Effects of Changing Distributions on Fisheries in the Big Bend Region

University of Florida
Sea Level Rise and Coastal Ecology: Science, Policy, and Practice
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"It is not the strongest of the species that survives, nor the most intelligent. It is the one that is most adaptable to change." - Charles Darwin

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Executive Summary

The Big Bend Region along the Gulf coast of Florida is characterized by its pristine estuaries which provide habitat and resources for a wide variety of marine and terrestrial species. Locally, freshwater flow from the Suwannee River into the Gulf of Mexico creates estuaries with brackish water and high nutrient levels. Tidal flow in out these estuaries acts as nature's clock, regulating the feeding habits and movements of many species. These estuaries are very productive and support complex food webs reliant of a variety of habitats including seagrass beds, oyster reefs, salt marshes, and mangroves. Currently however, these habitats and the species which rely on them are shifting distributions at various rates in response to climate change.

Specifically, increasing global temperatures associated with climate change will likely continue to cause species distributions in these estuaries to change. Warming air and sea surface temperatures may cause distributions to shift by relieving physiological threshold barriers to species movement, altering behavior, and affecting phenology. Species are expected to respond differently to climate change, thus outcomes vary. However, the expected general trend is that increasing temperatures will lead to a poleward expansion of species distributions. This may lead to a tropicalization of estuaries in the Big Bend Region and novel species interactions which may ultimately create a new ecological community. This has the potential to cause both positive and negative effects on local commercial and recreational fisheries.

Increasing global temperatures have allowed mangrove distributions to expand. Mangroves provide important habitat for tropical birds, act as nursery habitat for juvenile fish, and serve as habitat for adult fish as well. As mangroves increase in abundance, so do other tropical species associated with them such as the Common Snook (*Centropomus undecimalis*). Cedar Key has seen an exponential increase in the local density of Common Snook since 2007 (*See graph below)*. Like mangroves, Snook are intolerant of freezing temperatures. An extreme cold event in 2010 led to mass die offs of Snook all along Florida's Coast. With regulation, these populations were able to recover within one to four years. Based on these trends it is likely the Common Snook, as well as other tropical species, will increase in local abundance until a capacity that resources can support is met. Freeze events may control expanding species distributions to an extent. However, over time these species will continue to move poleward.

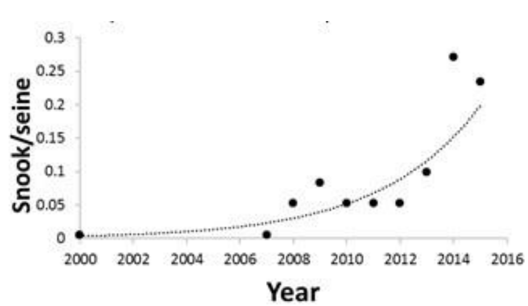


Figure 2. Data from monthly Florida Fish and Wildlife Research Institute Fisheries Independent Monitoring 183-m seines (n= 192 each year) indicate Snook density has increased exponentially since 2000 in Cedar Key, FL. [1]

It is likely that an increase in economically valuable fish species, such as the Common Snook, will lead to an increase nature-based tourism within the Big Bend Region. However, novel species interactions in combination with fishing pressure, may alter trophic dynamics and community structure. Increasing Snook abundance could decrease small baitfish and shrimp abundance through predator-prey interactions. Additionally, competition between Snook and subtropical fish species could alter the relative abundance of recreational sport fish such as Red Drum (*Sciaenops ocellatus*) and Spotted Seatrout (*Cynoscion nebulosus*). In addition, local fishing pressure across all recreationally valuable gamefish may increase in response to Snook population growth. Unknowns regarding non-native species introductions and the degree of climate variability make future outcome projections difficult to predict.

The relationship between human systems and the ecosystem is bidirectional.[2] Human well-being depends in many ways upon the goods and services provided by ecosystems and those supplies are in turn affected by human behavior.[3] The changing distributions of species will affect the ecosystems in which those species inhabit or formerly inhabited. It becomes clear that the impact of changing distributions on ecosystems will have negative and positive impact potentials for human health and economic activities.[4] Understanding the interactions and connections between human and ecological systems must be understood to facilitate effective ecosystem management.[5] A failure to facilitate effective ecosystem management can result in discontent, a breach of trust in the decision-makers, conflict, noncompliance like "shoot, shovel, and shutup," and/or generate expensive litigation. All of which slow down and hinder the decision-making process of agencies themselves.[6]

However, including the human dimension in ecosystem management is not without its challenges and opportunities. This is in part because management decisions must contemplate the future and "the future as it relates to the human dimension is, perhaps, less 'knowable' than that of the natural sciences."[7] Both "the natural environment and human societies are characterized by uncertainties, complex dynamics, natural variations and scale dependencies."[8] Furthermore, ecosystems themselves do not follow man-made jurisdictional boundaries and despite our efforts ecosystems can rarely be divided into separate working components.[9] Yet identifying and including the human dimensions in the decision-making process of ecosystem management aids in identifying potential actions, objectives, and trade-offs of policy outcomes.[10]

Taking into consideration expected outcomes and human impacts, it is imperative to begin to develop policy that will allow both the ecosystem and humans reliant on them to thrive. Future policies need to remain flexible as there are many unknowns regarding how the ecosystem will adapt to a new top predator, novel species interactions, and warmer temperatures. Policies will also need to be based on up-to-date science; several policy options rely on what the science says to determine whether the policy needs to change. Considering the important role that species interactions play in altering community structure and abundance, it is also important that ecosystem based fisheries management strategies are adopted. In conclusion, stakeholder involvement is crucial as these are the individuals the policy will affect most. Below is a list of recommended policies that will be discussed further:

- Harsher penalties and more enforcement of laws regarding importation, possession, and release of invasive species
- Adjusting the bag limits, slot sizes, and harvest seasons of popular gamefish such as the Common Snook, Red Drum, and Spotted Seatrout
- Implementing an ecosystem based fishery management plan that better represents community and population dynamics for managed species in a vulnerable ecosystem such as the Big Bend
- Developing spatial management or trophy zones in the Big Bend Region where Common Snook may be caught, but not harvested

Introduction and Background

Increased concentrations of greenhouse gases, changing temperature regimes, decreasing amounts of snow and polar ice, and sea level rise are all indicators of our changing (Stocker et al. 2013). These all have important impact on ecosystems and are resulting in changes in ecosystem function. These factors can lead to losses of biodiversity, changes in carbon sequestration, habitat loss, and many other effects. While all these symptoms of climate change have potential effects on ecological communities, increasing temperatures have the most apparent effects on shifting species distributions. It is believed that increasing global temperatures are responsible for many poleward shifting and expanding species distributions (Fodrie et al. 2010). These shifting distributions have the potential to alter local estuarine communities and impact both recreational and commercial fisheries.

In an ecological community, species are interconnected through relationships such as predator-prey interactions and competition. When these relationships are altered, either by environmental change or fishing pressure, they can have drastic and cascading effects on community structure (Chagaris et al. 2015). For example, a reduction in predator abundance can cause a population increase in the abundance of its prey as well as a decline in the populations of species up to two trophic levels below (Carpenter et al. 1985; Frank et al. 2005). A decrease in prey availability can lead predator populations to decline by affecting reproductive success and growth (Walters et al. 2005). Shifts in competitive relationships between species also have the potential to alter community structure. When two species utilize the same resource, they are described as in competition with one another. When two species are in competition with one another for a common resource, a change in abundance of one causes reciprocal changes in the abundance of the other (Hollowed et al. 2000).

Shifting species distributions associated with increasing global temperatures can cause species distributions to overlap in novel ways. Currently, tropicalization of the Bend Region is occurring as some tropical species are increasing in abundance at faster rates than sub-tropical species are decreasing. Mangroves and the Common Snook ar prime examples of this trend. Both, plant and fish respectively, are freeze intolerant tropical species expanding poleward and invading formerly subtropical habitat. This can create new interactions between species that were previously geographically separated. A single change in an association between two species can impact may levels of the food web. Thus, it is important for managers and policymakers to carefully consider the impacts these changes may have on local recreational and commercial fisheries as global temperatures continue to change. Changes in the abundance and distribution of commercially and recreationally valuable species such as the Common Snook, Red Drum, Spotted Seatrout, and Pink Gulf Shrimp may be viewed positively or negatively by stakeholders depending on if the species are increasing or decreasing in abundance. Additionally, a stakeholders' interests play a major role in how environmental changes are viewed.

Stakeholders are defined as those citizens who are beneficiaries but have particular investments directly involved in the management of the resources that will be affected by policy outcomes.[11] Literature on the human dimensions of ecosystem management assumes that including broad, diverse, and representative public participation in the decision-making process will foster consent because the policy outcome will reflect the society's values and preferences.[12] Effective public participation in the decision-making process of ecosystem management is important. Research demonstrates that continuous and persistent interactions between the agency and local community aids in knowledge transfer about complex systems like ecosystems.[13] When various stakeholders develop relational ties with other stakeholders, the community tends to be more resilient to changing circumstances or resource dilemmas.[14] Research demonstrates strong social networks developed through socializing frequently and in community situations are better able to overcome collective action problems.[15]

A sound decision-making process for ecosystem management includes a consideration of potential impacts on citizens and risk assessment. Including the human dimensions into decision-making in the context of ecosystem management involves identifying various levels of public participation, a basic understanding of the structures in social systems, as well as identifying and mitigating obstacles to meaningful public participation.

The policy and management of this new predator in the big bend region will be important as the northward movement of snook illustrates that tropicalization is taking place in the region and the ecosystem may be vulnerable to other species, some of which may be invasive. There are current statutes and regulations that address the importation and possession of invasive species which aim to protect our natural ecosystems from a species that may have negative impacts.[16] Policy should focus on strengthening these laws to prevent invasive species from negatively impacting the region. As the Snook population begins to increase exponentially in the big bend region, more recreational anglers may flock to the region targeting this gamefish.[17] This may also increase fishing pressure on other species such as the redfish.

Snook are managed differently in Atlantic and Gulf waters; as they migrate further north into the Gulf, it may be necessary to manage the snook in the big bend differently as they are a new predator in the region. This could involve, altering harvest season, and bag limits. Although the snook moving northward shows times are changing, this change is into bad. An ecosystem based fishery management plan[18] may be another option for the big bend region as it is currently susceptible to change as the snook and mangrove has shown. Lastly, a policy involving spatial management or no harvest zones may bring in more recreational fishermen, improving the local economy, and provide an opportunity for the snook population to thrive while not being overfished. Policy will be an important factor in the shifting distributions issue in Florida.

Shifting Distributions in Context

It is an unmistakable fact that the global system is warming at an unprecedented rate. This conclusion is supported by a combination of paleo reconstructed datasets (which go back in some cases cover millennia) and a diverse set of modern temperature records beginning in the 1950's (Stocker et al. 2013). Globally, sea surface temperatures are approximately 1 °C higher than pre-industrial times (Scheffers et al. 2016). Additionally, global sea surface temperatures are expected to increase by an additional 1-3 °C 2100 (Morley et al. 2016). Increasing temperatures are also apparent locally within the Big Bend region of the GOM. Air temperature data from Cedar Key, FL indicates that each year both minimum daily temperatures and the number of days experiencing temperatures greater than or equal to 25° C are increasing.[19]

Increasing temperatures are already impacting species distributions globally. Warming temperatures may lead to changes in distributions by relieving physiological thresholds baring species movement, altering behavior, and affecting the phenology of marine species (Hollowed et al. 2013). Various studies have found that ocean temperatures likely control species abundance and distributions. Barry et al. 1995 found that shifting invertebrate species distributions of the California intertidal zone were associated with increasing ocean temperatures (Barry et al. 1995). Other studies on fish associated with seagrass and reef habitats found similar trends. As temperature increased, species found at lower latitudes shifted poleward (Fodrie et al. 2010; Holbrook et al. 1997). On average, marine species are moving poleward 72 km per decade (Poloczanska et al. 2013). Furthermore, these distribution shifts are consistent with rates required to track changing temperatures (Barry et al. 1995; Poloczanska et al. 2013).

This trend towards tropicalization is also apparent along the coast of the Big Bend region. The distribution of mangrove species in the GOM has expanded and replaced salt marsh habitat over the last 60 years (Bianchi et al. 2013). Within Cedar Key, Black Mangroves (*Avicennia germinans*) are most common. However, Red Mangroves (*Rhizophora mangle*) are also increasing in abundance. Mangrove species are intolerant to freezing temperatures and experience significant decreases in performance between -2 and -6° C (Cavanaugh et al. 2015). Black Mangroves are most tolerant of freezing temperatures, followed by the Red Mangrove, and White Mangrove (*Avicennia marina*). Therefore, freezing temperatures are responsible for controlling their distributions. It is important to note that when a severe freeze event causing mangrove die-off occurs, the habitat is quickly colonized by salt marsh cordgrasses for a period. Despite this fact, various models project that mangrove species distributions will likely shift northward at rates between 1.3 and 4.5 km yr^{-1} (Cavanaugh et al. 2015). Mangroves serve as important habitat for many tropical fish species and serve as nursery habitat for juvenile fish. Additionally, mangroves provide important habitat for tropical birds.

The Roseate spoonbill (*Platalea ajaja*) range also appears to be expanding northward in this region. In 2013, the first three breeding pairs of Roseate Spoonbills were found in the Cedar Keys National Wildlife Refuge nesting in mangrove forest (SEAVEY et al. 2014). Previously, the closest nesting pair was observed in Tampa Bay. Furthermore, nesting individuals were also observed the following year. Thus, these observations appear to signal changes in the species' breeding distribution.

The Common Snook (*Centropomus* undemecialis) is another local example of the locally shifting distributions. The Common Snook is a popular recreational sport fish in the region prized for its fighting ability and flavor. Snook were historically found in Florida between Tarpon Springs in the GOM and Cape Canaveral in the Atlantic (Gilmore et al. 1983). However, near Cedar Key their density has increased exponentially since 2007.[20] Like mangroves, Snook are intolerant of freeze events, and mass die offs occur when temperatures dip below 12.5°C (Adams et al. 2012). However, research investigating the last major die off in 2010 found that local abundance recovered within 1-4 years of closing recreational fishing for the species (Stevens et al. 2016). Thus, while decreases in Snook abundance may occur in the future, we expect that the population will increase to a sustainable carrying capacity. As an economically valuable fishery, an increase in Common Snook abundance within the Big Bend may lead to a regional increase in nature-based recreation and revenue.

These changes may also have concerning effects on food webs and community structure. If all species distributions – both tropical and subtropical-moved at the same rate there would be very little change to community structure and we would simply observe a latitudinal shift of ecosystems. This however, is not proving to be the case in all circumstances. In general, tropical species are increasing in abundance at faster rates than subtropical species are decreasing. This can create novel species interactions which can alter the ecological community (Fodrie et al. 2010).

Within the Big Bend Region, changes in species distributions have the potential to change the abundance of species commonly fished recreationally in the region. Both Spotted Seatrout (*Cynoscion nebulosus*) and Red Drum (*Sciaenops ocellatus*) are sub-tropical fish that have historically been abundant along Florida's Gulf Coast. Common Snook, Spotted Seatrout, and Red Drum are all dependent on pinfish (*Lagodon rhomboides*) and gulf pink shrimp (*Farfantepenaeus duorarum*) as a prey source during part of the year (McMichael and Peters 1989; Scharf and Schlicht 2000; Blewett et al. 2006). Therefore, there is potential that regional increases in Common Snook abundance could lead to increased competition between these species. This may cause decreases in Spotted Seatrout and Red Drum abundance. Furthermore, there is a potential that as Common Snook become abundant, more predation of small fish species may occur (Matheson Jr et al. 2003). This can alter trophic dynamics within the food web at least short term.

Additionally, these trophic cascades could reduce commercial catch of bait shrimp within the region. Since the 1960's, Brown and White shrimp catch has steadily increased while the catch of pink shrimp has remained relatively constant (Nance et al. 1989). An increase in the number of predators or a change in their relative abundance could increase predation pressure. Reduction in bait shrimp abundance, thus has the potential to effect both commercial and recreational fisheries.

It is unlikely however, that increased competition between these species would lead to local crashes of Red Drum or Spotted Seatrout. Common Snook have been abundant within Tampa Bay for at least the last few decades. Yet, within the region Snook coexist with these species (Matheson Jr et al. 2003). This is likely due to seasonal partitioning of resources. By relying on different prey items and different times of the year, competition may be reduced, allowing for long term coexistence.

It is unknown whether an increase in the abundance of Common Snook will have a net positive or negative effect on recreational fisheries within the Big Bend region. Currently, local recreational fisherman must travel farther south to reliably catch Snook. Local changes in abundance may draw more recreational fisherman to the Big Bend Region. Increasing fishing pressure could affect the abundance of other sport fish species. Furthermore, modeling shows that the combination of climate change and fishing pressure can interact to produce different outcomes than each would separately (Hollowed et al. 2013). Shifting temperature regimes and extreme weather associated with climate change have the potential to effect maximum sustainable yield (Hare et al. 2010). Thus, it is vital that the combined impact of changes in fishing pressure and climate change are considered future fisheries management.

The impact that freeze events may have on controlling northward expansion of tropical species is also adds uncertainty to expected projections. Climate change models predict an increasing frequency of short, yet severe cold events (Kodra et al. 2011). Depending on the length of time and severity, these freezes may decimate mangrove habitat. This can indirectly affect local fisheries due to habitat loss. Moreover, fish recruitment success is highly dependent on environmental variability (Hare et al. 2010). A recent study by Morley et al. found that winter temperatures significantly explained interannual variability in marine species distributions and biomass (Morley et al. 2016). Temperature is believed to regulate recruitment success through juvenile mortality during the winter. Thus, depending on the frequency and severity, cold events may be able to control northward expansions of numerous tropical species (Stevens et al. 2006).

Another uncertainty regarding the impact of climate change on regional fisheries is the potential for non-native species invasions. Red lionfish (*Pterois volitans*) have caused havoc in certain areas of GOM (GOM). The first occurrence of Red Lionfish within the GOM was documented in 1985. Red Lionfish eat a wide variety of fish and have few native predators (Hackerott et al. 2013). Consequently, they rapidly increased in abundance and spread throughout the region (Evangelista et al. 2016; Morris and Akins 2009). This invasion has had a negative effect on fisheries both ecologically and economically (Evangelista et al. 2016). While there have been few Lionfish occurrences locally, the Big Bend Region considered suitable habitat for future range expansion. This prospect places local fisheries at risk. A reduction in small fish abundance because of Lionfish predation could reduce resources available to economically valuable fish species, ultimately reducing their abundance. Furthermore, a lionfish invasion within the region could act synergistically with other climate change and anthropogenic stressors to produce more drastic negative outcomes than expected (Albins and Hixon 2008).

Climate change, specifically increasing global temperatures, have potential to cause species distributions to change. The expected general trend is that increasing sea surface temperatures will lead to a poleward expansion of species distributions. This may lead to a tropicalization of the Big Bend Region and novel species interactions. These changes have the potential to cause both positive and negative effects on local commercial and recreational fisheries. It is likely that an increase in economically valuable fish species, such as the Common Snook, will lead to an increase nature-based tourism within the Big Bend Region. However, novel species interactions in combination with fishing pressure, may alter trophic dynamics and community structure. Unknowns regarding non-native species invasions and the degree of climate variability make future outcome projections more difficult. Considering these projections, understating how fisheries and the communities they support will be impacted is vitally important. Furthermore, it is vital that policy and management remain flexible to allow for future unknowns while simultaneously utilizing the most up to date information possible to inform management decisions.

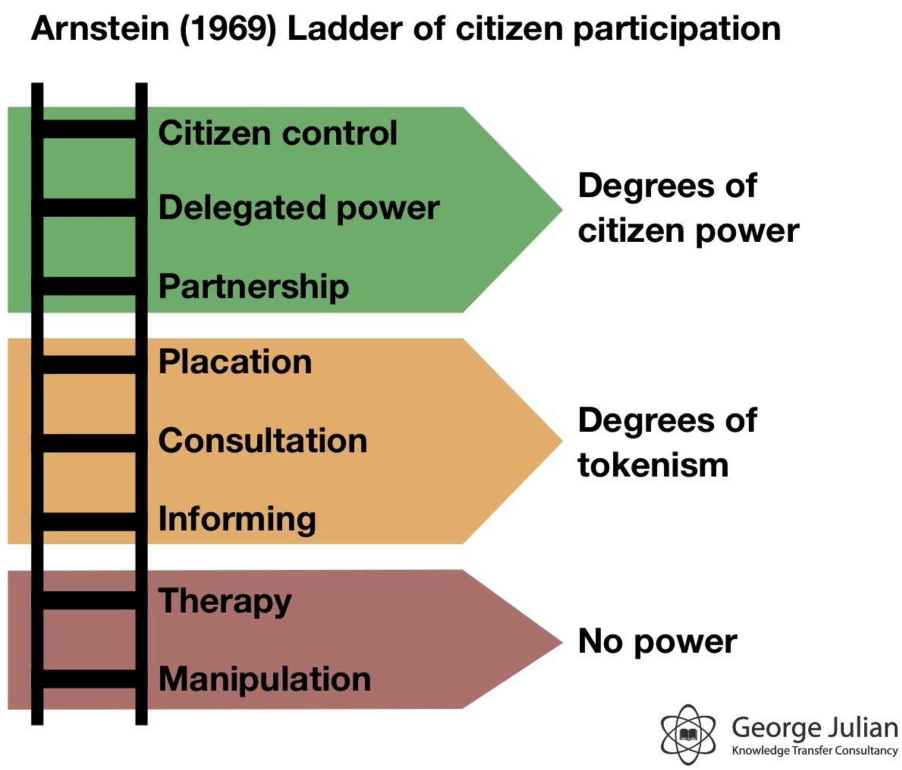
Human Dimensions

People are constantly interacting with ecosystems. Many think humans are a part of ecosystems.[21] Entire disciplines are founded to study the relationship between culture and community. If humans are a part of the ecosystem, then their communities depend in part on how their culture interacts with the ecosystem in which that community inhabits. Recognizing this relationship between human communities and their culture is coined the human dimensions of ecosystem management. The U.S. Forest Service defines the human dimensions of ecosystem management as follows:

> An integral component of ecosystem management recognizes that people are part of ecosystems, that people's pursuits of past, present, and future desires, needs and values (including perceptions, beliefs, attitudes and behaviors) have and will continue to influence ecosystems and that ecosystem management must include consideration of the physical, emotional, mental, spiritual, social, cultural and economic well-being of people and communities. [22]

PUBLIC PARTICIPATION

The best way for ecosystem management to achieve a recognition of community values and therefore increase the likelihood of successful policy outcomes is to include the public in the decision making process. Not all public participation in the decision-making process is created equal. Citizens may be included but their concerns or particular circumstances are not actually heeded and the result is often noncompliance or worse.



Arnstien's work is a useful starting point for understanding the dynamics of public participation. She developed "The ladder of Citizen Participation" as a simplistic breakdown of citizens' ability or power to influence policy outcomes into eight rungs and three broad levels. Arnstein takes time to caution the real-world is more complex than her simple break down, but it serves as an illustrative purpose. The bottom two rungs are examples of the first level called nonparticipation: 1) manipulation and 2) therapy. According to Arnstein both occur when decision-makers seek to unilaterally educate, advize, or cure participants rather than engage in genuine participation. The next level of citizen participation she coins as degrees of tokenism which include: 3) informing, 4) consulting, and 5) placating. She argues these are degrees of tokenism because although citizens are afforded an opportunity to be heard, they are not afforded the assurances that they will be heard, nor have recourse in the event they are not as the ultimate decision-makers preserve their power to decide the outcome. The top three rungs are the highest level of citizen "decision-making clot," conveniently coined the degrees of citizen power. They include 6) partnership which enables decision-makers and citizens to analyze trade-offs and citizens have real power to negotiate outcomes; 7) delegated power and 8) citizen control result in citizens themselves holding managerial or decision-making power. Broadly speaking she proposes that genuine participation, one of reciprocity, is the ideal for decision-making participation in policy outcomes.

SOCIAL SYSTEMS AND SOCIAL NETWORKS

Arnstein's ladder is more simplistic than real-life social systems where levels of participation with respect to ecosystem management takes place in communities built upon social networks. Successful communities have strong social networks with established social capital and effective civic engagement.[23] A collaborative, reciprocal and consensus-building approach to the decision-making process produces more politically stable management actions and policy outcomes.[24] Communities are complex social systems made of social networks that are defined as the social structure that provides order to human affairs.[25] Social networks are the linkages and relationships between people in communities, and they are responsible for generating and enforcing reputations and social norms.[26] Research on environmental resource management suggests that the existence of social networks is a, if not the key factor when stakeholders successfully overcome natural resource dilemmas.[27]

When assessing the strength of social networks the extent and density of relationships within networks, reciprocity or the existence of obligations and expectations regarding the relationships, the existence and extent of trust between relationships, and the use of punishing free-riding behavior must be considered.[28] To varying degrees these factors explain why social networks may be more important than formal institutions for actual enforcement and compliance with environmental regulations and policy outcomes.[29] This may also be explained in part by information dispersal because social networks informally and frequently diffuse information through relationships that may be more effective than a top-down agency approach.[30]

Furthermore, in the environmental context social networks have locally specific ecological and economic information that may otherwise be unknown to decision-makers.[31] Research on public choice and participation suggest that some of the roadblocks of larger participation are mitigated in small-group situations, when the potential participants know one another.[32] These are situations where social networks are strong, there is a greater opportunity for meaningful negotiations, and the likelihood of monitoring and punishing free-riding behavior is increased.[33] Strong social networks may account for the success local residents and neighborhood associations have at organizing and opposing unwanted development proposals in their areas.[34]

COLLECTIVE ACTION PROBLEMS

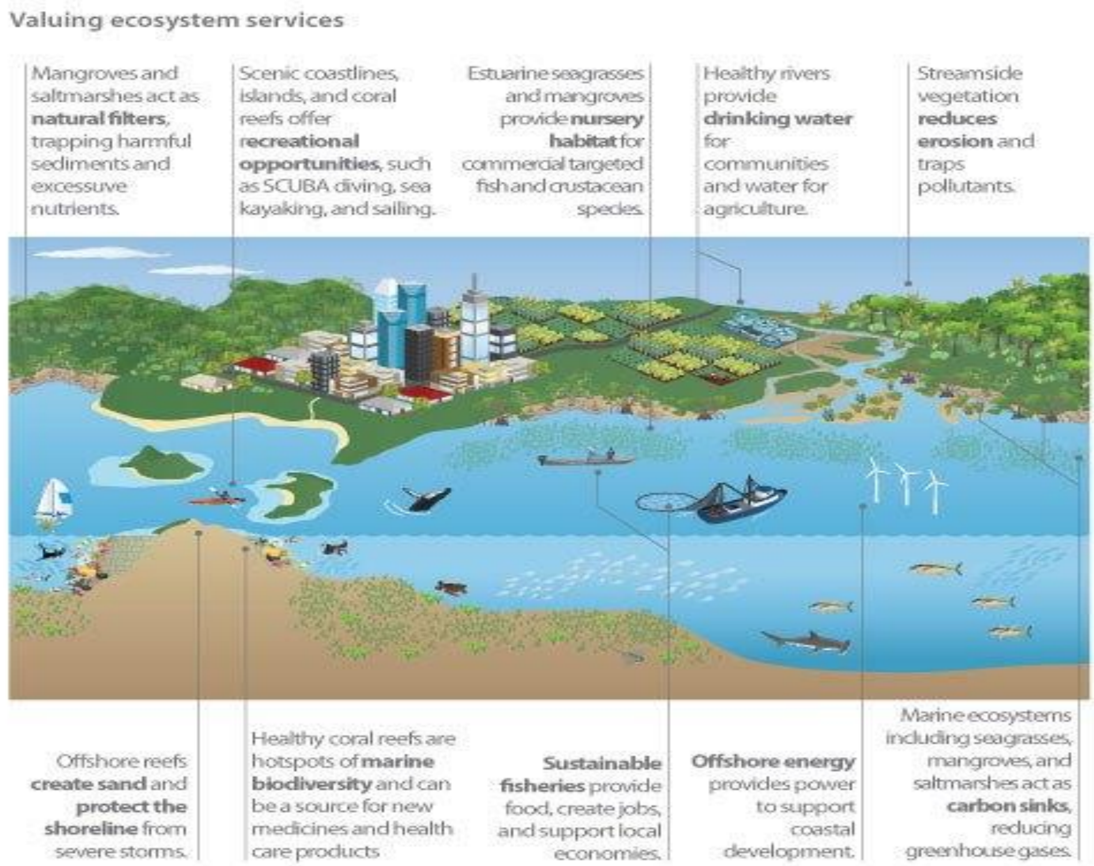
Literature suggests that strong social networks are vital to compliance and enforcement of environmental management policy outcomes. Involving the public in environmental management decisions assumes that broad representative public participation fosters consent because the policy outcome will reflect the society's values and preferences.[35] Policy outcomes that will reflect the public's values and preferences and therefore increase the likelihood of compliance is an outcome in which the public was able to engage in genuine participation. However, involving the public in the decision-making process of environmental management policy outcomes has a large challenge referred to as the collective action problem.

The collective action problem occurs when there is little incentive for the participation or mobilization of citizens.[36] An obvious example is when costs are dispersed over an unidentified large group, like air pollution.[37] Another collective action problem is referred to as rational ignorance. Rational ignorance the result of costs of participation being too high because the information collecting and processing takes time, effort, and resources from citizens, so they simply don't. [38] This is particularly problematic in the realm of ecosystem management because often unless it's NIMBYism citizen participation may be virtually nonexistent.

Rational ignorance and the lack of incentives explain why special interest groups are able to thrive and may capture agencies decision-making processes. Special interest groups have the incentive to participate and as organized citizenry they do not face the same associated costs with participation.[39] However, special interest groups may not represent the broader population's interests and values as they relate to a community's environmental resource management. In contrast to special interest groups which are always organized, stakeholders may not necessarily be. Stakeholders are defined as those citizens who are beneficiaries but have particular investments directly involved in the management of the resources that will be affected by policy outcomes.[40]

FLORIDA AND THE BIG BEND REGION: CEDAR KEY

Florida is a top travel destination in the world and it economy relies on tourism more than any other state.[41] Out of the domestic tourists, 40% reported beach and waterfront activities as top on their list. According to the Florida Fish and Wildlife Conservation Commission Florida ranks number one in the nation for saltwater anglers. It has more world record fish catches than any other state or country. Florida's commercial fishery is second in the nation for sales, income and value-added impacts. It is third in the nation for the number of jobs supported by commercial fishing. This trend is not new news. Florida has always been a fisherman's haven and since the 1800's it has become a well establish tourist destination in America.[42] Therefore tourism and fishing are critical components in the analysis of the human dimensions of changing distributions of species in Florida. The changing distributions of species has potential economic impacts because the ecosystems of estuaries supports over half of the species we like to fish (commercially and recreationally). In this and many other ways estuaries provide ecosystem services, which affects and are affected by us. Other values of ecosystem services relevant to human dimensions of ecosystem management in Florida by Dr. Kathryn Frank is provided.[43]



There are direct and indirect economic impacts of ecosystem services.[44] Direct economic impacts are those related to marine environment like fishing and tourism. Whereas indirect economic impacts are those that result from increases on marine-related regulations for activities not directly related to the particular ecosystem service. The changing distribution of species may result in localized novel regulations on fishing to protect a particularly sensitive resource from the negative impacts of changing distributions. These novel regulations will directly impact stakeholders and may indirectly impact other stakeholders whose activities are not related directly to the novel regulations like off shore mining or drilling. Both direct and indirect economic impacts must be considered in decision-making process of ecosystem management, particularly for trade-off analysis.[45]

Changing distributions will directly impact commercial fisheries and recreational fishing. Recreational fishing is important. In Florida it has direct and indirect economic impacts because recreational fishing is directly a part of Florida's tourism economy and agricultural economy. Furthermore, recreational fishing in America has had a long history that came across the pond along with other important cultural values. Davis describes recreational fishing and game hunting in America as akin with private landownership and voting as a sacred a democratic expression.[46] Indeed recreational fishing was a well established activity even before America was a country. One of the first books on sport fishing was published in 1642 by a woman named Juliana Berner called The Treatise on Fishing with an Angle."[47] However, Izaak Walton has been credited as one of the key founders in sport fishing with his first book in 1653.[48] Walton often compared recreational fishing to art and wrote "All that are lovers of virtue, be quiet and go a-angling."[49] A letter home from an outdoorsmen from the Gulf in 1878 exclaims "Success at fishing is a source of great contentment to the mind, dispels corroding cares, excites within a feeling of profound enjoyment . . ."(id) These attributes of recreational fishing are significantly related to the place in which the fishing occurs and people will travel to "go a-angling." It is therefore critical that any environmental management activities that may regulate fishing include those recreational fishermen as stakeholders because they are some of the people who will be most affected by different management strategies. Given the cultural value that folks place on recreational fishing, there are social networks and opportunities for collaboration as recreational fishermen are undoubtedly a diverse group. The group has the potential to enforce management policies, or disregard, and possibly combat them.

CEDAR KEY

Cedar Key has a well-defined sense of place with a working waterfront community and vast marshes that pre-date Disney. A sense of place is defined as a collection of meanings, beliefs, symbols, values and feelings that individuals or groups associate with a particular locality.[50] A space becomes a place when we endow it with value.[51] It is critical to recognize that a sense of place is not unique to only its residents. Tourists ascribe a sense of place and create emotional bonds with the ecosystems they visit. Cedar Key maintains its Old Florida character. Many other gulf destinations that were once working waterfronts have been transformed into condos and with little to do with their former working waterfront economies, but Cedar Key has not.[52] While other gulf destinations were being swallowed by industry, the big bend region in Florida remained relatively untouched.[53] Sea Horse key was declared a National Wildlife Refuge. Indeed the region is home to two national wildlife refuges and four state preserves.[54] In The Gulf: The Making of An American Sea , Davis explains Cedar Key's forests were recovering at a time other areas in Florida were being degraded. Cedar Key had once been home to thriving timber industry for pencil production, which fell apart in the 1890's. Shortly there after the rest of the timber industry for the collection of palm material used for broom manufacturing followed. Cedar Key adapted to a return to fishing. Cedar Key was already a well-settled working waterfront with a long history of sea turtles, fish, and bivalves. Eventually, it became an important destination for tourism and later ecotourism. Cedar Key is well known for its marshes which are an integral part of that Old Florida sense of place and were immortalized by John Muir's walk to the Gulf and visit to Cedar Key in 1916.

Cedar Key's history and culture is one of resiliency and innovation. In addition to changing industry, the community continually adapts to severe storms and hurricanes as evinced by the most recent, Hermine. Even before that storm, Cedar Key faced a nearly disastrous direct economic impact from an ecosystem management policy outcome, the net-ban. A community dependent on fishing after surviving a collapsed timber industry was faced with a serious natural resource dilemma. Remarkably, the community adapted. A relatively small community, (just over 700 in 2010) demonstrated its capacity for overcoming such dilemmas. With its smaller size, Cedar Key has a relatively strong social network. Public outreach and education by agencies responded to the net-ban and stakeholders were effectively involved in the decision-making process. The result? Cedar Key "re-clammed" its working waterfront title.

Policy and Management Considerations Regarding Shifting Distributions of Fish Species in the Big Bend Region

As discussed above, the science tells us that global air and sea temperatures are rising. These changes will and already have begun to cause habitats and species to shift throughout the world, particularly in Florida.[55] We have seen the mangrove slowly move northward up the Florida coast into the big bend region[56] and although the mangrove is taking over the salt marsh and replacing the productive spartina,[57] mangrove habitats are extremely productive, maybe even more so than the spartina marsh.[58] A natural inhabitant of mangroves lined shorelines is the snook, as they are sensitive to freezes just as mangroves are.[59] Snook thrive in southwest Florida where shores are lined with mangroves and temperatures are more suitable. Naturally, as mangroves move further up the coast into the big bend region, snook will and have started to follow.

Although a warming climate does have its negatives, especially for coastal towns here in Florida where the state may see relative sea level rise 20% greater than the rest of the world,[60] the shifting distributions of species typically found in more temperate climates such as mangroves and snook is not a bad thing. Snook are a popular gamefish and are considered a delicacy on the menu; recreational fishermen spent 20% of the time targeting snook when fishing in the everglades region.[61] Snook are sensitive to cold temperatures; therefore, they traditionally have a range in the southern half of Florida. As the Snook population begins to increase exponentially in the big bend region,[62] more recreational anglers may flock to the region targeting this gamefish. This may also increase fishing pressure on other species such as the redfish. As snook move northward into this region, they will become a new top predator; they will compete with other predators like the redfish for prey. Although the sound of a new top predator entering the food chain may imply that negative impacts will follow, this may not be the case with snook entering this food chain as snook and redfish coexist in southwest Florida. It may simply take some time for big bend ecosystem to adapt to an increasing snook population.

EXISTING POLICY

The policy and management of this new predator in the big bend region will be important as the northward movement of snook illustrates that tropicalization is taking place in the region and the ecosystem may be vulnerable to other species, some of which may be invasive. There are current statutes and regulations that address the importation and possession of invasive species[63] which aim to protect our natural ecosystems from a species that may have negative impacts on our ecosystems. It is the policy of the Florida Wildlife Commission (FWC) to maintain the state's natural resources and to provide incentives for those possessing prohibited invasive species to turn them over to qualified adopters instead of releasing them into the wild.[64] With the big bend region becoming more susceptible to change, it is vital to the ecosystem that the importation, possession, and release of invasive species be limited, laws enforced, and penalties stiffened. With coastal towns, such as Cedar Key, being working waterfront communities, the protection of the estuaries and ecosystems is important to the local economies and livelihoods of the people.

Another policy that may need to be implemented and be flexible as these shifting distributions of species continue, will be the management of the individual species, specifically the snook and redfish. Currently, the FWC conducts stock assessments of individual species of fish to determine how the species should be managed; these stock assessments are the only source of information used when creating management regulations.[65] Snook are regulated a bit more heavily than other gamefish as they are considered excellent table fare and are designated as a protected species to raise public awareness of the need to conserve and protect against endangerment.[66]

Currently, snook may be harvested in gulf waters on between March 1 and April 30 and between September 1 and November 30 of each year;[67] this means anglers are limited to 5 months out of the calendar year to harvest snook. In addition, the fish must between 28 and 33 inches to harvest;[68] this is a very small slot which encourages conservation of the species.[69] Anglers may only harvest one snook per day.[70] FWC has different regulations for snook in Atlantic waters. Malin Pinsky, a biologist at Rutgers University, stated that "Our fisheries regulations are built around the idea that fish distributions don't change very much. When they do, that makes things complicated for fishermen and for managers trying to maintain a sustainable fishery"[71] when discussing a study he conducted of shifting distributions of marine species. Policy should be focused on maintaining a sustainable fishery and changing management regulations to adapt to these changes.

As mentioned above, management regulations regulating the harvest of popular gamefish like snook and redfish are currently managed by FWC on a species by species basis. FWC uses stock assessments to determine the health of the population and whether the harvest needs to be limited or increased. NOAA has implemented an ecosystem wide management system and this may be an option for a region like the big bend where the ecosystem is susceptible to changes with a warming climate. A shift from individual species management to an ecosystem wide management plan may be a better alternative in these changing times.

Although the state does have management zones for trout, snook, and redfish among others, these management zones determine when anglers may harvest the species in the specific area. The regulations the FWC has implemented does not set aside certain areas where certain species may not be harvested. If a species or snook can be harvested in that zone or region, anglers are free to fish anywhere in that zone. As species begin to shift throughout the state, setting aside special zones or using spatial management[72] where a new species in an area may not be harvested, may be a policy that would allow the ecosystem to adapt successfully.

POLICY FOR THE FUTURE

Existing policy regarding shifting distributions may be satisfactory for now, but it appears changes will be occurring more rapidly and it would be in the best interest of the stakeholders and leaders to consider policy alternatives. A few policies were alluded to in the section above and will be discussed further. Placing harsher penalties on violators of the invasive species laws in addition to attempting to limit and prevent invasive species from negatively impacting the big bend region is possible option. Another policy consideration would be to adjust bag limits of the top predators that influence the ecosystem and this can be done by increasing stock assessments to determine whether harvest rates need to increase or decrease. An ecosystem wide management plan may also be a policy option as ecosystems become more vulnerable to change. Lastly, no harvest zones for the top gamefish like snook and redfish may incentivize recreational anglers to travel to the big bend region in search of trophy fish in addition to maintaining the stock with lower harvest rates.

The rate at which the climate is warming and sea level is rising is something the earth has never seen before.[73] The big bend region in Florida is also seeing changes it has never seen before with mangroves having populated much of the coastline, and snook beginning to exponentially increase in the region. This shifting distribution of species may be providing us with a glimpse into the future as the region is currently vulnerable to new species; some of which may negatively impact the ecosystem. Snook are a new species in the region, but at least until now, they have not had a negative impact on the area. Policy considerations that protect from other species that may have negative impacts should be considered. It is already the policy of the state to maintain the state's unique natural resources and prevent invasive species from entering the ecosystems.[74]

Although there are laws regarding the importation, possession, and release of invasive species,[75] the enforcement and punishment appears to be lacking considering the number of invasive species prevalent throughout the state.[76] Changing the punishment from the current first degree misdemeanor and maximum $1000 fine and 1 year in prison to a third-degree felony which carries a maximum 5 years in prison and a $5,000 fine may deter violators from releasing pets. It may also deter individuals from purchasing pets knowing that releasing them is not an option. Currently, it is the policy of FWC to incentivize individuals with invasive species as pets to return them to qualified handlers without punishment.[77] The threat of invasive species will come from pets and even with incentives to return them, there are other types of species that are not pets that may have a negative impact such as diseases and parasites.[78] With a warming climate leading to more erratic weather patterns,[79] events such as winter rains in Florida may push pathogens around when they otherwise wouldn't be.[80]A possible new policy would be to focus on the research and prevention of these types of organisms from infiltrating vulnerable ecosystems as temperatures rise and species distribution begins to increase.

As mentioned in the existing policy, snook and redfish (like most other saltwater gamefish) are managed by FWC and regulations provide the size that may be harvested, when the species may be harvested, and the bag limits for anglers.[81] As the distributions of these species shift, it may be necessary to change the regulations of species as the ecosystems adapt to a new predator such as the snook. Although we know that snook and redfish co-exist along with mangroves in southwest Florida, the big bend ecosystem has previously not had a significant population of snook and the ecosystem must adapt. It is unknown how the region will adapt and regulations need to be flexible and possibly changed if research and science indicate.

There is a possibility that the increase in snook population will have minimal effects and the current regulation in place including slot size, seasons, and bag limits may stay the as they are. However, because snook and redfish are both predators with a similar diet, the native redfish population, among other species, may see a decline in population. FWC conducts stock assessments of many saltwater fish species in Florida.[82] Because these assessments are the only way for rule makers to know how populations are doing, if these assessments showed that the redfish may be seeing a decline in population in the big bend region, it may be appropriate to increase the harvest of snook in the region. Bag limits should be higher, the slot size could be larger, and there could be a different season. FWC could manage the snook population in the big bend region separately from the Atlantic and the rest of the Gulf of Mexico as it currently does. With snook being a popular gamefish, more anglers could flock to the region which may place increased fishing pressure on the redfish as well, while anglers target snook. FWC may consider limiting the redfish harvest if stock assessments indicate the redfish population is declining.

The biggest issue amongst the shifting distributions of species is the uncertainty. We simply don't know how the ecosystem will handle this influx of snook. FWC took stock assessments of snook and redfish over the past 5 years.[83] Considering the unknowns of the effects of snook in the big bend region, taking stock assessments more frequently such as every year for the next 5 years will provide rule makers with better and more updated science that will determine whether regulations need to be changed. Only time will tell how the region will adapt and changed should only be made if the science indicates so.

A new approach to management of fisheries may be to move away from the single species regulations and implement a policy that favors Ecosystem-Based Fisheries Management (EBFM). NOAA issued a policy statement about what this type of management does:

> "NOAA's National Marine Fisheries Service (NOAA Fisheries) strongly supports implementation of Ecosystem-Based Fisheries Management (EBFM) to better inform and enable better decisions regarding trade-offs among and between fisheries (commercial, recreational, and subsistence), aquaculture, protected species, biodiversity, and habitats. Recognizing the interconnectedness of these ecosystem components will help maintain resilient and productive ecosystems (including the human communities on which they depend), even as they respond to climate, habitat, ecological, and other environmental changes."[84]

A management policy like this may be beneficial to the big bend region as this region is on the fringe of the shifting distribution issue currently taking place in Florida. This management policy should be geographically specific; in this case, for the big bend region. The importance of the working waterfront is immeasurable for the town of Cedar Key. The residents rely on aquaculture, eco-based tourism, and recreational fishing to drive the economy. An EBFM plan relies on the importance of all the organisms in an ecosystem as well as the human interaction and social aspects. A goal of this plans is to prioritize vulnerabilities and risks to ecosystems. A regional policy may be put in place focusing on prioritizing threats like the snook and possibly invasive species. Aquaculture is important to Cedar Key; a policy and plan that can implement the importance to the economy, the working waterfront, the aquaculture, and the fisheries may be a better option that single species management.

A final policy consideration may be to us spatial management for the snook and redfish.[85] This is similar to a trophy zone where snook may be caught, but not harvested. Certain areas may be designated as a no-take zone which may lead to increased resiliency in the ecosystem as it adapts and fishing pressure is increased.[86] Because of the importance of snook as a gamefish in Florida, the big bend region may become a new destination for recreational anglers targeting this species. An area dedicated to catch and release fishing may increase the size and density of snook and lead to even more recreational anglers coming to the region. This may lead to more dollars spent in the region. This will probably be unpopular with fishermen as many are reluctant for more regulations; especially a regulation telling them they cannot keep fish they catch in a certain area. Stakeholder involvement would be vital before moving forward with a policy if this nature. A key part of getting the stakeholders and recreational fishermen on board with a plan like this would be increasing education and awareness.[87] Education is also important in the case of a shift in species when the species may be harmful to humans as mentioned above.[88]

Results and Discussion

Changes in species distributions and tropicalization of the Big Bend Region are glaringly apparent in Cedar Key, Florida. The mangrove coverage in the area has increased considerably in the last ten years and tropical fish are becoming local residents. Fisheries play an important role in the economy of Cedar Key as well as the entire Big Bend Region. In Cedar Key, local fishing guides lead half and full day trips for both tourists and locals. It is a large industry and guides are fiercely protective over preferred fishing spots. Shifting species distributions have the potential to change the catch rates at these sites ultimately affecting guide businesses in the area.

On 7 March 2017 University of Florida's Sea Level Rise and Coastal Ecology course went electrofishing with the Florida Fish and Wildlife Conservation Commission (FWC) along the Suwannee River. The survey began at Fowlers Bluff located approximately 20 miles north of the GOM and ended at the Gulf. Salinity measurements were taken both near Fowler's Bluff and at the Gulf. These measurements showed a drastic salinity shift between fresh and brackish water at levels that were still feasible for electrofishing. In addition to salinity changes, there were clear habitat shifts from trees and freshwater aquatic plants upriver to salt marsh habitat downriver. Thus, we had the opportunity to sample both estuarine and freshwater habitats in order to examine the fish species present. Upriver, a variety of freshwater fish were caught. These included species such as the Bowfin (*Amia calva)*, Largemouth Bass (*Micropterus salmoides)*, Suwannee Bass (*Micropterus notius)*, Mullet (*Mugil cephalus)*, and Gar (*Lepisosteidae*). Surprisingly, we also caught a Common Snook close to Fowler's Bluff that was 78 cm in total length.[89] The Suwannee is currently considered the most northern edge of the species' distribution.[90] Even so, this was the first time that the Common Snook had been found in that area by the FWC crew we sampled with. This evidence clearly reinforces that the presence of Snook in the Northern GOM is becoming more commonplace. Downriver near the Gulf a variety of estuarine and freshwater fish were caught. These species included Red Drum, Largemouth Bass, and Mullet.

In the face of shifting distributions as species' ranges shift in response to climate change and all the ecosystem implications of such a transformation, Cedar Key has a working waterfront and an active tourist-base that spans the gambit of eco-tour charter boats, avid bird-watchers, and recreational fishermen. Cedar Key's sense of place and culture has braved many challenges related to direct economic impacts of a changing ecosystem services and the human dimensions of resource management. So long as strong social networks and continual participation of the community's diverse stakeholders in the decision-making process of ecosystem management suggest that Cedar Key will continue it's historic culture of innovation and resiliency.

Although there are uncertainties regarding what will happen in the future, we do know from science that these changes are real and are influencing the big bend region. It is important for the region to be on the leading edge of policy and management as these changes continue to occur. The existing policy and management in place is sufficient for the time being; however, the science, including stock assessments, will need to be continually updated to ensure the management of the snook and other species is being done properly. This is difficult with the uncertainty; other management plans such as the ecosystem based fishery management plan may assist with the management until it is clearer as to how the snook will affect the region. Stakeholder involvement is necessary when the policy and management changes as the stakeholders rely on the ecosystem for their livelihood.

Conclusions and Recommendations

Species distributions are shifting in the Big Bend Region leading to an overall tropicalization of the habitat. This has allowed for novel species interactions that could have drastic impacts on the abundance of economically valuable recreationally and commercially fished species. Species interactions and fishing pressure in combination with a changing climate make provide managers with a unique challenge. To manage fishery resources in light of unknowns associated with climate change. In order to do this effectively it is important to support local fisheries by managing with the most accurate and to date research available.

Thus, from a scientific perspective, we recommend ongoing research regarding how local shifts in species distributions-such as the Common Snook- may affect both population and community levels. This may include diet analysis, tagging studies, and mark recapture studies. Diet analysis can help to clarify feeding relationships between species in light of shifting distributions. In addition, tagging and mark recapture studies can help identify changes in population demographics.

As global temperatures increase we expect new tropical species such as the Common Snook to coexist with other recreationally valuable fish species. However, their relative abundance may be affected. In addition, it is unknown how extensively events and inter-annual climate variability may affect shifting species distributions over time. Therefore, it is important to monitor populations regularly and adjust fishing regulations appropriately.

To avoid special interest group capture and collective action problems in order to effectuate policy outcomes that reflect society's values and preferences such that those outcomes will be enforced and complied with by those actually affected by them, then agencies have a strong interest to include a diverse set of participants including relevant stakeholders in the decision-making process. When the decision-making process includes stakeholders and is transparent, inclusive, and fair in doing so the aforementioned problems can be mitigated.[91] A review of the literature recommends:[92]

- FAIR
    - transparent substantive and procedural info that builds a common knowledge base of agreed upon rules & practices such that citizens can negotiate various tradeoffs and participate effectively,
    - the possible personal conflicts of interest to decision-makers are kept to a minimum by agencies
- ACCOUNTABLE
    - there is an available recourse for citizens to hold administrators accountable
    - third party review of the agency is suggested
    - impacts of participation are made explicit (local media or education programs)
- ACCESSIBLE
    - Efforts to decrease costs of participation are made such as keeping meetings short and at a relatively accessible time, enough notice is provided
    - efforts can be made to increase the direct benefits of participation like socializing

The Big bend is in a unique position as far as shifting distributions go; the ecosystem's change to a more tropical environment provides those in charge of policy and management a unique opportunity. Some, but not all, policy and management considerations were discussed above and may provide decision makers with a starting point. Currently, the movement of snook into the region is not a bad thing as we know it. In fact, it may bring an increase in recreational fishing and boost the economy in the region. It is well known that policy and management often lacks behind the science; it may be too late to prevent problems if the exponentially increasing snook population is not managed in this region as the science indicates the region is currently vulnerable to change, some of which may not be good.

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[1]Based on Florida Fish and Wildlife Fisheries Independent Monitoring Data in Cedar Key, FL; Used with permission of Charlie Martin
[2] Segerson at 1.
[3] Segerson at 1.
[4] Madin et al.
[5] Carr at 21.
[6] Decker at 3.
[7] Carr at 20
[8] Beatrice & Bodin at 366
[9] Beatrice & Bodin at 366
[10] Decker at 3.
[11] Decker at 2.
[12] Pennington at 155
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[20] Florida Fish and Wildlife Commision's Fisheries Independent Monitoring Data from Cedar Key, Florida.
[21] Capek
[22] Carr at 20
[23] Pennington & Rydin at 161.
[24] Decker at 4.
[25] Carr at 21.
[26] Pennington & Rydin at 160.
[27] Beatrice & Bodin at 367.
[28] Pennington & Rydin at 161.
[29] Beatrice & Bodin at 367.
[30] Beatrice & Bodin at 368.
[31] Pennington & Rydin at 155.
[32] Decker at 4.
[33] Decker at 4.
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[35] Pennington & Rydin at 155.
[36] Pennington & Rydin at 156.
[37] Pennington & Rydin at 157-160.
[38] Pennington & Rydin at 157-160.
[39] Pennington & Rydin at 157-160.
[40] Decker at 2.
[41] Walton.
[42] Davis.
[43] Frank
[44] Madin et al.
[45] Madin et al.
[46] Davis at 158.
[47] Id at 157.
[48] Id.
[49] Davis at 159
[50] Williams
[51] Williams

[52] Davis
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