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Adaptive environmental management of tourism in the Province of Siena, Italy using the ecological footprint

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Abstract

Adaptive management as applied to tourism policy treats management policies as experiments that probe the responses of the system as human behavior changes. We present a conceptual systems model that incorporates the gap between observed and desired levels of the ecological footprint with respect to biocapacity. Addressing this gap (or 'overshoot') can inform strategies to increase or decrease visitation or its associated consumption in the coming years. The feedback mechanism in this conceptual model incorporates a gap between observed and desired ecological footprint levels of tourists and residents. The work is based on longer-term and ongoing study of tourism impacts and ecological footprint assessments from the SPIN-Eco Project. We present historical tourism and environmental data from the province of Siena, Italy and discuss the use of discrete, static environmental indicators as part of an iterative feedback process to manage tourism within biophysical limits. We discuss a necessary shift of emphasis from certain and static numbers to a process-based management model that can reflect slow changes to biophysical resources. As underscored by ecological footprint analysis, the energy and material use associated with tourism and local activity can erode natural capital foundations if that use exceeds the area's biological capacity to support it. The dynamic, and iterative process of using such indicators as management feedback allows us to view sustainability more accurately as a transition and journey, rather than a static destination to which management must arrive.
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Keywords: Adaptive management; Tourism; Ecological footprint

1. Introduction

Tourism is an important industry in almost every region of the planet. It touches the lives of most of the world's population, employing one-twelfth of all workers and contributing 11 percent of the global GDP (WTO, 1999, 2003). Tourism has long been identified as a powerful tool for development, spurring economic growth, increasing foreign exchange, smallholder investment, and local employment (Brau et al., 2003; De Kadt, 1979; Woods et al., 1994), In some cases, tourism results in increased environmental protection and funds for conservation (Pearce, 1981; Woods et al., 1994; Pigram, 1980; Boo, 1990; Sonnino, 2003; Bramwell and Lane, 1994).

All major intra-governmental organizations which address tourism (e.g., World Tourism Organization, United Nations, World Wide Fund for Nature, World Bank, European Union) have established definitions of 'sustainable tourism' (IWGIST, 1993), yet exactly what this means in practice continues to be hotly debated (summarized by Sharpley, 2000; Clarke, 1997; Hunter, 1997). While "strong sustainability" is implied in much of the sustainable tourism literature (Collins, 1999), growing evidence indicates that most all tourism activity contributes to environmental pressure (Duffy, 2001). These impacts can be tracked in a variety of ways. One technique is direct observance and measurement of impacts. Tourism has been documented to lead to direct changes in land cover, land use, water and energy (Becken and Simmons, 2002; Carlsson-Kanyama and Linden, 1999), increases in biotic exchange (including disease), disturbance of wild species, and changes in environmental perceptions of the host

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manufacturing, agriculture and a growing tourism sector. The exceptional density and quality of cultural, architectural and environmental assets make the Province of Siena a popular national and international tourist destination. Tourists are primarily motivated by art and culture (54%) and spas (29%) (Fig. 1). (Amministrazione Provinciale di Siena, 2005). Annual arrivals have grown from 133,255 to 341,449 between 1991 and 2002 (Fig. 2) (Amministrazione Provinciale di Siena, 2005). However, this growth has not been evenly distributed: a limited number of popular sites and towns in the Province suffer from overcrowding and congestion (such as Siena, San Gimignano and Chianciano Terme), while others languish for lack of visitors (Fig. 3). Visitation is prone to peaks throughout the year (Fig. 4).

Agenda 21 (as highlighted in the findings from this issue) focused Provincial leadership on five factors which were seen to limit the sustainability of the tourism industry in Siena; direct impacts (emissions, landscape impacts, privacy intrusions, etc) at especially popular sites and areas, lack of mechanisms to diversify the tourism product or distribute tourists spatially, lack of promotion or protection for historical–cultural patrimony, scarce environmental certification for the tourism sector, and a lack of means to address tourism's indirect impacts on ecologically fragile areas (Poggiali, 2002). Ultimately, the Province undertook a cultural inventory, identified and promoted a territorial identity through advertising vectors, and mandated a strategic environmental plan for impacts. The thrust of these efforts focused on voluntary and certification initiatives, yet tourism managers lacked the information and feedback structure which would allow decisions to incorporate information about the status of an area's natural capital (or biocapacity).

Erosion of natural capital is a concern relevant to rural areas of Italy, especially in light of trends in land-use which have removed many of the natural ecological buffers in the system (Patterson, 2005). For example, growth of tourism infrastructure has led to a rise in impervious surfaces which

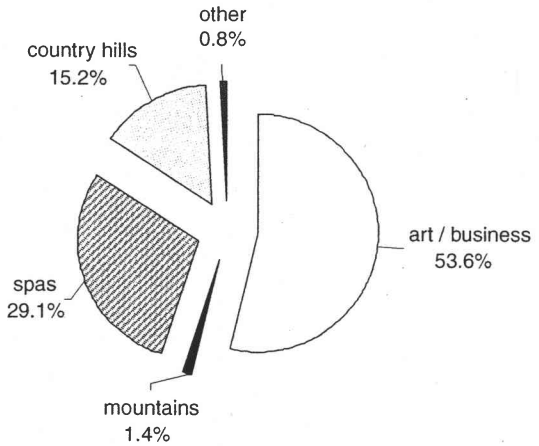

Fig. 1. Tourist visitation to Siena by motivation in 2002. *Source*: Amministrazione Provinciale di Siena, 2005.

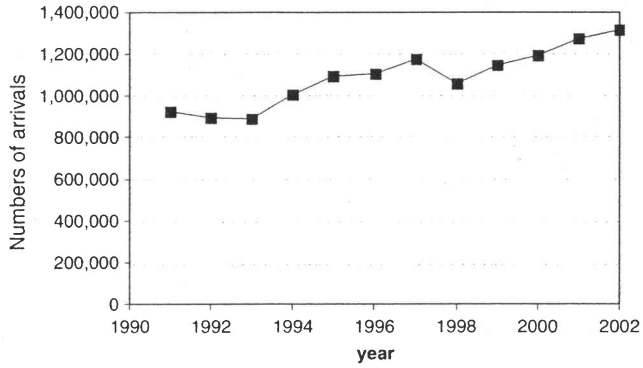

Fig. 2. Time series of arrivals in the Province of Siena (1991–2002). *Source*: Amministrazione Provinciale di Siena, 2005.

speed water, sediments and pollutants into streams. Landscape cover, species diversity, crop diversity, and riparian vegetation have particular implications for an area's natural capital and its consequent ability to deliver ecosystem services. An analysis of aerial photo sequences from years 1950 to 1996 revealed that each of these have undergone changes as a result of increases in tourism infrastructure and the mechanization of agriculture (ibid).

Rural areas of the province have undergone particularly sharp shifts in demography as residents have moved from an agrarian economy to what is industrial, specialized, or tourism based. Food, fertilizer, and other agricultural inputs take up a far greater share of domestic imports than in previous years. As economic transition based on consumption, importation, and petroleum use increase, local traditions of frugality, recycling, gleaning (the act of following behind a first harvest to salvage remains), knowledge of local plants, animals, have become less common (Patterson, 2005). Tourism development plays a subtle but pervasive role in the development transition that has occurred in the Province of Siena. The cumulative effect of these changes has had implications for the Province's natural capital. A need exists to relate these trends to Siena's growing energy and resource consumption by residents and visitors.

Pressures on civic infrastructure are the result of modern trends: demands for second homes, cheap trips, spontaneous decisions, more mobile travel behavior, more frequent, shorter trips, greater driving distance, 'exotic locations', rising expectations of amenities and service, rising habits of consumption. Acknowledging Siena's strong prospects for tourism growth, provincial planners have expressed concern for these as drivers of development, and their consequent effect on visitation, infrastructure, resource use, and environmental impacts, both direct and indirect, whether seen or unseen. Indication of the area's biophysical capacity to support rising population and consumption patterns would be a useful tool for management. An integrated and long-term strategy could then be better equipped to weigh the use of resources and waste production through time against the ability of an area's

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Province of Siena. Drawing off of existing and ongoing study of tourism impacts in Siena (Patterson, 2005), tourism ecological footprints (Patterson et al., 2006a), tourism carrying capacity (Patterson et al., 2006b), and resident ecological footprints (Bagliani et al., this issue), we propose an adaptive management framework for tourism policy to include biophysical conditions.

Recent innovations in sustainability science (Holling, 2001; Gunderson and Holling, 2002a), have suggested that a systems dynamic perspective might be useful in addressing especially challenging conditions posed by the structure of the system. This involves identifying components of the system, illustrating their linkages in terms of structure and feedbacks, and identifying a possible gap between observed and desired conditions of the system. To date, few studies have presented time series for biocapacity or the ecological footprint (Wackernagel et al., 2004; Erb, 2004). We employ time series of biocapacity and the ecological footprint to illustrate possible trajectories and longer-term consequences of relating tourism in Siena to a systems perspective.

3. Methods

This article takes a perspective underscored by Walters (1986) and Gunderson et al. (1995), that environmental problems are sometimes best addressed by setting aside for a moment the direct and obvious linkages between a problem and its manifestations, and instead concentrating on underlying dynamics. This approach stresses that management be flexible, adaptive, and experimental at scales compatible with scales of critical system functions. An understanding of how systems migrate towards states of increasing risk can help to better understand the impacts of tourism growth, and prevent unanticipated damages. As described above, this implies a longer-term view on tourism impacts, and not just those that can be immediately and directly perceived. In this section, we first present the methods used in systems dynamic modeling to illustrate the analytical context of the tourism management challenge. We describe the ecological footprint methodology and its comparison to biocapacity, and explain how this method has been adapted in prior studies to incorporate concerns regarding tourism population. This approach demonstrates management use for the EFA indicators of tourism pressure. Improving this form of application would allow environmental managers to respond to feedback regarding Siena's population, net consumption levels and visitation, as they relate to biophysical measures of natural capital.

3.1. System dynamics modelling

System dynamics identifies, explains, and attempts to eliminate problem behaviors in socio-economic systems principally by identifying feedback loops in the system. In cases of dynamic complexity, when cause and effect are not obviously related, this framework is particularly useful. System dynamics draws off of non-linear theory, cognitive and social psychology, organizational theory, economics, and other social sciences (for a review see Senge, 1990) and posits that the behavior of a system arises from its structure.

Interesting non-linear interactions are often noted between system elements. In the system dynamics view, dynamics (behavior over time) can be explained by the interaction of the two basic types of feedback loops: positive (or reinforcing) and negative (balancing) (for further explanation see Senge, 1990). As is typical for a dynamical systems description, we explain our systems model in terms of feedback (causal) loops, stocks (levels), flows (rates). Like all models, ours is a depiction of the tourism system as it relates to the natural capital that supports it. It is a conceptual model, whose principle value is to convey system insights by placing data from other studies within the analytical systems-based context of the tourism management challenge at hand. We relate this structure to the ecological footprint data derived from studies and procedures described below.

3.2. Ecological footprint analysis

The full methodology used to adapt EFA to resident and tourism statistics, respectively, can be found in Bagliani et al. (this issue) and Patterson et al. (2006a). Methods for using the ecological footprint as an indicator of environmental pressure due to tourism are similar to those used in prior study (Gössling et al., 2002b; Hunter, 2002; Patterson, 2005; Patterson et al., 2006a; Peeters, 2005; Bagliani et al., 2004). See Patterson et al. (2006b) for further explanation relating the ecological footprint to biophysical carrying capacity.

Ecological footprint analysis is not intended to be a determinant or encompass all concerns relevant to sustainability (see reviews in Roth et al., 2000; Troell et al., 2002; van den Bergh and Verbruggen, 1999). In this application we use the calculation as a proxy for the amount of the productive capacity of the biosphere that is occupied by tourist and resident activities. While we present data in time-series format, it is important to note that neither the ecological footprint nor the biocapacity predicts future demand or capacity, which are functions of future uses and technologies.

3.2.1. Biocapacity

We calculated provincial biocapacity using data from 1960 to 1996, at intervals of 10 years. Calculations follow the methodology outlined by Monfreda et al. (2004) and used yield and equivalence factor as reported in Living Planet Report 2000 (WWF, 2000). Accordingly, land-use data was organized into the six types of ecologically productive areas by IUCN classification: cropland, pasture, forest area, fishing ground, built up land and "energy land". Spatial data for each interval was taken from CORINE land cover analysis, an aerial photo survey of the

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unpredictable. Fig. 7 illustrates Holling's (2001) adaptive cycle, one depiction of complex system behavior as it exploits and conserves resources to the point of system collapse. The first phase (white) is one of rapid growth and eventual stagnation. The second (black) return phase of the diagram explains a system going through stages of release and reorganization.

The interplay of connectedness and potential has been a subject of much debate within circles discussing panarchy theory (ibid), much of which can be applied and hold insights for other complex systems. Yet if critical system functions and their associated non-linear responses have received only recent attention in the ecological literature, less has been written about the nested, linked ecological/social/economic systems which support tourism. Systems ecologists often illustrate the episodic view of change (Pritchard and Sanderson, 2002), underscoring the importance of "knowing where you are" in system cycles. A systems diagram such as that presented by Holling's (Fig. 7), can be used to facilitate dialog regarding aspects of tourism development which are in phases of rapid growth with increasing efficiency and rigidity, versus periods of slow change exposing areas of vulnerability, versus phases of complete disorder and disintegration, versus rebuilding stages of innovation where innovation begins to emerge in pulses.

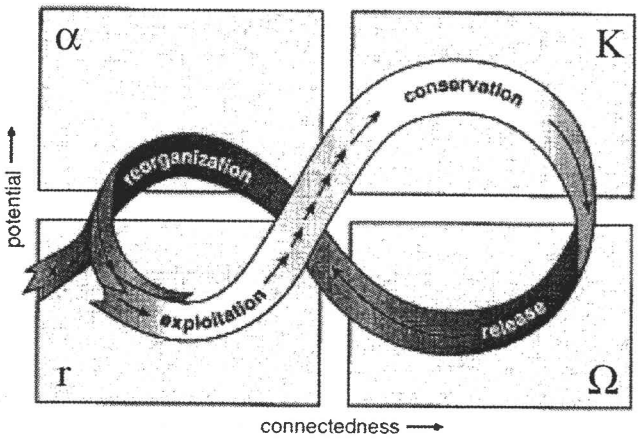

Fig. 7. The Adaptive Cycle, as proposed and illustrated by Holling (2001), with kind permission from Springer Science and Business Media.

Tourism researchers have commented on the similarities between the front half of Holling's (2001) resilience model (in white, Fig. 7) and Butler's tourism destination cycle of evolution (otherwise known as destination cycle) (Fig. 8) (Farrell and Twining-Ward, 2004; Petrosillo et al., 2006). This illustration of systems development is a key concept for many tourism industry representatives, policymakers, and researchers. The destination cycle describes the system behavior of changes in tourism visitation volumes as a function of local tourism assets and the increasing popularity of a destination over time (Butler, 1980). From left to right, as impacts from tourism development become apparent (including crowding effects from increased arrivals), the appeal of a destination begins to erode. The vibrancy of the socio-cultural experience, and the appeal of an ecologically healthy environment declines. As a result, growth in arrivals flattens, ultimately stagnating the local economy and producing a period of steady visitor decline (Butler, 1980, 1991). Barring effective mitigation or rejuvenation, a destination will 'burn out', as development impinges on the locale's natural and social capital which sustain positive experiences for visitors (ibid).

When a system is locked in a reinforcing loop, barring intervention, both variables will grow or decline exponentially. When initial growth is slow, it may be unnoticed until it becomes rapid, at which point it may be too late to control. The Butler cycle of tourism is an example of the consequences of a reinforcing-loop in a tourism system

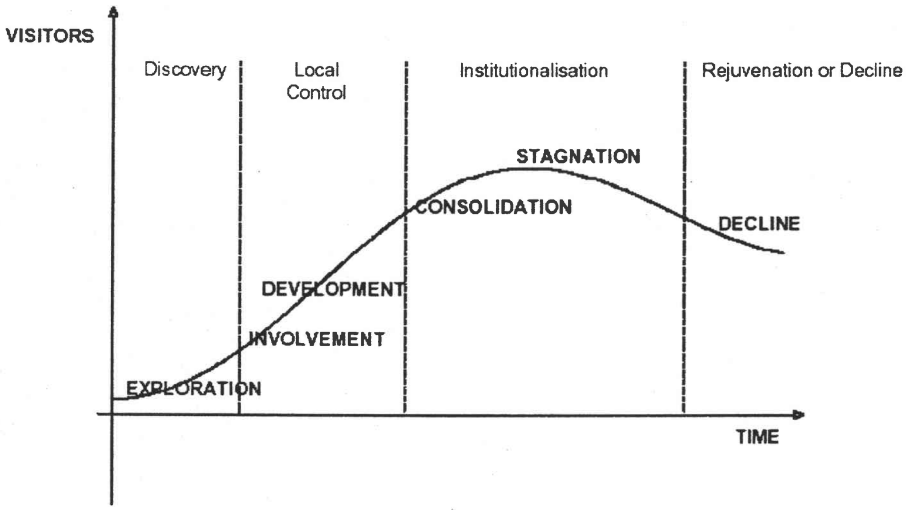

Fig. 8. The Destination Life Cycle from Butler 1980, as in Amelung et al. (2002).

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understood in terms of a single management objective that can be attained. It is critical that environmental managers are assisted in setting an adaptive, rather than static carrying capacity, which responds to "a framework of nature's rules, that captures the adaptive and evolutionary nature of adaptive cycles that are nested one within the other across space and time scales (Holling, 2001)". Incorporating indicators of environmental pressure from tourism (both from direct and input–output means of tracking these pressures) brings tourism management closer to responding to the variety of spatial and temporal scales that manifest tourism's impacts.

Little attention in tourism management has been cast upon slow variables of environmental change (such as an area's biological capacity). Often these are mistakenly assumed to be static. Meanwhile, reports have increasingly commented on the 'overshoot' of human consumption of energy and resources compared to global production. Tourism, as an energy and material resource intensive service, and as the world's largest industry, contributes to this trend. Recent ecological footprint applications can serve as inputs to inform management initiatives on the indirect impacts of tourism development. Incorporating this information into both the observed and desired condition statements for a feedback model, can result in a more accurate sense of the gap to be addressed by policy interventions.

There is a limited set of trajectories over which environmental problems generated by tourists will travel. These need to be understood in dynamic rather than static terms. The key to understanding tourism environmental management over time lies in understanding the dimensions around which patterns of structures and processes can be identified and studied. In ecosystems, the key dimensions are space and time. For social systems, Westley (2002) advocates adding a third dimension that references a social tendency to discount the future, and look backward rather than forward. Viewing ecological footprint and biocapacity data in time-series highlights the importance of addressing "overshoot" before it occurs. Should management fail to incorporate this forward-looking information, the Provinces capacity to respond to slow but pervasive changes will be reduced. As a result, the ecological footprint of the combined populations of the study area is at greater risk of surpassing the area's biocapacity.

We have described a time-series, systems-based approach to interpreting existing data on ecological footprint assessments of residents and tourists. The environmental management significance of this systems approach deserves some review. Environmental management for tourism is in need of tools to draw information from multiple scales, and in a forward looking way. In absence of information indicating the indirect impacts of the tourism population, tourism managers in the Province will be inclined to seek to distribute the flow of tourism spatially across the Province, and increase tourism visitation. The perspective presented by a comparison of provincial biocapacity draws attention to the broader context of rising consumption of energy and resources among residents, and the slow degradation of local natural capital. A systems dynamics perspective stresses the importance that the Province identifies ways to transition the whole system to less energy and resource use intensive ecological footprints.

Depicting the tourism system and its related consumption in terms of a systems dynamic model draws attention to areas relevant to future research. With respect to tourism, the relevant scale of a systems model is a challenging issue. Both temporal and spatial considerations need further review, in order to incorporate the full range of management concerns into decision-making. While one model will not be able to address all concerns, the systems approach outlined in this article can be adapted to a variety of temporal and spatial scales, from municipal to national application. Temporal scales are also relevant, for example, seasonal peaks in visitation are especially problematic for environmental management, exacerbating strains on infrastructure and waste processing, energy and water resources (Gössling, 2001; Kuvan, 2005; Sun and Walsh, 1998). The ecological footprint for visitors could be iterated on a monthly time-step, to reflect the rise and fall of tourism visitation throughout the year depicted in Fig. 4.

Prior to this analysis, the ecological footprint may have been grouped among those notions of sustainability which discourage experimentation by implying that there are unique, fixed targets for sustainability and only one way for management to optimize them. Throughout this article, we have underscored the importance of incorporating management feedback using a systems approach. The ecological footprint analysis is beneficial from two standpoints. First, it provides a more complete assessment of impacts by tracking the full range of impacts from their source. Second, it provides common denomination against which various populations across various spatial and temporal scales can be compared. This contribution is valuable in that it can support a dialog regarding efforts to widen the range of concern for tourism impacts. Increased understanding of tourism's indirect impacts, or pervasive impacts on biocapacity, are otherwise difficult to incorporate into decision-making. Disregard for supporting resources of tourism such as biophysical carrying capacity implies risks for undermining the natural capital which attracts tourism visitation. This risk is amplified in the presence of factors which point to a broad probability distribution of uncertainties, shortsightedness due to discounting of the future, and losses of social flexibility and ecological resilience (Carpenter et al., 2002).

A number of uncertainties prevent the full incorporation of indicators of both direct and indirect impacts of tourism. First, little guidance has been given regarding how or how often various tourism management institutions should respond to feedback from the environment, and how they use knowledge of indicators to learn and design more resilient tourism systems. The role of tourism management

Becken, S., Simmons, D.G., 2002. Understanding energy consumption patterns of tourist attractions and activities in New Zealand. Tourism Management 23 (4), 343–354.

Boo, E., 1990. Ecotourism: The Potentials and Pitfalls. WWF, Baltimore, MD.

Bramwell, B., Lane, B., 1994. Rural tourism and sustainable rural development. Journal of Sustainable Tourism 2, 1–2.

Brau, R., Lanza, A., Pigliaru, F., 2003. How fast are the tourism countries growing? The cross-country evidence. Tourism and Sustainable Economic Development, Chia, Sardinia, Fondazione Eni Enrico Mattei.

Butler, R., 1980. The concept of tourist area cycle of evolution: Implications for management of resources. Canadian Geographer 24 (1), 5–12.

Butler, R., 1991. Tourism, environment and sustainable development. Environmental Conservation 18 (3), 201–209.

Carlsson-Kanyama, A., Linden, A.L., 1999. Travel patterns and environmental effects now and in the future: implications of differences in energy consumption among socio-economic groups. Ecological Economics 30, 405–417.

Carpenter, S., Brock, W., Ludwig, D., 2002. Collapse, Learning and Renewal. In: Holling and Gunderson, Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington, DC pp. 173–194.

Clarke, J., 1997. A framework of approaches to sustainable tourism. Journal of Sustainable Tourism 5, 224–233.

Collins, A., 1999. Tourism development and natural capital. Annals of Tourism Research 26 (1), 98–109.

De Kadt, E. (Ed.), 1979. Tourism: Passport to Development? Oxford University Press, Oxford.

Duffy, R., 2001. A Trip Too Far: Ecotourism, Politics and Exploitation. Earthscan, London.

Erb, K.H., 2004. Actual land demand of Austria 1926–2000: a variation on Ecological Footprint assessments. Land Use Policy 21 (3), 247–259.

Farrell, B., Twining-Ward, L., 2004. Reconceptualizing tourism. Annals of Tourism Research 31 (2), 274–295.

Garrigos Simon, F.J., Narangajavana, Y., Marques, D.P., 2003. Carrying capacity in the tourism industry: a case study of Hengistbury Head. Tourism Management 25 (2), 275–283.

Giorgi, E., Orsi, S., Sorbi, U., 1966. L'agricoltura in Toscana. Vicende e prospettive di sviluppo Monte dei Paschi eds, Siena, Italy.

Gössling, S., 2001. The consequences of tourism for sustainable water use on a tropical island: Zanzibar, Tanzania. Journal of Environmental Management 61, 179–191.

Gössling, S., 2002a. Global environmental consequences of tourism. Global Environmental Change 12 (4), 283–302.

Gössling, S., Borgstrom Hansson, C., Horstmeier, O., Saggel, S., 2002b. Ecological footprint analysis as a tool to assess tourism sustainability. Ecological Economics 43 (2-3), 199–211.

Gössling, S., Peeters, P., Ceron, J.P., Dubois, G., Patterson, T.M., Richardson, R.B., 2005. The eco-efficiency of tourism. Ecological Economics 54, 417–434.

Graefe, A., Kuss, F., Vaske, J., 1990. Visitor Impact Mangement: The Planning Framework. National Parks and Conservation Association, Washington, DC.

Gunderson, L., Holling, C.S. (Eds.), 2002a. Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington, DC.

Gunderson, L.H., Holling, C.S., 2002b. Resilience and adaptive cycles. In: Gunderson, L.H., Holling, C.S. (Eds.), Panarchy Understanding Transformations in Human and Natural Systems. Island Press, Washington, pp. 25–62.

Gunderson, L., Holling, C.S., Light, S. (Eds.), 1995. Barriers and Bridges to the Renewal of Ecosystem and Institutions. Columbia University Press, New York, NY.

Holling, C.S., 2001. Understanding the Complexity of Economic, Ecological, and Social Systems. Ecosystems 4 (5), 390–405.

Hunter, C., 1997. Sustainable tourism as an adaptive paradigm. Annals of Tourism 24 (4), 850–867.

Hunter, C., 2002. Sustainable tourism and the tourist ecological footprint. Environment, Development and Sustainability 4, 7–20.

ISTAT, 2005. Istituto Nazionale di Statistica. Downloaded from: http://www.istat.it

IWGIST, 1993. International Working Group on Indicators of Sustainable Tourism, Indicators for sustainable management of tourism: Indicators for sustainable management of tourism. International Institute for Sustainable Development, Winnipeg.

Kuvan, Y., 2005. The use of forests for the purpose of tourism: the case of Belek Tourism Center in Turkey. Journal of Environmental Management 75, 263–274.

Lawson, S.R., Manning, R.E., Valliere, W.A., Wang, B., 2003. Proactive monitoring and adaptive management of social carrying capacity in Arches National Park: an application of computer simulation modelling. Journal of Environmental Management 68, 305–313.

Lindberg, K., McCool, S., Stankey, G., 1997. Rethinking carrying capacity. Annals of Tourism Research 24 (2), 461–465.

Manning, R., 1999. Studies in Outdoor Recreation. Oregon State University Press, Corvallis.

Monfreda, C., Wackernagel, M., Deumling, D., 2004. Establishing national natural capital accounts based on detailed Ecological Footprint and biological capacity assessment. Land Use Policy 21, 231–246.

Mowforth, M., Munt, I., 1998. Tourism and Sustainability: New Tourism in the Third World. Routledge, London.

National Park Service, 1995. The Visitor Experience and Resource Protection Implementation Plan Arches National Park. US National Park Serivce Denver Service Center, Denver.

Patterson, T.M., 2005. The Ecological Economics of Sustainable Tourism; Local Versus Global Ecological Footprints in Val di Merse, Italy. PhD Dissertation, University of Maryland.

Patterson, T.M., Niccolucci, V., Bastianoni, S., 2006a. Beyond "More is Better"; Tourism and Consumption in Val di Merse, Italy. Ecological Economics, in press.

Patterson, T.M., Niccolucci, V., Marchettini, N., 2006b. The Ecological Footprint in Determining Tourism Carrying Capacity in the Val di Merse, Italy. Ecological Economics, submitted.

Pearce, D., 1981. Tourist Development. Longman, New York.

Peeters, P., 2005. Manuscript in Progress. NHTV Breda University, Centre for Sustainable Tourism and Transport, Netherlands.

Petrosillo, I., Zurlini, G., Grato, E., Zaccarelli, N., 2006. Indicating fragility of socio-ecological tourism-based systems. Ecological Indicators 6 (1), 104–113.

Pigram, J., 1980. Environmental implications of tourism development. Annals of Tourism Research 7, 554–583.

Poggiali, E., 2002. Turismo Sostenibile: principi di base e possibili strategie per le Pubbliche Amministrazioni. Gruppo di Coordinamento Agenda 21 "Terre di Siena" http://www.agenda21.provincia.siena.it/page/home.asp.

Pritchard, L., Sanderson, S., 2002. The dynamics of political discourse in seeking sustainability. In: Holling and Gunderson, Panarchy: Understanding Transformations in Human and Natural Systems. Island Press, Washington, DC, pp. 147–172.

Regione Toscana, 1993. Inventario Forestale Toscano. Firenze, Italy.

Roth, E., Rosenthal, H., Burbridge, P., 2000. A discussion of the use of the sustainability index: ecological footprint for aquaculture production. Aquatic Resources 13, 461–469.

Schmidt di Friedberg, P., 1997. Studi di impatto ambientale applicati al turismo: il caso di Vernazza. Atti del Congegno Internazionale: Gli studi di impatto come strumento per un turismo sostenibile, Genova, 23 ottobre, Centro VIA Italia, Milano.

Senge, P., 1990. The Fifth Discipline: The Art and Practice of The Learning Organization. Doubleday, New York, NY.

Sharpley, R., 2000. Tourism and sustainable development: exploring the theoretical divide. Journal of Sustainable Tourism 8 (1), 1–19.

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