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Research article

Dynamically linking economic models to ecological condition for coastal zone management: Application to sustainable tourism planning

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ABSTRACT

While the development of the tourism industry can bring economic benefits to an area, it is important to consider the long-run impact of the industry on a given location. Particularly when the tourism industry relies upon a certain ecological state, those weighing different development options need to consider the long-run impacts of increased tourist numbers upon measures of ecological condition. This paper presents one approach for linking a model of recreational visitor behavior with an ecological model that estimates the impact of the increased visitors upon the environment. Two simulations were run for the model using initial parameters available from survey data and water quality data for beach locations in Croatia. Results suggest that the resilience of a given tourist location to the changes brought by increasing tourism numbers is important in determining its long-run sustainability. Further work should investigate additional model components, including the tourism industry, refinement of the relationships assumed by the model, and application of the proposed model in additional areas.

1. Introduction

1.1. Coastal zone management and ecosystem condition

A key challenge for coastal zone management is balancing the needs for economic development with preservation of the underlying natural resource assets. In national, regional, and local growth and development decisions, there is often a tradeoff between the direct monetary benefits accruing from economic development activity (e.g., tax revenues, jobs created) and ecosystem service benefits (e.g., clean water for fishing, drinking, bathing, wildlife for viewing) that may be impacted or lost due to negative environmental impacts. Models linking changes in ecosystem function or ecosystem condition to proposed or existing economic activity could therefore assist in characterizing the interrelationships between coastal economic activities and ecosystem services. Importantly, such modeling can also assist in understanding whether or not a coastal ecosystem is near a tipping point, beyond which it shifts into an alternate state with a different set of ecosystem service flows, and, consequently, beneficiaries.

The objective of this paper is to outline a theoretical approach for linking and then evaluating the dynamic effects of one type of economic activity, tourism, on indicators of ecosystem quality and on the behavior of future tourists and, therefore, future tourism pressure. Specifically, this paper focuses on one measure of ecosystem condition (water quality in the form of total coliform levels) and one type of ecosystem service benefit (in this case, beach recreation). The model components are developed and then tested in a range of potential scenarios.

1.2. Existing models of tourism development

Coastal tourism provides a useful context for investigating the tradeoffs between the coastal environment and economic needs of the coastal communities since it is an area where both economic sectors and environmental systems interact, with economic drivers (in the form of tourist-focused developments and infrastructure) leading to changes in the bundle of ecosystem services provided by a given coastal habitat. The addition of infrastructure, for example, may allow more individuals to visit an area, thereby increasing the ecosystem service benefits associated with recreational use; however, some ecological production functions may be changed or altered from the presence of the infrastructure and the increased user population, leading to a decrease in other ecosystem service

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benefits (e.g., loss of vegetation and its associated ecosystem service benefits) and, should the ecosystem asset degrade, eventual impacts upon the recreation benefits as well.

Sustainable tourism has been defined by the United Nations World Tourism Organization (WTO) and United Nations Environment Programme as "Tourism that takes full account of its current and future economic, social and environmental impacts, addressing the needs of visitors, the industry, the environment and host communities" (2005). Clearly there are tradeoffs that would arise in attempting to meet the needs of these different user groups. For example, construction of hotels or apartment houses can result in sediment runoff into nearby rivers and coastal waters and development of these tourist facilities without adequate sewage infrastructure can lead to increased bacterial counts in nearby waters (Brachya et al., 1994). Planners can present benefits associated with the revenue and employment generated by the industry and costs such as development of the property and operation and maintenance of the site. Environmental costs of proposed tourism development strategies are typically not readily quantifiable in dollar terms in a format useful for site-specific benefit-cost analyses. Moreover, the links between the project and the environmental asset are often indirect, requiring combinations, of biological, chemical, physical, economic, and social models.

Butler (1991) outlined a cycle for tourism destinations consisting of exploration and development of the destination, reaching and breaching of capacity limits, and then progression to stagnation and eventually decline (with the possibility of future rejuvenation). Intervention in the cycle prior to reaching the capacity limits could prevent the decline of the tourist area. Thomas et al. (2005) proposed that whether a tourism destination (in this case, a Caribbean island) experienced future decline or growth with increasing tourism penetration may be linked to differences in the sustainability of the tourism industry and measures in place to protect the local cultural and physical environment. Considered this way, the ecosystem characteristics of a tourism location could be important for differentiating it from other destinations.

Butler's lifecycle model has been expanded to capture the interaction between natural and physical capital (Hernández and Léon, 2007), allowing the visitation and infrastructure investments related to an environmental asset to depend upon the intensity of resource use. Casagrandi and Rinaldi (2002) propose a theoretical structure linking tourists, the environment, and capital investments. Increases in tourists and infrastructure may lead to damages, D, that degrades environmental quality over time. A variable, A, related to the attractiveness of the site is a function of the environment of the site, the tourists themselves, and the capital investments at the site. The authors suggest that the value of the particular parameters in the model can describe movement between the different states (or "attractors") for the tourism industry (e.g., long-run positive numbers or decline) in a given location. Patterson et al. (2004) developed a model for Dominica that combined social, ecological and economic components to evaluate potential changes in ecology over time. Although a variable "natural beauty" composed of reef and forest quality is defined to reflect the perceptions of the natural environment by tourists, no specific environmental economic model is proposed. While these models have provided important theoretical advances in evaluating the relationship between natural and physical capital they do not incorporate economic models that investigate the behavioral impacts of environmental changes on tourist populations.

1.3. Combined ecological and economic models for tourism impact analysis

Van Beukering and Cesar (2004) developed an integrated ecologic-economic model for Hawaiian coral reefs that included an ecosystem module and a module for tourism as one of the ecosystem service benefits. The model assumes that increased tourism growth will lead to a decrease in the ecological "state of the reef," and results from a scenario analysis suggested annual monetary benefits from the reef would decrease over time if tourists were not educated about their impact upon the reefs (and (consequently the assumption of more tourists leading to a decrease in the "state of the reef" holds). Chang et al. (2008) connected a pre-existing willingness-to-pay model with an ecological model of land-based pollution that results in degradation of the reef and impacts upon future tourist numbers. The modeling approach developed in this paper similarly provides a mechanism for linking environmental economic modeling approaches to an ecological model predicting coastal ecosystem condition.

Given the feedback between ecosystem condition and tourism pressure, resilience and thresholds become critical for describing both the response of the ecosystem condition indicator itself to the tourist inflow and in describing how shifts in the ecosystem condition indicator modulate future tourist trends. Ecosystem resilience has been broadly conceptualized as the ability of a system to accommodate pressures and avoid shifting into a different state with different structures and functions (Holling, 1973). In the context of the model developed in this paper, coastal waters are resilient to some level of tourism pressure until reaching a threshold ecosystem condition level. Once this threshold is crossed, the beaches shift into an alternate state, eliciting a behavioral response from future tourists to the coastal location. Given the potential importance of threshold effects, our model incorporates both an ecosystem condition (or environmental) threshold as well as an economic behavior response to the exceedance of the environmental threshold. The location of these thresholds is an empirical question that will differ depending on the tourist destination and may be related to local investments in coastal infrastructure.

2. Methods

2.1. Model development

Since multiple interacting elements affect the relationship between tourism development and water quality over time, this research pursued a systems dynamics approach to evaluating this question. The components of the model provide a framework for the type of monitoring data that would be valuable to collect when considering the carrying capacity of a coastal recreational area, explicitly considering the interaction between an indicator of the condition of the natural resource asset and economic decisions (for more model details, including equations for the linkages between stocks and flows, please see Supplementary Material).

As shown in Fig. 1 for Beach 1, a pattern of tourist arrival (Tourists Arrive) and tourist departures (Tourists Leave) is modified by a predicted probability of visitation to Beach 1 (PredProbB1) based on the relative indirect utility (V) of Beach 1 versus Beach 2. An identical model (along with economic and ecological submodels) exists for Beach 2. V is provided by the economic component, described in section 2.2, and the value for the environmental threshold (Environmental Threshold) is provided by the ecological component, described in section 2.3. The number of tourists arriving on a beach in a given month (Monthly Tourists Beach 1) influences whether or not the beach exceeds the environmental threshold, and an annual tally of beach days above the threshold (Beach 1 Annual Days Above Threshold) is compiled ("Memory Fades" is an outflow of the beach days above the threshold, as we assume the past 12 months of days above the