Social-Ecological Resilience on New Providence (The Bahamas)

A Field Trip Report – Summary

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Institut für Geographie

Hamburg 2012

Introduction

In the context of increasing natural or man-made hazards and global environmental change, the study of (scientific and technological) **uncertainty**, **vulnerability** and **resilience** of social-ecological systems represents a core area of human-environmental geography (cf. CASTREE et al. 2009; ZIMMERER 2010). Extreme geophysical events, coupled with the social construction and production of risks and vulnerabilities (viewed as hazards), raise questions on the limits of knowledge and create long-term social uncertainty that has to be acknowledged as such. Recent means of socioeconomic production and consumption have frequently led to the loss or degradation of ecosystem services on which humans depend (HASSAN et al. 2005). In order to move towards resilience and sustainability, significant changes thus need to be considered at multiple levels in emergency and environmental planning, policies and institutions. When it comes to diagnosing why social-ecological systems develop sustainably or not, a major challenge is to find common frameworks for investigating the dynamic interactions between social systems integrated by governance and communication, and biophysical systems connected by material and energy flows (e.g. HABERL et al. 2006; OSTROM 2009).

Coastal and island ecosystems are some of the most valuable and productive ecosystems worldwide yet highly threatened (HASSAN et al. 2005). Numerous small island developing states (SIDS) are sensitive to natural hazards such as landfall storms, flooding, tsunamis, increases in sea temperature and sea-level rise (PELLING/UITTO 2001; UNFCCC 2007). Small islands sharing the 'isola effects' (or 'insularity', cf. BAYLISS-SMITH 1988; ROYLE 2001) are particularly vulnerable to external shocks and the impacts of social-ecological interplay. Climate and environmental change are some of the obvious concerns, but the social-ecological vulnerability of small islands is exacerbated by limited land-based resources, economic dependency, emigration or manipulation by richer governments and corporations. Recent **island studies** have suggested limits in the interdisciplinary understanding of long-term social and ecological trends and vulnerabilities. Shortcomings are also noted when it comes to the integration of local and traditional knowledge in assessing the impacts of external stressors (e.g. MÉHEUX et al. 2007; KELMAN/WEST 2009).

In the Caribbean, small island coastal ecosystems provide both direct and indirect use values. Indirect environmental services of coral reefs, sea grass beds and coastal mangroves include the protection of coastlines against wave action and erosion, as well as the preservation of habitats of animals including those of commercial importance. Human activity threatens the regenerative capacity of these inshore marine ecosystems, e.g. by pollution, reef degradation through chronic overfishing and bomb fishing, land development (cf. Fig. 1), mangrove degradation and increased nutrient and sediment run-off (LEWSEY et al. 2004; BRETON et al. 2006). With the added impact of external shocks such as hurricanes, many degraded reefs have undergone phase changes or regime shifts (e.g. coral bleaching, macroalgae domination), which is equivalent to erosion of the ecosystem's resilience (cf. GARDNER et al. 2003; MUMBY 2007).

Ecological and social vulnerability to such disturbances and disasters is influenced by the build-up or erosion of resilience. Concepts of resilience generally focus on the capacity of the system to absorb shocks whilst still remaining functional, as well as the system's capacity of renewal and development in coping with change and crisis (FOLKE 2006; GAILLARD 2010). An ecological resilience perspective (HOLLING 1973, 1986) has come to be embedded in theories of complex adaptive systems based on multi-agent systems. The question is how periods of gradual change interplay with periods of rapid change and how such dynamics interact across temporal and spatial scales.

Fig. 1: Urban and marina development in SE-Nassau, The Bahamas (Photo: A. Holdschlag 2011)

In this report, the island of **New Providence, The Bahamas**, is regarded as a complex social-ecological system faced with environmental change and stressors. In the following we briefly review ideas and concepts of complexity before presenting approaches that can enrich research on and also policy development for small islands and coastal communities. Our focus is on the socioeconomic dimension of social-ecological system dynamics. We address various subsystems, i.e. **natural hazard management**, **coastal ecosystem management**, **water and energy supply**, **land traffic**, **tourism** as well as **environmental education** as an adaptability attribute. In order to comprehend agent behavior and interaction, we argue that understanding is required of the environmental knowledge systems held by those agent groups that shape natural resource utilization and hazard management. Such understanding is important for developing flexible and adaptive policy based on institutional and social learning (BERKES 2009).

Complex Social-Ecological Systems in the Anthropocene

The anthropocene is characterized by increasingly widespread and disruptive influence of humanity on ecological systems (TURNER ET AL. 1990; VITOUSEK et al. 1997; EHLERS 1998, CRUTZEN/STOERMER 2000, EHLERS 2008; ZALASIEWICZ et al. 2010). Accordingly the body of literature on interdisciplinary and cross-scale notions and models of coupled **social-ecological systems** has grown rapidly. Although such concepts have been criticized because of empirical and analytical problems (WALTERS/VAYDA 2009: 540), research on human-environment interactions based on theories of complex systems is gaining increasing acceptance (e.g. BERKES/FOLKE 1998; GUNDERSON/HOLLING 2002; REDMAN et al. 2004; HABERL et al. 2006; OSTROM 2009; MORAN 2010; EVANS 2011). In human geography, theories concerned with complex systems have been of interest for about two decades (e.g. FLIEDNER 1997, 1999, 2010; RATTER 1998, 2001, 2006, 2012; FUNNELL/PARISH 1999; POSSEKEL 1999; THRIFT 1999; MANSON 2001; CHAPURA 2009). There are different, sometimes conflicting notions of complexity, as 'the value of complexity exists in the eye of its beholder' (MANSON 2001: 412). But as this is 'a body of theory that is preternaturally spatial' (THRIFT 1999: 32), it can be of relevance for further geographical analysis.

In general, **complexity research** is about non-linear dynamics and relationships between constantly changing entities. It asks how systems evolve over time due to the interaction of their constituent elements (MANSON 2001: 406). Basic notions are indeterminism and the absence of prediction, irreversibility, uncertainty and surprise. The idea focuses on the operation of within-level and cross-system linkages, giving importance to scale both at the spatial and temporal level. Complexity stresses the existence of diverse networked time-space paths and frequent disproportionateness between causes and effects (URRY 2003: 7). It examines the qualitative characteristics of system component behavior, which is largely limited to local interactions. Thus, complex systems are more defined by relationships than by their constituent parts (MANSON 2001). Dealing with these systems demands a special adaptive management approach (RATTER 2001).

Complex non-linear interactions may occur through feedback processes which can be understood as intricately interlinked loops within a large network. As a result of these processes, system elements may re-form into a larger, relatively autonomous unit, although this process cannot be explained in terms of the elements themselves (so-called emergence, e.g. FLIEDNER 1997, 1999; RATTER 1998, 2006, 2012). Emergent properties display unique qualities and result from the ability of complex systems to organize themselves across time and space (self-organization). System elements also have a capacity for learning and self-reinforcement, enabling them to adapt to disturbances (HOLLAND 1995; LEVIN 1999). Non-linear interactions of system components can produce unexpected dynamics and give rise to multiple stable basins of attraction (HOLLING 1973). These 'attractors' or 'regimes' of system behaviour may exceed critical mass thresholds or tipping points, resulting in qualitative regime shifts or leading system trajectories to so-called bifurcation points. The resilience of the system can be described as the ability to tolerate disturbance within the same domain of attraction, the ability to maintain identity, and the degree to which it can build capacity for learning and adaptation (e.g. FOLKE 2006; CUMMING 2011).

In this report, we draw on the heuristic models of the adaptive renewal cycle and panarchy (GUNDERSON/HOLLING 2002), which are embedded in the theory of complex adaptive systems and which we regard as appealing concepts for understanding and interpreting social-ecological system behaviour. Developed from the perspective of ecology, the **adaptive renewal cycle** describes four functions or phases of adaptive change (Fig. 2). The r phase represents 'exploitation', in which colonization takes place. In a broader sense, it is a phase of entrepreneurial exploitation, growth and exponential change. It is succeeded by the K phase of 'conservation', characterized by accumulation and storage of energy and material, or organizational consolidation, growing stasis and less flexibility. These two controlling functions represent traditional views in ecology and may be perceived as the fore loop of the cycle. Two subsequent phases can be added as the back loop. The rapid Ω phase of 'release' depicts the collapse or creative destruction of the system. The fourth α phase of 'reorganization' stands for restructuring,

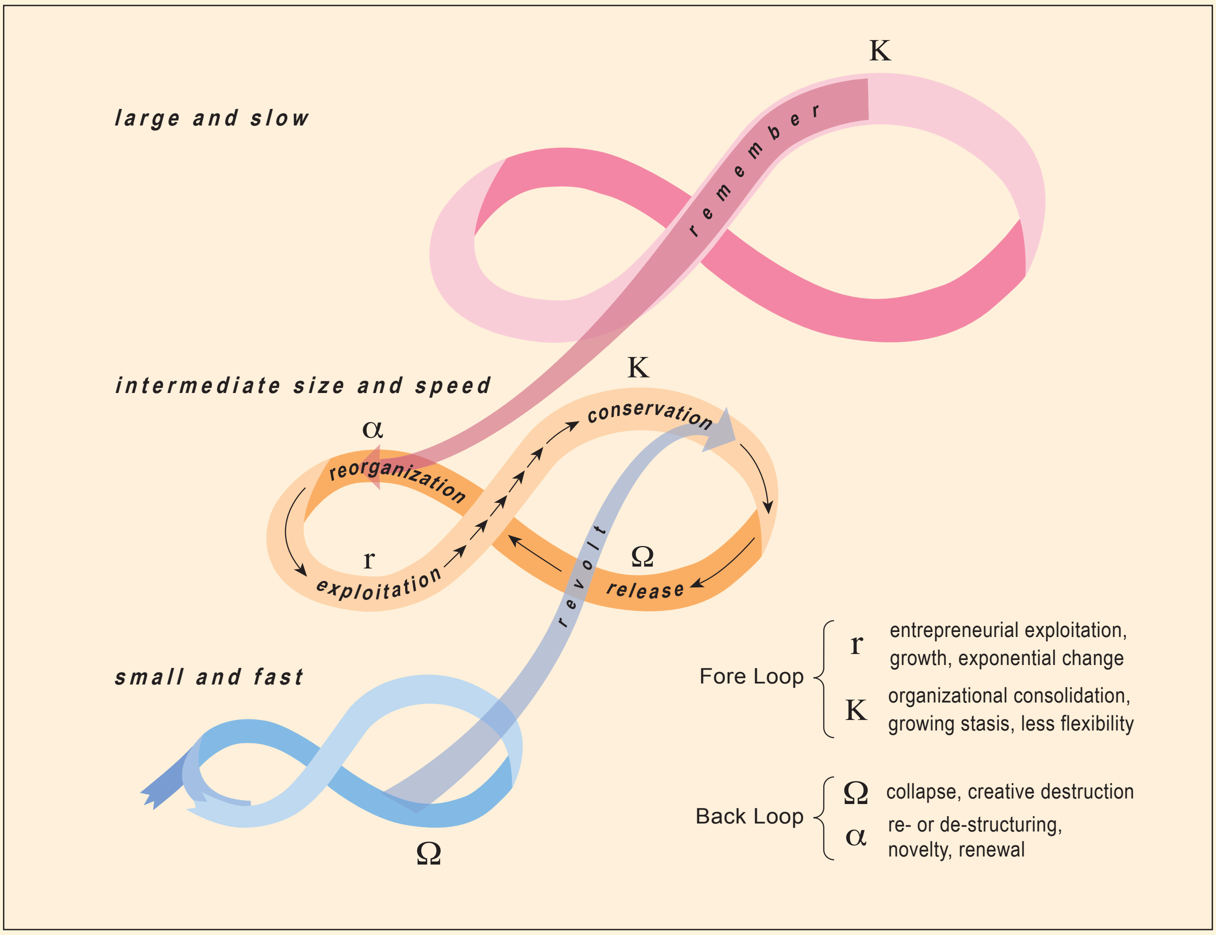

Fig. 2: Heuristic models of the adaptive renewal cycle and panarchy (Modified from Gunderson/Holling 2002, Graphic: C. Carstens)

novelty and renewal and symbolizes the beginning of a new cycle. The stylized fracture represents a possible flip into a different system. The arrows show the speed of the flow in the cycle, where the short arrows indicate slow and the long arrows rapid change. Resilience decreases when the cycle develops towards K and increases in the phase of reorganization α.

The metaphor of the adaptive renewal cycle has been extended to the model of **panarchy**, which describes a cross-scale, nested set of the four phase adaptive cycles. In contrast to the term 'hierarchy', which commonly implies a rigid, top-down structure, panarchy – derived from the Greek god of nature Pan – is to represent the creative and destructive, adaptive, sustaining and evolutionary nature of nested system dynamics. It depicts interactions within and across spatiotemporal scales, between large and slow and small and fast structures as well as top-down and bottom-up relations. Out of the potentially multiple interactions, two connections are emphasized which are important for adaptive capacity. The 'revolt' arrow in Fig. 1 suggests a cascade effect where small and fast events trigger a critical change in large and slow cycles. The 'remember' connection facilitates restructuring, drawing upon the experience and potential of maturity accumulated by a larger and slower system in its K phase. Consequently, panarchical relations can shape the adaptive capacities and opportunities for resilience (ibid.).

Methodology and Research Site

Humans are the constituent elements in the social sphere of a social-ecological system. They organize in collectives, composed of individual **agents** that have limited information about the system as a whole. They also have distinct views, roles and agendas. It is their interactions at the micro-level (locally in space and time) that lead to emergent structures at the macro-level (RATTER 2006, 2012). Agents self-organize to fulfill certain functions of the system such as resource allocation and decision making, a process which requires certain forms of knowledge, norms and power relations. The management of a complex, constantly changing social-ecological system demands a wide **range** of knowledge, which is why knowledge production, learning and uncertainty play a key role when it comes to developing policies for resilient system dynamics (e.g. BERKES 2009). Often, social networks are essential in that they connect multiple levels and sources of information. However, bringing together different forms of knowledge is a difficult task (ibid.).

So far only a limited number of studies have been undertaken on adaptive cycles and panarchical relations of small island social-ecological systems (e.g. BUNCE et al. 2009). In this report, we examine the island of New Providence, The Bahamas, as a case study. Focusing on different spatial and temporal scales, various social-ecological subsystems are analyzed. Management practices are highlighted in each case, taking into account various systems of **knowledge generation** and **communication**, forms of **organization** and **networks**. We also intend to cover the role of **spatial-temporal cross-scale processes**. The aim is to better understand the principles of the system's

Fig. 3: The Commonwealth of The Bahamas (Cartography: C. Carstens)

Fig. 4: Satellite image of New Providence
(Image: Google Earth 2012)

Fig. 5: Urban Nassau
(Photo: A. Holdschlag 2011)

dynamics (or adaptive renewal cycle) and to identify potentials to enhance resilience.

The Commonwealth of The Bahamas (Fig. 3) may be regarded as an extended coastal zone. It consists of over 3000 low-lying carbonate islands, cays and rocks that comprise the largest tropical shallow water area in the Western Atlantic. Most of the Bahamian waters have a depth of less than 20 m, resulting in an 'extremely important marine resource with both ecological and economic value' (BUCHAN 2000: 94). According to the latest census (2010), the country's population has grown by 16.5 % between 2000 and 2010 and now stands at about 354,000 (Department of Statistics 2011). Apart from banking and finance, the economy is dominated by two interrelated sectors. The first

• System *(size, components, boundaries)*	• Risk, uncertainty	• Social networks
• Feedback	• Adaptation	• Power relations
• Change *(environmental and social, gradual and rapid)*	• Renewal, re-organization	• Institutions
	• Thresholds	• Norms
	• Cross-scale interactions	• Knowledge systems
	• Emergence	• Communication
• Path dependence	• Connectivity	• Memory
• Self-organization	• Diversity	• Learning
• Disturbance, stressors	• Social agents	• Innovation

Table 1: Key categories of analysis

is tourism whose output accounts for some 40 % of the economy. Tourism has shown continuous recovery since the 2009 world-wide recession (Central Bank of The Bahamas 2012) although the sector is not significantly diversified, specializing essentially coastal '3S tourism' (Sun, Sand, Sea) and a single type of visitor. The sector shows remarkable resilience, having represented a major pillar of the national economy for decades in spite of stressors like hurricanes, 9/11 or financial crises (cf. CLEARE 2007). Second are the interrelated real estate and construction sectors, e.g. of tourist resorts and new and second homes, which account for approximately 25 % of the gross value added (2011, Department of Statistics 2012). Socially, The Bahamas are characterized by diversity, fragmentation and informality of the social sphere. The environment is fundamental in the construction of identities (BETHEL 2002; STORR 2004). Our research site, Nassau/New Providence, is the capital and the central urbanized area of the archipelago (Fig. 4 and 5). Currently, it comprises a population of 249,000 with a population density of 1200/km^2 (Department of Statistics 2010).

Against this background, we address New Providence as a complex social-ecological system engaged in an adaptive renewal cycle and composed of multiple subsystems shaped by interacting ecological and social components. These interactions produce outcomes that affect specific subsystems and their constituent elements, as well as other, smaller and/or larger, social-ecological systems (panarchy). Table 1 shows the key analytical categories applied.

In the following, we present findings with regard to natural hazard management, coastal ecosystem management, water and energy supply, land traffic, tourism and environmental education. In investigating the different subsystems and 'adaptability attributes' as comprehensively as possible, we aimed at maximum **methodical plurality**, drawing on complexity literature with a geographical focus, interdisciplinary island studies and various materials from The Bahamas, e.g. socioeconomic statistics, historical records as well as published and unpublished reports and plans of governmental and non-governmental agencies. In addition, in-depth semi-structured interviews were conducted with government officials, experts of semi- and non-governmental organizations (NGOs) and academics with direct or indirect influence over policy formation. Interviews were conducted in Nassau/New Providence during two weeks of fieldwork in September and October 2011. Respondents represented the fields of emergency preparedness and management, environmental planning, management and conservation, water, electricity and traffic management, tourism, meteorology, ecology, marine biology, geography, history, economics and sociology. These inquiries were supplemented by random population surveys as well as (focus) group discussions (cf. Fig. 6-10). The support of all respondents is gratefully acknowledged.

Fig. 6:
Group discussion at the College of The Bahamas (Photo: A. Holdschlag 2011)

Fig. 7:
Group discussion with a member of the Bahamas National Trust at the Harold & Wilson Ponds National Park (Photo: J. Tribukait 2011)

Fig. 8:
Group discussion at the BEST Commission (Photo: A. Holdschlag 2011)

Fig. 9:
Interview situation (Photo: S. Ehlert 2011)

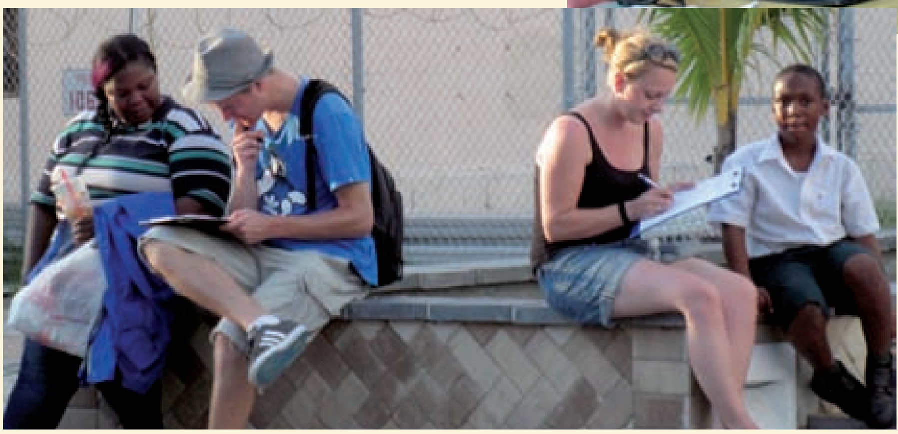

Fig.10:
Interview situation (Photo: S. Ehlert 2011)

Results and Conclusion

From a systems perspective, **natural disasters** can be regarded as perturbations to a social system. Tropical storms and hurricanes are a major natural threat for the population of New Providence and a cause of large-scale ecosystem disturbance. The long-term risk posed by an event, and the uncertainty associated with it depend on awareness, perception and knowledge of the event, as well as the actions taken and adaptation to disaster. Hazard memory and learning from experience play a pivotal role in improving future disaster policy responses and institutional capacities.

Resilience can be defined as the ability of the New Providence population to deal with shocks and persist after a hurricane-based system disturbance. New Providence society was analysed in terms of its ability to immediately deal with shock, recover from shock, learn for future disasters and restore societal conditions to 'normal' after a hurricane event. A cycle of four phases of emergency management can be identified. 'Preparedness' and 'mitigation' measures in the potentially affected area have to be implemented to achieve an efficient 'response' and 'recovery'-phase. The emergency management system is a complex network of public, private and non-profit organisations and individuals. Agents in the system therefore comprise not only the national emergency institutions but also numerous other entities in the subsystem as well as in larger scale and smaller scale systems.

Findings show that the population of New Providence has learned to live with the constant hazard of hurricanes. So far, numerous efforts have been made to increase coping and adaptation capacity (cf. Fig. 11). Preparedness and mitigation measures include adaptation of building codes as well as education to enable and improve the short-term response during a hurricane event. Information and warning mechanisms are well established and maintained by the National Emergency Management Agency (NEMA), the Red Cross and the Bahamas Department of Meteorology as the main agents. In the case of a disaster, The Bahamas can also tap international assistance through international connections and co-operations, increasing its resilience to natural hazards. International connections include relations with US agencies, the Caribbean Disaster Emergency Management Agency (CDEMA), the Panamerican Disaster Response Unit (PADRU) as well as the International Federation of the Red Cross. These connections contribute to more efficient handling of response measures against the unknown characteristics of an approaching hurricane as well as faster recovery of the affected areas. Interestingly, our surveys reveal that a hurricane event is not only viewed as a danger or obstacle to development but also as an opportunity for positive change by many agents.

To increase social-ecological resilience on New Providence, various knowledge systems and knowledge transmission need to be maintained at a high level. This can be done through all-year-round institutional educational programs, such as giving talks in schools or other public institutions. The link between the subsystems of natural hazard management and education is thus crucial in terms of awareness-raising. At an individual scale, social networks are important means of support for the local population, enabling knowledge transfer as well as mutual help and support before, during and after a hurricane event. Apart from the institutional scale, individual-scale connectivity is thus another important aspect of natural hazard management.

The link between the subsystems of natural hazard management and transport and road traffic only becomes visible in its entirety after a hurricane has hit the island of New Providence. After heavy rainfall, failures in the drainage system as well as excessive soil sealing on New Providence induce several problems which affect both subsystems. Streets and homes are inundated due to soil sealing in densely populated areas. This can result in pollution of drinking water and problems

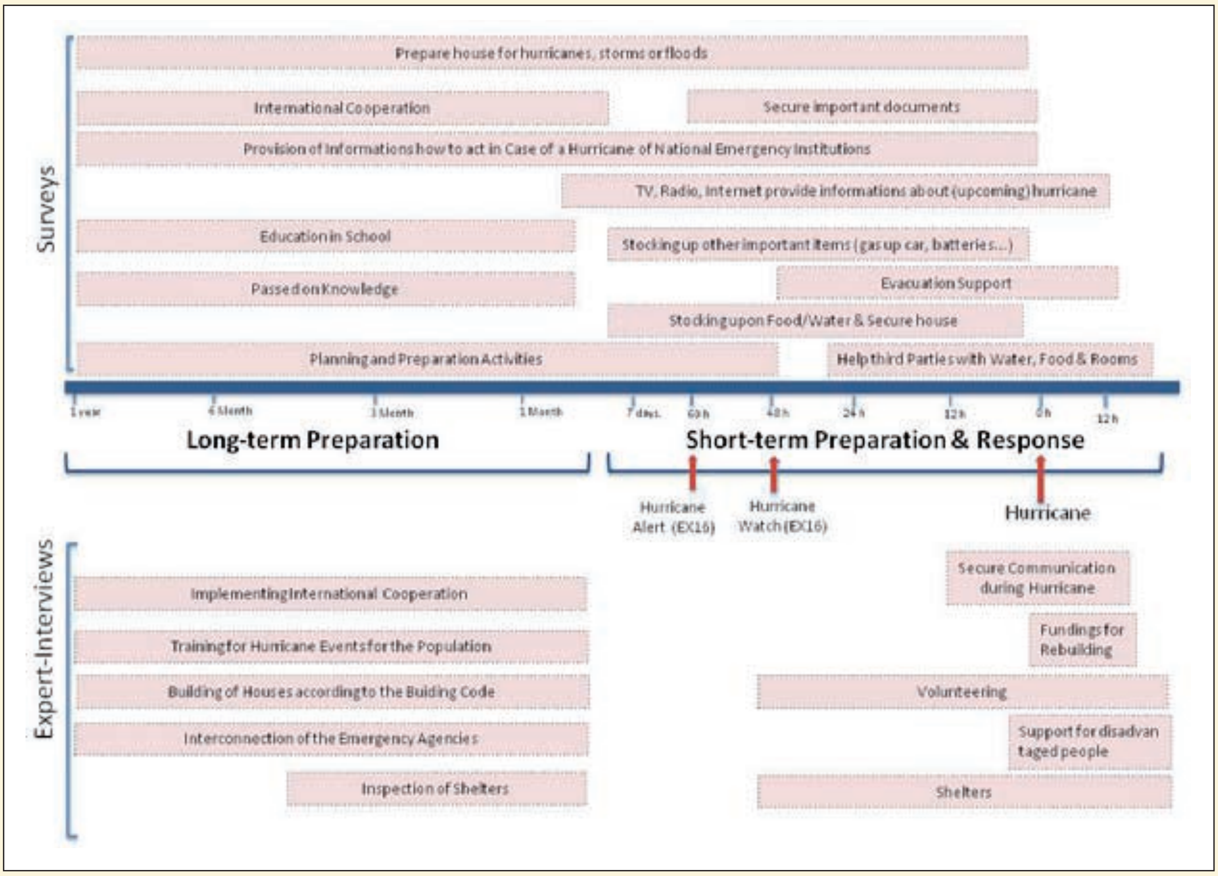

Fig. 11: Long-term and short-term disaster management strategies (Draft and Graphic: J. Bornemann, C. Meyer)

with the discharge of waste water, linking the subsystem of natural hazard management to the subsystem of water supply. These aspects also need to be considered in emergency management. Further research is necessary, e.g. on the enforcement of building codes or comparison of New Providence and the Bahamian 'family islands' in terms of resilience.

Coral reef and mangrove ecosystems can significantly contribute to shoreline protection in case of a tropical storm or hurricane event, enhancing social-ecological resilience as a result. Drawing on an ecosystem services approach, these ecosystems were further examined for external stressors, system functions, agents' knowledge and awareness of these systems, as well as use and management practices. According to our respondents, the main functions of coral reefs and mangroves are the provision and protection of coastal habitats. As a cultural service, the ecosystems support traditional and commercial fisheries. Shocks affecting the ecosystems may be hurricanes and storm waves as well as various kinds of man-made pollution. Moreover, coral reefs are affected by bleaching events, with fire and construction representing significant threats for mangroves.

The vulnerability of mangroves and coral reefs is defined by the interplay of external shocks, trends in ecosystem development, and social agent's awareness of ecosystem functions and management practices 'Remember and revolt capacities' within the broader socio-ecological system also play a role, as does the ability of ecosystems to adapt. These indicators determine New Providence's resilience with regard to coral reefs and man groves. Analysis shows that existing mangroves have greater resilience than coral reefs. However, this is due to fact that large parts of mangrove forests have been removed and the remaining small

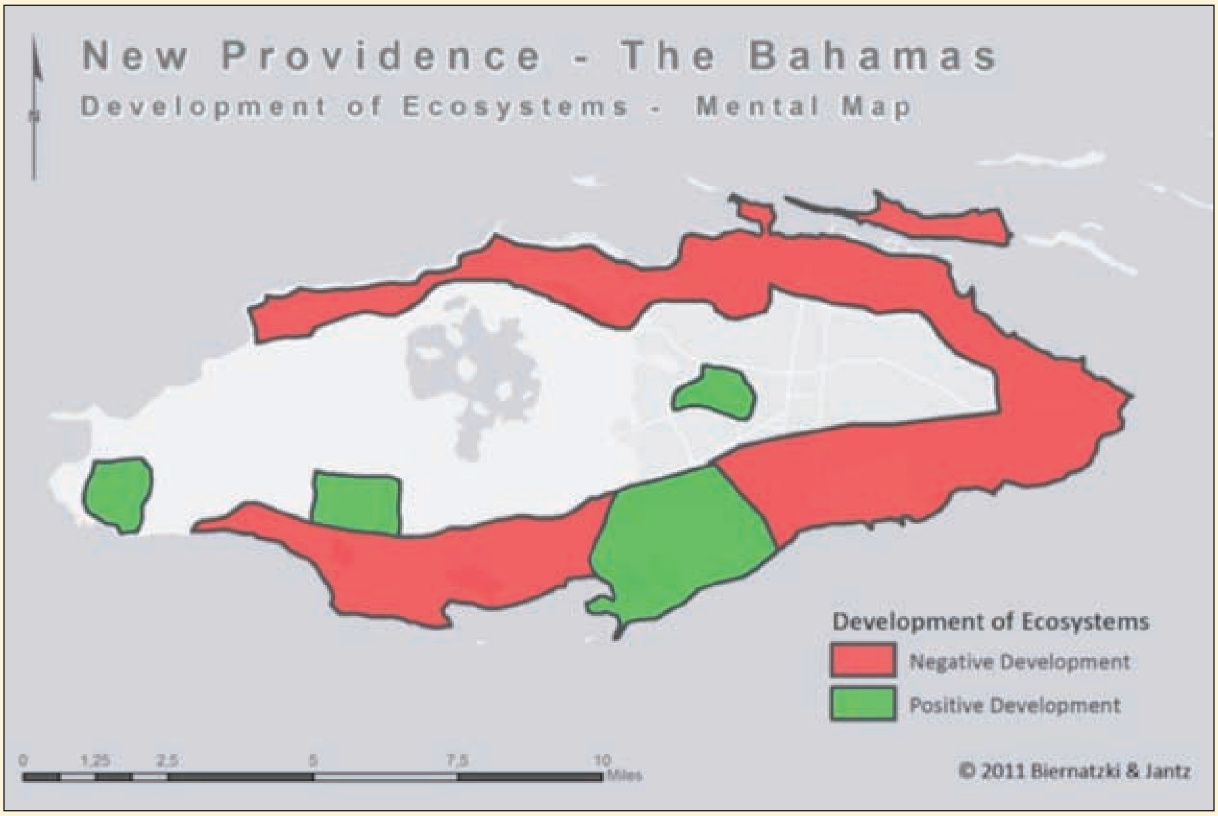

Fig. 12: New Providence – development of ecosystems (mental map)
(Draft and Cartography: J. Biernatzki, P. Jantz)

patches are strictly protected. The ecological function of the remaining coastal mangroves for the island is negligible. In contrast, coral reefs are more threatened at present but may have greater significance in terms of resilience-enhancing functions and services. Especially in the context of coastal protection, existing reefs play a more important role than mangroves. But the current trend of degradation (cf. environmental experts' mental map, Fig. 12) has a negative effect on the island's social-ecological resilience and, thus, has to be taken seriously. A promising strategy may be to work on remember and revolt capacities within society to reduce vulnerability and support adaptability in regard to the services made available by coral reefs and mangroves.

A different insight into socio-ecological relations with an impact on New Providence's resilience is gained from analysing the island's inland wetlands. Although New Providence receives a significant part of its (drinking) water from the island of Andros (see below and Fig. 13), all inland wetlands on New Providence are freshwater based. They fulfil an important function as water catchments, influencing the condition of the island's freshwater lens. With the help of plants growing in these areas, e.g. mangroves, excess nutrients are removed from the water before it reaches the ground water table. During the rainy season, inland wetlands can collect and store water away from homes and roads. Nevertheless, a lot of building was and is still done along these shallow basins. Consequently, the ecosystem's ability to prevent flooding is diminished. Further investigation in the field of inland wetlands would provide a new perspective on socio-environmental interconnections.

Water and electricity supply are crucial functions of the small island social-ecological system. In a first step, we tried to show the structure of both subsystems and identify their main stressors. In a second step, we focused on the interactions

Fig. 13: Water barge from Andros Island at Arawak Cay, Nassau (Photo: A. Holdschlag 2011)

between each subsystem and the main island system, the perception of stressors and external effects as well as the resulting learning effects. The findings have lead to the conclusion that the subsystem of water supply on New Providence is currently situated in the exploitation phase (r phase) of the adaptive cycle. A previous reorganization was accompanied by a regime shift because depletion of groundwater resources on New Providence led to a new way of obtaining fresh water, i.e. its import from another island (Andros) and the generation of freshwater through desalination. Nonetheless, the formerly dominant way of obtaining freshwater, the exploitation of groundwater sources, still plays a minor role in the subsystem. Today's water supply on New Providence thus relies on the three pillars of desalination, import and groundwater abstraction, with desalination providing the largest share. The regime shift changed the linkages between the main system and the subsystem and also between the subsystem and other subsystems. Water supply took on a new role within the systemic interlinkages ('panarchy') on New Providence and in The Bahamas as a whole as an intertwined island collective, especially on account of a new dependency on water import. The separation of drinking water – the majority of the population consumes bottled drinking water – and service water supply has also modified the system.

Although various stressors such as dependence or increasing costs affect the system, it can be stated that in general, water supply on New Providence is resilient at the present time. This also results from the system's agents' willingness and ability to adapt, learn and improve. According to governmental plans, the stressing effect of import dependence will be removed through further expansion of desalination. But as this procedure relies on the input of electricity, future resilience of water supply will heavily depend on the stability of the subsystem of electricity supply and the increasing prices within this specific subsystem which are determined by the fuel price development. Awareness of this growing financial stressor emerging from the growing connection with the subsystem of electricity supply seems to be low, especially since service water is still provided at an acceptable price due to public subsidies. Similarly, the perception of stressors concerning the environment as resource base is not very pronounced – neither in the subsystem represented by experts, nor in the main system represented by government and consumers. With respect to

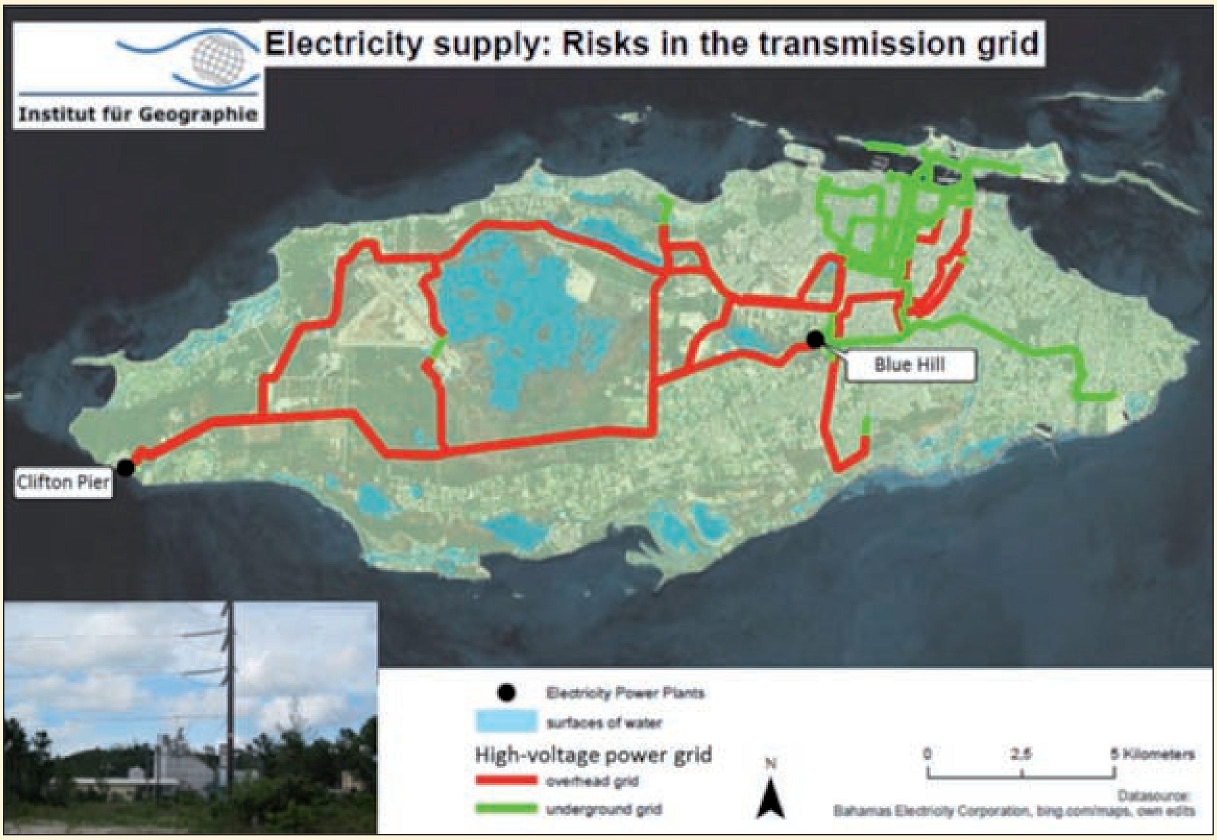

Fig. 14: Electricity supply – risks in the transmission grid (Draft and Compilation: S. Klatt, S. Rhodes, J. Tribukait)

groundwater pollution as the most important environmental stressor, it seems evident that the sewerage and drainage system should be upgraded, not least because the latter also plays an important role in handling heavy rains and storm events (see above). Small-scale, decentralized solutions may be an option for New Providence in the sense of closed-cycle-applications that allow for the use of wastewater. Another way of improving the subsystem's resilience could be to upgrade public water quality in order to reverse the separation between service water and drinking water.

The subsystem of electricity supply is in a different phase of stability. Although the transmission grid shows vulnerability to tropical storms and hurricanes (Fig. 14), the stressors to the system are predominantly economic. Rising fuel prices lead to an excessive increase in operation costs, leading to a growing debate on introducing alternative methods of electricity generation. Renewable energies, especially the use of solar energy, are part of this debate which involves bodies of experts and the island's public as the main agents. However, the system is still conventionally run so far. At a small scale, an option has been created for using solar power, e.g. for heating water, by introducing a law that permits the production of a limited amount of energy for private purposes. The static position of the system implies it has reached the end of the K phase of the adaptive cycle, suggesting a regime shift may be imminent which could change the structure of the subsystem. Since the stressors are predominantly economic, the likelihood of a system shift largely depends on the development of fossil fuel prices and investment costs for renewable energies. Nevertheless, the electricity supply system can be described as resilient because it is guided by national government which ensures electricity supply through price regulation.

Fig. 15: Daily traffic jam in Nassau (Photo: A. Holdschlag 2011)

Dependence on fossil fuel prices was identified as the strongest connecting element between both supply systems. A measure under consideration to overcome fossil fuel dependence is the construction of ocean thermal energy conversion (OTEC) plants. OTEC allows for the co-production of energy and drinking water without expensive fossil fuel input. Admittedly, the investment is very expensive and hence only realistic if there is a sharp increase in fossil fuel prices. The exchange with the main island system plays a key role in determining the resilience of both supply systems. The main system's need for the subsystems' products (water and electricity) is the most powerful stabiliser for both supply systems. At the same time, the desire to keep down costs and prices is a stressor for both subsystems. Cost regulation can thus be identified as the main factor influencing decisions and actions in both subsystems. This makes the island's income a key stabilising factor for both supply systems. Accordingly, the overall significance of the subsystem of tourism as a main income generator and stabilizing force has to be emphasized. In spite of the financial pressure, both supply systems are currently far from collapse. A conclusion is that key agents in the main island social-ecological system put much effort into their stability because of their overall importance.

The **motorized land transport system** of New Providence is currently in a state of growing stasis (K phase). Many urban roads are characterized by temporary gridlocks, confining agents' mobility patterns (Fig. 15). The main reason for this is the predominance of private cars in the island's transport system. Although local jitneys also play a role, the car is the dominant mode of passenger transport. Apart from offering comfort, car ownership is a symbol of prestige on the island. Direct stressors on the motorized transport system include all factors impeding traffic flow, whilst unused potentials such as public transport represent indirect stressors. Road construction and maintenance activities can be identified as stabilizers, but in the short-run they also act as stressors, e.g. further loss of flow capacity caused by road works.

The factors influencing the traffic system's resilience include the increasing number of vehicles on the island, the modal split, traffic planning and policy, the overall concept of transport of the authorities, the attractiveness of traffic alternatives, the role and diversity of the agents involved (cf. Fig. 16), (changing) social norms and learning capacities and, predominantly, transport costs. Based on the indexing of various analytical categories it can be assumed that the subsystem road traffic is at present highly vulnerable due to capa-

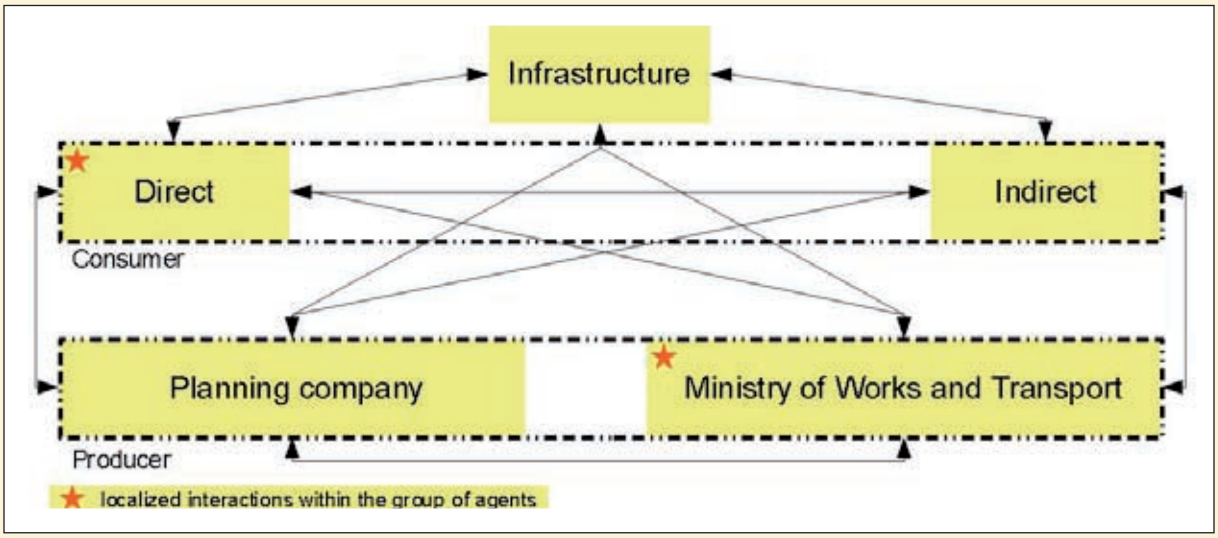

Fig. 16: Motorized traffic system – agents and connectivity (Draft and Graphic: S. Denker, T. Reisch)

city utilization and sensitivity to disturbance. However, an intact road transport system is necessary for modern economies and the mobility of its citizens, and greater disturbances would affect other sectors of the economy and areas of society. Ecological issues are of prominent concern in the development of the transport system, but the environment does not play a major role in the various agents' mindsets.

In order to enhance the resilience of the transport system, changes in the perception and conception of mobility seem essential. A possible way to solve the problem of the increasing number of vehicles on the island is to advance the attractiveness of public transport, e.g. by means of island-wide coverage, reliable schedules as well as high quality standards applied throughout. The dilemma may be that such actions can result in higher prices for transportation or increased taxes. So the establishment of a state-run public transport has to be carried out with the right sense of proportion. Another way to deal with the problem is to lower the advantages that individual motorisation brings. This can be organised by creating longer travel times for cars compared to busses covering the same distance, e.g. by introducing bus lanes, or by increasing the monetary benefit of public transport. Both can be carried out at the same time. Yet small steps are recommended in order to avoid shocks in public perception as well as monetary stress for disadvantaged groups and the state's finances.

The environment does not play an important role in the mindsets of **tourism** agents either. While the natural environment is predominantly viewed as scenery and as a main resource for tourism, its protection is not a big issue for agents in the tourism sector. Our population survey and expert interviews show that economic benefits are generally considered more important than environmental protection. The very positive perception of tourism may prevent people from seeing its negative impacts. Tourism is the backbone of the Bahamian economy and thus a dominant factor in everyday life on New Providence. Findings indicate that the subsystem of sun, sand and sea (3S) hotel tourism creates an outstanding and highly competitive destination for a special type of tourist. New Providence possesses a specialized tourism orientation and image and achieves high consumer satisfaction. Proven and trusted concepts have made tourism a long established and reliable industry which has shown the ability to absorb shocks and regenerate rapidly, e.g. from a decrease in tourist numbers in the wake of 9/11 or hurricane events. There is confidence in the

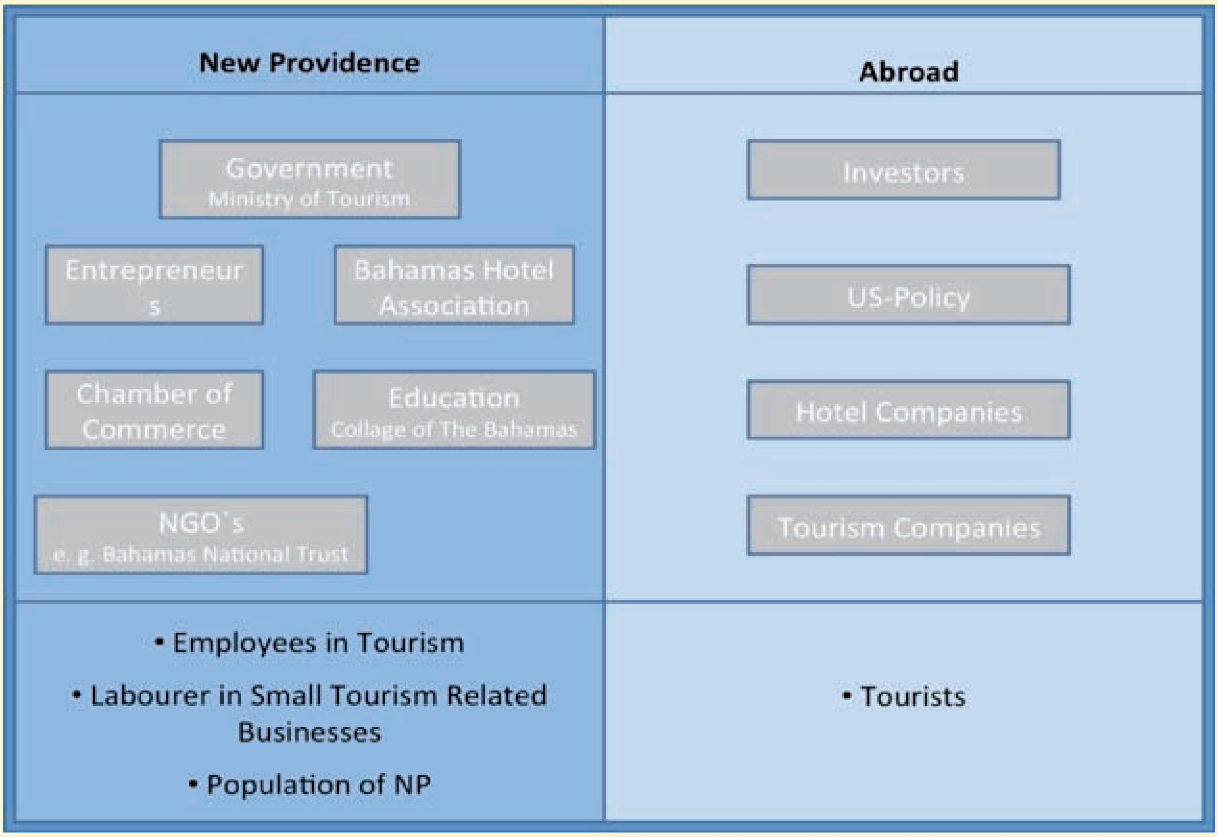

Fig. 17: Stakeholders in the tourism subsystem (Draft and Graphic: L.-M. Bott, S. Diesener)

system's ability to recover and in the approved tourism strategies that have been successful over a long period of time. However, different levels of impact should be noted. While the dominant foreign-owned companies have been able to absorb shocks, smaller local tourism related businesses had greater difficulties in coping with decreasing numbers of visitors. The differences in size also reflect power relations and structural influence. The recent economic crisis is a long-term disturbance which has forced numerous small and medium-sized enterprises to give up. Nevertheless, the tourism system as a whole, consisting of various stakeholders as shown in Fig. 17, will remain a reliable economic vehicle that provides employment, income and foreign exchange. This statement can be substantiated by the fact that currently large amounts are invested in tourism projects like the 'Baha Mar' resort at Cable Beach (Fig. 18).

In terms of risks, tourism almost totally depends on external agents and factors. It is very susceptible to global changes or single events in important source regions of tourists (USA). Moreover, the sector has a very low degree of diversification. Nevertheless, the size of the system (no. of visitors) and its successful image largely keeps it from being vulnerable. Because of this, no comprehensive development strategy, plan for coping with disturbances or plans to diversify the sector have been developed by the responsible authorities. Some efforts have been made with regard to spatial diversification (e.g. island branding), product diversification (e.g. ecotourism) and diversification of the visitor's source regions (e.g. Latin America) as processes of innovation and learning. In summary, tourism is a dominant and highly reliable subsystem which significantly contributes to the long-term economic stability of the overall island system. Spatial cross-scale interactions play an important role in shaping the dynamics of this subsystem. However, the relevance and external control of this sector may weaken the island

Fig. 18: New beach resort ('Baha Mar') development at Cable Beach, Nassau (Photo: A. Holdschlag 2011)

system's resilience in the future. The confidence in the proven system and the almost exclusive focus on external stressors brings the risk of overlooking local problems that could have a negative impact on tourism, such as man-made ecological problems (e.g. shipping accidents, oil spills) or the rising crime rate.

Learning as an adaptability attribute is a necessary part of a resilient system. Therefore, our research also focused on environmental education in public and private schools of New Providence (Fig. 19). Since today's pupils are the future of the island's society, the aim was to determine levels of awareness of potential threats or shocks to the social system and responses towards these threats. Results indicate high awareness of crime and violence as societal threats and natural hazards, endangered ecosystems, pollution and littering or climate change as environmental threats. Both categories had the same relevance for the students interviewed. Interestingly, students also had a wide range of ideas of how to respond. Some of their ideas can easily be implemented in their daily life, for example re-using plastic items or using public transport services. Some students also mentioned solutions for higher-level problems, e.g. using renewable energy sources or building eco-friendly and energy-efficient vehicles and buildings. At the same time realize that they – as children – usually cannot change things such as crime rates even if they wanted to. Consequently, theoretical knowledge of alternative behaviour is not implemented by the students. Cognitive experiences seem to be more important for daily life than knowledge of threats and possible responses which is e.g. gained at school. By teaching students how to use information about particular problems in their everyday life and en-

Fig. 19: Classroom of St. Andrews Private School (Photo: S. Ehlert 2011)

hancing their ability to participate in public decision making – for example by establishing a youth parliament –, schools can have an important share in improving the development of society.

Based on these findings, we conclude that the majority of the students know how to respond to potential threats (Fig. 20), which might moderately or even strongly increase their personal resilience and/or the resilience of the population. Our analysis shows no correlation between awareness and responses on the one hand and pupils' age, gender and school type on the other. All schools contribute to the build-up of knowledge about potential social-ecological threats and teach their students how to respond to different problems. Nevertheless, schools are only one part of the social system, and knowledge learned at school needs to be absorbed and implemented at home. Environmental knowledge needs to spread throughout society and become an important part of the public debate. All members of society need to be involved in collecting information and building up knowledge. Putting this knowledge into action can be regarded as one of the greatest challenges for every society trying to increase its resilience in the long term. However, by successfully integrating knowledge on problems and possible solutions into daily action New Providence society might create a solid foundation for facing problems now and in future.

To conclude, we need to make clear that our short-term study could not aim to provide a comprehensive examination of the small island of New Providence as a complex social-ecological system including most kinds of subsystems and interactions. Nevertheless, the overview of the case studies presented reveals different modes and speeds of subsystem dynamics with relevance for a more resilient system trajectory. At present, various agent interactions contribute to relatively stable overall island system development. Panarchical cross-scale relations, e.g. transnational networks, play a significant role for the entire system as well as in the subsystems of tourism, supply systems or disaster management. However, some small-scale systems run in phases of reduced resilience, e.g. coral reefs or road transport. In addition, the social system of the island is facing a range of serious challenges such as crime, unemployment, social polarisation, racism and discrimination, drug and alcohol abuse, single-mother households and teenage pregnancy or HIV/AIDS – to quote the most significant responses from our population survey.

Future studies on social-ecological resilience of New Providence are desirable and need to in-

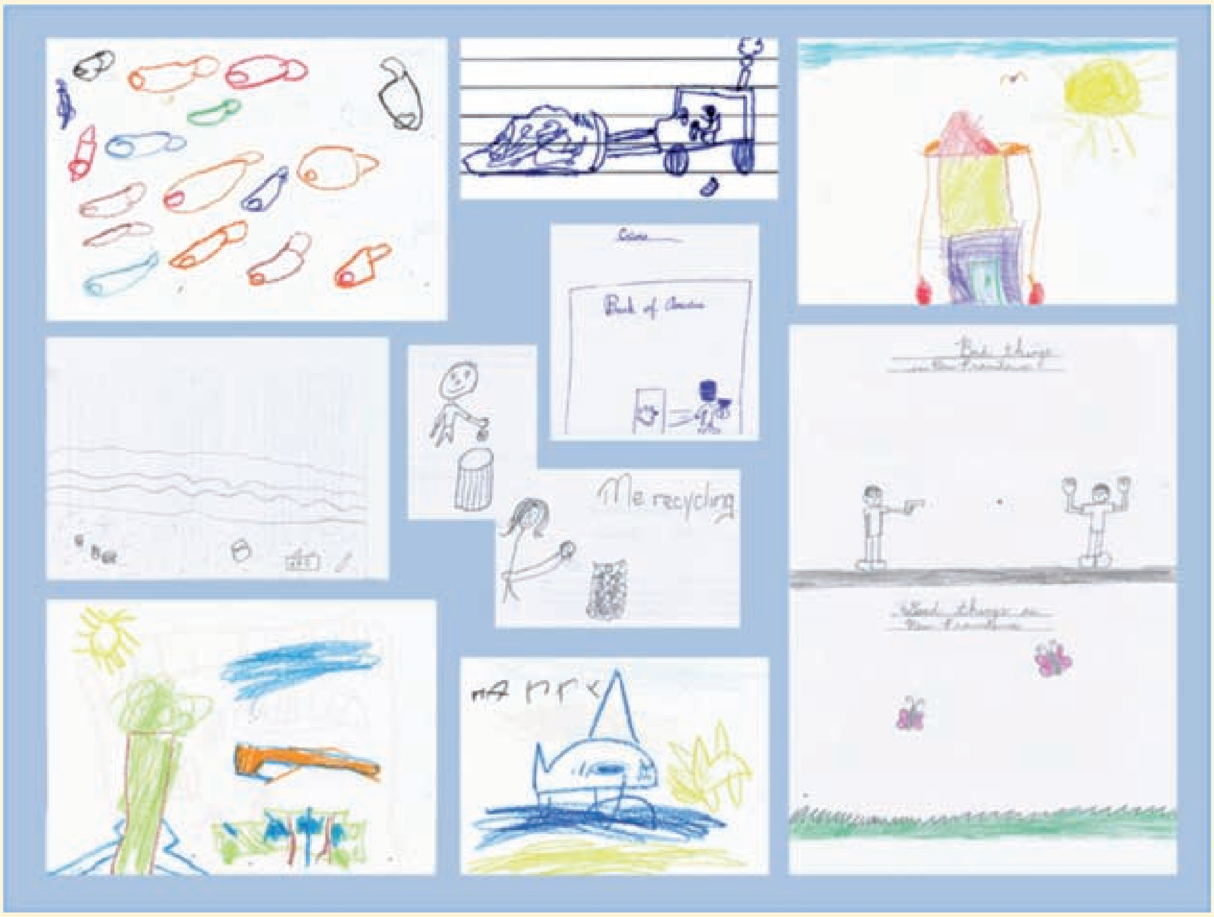

Fig. 20: Mental maps (from top left to bottom right): fish; waste management; strapped house; waste at the beach; students recycling; crime; tree, car and gun; shark; good and bad things in New Providence (Compilation: S. Ehlert, A.-C. Hake)

clude deeper and long-term insights into other subsystems, scales, agents and interactions not explicitly considered here. Among such fields of interest are the role of land ownership and conflict in the context of land development, problems of sewerage and dumping or the numerous inland wetlands (cf. Fig. 21), their value and utilisation. Moreover, the mechanisms of the overall economy and the relevance of financial capital, human capital and social capital should be examined thoroughly. In addition, future studies must put emphasis on the resilience of different agent groups, taking into account the social fragmentation and diverse vulnerabilities of the island.

Fig. 21: Lake Killarney
(Photo: A. Holdschlag 2011)

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