PLANNING FOR COASTAL RESILIENCE: THE INTERSECTION OF THEORY AND PRACTICE

by

Adam D. Griffith

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Approved by:

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Dr. Wei-Ning Xiang

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Dr. Robert Boyer

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Dr. Harrison Campbell

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Dr. Lyn Exum

ABSTRACT

ADAM D. GRIFFITH. Planning for coastal resilience: the intersection of theory and practice. (Under the direction of DR. WEI-NING XIANG)

In the face of accelerating sea-level rise, people continue to live near and develop the coast. In the United States, we have chosen adaptation and protection, via coastal defenses, over retreat from the coast despite the unsustainable nature of efforts to rebuild our towns after storms. Coastal resilience has emerged as the dominant post-disaster narrative and has reinvigorated efforts to help our coasts recover from storms, but the application of theory-based principles of coastal resilience remains unclear. Here, I show that coastal resilience plans incorporate theory-based elements of coastal resilience significantly more than beach management plans. I reviewed over 3,000 pages in 22 planning documents and recorded use of 27 management techniques in five categories associated with coastal resilience. A Mann-Whiney U test found that resilience plans (n=10) contained significantly more ($p < 0.05$) techniques than beach management plans (n=12) overall, but none of the differences in plan scores was significant when examined by category of technique. This research uncovers inadequacies of the current level of adaptation for sea-level rise, challenges the current process of coastal land use planning, and suggests improvements municipalities can implement to maximize impacts of coastal resilience planning such as developing holistic, diverse plans that include socio-economic resilience and collaboration between practitioners and theorists.

DEDICATION

I dedicate this dissertation to inquisitive students of all ages everywhere. Keep asking questions! The truth is out there.

ACKNOWLEDGMENTS

My family, friends, classmates, and professors have been instrumental in supporting me throughout this process. Without their encouragement, I might have been lost, but fortunately their light has been able to guide my ship ashore. Susan, Simon, Ninja, and Chloe have comforted me in my times of need when things got rough. Jing, Alex, Jiyang, Minrui, Yu, Meijuan, Wenpeng, Michael, Claudio, Coline, Danny, Ran, Abel, Thomas, and many others provided laughs, smiles, problem solving, scholarly conversation, chocolate, and the occasional sofa on which I crashed. My committee (Dr. Xiang, Dr. Boyer, Dr. Campbell, and Dr. Exum) provided invaluable feedback throughout my academic journey along with valuable insight from their experiences. Other professors, notably the Delmelles, Dr. Chen, Dr. Tang, Dr. Shoemaker, Dr. Smith, and Dr. Allen, have also listened and supported me at UNCC. Thank you to CAGIS for computer support and to the department for travel funding. Stephen Bowman deserves huge thanks for helping with all the paperwork associated with obtaining a PhD and related travel along with Teena, Theresa, and the department office staff. Thank you all so much! Lastly, I would be remiss if I didn’t thank Dagger for making such fine whitewater kayaks.

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CHAPTER 1: INTRODUCTION

Most casual visitors to the coast do not view the intersection of land and water as the frontline of a war between humans and nature. This coupled human and natural system, the coastal zone and beaches, are a top vacation destination and contribute billions of dollars to local, regional, and national economies. Millions of people flock to the coast each year, many unaware that beaches, probably including their favorites, are threatened by erosion due to tropical weather systems, seasonal storms, and sea-level rise, all exacerbated by climate change. These storms are growing in both cost and intensity making some scholars question the presence of humans along the coast. After large shocks to the system, some coastal communities have been moved and some have fractured, but communities that exhibit high levels of resilience persist.

People love spending time close to the water, but living on coast comes at a price: globally, tropical storms and floods together kill more people and cause more damage than other disaster types (Hewitt, 2014). Compounding this are population centers heavily distributed along the coast: 50% of the world's population is predicted to live within 100km of the coast by 2050 (Small and Nicholls, 2003). This trend is evident in the United States where plans exist to develop over half of the land below 1 m on the east coast (Titus et al., 2009). These settlements will need to display unprecedented levels of resilience to persist for the coming century given predicted increases in tropical cyclone intensity (Melillo et al., 2014). Communities vulnerable to erosion and sea-level rise have latched onto coastal resilience with tenacity, but how has coastal resilience been defined and used and has significant attention been given to testing the utility and efficaciousness of the concept?

The concept of resilience of natural systems has been applied across a wide variety of disciplines since Holling's introductory work in 1973. I argue here that resilience not only pertains to the natural coastal landscape, but that the coupled system provides an archetype of Holling's thinking. Holling writes in his introduction that "attention shifts, therefore, to the qualitative and to questions of existence or not (p. 1)." To exist or not at the coast is the question. At various times, humans have made the decision to live on the coast, but I believe it is time to reevaluate this decision.

The emergence of a resilient coast has become the dominant post-disaster narrative in the United States and internationally, particularly after Sandy. For communities and regions that suffered heavy casualties and economic losses to storms, building resilience has become a significant goal and many communities have developed plans purportedly based on coastal resilience concepts as a result. Two bodies of coastal management plans now exist: those that purport to adhere to principles of resilience and those that do not, typically called beach management plans. The most basic question is: are those two bodies of plans different? Following are the core questions this research seeks to answer:

1) Do coastal resilience plans contain the expected theory-based management techniques identified in the literature?

2) Do coastal management plans developed without coastal resilience principles contain theory-based coastal resilience management techniques?

3) Are there statistically different levels of inclusion of management techniques between the two bodies of plans and, if so, what are the consequences of finding or not finding a significant difference?

Additional questions relating to question three above include why the plans do or do not incorporate principles of resilience and what planners can do to better integrate principles of coastal resilience. In section 2.2.2, I describe the research gap between planners and academics. Do the results show that the gap is closing or widening? What are the consequences of plans not aligning with resilience theory for planners, academics, and coastal communities? Who suffers the consequences of this gap? What inferences can be made about communication between planners and academics and finally, what can be done to reconcile the gap? Regardless of the outcome of the statistical tests, the research questions are structured such that the results will be interesting and lend themselves to practical suggestions.

These questions appear to be novel and are certainly important and relevant. Section 2.2.2 highlights the gap between theory and practice in other domains, but conspicuously absent are studies in the area of coastal resilience. General studies pertaining to gaps in theory and practice of resilience exist (Shaw, 2012; Davoudi, 2012), but do not mention coastal resilience. Despite the popularity of coastal resilience in the literature, few, if any, studies have emerged highlighting this research gap. Studies surveying climate change adaptation strategies exist (e.g. Schechtman and Brady, 2013; Mawdsley et al., 2009; Hunt and Watkiss, 2011), but do not highlight resilience as the key. The detailed description of the coastal resilience gap proposed here appears to be novel.

The application of coastal resilience principles is of critical importance for economic, social, and public health reasons. U.S. coastal resilience planning documents propose expenditures of millions of public tax dollars over long periods of time. The economic cost of living near the coast is rising, as shown in section 2.1.5. The debt load of the NFIP will not diminish absent a decades long hurricane drought. The increase in the number of billion-dollar disasters (Smith, 2017) establishes this as the new norm to which we must adapt. The encouragement of continued coastal development (Titus et al., 2009) ultimately places more people at risk and the possibility of increased injuries and death (over a do-nothing scenario) is one possible outcome.

The relevance of coastal resilience principles cannot be understated. The ability of the coastal landscape to rebound after a storm will diminish as storms increase in intensity. Predictions of increased hurricane activity as a result of global warming (Saunders and Lea, 2008) will exacerbate tropical weather systems and the increased level of hurricanes is expected to continue for decades (Goldenberg et al., 2001). This is combined with plans by coastal municipalities to develop the majority of land below 1 m on the east coast of the US (Titus et al., 2009). The call for development is at odds with sea-level rise and time to act is now, not after the next Katrina or Sandy or Florence.

I have multiple research objectives. My first objective of reviewing literature for a research gap in the domain of coastal resilience is addressed in the literature review in Chapter 2. My second objective is to analyze coastal resilience plans and coastal or beach management plans for inclusion of theory-based coastal resilience techniques. The methods of this objective are addressed in Chapter 3 and the results and analysis comprise Chapter 4.

My final and most complicated research objective is to examine why the results are observed and make recommendations on what can be done moving forward. Chapter 5 discusses options for coastal community planning and makes recommendations for how municipalities can better plan for resilience. Chapter 6 includes my conclusions, possible future research, and publication options.

The ultimate goal of this research is to influence coastal management practices in the US. This research falls under the larger academic umbrella of ecological wisdom, an idea antipodal to many coastal planners. Liao and Chan (2016) conceive of ecological wisdom as a way of doing things that is harmonious with other life forms while relying on practical wisdom. The field draws upon the works of Arne Neass and Aristotle. My work is facilitated by a systematic search and review of peer-reviewed literature and planning documents that explore the gap between the theory and practice of coastal resilience.

CHAPTER 2: LITERATURE REVIEW

2.1 The science of resilience and coastal resilience

Resilience has evolved into a large field of study over the last four decades. Here, I focus on the academic roots of resilience and coastal resilience, the concept of resistance, climate science, and the sustainability of current coastal management practices.

2.1.1 The academic roots of resilience

The academic roots of resilience can be traced to ecologist C.S. Holling who defined resilience as the ability of a system to persist and the system's "ability to absorb change and disturbance and still maintain the same relationships between populations and state variables (1973, p. 14). This is frequently and colloquially referred to as the ability to "bounce back" and most closely mirrors dictionary definitions of resilience. Through time, however, more specificity emerged in the literature and his original idea of simple resilience bifurcated into ecological resilience and engineering resilience. Holling (1996) clarifies that engineering resilience should be used for relatively stable systems with single domains of attraction. The time it takes for the system to return to its stable state after perturbation can be thought of as the system's engineering resilience and the term has emerged from disciplines with stronger use of deductive reasoning, such as math, pointing to Pimm (1984) as an example. Ecological resilience is preferred for unstable systems that can revert to an alternate stable state (p. 33). It should be noted that Holling's portrayal of change in ecological systems as sudden seems heavily influenced by the theory of punctuated equilibrium by Eldredge and Gould (1972) despite his lack of citations (p. 31).

Later variations on resilience include Gunderson (2000) who complicated things by introducing the term adaptive capacity and pointing out that resilience is not a static property of a system (p. 428). He defines adaptive capacity as how well a system can remain in its stable state or domain of attraction. Gunderson (2000) interprets Holling's ecological resilience as having multiple domains of attraction or stable states and the engineering resilience as the shape of the domain of attraction (p. 427). Carpenter et al. (2001) contribute that understanding fast and slow variables are critical to estimating resilience and encourage authors to specify what system is under study and what is eroding the resilience of that system.

From Holling's initial 1973 paper, a wide variety of definitions of resilience sprung from disciplines such as psychology, ecology, planning, sociology, and more. Norris et al. (2008) well summarize 21 definitions of resilience all of which involve a stress or shock to a system (p. 129), but with a focus on their particular interest, community resilience. The authors describe adoption of the resilience metaphor by psychologists, which can be compared to adoption of the metaphor by geoscientists and geographers.

Norris et al. (2008) adopt the resilience metaphor wholeheartedly, but in hindsight suggest that making a new term of their own “free from inherited definitions” might have been better for their discipline (p. 128). They continue that defining the term “community resilience” increases the complexity greatly due to differences in the meaning of community, compounded by the differences of the term “resilience.” Such parsing of words also hinders the term “coastal resilience.” Coastal geomorphologists may wish to confine the coast to the highly dynamic near-shore environment devoid of human habitation while geographers may wish to define the coast as all land within a 25, 50, or 100 km from the mean high water line. Given the popularity of “coastal resilience” and “coastal resiliency” presented below, it may be too late to coin terms specific to the coast. (This does not exempt practitioners from clearly defining terms and rooting words to a philosophical framework).

More recent research has turned to isolating principles required to build resilience. Biggs, Schluter, and Schoon (2015) identify seven principles they consider the most important: diversity and redundancy, connectivity, slow variables and feedbacks, complex adaptive systems thinking, learning, participation, and polycentric governance. A variety of research groups now weigh in on a cadre of resilience related topics including The Resilience Alliance, The Stockholm Resilience Centre, The Coastal Resilience Center, The Resilience Center, and many more.

2.1.2 The academic roots of coastal resilience

The first use of resilience with reference to the coast comes from the Dutch in 1997 with the Baan et al. (1997) work entitled "Resilience of the coastal development and operationalization of a 'resilience meter.'" This report is the result of a conference in the Netherlands in October of 1996. Baan et al. (1997) do not directly cite Holling's work, but rather the work of Van der Aarsen (1989), which cites Holling. (The Dutch rely heavily on beach renourishment and are depleting offshore sand reserves in the near-shore environment.) Despite the absence of direct citation of Holling, Baan et al. (1997) recognize the importance of Holling's definition and its applications to the coastal environment. They give a dictionary definition of resilience at the conclusion of the report as the ability of a system to bounce back after a shock. The authors track usage of the word resilience in the national sand balance reports of 1995 (p. 3-2), recognize positive contributions of resilience in their current coastal management model (p. 3-5), and admit the transient nature of some land management concepts (and use sustainable development as an example) (p. 3-6).

The goal of Baan et al. (1997) is to operationalize and quantify ecological resilience for application to the Dutch coast. They conclude that resilience, as it applies to the coast, consists of objective and subjective subcomponents, the former being potential coastal dynamics and the latter being "determined by the functions of the coast (p. 8-1). They recommend further research into the ecological and socio-economic subcomponents within their "resilience meter" (p.

8-1). The influence of this conference on the attendees (listed on Appendix 3 p. 9) is clear: in 1998 the first journal articles in English were published using the term "coastal resilience," the most detailed being Klein et al. (1998). The paper references the main dichotomy in coastal management practices. Coastlines are naturally dynamic and move *many* meters per year in areas of erosion or accretion. Option A is to allow natural coastal dynamics to happen while option B is to armor the shoreline with hard and soft defenses in an effort to keep the shoreline in place, summarized in the title simply as "Dutch Dikes." Klein et al. (1998) recognize that the resilience of the coast is dependent upon three subcomponents: morphological resilience, ecological resilience, and socio-economic resilience (p. 261-262). These three types of resilience determine the overall coastal resilience, but the authors reject two previous definitions of ecological resilience - the ability of a system to absorb changes (Holling, 1973) or the time it takes the system to recover (Pimm, 1984). The authors argue that neither definition is appropriate for the Dutch coast due to the level of engineering and manipulation that has caused the coast to be at "disequilibrium." Instead, they suggest using the Baan et al. (1997) definition and provide the first English translation:

> The resilience of the coast is its self-organizing capacity to preserve actual and potential functions of coastal systems under the influence of changing hydraulic and morphological conditions. This capacity is based on the

> (potential) dynamics of morphological, ecological and socio-economic processes in relation to the demands that are made by the functions to be preserved. (p. 7-1)

The distinction between potential and actual coastal dynamics is recognition that the Dutch coast is heavily diked and walled and perpetually nourished with millions of cubic meters of sand that completely alter natural coastal geomorphological dynamics. The possibility for dynamics to occur is removed by hardened beach stabilization structures because there is no beach. The complex definition of resilience above is described as functional (p. 263) and is significantly different from definitions of resilience by Holling (1973, 1996). Table 1 below summarizes definitions of resilience and related terms discussed.

Table 1 - Terms and definition relating to resilience.

Author(s)	Year	term	definition
Holling	1973	resilience	How well a system absorbs change and maintains the same relationships and functions
		stability	How well a system returns to a stable state after perturbation
Pimm	1984	resilience	How quickly a system returns to a stable state following disturbance
Holling	1996	ecological resilience	How well a highly dynamic system absorbs change and maintains the same relationships and functions
		engineering resilience	Stability of a near-equilibrium state measured by resistance and return speed to stable state
Gunderson	2000	adaptive capacity	Ability to remain in a domain of attraction as it changes shape
Carpenter et al.	2001	resilience	Ability of a system to stay in a domain of attraction, degree of self-organization, level of adaptive capacity

2.1.3 Resilience versus resistance

Resistance warrants special attention in this case due to the history of its use, similarity to and confusion with resilience, and applicability to coastal systems. Holling (1996) thinks of resistance as a function of engineering resilience (p. 33). Carpenter et al. (2001) expand on this explaining resistance is a function of persistence. Resistance is the "amount of external pressure needed to bring about a given amount of disturbance to the system" (p. 766). Finally, Walker et al. (2004) add additional context by describing four subcomponents of resilience: latitude, precariousness, panarchy, and resistance. Latitude is a tipping point or threshold, precariousness is how close a system is to that threshold, and panarchy refers to external factors that may have a dramatic effect on a system such as legislation, war, or market changes. Resistance is visualized as the depth of the basin of attraction, something akin to the activation energy of a chemical reaction. Latitude is the width of that basin and precariousness is its position within the basin (shown in Walker et al., 2004, Fig 1a).

In the context of coastal systems, Klein et al. (1998) make the distinction between resilience and resistance clear. Coastal resistance is how well the system can elude disturbance while coastal resilience is how the system can resume functions after disturbance. The authors make an important *temporal* distinction here - that resistance is "more important before the system is perturbed, and resilience comes into play after the system has been perturbed"

(p. 260). Applied to a simple sea wall, the term *resistance* may better apply to the role the wall plays in the ecological system because the wall does little after the shock to the system. Before the shock to the system, however, the wall increases the level of perturbation the system may withstand before a critical threshold is reached – overtopping of the wall by the sea.

Klein et al. (1998) also note resilience and resistance are factors that determine the stability of the system and part of the system's natural ability to cope with disturbance. Resilience and resistance together with susceptibility (the system's potential to be disturbed) comprise the natural vulnerability of the coastal system (p. 260). This is only part of their conceptual framework outline in their Figure 1 where natural systems and socio-economic systems are shown in parallel.

2.1.4 Climate change and human response

Climate change driven sea-level rise (SLR) presents challenges for homeowners, coastal communities, land managers, policy makers, cities, states, and countries. Sea-level rise is caused by thermal expansion of water and melting of ice on land (Nicholls and Cazanave, 2010). Rates of SLR have been accelerating since 1900 and as recently as 120,000 years ago, sea level was 5 – 10 m higher than present levels (Stocker et al., 2013), extremely troubling if the past higher levels portend the future. Higher sea-level poses a direct threat to the 3.7 million people living within 1 m of high tide in the US (Strauss et al., 2012) and 50% of the world's population that is predicted to live within 100km of the coast by 2050 (Small and Nicholls, 2003).

Current estimates of the global rate of SLR are around 3.2 mm per year (Stocker et al., 2013). This rate has been accelerating, but if remaining constant, equals about 26 cm (10 in.) of SLR by the year 2100. The IPCC estimates are considered conservative by the National Research Council, which considers a possible rise of 56 - 200 cm (22 - 79 in) (National Research Council, 2010). Rates of local SLR vary greatly due to ocean circulation patterns, global sea level, winds, and land movements. For these reasons, the east coast of the US has relative rates of SLR higher than the global averages. In Louisiana, the rates are among the highest in the world, around 9.5 mm per year, due to a complex of factors including subsidence from extraction of oil and water and low sediment supply from dams in the Mississippi River watershed. The distinction between local (or relative) rates of SLR and global averages is crucial: in Scandinavia and other northern latitudes, sea level is *falling* due to the bedrock expansion after glacial retreat, in excess of 10 mm per year, in some locales (NOAA, 2018).

Policy experts typically place SLR adaptation strategies into one of three categories: protection (shoreline armoring and beach nourishment), adaptation (lifting houses, roadways, and infrastructure), and retreat (moving inland) (Titus, 2011; Kousky, 2014). Globally, protection and adaptation have been strongly favored over managed retreat, which is unpopular among local political leaders in coastal communities and very expensive. The Army Corps of Engineers estimated a cost of $110 million (in 2004) to move the small town of Shishmaref, Alaska to the mainland of Alaska (in Pilkey and Young, 2009, p. 11) and $50 million only covered partial costs for the Biloxi-Chitimacha-Choctaw Tribe in Louisiana (Hino et al., 2017). The only literature review on climate induced managed retreat finds only 27 cases globally of retreat to date (Hino et al., 2017). Protection and adaptation are more popular SLR strategies and here I review specifics of the US and Dutch strategies. It should be noted that in the following sections, the Netherlands approach is treated as a response to SLR and storms.

Beach nourishment and shoreline armoring have been the *de facto* policy of US states and towns for decades and now some 225 beaches on the East and Gulf Coasts rely on beach nourishments (Pilkey and Pilkey - Jarvis, 2007, p. 121). The story is the same in the Netherlands and England where the term *coastal squeeze* originated (Doody, 2004). Developed shorelines are squeezed between the sea and human development and those shorelines are narrowing due to erosion and SLR. The shoreline does not have the ability to migrate landward, as beaches do in some places multiple meters on a daily basis, because of development and frequently a sea wall built to protect houses and buildings (as shown in 4 of Doody, 2004). Shoreline armoring and hardened beach structures are known to accelerate erosion (Pilkey and Pilkey-Jarvis, 2007; Pilkey and Young, 2009) and destabilize natural coastal shoreline dynamics (Kittenger and Ayers, 2010). Experts in California recommend using legal mechanisms to discourage construction of hardened beach structures due to the economic and ecological harm they cause to the coast (Mellus, 2015). In the Netherlands, the lack of available land significantly above sea level has driven their approach to armoring.

The Dutch are global leaders in the field of shoreline protection stemming from a 1937 report noting significant vulnerability to coastal storms for much of the Netherlands due to low elevation. WWII delayed their plans to combat the risk with multiple engineering structures including large sea walls, but work finally began in 1950 (Delta Programme, 2014). Unfortunately, protection measures were not completed by 1953 when the North Sea Flood killed more than 1700 people (Baxter, 2005). Annual Dutch expenditures on flood control annually top $1.3 billion, but this is merely a maintenance cost: construction costs totaled more than $13 billion and took over 40 years to finish (Higgins, 2012). According to Wim Kuijken, the highest-ranking Dutch official overseeing coastal protection measures, the US excels after the disaster strikes, but “working to avoid disaster is completely different from working after a disaster” (in Higgins, 2012). Like the Dutch, Americans have also settled in highly flood-prone areas, but the Dutch coastal defenses are built to 10,000-year storm events (Higgins, 2012) unlike U.S. defenses built to lower standards.

Adaptation strategies include lifting structures, roadways and other infrastructure. Titus (2011) recommends the use of rolling easements, a legal mechanism by which the public has access to beaches, allowing islands to migrate naturally. Other adaptation strategies include minimizing impervious surfaces, changing building codes, or minimizing shoreline stabilization structures (Cruce and Yurkovich, 2011). Frank et al. (2015) advocate for protection in highly urban areas (p. 244), accommodation for less urbanized areas (p 248), relocation in areas with high ecological potential value (p. 250), avoidance when possible (p. 252) and low impact development (LID) in areas with low vulnerability (p. 253). Love et al. (2013) also suggest inclusion of green infrastructure such as stormwater retention technologies (p. 13), floodgates, and transfers of development rights of homeowners to less flood-prone areas (p. 11).

2.1.5 Sustainability of current coastal management practices

The practice of shoreline armoring and beach renourishment as a strategy to combat SLR and erosion goes against principles of sustainability outlined by Beatley (1995) as maximizing equality, acknowledging ecological limits, and acknowledging environmental costs. The benefit of coastal protection measures is not equal: residents proximal to the protection measures benefit the most while some distal do not benefit. Yet US beach nourishment projects are paid for primarily by federal tax dollars (65%) and state funds (25%), with local residents and municipalities shouldering only one tenth of the total coast (NOAA, 2000, p. 14). In Shishmaref, Alaska (population 600), temporary protection measures totaled $34 million by 2006 with local residents paying none of the costs (Pilkey and Young, 2007, p. 11). The benefit of coastal protection measures in the

Netherlands is more equally shared since a higher proportion of the population is vulnerable to coastal flooding, as evidenced by the 1953 North Sea Flood.

The economic sustainability of shoreline protection is grim. Analysis of New Jersey data from the Program for the Study of Developed Shorelines (2018) show a steady increase in cost of nourished beach sand from 1936 through the early 1970s, but a dramatic increase thereafter. This is shown in Figure 1 below in cost per cubic foot of sand in 2016 dollars.

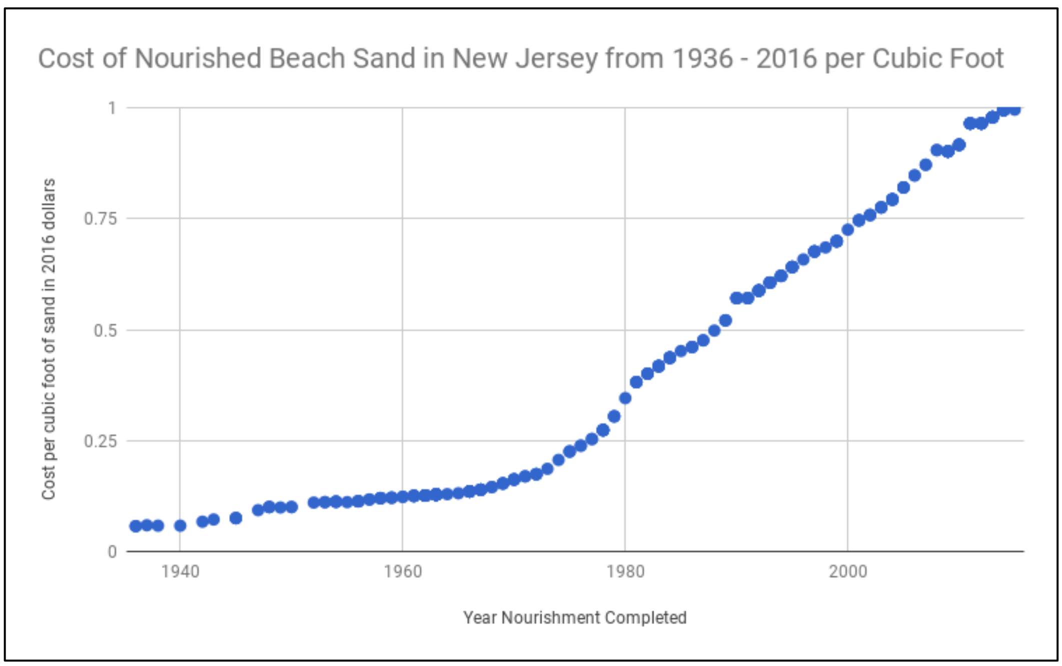

Figure 1. Increases in beach nourishment costs in NJ (Data from Program for the Study of Developed Shorelines, 2018).

The cost of beach nourishment has risen steadily due to increased costs of labor, fuel, and underwater sand extraction. Estimates of cost per mile of beach nourished range from $1 million to $10 million (Pilkey and Pilkey, 2007, p. 121).

Another problem for economic sustainability in the US is the federally subsidized National Flood Insurance Policy (NFIP).

The NFIP was conceived after Hurricane Betsy ripped through Louisiana killing 75 people and causing $1.425 billion dollars in damage to mostly uninsured property (Blake et al., 2011). In order to promote the economic development of the coast and for residents of flood prone areas to have insurance options, the government offered coastal flood insurance at below-market rates. Relatively quiet Atlantic hurricane seasons from 1970 through the mid-1990s resulted in steady home construction and business development in high-risk coastal flood zones. Through the 1950s and 1960s, private insurance companies got out of the flood insurance business because they recognized the financial gains were very small compared to the large risks associated with catastrophic flooding (Michel-Kerjan, Lemoyne de Forges, and Kunreuther, 2012). On August 29, 2005, Katrina made landfall in Louisiana killing 1200 people and causing $108 billion in damages (Blake et al., 2011). The premiums paid were far lower than claims and the NFIP had to borrow from the US Treasury to pay the claims from Katrina in 2005 and from flooding in 2008 totaling $19 billion (Michel-Kerjan, 2010). Payouts must be below premiums paid, or the program runs a deficit. After Hurricane Sandy in 2012, the situation became even worse. Despite record policies purchased in the years following Katrina, the program dipped further into debt after paying out claims of $7.9 billion for Sandy for a total of $24 billion in debt (Kousky and Shabman, 2014).

2.2 The practice of coastal resilience

Some planners are now incorporating coastal resilience concepts into planning documents based on the popularity of coastal resilience. Here I focus on the rise of coastal resilience in the literature and the research gap between academics and practitioners of coastal resilience.

2.2.1 The recent rise of coastal resilience

In 2008, the World Bank announced establishment of the $6.1 B Climate Investment Fund (CIF) with the stated goal of “increasing climate resilience in developing countries” (World Bank, 2008). Perhaps keying off the word resilience in the CIF press release, the White House (2010) then released the Progress Report of the Interagency Climate Change Adaptation Task Force: Recommended Actions in Support of a National Climate Change Adaptation Strategy in which the word resilience appears 46 times. The most frequent uses were ecosystem resilience and community resilience. In 2013, the Rockefeller Foundation announced its 100 Resilient Cities initiative and in 2014, partnered with the U.S. Agency for International Development and the Swedish International Development Cooperation Agency to fund the Global Resilience Partnership.

The global efforts above are matched by a concomitant rise in the popularity of resilience in academic literature. The terms “coastal resilience” and “coastal resiliency” have increased dramatically since their first appearance in

1998 at the conference mentioned in section 2.1.2 above. Figures 2 and 3 below show the number of articles yearly from 1998 ~ 2017 from one database and from the largest three academic databases, respectively that contain the words "coastal resilience" or "coastal resiliency" anywhere in the paper.

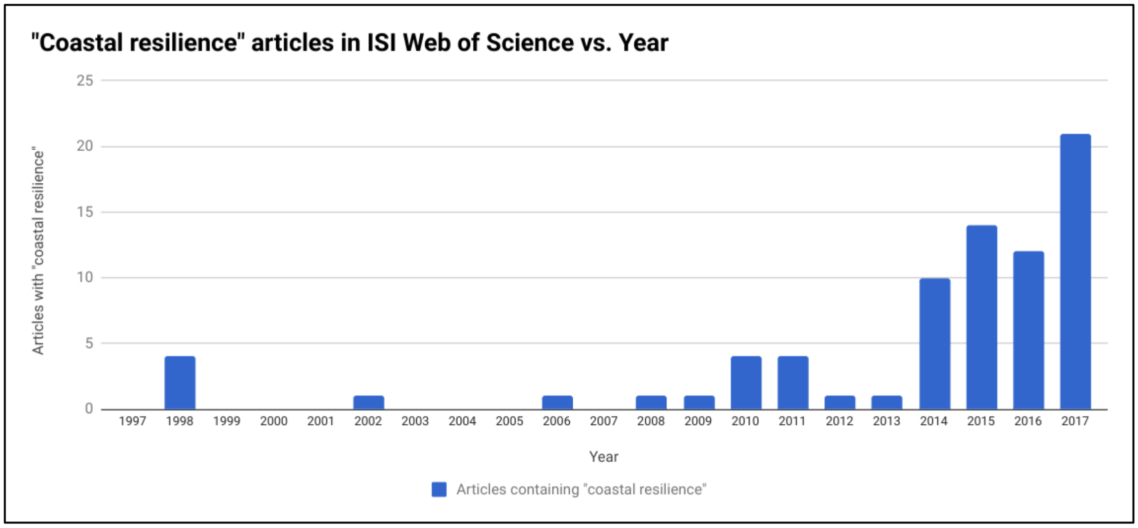

Figure 2. Articles containing the term "coastal resilience" anywhere in ISI Web of Science (search date March 23, 2018).

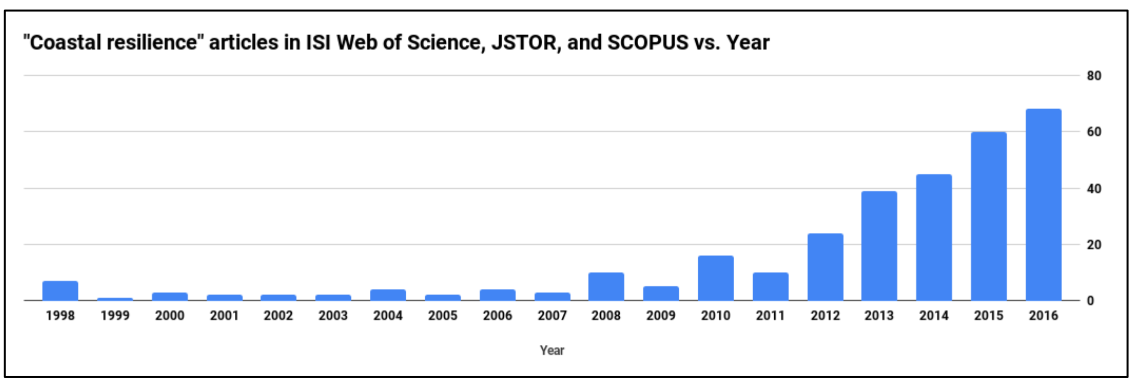

Figure 3. Articles containing the term "coastal resilience" anywhere in ISI Web of Science, JSTOR, and SCOPUS databases (search date March 23, 2017).

It should be noted, however, that coastal resilience has become a popular term that is usually used without being defined in the article. Of 51 references published between 1999 and 2016 in ISI Web of Science, only two articles linked the terms to any formal definition (Bamford and Kavanaugh, 2015; Marchand et al., 2011).

2.2.2 Coastal resilience plans and gaps between theory and practice

Each year, and given the available funding described in the previous section, an increasing number of plans for building coastal resilience are written at the local and state level across the US. An influx of funding in a nascent area (coastal resilience) may encourage municipalities to simply repackage their existing coastal management practices as complying with coastal resilience grant applications. Although this is not a goal of this research, more research in this area is required. A common channel for municipalities to receive funding to create their own coastal resilience plans is through NOAA Coastal Resilience Grants. NOAA has given out $21 M in funding for coastal resilience projects in their 2015-2016 grant cycles, $13.8 M in the 2017 cycle, and pledged another $15 M for 2018 for a total of $50.8 M (NOAA, 2018). Funded projects have varied greatly: efforts to build community resilience in Charleston, SC; oyster reef restoration in Naples Bay, FL; wetlands restoration in Washington; and improving disaster communications in Washington. Other major channels for coastal resilience plans are through local governments, HUD, or the Nature

Conservancy. Under a directive from Mayor Bill de Blasio, New York City's Office of Recovery and Resiliency began in 2014 and administers the $20 billion plan to build climate change resilience (NYC, 2018). Parts of that larger plan include the Lower Manhattan Coastal Resiliency (LMCR) and East Side Coastal Resiliency (ESCR) projects. The ESCR project is a $505 million effort (Wachs, 2016) while the LMCR projects total in excess of $300 million (NYC, 2016). After hurricane Sandy, HUD also funded multiple coastal resilience plans in Connecticut.

The plans frequently focus on hardened shoreline protection measures, as is called for in the plans for New York City and plans from the towns of Guilford, Branford, Madison, and West Haven in Connecticut. These projects range in scope and cost, but common to all are increased levels of development in flood prone areas and activities that promote future increased levels of development in flood prone areas. This violates multiple principles of planning for coastal resilience outlined by Beatley (2012) and Nicholls and Branson (1998) who all advocate for a holistic approach to coastal land use planning. Planning for coastal resilience should consider long time scales, preserve ecosystem functions, and guide growth away from low elevations (Beatley (2012), p. 59 – 71). Hardened shoreline protection and increased coastal development also violate fundamental hazard assessment and planning principles (Burby et al., 2000). These cases illustrate the gap between the theory of planning for resilience in coastal areas and the application of those principles, but this is not unique to coastal resilience planning.

Gaps between theory and practice are common in a wide variety of disciplines. Hoppner et al. (2012) found such a gap in the field of risk communication in Europe where communication flows between the two groups were sub-optimal. Gaillard and Mercer (2013) describe a similar gap between theory and action in disaster risk reduction. We know where flood prone areas exist; yet progress in reducing risk in these areas is painfully slow, deadly, and expensive. The same gap between theory and practice is found in climate change adaptation in cities (Wamsler et al., 2013), building flood resilient communities (Lopez-Marrero and Tschakert, 2011), and drinking water reservoir management (Simonovic, 1992). Gaps between theory and practice are common, but what can be done in the area of coastal resilience? What would an ideal plan for coastal resilience look like?

2.3 Theoretical coastal resilience: the ideal coastal resilience plan

A number of sources outline principles of resilience specifically geared toward the coast (Beatley, 2012; Nicholls and Branson, 1998; NOAA, 2018; The Nature Conservancy, 2018). The most comprehensive of these is Beatley (2012) who encourages planners to incorporate a number of principles for coastal resilience. These include taking a long-term approach, not developing high-risk areas, locating critical infrastructure out of high-risk areas, using natural assets such as wetlands, decentralizing infrastructure, and planning sustainably (p. 59-71). The scope of Beatley (2009) is specific to resilience at the coast, but his principles can be applied concomitantly with the general resilience principles outlined by Biggs, Schluter, and Schoon (2015), which include diversity and redundancy, connectivity, slow variables and feedbacks, complex adaptive systems thinking, learning, participation, and polycentric governance. Concepts of psychological resilience (Norris, 2008) are also critical for effective disaster recovery and represented in some plans. Above all, the holistic thinking advocated by Beatley (2012) and Nicholls and Branson (1998) is required when planning at any geographic scale.

As such, I offer the essential principles of coastal resilience based on the literature reviewed here that I use for my analysis:

1. *Long-term approach*. Communities should consider local rates of sea-level rise when planning for growth. Moving assets now may be less expensive now compared to when flooded regularly. Initial costs may be higher, but will save money in the long run, so cost benefit analyses need to be computed up to 100 years into the future. Communities should evaluate over what time scales they can continue their current course. Retreat may make sense, depending on the timescale.
2. *Guided development.* New residential and commercial development should not be permitted in low-elevation areas or high-risk areas. This seems like common sense, but the desire to increase the tax-base

rules and common sense is ignored. Incentivize relocation of existing structures in high-risk areas through zoning, buybacks, and redevelopment and prohibit new development in risky areas.

3. *Relocate infrastructure*. Move water treatment facilities and emergency services out of areas likely to be flooded. Plan to move one system at a time and stagger the work over the course of years, if necessary. This will allow systems to function sooner after floods.
4. *Community approach.* Engaged communities are more resilient and residents will be more engaged if they are involved in planning through public participation forums and charettes. Anger can also be mitigated.
5. *Diverse approach.* Soft coastal defenses are not sustainable and hard defenses require more hard defenses to counter the associated accelerated erosion in adjacent areas. This approach also encourages residents to stay put and lulls them into a false sense of safety. Despite these drawbacks, coastal defenses can protect infrastructure and structures in highly urban environments when lack of available land may drive decisions.
6. *Cohesive plan.* Departments within a city may have competing goals and decision makers must take a holistic approach, even if it means working against the short-term goals of some groups. Multiple agencies within the municipality must be invested in the process. Solving one problem should not create additional problems.

7. *Plan for disasters.* Coastal disasters are inevitable and the best part is that we have a very good idea where they will strike. Having detailed plans in place will speed recovery and eliminate confusion during and after the flooding.

Above are guiding principles that are a list of *shoulds*, but how can this be accomplished? In addition to resilience literature, the climate change adaptation literature provides techniques for maximizing coastal resilience. Schechtman and Brady (2013) suggest use of local hazard mitigation plans, comprehensive plans, zoning, and coastal setbacks from the high tide line. Other ideas include use of sea-level rise predictions in planning and community involvement (Beatly, 2009; Schechtman and Brady, 2013). Although protection measures have their detractors, most notably Pilkey and Pilkey-Jarvis (2007) and Pilkey and Young (2009), coastal defenses serve to protect coastal assets by mitigating storm impacts and when used sparingly, can increase coastal resilience locally.

The resilience theory and coastal literature reviewed above highlight what techniques theory-based coastal resilience planning documents should contain. The coastal resilience plan techniques detailed below are a combination of the concepts described in this literature review. Table 2 shows the cadre of possible options for coastal resilience planning compiled from the references in this literature review. Hard coastal defenses include sea walls, jetties, and groins whereas soft coastal defenses include beach nourishment, dune protection, or oyster reef installation. Private transfers of development rights operate differently than buyouts in that the transaction is voluntary and on an individual parcel basis. Guided development that discourages rebuilding in floodplains is used in riverine areas primarily, but has been applied to the coast in some areas.

Table 2. Theory-based hypothetical coastal resilience planning techniques compiled from references in sections 2.1.4 and 2.3.

Property Management
Relocation of critical infrastructure (emergency services, water, etc.)
Relocation of municipal assets to higher elevation
Private transfer of development rights
Guided development discouraging rebuilding
Elevated homes or businesses
Infrastructure
Hard coastal defenses
Soft coastal defenses
Elevated roadways
Elevated infrastructure
Stormwater backflow prevention devices
Elimination of utilities and services in routinely flooded areas (electricity, street maintenance, etc.)
Floodgates
Preservation of natural coastal defenses
Financial structures
Buyouts of flood-prone properties
Incentives to elevate structures
Phase-outs of flood insurance
Social Structures
Non-profit support networks (faith-based orgs, Red Cross, etc.)
Access to healthcare including psychological services
Healthcare access including psychological services
Governance
Comprehensive plan
Emergency plan
Prolonged disaster plan
Climate-change plan
Hazard mitigation plan
Coastal zone setbacks exceeding state law
Rolling easements
Managed retreat

CHAPTER 3: METHODOLOGY

To analyze and evaluate the gap between theory and practice in coastal resilience using the research questions presented in the previous chapter, I utilized a two-pronged approach: selection of coastal management plans followed by an evaluation of those plans to determine how theory is or is not applied. The overall methods outlined below are based primarily on Berke and Conroy (2000) and Berke et al. (2012).

3.1 Plan search and selection

I searched for municipal plans using on-line search engines with the terms “coastal management plan pdf”, “beach management plan pdf”, and “coastal resilience plan pdf”. This initial group of plans was bolstered by input from a panel of experts (Saha and Paterson, 2008) who identified plans that exemplified principles of resilience. I identified additional plans from websites of policy groups, research groups, and state and local agencies that similarly highlighted excellent examples of planning for coastal resilience and/or planning for climate change. My goal was an exhaustive search, the results of which are show in Tables 3 and 4 below.

Due to the recent spike in popularity of coastal resilience (highlighted in section 2.6 above), the plans with coastal resilience all were released after hurricane Sandy (landfalls in October, 2012). This is not coincidental as Sandy prompted the funding for many of these plans. As a result, seven of the ten plans with resilience concepts are from states impacted by Sandy and all were released from 2013 - present. I made every attempt to select plans without resilience concepts from the same time period, in an effort to make the comparison equal, but I included some older coastal management plans. Other factors are geographic unit, population, geomorphic position, and location.

In order to minimize selection bias, I analyzed the content of all the plans in Tables 3 and 4, rather than a subset of plans. While the number of plans is somewhat limited, their content is not: the plans with resilience total 1,353 pages and plans without resilience total 1,796 for a total of 3,149 pages for analysis. There is relative equality with regard to geographic unit of the groups of plans. The plans with resilience include one state plan, six city plans, and one county plan versus the plans without resilience include no state plans, seven city plans, and three county plans. The geographic diversity of plans with resilience is skewed to the north and exists because of post-Sandy funding made available to create coastal resilience plans in states impacted by Sandy. This cannot be controlled for, but three of the ten with resilience plans (New Orleans, Clatsop County, OR, and Hampton Road, VA) come from areas not significantly impacted by, or receiving funding as a result of, Sandy.

Overall population size of municipalities is difficult to calculate given several of the multijurisdictional or sub-jurisdictional boundaries (East Boston and Charlestown, Hampton Roads, Sylvia State Beach, Ocean Beach). The average population of plans with resilience is considerably higher due to the inclusion of

New York City and New Jersey. The evaluation methods detailed below are designed for discrete data and to overcome these obstacles.

Table 3. Coastal resilience plans for analysis and evaluation. Population estimates from Census Bureau.

WITH Resilience					
Name	Plan Year	State	Unit	Population	Funding
A Stronger, More Resilient New York	2013	NY	city	high	
Branford	2016	CT	town	28,026 (2010)	HUD
West Haven	2017	CT	town	55,564 (2010)	HUD
Guilford	2013	CT	town	22,375 (2010)	NOAA
Hampton Roads	2013	VA	region	1.7 M (2010)	NOAA
Madison	2016	CT	town	18,269 (2010)	HUD
East Boston and Charlestown	2017	MA	neighborhood	40,000 (2010)	Foundation
New Jersey	2016	NJ	state	high	NOAA
Clatsop County	2015	OR	county	37,039 (2010)	NOAA
New Orleans	2015	LA	city	391,495 (2016)	

Table 4. Coastal management plans for analysis and evaluation. Population estimates from Census Bureau.

WITHOUT Resilience				
Name	Plan Year	State	Unit	Population
Broward County	2015	FL	county	1.9 M (2015)
Duxbury	2016	MA	town	15,059 (2010)
Folly	2015	SC	town	2,782 (2016)
Horry County	2013	SC	county	309,199 (2015)
Longboat Key	2008	FL	town	7,326 (2016)
Marshfield	2017	MA	town	25,807 (2016)
Plum Island	2009	MA	town	17,987 (2016)
Sylvia State Beach	2008	MA	State Park	N/A
Tybee Island	2014	GA	town	3,113 (2016)
Virginia Beach	2002	VA	city	452,602 (2016)
Pinellas County	2012	FL	county	949,827 (2015)
Ocean Beach	2015	CA	neighborhood	11,000 - 27,000

3.2 Plan evaluation

The evaluation scheme here assigns scores to plans based on presence or absence of theory-based techniques of coastal resilience from Table 2 in section 2.3 above. Techniques fall under seven principles of coastal resilience listed in the same section. The techniques identified by the literature in Table 2 are the standard by which to compare and score all the plans in Tables 3 and 4 above. I reviewed each planning document and scored proposed actions based on presence or absence in the plan. I awarded one point if a technique was present in a plan and no points if a technique was absent. The only exception to this was case studies, side-bars, or sections of plans showing success in other towns. Town A was not awarded a point for discussing techniques used by Town B. Town A was only awarded points for techniques discussed in reference to Town A. Based on the 27 techniques listed in table 2, the maximum possible score for any plan was 27 and the minimum score zero.

The binary scoring system used here is also used by Berke et al. (2012) to evaluate state hazard mitigation plans. Benefits of binary plan scores based on presence or absence include its simplicity and the lack of subjectivity thereby eliminating guessing or use of judgment by plan coders (Berke et al., 2012). The process of scoring plans and evaluation techniques are an important area of research in their own right, particularly because they heavily influence results. For a more complete discussion of plan scoring techniques and additional studies using binary scoring systems, see Berke and Godschalk (2009).

Berke and Conroy (2000) evaluated plans based on level of intent of techniques listed in the plans. As opposed to this approach, I used a binary scoring system for three reasons. One, the plans listed here are fundamentally broader than the narrowly selected and defined planning documents for sustainability analyzed by Berke and Conroy (2000). Two, unlike Berke and Conroy (2000) who were accompanied by a team, I was unable to perform a double blind review of each plan, as I am working alone. Lastly and most importantly, the nascent nature of the coastal resilience movement has made some communities more reticent to firmly commit to action. The majority of the plans with resilience used language typical of brainstorming sessions with words *could, suggest,* and *possibly*. Additionally, the concept of sustainability is probably less debated compared to coastal resilience. Some of the higher scoring plans with resilience discussed managed retreat, a highly controversial issue that will require abandonment or relocation of homes and businesses. Limitations of binary scoring techniques include a reduced amount of information contained with the data (Berke et al., 2012) and reduced number of options for statistical analysis.

This evaluation resulted in tables similar to Table 1 and Table 2 in Berke and Conroy (2000). I compared results from the two groups of plans using a Mann-Whitney U test (the non-parametric equivalent of a t-test) with the null hypothesis that the two groups come from the same population. While it is common practice to perform a t-test or similar test on groups of 30 or more, it was not possible in this case. There simply weren't enough plans: coastal resilience plans are relatively new, emerging only since 2013. Raising the number of plans evaluated would require evaluating plans of a broader scope. The plans without resilience evaluated here are specific to the beach or coast in each municipality and analysis of a larger geographic area would not be appropriate. Similarly, analysis of older plans is not a preferable option.

CHAPTER 4: RESULTS AND ANALYSIS

4.1 Results

The scores of all 22 plans ranged from 2 – 13 points (out of a maximum of 27 points) and are shown in Table 5 below. The plans with resilience ranged from 4 -13 and the plans without resilience ranged from 2 - 13. The cumulative scores for each plan are shown in Table 6 and 7 below. The highest scoring plan that was not created specifically with coastal resilience in mind was from Horry County, SC. That plan includes a diverse range of management techniques including property management, infrastructure, and governance. The property management methods were diverse and the plan included long-term retreat planning. The three highest scoring resilience plans all came from Connecticut and were a collaborative effort between each local government and the Connecticut-based consulting firm of Milon and MacBroom. The Branford, Madison, and West Haven plans all scored more than half of their 13 points in the areas of infrastructure including hard and soft coastal defenses, lifting roads and infrastructure, and preservation of natural coastal defenses.

Cumulative scores from neither individual group of plans nor all 22 plans together had a normal distribution violating one of the assumptions of a t-test. Regardless, I performed a t-test the results of which indicated a statistically significant difference between the two groups of plans ($p \leq 0.05$). Additionally, I performed a Mann-Whitney U test, also known as a Wilcoxon rank-sum test or Mann-Whitney-Wilcoxon test, as outlined by Mann and Whitney (1947). This test ranks all scores, sums them, and compares the smaller sum to a probability distribution of randomized rank sums (Quinn and Keough, 2002, p. 47). The results of this test confirm that the sample plans were selected from populations with different means and/or medians ($p \leq 0.05$). The Mann-Whitney U test is a less powerful test than a t-test, but only by 5%, at most (Quinn and Keough, 2002, p. 48). The U statistic of 23 is less than the critical value of 29 for sample sizes of 10 and 12. The rank sum tables can be found in the appendix.

Table 5. Plan scores and summary statistics from evaluation of presence/absence of elements of coastal resilience.

WITHOUT Resilience	
	Score
Broward County, FL	6
Duxbury, MA	2
Folly Beach, SC	10
Horry County, SC	13
Longboat Key, FL	2
Marshfield, MA	6
Ocean Beach, CA	3
Pinellas County, FL	2
Plum Island, MA	4
Sylvia State Beach, MA	3
Tybee Island, GA	4
Virginia Beach, VA	3
sum	58
n	12
mean	4.83
standard deviation	3.46

WITH Resilience	
	Score
Branford, CT	13
Clatsop County, OR	4
E. Boston and Charlestown, MA	6
Guilford, CT	11
Hampton Roads, VA	5
Madison, CT	13
New Jersey, NJ	4
New Orleans, LA	7
New York, NY	10
West Haven, CT	13
sum	86
n	10
mean	8.6
standard deviation	3.81

Table 6. Cumulative plan scores for beach management plans without the integration of principles of coastal resilience.

Without Resilience Plans	Broward County, FL	Duxbury, MA	Folly, SC	Horry County, SC	Longboat Key, FL	Marshfield, MA
Property Management						
Relocation/Protection of critical infrastructure (emergency services, water, etc.)	1			1		
Relocation/Protection of municipal assets to higher elevation				1		1
Private transfer of development rights						
Guided development discouraging rebuilding	1		1	1		
Elevate homes/businesses			1	1		
Infrastructure						
Hard coastal defenses	1		1	1	1	1
Soft coastal defenses	1	1	1	1	1	1
Elevated roadways						
Elevated infrastructure				1		
Stormwater backflow prevention devices						
Elimination of utilities/services/roads in routinely flooded areas						
Floodgates						1
Preservation of natural defenses	1	1	1	1		
Financial structures						
Buyouts of flood-prone properties			1	1		
Incentives to elevate structures			1			
Phase-outs of flood insurance						
Social Structures						
Non-profit support networks (faith-based orgs, Red Cross, etc.)						
Financial support services						
Access to healthcare including psychological services						
Governance						
Comprehensive plan			1	1		1
Emergency plan				1		
Prolonged disaster plan				1		
Climate-change plan						
Hazard mitigation plan			1			
Coastal zone setbacks exceeding state law						
Rolling easements						
Managed retreat	1		1	1		1
Plan Total	6	2	10	13	2	6

Table 6 (continued). Cumulative plan scores for beach management plans without the integration of principles of coastal resilience.

Without Resilience Plans	Plum Island, MA	Sylvia State Beach, MA	Tybee Island. GA	Virginia Beach, VA	Pinellas County, FL	Ocean Beach, CA
Property Management						
Relocation/Protection of critical infrastructure (emergency services, water, etc.)						
Relocation/Protection of municipal assets to higher elevation						
Private transfer of development rights	1					
Guided development discouraging rebuilding	1		1			
Elevate homes/businesses						
Infrastructure						
Hard coastal defenses				1	1	1
Soft coastal defenses	1	1	1	1	1	1
Elevated roadways						
Elevated infrastructure						
Stormwater backflow prevention devices			1			
Elimination of utilities/services/roads in routinely flooded areas						
Floodgates						
Preservation of natural defenses		1		1		
Financial structures						
Buyouts of flood-prone properties	1					
Incentives to elevate structures						
Phase-outs of flood insurance						
Social Structures						
Non-profit support networks (faith-based orgs, Red Cross, etc.)						
Financial support services						
Access to healthcare including psychological services						
Governance						
Comprehensive plan			1			
Emergency plan		1				
Prolonged disaster plan						
Climate-change plan						1
Hazard mitigation plan						
Coastal zone setbacks exceeding state law						
Rolling easements						
Managed retreat						
Plan Total	4	3	4	3	2	3

Table 7. Cumulative scores for coastal resilience plans.

With Resilience Plans	New York City	Branford, CT	West Haven, CT	Guilford, CT	Hampton Roads, VA
Property Management					
Relocation/Protection of critical infrastructure (emergency services, water, etc.)	1	1	1	1	1
Relocation/Protection of municipal assets to higher elevation	1				
Private transfer of development rights					
Guided development discouraging rebuilding				1	1
Elevate homes/businesses		1	1	1	
Infrastructure					
Hard coastal defenses	1	1	1	1	1
Soft coastal defenses	1	1	1	1	1
Elevated roadways		1	1	1	
Elevated infrastructure		1	1		
Stormwater backflow prevention devices		1	1		
Elimination of utilities/services/roads in routinely flooded areas		1	1		
Floodgates	1	1			
Preservation of natural defenses	1		1	1	
Financial structures					
Buyouts of flood-prone properties	1	1	1	1	
Incentives to elevate structures		1	1		
Phase-outs of flood insurance					
Social Structures					
Non-profit support networks (faith-based orgs, Red Cross, etc.)					
Financial support services	1				
Access to healthcare including psychological services	1				
Governance					
Comprehensive plan	1				
Emergency plan					
Prolonged disaster plan					
Climate-change plan					1
Hazard mitigation plan				1	
Coastal zone setbacks exceeding state law					
Rolling easements		1	1	1	
Managed retreat		1	1	1	
Plan Total	10	13	13	11	5

Table 7(continued). Cumulative scores for coastal resilience plans.

With Resilience Plans	Madison, CT	East Boston and Charlestown, MA	New Jersey	Clatsop County, OR	New Orleans
Property Management					
Relocation/Protection of critical infrastructure (emergency services, water, etc.)	1			1	
Relocation/Protection of municipal assets to higher elevation	1	1			
Private transfer of development rights			1		
Guided development discouraging rebuilding				1	
Elevate homes/businesses	1				1
Infrastructure					
Hard coastal defenses	1	1		1	1
Soft coastal defenses	1				1
Elevated roadways	1	1			
Elevated infrastructure	1				
Stormwater backflow prevention devices	1				1
Elimination of utilities/services/roads in routinely flooded areas					
Floodgates	1	1			
Preservation of natural defenses	1	1	1		1
Financial structures					
Buyouts of flood-prone properties	1		1		
Incentives to elevate structures					
Phase-outs of flood insurance					
Social Structures					
Non-profit support networks (faith-based orgs, Red Cross, etc.)					
Financial support services					1
Access to healthcare including psychological services					
Governance					
Comprehensive plan					
Emergency plan					
Prolonged disaster plan				1	
Climate-change plan		1	1		1
Hazard mitigation plan					
Coastal zone setbacks exceeding state law					
Rolling easements	1				
Managed retreat	1				
Plan Total	13	6	4	4	7

4.2 Analysis

The distribution of high scoring plans is skewed toward plans with resilience. The plans from Branford, Madison, West Haven, and Guilford, CT along with New York City rounded out the top half of the highest scoring resilience plans. These plans scored the most points in the area of infrastructure all scoring points for discussing hard coastal protection measures and beach nourishment. Four of the five plans also mentioned preservation of natural coastal defenses, and elevated roadways. The other major management technique through which these plans promulgated resilience was through property management by mentioning relocation of critical infrastructure and elevations of homes and businesses. These resilience plans scored points in ways similar to the highest scoring plans without resilience in name; the Folly Beach and Horry County plans, both from South Carolina. Horry County and Folly Beach scored points for their discussion of beach nourishment, hard coastal defenses, and preservation of natural defenses, but were less dependent on infrastructure for most of their points. The SC approach is more balanced also scoring points in the areas of governance and property management. The SC plans discussed strategic retreat, elevation of homes and businesses, and discouraging rebuilding in flood-prone areas. The SC plans also did the best job of any plans through integration of other planning documents (governance technique) such as comprehensive plans, disaster plans, prolonged disaster plans, and hazard mitigation plans. The points awarded to the SC plans were distributed more evenly amongst the categories of management techniques.

In general, low scoring plans were narrowly focused on specific management techniques, did not make concerted efforts to integrate resilience principles, or were devoid of resilience theory (e.g. only used resilience in the title). The lowest scoring plans of all were Duxbury, MA, Longboat Key, FL, and Pinellas County, FL each only scoring two points. Duxbury, MA is a unique situation where a non-profit entity manages the beach in conjunction with the town of Duxbury. Absent in both plans was mention of retreat or long-term adaptation strategies. The plan with the narrowest focus was Ocean Beach, CA developed to prevent erosion of a short section of beach containing a combined sewer and stormwater waste tunnel exposed to high tide events. The only viable option for this stretch of beach discussed was hard defenses (a sea wall) paired with nourishment. Retreat or relocation of the facility was not considered and the plan picked up a third point by discussing future climate change.

Management techniques varied by plan. Table 8 below shows the distribution of points allocated to each municipality according to the management technique. The means are fairly different for all categories and particularly when considering the low ranges of the values. To test for significant differences between the groups of values in each category of management technique, I performed a Mann-Whitney U test on each of the five sets of data. In each of the five cases, the null hypothesis that the groups of numbers came from populations with identical distributions was accepted. The two sets of numbers are not significantly different. To be clear, the cumulative plans scores of the with resilience and without resilience plans came from populations with different means or medians, but the individual components of those cumulative results came from populations with identical distributions. The statistical significance exists and does not exist at the $p < 0.05$ level for the cumulative totals and individual components, respectively. It appears as though the results are at the boundary of statistical significance and may be influenced by the large number of ties in the rank orders (Quinn and Keough, 2002, p. 47).

Table 8. Plan results by management technique category.

Without resilience	Property Management	Infrastructure	Financial structures	Social Structures	Governance	Total
Broward County, FL	2	3	0	0	1	6
Duxbury, MA	0	2	0	0	0	2
Folly, SC	2	3	2	0	3	10
Horry County, SC	4	4	1	0	4	13
Longboat Key, FL	0	2	0	0	0	2
Marshfield, MA	1	3	0	0	2	6
Plum Island, MA	2	1	1	0	0	4
Sylvia State Beach, MA	0	2	0	0	1	3
Tybee Island. GA	1	2	0	0	1	4
Virginia Beach, VA	0	3	0	0	0	3
Pinellas County, FL	0	2	0	0	0	2
Ocean Beach, CA	0	2	0	0	1	3
Sum	**12**	**29**	**4**	**0**	**13**	**58**
Mean	**1.0**	**2.4**	**0.3**	**0.0**	**1.1**	**4.8**
With resilience	**Property Management**	**Infrastructure**	**Financial structures**	**Social Structures**	**Governance**	**Total**
New York City	2	4	1	2	1	10
Branford, CT	2	7	2	0	2	13
West Haven, CT	2	7	2	0	2	13
Guilford, CT	3	4	1	0	3	11
Hampton Roads, VA	2	2	0	0	1	5
Madison, CT	3	7	1	0	2	13
East Boston and Charlestown, MA	1	4	0	0	1	6
New Jersey	1	1	1	0	1	4
Clatsop County, OR	2	1	0	0	1	4
New Orleans	1	4	0	1	1	7
Sum	**19**	**41**	**8**	**3**	**15**	**86**
Mean	**1.90**	**4.10**	**0.80**	**0.30**	**1.50**	**8.60**

CHAPTER 5: DISCUSSION AND RECOMMENDATIONS

5.1 Discussion

The results support the notion that municipalities are incorporating some theory-based principles of resilience into planning documents, regardless of intent by the municipality to incorporate those principles. The results of the Mann-Whitney U test confirm that coastal management plans scored significantly higher than beach management plans. Resilience plans use a wider variety of techniques but what other factors may have impacted impact plan scores? To tackle this, I will discuss four groups of plans: low and high scoring plans in the with resilience group and low and high scoring plans in the without resilience group.

The without resilience plans from Duxbury, MA, Longboat Key, FL and Pinellas County, FL were the lowest scoring plans; all scoring a two. Coastal development levels in Florida are very high overall, but particularly so in Pinellas County and Longboat Key. Progressive options such as retreat are less preferred in these areas because there is little available land for retreat or purchase and available land is expensive. The large federal subsidy of nourishment costs (65%) also provides a perverse incentive for such communities to remain in place. Duxbury is a very small, privately managed beach. Much of the focus of this plan is compliance with endangered species regulation at the federal and state levels and attempting to ensure beach stability allowing beach access for local homeowners via driving on the beach. All three locations have used beach nourishment, dunes, and seawalls as the primary protection mechanisms and the only options mentioned in the plans were hard shoreline protection measures, nourishment, and protection of existing dunes. In fact, these municipalities have been managing their beaches using the techniques that scored points prior to the emergence or resilience as a beach management concept. These plans represent a status quo, more-of-the-same, and non-reflective attitude.

The lowest scoring plans in the with resilience group were the state plan for New Jersey (4 points), Clatsop County, OR (4 points), and Hampton Roads, VA (5 points). The audience for the New Jersey plan is NJ cities and towns seeking to improve coastal resilience. Much of the document is written at the process level such as encouraging communities to define resilience and seek collaboration with other neighboring communities to build resilience. This approach is less pragmatic at the sub-state level and did not score as highly as a result, despite inclusion of a few fairly progressive approaches. The focus of the Hampton Roads, VA plan was to communicate the importance of and methods for planning for sea-level rise in the area. It is a list of *shoulds* for municipalities and includes best practices for floodplain mapping, a component of planning for resilience, rather than a specific focus on resilience. Lastly, the Clatsop County, OR plan was designed for local communities to use to evaluate their level of resilience using a scoring system and suggestions for increasing resilience. In all three plans, the audience was smaller municipalities and the plans were written at a multi-jurisdictional level omitting the level of specificity seen in the high-scoring Connecticut plans. It is tempting to think that these plans do not belong with city or town specific plans, but the New Jersey, Clatsop County, and Hampton Roads plans all met the a priori criteria for inclusion in the study.

The highest scoring plans in the with resilience group were the Connecticut plans from the towns of Branford, Madison, and West Haven each scoring 13 points. These plans were all the result of a collaborative effort between each local government and the Connecticut-based consulting firm of Milon and MacBroom. The format was similar for each and the resulting executive summaries featured specific actions each town can take, timelines, and funding options. The similarities for the plans can be explained by their common provenance, similar vulnerability and similar geomorphic position. These plans also represent the most diverse array of options of any plans examined: the scored points in every category of management activities except for social structures. The collective impact of the Connecticut plans on the results of this study is profound: if any two of them are removed, the statistical significance disappears.

The highest scoring plans without resilience were from Folly Beach (10 points) and Horry County, SC (13 points). The plans were diverse in management technique and scored well due to numerous state regulations that incorporated resilience including a 40-year strategic retreat plan. A primary motivator in the diversity of options in SC is due to state regulations prohibiting hard shoreline protection measures (Horry County, 2013, p. 42). Another factor: rates of sea-level rise are higher on the SC coast than those to the north (NC) and south (FL) (NOAA Sea Level Trends, 2018).

The plans differ widely in the technique implementation shown in Table 8. Infrastructure was easily the most popular option and has been the heavily favored category historically. Most beaches with erosion problems nourish beaches and build dunes to slow erosion and encroachment on buildings and roads. Leaning heavily on infrastructure, however, does not represent new thinking or creative problem solving. It is what most municipalities are doing now, so this simply is a continuation of the status quo. Florida has nourished their beaches nearly 500 times at a nominal cost of $1.5 B (Program for the Study of Developed Shorelines, 2018) and it will continue on.

Property management and governance techniques were second and third in points accrued and represent more creative problem solving. Purchase of flood-prone property admits that nature cannot be tamed and runs counter to the command and control pathology of management (Holling and Meffe, 1996) and this sentiment is not popular in many local governments. Threats to infrastructure are also rather acute in some areas compared to others. The record storm surge from Sandy is in recent memory for many in the northeast and a motivating factor in the New York City plan, while other areas have been spared a hurricane hit for more than a century (most notably Savannah, GA) leading to complacency. The director of FEMA recently called the Georgia coast a “ticking time bomb” with regard to hurricanes and continued, “I don’t think they realize the Georgia coast got hit 14 times from 1850 to 1900” (Landers, 2018).

A key problem for changing hurricane preparedness and recovery is politics: key decision makers are elected officials. Few mayors promote strategic coastal retreat because it is wildly unpopular with their constituents and this probably influenced the options put forth in the plans examined in this study. Unless the town can annex land, coastal retreat reduces the tax base. Coastal retreat can save lives and loss of property, but at the cost of votes. One benefit of buyouts of flood prone properties, a slow-motion version of retreat, is that residents forced from their homes typically cannot gain significant traction to oppose election of vocal officials. Planners, however, are not elected officials and can serve as an intermediary between the elected officials and the public.

Another important finding is the lack of social resilience in the planning documents. Many plans failed to define the term coastal resilience and when the term was defined, there was no link to the human side of resilience. But the literature review here highlights the importance of an holistic definition of coastal resilience including social aspects, such as the socio-economic resilience described by Klein et al. (1998). It is doubtful that any mayor or city council member would not say that the citizens are the most important component of a coastal community, yet only New Orleans and New York included social components in their coastal resilience plans. These are the two largest cities in the study, which may account for the inclusion of financial support services in their resilience plans, but both cities were also recently impacted by two of the five costliest hurricanes in US history. The inclusion of social components may be a desire to minimize long-term economic impacts in these cities or a reflection of the holistic ideal for which all the plans examined fall short.

Lastly and perhaps most significantly, cohesive and holistic planning (the sixth principle of effective coastal resilience planning identified in the literature review) serve as a metaphor for the results of this study. An ideal coastal resilience plan would weave together disaster plans, hazard mitigation plans, emergency plans, and comprehensive plans the total impact of which would be greater than the sum of its parts. The results of the Mann-Whitney U test parallel this holistic ideal: none of the differences in the five categories of management technique were significant when examined individually, but the collective differences between coastal resilience plans and beach management plans are significant. The category with the greatest difference in means was infrastructure (2.4 points without resilience versus 4.1 points with resilience) followed by property management and financial structures (see Table 8 above), but none of these differences are significant.

These seemingly insignificant differences are the most striking finding of this research: small actions that municipalities take may not appear to be important, but do matter when considered holistically. As Beatley (2012) notes, our efforts need to be holistic because coastal disasters impact every aspect of our lives. While none of the plans exhibited this characteristic individually, some plans clearly had input from multiple departments in the same municipality. The plans from New York and Connecticut are excellent examples.

One limitation of this work is the relatively low number of plans that fit the criteria of coastal resilience plans. I have made every effort to cut plans that did not meet my *a priori* criteria for inclusion, but an additional 10 plans on either side might open a new host of statistical options. Another limitation of this study is that it may be subject to the modifiable areal unit problem: a larger municipality should have more diversity in geomorphology and urban development necessitating a more diverse array of management techniques. This would lead to a higher plan score. I made no effort to control this

5.2 Recommendations

Based on my extensive literature review and research, I have four recommendations for planners detailed below the list. Simply put, for coastal towns to continue to exist in their current locations, a paradigm shift must occur in thinking about how to combat sea-level rise. Incorporating principles of coastal resilience will likely play a pivotal role, but can be leveraged more effectively if the brand of coastal resilience practiced aligns with the theory.

1. Develop a diverse and holistic plan.
2. Plan to protect places *and* people.
3. Use this literature review for ideas for your municipality.
4. Planners and academics need to talk!

Develop a diverse and holistic plan. Most of the plans in this study did not make apparent consideration of the multifaceted aspects of coastal resilience. Most of the plans relied heavily on infrastructure and property management tools for coastal management instead of incorporating aspects of social structures, financial structures, and governance. The literature review highlights the importance of holistic planning and the benefits: more diverse solutions stand a greater chance of overcoming a diverse array of obstacles. A narrowly focused plan is less adaptable to change and unknown variables, in this case, sea-level rise, ever-changing subsidized federal insurance, disaster declarations, seasonal storms, unsecured funding for beach nourishment, and more.

Plan to protect places *and* people. The literature review here conveys a high degree of agreement within academics that coastal resilience is a broad concept including physical locations, buildings, and the people that live in and visit those places. Protecting people and their mental, physical, and economic wellbeing (social capital) should be prioritized as least as highly as protecting buildings and high-value assets. Norris et al. (2008) represent the human side of resilience that is sorely lacking in the plans analyzed: only New York and New Orleans incorporated any social support for people in their resilience planning. Perhaps it is because they are major cities, or perhaps it is because they were both ground zero for Katrina and Sandy, but coastal communities can do much more to support their residents as humans rather than focus on property. This includes access to psychological services, cash reserves for economic hardship, and tighter working relationships between low-income services provided by municipalities and non-profits organizations with overlapping goals. If coastal municipalities are considering social structures and social capital as key components of disaster recovery, those ideas and support mechanisms need to be included in the coastal resilience planning documents. If municipalities do not currently have plans for post-disaster recovery of social capital, the literature review may serve as a primer on the importance of the issue.

The literature review here is logically organized into three sections: the science of coastal resilience, the practice of coastal resilience, and theoretical coastal resilience manifested in the ideal coastal resilience plan. This literature review here accompanied with high scoring plans and the techniques listed in Table 2 together serve as a first step toward development of or improvement to coastal resilience plans. Planners are in a unique position and can positively impact the future of the coastal communities they serve.

Lastly, planners and academics need to talk. Based on my literature review of coastal resilience, some 27 management techniques were found to promote principles of resilience, but my analysis shows no single plan including more than half of these options demonstrating the gap is real. Management options are clearly laid out in the literature, but the integration of management techniques is not happening. To wit, the lead at Milone and MacBroom on the highest scoring resilience plans from Connecticut had not heard of Beatley or his book *Planning for Coastal Resilience* (D. Murphy, personal communication, 6

AUG 2018). While the process the firm used to delineate coastal resilience incorporated multiple components of public outreach and consultation with an academic (Alex Felson of Yale), much more can be done. Planners can use the literature review here as a tool to find academics with whom their ideas align and reach out to them. Similarly, academics can reach out to planners and consulting firms for informational presentations and exchange of ideas.

Even the best plans noted here omitted 14 management techniques identified by the literature. Assuming that more diverse plans are better able to respond to an unknown future disaster, this leaves much room for improvement in depth and scope of plans. Beatley (2012) remains the best single resource for building coastal resilience, but there are many more. Lloyd et al. (2013) recommends paying attention to geomorphological processes in coastal planning and Kim et al. (2017) highlight sustainable land use as integral to building coastal resilience.

CHAPTER 6: CONCLUSIONS

This study yields two major findings. The statistically significant difference in rates of inclusion of coastal resilience management techniques is evidence that planners are integrating coastal resilience concepts into their plans. Coastal resilience plans have integrated resilience concepts. However, the lack of variety in techniques used relying heavily on infrastructure and devoid of integration with other planning documents is troubling and indicates much more can be done.

My first objective of reviewing literature for a research gap in the domain of coastal resilience has been achieved in the literature review in Chapter 2 of this dissertation. I have made suggestions for closing this gap in the previous section through various means, the primary of which is increased communications between academics and planners. For coastal communities to be prepared for calamity, they must work together with a wide variety of stakeholders for the good of all.

My second objective to analyze coastal resilience plans and coastal or beach management plans for inclusion of theory-based coastal resilience techniques determined there is a statistically significant difference between the two types of plans. I have answered questions pertaining to the ramifications of these findings in the analysis section.

My final research objective was to examine why the results are observed and make recommendations on what can be done moving forward. My analysis discusses why the results were observed and my recommendations section represents my humble offerings to coastal planners.

Many questions remain, however. Future research might examine how municipalities decide which suggested activities to execute and how they prioritize options. Simply because an option exists in the coastal resilience or beach management plan does not mean that option becomes a reality. Another study could examine where these same municipalities are in 10 years regarding the implementation of their plans. Lastly, it should be noted that the management techniques identified by this research are the *what to do,* but the *how to do them* is important. As an example, David Blatt with Connecticut Department of Energy and Environmental Protection reports that the town of Guilford, CT, “which was a pioneer of adaptation planning, committed a major violation filling tidal wetlands in the course of a project to elevate a flooded road” (personal communication, 1 MAY 2018). Let us hope that the execution of coastal resilience planning is cohesive and holistic, as the literature implied it should be.

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APPENDIX: RANK SUM TABLES

Rank sum tables for the Mann-Whitney U Test.

Table 1. Cumulative plans scores in rank order

Group 1: with resilience	Group 2: without resilience
4	2
4	2
5	2
6	3
7	3
10	3
11	4
13	4
13	6
13	6
	10
	13

Table 2. All plan score data in rank order. Ties are given the average of their rank (Quinn and Keough, 2002, p. 47). The U statistic is compared to the critical U value obtained from standardized tables that originally appeared in Mann and Whitney (1947) and were later updated by Milton (1964).

Group #	**All data**	**Rank**	Rank sum group 1	55
2	2	2	Rank sum group 2	198
2	2	2		
2	2	2	Mean sum group 1	5.5
1	3	5	Mean sum group 2	16.5
2	3	5		
2	3	5		
2	4	8.5	u_stat	23
1	4	8.5	u_critical	29
2	4	8.5		
2	4	8.5		
1	5	11		
1	6	13		
2	6	13		
2	6	13		
1	7	15		
1	10	16.5		
2	10	16.5		
1	11	18		
1	13	20.5		
1	13	20.5		
1	13	20.5		
2	13	20.5		