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Research, part of a Special Feature on A Systems Approach for Sustainable Development in Coastal Zones

Environmental and Management Constraints on Tourism in Varna Bay, Bulgarian Black Sea Coast

Snejana Moncheva [1], *Eleonora Racheva* [1], *Lyudmila Kamburska* [2], *and Johanna D'Hernoncourt* [3]

ABSTRACT. We used the systems approach framework (SAF) to study the conflict between the development of tourism and marine environmental quality in Varna Bay, a critical regional policy issue selected for study after stakeholder consultation. Water quality is of central importance to the tourism industry, as a minimum level of water clarity is required to make the water attractive for swimming and bathing. Rampant development of coastal resorts in Varna Bay has led to water-quality deterioration because the tourism capacity has expanded without concurrent increases in the capacity to collect and treat sewage. We used a numerical model to simulate the Secchi depth (as a proxy for transparency) as a function of the nitrogen loading and total suspended solids. The SAF proved valuable for illustrating the relationship between bathing water quality and the capacity of sewer systems and wastewater treatment plants, and it was helpful in evaluating policy options, even though it does not yet allow precise quantitative prediction of water quality. Results indicate that a combination of storm water management by sewer system improvement (reducing direct runoff by 80%) with construction and upgrading of wastewater treatment plants to 75% nitrogen removal could achieve the improved water quality needed to prevent a failure of recent major investments in the tourist industry, with consequent loss of jobs and profits.

Key Words: *Black Sea; coastal tourism; eutrophication; simulation models; systems approach*

INTRODUCTION

Varna Coastal Zone

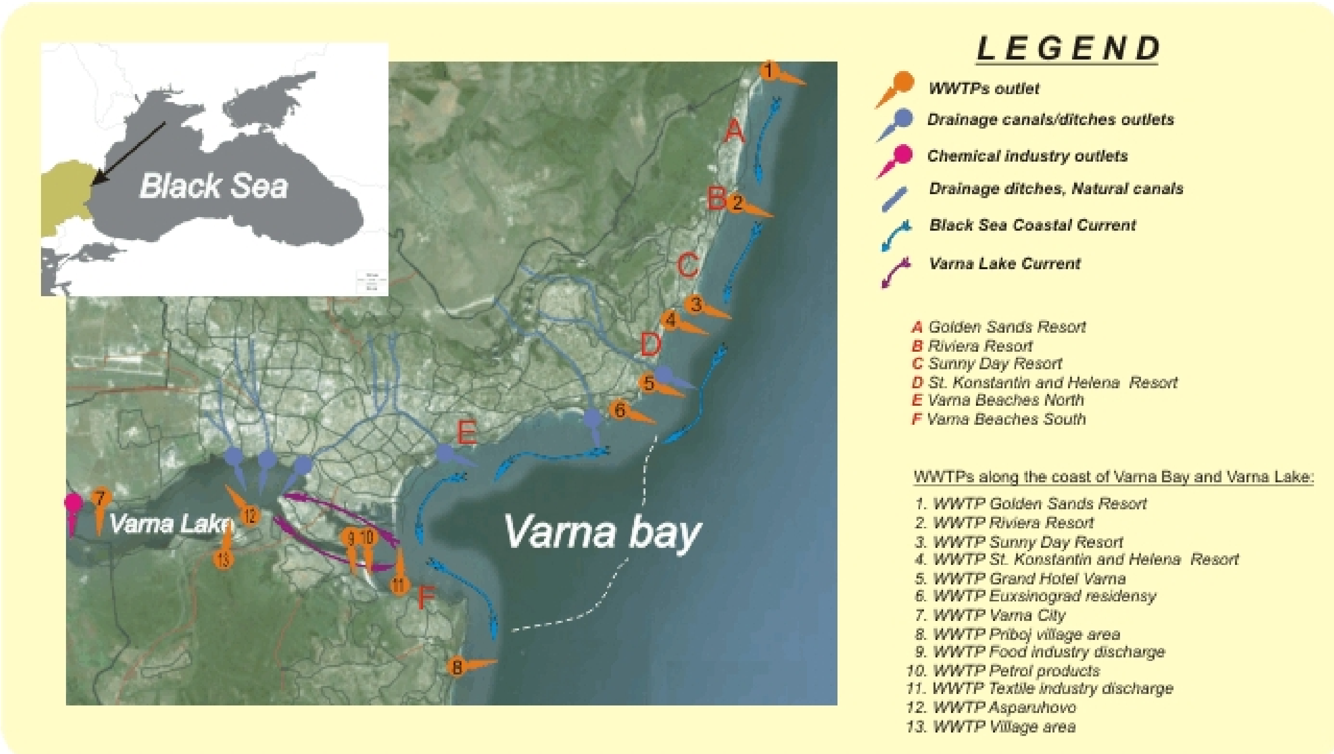
The city of Varna is Bulgaria’s second-largest economic center and one of its fastest growing cities. From 1934 to 2001, its official population increased fourfold to 320,000, and Varna now has 900,000 inhabitants, unofficial residents included. Many interacting stressors from human activities impact the coast of Varna Bay (Fig. 1), e.g., industry, tourism, urbanization, and global climate change. After the construction of two shipping channels in the 1990s and the Varna-West port, with its chemical industrial complex, the Lake-Bay system became strongly modified, with an altered hydrological regime, ecosystem characteristics, and water quality (Veselinov and Gergov 1980, Rozhdestvenskiy 1992, Shtereva et al. 1999, Moncheva et al. 2001). Industrial nutrient loads to the Bay caused eutrophication, phytoplankton blooms, and hypoxia and resulted in serious deterioration of the ecological state of the area, especially during the 1980s (Velikova et al. 1999, Moncheva et al. 2002, 2003, Trayanova et al. 2002).

The poorly maintained wastewater treatment plants (WWTPs) have not changed in number and type since 1975. Most of the newly constructed tourist facilities in the resorts (A, B, C, D in Fig. 1) lack connection to the sewer system (Milkova et al. 2007), increasing the input of nutrients and suspended solids to coastal waters (Moncheva et al. 2008). Climate change is likely to further stress both ecosystem and resource management, as the meteorological records of the last 10 years show that summer temperatures, as well as the frequency and intensity of rain and storm events, have increased substantially along the Bulgarian Black Sea coast (NIMH-Varna 2010).

The tourist resorts, built on the coast of Varna Bay from the early 1950s on, expanded greatly after the mid-1990s, and tourism became one of the area’s main sources of income, wealth, and employment, while exerting additional pressure on the ecosystem. Seaside tourism in Varna dates back to the early 19th century period. In the early 1970s, Bulgarian Black Sea tourism had a 1% market share worldwide, attracting mostly visitors from the socialist countries. The hardships of the political transition in the early 1990s pushed environmental issues down on the political agenda (Klarer and Moldan 1997), and the tourism market share dropped to 0.4 % in 1999 (Bachvarov 1999). Privatization of former state property led to a revival in resort development in mid-1990s, and today, tourism is one of the fastest-growing sectors of the local economy and accounts for 61% of the local gross domestic product (GDP), with trade services included (Varna Municipality 2008b). The Varna coastal area was one of the preferred tourism destinations in Europe in 2008 (EUROSTAT 2008). This tourism was based mainly on all-inclusive package programs that offered relatively low prices and attractive gambling and casino access (Witt 1994, Gillmor 1996, Madanoglu 2003, Bramwell 2004, WTTC 2010). From 2000 to 2004, the number of hotels almost doubled from 130 to 282. The Golden Sands resort alone, with over 70 hotels, attracted investments of 500 million €. The infrastructure development satisfied the tourist demands for leisure and

[1]IO-BAS, [2]EC DG-JRC, Institute for Environment and Sustainability, [3]Université Libre de Bruxelles, Centre for Economic and Social Studies on the Environment

Fig. 1. Map of Varna Bay–Varna Lake system–environmental pressures and their pathways: Varna Lake current, Black Sea coastal current, waste water treatment plants (WWTPs); dashed line = modeled area (more details in the main text)



entertainment facilities (yacht port, bars, restaurants, casinos etc.), but failed to protect water quality (Meinier 2002).

Governance

The progress in applying integrated water management in Bulgaria is rather limited due to economic, political, and institutional constraints inherited from the previous communist regime. The implementation of proper management is hampered by the lack of cooperation between the different stakeholders and decision makers, and within the ministerial infrastructure. At the national level, the Ministry of Development and Internal Affairs is responsible for the sewer system (SS) and WWTP management; the Ministry of Environment and Waters (MOEW) is responsible for environmental issues and administers the Black Sea Basin Directorate (BSBD); and the Ministry of Health is in charge of problems concerning microbial contamination. According to the Tourism Act, the Ministry of Economy implements the state policy in the field of tourism. Beaches are under annually renewed concession contracts, whereas hotels and restaurants are private property. Bulgaria's recent European Union membership requires implementation of the EU water policy. An approved operational program (2007–2013) for reconstruction and upgrade of WWTPs (MOEW 2007) is financially secured; yet, despite the designation of the Black Sea coastal zone as a sensitive area (ordinance 970/2003), not all of its WWTPs are scheduled for an upgrade to nutrient removal.

Simulation Objectives

Decisions that affect ecosystem services cause trade-offs between social values and environmental outcomes. The challenge is to find solutions that achieve both social and environmental goals (Young et al. 2006, Tallis et al. 2008) by bringing together multiple sources of knowledge in recognition of the new social contract for science (Lubchenco 1998).

This study employed the systems approach framework (SAF) developed in the European Union integrated project "Science Policy Interface for Coastal Systems Assessment" (SPICOSA; see Hopkins et al. 2011) to formulate management options for tackling the policy issue of "How to maintain good bathing water quality in Varna Bay" and resolve the conflict between tourism and ecosystem health in Varna Bay. After consultation with the stakeholders (see below), we chose to examine the following scenarios for the ecosystem of Varna Bay:

Scenario I: Introduction of 75% nitrogen (N) removal in resort WWTPs, in compliance with EU DIRECTIVE 98/15/EO.
Scenario II: Upgrade of the WWTPs as above, plus

improvement of the local sewer system (SS) to properly collect and treat rainwater, reducing direct rainstorm and total suspended solids (TSS) input by 80%.

The objective of our simulation analyses was to provide information on the potential consequences of these two scenarios as policy choices. The environmental component simulated the quality of bathing waters in Varna Bay as a function of loads of nutrients and TSS. Secchi depth became the link to scenario simulations that addressed social–ecological responses caused by changes in water clarity.

METHODS

Stakeholder Involvement

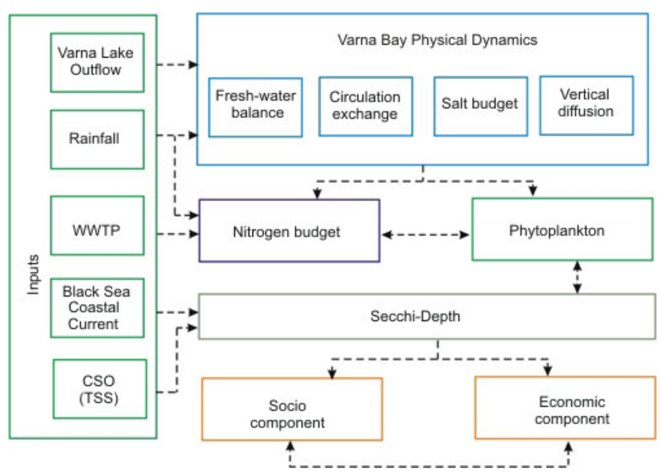
The policy issue studied was selected with strong stakeholder involvement. Initially, we invited a core group of policy decision makers and management authorities to recommend the most relevant pool of stakeholders (Table 1). The BSBD volunteered its regular council meetings as a venue for our first meetings and facilitated the iterative process of selecting the main policy issue. After our initial end-user mapping of the design step, we conducted our first meeting with the stakeholders group to present and discuss the choice of policy issue for the SAF. During our second stakeholder meeting, we presented our conceptual model, which stimulated constructive discussion of the value of WWTPs for the Black Sea coastal ecosystem and the neglect of the city's sewer system (SS) in the BSBD Management Plan for the period 2010–2015. At the subsequent two stakeholder forums in 2009, we presented the functional components of the model, coupled into a single model, and the scenarios. At the final meeting in 2010, we discussed the model output and its utility to indicate effective solutions for overcoming the conflict between tourism and water quality. Some of the stakeholders were concerned that the untreated wastewater occasionally caused bacteria levels in the water to exceed established safety levels and temporary beach closures. We explained that bacterial contamination was not yet considered in the model because the survival rate of enteric bacteria in the Black Sea is low (Yukselen et al. 2003), with concentrations of *E. coli* only very rarely reported above maximum allowable limits (BSBD reports).

Ecological Component

Our simulation model used ExtendSim™ software. The ecological component simulation is based on daily meteorological data (http://www.tutiempo.net/en/Climate/Varna/155520.htm), on chemical and biological parameters sampled twice monthly at two sampling stations in the Bay (Alexandrova et al. 2007, Doncheva et al. 2003; Moncheva, *unpublished data*), and on local data (WWTP discharge and treatment capacity, freshwater use per capita). The estimated contributions from WWTPs in the resorts were calculated roughly from the number of tourists per day, the average water consumption per tourist (450 L/d) using a fixed value of 10.9 $gN/m^3\ d^{-1}$ per person (Varna Municipality 2008a, Milkova et al. 2007). Oceanographic data from year 2001 were the most complete and were used for model calibration. The period 2002–2006 was then hindcast as described below, and the output results used to estimate future income in the tourism industry in the social–ecological system assessment.

A conceptual model of the Varna Bay system is shown in Fig. 2. The organization of the Extend model follows the cause–effect chain by identifying clusters of interactions that represent a larger discrete function within the modeled system. The major land-based inflows or inputs to the Bay come from the Varna Lake outflow, the Black Sea coastal current, local WWTPs and combined sewer overflow (CSO). The CSO discharges of water, TSS, and N to the system were calculated from the rainfall and the watershed area using a yield factor. These inputs directly influence the water exchange, Secchi depth, and N content of Varna Bay. The Secchi depth is a function of both the phytoplankton biomass and TSS, and it serves as the linking variable (indicator of transparency) between the ecological and socioeconomic components of the system (Fig. 2).

Fig. 2. Major components of the Varna Bay model (only primary interactions are shown)



The model formulation is based on the key relationship between nitrogen inputs and phytoplankton growth. This requires formulating an approximate N budget, the sources of which are complicated by their various external exchanges, which are strongly controlled by the weather. The Black Sea coastal current transports N and TSS from the sewer and WWTP discharges of the resorts into Varna Bay; we approximated this N flux by assuming that the average flux is modified significantly by variations in the local wind speed and direction (Hopkins 1974, 2002) and by upstream discharges of N and TSS. Another major input is Varna Lake

Table 1. Stakeholder groups and meetings.

Meeting date	Meeting Objective	Meeting Location	Particip-ants (number)	Stakeholders
4 October 2007	System Design Step	Varna, BSBD	50	***Core group***[†]-Black Sea Basin Directorate; Regional inspectorate for environmental protection and water – Varna; Regional inspectorate for environmental and health protection; Water supply and sewer system Agency; Municipality-Varna District;
19 May 2008	Formulation Step-Phase 1	Varna, Hotel Aqua	18	***Stakeholders group***-Port Authority-Varna; Chemical industrial Consortium- Devnya AD; Institute of Meteorology and Hydrology, BAS, Varna; NGOs/Environmental agencies –
20 June 2009	Formulation Step-Phase 2	Varna, BSBD	25	National Tourism Agency-Varna; Executive Agency for Fishery and Aquaculture-Varna; Time Foundation (NGO); Black Sea NGO Network-Varna; Foundation Institute of Ecological
16 October 2009	Appraisal Step	Varna, Golden Tulip Hotel	45	Modernization; Varna Tourism Chamber; Governmental and Municipal authorities – Municipal Administration Varna, Regional Administration Varna; Civil protection authorities,
14 June 2010	Output Step	Varna, Golden Tulip Hotel	35	Coast-protection agencies, Local communities/owners

[†]Core group attended all meetings

outflow, which is calculated by a stand-alone sub-model of the lake's exchange with Varna Bay and calibrated by using observations in the navigation channel (Alexandrova et al. 2007). Atmospheric deposition and land runoff simulations are based on precipitation data, drainage area, and yield factors from the literature. Because the local sewer system has a limited capacity, we assumed that the main TSS inputs are generated from land runoff from the heavy rainstorms (Varna Municipality 2008a). Wind direction and speed influence the distribution within Varna Bay of both the Black Sea coastal current and the Varna Lake outflow, e.g., southeasterly winds tend to hold the Varna Bay water in and oppose the entry of the coastal current, whereas northeasterly winds increase the entry of the coastal current and the exit of the Varna Bay water. Rainfall increases the inputs of freshwater, N, and TSS from CSO, thus lowering beach water quality.

We used Secchi depth (Preisendorfer 1986) as a measure of water clarity and a proxy for bathing water quality. The main model assumption is that Secchi depth (in m) is a function of TSS (HÅkanson 2006) and phytoplankton biomass, with the latter controlled by the nitrogen discharges, available light, circulation, and zooplankton grazing. Multiple regression analyses of data from two sampling stations in Varna Bay yielded a close-fitting equation (Append. 1).

In the multiple regression analysis relating Secchi depth to the concentration of TSS and phytoplankton biomass, the predictor variables (concentration of TSS and phytoplankton biomass) are independent of each other. The correlation is significant, although R is not very high (0.78) most likely due to the crudeness of the data used. For the socioeconomic analysis, the Secchi depth is assumed to have a critical threshold of <3 m, which represents tourist "concern" for water clarity (Taylor and Longo 2010). The model results were validated against field measurements (Alexandrova et al. 2007, Doncheva et al. 2003).

Social–Ecological Component

The social–economic component calculates the direct euro income of the tourism industry and its associated labor demand (number employed) to represent the effects on community welfare (Ivanov and Webster 2007). The causal link to the socioeconomic response is tourist perception of water quality (critical threshold) and tourist motivation to travel (preferred activities). The link between the ecological and socioeconomic components of the model is the degree to which water transparency influences the attractiveness of the resorts. This was quantified by using the results of questionnaires sent to 1000 randomly selected people (Taylor and Longo 2010) and reports from Varna municipality (number of tourists, length of stay, net income/tourist) to support the simulation and interpretation of the result.

The model was run to simulate tourist trends for the period 2001–2015 using a correlation between the capacity utilization and regional economic growth (Proenca and Soukiazis 2005). The variables used in the socioeconomic simulations were the number of tourist visits, the Secchi depth, the critical water clarity threshold, the tourism industry profit, the tourism industry employment, and the motivation profile of the tourists. The yearly net profit of the tourism sector was calculated using values for net income per tourist (Varna Municipality 2008b) and the number of visits. The increase in nights spent in hotels and campsites, annual rate for the period from 2000 to 2006 for Varna Region falls in the range 1%–2.5%, e.g., 0.2%/year on average (EUROSTAT 2008). In order to reflect the cumulative trend in the model, it was adjusted to 1.16%.

We simulated the long-term scenarios of Varna Bay bathing water quality (Secchi depth) by considering the influence of the nutrient discharges by the resorts (on nutrient concentration, phytoplankton biomass, and Secchi depth), the influence of meteorological storm events (on CSO discharges and Secchi depth), and their cumulative effect. We ran the model with data from the period 2001–2006, where 2001 data were used as initial input variables and by assuming that 80% of the land runoff was directly released into the system, bypassing the WWTPs. The model simulations were run for 15 years ahead to conform to the timeframe of the European Water Framework Directive (WFD Directive 2000/60/EC 15: "all European water bodies should reach good ecological status by 2015").

RESULTS

We used annual model simulations of different external loads of nutrients, along with modeled values of nitrogen concentration in the bay (2001 as the test year), to compare the contribution of Black Sea coastal current and Varna Lake input to the level of total nitrogen in Varna Bay (g/m³) (Fig. 3B). Modeled nitrogen concentrations (not shown here) in front of the resorts were consistent with field measurements (0.1–0.4 g N/m³). As shown in Fig. 3A, the N input by the Black Sea coastal current, mostly derived from the upstream coastal resorts, is considerable during the summer months (red line), whereas the Varna Lake input peaks in spring and autumn (green line). The modeled N concentrations in Varna Bay (cyan line) agree reasonably with field measurements of total N (g/m³) (blue symbols) (Fig. 3B).

When the model is run for 5 years (to 2006) without improvements in sewage handling, it is evident that, although the model results fall within the range of measured values, all details are not reproduced (Fig. 4). At times, the model output and the measured values are quite different, which could be due either to limitations in the design of the model or to special events that are apparent in the observed data only. The dearth of data for adequate calibration of the model clearly introduces some uncertainty.

The model simulation for Scenario I (Fig. 5A) indicates that 75% N removal in resort WWTPs as a management option would significantly reduce the summer nitrogen peak and leave the system controlled by the inflow from Varna Lake. Nitrogen removal could improve Secchi depth by about 0.7 m in the period June to October, and by up to 1 m in July, the high tourism season (Fig. 5A - blue line). Yet, water transparency would still fall below the 3-m threshold for some 10–15 days in June (Fig.5A).

Fig. 3. (A) Contribution of different sources of N inputs (Kg/d) to the system of Varna Bay: green line—Varna Lake Current input, red line—Black Sea coastal current input (Resorts' WWTPs), black line—cumulative nutrient inputs; (B) N concentration (g/m³) in Varna Bay: model results (cyan line) and data from field measurements (dark blue symbols).

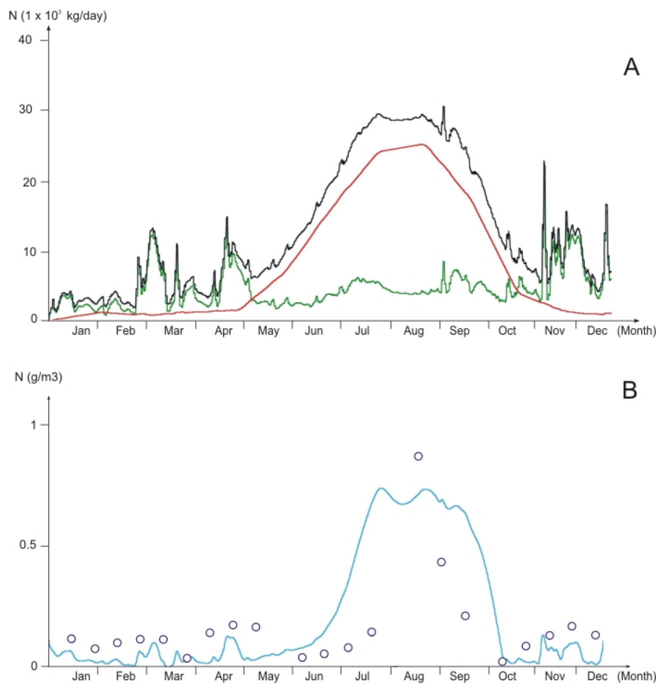


Fig. 4. Secchi depth (m): observed data (green crosses) and model output (red line) in Varna Bay during 2001–2006; black line–threshold value = 3 m.

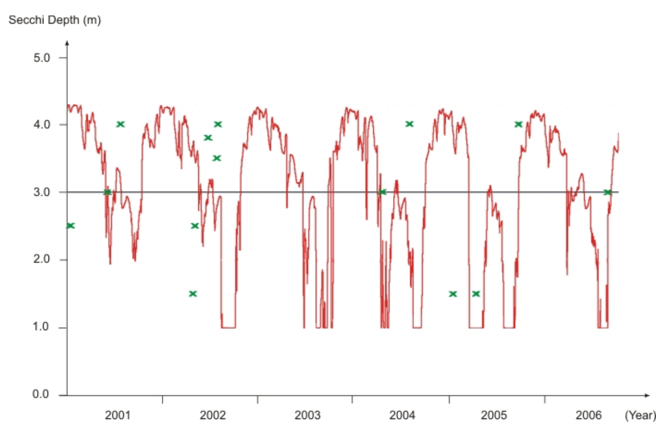
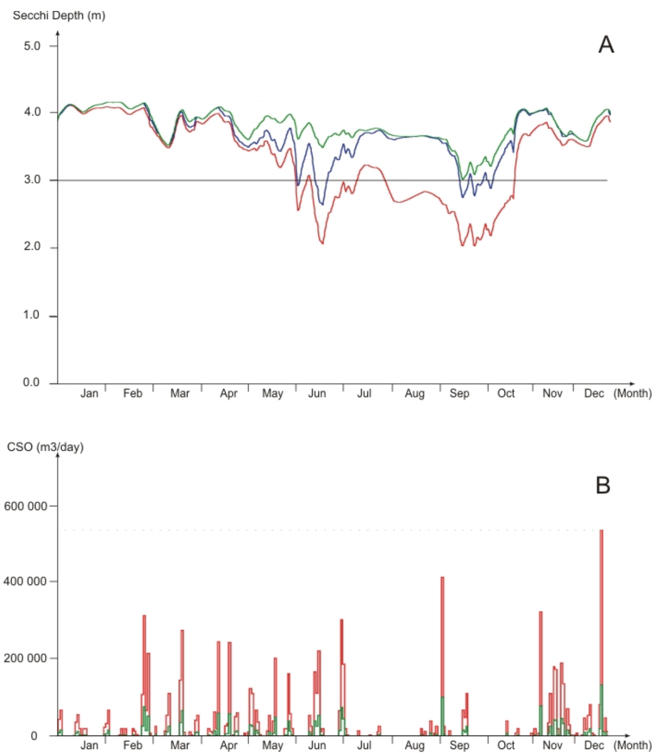


Fig. 5. (A) Secchi depth (m) model output for Varna Bay (year 2001): red line—without N removal, blue line—with 75% N removal (Scenario I); green line—with 75% N removal and CSO reduced by 80% (Scenario II); (B) red bars—volumes of CSO (m³/d), green bars—volumes of WWTP discharged storm waters (m³/d)



The influence of CSO events on Secchi depth is further explained by Fig. 5B, where CSO is the sum of overland runoff and the WWTP overload discharges (m³/d). Green bars represent the volume of storm waters collected and treated in the WWTPs compared to their total current capacity of 170 000 (m³/d), and the red bars are the volume of CSO (m³/d) directly released to the coastal water. As the volume of storm waters currently treated by WWTPs is low (80% of CSO water is directly released), the model indicates that increasing the drainage capacity of the sewer system is of great importance, and Scenario I is not a sufficient option to keep water transparency above the Secchi depth "swimming threshold" of 3 m (Fig. 5A).

The model output for Scenario II suggests that the TSS originating from non-point sources are responsible for the remaining episodes of reduced water transparency. Simulations of CSO discharges clearly show a relationship between sewer systems options and WWTP improvement, the two are complementary. In the model, desired levels of water clarity above the 3-m threshold can be achieved provided 80% of the rainwater is collected by the sewer systems and WWTPs are upgraded to 75% N removal (Fig. 5).

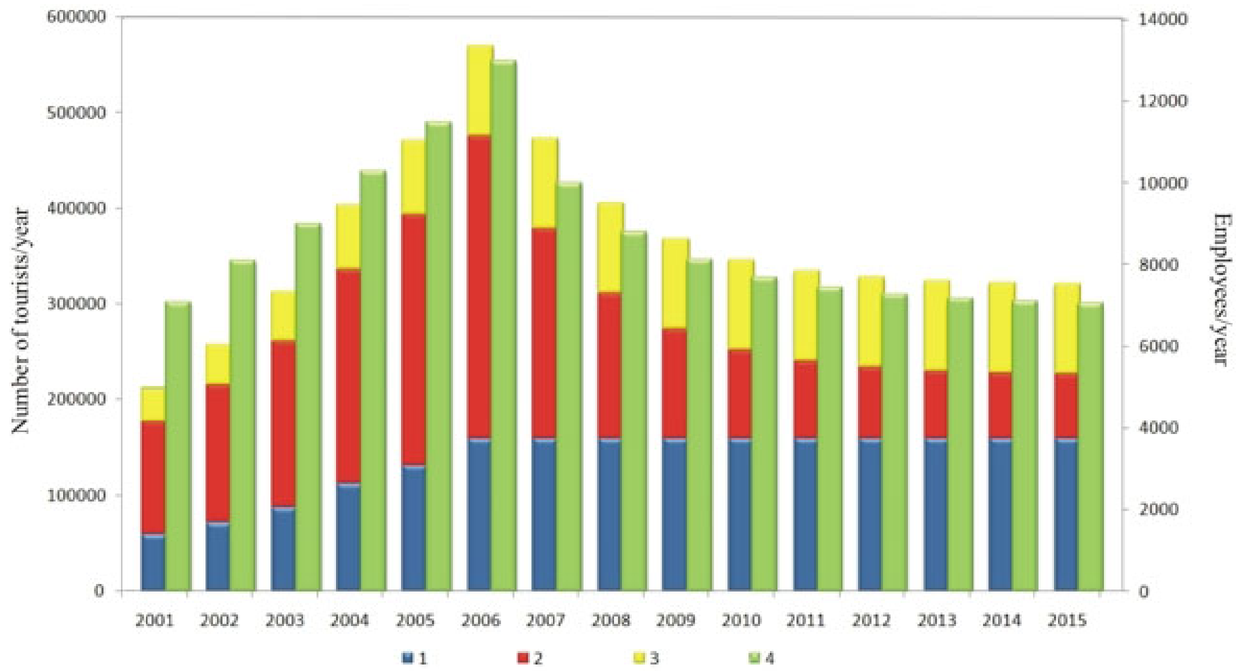
Several socioeconomic simulations directly linked to the ecological component (WWTP and sewer systems improvements) were run in long-term model simulations for the period 2001–2015. The simulations are based on available reports on tourist preferences and motivation to visit the destination. According to the State Tourism Agency (STA 2007), 72% of all tourists come for recreation and beach activities, with the remaining 28% attracted by other activities (gambling, spas, etc.). Taylor and Longo (2010) document that nearly two-thirds of those interested in beach activities are concerned with water quality and demand water transparency above the critical "swimming" threshold. Thus, we subdivided the tourists into the following categories (color-coded bars in Fig. 6): 1 (blue)—tourist not interested in beach activities (28% of total tourists); 2 (red)—tourists interested in beach activities and concerned with water quality (two-thirds out of the 72% of total tourists); 3 (yellow)—tourists interested in beach activities and not concerned with water quality (one-third out of the 72% of total tourists). For the period 2001–2006, the model reproduces the total number of tourists reported officially (Varna Municipality 2008b), whereas calculating projections for the period 2007–2015. Based on tourist motivation to revisit the destination (STA 2007), we assume that, for the period 2001–2006, the share of all categories increases proportionally to the total number of tourists, while after 2006, the disproportion is on account of category 2 (category 1 and 3 will hold the 2006 totals). If the status quo is maintained, the annual number of total tourists after 2006 drops gradually down almost to the values reported for 2003. Figure 6 shows the progressive loss of attractiveness of resorts when Secchi depth remains below the 3-m threshold.

A modeled decline in employment (green bars, Fig. 6) follows the decrease in tourist visits, suggesting that the projected community welfare loss due to the reduced resort attractiveness could have far-reaching consequences for the tourism industry. Estimates of the tourism industry's revenue prospects show a domino effect, indicating a total loss of 1,230 million € in 10 years (figure not shown), which greatly exceeds the 200 million € investment needed for WWTPs and sewer systems improvement.

DISCUSSION

The SAF applied in this study helped emphasize the value of transdisciplinary analysis, which incorporates the interactions among ecology, economy, and society. Even though the importance of tourism for the Varna region was recognized by all stakeholders, the process of scenario discussion vividly illustrated the direct link between ecosystem health and tourism development—why natural resources should not be managed as mere production inputs, but more as ecological

Fig. 6. Trends in annual number of tourists and employees in tourism sector for the period 2001–2006 and projections for 2007–2015: left axis shows distribution of tourists by categories: 1(blue)—tourist not interested in beach activities; 2(red)—tourists interested in beach activities and concerned with water quality; 3(yellow)—tourists interested in beach activities and not concerned with water quality; right axes: 4(green bars)—employees (hotels and restaurants only). Year denotes active season (May–September).



systems of integrated processes (Mitchell 2004, Mitchell and Shrubsole 1994, Sharpley 2000).

The results made it obvious that water quality (as Secchi depth) in the Varna region is reduced by the current insufficient capacity of both WWTPs and sewer systems. Although the nutrient loads from Varna Lake were previously considered the major ecosystem pressure, the model shows that the resort contribution peaks in summer (WWTPs), whereas Varna Lake input is important mainly during spring and autumn (Fig. 3A). Based on physicochemical analysis from monitoring stations in Varna Bay, Simeonova et al. (2010) report that, in the period August–October 2007, many bathing water measurements exceeded the water quality limits for NH_4^+ and PO_4^{3-}. Apparently the coastal current nutrient inputs from the resorts upstream of Varna Bay, dominate the N concentration near its high season maximum (Fig. 3B), leading to a long periods of Secchi depths below the critical threshold (Fig. 5).

The model outputs stress the originally neglected role of TSS loads for Secchi depth variability (Fig. 5). The capacity of the sewer systems and the WWTPs is insufficient for dealing with sudden increases in rain overflow (Irish et al. 1995). Given the increased frequency and duration of heavy rainstorms reported in recent years (NIMH-Varna 2010), the model results suggest that the contribution of the TSS is important for water clarity. Simulations of CSO discharges make evident the relationship between sewer system options and the operational capacity of the WWTPs, i.e., storm-water management and improvement of the sewer systems is critical for management of water quality in Varna Bay. The model results indicate that if measures are taken to decrease the land-based direct runoff overflow by 80% then the TSS concentrations are significantly reduced and a further 0.4-m improvement in water transparency is achieved (Fig. 5).

The long-term model simulations reveal that adequate treatment (75% N removal in WWTPs), quite similar to the target value in the North Sea countries (Crouzet et al. 1999), should result in improved water quality in Varna Bay. This underlines the importance of upgrading and proper maintenance of sewer systems and WWTPs. Thus, design and planning procedures firmly based on the fundamental processes governing the quantity and quality of urban flows (Scenarios I and II) could provide effective solutions to the problems facing planners and decision makers (Wanielista and Yousef 1993, Mitsch and Jorgensen 2004). As demonstrated by the Varna Bay model, such measures should be complementary to improvement of WWTPs in order to achieve “good ecological status” (Water Framework Directive (WFD) 2000) by 2015.

Continued inaction could cause the local economy great losses in the near future, as suggested by the functional cause–effect chain of the environmental and socioeconomic components of the model itself. According to model simulations, reduced water quality will affect annual revenue from the tourism industry, leading to large losses for the local economy, as the resorts not only provide about 10% of direct employment in the tourist sector, but are also a source of income for others temporarily engaged in seasonal jobs. According to the World Travel and Tourism Council (WWTC 2010), by 2011, the travel and tourism industry will contribute 11% to global GDP and generate 260 million jobs worldwide. For Bulgaria the projections are for travel and tourism to generate 9.7% of total GDP and 220,000 jobs, representing 7.6% of total employment, or 1 in every 13 jobs. This requires creation of 182,000 jobs over the next decade. In contrast to these projections, the model results suggest that, even under long-term economic stability, decreased employment and major economic loss could result unless proper action is taken to prevent further environmental deterioration.

A decline in tourist interest in the Black Sea resorts has recently been reported, in addition to a shift of tourist preference toward low-cost, short-term “all-inclusive“ travel options. Irrespective of its large potential, the Bulgarian tourist sector is still characterized by seasonality, unevenness, and lack of purposefulness (Bachvarov 1997). Cheap summer-package tourists still prevail, indicating a tourism product monoculture. It is unclear how long the existing indecisiveness and decline in consumer confidence will last. Even if “recreational tourism” could be replaced by “gambling tourism” (STA 2007), this would not reduce the pressure on .water quality, for example, tourists may not go to the beach, but they will still indirectly “contribute” to the environmental deterioration. If the attractiveness of the resorts for seawater-related leisure activities is lost, the local economy could be seriously affected (Manning and Prieur 1998).

Unfortunately, the ecological history of the Varna Bay exemplifies the “pathology of environmental and tourist industry management.” Experts compare the situation in Bulgaria to that of the Spanish coast in the 1960s. Forty-five years later, the Spanish tourism market, although radically changed, is still in the process of reinventing itself (Beluhov 2006). Growing tourism often constrains its own development, through its impact on the environment. Taylor and Longo (2010) discuss threshold effects for the effect of marine environmental quality on recreational users in Varna Bay and show that water quality influences tourist attitudes and motivations. As sunbathing and swimming are among the preferred tourist activities, good water quality and clean beaches are essential for about 70% of respondents, who indicate that about 80% will bathe provided visibility is above 3 m. Water clarity is therefore considered the main factor affecting tourism and resort attractiveness and must be conserved to maintain a sustainable benefit for the Varna Bay region.

Although a number of economic and political obstacles, some legacies of the past, still prevent Bulgaria from allocating the resources necessary for ensuring sustainable development, the main problem is the implementation of legislation, not the legislation as such. Bulgaria should seize the opportunity offered by its EU accession to establish new patterns of environmental management when restructuring its political and economic system (Holden 2008).

CONCLUSIONS

This study demonstrates the value of the systems approach framework for understanding and explaining the complexity of the tourism–environment interface and the importance of translating that knowledge into scientifically credible management recommendations for sustainable tourism.

The model simulations clearly show that improvements in the capacity of the sewer systems and WWTPs will be complementary. Storm-water management through improvement and expansion of the sewer systems (which could reduce direct runoff by 80%, and building/upgrading WWTPs could achieve 75% N removal) could be the key to successful water quality management in Varna Bay. To achieve this, the institutional limitations, which are the main barrier for improving resource management, must be overcome.

We have used modeling as a tool to track the interaction of a large set of heterogeneous data and assumptions. We found that this approach provided a means of synthesizing data and theories, allowing for better understanding and planning of tourism in the Varna region, which was valuable for both scientists and stakeholders. The simulation model allows for new data to be added as they become available and for other functional components to be included as new issues arise and require evaluation. Certainly, the engagement of the stakeholders and policy makers in a science-based cooperative format demonstrates the value of the system approach framework as an effective tool for successful management of tourism in Varna region.

Responses to this article can be read online at:
http://www.ecologyandsociety.org/vol17/iss3/art35/responses/

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APPENDIX

Details of model key variables and processes are provided below.

Nitrogen Processes

Nitrogen processes considered are: sinking, regeneration, and uptake by phytoplankton in the top layer and burial and denitrification in the bottom layer. The nitrogen content in the two different layers depends also on diffusive exchange driven by physical processes.

In constructing the N budget, we assumed that only the nitrogen stored in the top layer is available for photosynthesis and that not all of this nitrogen is immediately available for primary production, i.e. some might be of terrigenous origin.

The surface layer receives inputs from the atmospheric deposition, the land runoff, point-source discharges, and from the bottom layer, via entrainment and diffusion processes. The surface layer loses nitrogen through phytoplankton uptake, advective outflow, and sinking through the pycnocline. The bottom layer gains N from regeneration, advection, and it loses N to the upper layer through the same entrainment and diffusion processes and through burial.

Nitrogen processes are formulated as follows:

a. Entrainment, as an upwelled flux of bottom water;
b. Diffusion, as proportional to the vertical N-gradient using the same diffusion coefficient as salinity;
c. Uptake, as the amount available up to the saturation value (associated with each of the three phytoplankton classes);
d. Sinking, calculated as a constant percent of the surface N sinking to the bottom layer. The sinking rate takes into account the opposing upwelling rate of entrainment.
e. Regeneration, calculated through a conversion algorithm between biomass produced by phytoplankton with stoichiometric ratio of N:C while sinking out of the surface layer at constant rates for each phytoplankton class taken from literature. A loss due to zooplankton grazing is also added.
f. Advection, as the flux of inflow or outflow times the N concentration;
g. Sediment burial, as approximately equal to literature values for similar deposition rates in estuaries, e.g. ~10% of new N inputs ;
h. Denitrification, as proportional to the bottom oxygen values and calibrated to satisfy the total N budget.

The total new N reflects the seasonality of the rainfall and, at a shorter time scale, the larger runoff events. The Nitrogen concentration is primarily controlled both by runoff variability and by primary production

Phytoplankton Growth

The phytoplankton growth is driven by the light and nutrient conditions, modified by the circulation and diffusion. Its representation is complicated due to the feedback with nutrient regeneration and predation by zooplankton. Three phytoplankton groups are simulated e.g. diatoms, dinoflagellates, and others in order to simulate seasonal succession. The population balance of growth (nutrients & light), respiration, death, and grazing is expressed in the following equation:

$$dPhB/dt=PhB*(MU\_n+MU\_reg+Light*KI)-(Kr+Km)*(PhB)^2 - Kg*PhB \quad [1]$$

where:
dPhB is change in phytoplankton biomass;
PhB phytoplankton biomass is calculated for the three different groups- diatoms, dinoflagelates and others;

The coefficients, MU_n, MU_reg, KI, Kr, Km, Kg are explained in Table 1.

Table 1. Coefficients and values of equation 1.

Variable	Coefficient	Explanation	Value
Light	KI	Photosynthesis efficiency parameter	0.01 $m^2 W^{-1}$
Grazing Zooplankton	Kg	Percent of total biomass	0.1 %
Mortality	Km	Diatoms	0.028÷0.080 day^{-1}
		Dinoflages	0.015÷0.028 day^{-1}
		Others	0.200÷0.480 day^{-1}
Growth rate	MU_n	Growth based on new N:	
		Diatoms	0.7 day^{-1}
		Dinoflages	0.5 day^{-1}
		Others	0.2 day^{-1}
	MU_reg	Growth based on regenerated N	T dependant (conversion table)
Respiration	Kr		0.01 day^{-1}

Light. The observed light is corrected for cloudiness. Its value for the euphotic zone (surface layer) is a vertical integral of the light using a linear attenuation function with an absorption coefficient (KI) through a conversion table.

Nutrients. Nutrients are assimilated considering a specific uptake function (Michaelis-Menten) for each phytoplankton group taking into account the assimilation of new-nitrogen (Nitrate) and regenerated-nitrogen (Ammonium).

Phytoplankton growth rate. We considered the fact that each group has its specific nutrient assimilation ability, which allows diatoms to grow faster in presence of new-nitrogen. By this we obtain two growth rates (MU_n and MU_reg) of each phytoplankton group (Table 1), one based on nitrate and one on ammonium which, when summed, give the total assimilation. The growth rate in presence of regenerated nitrogen is also temperature dependent.

Respiration and Mortality. These are simulated using a quadratic dependency with constant death (Km) and respiration rates (Kr).

Grazing by zooplankton. These are simulated as a linear proportion of the total population through a constant grazing coefficient (Kg).

All calculations are expressed in grams of carbon per cub. m ($gC.m^{-3}$).

Secchi depth

$$\text{Secchi disc (m)} = 4.592 - 0.071 * PhB - 0.4 * TSS \qquad [2]$$

where, PhB is the total phytoplankton biomass ($gC.m^{-3}$), TSS is the total suspended solids in ($g.m^{-3}$), and $R=0.78$, $p=0.005$.

The database used to estimate these coefficients considered 26 pairs (phytoplankton biomass and TSS).

Further explanation and details are available from the authors, e-mail: snejanam@abv.bg.