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Multiple Carrying Capacities from a management-oriented perspective to operationalize sustainable tourism in protected areas

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ABSTRACT

This article describes how the concept of Tourism Carrying Capacity (*TCC*) has shifted from a unidimensional approach to incorporating environmental, social and political aspects. This shift is demonstrated by a study of a large, internationally popular protected area used by trekkers, the Mt. Everest Region, where qualitative data collected from visitors was combined with environmental modeling using a participatory framework. Tourist satisfaction showed positive margins for further tourist industry expansion, but current environmental conditions limit growth and further development. Space and time dimensions were also considered. We observed that the limits on growth and further development can be manipulated, with a certain degree of flexibility, through investments and regulatory measures. We hypothesized that *TCC* can play an important role in the management of protected areas only if it is viewed as a systematic, strategic policy tool within a planning process rather than as a unique, intrinsic number that is not modifiable. We conclude that to translate the strategy into action using standard measures, further investigation is needed to balance the various *TCC* components as a part of a decision-making framework that includes the integration of different cultural approaches and policy needs.

1. Introduction

As emphasized by the World Tourism Organization (WTO), tourism operations in protected areas need to be carefully planned, managed and monitored to ensure their long-term sustainability (WTO, 2005). Otherwise, such operations will have negative consequences, and tourism will contribute to the further deterioration of these areas. While the negative effects of tourism are of significant concern, many protected areas have promoted tourism development to improve their economic conditions, particularly to generating revenue to finance other social and economic development activities and to provide direct income and employment opportunities for local people (Nepal, 2002, 2005; WTO, 2005).

The debate on the limits of growth is not new; it has existed since the 1930s in the case of the tourism sector (Saveriades, 2000). Starting as early as the 1960s, outdoor recreation research used the concept of *Tourism Carrying Capacity* (*TCC*) to address the resource and social effects of visitor use (Wagar, 1964; Manning et al., 1999; Lawson et al., 2003). The concept has been adopted by researchers and managers in the context of tourism and environmental sciences to address financial resources and avoid negative social impacts (Manning et al., 1996). It mainly includes ecological and social parameters, such as environmental quality and visitor experience, respectively, and is conventionally defined as "*the maximum number of visitors which an area can sustain without unacceptable deterioration of the physical environment and without considerably diminishing user satisfaction*" (Mathieson and Wall, 1982; Prato, 2001). Clearly, the basic element of this concept is the need to establish a limit on tourist activity that reflects the concerns and priorities of local managers and planners (Coccossis and Mexa, 2004).

By the early 1990s, the concept of *TCC* was largely replaced by the idea of *sustainable tourism*, but many of the challenges outlined for this new concept are similar to past issues concerning *TCC* in terms of definition of objectives, practices, utility and diversity of types (Navarro Jurado et al., 2012). Both ideas emphasize the need to limit tourism growth and determine which changes to the

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Nomenclature

TCC	Tourism Carrying Capacity
SCC	Social Carrying Capacities
ECC	Environmental Carrying Capacities
SNPBZ	Sagarmatha (Everest) National Park and Buffer Zone
SOT	Spreading Over Time scenario
SOS	Spreading Over Space scenario

physical and social environment are deemed acceptable (Butler, 1999; Liu, 2003).

In the meantime, the need for a limit defined by the concept of *TCC*, although widely used, is subject to a significant amount of criticism, casting doubt on the concept's ability to be replicated in different situations (e.g., Lindberg et al., 1997; McCool and Lime, 2001). However, it is surprising to see that a concept that is so criticized remains widely used and has been developed in various ways to consider ecological, economic, sociological and perceptual aspects (Briassoulis, 2000; Papageorgiou and Brotherton, 1999; Buckley, 1999). This may well be due to the absence of attractive alternatives (Hausser et al., 2006). Watson and Kopachevsky (1996, 177) indicated that "the fact that we have not devised tools with which to measure *TCC* does not justify dismissing it from the discussion." However, the debate has not concluded because there is an interest in presenting theoretical and practical advances in scientific research. An example is the systematization that Saarinen (2006) applied to sustainability limits. Consider also that the (legitimate) demand of managers of natural resources for estimates of measurable thresholds beyond which ecosystem functions become irreversible has prevented some researchers from discarding the concept of *TCC*, even though it implies substantial uncertainty and complexity (Castellani and Sala, 2012).

In this context, following the example of Navarro Jurado et al. (2012), the goal of this study was not to break any paradigms but rather to revive the present debate on growth limits in tourist destinations, looking for solutions to the main weaknesses of this approach and contributing to the operationalization of sustainable management of protected areas.

2. Case study

This study was conducted as a 3-year (2006–2009) project (http://www.evk2cnr.org/cms/en/research/integrated_programs/hkkh) developed using the framework for the Plan of Implementation of the 2002 World Summit for Sustainable Development (UN, 2002), with the goal of creating methodologies to facilitate the management processes of protected mountain areas (Amatya et al., 2010). The Sagarmatha (Everest) National Park and Buffer Zone (*SNPBZ*) in Nepal was the main case study for this project, due to the abundance of information available about the local socio-ecological system. The *SNPBZ* is the world's highest protected area. Exceptional natural beauty and diversity in cultural and biological endowment dominated by Mount Everest make *SNPBZ* a prime destination for nature, unique cultural attractions (i.e., the Sherpa culture and ancient Buddhist monasteries) and adventure loving tourists (Salerno et al., 2010a). Normally accepted criteria for management of Nepali national parks have been substantially modified in the case of Sagarmatha in order to reconcile the requirements of the resident population with those of conservation objectives and to accommodate special demands made on the area by tourism and mountaineering. Objectives outlined in the management plan seek to ensure the protection of wildlife, water and soil resources, not only because of the park's national and international significance but also to safeguard the interests of the resident local population (DNPWC, 2003).

2.1. Tourist profile

When Sir Edmund Hillary and Tenzing Norgay Sherpa climbed Mt. Everest in 1953, the area was brought to the attention of international mountaineers, trekkers and explorers. However, access to the *SNPBZ* (1400 km^2) was difficult, and visitors had to hike for two weeks to reach Namche from Kathmandu. This situation changed drastically when the Lukla airstrip was built in 1964. The number of tourists increased from 20 visitors in 1964 to 30,599 in 2008, with a major decrease coinciding with both the internal civil conflict and the terrorist attacks of 11 September 2001, which increased fear of flying among people worldwide (Fig. 1(a)). Visitors are most abundant during the spring and autumn, while there are almost none during the monsoon period from June to August (Fig. 1(b)). The increase in tourism has created new job opportunities for the local people, most of whom have become minor entrepreneurs, leading to a change in the local economy (Daconto and Sherpa, 2010). Up to the present, the number of visitors to the *SNPBZ* has never been limited to avoid negative effects on the rural poverty level (Nepal, 2000).

In this paper, we refer to the most popular trails, assuming that the number of visitors in Namche is equal to number of visitors entering the park at Monjo (Basnet, 1993; Nepal, 2003). Therefore, our analyses are focused on trails 2–7, (Fig. 1(c)). The tourist flow pattern along the park trails in autumn over the last 30 years (Basnet, 1993; Nepal, 2003 and this study) shows that the number of visitors directed to Mt. Everest (trails 3 and 4) has decreased, particularly between 1978 and 1997, in favor of all other trails. In particular, we observe an increased interest for the central ring (trails 5 and 7 via Gokyo & Dzonghla) and Island Peak (trail 6 via Chukung) and a slight increase for the trail to Thame (trail 2).

3. Tourism carrying capacity: re-evaluation and principle setting

The main criticism is that made by McCool and Lime (2001), who note that at an ontological level, we are unable to evaluate whether this limit is an intrinsic or innate feature of the system or whether it is driven by human and political objectives. Such a limit cannot be an intrinsic feature of the system, and thus, for these authors, it does not exist. We agree instead with those authors who consider both aspects of *TCC: the intrinsic and cultural aspects* (e.g., Lawson et al., 2003; Saarinen, 2006; Navarro Jurado et al., 2012). Both of these aspects contribute to determining the sustainable limit to growth and are included in the concept of sustainability (Saarinen, 2006), which, in our opinion, provides the means of incorporating *TCC* in a decision-making framework. The first aspect, as suggested by Navarro Jurado et al. (2012), represents the descriptive component of the system, which defines the resource status (State), the response (Impact) to tourist (Driver) pressure (Pressure) and the possible management mitigation (Response). Therefore, the intrinsic aspect can be evaluated using an approach such as DPSIR (Driver, Pressure, State, Impact, Response), (EEA, 2005). The cultural aspect (Saarinen, 2006) is dictated by the need to define a threshold of acceptability with respect to the social and environmental aspects of the system. Saarinen (2006) states that the local community is better able to define limits for the protection of resources than the tourist business. In this regard, as will be detailed below, we agree with those authors who stress that the management of systems where human–ecosystem interactions are intricately linked must be assisted by a participatory approach involving interested stakeholders. Pirot et al. (2000) give 4

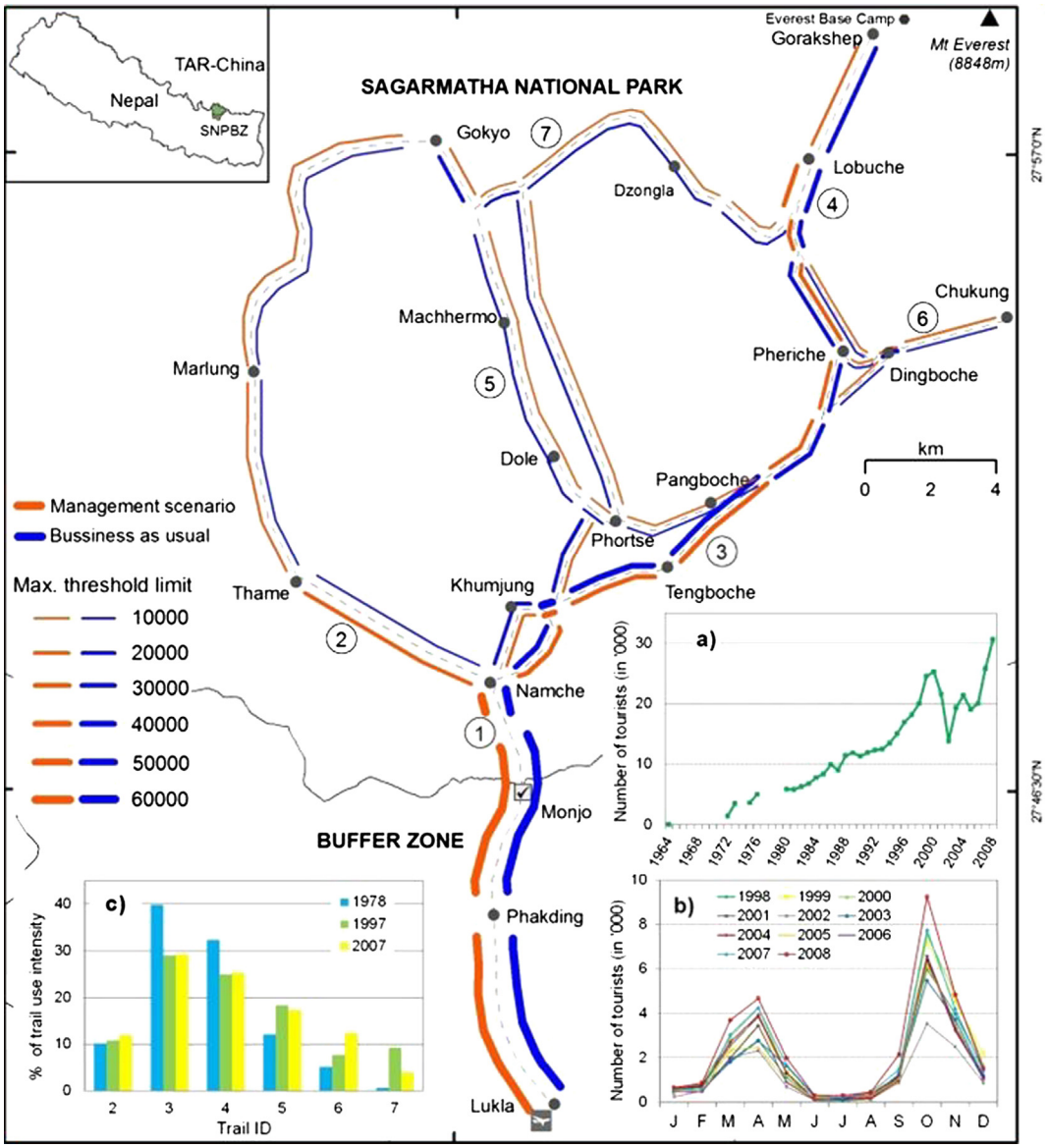

Fig. 1. The map of the Sagarmatha National Park and Buffer Zone (*SNPZB*) with indications of the main settlements, tourist trails, and major cultural attractions. (a) Yearly entrances in the park from 1964 to 2008. (b) Monthly tourist flow (1998–2008). (c) Autumn tourist flow patterns along the park trails over the last 30 years: 1978, 1997 and 2007 (present study). See Suppl. material (2).

justifications for stakeholder participation: (1) local stakeholders have a strong interest in the management process, being dependent on the services that ecosystems provide; (2) they often have considerable relevant knowledge of the ecosystem and the ways in which it can be managed; (3) in some cases, the cultural, ethical, and spiritual values of local stakeholders have developed on the basis of a longstanding interaction with an ecosystem, so their interest goes beyond simply deriving material benefits from the system; and (4) in many cases, they have developed local use or tenure systems that can be adapted to the aims and objectives of an ecosystem management program (see also Bajracharya et al. (2010)).

The second criticism, highlighted by many authors and well described by Saarinen (2006), consists on the one hand, of recognizing, and on the other hand, of integrating the various aspects and perspectives of *TCC*, which can differ in focus and in relation to the resources used. The result is that limited evidence of the application of *TCC* exists in practice. Most of the existing experience pertains to coastal areas and islands, although all protected areas represent possible cases for the application of *TCC*, considering that carrying capacity issues concern the number of tourists, visitor flows, protection of nature and the quality of the experience for visitors (Manning, 2002; Coccossis and Mexa, 2004). The application of *TCC* is often limited to a few measurable dimensions, which may limit its use as in planning.

Some authors continue valorizing two central components of *TCC*. Among these authors (Seidl and Tisdell, 1999; Manning, 2007), according to the definition of Lawson et al. (2003), the *Social Carrying Capacity* (*SCC*) refers to the level of visitor use that can ultimately be accommodated in parks and protected areas without considerably diminishing the quality of the visitor's experience and satisfaction beyond an acceptable degree. This concept considers crowding tolerance, including in this way the *Perceived Carrying Capacity* (*PCC*), as suggested by Pearce (1989). Assessing *SCC* provides an understanding of the pressures on ecosystems that contributes to the implementation of public policies that enable authorities to develop responses in view of the development of "sustainable tourism" (Hunter, 1997; Saveriades, 2000; Saarinen, 2006). Using the concept of a destination life cycle, *SCC* can be

matched to the upper limit of the tourism business (Saarinen, 2006). The other main *TCC* component is the *Environmental (Physical and Ecological) Carrying Capacity* (*ECC*), which reflects the impacts on ecosystems, the built cultural environment and the infrastructure (Coccossis and Mexa, 2004). The physical–ecological set comprises fixed and flexible components. The first of these pertain to the capacity of a natural system. They cannot be manipulated easily by human action, and to the extent that these limits can be estimated, they should be carefully observed and respected as such. The "flexible" components refer primarily to infrastructure systems such as the water supply, sewerage, electricity, transportation and social amenities (Coccossis and Mexa, 2004; Castellani and Sala, 2012).

Few studies have combined both *Social* and *Environmental Carrying Capacities* (*SCC* and *ECC*) (Patterson et al., 2004; Schianetz et al., 2007); most studies have focused on each of these aspects separately (Coccossis and Mexa, 2004; López-Bonilla and López-Bonilla, 2008), thus violating the requirements of sustainable tourism analysis (Saarinen, 2006). The main effort of the present study was to analyze jointly the different aspects of *TCC*, thus avoiding violating the requirements of sustainable tourism analysis (Saarinen, 2006). In Section 3.5, based on the studies by Diedrich et al. (2011), Saveriades (2000) and Papageorgiou and Brotherton (1999), the limits of tourism growth are defined according to the visitors' perception of the main issues of the park, the effects on local communities (protection of local traditions), their level of satisfaction with their visit to the *SNPBZ* (*SCC*), and the deterioration status of the resources (*ECC*).

4. Methods and data

4.1. Participatory modeling framework

The assessment and implementation of *TCC* needs to be considered within a wider planning process for tourism development (e.g., Saarinen, 2006). These should be carried out in the context of democratic community strategic planning, which requires the participation of all major actors and the community at large (Coccossis and Mexa, 2004). In this study, we implemented the participatory modeling framework developed by Salerno et al. (2010b). This framework, based on local stakeholders' demands and needs, consists of 5 stand-alone modules coupling hard and soft methodologies. It begins with a participant-led system bounding (Module 1), including a historical profile, assessments of issues and drivers, and the development of a common understanding of the future (presented in Section 4.1). Module 2 (*Qualitative modeling*) represents the conceptualization of the system, exploring the socio-ecosystem in an iterative way (refer to Salerno et al., 2010b). *Management-oriented research* (Module 3) uses the outputs from Modules 1 and 2 to define data requirements to supplement mental models with quantitative relationships (presented in Section 3.2 and the Suppl. material (1)). Module 4 (*Quantitative modeling*) makes it possible to properly anticipate system change by employing mathematical models, theories, and hypotheses pertaining to natural phenomena (presented in Sections 3.4 and 4.3). *Adaptive management* (Module 5) is an iterative and cyclic stakeholder evaluation of the process and outcomes in terms of policy and management implications (presented in Section 4.4 and the Suppl. material (1)).

4.2. Survey methods

Management-oriented research was carried out to assess the park's forest conditions, energy situation, solid waste management and water quality in field campaigns conducted between 2006 and 2008. A description of the data and methods can be found in Salerno et al. (2010a) and Manfredi et al. (2010). To collect information on visitor flow (i.e., quantification of visitors entering the park, their profiles, trip information and destinations) and to investigate their perceptions about the issues of major concern in the park, a field survey was conducted from October through November 2007 and from the middle of March to the middle of June 2008, to ensure the collection of comprehensive information concerning one year of tourism in the park. The level of participation for the surveys was high, with 5000 questionnaires completed and analyzed (over 20% of the entering visitors for the season). See Suppl. material (1) for details on survey methods.

4.3. The use of a Time-for-Time substitution model to assess the Social Carrying Capacity

The space-for-time substitution assumes that spatial and temporal variations are equivalent (Pickett, 1989). In our case, considering that we wish to evaluate the impact of tourist pressure on the perceptions of visitors and their overall satisfaction, it is not possible to apply this substitution because the same driver may result in different impacts depending on the condition of the local tourist site. Otherwise, a time-for-time substitution (weekly for year) could be considered effective within the same site. Less congested weeks at the park are representative of the mean annual conditions that the park could have experienced in the past. Additionally, the more crowded weeks are representative of a future situation that could be determined by assuming a continuous increase in the number of tourists. The correlation between the weekly number of tourists and the relevant number of annual entrances was determined by matching the actual average weekly number of tourists (588) with the current number of annual tourists (30,599) and extrapolating the other values proportionally. The large weekly fluctuations (standard deviation equal to 590 visitors, 100% of the average) of tourist entrances allowed the exploration of changes in perceptions in relation to different levels of resource use.

4.4. Individual-Based and System Dynamics models used to determine the Environmental Carrying Capacity

Two major non-linear and complementary modeling techniques can be applied in participatory modeling to analyze the complexity of a socio-ecological system: Individual-Based modeling (*IB*) (Bousquet and Le Page, 2004) and System Dynamics modeling (*SD*) (Forrester, 1994). Here, we used the *IB* technique for modeling the tourist flow with the goal of capturing and analyzing its main dynamics by simulating the behavior of a single individual (the visitor). In contrast, the main environmental dynamics were modeled using the *SD* technique, which requires more data.

The overall structure developed here to assess the *ECC*, explored during the qualitative modeling phase (Module 2), is described in Fig. 2. The flow of information occurs through the variable, number of tourists, which is provided as an output from the *Tourism Flow sub-model* to become an input for the other sub-models. This sub-model simulates the daily flow of visitors entering the park according to their itinerary and combines those data with the current accommodation capacity to determine the daily overcrowding index for each village (18 settlements). The *Energy sub-model* simulates the monthly energy demand and supply for each village. The *Forest sub-model* was developed to address the problem of decreased forest biomass due to fuel-wood extraction (13 forests, yearly time step). The *Solid Waste sub-model* simulates the monthly process of waste production, collection, and treatment, providing the amount of solid waste produced, treated, and discarded in the

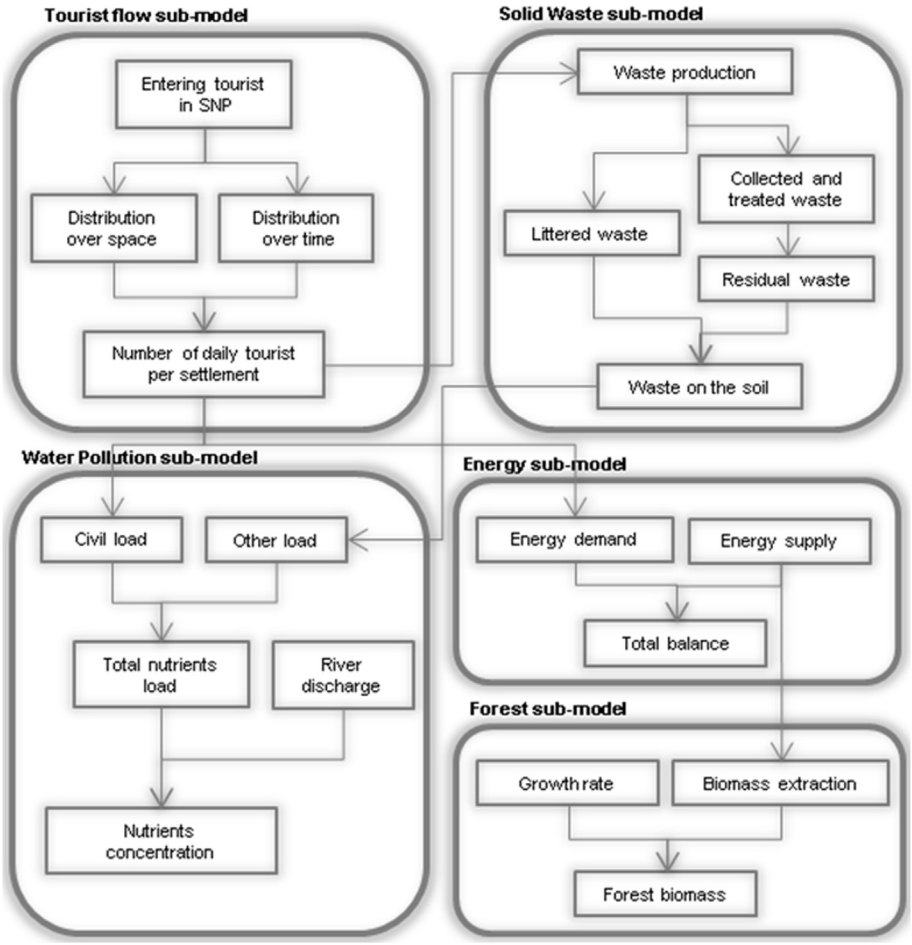

Fig. 2. The overall modeling structure used to assess Environmental Carrying Capacity in the Sagarmatha National Park.

soil (18 settlements). The *Water Pollution sub-model* was developed for evaluating the monthly water quality in selected stream sections (5 watersheds) by assigning a judgment of excellent, good, sufficient, poor, or very bad. Descriptions of the sub-models, including their design, objectives, and main outcomes, are provided by Salerno et al. (2010a) and Manfredi et al. (2010).

4.5. Indicators and acceptable thresholds

The tourist perception of the main issues of the park (Suppl. material (1)), their general level of satisfaction and the deterioration status of investigated resources are cross-referenced with the number of tourists (Fig. 3). The point of convergence, i.e., the point where the percent of respondents who perceive that the degree of deterioration is adequate equals the percent of respondents who perceive the contrary, represents the number of tourists (C-per$_i$) that corresponds to the perceived acceptable threshold for each investigated sector (Fig. 3(a)) (Diedrich et al., 2011).

Destination life cycle analysis provides an indication of the likely behavior of tourists as a destination becomes more popular. Visitor satisfaction (Suppl. material (1)) declines as the use level increases due to a decrease in marginal satisfaction, allowing the identification of a level (C-sat) beyond which satisfaction begins to decline (Fig. 3(b)) (Saveriades, 2000).

Increasing levels of use have an increasingly damaging effect on the investigated resource (i). The level of use that causes unacceptable damage sets the threshold for each resource (C-env$_i$) (Fig. 3(c)) (Papageorgiou and Brotherton, 1999). The indicators of the deterioration status of resources, the relevant reference conditions (thresholds), and the divergence degree between their current condition and the established reference are detailed in the Suppl. material (2).

5. Results

5.1. System and problem bounding

In agreement with Walker et al. (2002), who like us sought to analyze the system starting from a local perception, from which the real issues and drivers of change could emerge, we adopt the Scenario Planning method (Schwartz, 1998), which permits the creation of models that address the major issues of concern to stakeholders and decision-makers and explore how the system will respond to drivers of change. This activity allows the system to be bounded by restricting the analysis solely to specific aspects rather than investigating the whole system.

Daconto and Sherpa (2010) report in detail on our experience in applying Scenario Planning in the park context. Here we underline how this tool became part of the general context of the overall participatory modeling process. It was introduced through 2 exploratory scenario workshops involving different key local stakeholders, such as representatives of the tourism industry, NGOs and trade associations, religious institutions, park managers, decision-makers, development and research organizations, and park communities. Participants were asked to identify the key events and changes in the *SNPBZ* over the last 100 years and to

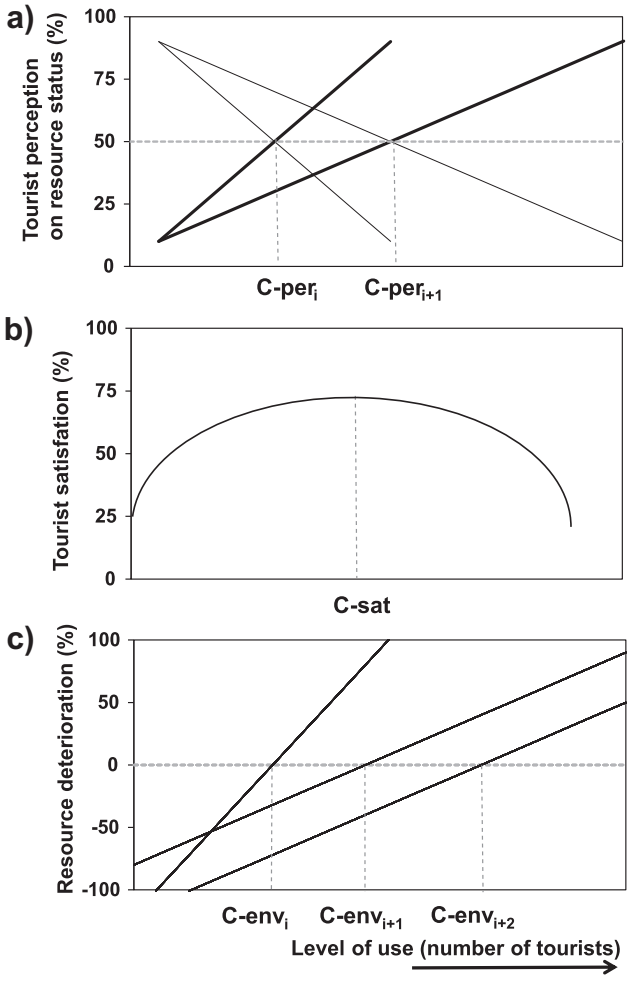

Fig. 3. Acceptable thresholds. (a) Tourist perceptions. The thin, black lines show the perception of acceptability or unacceptability, respectively. C-per$_i$ represents the number of tourists corresponding to the perceived acceptable threshold for each sector investigated (i). (b) Aggregate tourist satisfaction. C-sat represents the total number of tourists that maximizes tourist enjoyment. (c) Deterioration status of resources. C-env$_i$ represents the number of tourists corresponding to the modeled acceptable threshold for each resource investigated (i).

imagine and write credible descriptions of the status of the park 25 years in the future (what they hoped to see and their main fears about what they might see). They were also asked to identify major questions, challenges, and concerns about the future of the *SNPBZ*.

A high level of consensus emerged regarding the main challenge: "*How can quality and sustainable ecotourism be developed in the SNPBZ?*" As the main output, a text-based exercise allowed stakeholders and decision-makers to identify the increase in tourism as the main driver of change. Most of the participants agreed that energy consumption, the forest state, water pollution, and solid and human waste management are the main areas in which a further increase in the number of tourists could have negative impacts.

5.2. Social Carrying Capacity

Visitors were asked to judge the level of crowding perceived during their visit as well as the status of the water quality, the energy efficiency, the solid waste management and the protection of local traditions (Suppl. material (1)). In Fig. 4, we can observe that there is a significant relationship between the response of tourists and the number of tourists ($p < 0.001$) on all outcomes except for the protection of local traditions. For all significant relationships, we observe that an increased number of tourists in the park corresponds with a judgment of greater inadequacy with respect to the issue (the black lines).

The slope of these relationships is greater for crowding ($m = 7 * 10^{-4}$). In contrast, over 75% of the visitors consider the protection of local traditions unsuitable, independent of the number of tourists entering the park ($m = 0 * 10^{-4}$ and $R^2 = 0.04$). The perceived acceptable threshold is determined to be 32,500 visitors for crowding, 31,000 for water quality and 45,000 for energy management. No point of convergence is reached with regards to the perception of waste management. For this sector, a decline in management is observed with an increasing number of tourists, but the majority of them consider the levels of waste disposal to be inadequate.

Tourists were also asked to provide an opinion on their experience in the park (Suppl. material (1)). The majority responded that they were satisfied (51%) or very satisfied (30%) with their experience. Fig. 4(f) shows the re-coded responses for tourists were satisfied or very satisfied (Suppl. material (1)). We can conclude that visitor satisfaction increases until a threshold of 34,000 tourists is reached, beyond which satisfaction begins to decline (see Fig. 3(b)).

5.3. Environmental Carrying Capacity

The business-as-usual scenario, obtained by running the model without implementing a management strategy, has been tested using data acquired during the management-oriented research (Module 3). This phase set the model parameters using field data (Salerno et al., 2010b). Different scenarios were developed by varying the current number of annual tourists but maintaining the seasonal distribution observed for 2008 (Fig. 1(b)). In Fig. 4(g), the resource status at the park level and on an annual basis, represented by the indicators reported in the Suppl. material (2), is plotted against the number of tourists. It is defined as the percentage divergence between the current status of the resource and the established reference condition. The business-as-usual scenario is represented by the intercept point between each trend and the actual number of annual tourists (vertical red line). We can observe that river water quality, solid waste and overcrowding index present a value under the threshold of −10%, −11%, and −86%, respectively. The actual mean river water TP concentration is 0.13 mg L^{-1}, compared with a referenced "Good" condition of 0.15 mg L^{-1}. For the solid waste management, we found a monthly mean of 720 kg of waste in each settlement compared to a reference of 815 kg (collection efficiency equal to 100%). The relevant trends show that the threshold could be reached with 32,000 and 40,000 annual tourist entrances, meaning that the actual number of tourists entering the park (30,599) is appropriate to guarantee suitable conditions for these sectors. Conversely, the energy demand and the forest biomass are at unsuitable levels (12% and 33%, respectively) under the current number of visitors. The actual energy deficit corresponds to approximately 1.8 GWh y^{-1} (e.g. a new hydropower plant (200 kW) or two or three micro-hydropower plants similar to those already installed in the park). In the period between 1992 and 2008, there was a mean annual loss of 2.3% of the forest biomass (Salerno et al., 2010a). These deficiencies would be mitigated with 17,000 entrances, 23% less than the current number of visitors, with respect to energy and with 14,700 entrances, 53% less than the current number of visitors, with respect to forest conditions.

5.4. Tourism Carrying Capacity over time and space

The park is characterized by disproportionate trail use and tourism seasonality (Fig. 1(b) and (c)). As a consequence, *TCC* needs

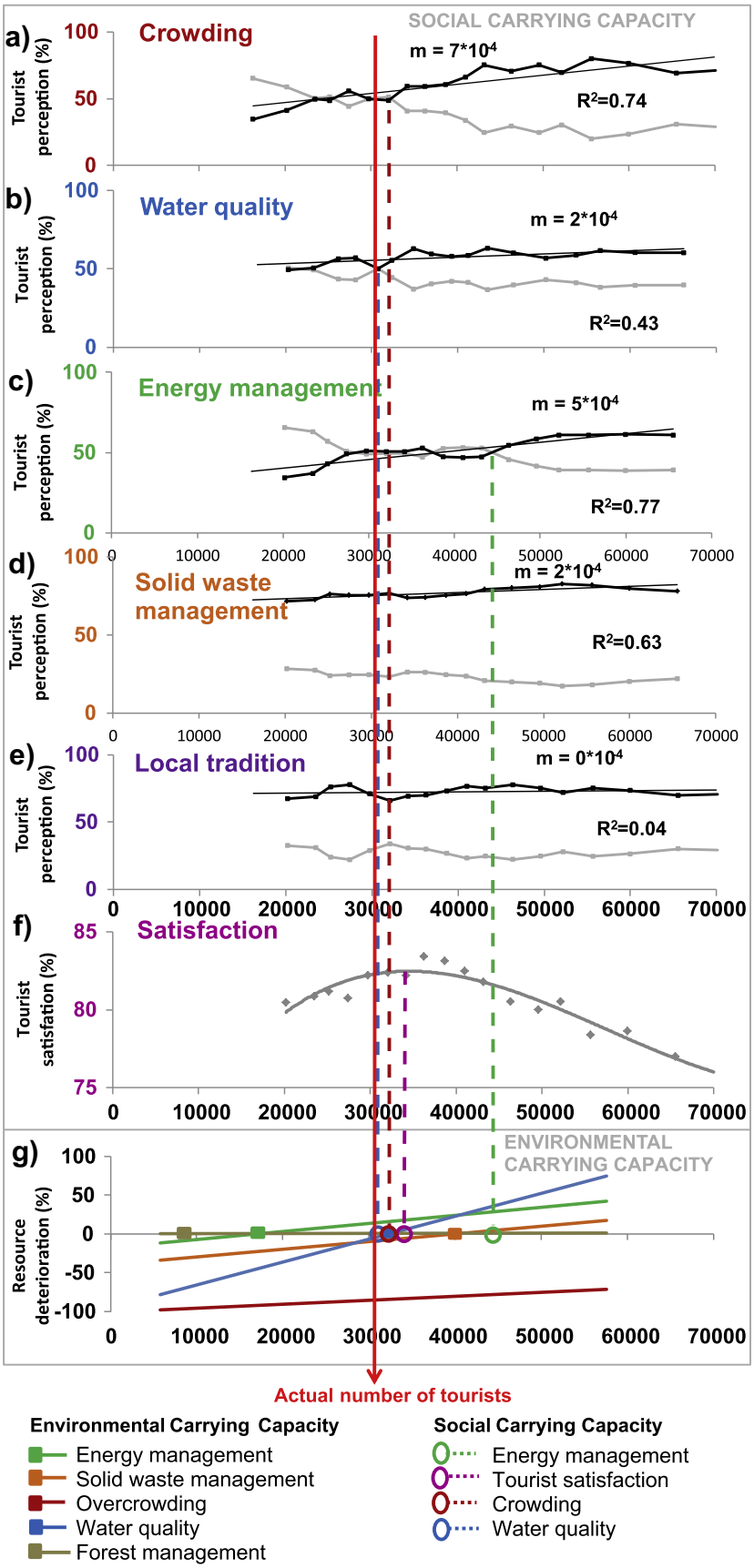

Fig. 4. Joint analysis of different aspects of Tourism Carrying Capacity in the Sagarmatha National Park. For all graphs the *x*-axis represents the number of annual tourists entering in the park. From (a) to (e) tourist perceptions of resource status. The *y*-axis represents the percentage of responses. The thin and the black lines show the perception of acceptability or unacceptability of the resource status, respectively (see Fig. 3(a)); m = slope. (f) Aggregate tourist satisfaction (see Fig. 3(b)). The *y*-axis represents the percentage of satisfied or very satisfied tourists. (g) Modeling of the deterioration status of resources (see Fig. 3(c)). The *y*-axis represents the deterioration status defined as the percentage divergence between its current condition and the established reference (threshold) (see Suppl. material (2)).

to be analyzed in relation to the spatial and temporal heterogeneity of the visitor flow. Here we show only *ECC* (Fig. 5), but an analogous pattern was observed for *SCC*. Local stakeholders involved with solving these critical issues agreed to analyze the management scenarios that would spread the tourist flow over time (*SOT*) and space (*SOS*). The feasibility of these model scenarios is based on the recreational possibilities constrained by the climatic conditions for the SOT (Suppl. material (1)) and on prior experiences for the SOS (Fig. 1(c), Suppl. material (1), scenario 2).

We observe in Fig. 5 that the actual energy deficit is concentrated during the two tourist seasons (around 50% in spring and 90% in autumn), while the other months do not experience an energy deficit. Along the trails, the deficit is more evident for trails 3, 4, and 6 (around 40%). Therefore, the overall annual deficit (12%) is due to the tourist season and the more crowded trials. The implementation of the spreading over time (*SOT*) as well as the spreading over space (*SOS*) scenarios is able to reduce the deficit to approximately 25% in autumn and to 30% along the mentioned trails. Even for solid waste management, the main issues are localized during the tourist seasons (over 30% in April and October). The other months register a suitable condition that, on an annual basis, determines a mean annual sustainable management (−11%). Considering the spatial distribution of waste management, there is no single trail with a particular critical situation. The *SOT* scenario is able to improve the management efficiency by reducing the negative conditions for the mentioned months to 35%. The river water quality sub-model reveals that the TP concentrations range between 0.02 and 0.66 mg L^{-1}, reaching the worst conditions ("Very bad") in November, due to the high tourist pressure, and in December, due to low river discharges (Salerno et al., 2010a). The implementation of the *SOT* scenario does not produce any significant effects on river water quality, but an improvement (40%) is reached for trail 2.

6. Discussion and lesson learned

We explored the major concerns of local stakeholders with regard to tourist management. The park's *TCC* is currently limited by the quality and quantity of energy available in the park. The loss of forest biomass is caused by an increasing demand for fuel–wood, which is used as the main source of energy for heating and cooking, and leads to fragmentation, decreased forest thickness and general habitat deterioration (Salerno et al., 2010a). Solid waste management and river water quality show critical conditions related to the tourist season and along the main trails, although tourists consider waste disposal to be unacceptable, independent of the number of tourists present in the park. Moreover we explored the tourist perception on the current protection of local traditions. Our findings demonstrate that the lack of protection is perceived independently from the number of tourists. Therefore it makes no sense to assume a limit to growth, but rather regulatory measures. On the other hand, the actual degree of tourist satisfaction still indicates room for further development of the tourist industry, although, due to current conditions, the *ECC* imposes harsh limitations on future growth.

Nevertheless, the *ECC* components can be manipulated with a degree of flexibility, which means that the induced restrictions to growth might be mitigated through investments and regulatory measures (Coccossis and Mexa, 2004). We have observed that policies designed to spread the number of tourists over time (*SOT*) and space (*SOS*) can increase the *ECC* for the investigated sectors. On the other hand, Salerno et al. (2010a) and Manfredi et al. (2010) propose management scenarios and the assessment of relevant costs to completely bridge the energy deficit, preserve sustainable forest conditions, establish restrictions, promote alternative energy

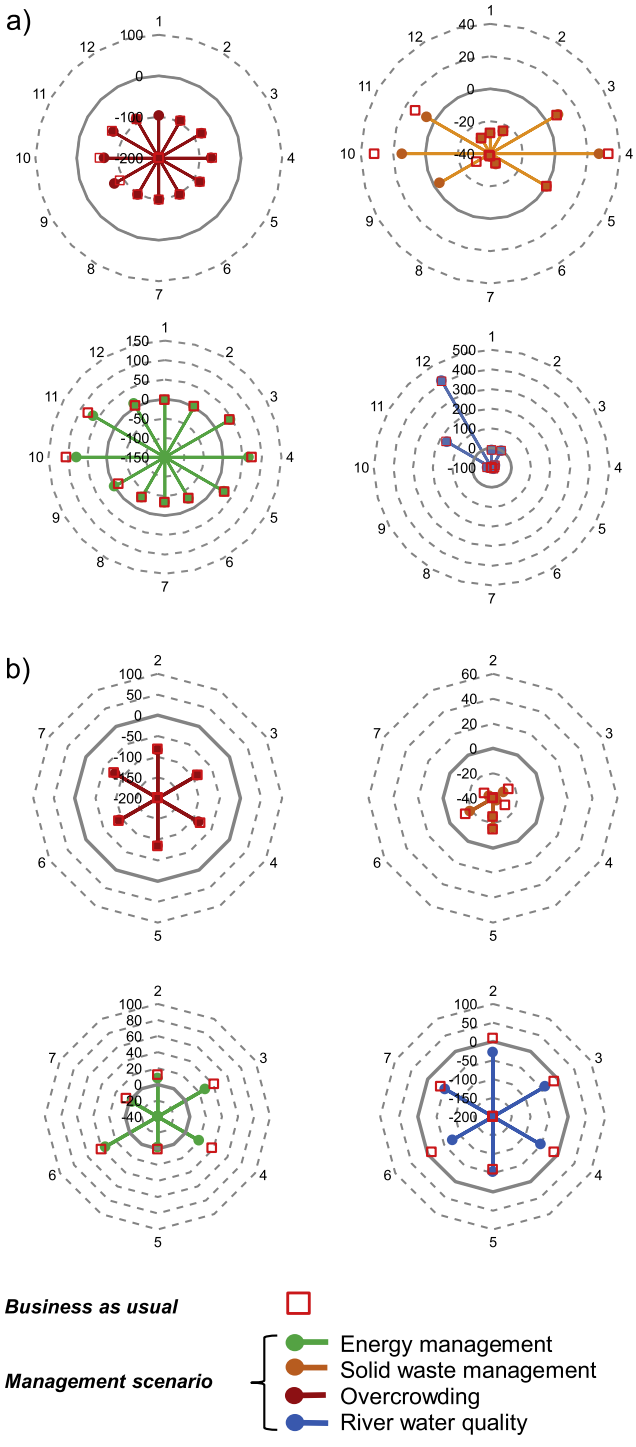

Fig. 5. Assessment of Environmental Carrying Capacity over time (a) and space (b) and relevant modeling scenarios aimed to reduce tourist congestion and relevant impacts (Month and Trail ID on circular axis, respectively; Indicators of the deterioration status of resources on radial axis. See Suppl. material (2)).

sources, dispose of and properly treat solid waste, and to mitigate the impact of tourists on river water quality. Regulatory measures are also proposed for protecting local traditions (Spoon, 2011).

In this study, *TCC* is viewed as a systematic, strategic policy tool within a planning process rather than a unique number that is intrinsic and unable to be modified. The *TCC* must not be used as an absolute limit, but as a means to identify acceptable thresholds that need attention and by removing obstacles, where possible, or

applying controls. By using a participatory approach, *TCC* can be used as a problem-structuring, consensus-building tool, as a problem-solving method, or both. We realized how important it is to have flexibility in the framework: it is possible to interrupt the process at any time under different conditions (local constraints, specific project aims, availability of funds, participants' attitudes and backgrounds), without losing the value of the participatory and exploratory work achieved. In the future, this process could be used to identify key management-oriented data to monitor *TCC* over the long term and to involve key stakeholders in field surveys, thus increasing awareness and capability (Lawson et al., 2003; Amatya et al., 2010).

A further challenge is the need to balance the various *TCC* components both temporally and spatially. Thus, *TCC* has shifted to a multi-dimensional tool that incorporates environmental, social and political aspects. Quantitative and qualitative approaches are also combined. We realized that different components of protected areas have to be considered when attempting to assess the carrying capacity, which implies that for any one area, there could be multiple carrying capacities. Additionally, the carrying capacity is not fixed in time, but might be modified by management policies.

7. Conclusion

The difficulty of determining the appropriate limits on tourism growth has led some authors (see, for instance, Lindberg et al., 1997; McCool and Lime, 2001) to evade the problem by shifting from the question of "How many is too many?" to "How much change from natural conditions is acceptable, given the goals and objectives of an area?" Different planning frameworks have thus been developed to provide park managers and policy-makers with a basis for making decisions about the *TCC* of protected areas, including Limits of Acceptable Change (LAC) (Stankey et al., 1985), Visitor Impact Management (VIM) (Graefe et al., 1990; Farrell and Marion, 2002), and Visitor Experience and Resource Protection (VERP) (Shelby and Heberlein, 1986; National Park Service, 1997; Manning, 2001). However, while these frameworks have been successfully applied in a number of protected areas, a potential weakness of this approach to *TCC* in particular, and to adaptive management in general, is the arguably reactive nature of such frameworks (Lawson et al., 2003). Furthermore these methods are non-quantitative and lack analytical rigor (Prato, 2001).

In this study, we proposed a re-evaluation of the *TCC* concept from a more management-oriented perspective to operationalize sustainable tourism in protected areas. We provided a complete practical application and an example of best practices describing how *TCC* has shifted from a uni-dimensional approach to incorporating environmental, social and political aspects. Qualitative data collected from visitors (perceptions of the main issues of the park, protection of local traditions, level of satisfaction with their visit) have to be combined with environmental modeling using a participatory framework. *TCC* can thus play an important role in the management of protected areas because it is viewed as a systematic, strategic policy tool within a planning process rather than as a unique, intrinsic number that is not modifiable. Nevertheless, we think that to make the *TCC* a more effective tool, it is necessary to develop further operative, systematic examples, like the one discussed here, to help the researchers and the decision-makers translate the concepts into action through unambiguous standard measures.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.jenvman.2013.04.043.

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