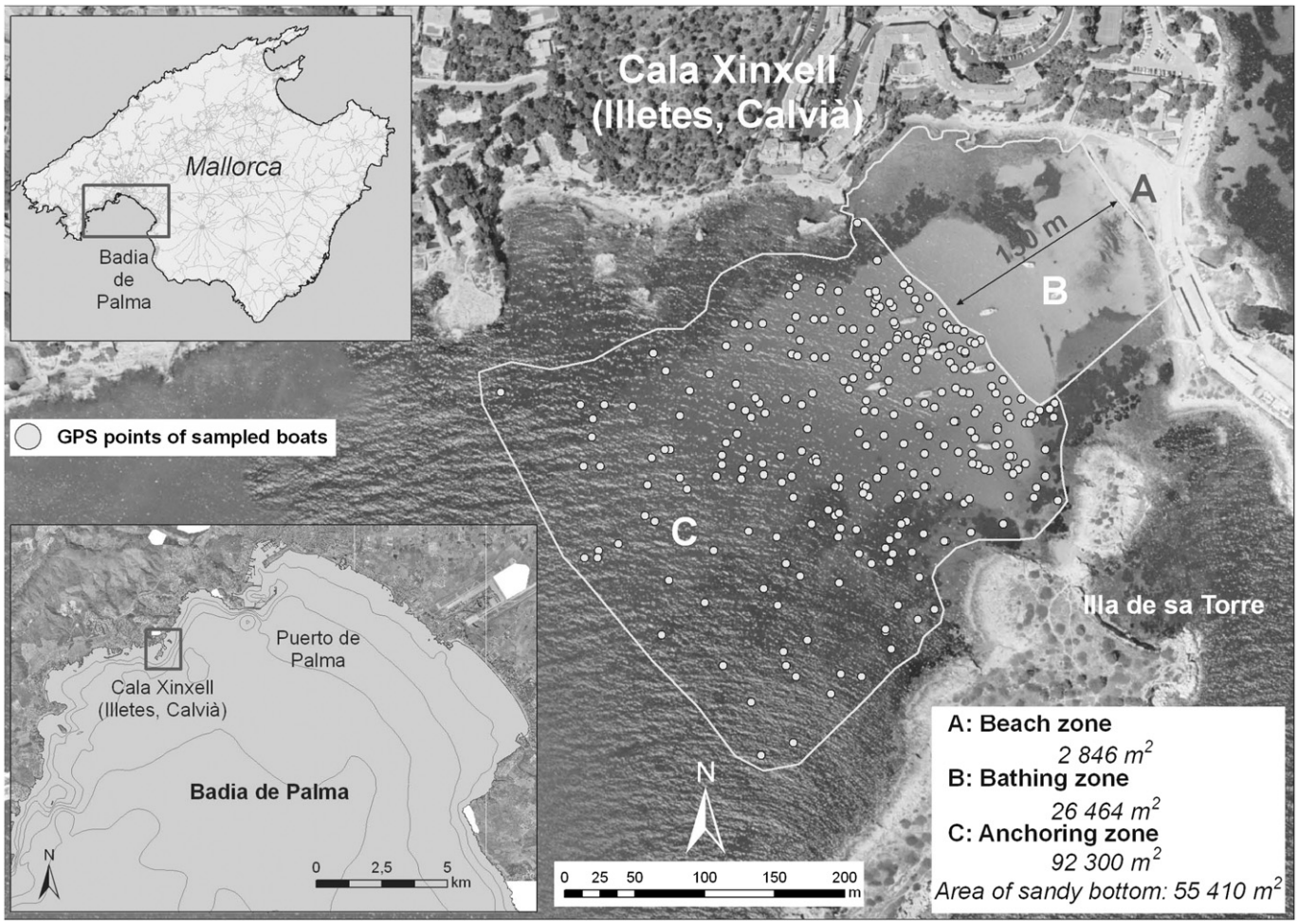

Fig. 1. Map of the study site (Cala Xinxell, Illetas) including zones and GPS references for anchoring points of sampled boats.

without unacceptable environmental and social impacts (Manning and Lawson, 2003).

The LAC process responds to the doubts raised by Wagar (1964) and the other studies cited above by providing measures for managing visitor impacts as opposed to visitor numbers. The process consists of a series of general steps which include the definition of management objectives (future desirable social and environmental conditions), the identification of measurable variables that describe resource and social conditions (i.e. indicators), and the establishment of measurable standards for maintaining those conditions (i.e. the minimum acceptable value for indicators of quality). These measures are used to inform the establishment of monitoring programs and management activities to ensure standards are maintained (Stankey et al., 1985). The process is intended to be collaborative and achieve compromises, with resulting decisions being based on the amount of change that is acceptable to a variety of stakeholders (Cole and Stankey, 1998; Stankey et al., 1985; Ahn et al., 2002).

1.1. LAC in a recreational boating context

Although originally intended for application in land based protected areas (Lawson et al., 2003; Manning et al., 2002), LAC has been defined more generally as a tool for operationalizing the sustainability concept (Ahn et al., 2002; McCool, 1994). LAC and related procedures have been applied in a number of spatial and management scenarios including human interactions with cetaceans (Higham et al., 2009), regional tourism planning (Ahn et al., 2002; Frauman and Banks, 2011; Garrigós et al., 2004), SCUBA diving (Rouphel and Hanafy, 2002), snorkeling (Roman et al., 2007), and marine protected areas (Denny and Fish, 2006; McCallum, 2006; Shafer and Inglis, 2000). In a recreation context, a number of authors claim that the process can be converted from conceptual to operational more easily than the recreational carrying capacity concept (McCool and Lime, 2001; Ahn et al., 2002; Buckley, 1999).

Applications of the LAC to recreational boating scenarios are rare and recent research has cited the value of this approach in informing associated management measures (Gray et al., 2010). LAC is adaptable to recreational boating because this activity tends to occur in a space that can be easily be defined, and where there is a necessity to balance environmental and recreational goals. From a social perspective, overcrowding of recreational boats can affect the well-being and safety of visitors (Ashton and Chubb, 1972; Tseng et al., 2009). From the environmental perspective, boats can have negative impacts on marine ecology through poor anchoring practices and pollution (Francour et al., 1999; Lloret et al., 2008; Marba et al., 2002; Roig i Munar, 2003; Swett et al., 2009). The negative impacts of anchoring on *Posidonia oceanica*, a sea grass endemic to the Mediterranean, is one of the more common foci of recreational boating impact studies, and has been observed in the Balearic Islands (Lloret et al., 2008; Marba et al., 2002; Roig i Munar, 2003) and in the broader Mediterranean (Francour et al., 1999; Ceccherelli et al., 2007; Montefalcone et al., 2006). *P. oceanica* is included on the

Red List of threatened marine species, is considered a priority natural habitat in Annex 1 of the EC Directive 92/43/EC (European Economic Community (EC), 1992) and is also protected by the Spanish National Law 42/2007 of Natural Heritage and Biodiversity. Although measures have been implemented in a number of protected areas around the islands (e.g. ecological mooring buoys and patrol boats), there is a need for additional enforcement and management practices to limit or, ideally, eliminate anchoring in *P. oceanica* beds in Mallorca and many parts of the Mediterranean.

1.2. The case of recreational boating in Cala Xinxell, Mallorca, Balearic Islands

The Balearic Islands are an autonomous region (first level political division) of Spain located in the Western Mediterranean and are one of Europe's leading destinations for recreational boating and beach tourism. The islands cover an area of 4970 km^2, with a coastline of 1428 km, and a population of just over one million in 2006 (Instituto de Estadísticas de las Illes Balears (IBAE), 2006). Mallorca is the largest and most populated of the four islands. In 2007, 13.3 million tourists visited the islands. Mallorca received 9.7 million of these tourists, which is 73% of the total (Centro de Investigación y Tecnologías Turísticas (CITTIB), 2009a). In 2008, the recreational boating industry generated over 537 million € and the number of recreational boaters to the Islands was 324 522 (Centro de Investigación y Tecnologías Turísticas (CITTIB), 2009b). In addition to being one of the most lucrative sectors of the tourism industry, recreational boating is a popular activity for the resident population. The methodology for defining LAC standards for recreational boating is applied in the Cala Xinxell in the Illetas zone of Mallorca, Balearic Islands Spain (see Fig. 1). This zone, which is in the municipality of Calviá, is one of the most heavily used recreational boating and beach tourism areas of the island. In addition to many hotels and secondary services, the area hosts a large resident population and is a popular beach and boating destination for nearby residents of Palma, the largest city and capital of Mallorca.

Coastal development, pollution and residuals, overcrowding of anchoring zones and beaches and periodic, increased pressure on natural resources during the summer season all pose threats to the sustainability of the tourism industry and the coastal zone of Mallorca (Tintoré et al., 2009). The threat of such impacts is exacerbated by the insular environment of the Balearics characterized by, among others, limited space, natural resources, and waste assimilation capacity.

Sustainable development has been recognized as a priority by government, private sector and civil society in the Balearic Islands. However, systematic, integrated management approaches to achieving sustainable development goals in Spain and in the islands are challenged by limited scientific information, supporting legislation and the absence of a coordinated governance structure that responds to these goals (Barragán, 2010; Diedrich et al., 2010). For the last five years, the scientific research community of the islands, with the support of the public administration and other civil society groups (e.g. Chamber of Commerce, Economic and Social Council) have been working to develop scientific tools to support the implementation of Integrated Coastal Zone Management [ICZM (Tintoré et al., 2009; Diedrich et al., 2010; Balaguer et al., 2008)]. This study forms part of a broader science-based ICZM initiative on the islands.

2. Methods

Concurrent with the previous definition of the LAC process, this study was based on a four step methodological procedure which defines the management objective for the Cala, identifies associated indicators and standards of quality. These are used to determine potential management measures. The steps are outlined in the following subsection. Following this, the methods for data collection are described.

2.1. Methodological steps

(1) Definition of the management objective

The management objective for the Cala is to establish measures for managing recreational boating use that maintain acceptable social and environmental conditions.

(2) Definition of LAC standards

The following standards were defined for maintaining acceptable social and resource conditions. These conditions were selected because, based on the previous literature review, they are highly relevant from an impact perspective, because they can be evaluated using indicators (see step 3) that are relatively easy to measure from a methodological perspective, and because they are manageable through the implementation of *in situ* measures:

i. The majority of users are content with the total number of boats in the Cala (social standard).
ii. The majority of users are content with the distance between the boats in the Cala (social standard).
iii. No boats are anchored in *P. oceanica* areas (environmental standard).

(3) Identification of indicators

Eight indicators were selected to describe social and resource conditions in the Cala associated with the LAC standards (see step 2):

i. Biophysical characteristics of the study area (area (m^2) of beach, anchoring area, sandy bottom, *P. oceanica*)
ii. Levels of use (number of boats in the Cala)
iii. Characteristics of users and boats (demographics of users, type and size of boat, port of origin of the boat)
iv. Visitor perceptions of the number of boats (do they wish to see fewer boats or are they satisfied with the current number?)
v. Effects of the number of boats on well-being (does an increase in the number of boats increase or decrease well-being of the users?)
vi. Visitor perceptions of the distance between boats (are they content with the distance between the boats?)
vii. Effects of the distance between boats on well-being (does a decrease in the distance between boats increase or decrease well-being of the users?)
viii. Visitor satisfaction (what is the level of satisfaction of the users with their experience in the Cala?)

(4) Definition of management options for maintaining LAC standards

A number of calculations were conducted using the indicators listed in step (3) were carried out to estimate optimal use levels and distances that should be permitted between boats in order to maintain LAC standards. These are presented in the Results section. Potential management options using these results are described in the Discussion section.

2.2. Data collection

The majority of the data were collected during a fieldwork study carried out in the Cala Xinxell in the high season of summer of 2008 (21 June to 11 September). The biophysical data were processed using Geographic Information Systems (GIS) and aerial photographs, and the perception, use, and demographic data were collected using a survey instrument and through participant observation. These data include:

Descriptive (indicators i–iii)
- Biophysical characteristics of the study site
- Levels of use
- Demographics of boaters anchored in the Cala
- Boat characteristics

Perception (indicators iv–viii)
- Perception of boaters of the number and distance between boats
- The effect of the number of boats and the distance between them on general well-being of boaters
- Satisfaction of boaters

The biophysical characteristics of the study site (total area with and without *P. oceanica*, zoning, Fig. 1) were processed using aerial photographs[2] and Geographic Information Systems (ArcGIS 9.0). The rest of the data were collected through participant observation and the implementation of a survey which was administered to recreational boaters anchored in the Cala. There is a designated swimming area in the Cala (zone B, Fig. 1) which means that users of the beach and recreational boaters do not share the same physical space. For this reason, boaters are the only users who were surveyed in this study.

The fieldwork was conducted on two days of every week during the sample period – one weekday and one day of the weekend. Weekend days (i.e. Saturday or Sunday) and weekdays (Monday or Tuesday, etc.) were also alternated to ensure a representative sample of days across the summer season. The surveys, which were printed in Catalan, Spanish, French, English and German, were designed to measure boaters' perceptions of: the number of boats in the Cala, the distance between the boats in the Cala, the effect of the number of boats and the distance between them on general well-being, general satisfaction, demographic data, and boat characteristics.

The surveys, which took about 5 min to complete, were distributed by two researchers who drove between the anchored boats in a small Zodiac (one driver and one surveyor). A minimum sample was calculated for each day based on the total number of boats and using a standard sample size calculation formula (set to alpha level 0.05, 15% relative standard error of the mean). The researchers arrived at midday and left once the adequate number of boats had been sampled. This generally took between 2 and 4 h. The Cala is small enough that the total number of boats can be counted visually from any location within it. The surveyors maximized randomness by zigzagging through the Cala and, based on the required sample and total number of boats, picking every *n*th boat accordingly. The number of repeats (i.e. boats that had already been surveyed and therefore could not be surveyed again) increased significantly throughout the study, meaning that the number of new surveys obtained became proportionally lower as the study progressed. The researchers also counted the total number of boats upon arrival and departure, recorded the GPS points of the boats that were surveyed, including the names of the boats in order to avoid repeated requests to fill out the questionnaire.

[2] SITIBSA (Servicio de Información Territorial de les Illes Balears), Environment and Mobility Council, Government of the Balearic Islands, 2002 (scale 1/5000).

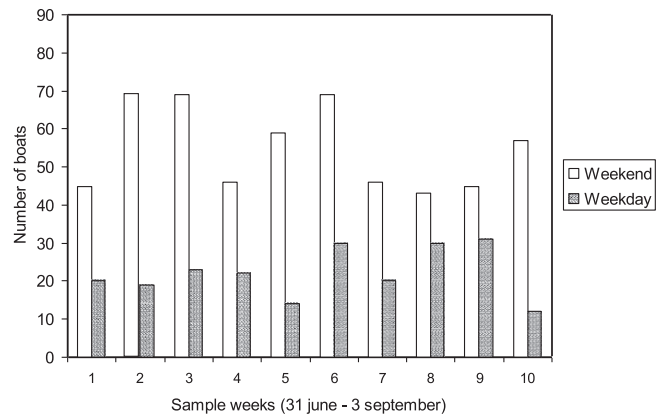

Fig. 2. Mean number of boats on sample days.

A total of 340 surveys were completed over a period of 20 days with a response rate of 92%. The results of the surveys were entered into an SPSS 16.0 database and the GPS points were superimposed onto an aerial photograph of the study area (Fig. 1). The results were analyzed statistically using SPSS and spatially using GIS.

The following subsections describe the data for the indicators selected for this study (methodological step (3)). These include biophysical characteristics and use levels of the study site, and the demographics, perceptions, and satisfaction of the users. These data are then used calculate a series of potential management measures for maintaining LAC standards (i.e. optimal levels of use, distance between the boats). The implementation of these management measures is discussed in detail in the Discussion section.

3. Results

3.1. Biophysical characteristics of the study area

Fig. 1 shows the location and size of the Cala Xinxell. The total anchoring area was determined using the GPS points collected from the boats that were surveyed (zone C, 92 300 m^2). Zone B is an area that has been sectioned off for swimming and zone A is a beach. The dark areas of zone C are mainly *P. oceanica* (including some rocks) and therefore not considered suitable for anchoring from an environmental perspective, although the location of the GPS points shows that boats do anchor in these areas. The presence of *P. oceanica* was confirmed by observations made by the researchers during the fieldwork. The area within zone C that is considered to be suitable for anchoring because it is made up of sandy bottom (light areas of zone C). This area is 55 410 m^2, which is 60% of zone C.

3.2. Levels of use

Fig. 2 shows the number of boats that were counted in the Cala on each sample day. An average was taken of the number of boats at the beginning (12pm) and the end (between 2 and 4pm) of the survey period.

The average change in the number of boats at the beginning and the end of the survey period across the 20 sample days was an increase of 32%. Fig. 2 shows that the mean number of boats is 23 during the week and 57 on weekends. An independent sample *t*-test showed a significant difference between the mean number of boats on weekends and on weekdays ($t = 30.26$; std.err. 1.1; $p < 0.001$).

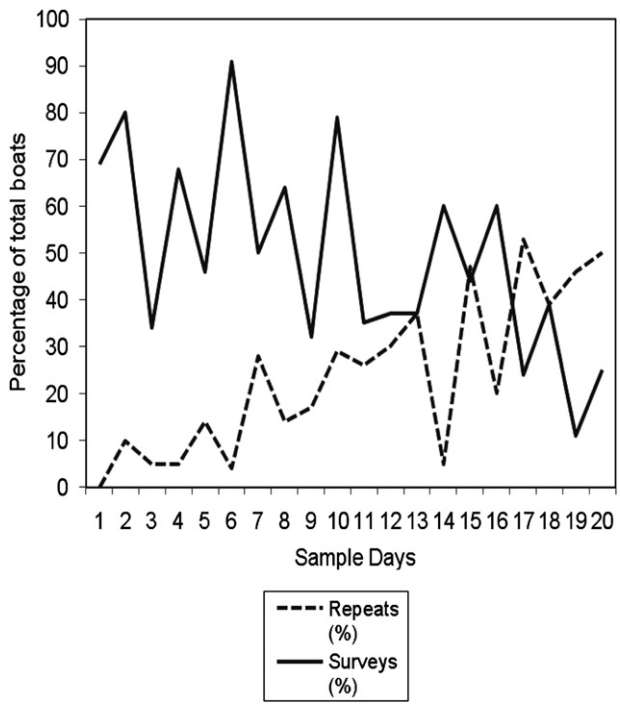

Fig. 3. Percentage of total boats surveyed.

Fig. 3 shows the number of boats that were surveyed each day as a percentage of the mean number of boats on that day. The figure also shows the percentage of repeats (i.e. boats that had already completed the survey on another day) for each day.

There is a general increase in the number of repeats which, by the end of the sampling period is close to 50%. Based on the increasing number of repeats, the average daily sample size of 49% of the total boats, the techniques used to maximize random selection, and the sample size of 340 boats, it may be assumed that the final sample is representative of the visitors to the Cala during the months of sampling period.

3.3. Characteristics of users and boats

Table 1 shows the general characteristics of the respondents (A) and the boats on which they were situated (B). The data are separated for weekdays and weekend days.

The table shows that visitors to the Cala tend to be Spanish residents[3] of the island, over 40 years old, who visit the Cala habitually (i.e. have visited more than 40 times in their lifetime). The most notable difference between the respondents sampled on weekdays and on weekends is that the proportion of residents is higher at weekends. There are also some differences between the boats that come on weekdays and at weekends. The data show a balance between sailboats (49%) and motorboats (41%) on weekdays, that tend to be between 4–8 m (24%) and 8–12 m (37%) long. At weekends, there tends to be a higher proportion of motorboats (71%) and smaller boats of between 4 and 8 m (44%) long. The majority of the boats that visits the Cala on weekends come from ports in Palma (see Fig. 1). During the week, their origin tends to be more balanced among ports in Palma, other parts of Mallorca, and abroad. This is logical if one considers that there is a higher proportion of residents visiting the Cala at weekends.

[3] For the purpose of this study, residents are defined as individuals who spend more than 6 months a year living on the island.

3.4. Perceptions of the number of boats in the Cala

Fig. 4 shows the perception of the respondents of the number of boats in the Cala at the time they were surveyed using three ordinal response categories (1 = prefers fewer boats, 2 = acceptable number of boats, and 3 = prefers more boats).

A three-point scale was considered adequate to obtain these data because the survey contained a follow-up question asking respondents to specify the exact increase or decrease in number of boats they would prefer. Perceptions (y axis) have been cross-referenced with the actual number of boats in the Cala for each of the sample days. The actual number of boats on the x axis have been categorized into 4 increasing, equally distributed crowding scenarios to simplify the figure, however, the raw data have been used for the correlation of response categories and the number of boats to ensure a more statistically powerful result. It is important to note that these are not continuous data as a line graph may suggest, the data have simply been displayed this way to demonstrate the relationship between the variables more clearly.

A Spearman rank-order correlation between the response categories and the number of boasts shown in Fig. 4 showed a significant negative relationship ($r = -0.2$; $p < 0.001$; $n = 331$). This tendency towards a preference for fewer boats as the number of boats increases is what one would expect. However, although the correlation analysis shows a general relationship we would expect, Fig. 4 shows a reverse in the direction of this relationship when the number of boats reaches 48–65. After this point, the proportion of people who would prefer fewer boats decreases. This inflection point is also the point where the proportion of people who would prefer fewer boats surpasses those who feel the number is adequate. Given the fact that the average number of boats on weekends is 57 and on weekdays it is 23, coupled with the assumption that the visitors to the Cala are different on weekends and during the week (Table 1), we assert that the inflection point in Fig. 4 could be due to different levels of tolerance of weekend and weekday visitors.

3.5. Effect of the number of boats on well-being

Following the question about perceptions of the number of boats, respondents were asked how their well-being is affected as the number of boats in the Cala increases using five ordinal response categories (1 = decreases a lot, 2 = decreases, 3 = does not change, 4 = increases, 5 = increases a lot). Well-being is not defined in the survey. Since it means different things to different people, the term is left to the interpretation of the respondent although this study does make the assumption that well-being represents a positive state for the respondent. The general tendency, as expected, was a perceived decrease in well-being in relation to an increase in the number of boats (62% said well-being decreases (1 or 2), 34% said it does not change (3), 4% said it improves their well-being (4 or 5)).

In order to test the previous assumption that the visitors who come at weekends are less negatively affected by a higher number of boats than visitors during the week, a series of Mann–Whitney U tests were carried out to test for significant differences between residents and tourists and between weekend and weekday visitors. The results showed a significant difference between residents who visit the Cala at weekends and on weekdays (weekend rank 103, weekday rank 82; $z = -2.2$; $p < 0.05$; $n = 196$) and between tourists and residents who come at weekends (resident rank 102, tourist rank 82; $z = -2.1$; $p < 0.05$; $n = 196$). This supports the assumption that weekend and weekday visitors have different levels of tolerance of the number of boats anchored in the Cala. Specifically, the results suggest that the residents who visit the Cala on weekends

Table 1
Characteristics of the sample ($n = 340$).[a]

			Weekday		Weekend		Total	
			Frequency	%	Frequency	%	Frequency	%
A. Respondents								
Gender		Male	82	75	113	61	195	66
		Female	28	25	71	49	99	44
Age		18–20	1	1	2	1	3	1
		21–30	4	4	14	7	18	6
		31–40	16	14	45	24	61	20
		41–50	32	29	49	26	81	27
		51–60	31	28	55	29	86	29
		61+	27	24	24	13	51	17
Tourist			74	63	42	21	116	36
Resident			44	37	159	79	203	64
Nationality	Tourist	English	22	30	10	24	32	28
		Spanish	13	18	10	24	23	20
		German	14	19	6	14	20	17
		Other	25	33	16	38	40	35
	Resident	Spanish	39	89	147	93	186	92
		Foreign	5	11	12	7	17	8
Number of visits	Tourist	First time	14	21	8	21	22	21
		2–10 times	27	40	16	41	43	40
		11–20 times	8	12	2	5	10	9
		21–30 times	9	13	1	3	10	9
		31–40 times	2	3	3	8	5	5
		>41+ times	8	11	9	22	17	16
	Residents	First time	1	3	2	2	3	2
		2–10 times	3	8	16	13	19	12
		11–20 times	8	22	18	15	26	16
		21–30 times	2	6	6	5	8	5
		31–40 times	1	3	3	2	4	3
		>40+ times	21	58	78	37	99	62
B. Boats								
Type		Sail	60	49	59	29	119	37
		Motor	61	51	142	71	203	63
Ownership		Private	99	86	181	97	280	93
		Charter	16	14	6	3	22	7
Size (m)		4–8	29	24	89	44	118	36
		8–12	45	37	69	34	114	35
		12–16	28	23	22	11	50	15
		>16	19	16	23	11	42	13
People on board		1	4	3	1	0.5	5	1.5
		2	32	27	47	24	79	25
		3–5	61	53	103	52	164	52
		6–10	16	13	46	23	62	20
		11–20	4	3	1	0.5	5	1.5
Nationality (boat)		Spanish	200	76	161	81	216	68
		Foreign (EU)	61	23	36	18	97	31
		Foreign (non-EU)	2	1	2	1	4	1
Port of origin		Palma[b]	41	38	117	60	158	52
		Mallorca (not Palma)	28	26	61	31	89	29
		EU (not Mallorca)	36	33	17	8	53	17
		Non-EU	4	3	1	1	5	2

[a] Note: total frequencies vary due to missing responses.
[b] Note: ports in Palma include Club de Mar-Portixol.

are less negatively affected by an increase in the number of boats, or more tolerant, than residents who come during the week and tourists who come at weekends.

3.6. Perceptions of the distance between boats

Perceptions of the respondents about the distance between the boats were obtained using five ordinal response categories (1 = much too close, 2 = a little too close, 3 = adequate distance, 4 = a little too far, and 3 = much too far). Fig. 5 shows the percentage of responses in each category in relation to the four crowding scenarios (also used in Fig. 4). The ordinal response scale has been re-coded to a scale of three (1 and 2 = too close, 3 = adequate distance, 4 and 5 = too far) to simplify the graph but the data were not aggregated for the statistical analysis.

A Spearman rank-order correlation analysis between the response categories and the number of boats in Fig. 5 showed a negative correlation of the same magnitude as for the perception of the number of boats ($r = -0.2$; $p < 0.001$; $n = 279$). Unlike in Fig. 4 there is no point of inflection shown for this data. As one would expect, the perception that the boats are too close increases and the perception that the distance is adequate decreases as the number of

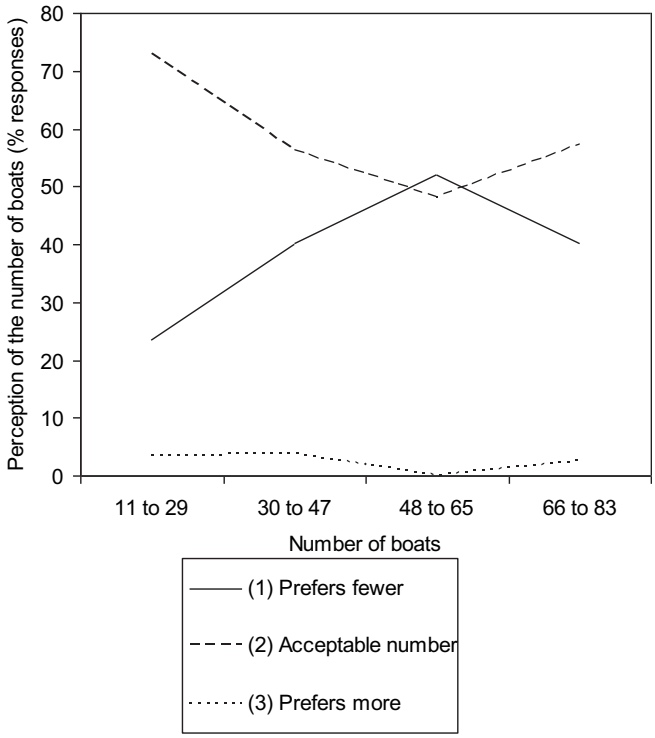

Fig. 4. Relationship between perceptions of the number of boats and the actual number of boats in the Cala (% responses, $n = 331$).

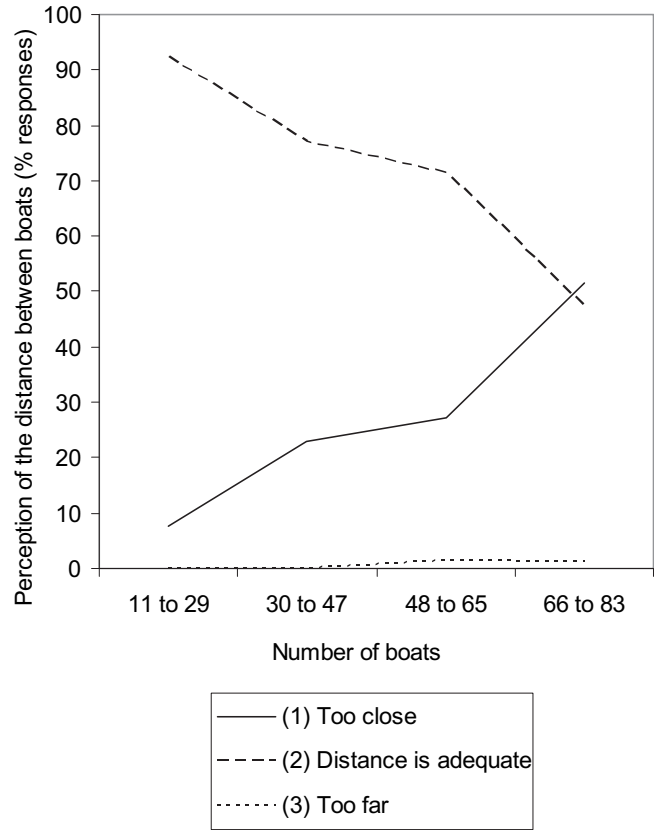

Fig. 5. Relationship between perceptions of the distance between boats and the actual number of boats in the Cala (% responses, $n = 279$).

boats increases (and hence, average distance between them decreases). However, the point of convergence, where the percent of respondents who perceive that the boats are too close is higher than the proportion who perceives them to be an adequate distance from each other corresponds to a higher crowding scenario (66–83 boats) than the perceptions in Fig. 4 (48–65 boats).

3.7. Effect of the distance between boats on well-being

Following the question about perceptions of the distance between the boats, respondents were asked how a decrease in the distance between the boats in the Cala affects their general well-being using five ordinal response categories (1 = decreases a lot, 2 = decreases, 3 = does not change, 4 = increases, 5 = increases a lot). The general tendency, as expected, was a perceived decrease in well-being in relation to a decrease in the distance between boats (75% said well-being decreases (1 or 2), 24% said it does not change (3), 1% said it improves well-being (4 or 5)). A series of Mann–Whitney *U* tests were carried out to test for significant differences between the perceptions of residents and tourists and between weekend and weekday visitors. The results showed a significant difference between residents who visit the Cala at weekends and on weekdays (weekend rank 104, weekday rank 81; $z = -2.4$; $p < 0.05$; $n = 197$). Again, this suggests that the residents who visit the Cala on weekends are more tolerant of a shorter distance between the boats than the residents who come during the week.

3.8. Visitor satisfaction

Respondents were asked about their general level of satisfaction with their visit to the Cala using five ordinal response categories (1 = very unsatisfied, 2 = unsatisfied, 3 = neutral, 4 = satisfied, and 5 = very satisfied, $n = 326$). The majority responded that they were satisfied (48%) or very satisfied (29%) with their experience on the day of their visit. Twenty percent gave neutral responses with 3% stating that they were unsatisfied. Spearman rank-order correlations were carried out to test for correlations between satisfaction and both perceptions of the number of boats ($n = 318$) and perceptions of the distance between the boats ($n = 266$). Relatively strong positive correlations were found between satisfaction and both variables ($r = 0.4$; $p < 0.001$).

3.9. Definition of management options for maintaining LAC standards

Four measures for informing management of recreational boating in the Cala were determined using the LAC indicators described in Sections 3.1–3.8. These include, optimal number of boats in the Cala, mean acceptable swing range, minimum distance between boats, and the optimal number of boats that can anchor in the sandy area. These measures are intended to maintain the LAC standards defined previously in the Methods section:

i. The majority of users are content with the total number of boats in the Cala.
ii. The majority of users are content with the distance between the boats in the Cala.
iii. No boats are anchored in *P. oceanica* areas.

3.9.1. Optimal number of boats in the Cala

This measure can be determined using the data in Figs. 4 and 5. The data show that social standard (i) is violated at a lower crowding scenario of 48–65 boats (Fig. 4) than social standard (ii), which is violated at 66–83 boats (Fig. 5). This means that standard

(i) is the limiting social standard for establishing optimal use levels of the Cala. Therefore, the optimal number of boats in the Cala has been estimated to be 48 boats, which is the lower range of the crowding scenario at which standard (i) is violated.

3.9.2. Mean acceptable swing range

The *swing range* is the maximum distance that a boat swings out and around its anchoring point – it is contingent upon depth, length of the anchor line and the length of the boat. The direction in which the boat swings depends upon the wind direction but, in safety terms, each boat should occupy a space that allows it to swing a full 360° around its anchoring point without encountering another boat. The swing range is the radius of that circle. Fig. 6 shows the method we used to estimate the average swing range per boat on the basis of available space and the total number of boats.

Calculating the mean swing range for the optimal use level of 48 boats can inform management decisions about the average distance that should be allowed between mooring buoys, should they be used as a management option. It also allows for the calculation of the number of boats that could fit into the smaller area constituted by sandy bottom[4]. Using the formula in Fig. 6, the average swing range for a use level of 48 boats has been calculated as:

$$\text{Total area/optimal use level} = 92\,300\ \text{m}^2/48\ \text{boats} = 1923\ \text{m}^2\ \text{per boat}$$

$$\sqrt{1923} = x = 44\ \text{m(average distance between boats)}$$

$$\text{Average swing distance per boat} = x/2 = 22\ \text{m}$$

3.9.3. Minimum distance between boats

The data in Fig. 5 show the point of convergence of perceptions that the boats are too close and that the distance is adequate corresponds with a higher crowding scenario (66–83 boats) than perceptions about the number of boats. Using the lower bound number of 66 and the formula in Fig. 6, the average swing range has been calculated as 19 m, which pertains to a distance of 38 m between boats. This distance should be the minimum distance permitted between boats in the Cala.

3.9.4. Optimal number of boats that can anchor in sandy area

The number of boats that can fit into the sandy areas in zone C (Fig. 1), while maintaining social standards has been calculated as:

$$\text{Area of sandy bottom/average area per boat (optimal use level of 48 boats)} = 55\,410/1923 = 29\ \text{boats}$$

4. Discussion

The objective of this study is to propose a simple methodological approach, based on the LAC process, which supports the definition of management measures for recreational boating. The application in Cala Xinxell was essentially a pilot test of this process, which brought to light a number of methodological considerations that could lead to improvements in subsequent applications. These are discussed in detail in the following subsection. Following this, potential management measures for the Cala are discussed.

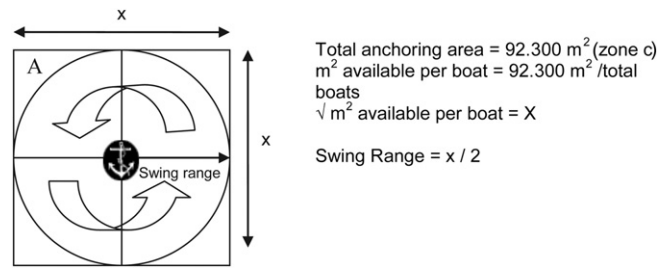

Fig. 6. Method for calculating the mean swing range per boat.

4.1. Methodological considerations

A first methodological consideration, relevant to any application of the LAC process, relates to the appropriate selection of indicators and standards. Stankey et al. (1985) wrote that LAC standards should be realistic as opposed to idealistic. Although there are clearly more factors that influence the sustainability of recreational boating in Cala Xinxell, this study is based on only three standards which, as mentioned previously, are considered to be highly relevant from an impact perspective, indicators that are relatively easy to measure from a methodological perspective, and manageable through the implementation of *in situ* measures. The effect of anchoring on *P. oceanica* can be regulated through the installation of buoys or enforcement and has been reported as one of the most significant threats to the environment caused by recreational boating in the Mediterranean (Lloret et al., 2008). It therefore makes sense to set the standard for no anchoring in *P. oceanica areas*. Overcrowding is an established threat to the well-being and safety of recreational boaters (Ashton and Chubb, 1972; Tseng et al., 2009) and should therefore also be taken into account at the study site. However, it would be unrealistic to assume that the needs of all users can be accommodated so associated standards were set so that the majority would be content with the number and distance between boats. Other less tangible impacts such as pollution should be addressed through broadly applied management policies and Best Practices, an issue that is discussed more in the following section about management measures.

A second methodological consideration relevant to this study is that the methods and utility of quantifying human needs and values, the normative aspect of recreational carrying capacity, have been highly debated in the academic literature. Such debates are especially prevalent in relation to social crowding norms in terrestrial parks and wilderness areas (Inglis et al., 1999; Manning et al., 1999; Shelby et al., 1996). Norms may be defined as evaluative standards regarding acceptable behaviors or conditions in a given context or shared judgments about what ought to be (Shelby et al., 1996). Some researchers contend that perception studies can be used to establish norms (Shelby et al., 1996; Vaske et al., 1986), where others suggest that visitor responses may vary in relation to a number of factors including expectations, types of visitors, the number of people that are encountered on that day, or the time at which they were interviewed (Cole and Stewart, 2002; Heywood, 1996; Roggenbuck et al., 1991). The latter view is reflected in the results of this study, which was not intended to establish norms; rather, it was designed specifically to measure the perceptions of users of this site during the specified summer months. Table 1 shows that the majority of respondents are habitual visitors of the Cala which means that they arrive with

[4] It is important to note that these calculations are only general averages. Boats do not occupy square areas, however, the hypothetical space that is not occupied (e.g. area A, Fig. 6) will always remain empty unless the swing ranges overlap, which is not an acceptable scenario from a safety perspective.

pre-established expectations about the experience they will have while they are there. The influence of expectations is also reflected in the fact that weekend visitors tend to have a higher tolerance of boats than those who come during the week. Rather than interpret variability as a potential flaw in perceptions research, the observation of such trends should be a testament to the utility of surveys in identifying and highlighting the complexity associated with the needs and behavior of recreationists. However, it is important to note that the existence of expectations and choice means that the management measures established in this study cannot be applied to other Calas in Mallorca that may be habitually less/more crowded or aesthetically different, thus attracting different types of visitors. This concept is discussed in a management context in the following subsection.

A third methodological consideration relates to the perceptions that the respondents had of the research study. The fieldworkers were asked on a number of occasions whether the objective of the study was to install mooring buoys with an associated fee. The majority of the respondents who had this concern viewed paying for use of the area in a negative way. In fact, the few instances where individuals responded that they would prefer more boats in the Cala, these perceptions were linked to additional negative comments on the questionnaire regarding the installation of mooring buoys with associated user fees. Fieldworkers were careful to assure respondents that they did not represent any decision-making body but were unable to totally eliminate such concerns. This consideration, in addition to the role of expectations explained in the previous paragraphs could have contributed to an over-estimation of optimal use levels, which further necessitates the use of a precautionary approach (i.e. selecting the lower range of the crowding scenario in Fig. 4, setting the limit for the most sensitive users). This approach also compensates for the average increase of 12 boats during the survey period across the sample days.

A final important methodological consideration relates to the use of a three-point scale for the survey question about perceptions of the number of boats in the Cala. Generally, such questions should be based on at least a five-point scale, such as the one used to ascertain perceptions of the distance between boats, in order to capture a more detailed range or responses. However, since this question was followed by a more specific one about how many more or less boats the respondents would prefer to encounter, a three-point scale was considered to be adequate. Given that this was a trial run of the methodology, the questions about number of boats and the distance between them were formatted differently in order to test both approaches. However, the follow-up question about the desired change in the number of boats received a considerably lower response rate than the other questions on the survey. Given this result, future applications of this study should use of a five-point scale for both perception questions.

4.2. Management implications

The results of this study confirm the fact that unregulated recreational boating can have negative impacts on the well-being of visitors and on *P. oceanica*, hence necessitating management measures. Specifically, the perceptions data show that an increase in the number of boats in the Cala and a decrease in the distance between them can diminish the well-being and satisfaction of users. Additionally, Fig. 1 shows that boats do anchor on *P. oceanica*. This was confirmed by observations of the fieldworkers, who saw anchors pulling up clumps of sea grass on a number of occasions. The depth of the Cala is greater near its mouth, which is where the majority of the *P. oceanica* beds are located. This is where larger boats tend to anchor which, due to their weight and size of their anchors, can produce significant physical impacts.

The average number of boats on weekends during the sample period is 57, which surpasses the estimated optimal use level of 48 boats. If the use level is calculated taking into account impacts of anchoring on *P. oceanica*, only considering the sandy areas of zone C (Fig. 1) as suitable for anchoring, the optimal number of boats is reduced to 29, which is less than half the average number of boats in the Cala during summer weekends. Similar to the majority of sustainability scenarios, the ultimate decision about management measures is contingent upon more factors than simply what the data suggest should be done. Common factors include available resources and the values of decision-makers (e.g. whether they value conservation more than satisfaction of tourists and vice versa). The range of management options proposed in the following paragraphs are adaptable to availability of resources and the priorities of decision-makers.

Permanent ecological mooring buoys have been proposed as a solution for balancing recreational needs with impacts of anchoring on *P. oceanica* because they still allow access to these areas but eliminate the need to anchor (Francour et al., 2006). Currently, ecological mooring buoys have been installed in four of the approximately 163 bays, coves and natural harbours around Mallorca, so recreational boating remains largely unregulated on the island. The number and positioning of the existing buoys were based on the presence of *P. oceanica* and safe distances required for different sized vessels but did not take into account the perceptions of users. The installation of additional ecological mooring buoys could be a potential management measure for regulating boating in the study site and around the island but subsequent installations should be based on studies such as this one that take into account user perceptions.

The most precautionary and expensive management option would be the installation of 48 mooring buoys in the Cala. This option would eliminate the risk of anchor damage to *P. oceanica* and would also ensure that the users with the lowest tolerance would be minimally affected by the number of boats in the Cala. Additional work would need to be carried out to determine the exact positioning of the buoys using the minimum distances calculated in this study as guidelines, in addition to data on bathymetry and the size distribution of the boats in the anchoring area (i.e. smaller boats tend to anchor closer to the beach). The majority of these data have already been collected (i.e. GPS points associated with different boat characteristics in Table 1) so the distribution would require minimal effort to calculate.

A less restrictive and less expensive management option would be to install mooring buoys only in the area where there is *P. oceanica* and not restrict use of the sandy areas. This option still provides environmental protection measures but does not take into full consideration the social criteria. However, in the event that financial resources are limited or political commitment is low, this would be a more realistic management option. Another option would be simply to enforce existing regulations against anchoring on *P. oceanica* in the Cala without installing any buoys. If social factors are taken into consideration, a limit of 28 boats would also have to be enforced.

A relevant planning concept that has not been addressed in this study is the recreational opportunity spectrum (ROS) (Clark and Stankey, 1979; Driver and Brown, 1978) which has also been developed specifically for marine environments (Orams, 1999). This concept is based on the realization that different physical settings (e.g. rural, urban) are appropriate for different types of activities and for accommodating the needs and desires of different types of visitors. Roman et al. (2007) propose zoning as part of the LAC process for managing snorkelling tourism in Marine Protected Areas. Gray et al. (2010) also suggest that different boaters may have differing definitions as to what constitutes a natural setting

and should therefore be provided with a variety of recreational options. This aspect of the LAC process, which is referred to as opportunity class allocation in the original documentation (Stankey et al., 1985), was not incorporated in the methodology for this study because it was only applied in one location. However, should this research be extended to include other Calas on the island, the ROS would be a relevant component of a broader LAC process. Managers wishing to maximize use levels of Cala Xinxell might also consider the option of allowing more visitors to use the Cala at weekends than during weekdays in order to accommodate the different needs of weekend and weekday users.

Finally, it is important to note that, as mentioned in the section on Methodological considerations, this study only takes into account two major impact variables (crowding and impacts on *P. oceanica*), which can be managed *in situ*. However, there are a number of other impacts that should also be taken into account in a broader management context. Pollution, from both solid and liquid waste, is particularly important. A small number of boats, if they do not dispose of waste properly, can have profound negative impacts on the marine environment regardless of any efforts to limit use levels. Cleaning products used in the harbour or oil that is not properly disposed of during oil changes can also be extremely harmful to the marine environment. In this context, the implementation and enforcement of Best Practices of recreational boating, supported by local facilities and regulations, are essential complementary actions to the proposed management measures. This study also does not take into account economic factors, which would need to be considered if buoys were to be installed with associated mooring fees. Economic valuation of recreational boating activities and the losses associated with lowered satisfaction and decreased visitation rates could also be useful for generating motivation to manage this activity at the governance level.

The potential management measures described above should be extended to other Calas, include regulatory measures and infrastructure development in Ports and, in the future should also take into consideration the interrelationship of recreational boating with other sectors using the marine and coastal environment. This necessitates an integrated approach to management of marine and coastal resources on the island, which is currently being developed in an ICZM framework (see Section 1.2).

5. Conclusions

This study proposes a simple, low-cost methodology that may be used to establish management measures for any bay (locally or internationally) used for recreational boating and could be applied in other recreational environments or in additional situations where environmental and social goals need to be balanced (e.g. in a beach environment (Pereira da Silva, 2002)).

All of the proposed management options would require the dedication of financial resources because they would need to be actively enforced. The most restrictive and expensive option would be the most desirable from the perspective of maintaining environmental and social criteria in the long term and therefore is the one that is most strongly recommended. However, as is often the case in sustainability scenarios, maximizing environmental protection and social well-being for the long term requires a short term financial investment. This could imply a political risk, particularly in times of financial crisis, and is also dependent on the availability of resources. This reality can overshadow the long-term benefits of the proposed actions. In this context, science-based management advice must be amenable to local socio-economic and political realities to avoid alienating decision-makers and promote the highest level of action possible given that reality. Once some measures are in place and the benefits become evident, this can be a way of promoting further, more stringent actions.

In practical terms, this study goes a step beyond many articles that propose complicated models and frameworks for addressing sustainability problems. Where such developments are undoubtedly essential to advancing knowledge, in today's climate of rapid growth and global change, science also needs to take a practical approach to solving sustainability problems, which might mean accepting more uncertainty and compensating with more precaution. Studies such as this that combine perception data with on site observations and biophysical data can be useful for identifying limits which are based on environmental and social parameters.

The LAC process was originally applied to protected areas, but can be extended to accommodate a wide range of sustainability scenarios (Cole and Stankey, 1998; Ahn et al., 2002). Potential conflicts between resource protection and use are not just characteristic of protected areas and are particularly prevalent in island tourism destinations such as Mallorca where space is limited, there are many competing uses of coastal and marine areas, and preservation of the local environment is critical. Since the LAC process was established in 1985, continued debates about the application and overall utility of the recreational carrying capacity concept have resulted in the development of a number similar processes aimed at balancing visitor use and natural resource protection through the establishment of site specific management measures, indicators, and associated standards for informing management and monitoring site conditions (Graefe et al., 1990; National Park Service, 1997). Integrated frameworks for managing marine and coastal environments such as ICZM (Cisin-Sain and Knecht, 1998; Intergovernmental Oceanographic Commission (IOC) of UNESCO, 1997) and MSP (Ehler and Douvere, 2009) are similar in their approach to defining management objectives, indicators, goals, monitoring and actions using a participatory process. The widespread use of such frameworks is a testament to the fact that sustainability, although it is a universal concept, only becomes operational in locally specific contexts (Gale and Cordray, 1994; Kelly, 1998). Processes such as LAC, nested in broader frameworks such as ICZM, can help provide a systematic, replicable way of defining the necessary elements of sustainability on a case by case basis.

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