Chapter 6
Decision Tools and Approaches to Advance Ecosystem-Based Disaster Risk Reduction and Climate Change Adaptation in the Twenty-First Century

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Abstract Organisations and governments around the globe are developing methodologies to cope with increasing numbers of disasters and climate change as well as implementing risk reducing measures across diverse socio-economic and environmental sectors and scales. What is often overlooked and certainly required for comprehensive planning and programming are better tools and approaches that include ecosystems in the equations. Collectively, these mechanisms can help to enhance societies' abilities to capture the protective benefits of ecosystems for communities facing disaster and climate risks. As illustrated within this chapter, decision support tools and approaches are clearly improving rapidly. Despite these advancements, factors such as resistance to change, the cautious approach by development agencies, governance structure and overlapping jurisdictions, funding, and limited community engagement remain, in many cases, pre-requisites to successful implementation of ecosystem-based solutions. Herein we provide case studies, lessons learned and recommendations from applications of decision support tools and approaches that advance better risk assessments and implementation of ecosystem-based solutions. The case studies featured in this chapter illustrate opportunities that have been enhanced with cutting edge tools, social media and crowdsourcing, cost/benefit comparisons, and scenario planning mechanisms. Undoubtedly, due to the large areas and extent of exposure to natural hazards, ecosystems will increasingly become a critical part of societies' overall responses to equitably solve issues of disaster risk reduction and climate change adaptation.

Keywords Ecosystem-based solutions • Community resilience building • Risk matrix • Floodplain by design • Water funds • Connecticut • Resilience planning to action framework

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6.1 Ecosystem-Based Risk Reduction and Adaptation

International consortia, national to local governments, academic institutions, and non-governmental organizations are developing methods to cope with an escalating number of disasters and climate change impacts as well as implementing risk reducing measures across diverse socio-economic and environmental sectors and scales. The urgency expressed by recent publications such as the World Risk Report (2012), the Global Assessment Report on Disaster Risk Reduction (2013, 2015), the Intergovernmental Panel on Climate Change 5th Assessment Report (2014) and the United States National Climate Assessment (2014) are serving to accelerate this dialogue across diverse governance structures. What is often overlooked and certainly required for comprehensive planning and programming are better tools and approaches, which explicitly include ecosystems in disaster risk reduction and climate change adaptation. This is particularly true of our collective ability to capture the additional benefits of ecosystems for communities subjected to disaster and climate risks. Fortunately, ecosystems are indeed being increasingly viewed as a critical asset in helping achieve resilience to disasters and climate change (Jones et al. 2012; Renaud et al. 2013; Temmerman et al. 2013; Spalding et al. 2014).

Ecosystems provide protective services among other functions that, if recognized, can be integrated into comprehensive risk management planning and risk reduction actions (Hale et al. 2009; Spalding et al. 2010; World Bank 2016). Recent science supports the ability of globally distributed coastal habitats such as salt marshes (Sheppard et al. 2011; Moller et al. 2014), mangroves (Spalding et al. 2010), oyster reefs (Beck et al. 2011), and coral reefs (Shepard et al. 2005; Ferrario et al. 2014) to reduce risk from flooding and storm surges. Furthermore, governments and businesses are identifying where coastal habitats can be cost-effective defenses (CCRIF 2010; van den Hoek et al. 2012; Temmerman et al. 2013; NYC Special Initiative for Rebuilding and Resiliency 2014). The benefits of intact, vegetated watersheds, inland wetlands and riparian zones have also been recognized as critical for reducing downstream flood risks (Warner et al. 2013).

What is also clear are the co-benefits provided through the integration of ecosystems into disaster risk reduction and climate change adaptation (Eco-DRR/CCA). In addition to shoreline protection, Eco-DRR/CCA can help sustain local livelihoods (Green et al. 2009) and regulate climate via carbon sequestration (Pritchard 2009). With a vast majority of people on earth depending on freshwater supplied from rivers and lakes (Morris et al. 2003), coupled with escalating degradation and anticipated water shortages for two-thirds of the world's population by 2025 (WWAP 2009), the imperative to relieve risks where feasible through freshwater ecosystems management is paramount.

6.2 Rationale for Eco-DRR/CCA Tools and Approaches

One of the central challenges in ensuring ecosystems are mainstreamed into DRR/CCA is the limited knowledge about the many facilitative tools and approaches, or more importantly, understanding how they can and have been used to support decisions for DRR and CCA (see also Krol et.al., Chap. 7). In the broad sense, there are a growing number of tools and approaches but with fewer examples of how these have actually advanced decisions involving Eco-DRR/CCA. Central to the practitioner's ability to remedy this challenge, therefore, rests on addressing the following critical questions:

1. What tools and/or approaches are used or could potentially be used to design and implement Eco-DRR/CCA?
2. How can these tools and/or approaches help with the implementation of Eco-DRR/CCA?
3. What are the limitations or gaps in existing tools and/or approaches to operationalise Eco-DRR/CCA, either at project or programmatic levels across diverse and interconnected scales?

Clearly, an examination of available and future tools and approaches is required to better understand how Eco-DRR/CCA can be integrated into existing planning (i.e., integrated watershed management, protected area/fire/drought management) as well as identify other pre-requisites. Such pre-conditions include the ability to connect the right expertise with planning efforts that are enabled by financial and policy incentives and supported within governance structures. As discussed below, there is a growing call for integrating ecosystems in immediate and long-term resiliency efforts.

6.2.1 Distinguishing Between "Tools" and "Approaches"

In this chapter, we make a distinction between tools and approaches in the context of Eco-DRR/CCA. Generally, tools consist of software or documented methods used to support decision-making and help a community through various information-gathering endeavors towards a more comprehensive understanding of a particular situation. Many tools with potential for advancing Eco-DRR/CCA implementation focus on the geospatial presentation of environmental and/or socio-economic data guided by planning needs, with some tools allowing for future scenarios runs. Some tools are in the public domain; others must be purchased or licensed, and the degree of technical training required to operate the tools varies considerably. In some data rich parts of the world, more advanced tools provide complex modeling and quantitative analysis of disasters and climate change impacts to natural and/or human systems (e.g., coastal engineering tools such as Delft3D and Mike21). Often a combination or suites of tools are used to provide for a robust planning process. Cutting edge tools are able to illustrate spatially and quantitatively the consequences of risk management decisions. Regardless of a tool's sophistication, community-based efforts often benefit by having tools integrated into collaborative processes that are connected to ongoing or upcoming action plans and management efforts.

Approaches include qualitative, semi-quantitative, and/or quantitative processes; from informal panels of experts to community-driven applications intended to aid Eco-DRR/CCA. Many approaches used for Eco-DRR/CCA planning were not developed specifically for that purpose. Many approaches are drawn from other applications such as land-use planning, environmental monitoring, and fire management, which in many cases already recognize Eco-DRR/CCA as a co-benefit. As with any newly expanding field, the diversity of approaches being put into practice presents a challenge for practitioners in search of transferability, reliability, and consistency.

Comprehensive and effective Eco-DRR/CCA planning and implementation can and is being enhanced with decision-support tools and approaches by addressing several core considerations:

- Knowledge of type, intensity, frequency, spatial distribution and duration of disasters (past, current and/or future events) and relationship with climatic variables (e.g., precipitation, temperature, sea level rise) over time;
- Assessment of disaster and climate vulnerabilities (e.g. assessing ecosystems, infrastructure or populations) and strengths (e.g., healthy/intact natural infrastructure, availability/accessibility of social services) over time;
- Prioritization of adaptive strategies to reduce risk and reinforce resilience;
- Governance structure and stability/diversity of partnerships (i.e., private/public/NGO) coupled with incentives to induce and sustain action.

These core considerations can be integrated into and used to advance a stepwise, planning-to-action framework as presented here:

1. Identify near-term and long-term disaster and climate change impacts;
2. Construct risk profiles and prioritize strengths and vulnerabilities;
3. Develop initial and sequenced adaptation strategies for highest priorities;
4. Link strategies to ongoing decision making;
5. Prepare and implement adaptation plans;
6. Monitor and reassess effectiveness of actions taken;
7. Routinely re-integrate best available disaster and climate change data and tools.

The challenge for practitioners, of course, lies in knowing which tools and approaches are best suited to address these core considerations and planning-to-action framework steps at an appropriate scale (e.g. from multi-national to local community) in order to ensure that Eco-DRR/CCA is integrated and operationalised across disciplines, sectors, and management constructs. Herein resides one of the principal opportunities and constraints for Eco-DRR/CCA. A

Table 6.1 Approaches and tools used to advance the planning-to-action framework steps

Approach	Tool(s)	Steps (see text above)
Community Resilience Building:	Risk Matrix[c]	#2, #3, #4, #5, #6
Community Resilience Building - Connecticut[a]	Coastal Resilience Tool	#1, #7
Watershed Management:	InVEST	#1, #2, #3, #6, #7
Floodplain by Design[a]	Community Engagement	#4, #5
Watershed Management:	RIOS/Financial Incentives[c]	#1, #2, #3, #6, #7
Monterrey Metropolitan Water Fund-Mexico[b]	Community Engagement	#4, #5
Coastal Zone Management: Belize[b]	InVEST/Scenarios	#1, #2, #3, #6, #7
	Community Engagement	#4, #5
Additional Tools Available		
	Climate Wizard	#1, #7
	Coastal Defense[c]	#1, #2, #6, #7
	Crowd Sourcing/Social Media	#1, #2, #6

[a]Focused on Eco-DRR/CCA as outcome
[b]Recognizes Eco-DRR/CCA as a co-benefit
[c]Provides for balance between Eco-DRR/CCA and socio-economic tradeoffs

summary of the approaches and associated tools featured in this chapter, along with their respective connections to the planning-to-action framework steps described above, are provided in Table 6.1, which serves as a guide to the different case study examples presented.

6.3 General Resources and Case Studies

There is a multitude of approaches and tools currently available for many areas of the globe that can deliver actionable information on the core considerations and support the planning-to-action framework steps identified above. In addition to a summary of web-based portals, a series of case studies are provided below to generate lessons learned and recommendations for decision makers and practitioners. The following materials are not meant to be exhaustive nor prescriptive, but simply a window into real-world situations that have employed approaches and tools for Eco-DRR/CCA.

A summary of the more prominent web-based portals providing data, tools, approaches, and case studies applicable to the core considerations and planning-to-action framework steps, as discussed above, are provided in Table 6.2.

Table 6.2 Prominent web-based, freely accessible portals and tool-sheds

Name	Managing entity	Web address
Climate Adaptation Knowledge Exchange	EcoAdapt	http://www.cakex.org/
Climate Change Knowledge Portal	The World Bank Group	http://sdwebx.worldbank.org/climateportal/
Adaption Learning Mechanism	United Nations Development Programme	http://www.adaptationlearning.net/
weAdapt	Stockholm Environmental Institute	https://weadapt.org/
Digital Coast	National Oceanic & Atmospheric Administration	http://coast.noaa.gov/digitalcoast/

6.3.1 Planning-to-Action Framework Steps and Case Studies

Where obstacles such as lack of available resources (i.e., data, expertise, funding, governance, etc.) have been minimized, a proliferation of tools that focus directly or indirectly on Eco-DRR/CCA has emerged. In many situations, these tools can be instrumental at enabling the incorporation of ecosystems into DRR/CCA efforts. Tools can also be used as stand-alone assessment independent of or towards the beginning of a DRR/CCA process; particularly for framework step #1 (identify near-term and long-term impacts), #2 (construct risk profiles), and #7 (routinely re-integrate best available data). To move comprehensively through the planning-to-action framework steps (see 6.2.1), a broader and more collective approach that seeks to integrate available tools is required to successfully advance Eco-DRR/CCA. In particular, step #3 and #4 (development, prioritizations, sequencing and linkage of adaptation strategies) are ideally derived through community-based engagement, adaptation strategy synthesis, and/or consensus building approaches. As is often the case, these approaches naturally lead to implementation of step #5 and #6 (prepare and implement plan; monitor and reassess effectiveness). The following sections provide case studies of approaches (refer to Table 6.1) that integrate tools to enable Eco-DRR/CCA via the planning-to-action framework steps.

6.3.1.1 Community Resilience Building in Connecticut (USA)

Along the eastern seaboard of the United States – particularly in the aftermath of Tropical Strom Irene (August 2011) and Sandy (October 2012) - it has become apparent that the operationalisation of Eco-DRR/CCA requires further investment in certain pre-requisites that focus on process and stakeholder engagement. In essence, tools and applications (apps) are instrumental in identifying near and long-term impacts (step #1) and initial construction of risk profiles (step#2) but are most impactful when integrated within a flexible and adaptive, community-based approach (steps #2 - #6). This critical learning leap resulted in the launch of a Community Resilience Building Workshop (www.CommunityResilienceBuilding.com) process in Connecticut (USA) developed by The Nature Conservancy (TNC) to assist federal and state agencies, regional planning agencies, municipalities, corporations, and other stakeholders (Whelchel 2012). The Workshop process helps to build resilient communities and mainstream Eco-DRR/CCA by providing a way to combine tools within a facilitated community-engagement construct. One such tool is the Coastal Resilience decision-support platform.

The Coastal Resilience (www.coastalresilience.org) decision-support platform was partially initiated due to the recognition that Eco-DRR/CCA was not being fully integrated into disaster and climate planning (Ferdaña et al. 2010; Gilmer and Ferdaña 2012; Beck et al. 2013). From its origins in New York and Connecticut (USA) beginning in 2007, this web-based tool has expanded to include 10 states (USA) and several other nations (Honduras, Guatemala, Belize, Mexico, Grenada, Saint Vincent and the Grenadines). This tool focuses on spatially defining the risk reduction characteristics of ecosystems within disaster (i.e., storm surge, inland flooding) and climate change (i.e., sea level rise, precipitation) applications, alongside socio-economic considerations from local to national scales. The tool is being applied internationally in places such as Grenada in partnership with the Red Cross to assess social and ecological vulnerability as well as by international organizations to develop Coasts at Risk indicators (UNU-EHS 2014) and the World Risk Report's (2012) Index. The tool provides decision makers a much needed suite of map layers and apps via an intuitive, user-friendly interface. For Coastal Resilience, the overarching framework includes: (1) awareness of hazards, (2) risk assessment of strengths and vulnerabilities, (3) development of choices, and (4) evaluating the impact of resilient actions (Beck et al. 2013) (see also discussion by Krol et al., Chap. 7).

At the core of the Community Resilience Building Workshop approach is the focus on obtaining a diverse suite of stakeholders engaged as planning commences, during, and afterwards to ensure the community champions the outcomes. Such a process often requires expanding beyond the disaster response professionals to include among others: elected officials, planners, employers, neighborhood or community representatives, natural resource managers, health care providers, finance professionals, and legal counsel. Essentially, the approach must include those who make decisions, have influence over decisions, or are impacted by the decisions made. Arguably this is one of the most important - yet under-emphasised - foundational requirements to ensuring comprehensive, community-driven support for actions that will incorporate Eco-DRR/CCA projects and policies.

Once assembled, the community representatives are asked to develop 'profiles' for hazards in their communities as well as for ecosystems, infrastructure, and societal sectors (Fig. 6.1). To do this, the Risk Matrix tool, is used along with a facilitated, participatory-mapping exercise. The Risk Matrix allows the participants to collaboratively identify vulnerable sectors and those assets that already support resilience in their community. Identified community assets often

Fig. 6.1 Community-based participatory mapping during Community Resilience Building Workshops in Bridgeport, Connecticut (USA) (Whelchel 2012) (Author's own photo)

include natural resources such as wetlands, beaches and dunes, and floodplains, which reinforce the community's recognition of ecosystems in a risk management context. Participants then utilize base maps to mark vulnerabilities and strengths as well as identify ownership or responsibility for those community elements. This process serves to spatially translate the dialogue and generate an overall profile of ecological, infrastructure, and societal elements along with overlaps/proximity of inter-dependent, complex situations (e.g., routine flooding on a road that is used by an elderly population, who are surrounded by protective salt marshes and floodplains). Participants then identify actions that either reduce the vulnerability or reinforce the strength for each identified community element. Once completed, participants are asked to relatively rank the importance (high, medium, low) and determine the urgency (ongoing, short-term, long-term) of each community-based action. Finally, participants are asked to further prioritize all the high importance, short-term actions through the community's Risk Matrix (Fig. 6.2) and select the three top priority needs across the three 'profiles' for the community to pursue immediately. This helps to ensure that the community is fully embracing Eco-DRR/CCA as a priority in the communities' overall approach to resiliency.

The Workshop process using the Risk Matrix is flexible enough to address all hazards (e.g., extreme heat, drought, storm surge, tornadoes, sea level rise, landslides, tsunamis), in any setting (e.g., inland, coastal, high elevation, deserts, urban), across multiple governance/societal structures (e.g., neighborhood, municipal, multi-municipal, regional, national, multi-national) and at any geographic scale. To date, 24 municipalities in Connecticut (USA) serving over 787,000

Community Resilience Building Workshop Risk Matrix (www.communityresiliencebuilding.com)

H-M-L priority for action over the **S**hort or **L**ong term (and Ongoing)
V = Vulnerability S = Strength

Top Priority Hazards (sea level rise, wildfire, flooding, tornado, ice, heat wave, hurricanes, etc.)

V or S	Vulnerabilities and Assets	Location	Ownership	Coastal Flooding: Sea Level Rise/Storm Surge	Inland Flooding: Rain Events	Ice and Snow	Wind	Priority H - M - L	Time S/L term ongoing
	Infrastructure								
V	Evacutation Routes - Roads/Intersections	Municipal-wide	State/Utility	Implement supportive communication program and install highly visible evacuation route signage.				H	S
V	Electrical Distribution System	Multiple	Utility	Within floodplain area need plan to address protection and long-term relcoation of equipment.		Maintain power line protection zone (tree trimming).		H	S-L
V	Dams - (Inland and Coastal)	Multiple	Private	Prevent possibility of castastrophic dam failure; prepare contingency plan(s).				M	L
V	Landfill/Rubbush Factility	Specific	Private	Secure facility against future flooding and rain events.				L	L
S	Commercial/Industrial Facilities (Zoning Regulations)	Multiple	Municipal	Current buidling codes and zonig overlays limiting development in high risk areas.					Ongoing
S	New Ambulance/Heath Center	Specific	Municipal	Continue to support ambulance services and awareness amongst vulnerable populations.					Ongoing
	Societal								
V	At-Risk Neighborhoods and Populations	Municipal-wide	Private	Education on best practices to reduce risk; initiate "Neighbor helping Neighbor Program".				H	S
V/S	Coastal Homeowners	Coastline	Private	Review building codes and zoning regulations; Continue frequent communciation about risks and evacuation procedures.				M	Ongoing
S	Full-time Emergency Managers (Fire and Police)	Municipal-wide	Municipal	Continue support (well equiped and experienced) to further strengthen services.					Ongoing
S	Regional Cooperative Agreements	Multiple	Municipal/Utilities	Maintain regional cooperative service agreement over time (sheltering, food and water supply, etc.)					Ongoing
	Ecosystem								
V	Forest (uniform age structure and diversity)	Municipal-wide	Municipal/State	Seeks management that diversifies the age structure of forests; assess key vulnerabilities from tree fall on elerical system				H	S
V/S	Coastal Natural Infrastructure (Salt Marsh, Beaches, Dunes)	Multiple	State/Private	Assess risk reduction potential from existing and future wetland advancement zones. Restore/maintain beaches and dunes.				H	L
V	River Systems/Riparian Corridors (Inland Erosion)	Multiple	Municipal/Private		Education/Map impacts/identify solutions to reduce risk to people and property: green infrastructrue, restoration, abandonment.			M	S
S	Protected Open Space/Public Amenities	Multiple	State/Municipal	Maintain existing open space to help reduce risk to Town/Seek to increase open space with the highest risk reduction charateristics.					Ongoing

Fig. 6.2 Abbreviated community-driven Risk Matrix used during the Community Resilience Building Workshop to generate comprehensive and prioritized resilience action plans across and between sectors (infrastructure, societal, ecosystems) that incorporate Eco-DRR/CCA (Whelchel and Ryan 2014) (Author's own graphic)

residents have completed this workshop process resulting in prioritized action plans to improve resilience that feature Eco-DRR/CCA (Box 6.1).

One key effort undertaken in advance of the Workshops is a full analysis of existing ecosystems, alongside projections of the future distribution of critical habitat such as salt marshes given ongoing increases in sea levels (Hoover et al. 2010; Hoover and Whelchel 2015). For each of the 24 coastal communities in Connecticut, a Salt Marsh Advancement Zone Assessment was conducted that identifies where the future habitat will be at the parcel scale (i.e. finest scale of land ownership and land-use decisions) (Horton et al. 2014; Ryan and Whelchel 2015). This helps to facilitate community dialogue on potential conflicts and opportunities arising from the current built environment and protected natural management areas, respectively (Fig. 6.3). The assessments are critical in shaping risk considerations at the community scale by requiring recognition of ecosystems and their risk avoidance services for people and property; and not just the recognition of the exposure and vulnerability of infrastructure and society to hazards.

Box 6.1 Common Community-Derived Prioritized Actions Via Community Resilience Building Workshops Using the Risk Matrix Tool

Environmental/Ecosystems

- Protection of conserved lands, natural buffers around waterways, and ongoing maintenance of wetlands.
- Resilient Conservation Practices: Anticipate changes in location, size, and distribution of wetlands and waterways under future conditions and prioritize acquisition to reduce development in risk-prone areas.
- Develop and/or strengthen low impact development policies and green infrastructure projects.

Infrastructure/Facilities

- Design and plan for infrastructure (transportation, sanitary, communications, etc.) conversion during redevelopment and prioritized upgrades. Prior to improvements carefully consider the future "design storms" for infrastructure given anticipated changes in precipitation patterns (3 cm/24 h. vs. 12 cm/24 h.).
- Prioritize the location of water retention systems, maximize infiltration rates, and increase separation between storm-water runoff and sewer systems. Design to minimize polluted discharges to wetlands, rivers, and other potable water sources.
- Modify existing land use and development policies to reduce the risk to building stock and public amenities over time (i.e., building codes, zoning

(continued)

Box 6.1 (continued)

overlays, voluntary buy-outs followed by ecosystem restoration, increased density in lower risk areas).

Societal/Community Fabric

- Improve sheltering capacity for and preparedness of citizens.
- Strengthen support for ecosystems as protective features that reduce exposure of people and property within communities to disasters.

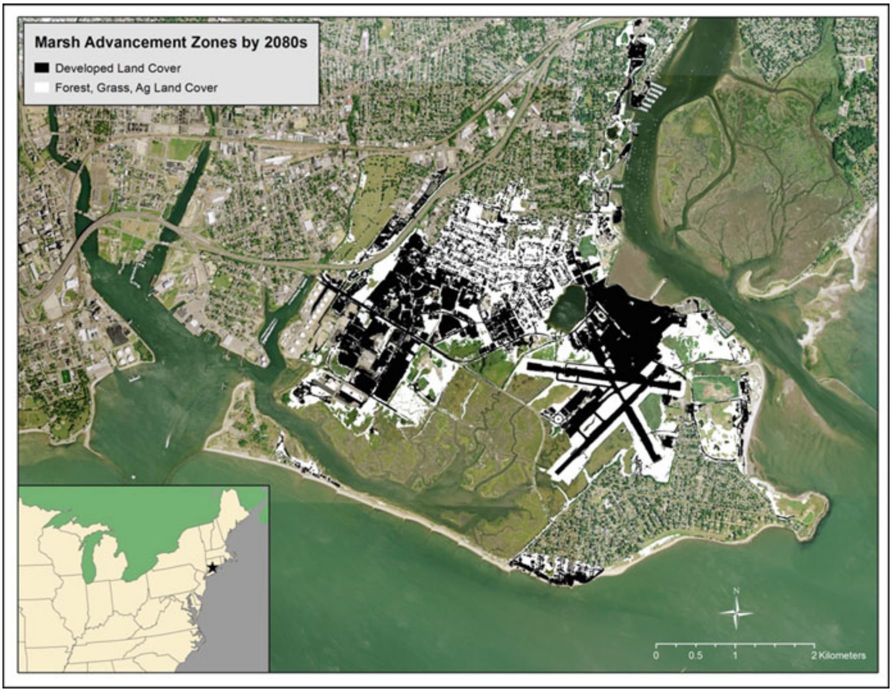

Fig. 6.3 The Salt Marsh Advancement Zone Assessment tool depicts built environment impacts due to inundation (*developed land cover (black)*) and potential salt marsh advancement zones (*undeveloped land cover –currently forest, grass, and agriculture (white)*) using downscaled sea level rise projections (1.32 m by 2080s depicted) in Stratford, Connecticut (USA) (Ryan and Whelchel 2014) (Author's own graphic)

The Community Resilience Building Workshop approach is currently being promoted for national deployment in the USA and internationally. This approach is also being used to build and integrate resilient communities into a larger regional framework for resilience in the central coast of Connecticut (USA), including the metropolitan areas of greater Bridgeport and New Haven (30 % of Connecticut's coast with 591,000 people). Application of the approach highlights one of the most critical aspects of integrated Eco-DRR/CCA, i.e. broad yet directed engagement and consensus-building with communities around risks, planning, and actions.

In some cases, the recognition of ecosystem importance and their incorporation into resiliency approaches requires a triggering event. The impact of Tropical Storm Irene and Sandy (National Weather Service 2013) on the eastern seaboard of the USA has resulted in the incorporation of Eco-DRR/CCA principles in the recovery plans at the federal (Hurricane Sandy Building Task Force 2013) and state (New York 2100 Commission 2013; Ambrette and Whelchel 2013) level. These two storm events have also facilitated progressive funding for significant, resilience-orientated projects (i.e., Rebuild by Design – Resilient Bridgeport (Connecticut)). Approaches that integrate tools as illustrated by this Coastal Resilience case study have been instrumental in setting the standard for enhanced resiliency amongst coastal and inland communities affected by major disasters and subjected to increasingly intense rainfall in the USA (Horton et al. 2014).

6.3.1.2 Floodplain by Design – Integrating Flood Risk Reduction in Puget Sound (USA)

The state of Washington is currently one of the most flood-prone in the USA. Currently, there are 57,000 flood insurance policies in the state providing insurance coverage for assets totaling $13 billion (USD), with 35 % of those policies outside of the federally designated flood areas (Sumioka et al. 1998; Washington Department of Ecology 2004). Across the Puget Sound watershed (Fig. 6.4), flood management efforts are lagging the pace of population expansion and development resulting in more people and property in flood-prone areas, water quality declines, and loss of fish habitat (Fig. 6.5). While there is an understanding of the short and long term characteristics of flood risk (types, locations, re-occurring costs) in the watershed, the systems for managing the floodplain are recognized as disjointed, uncoordinated, and inadequately resourced. As is often the case in larger, multi-jurisdictional geographies, the impediment to advancing priority strategies is fragmentation or overlap within decision-making/regulatory systems and structures. To adjust that prognosis in the watershed, the Floodplain by Design (FbD) approach is being implemented.

The FbD approach seeks to ensure better management of shared floodplain resource through the integration of flood hazard reduction, habitat protection and restoration, and improved water quality and outdoor recreation. The FbD is a merger between a science-driven framework known as the Active River Area (Smith et al. 2008) that requires consideration of the dynamic connections and interactions of land and water through which a river flows and a modeling application that maps ecosystem service values and trade-offs between conservation and development. The modeling application used is the Natural Capital (NatCap) Project's Marine Integrated Valuation of Environmental Services and Tradeoffs (InVEST) program (Sharp et al. 2014; see also Bayani and Barthélemy,

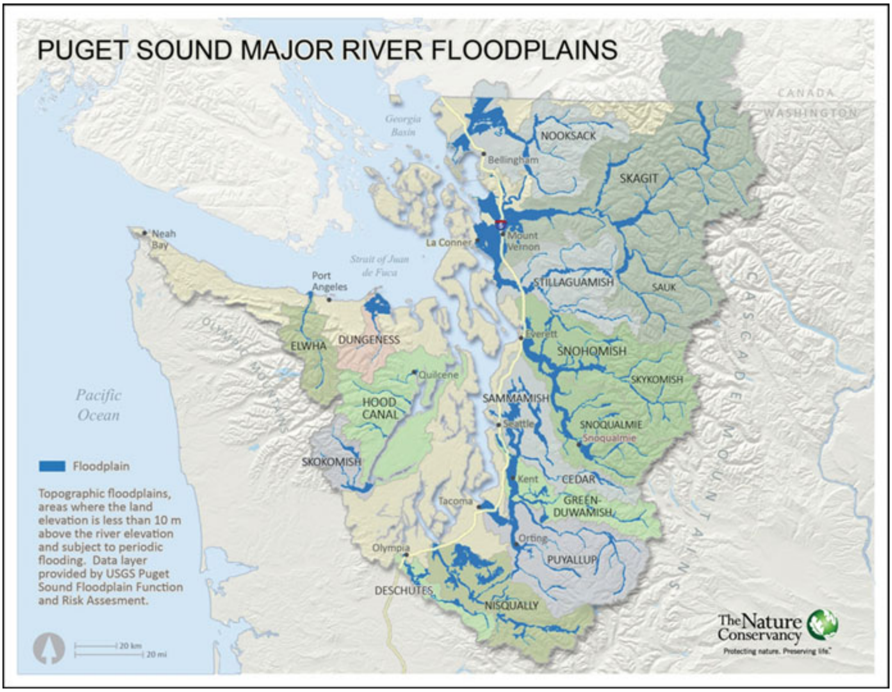

Fig. 6.4 Map of Puget Sound watershed in state of Washington (USA) depicting the 17 major rivers and current distribution of floodplains contributing to Floodplain by Design (Graphic reproduced or used with permission)

Fig. 6.5 Extreme flooding on the Snoqualmie Valley within the Puget Sound watershed in Washington (USA) (Photo reproduced or used with permission)

Chap. 10). The intended outcomes of FbD are to make river dependent or surrounding communities safer, improve the ecological health of the river, and increase the cost-effectiveness of long-term river management and immediate post-disaster recovery of the communities. This approach relies on a tool to satisfy many of the planning-to-action framework steps (see 6.2.1) alongside state/regional partnership and an incentivized community engagement process to link strategies and plan implementation (framework steps #4 and #5).

FbD is originating a new private-public partnership across local, state and federal agencies and organization that could simultaneously achieve floodplain management and ecosystem recovery goals in the most cost-effective manner possible. This innovative and collaborative FbD partnership seeks to reduce impediments to achieving collective actions by linking decision-making to actions through funding incentives, in effect changing the collective paradigm towards better management of the entire watershed. An overarching framework is used across the Puget Sound watershed to advance the FbD approach: (1) Implement integrated floodplain projects across the 17 largest rivers; (2) Craft regional vision and work plan (10-year) for each river; (3) Match funding to needs via vision/work plan by sustaining existing, securing new, and aligning state and federal funding programs with these regional visions (i.e. coordinating investment); and (4) Build technical and permitting assistance capacity to ensure further integration across jurisdictions. This FbD framework is a main driver to advance Eco-DRR/CCA efforts in the entire Puget Sound watershed (Box 6.2).

Box 6.2 Key Eco-DRR/CCA Principles of Floodplain by Design

Step 1: Maximize Natural Infrastructure Use – work with, not against, natural processes such as flooding frequency and extent (annual, 100 year, 100–500 year) by incorporating floodplains, wetlands and open areas in management decisions. Some key tactics to assist with this step may include:

- **Setback Levees**: levees or berms constructed or moved farther from the river and ideally out of the floodplain, thereby allowing rising rivers more room to adjust and flood.
- **Connected Floodplains**: connected or never "cut off" from the river by levees or other structures or "reconnected" by the removal or management of levees.

Step 2: Diversify Portfolio of Flood-Risk Management Techniques – tailor techniques to specific requirements of the watershed. In addition to dams and levees as well as setback levees and connected floodplains, such techniques can include floodways and flood bypasses, which are large-scale floodplain reconnections for storage and conveyance of water.

Step 3: Maximizing Community Benefits – from initial identification of community needs/values, seek to enhance benefits of floodplains and rivers to

(continued)

Box 6.2 (continued)
local entities by improving access, safety and health of river systems through collaborative consideration of solutions; not only reducing flood risk but also improving habitat for fish and wildlife and water quality impacts at the source.

Step 4: Plan and Implement Resilient "Whole-River" Practices - dams, levees, floodways, natural areas, topography, croplands, existing and planned developments, and river uses – such as for recreation, municipal water supply, irrigation, and navigation – are all inter-related and must be managed as such.

Step 5: Develop Mosaics of Accommodating Land Uses – a mosaic of diverse land uses that are both resilient to floods and consistent with vibrant communities; tailor land use for the average frequency and duration of floods the area is subjected to.

The principal vehicle to orchestrate this systemic change is a funding program administered by the Washington Department of Ecology. Nine projects using the FbD approach have been funded via a $33 million (USD) investment by the state matched by $80 million (USD) from other sources. For example, an integrated floodplain plan was developed in response to funding opportunities for the Puyallup River (one of the 17 major rivers in Puget Sound watershed) that was designed to reconnect floodplains and estuary habitat, permanently preserve 600 acres of farmland through conservation easements, provide critical habitat to support populations of Chinook salmon, and reduce flood risk to municipalities and shared infrastructure. An early investment in 2014 in the Puyallup River of $4.7 million (USD) has been matched with over $17.5 million (USD) in state, county, and local funding sources, reflecting an investment leverage ratio of 3.7 to 1.

State grant criteria continue to be the principal mechanism to ensure projects like the Puyallup River meet the requirements of FbD. The criteria awarded more points and subsequent higher ranking for projects that demonstrate effectiveness at advancing multiple benefits, such as flood risk reduction, floodplain ecosystem protection and restoration, agricultural viability, water quality and open space access. Additional points are awarded for proposals that avoid ongoing costs including maintenance and emergency response and longer-term changes in hydrology, sedimentation, and water supply due to extreme weather events. State grant criteria also serves to prioritize pilot and design projects that seek creative solutions, fill funding gaps at the local level, and favor underserved communities and social justice issues. Eligible applicants across the watershed have readily accepted the state grant criteria, as evident through the 71 proposals submitted towards a second call for proposals.

Recognition that different governance structures and regulatory mechanisms are needed to realize collective and cumulative gains is not enough to generate the implied transformation. In the Puget Sound watershed, introduction of state grant criteria that favor the integration of multiple objectives has been well-received and will likely over the long-term incentivize a more resilient future at ever increasing scales via locally-driven creative solutions that mainstream Eco-DRR/CCA.

6.3.1.3 Water Funds – Financially Linking Watershed Management with Risk Reduction

In 2000, a catalytic approach to integrated watershed management known as ‘water funds’ was launched in Quito, Ecuador (Tallis et al. 2008). Since then, this approach has been successfully replicated through over 60 water funds across South America, Australia, Central America, USA, and East Africa (Goldman-Brenner et al. 2012). The approach brings water users (typically large businesses, government agencies, municipalities) together to jointly invest via a financial mechanism that directs funds to top priority ecosystem-based projects within defined watersheds. The joint investments, often private-public partnerships, result in benefits via returns to all the investors. These water fund collaboratives also provide a governance structure to collectively derive and sustain decisions on priority funding needs and water resource management (i.e., conservation, power generation, drinking water supply). The success of the water fund approach is due in large part to flexibility of the financial mechanism or investment vehicle (i.e., endowment, direct incentives to landowners, direct investment towards actions) through which objectives are funded. The pooling and leveraging of funds through an independent fiduciary administrator towards common outcomes is paramount to maintaining existing programmes and attracting other regions to water funds. Water funds typically rely on tools and financial incentives to advance through many of the planning-to-action framework steps, namely facilitating fiduciary and action-orientated partnerships and community engagement (step #4 and #5).

Once established, each water fund defines the core objective(s) of watershed management and goes about identifying and prioritizing opportunities. To ensure that capital derived through water funds is allocated to (1) achieve the greatest return for multiple objectives, (2) quantify improvement through various investment portfolios, and (3) compare these improvements against the ongoing status-quo management, the Resource Investment Optimization System (RIOS) (http://www.naturalcapitalproject.org/RIOS.html) tool was developed for water funds. The tool couples biophysical data (i.e., soils, land use, slope, flood risks) with water consumer demand (i.e., population density and distribution) to geospatially determine the optimal places to maximize returns on conservation investment (ROCI) within a defined watershed. The tool provides a relative ranking of optimal places for conservation investment, informed by the most urgent needs of stakeholders (e.g. tackling floods, drought, groundwater supply) and taking into account constraints (e.g. security risks, policy restrictions). For example, if a water fund manager is looking to reduce downstream flood risk, tools such as RIOS can now help determine the most prudent suite of investments, such as buying farmland along streams, reconnecting floodplains through restoration and/or voluntarily relocating at-risk populations to higher ground. Ecosystem services tradeoffs of various investment portfolios are estimated by RIOS and can be monitored and adapted over time for greater effectiveness on the ground. Tools like RIOS are particularly attractive to decision makers because they generate reliable and comparable estimates on locally relevant ROCI and provide a way to monitor action effectiveness. In addition, the application and outputs from RIOS can effectively establish a regional platform from which Eco-DRR/CCA can be incorporated into a supportive financial and governance construct.

The integration of tools into initial design and scoping of water fund projects is also being expanded in several locations to incorporate forecasts of disasters and climate change. This type of consideration is of particular concern to large water users/providers and governments when assessing flood and drought risks. One foremost example is the Monterrey Metropolitan Water Fund (FAMM) centered in the watersheds of Monterrey, Mexico, which is one of the most important industrial capitals in Latin America and home to over four million people who are routinely subjected to devastating floods and extreme drought (Gonzalez 2011). The FAMM is part of the Latin America Water Fund Partnership established in 2011 by TNC, FEMSA Foundation, The Inter-American Development Bank and the Global Environmental Facility to advance the 14 water funds underway and the 18 under evaluation across Brazil, Colombia, Panama, Venezuela, and Mexico.

With over 40 partners engaged, including various business sectors, academia, conservation groups, civil society organizations, and multiple levels of governments, the FAMM is specifically designed to improve water management through compensating and incentivizing actions that reduce flood risks and increase availability of drinking water during droughts through aquifer recharge. The focus of this water fund is on the Cumbres de Monterrey National Park (Fig. 6.6) upstream from

Fig. 6.6 Cumbres de Monterrey National Park within the San Juan River Watershed above City of Monterrey, Mexico (Photo reproduced or used with permission)

the city of Monterrey, all located within the San Juan River watershed. The Park meets approximately 60 % of the water consumption needs but is also the principal origin of flash flood risks to downstream communities such as Monterrey. Reforestation and soil conservation projects funded through FAMM are intended to significantly reduce the speed and peak volume of downstream runoff. The FAMM is also directing capacity to educating Monterrey residents and consumers on water conservation measures. In this regard, this water fund provides a meaningful example of an approach informed by tools and driven by partnerships and financial mechanisms towards common goals and outcomes with Eco-DRR/CCA priorities.

6.3.1.4 Integrating Coastal Zone Management in Belize

The Government of Belize tasked the Coastal Zone Management Authority and Institute (CZMAI) with the design of the Integrated Coastal Zone Management Plan for the entire coast of Belize. To inform its development, the CZMAI partnered with World Wildlife Fund and NatCap, to focus on three critical ecosystem services: lobster fisheries productivity, recreational activities, and coastal risk reduction. The NatCap developed an integrated database on biodiversity, habitats, and marine and coastal uses. Then, together with local stakeholders, the team formulated three possible future scenarios: (1) a conservation scenario emphasizing sustainable use and investment in coastal habitats; (2) a compromise ('informed management') scenario that advanced development and conservation; and (3) an infrastructure development scenario. These scenarios were analyzed with InVEST (Sharp et al. 2014) to determine the tradeoffs among options, the quantity of services provided, and iterations of other possible scenarios. Similar to the other case studies presented in this chapter, the integrated coastal zone management planning approach in Belize employs a tool and various scenarios to advance through the framework steps and contributes directly to partnerships and community engagement processes (steps #4 and #5; and steps #2 and #3 for scenario generation) (see also Bayani and Barthélemy, Chap. 10).

The importance of coastal risk reduction in the scenarios was made clear. The benefits in terms of disaster damages avoided totaled billions (in Belize Dollars or BZD), whereas other benefits (i.e. tourism and lobster fisheries) totaled in the millions (BZD). However, there were significant tradeoffs with respect to benefits. For example, more development would generate a higher recreation value, but also much higher disaster damages to infrastructure due to the loss of coastal habitat risk reduction services. By categorizing and integrating marine and coastal uses and visualizing them in maps, stakeholders were better informed with potential conflicts arising from different land-use and the opportunities for negotiating between competing interests.

The development of alternative scenarios has proven to be one of the greatest difficulties because stakeholders are often not able to visualize and articulate multiple and inter-dependent future scenarios, particularly at a national level

(Gleason et al. 2010; Halpern et al. 2012). In summary, the CZMAI was tasked with developing a coastal zone management plan (submitted September, 2013) with the help of alternatives assessed with InVEST, and the scenarios developed in stakeholder workshops were useful in presenting land-use tradeoffs to decision-makers. The integration of Eco-DRR/CCA as a key variable at the front end of this effort is instructive and was critical in determining disaster and climate resilient outcomes. This case study highlights a growing trend in the use of scenario planning or 'future visioning' that allows for comparisons (i.e. costs/benefits, effectiveness) between various, individual or sequenced series of risk avoidance actions (Dawson et al. 2011; Mahmoud et al. 2011) and represents a critical next step for tool development that balance ecosystem and socio-economic tradeoffs in a disaster and climate altered future (Shepard et al. 2011).

6.3.2 Additional Tools Available for Select Planning-to-Action Framework Steps

The following provides an additional set of tools that have been proven effective for stand-alone assessments independent of or towards the beginning of a DRR/CCA process and for fulfilling the core considerations and specific framework steps – particularly steps #1, #2, and #7 (see Table 6.1).

6.3.2.1 Climate Wizard – Future Climate Change Projections for Decision Makers

The Climate Wizard tool suite arose in 2009 from the need to provide modelled projections of future climates in a format and at a scale useful for decision makers. TNC along with partners from the University of Washington, Santa Clara University, The University of Southern Mississippi, and Lawrence Livermore National Laboratory worked together to create tools to view and access current climate change information, and visualize observed and expected temperature and precipitation as well as derived climate variables such as moisture deficit, moisture surplus trends and measurements of extreme precipitation and heat events anywhere on earth. Climate Wizard tools offer a straightforward interface for processing and visualizing numerous climate variables for both past climate and future climate models and greenhouse gas emission scenarios (Fig. 6.7). Users can download map images and graphics for three time periods (past 50 years (1951–2006); mid-century (2040–2069); end of century (2070–2099) as well as annual, monthly and seasonal time steps. This tool has provided a valued resource for planners addressing framework steps #1 and #7 independently or as part of a more comprehensive approach.

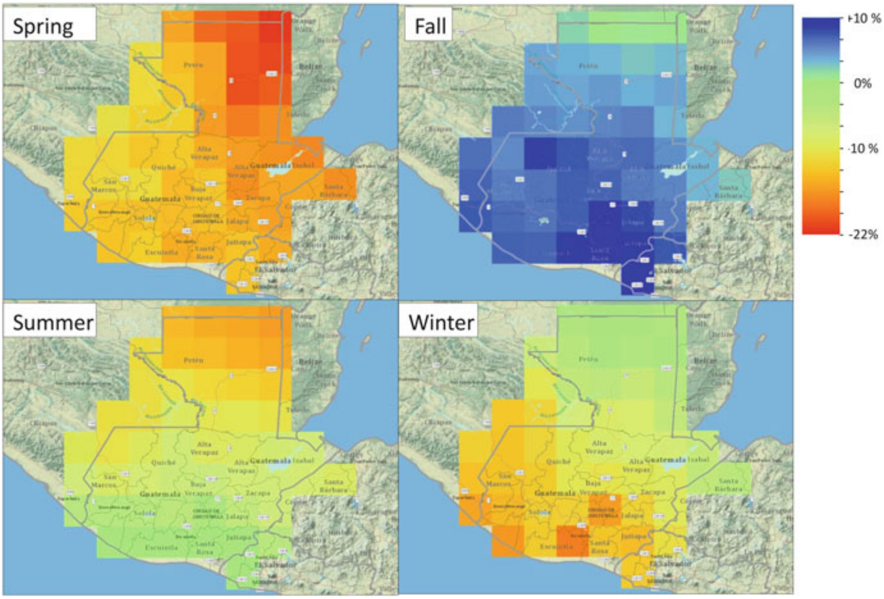

Fig. 6.7 An ensemble analysis from the Climate Wizard tool of 16 General Circulation Models showing the projected changes in precipitation quantity (mm/year) and distribution by 2050s (2040–2069) for the A2 emissions scenario across the Sierra Madre de Chiapas (Mexico, Guatemala, El Salvador) (Graphic reproduced or used with permission)

One of the key abilities of Climate Wizard is to bridge the divide between climate science and practitioners through the production of novel, downscaled, future-climate data sets, thus making climate change information more relevant and useable. Recent advancements through the Climate Wizard Custom framework provide globally, daily downscaled climate projections for a range of future projections which have been adopted by The World Bank via their Climate Change Knowledge Portal (see Table 6.2) (http://climateknowledgeportal.climatewizard.org). This availability of climate projections highlights a pre-requisite to refine and customize tools to inform decisions on climate impacts to water, agriculture and ecosystems. In this case, the tool demonstrates future aridity impacts by modeling the interactions of precipitation and rising temperature patterns. It also provides unprecedented access to future projections globally for various aridity metrics (Aridity Index, Climate Moisture Deficit and Surplus) for nine general circulation models.

A Mandarin version of Climate Wizard with data developed by the Chinese National Climate Center was released in 2014 to support a national future flood risk assessment and investment plan for floodplains (http://www.climatewizard.org.cn.s3-website-us-west-1.amazonaws.com). Applications of the tool along critical waterways like the Yangtze River illustrate the potential to influence flood risk reduction projects throughout China and in countries where Chinese companies invest. Ultimately, tools like Climate Wizard increase the accessibility to locally relevant projections with actionable visualization of climate change, which could then be used to forecast the implications of adaptive actions that incorporate Eco-DRR/CCA.

6.3.2.2 Coastal Defense Application

Coastal Defense Application resides in the Coastal Resilience tool as an open source app that integrates coastal hazards with social, ecological, economic, and coastal engineering to match adaptation with priority needs (framework steps #1, #2, #6, #7). This app helps to advance Eco-DRR/CCA by identifying the coastal protection value of existing reefs (Fig. 6.8) and wetlands and allowing the user to design and tailor implementation of natural infrastructure projects. More specifically, this app helps (1) identify areas that may be at risk of coastal erosion and inundation from wave action and storm surge; (2) interactively examine the role of coastal habitats in attenuating wave height and energy (Fig. 6.9); and (3) in a broader planning context determine appropriate disaster risk and climate adaptation strategies that incorporate green (habitats) and grey (seawalls and other man-made structures) infrastructure trade-offs. To generate these outputs the model InVEST (Sharp et al. 2014) builds in standard engineering techniques to calculate the reduction of wave height and energy in the presence and absence of coastal habitat. The app allows the user to define the value range for model variables within an

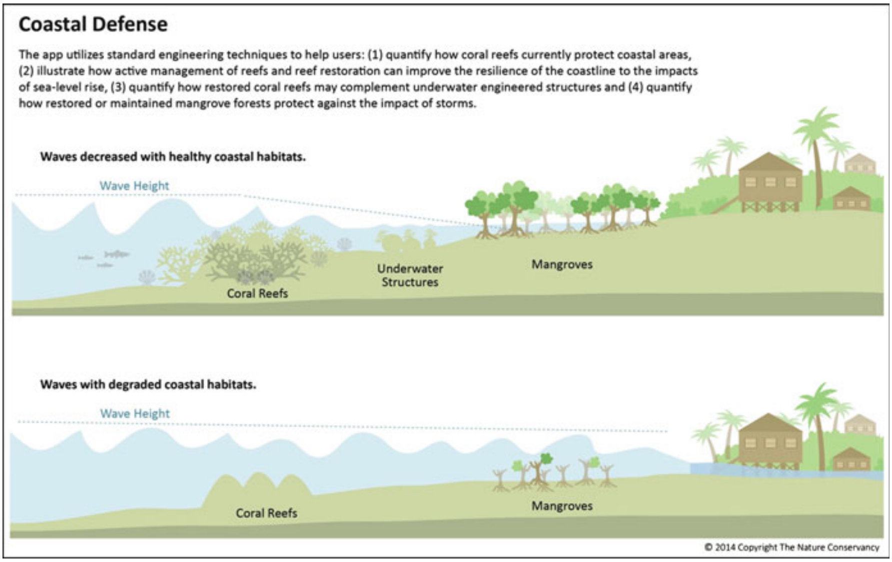

Fig. 6.8 Conceptual diagram of coastal defense application using coral reefs and mangroves protection and restoration to assist with disaster risk reduction and climate adaptation (Graphic reproduced or used with permission)

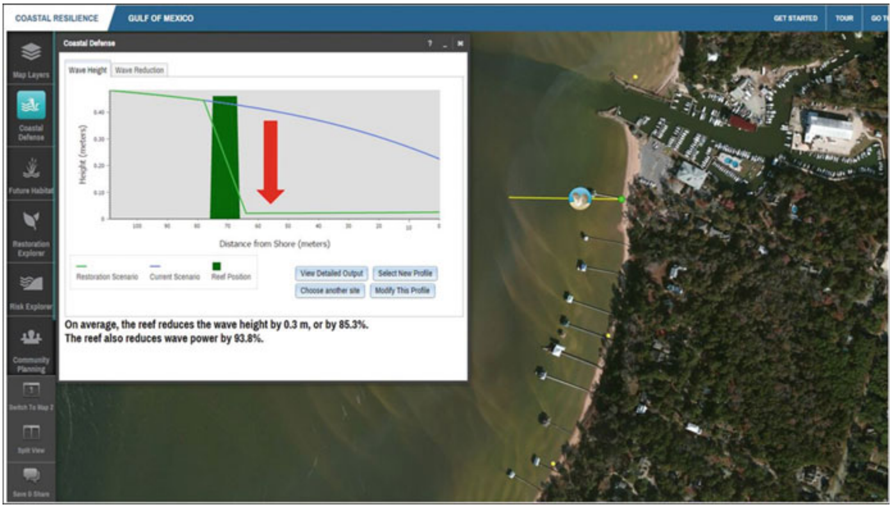

Fig. 6.9 Coastal Defense application output within Coastal Resilience tool depicting the reduction in wave height by oyster reefs designed with specified height characteristic in coastal Alabama (USA) (Graphic reproduced or used with permission)

intuitive and user-friendly interface thus reflecting real world scenarios. For the Coastal Defense app this includes user-specified offshore forcing conditions (wave and surge characteristics), a sea-level rise value, locations of restored or degraded coastal habitats and built infrastructure. In the USA, the app has been deployed in Puget Sound, Washington (tidal marshes), Mobile Bay, Alabama (oyster beds), and the Florida Keys (coral reefs and mangroves), with the potential for replication around the globe. In addition, the app has been used to assist in the identification of appropriate Eco-DRR/CCA projects in the Gulf of Mexico following the Deepwater Horizon oil spill (see also Bayani and Barthélemy, Chap. 10).

6.3.2.3 Crowd Sourcing/Social Media Tools

Emerging technological trends have resulted in a proliferation of decision-support tools that harness social media venues, specifically crowd sourcing. If harnessed appropriately, crowd sourced data can help to inform framework steps #1 and #2, and most importantly, help to monitor in real time during major events the effectiveness of actions taken that incorporate Eco-DRR/CCA. The use of crowd sourcing has expanded in the context of flood risk management (Haklay et al. 2014; Wan et al. 2014) principally because geographic information systems and technology are already an integral part of flood preparation activities. The information derived helps to reinforce the flood reduction services provided by ecosystems through eye-witness accounts and ultimately helps build local acceptance for ongoing and future actions that establish Eco-DRR/CCA solutions.

In a growing number of places like Brazil (Degrossi et al. 2010), the Philippines (Pineda 2012), and Jakarta, Indonesia (Holderness and Turpin 2015), citizen-derived reports sent through electronic messages assist emergency managers and responders by providing immediate, local flooding assessments across large areas. The use of technology in this way can help to direct disaster response efforts to areas of greatest need. Over time, data from multiple events help to drive flood risk reduction actions, such as the voluntary relocation of people followed by floodplain restoration in those self-identified locations. Of concern, however, is the level of accuracy in citizen reports, the ability of emergency management systems to process increased data volumes, and ultimately, the capacity of disaster response structures to incorporate the information and efficiently respond in appropriate timeframes (i.e., crowd sourcing outpacing the adaptive capacity of emergency management).

6.4 Lessons Learned and Recommendations

What is clear from these case studies (see Table 6.1) and many others (see Table 6.2) is that decision-support tools and approaches have improved rapidly in the last decade and continue to demonstrate the importance of Eco-DRR/CCA. A deeper understanding by decision makers, stakeholders, and practitioners of what mechanisms are being used to implement Eco-DRR/CCA, how these mechanisms can be used, and their inherent limitations, remains a critical challenge as illustrated by the case studies above. Despite the advances, external factors such as governance and funding remain pre-requisites to successful implementation. This is keenly evident in the Puget Sound watershed example whose successes thus far are largely driven by publicly-sourced finance commitments and funding processes (see Box 6.2) and by larger-scale collaboration around multi-objectives, including Eco-DRR/CCA.

Further lessons learned from the Coastal Resilience Program in Connecticut (USA) include the need to engage diverse stakeholders through a community-driven workshop approach that integrates tools within the planning-to-action framework steps. The recommendation therefore is to engage a broad suite of stakeholders at the beginning, during, and routinely thereafter, with particular emphasis on elected and appointed officials (i.e. decision makers), as a community works through the framework steps (see Box 6.1). This case study also highlights the importance of a trigger event (e.g. Tropical Storm Irene and Sandy) to advance Eco-DRR/CCA through recovery efforts.

The integrated coastal management efforts in Belize further reinforce this need to activate stakeholders more broadly through proactive engagement processes. The work in Belize, however, also highlights one of the ongoing challenges for decision-support tools and subsequent framework steps: the limited ability of tools to help stakeholders visualize alternative and inter-dependent future scenarios across larger geographies. A recommendation, therefore, is to develop tools that generate comparative outcomes from decisions or scenarios (i.e., cost of 'no-action', delayed action(s), and/or action sequences) that are easily understandable by stakeholders and are coupled with a progression through the framework steps. For example, this need is directly linked to the ability to sequence adaptation strategies (step #3) and assess action effectiveness (step #6). Of course, the critical consideration for 'future visioning' efforts is the ability to display comparisons of costs/benefits and effectiveness of Eco-DRR/CCA policies and projects. Social media that generate crowd sourcing of information in places like Brazil, Philippines, and Indonesia, have shown promise in fostering greater community receptivity towards scenario planning with Eco-DRR/CCA as a desired outcome, as well as in prioritizing voluntary relocation and subsequent ecological restoration to reduce flood risks.

In the case of the Water Funds approach and projects like the Monterrey FAMM, the importance of private-public partnerships in a financial construct can result in the prioritization and implementation of Eco-DRR/CCA projects at a watershed scale. One recommendation to improve the Eco-DRR/CCA linkages is to include in the prioritization process information on the size, configuration, and proximity of various habitats that can optimize benefits to society such as flood prevention. Establishment of a dedicated and sustainable funding source is certainly key to success with Water Funds throughout Central and South America and serves as a core enabling factor for Eco-DRR/CCA implementation (which is also a lesson derived from the Puget Sound watershed example). Another clear recommendation is the need to support efforts that prioritize projects and quantify the true cost-effectiveness of Eco-DRR/CCA over time. This would require standardization in the design and specifications for Eco-DRR/CCA projects in order for engineers to assign comparative costs for implementation and maintenance over the longer term, alongside traditional hard engineering projects.

Undoubtedly, organisations and governments around the globe will continue to develop tools and approaches in response to the mounting ecological, social and economic costs of disasters and climate change. These tools and approaches will continue to collectively enhance societies' ability to capture the additional and protective benefits of ecosystems. Nonetheless, decision makers and practitioners also need to point out the limitations of existing tools and approaches and express urgency for improvements. As illustrated within this chapter, it is clear that Eco-DRR/CCA decision-support mechanisms have improved rapidly in the last decade. Despite these advancements, factors such as resistance to change, the cautious approach by development agencies, governance structure and overlapping jurisdictions, funding, and limited community engagement remain, in many cases, pre-requisites to successful implementation of ecosystem-based solutions. The planning-to-action framework steps outlined in this chapter help guide communities to overcome these challenges and work towards maximizing resilience opportunities. What is certain is that ecosystems will increasingly be a critical part of societies' overall response to equitably solving issues associated with disasters and climate change in the decades and centuries to come.

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