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A Case Study of Turkey Point Nuclear Generating Station: Perception and Power in Environmental Assessment

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UNIVERSITY OF MIAMI

A CASE STUDY OF TURKEY POINT NUCLEAR GENERATING STATION: PERCEPTION AND POWER IN ENVIRONMENTAL ASSESSMENT

By

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The Turkey Point Nuclear Generating Station (TPNGS) is a nuclear power plant situated on the shores of Biscayne Bay, FL. The fringing mangrove shoreline of Biscayne Bay provides essential habitat for a variety of ecologically and commercially important species of fish. There is concern among stakeholders that proposed expansion at TPNGS may pose environmental risks. The goal of this thesis was to investigate current status of knowledge of environmental risk to the nearshore fish communities inhabiting the mangroves adjacent to TPNGS. Specific objectives included: 1) examining perception of environmental risk from TPNGS by stakeholder groups in the environmental regulatory arena; 2) establishing baseline trends in fish community metrics of mangrove fish populations in the vicinity of TPNGS; 3) evaluating the logistical efficiency of current fish community sampling methods for detecting relevant indicators of change in this location.

Results of a targeted, qualitative study of stakeholder perceptions indicated that perceptions held by stakeholders relating to the need for increased nuclear generating capacity, environmental threats to Biscayne Bay, risk to Biscayne Bay specific to TPNGS; and transparency, efficacy and equity within the permitting process, were often highly diverse. The diversity of perception, itself a result of a combination of uncertainty

and differences in information accessibility, jurisdictional proximity to the site, and other factors, contributes to the list of challenges faced by decision-makers in the environmental assessment process.

Based on perceived environmental risk to the nearshore habitat identified in the perception study, I evaluated the ability of an ongoing mangrove shoreline fish community monitoring effort of the wider Biscayne Bay and southern sounds to detect changes on three spatial scales relevant to TPNGS. Results indicated that patterns in taxonomic richness, total fish density and frequency of occurrence of a key species, gray snapper (*Lutjanus griseus*), were highly seasonal. Current mangrove fish community monitoring effort in the vicinity of TPNGS is sufficient to detect subtle changes in the metrics of taxonomic richness and total fish density on a seasonal basis. However, sampling effort would need to be increased to effectively detect change in gray snapper occurrence in the dry season at each spatial scale. Using a precautionary approach, efficient monitoring studies can be developed based on this preliminary analysis. The study provided insight into the complex interaction of the socio-cultural dimension of environmental policy with the natural resources being regulated.

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CHAPTER I: Introduction to Biscayne Bay and Turkey Point Nuclear Generating Station

1.1 Introduction to Biscayne Bay, FL

1.1.1 Overview of Recent Ecological History of Biscayne Bay

Biscayne Bay (southeastern Florida, USA) is a formerly estuarine (Smith 1896, Browder & Ogden 1999, Marshall et al. 2009), subtropical coastal embayment that, over the last century, was converted to a freshwater-pulsed lagoon through the construction of an extensive inland and coastal canal system known as the Central and South Florida Flood Control Project (Light & Dineen 1994, Serafy et al. 1997, Browder et al. 2005). Bordered to the north by encroaching development of the city of Miami, and enclosed by the northernmost extent of the Florida Keys Reef tract, Biscayne Bay serves as the principal eastern outlet for the Everglades watershed (Browder & Ogden 1999). The littoral zone of Biscayne Bay and contiguous intertidal mangrove forests are part of a larger mosaic of habitats including the estuaries of Everglades National Park, Florida Bay and the southwest mangrove estuaries, Biscayne National Park, Big Cypress National Preserve and several wildlife refuges (Browder & Ogden 1999). Though significantly altered by human activities, this broad wetland area has been designated an International Biosphere Preserve, a World Heritage Site, and a Wetland of National Importance (Davis & Ogden 1994). Historical accounts describe freshwater delivery as diffuse and continuous via surface sheet flow, ground water and freshwater springs within the bay (Smith 1896). Fragmentation and hydrologic alteration (Light & Dineen 1994, Ogden et al. 2005) have led to loss of sheetflow across the habitat mosaic (Browder & Ogden 1999) of the greater Everglades system. In 1948, Congress approved the Central and South Florida Project, diverting fresh water from Biscayne Bay through the construction of the Eastern Perimeter Levee ca. 1950. The timing and delivery of freshwater has been radically altered by the retention (to recharge municipal water supplies) and release (during flood threat) of large volumes of freshwater in the Water Control Areas (Light and Dineen, 1994) often resulting in dramatic salinity fluctuations in the nearshore area (Kohout & Kolipinski 1967) that are outside of the range of variability of the natural system (Montague & Ley 1993, Marshall 2009). Degradation of the nearshore area from anthropogenically-induced fluctuations in salinity has reduced habitat quality for many organisms that utilize the intertidal mangrove fringe zone (McIvor et al. 1994). Browder et al. (2005) identified anthropogenic alteration of freshwater inflow as one of four important stressors to the ecosystem of Biscayne Bay, which drastically reduce mangrove habitat functionality though the processes of freshwater habitat loss, changes in salinity frequency and amplitude patterns, estuarine and freshwater fish and invertebrate community loss, loss of freshwater creek systems and overall reduction of natural estuarine conditions. By the time that Turkey Point Nuclear Generating Station began operation in 1967, these stressors had been acting on the ecosystem of Biscayne Bay for several decades, but had become more intense as additional watershed modifications ensued. In an effort to protect the resources of the bay, the southern end of Biscayne Bay was declared a national monument in 1968, four years after FPL was granted a permit to build two oil-fired electric power generators at the Turkey Point property.

1.2 Introduction to Turkey Point Nuclear Generating Station

1.2.1 Overview of the History of Environmental Study at Turkey Point

Turkey Point Nuclear Generating Station (TPNGS) is a case study of operating a thermoelectric power plant in the coastal zone. TPNGS (Figure 1.1) is a twin reactor nuclear power station located on an 11,000-acre property on the shores of Biscayne Bay (Figure 1.2). It is the 2nd largest power plant in Florida in terms of generating capacity, and the 6th largest in the nation (NRC 2012). The Turkey Point plant property is approximately twenty-five miles south of Miami, eight miles east of Florida City, and less than five miles east of the southeastern municipal limits of Homestead. The property is approximately two miles south of the Biscayne National Park Visitors Center, and is within three miles of a South Florida Water Management District conservation area (Model Lands Basin). A portion of the Biscayne Bay Aquatic Preserve, established in 1974, runs along the coastal boundary of the Turkey Point plant property. The TPNGS property is situated between the submerged lands of Biscayne National Park to the immediate east, and nearby Everglades National Park, less than twenty miles to the west.

In June 1964 the Florida Power and Light Company (FPL) was granted a permit to build two oil-fired electric power generators at Turkey Point. The first of these units went into operation on April 22, 1967, and the second began operating on April 25, 1968. These units ran on an open-cycle cooling system: water to cool the reactors was drawn directly from Biscayne Bay at an intake just north of Turkey Point and discharged back into the Bay via a series of short canals. Construction of the first two nuclear reactors, Units 3 & 4, was completed in 1971 and 1972. These two are nuclear powered with a maximum output of 760 MWt each. When all four nuclear units were operating, the plant required 10.4 X 10^6 m^3 d^{-1} of cooling water. Under a normal full load at the time of 2,080 MW, the temperature of the plant's cooling water was raised 7.9°C and at the maximum load (prior to the uprate) of 2,384 MW the temperature rise was 8.8°C (FWPCA 1970, Laws 2000). The average maximum daily temperature for Biscayne Bay is normally 30-31°C during the months of July and August. Many of the organisms of subtropical Biscayne Bay live close to their thermal maxima, thus artificially raising the temperature in excess of 30-35°C would be expected to negatively affect the bay's biota.

Environmental studies began in the Turkey Point vicinity in May of 1968. Early work was devoted largely to a description of the area reviewed in detail by Roessler & Tabb (1974). The first adverse effects of heated effluent from the power plant was detected in a survey of south Biscayne Bay during late July 1968, three months after the second oil-fired generator went on line. An area of barren sediment covering 8-12 x 10^3 m^2 was found off the mouth of the discharge canal. The turtle grass (*Thallasia testudinum)* beds, which once flourished in the area, were denuded and replaced by mats of cyanobacteria. As the heat stress increased during summer months, the damage developed a consistent pattern: there was an increase in the die-off of *Thallassia* leaves with increases in temperature above ambient, causing a decline in abundance and density of the seagrass (Zieman & Wood 1975). By the end of September 1968, 14 ha of sea grasses had been destroyed (Zieman & Wood 1975). By June 1969, 50-75% mortality of coral colonies within 750 m of the outfall was documented and *Thallassia* degradation was documented up to 900 m from the outfall. A large mortality event of fish and benthic organisms occurred on June 25, 1969, extending up to 1.4 km from the outfall with the center of mortality occurring 900 m from the outfall. Sublethal effects were documented by Nugent (1970), who surveyed macrofauna within two creeks near Turkey Point to compare areas affected with those unaffected by heated effluents, finding significantly greater total fish density in the control area versus the impacted one in the wet season only. Water temperatures in Biscayne Bay during June of 1969 were measured to exceed threshold levels set by the EPA and Miami-Dade County, at distances of up to 1.4 km from the discharge canal (FWPCA 1970). The violation of water quality standards prompted FPL and the Florida Department of Environmental Protection to address the thermal effluent problem before the new nuclear generators Units 3 & 4 officially went on line.

The Card Sound Canal was a 9.7 km long canal designed to minimize impact by allowing the effluent to cool down by about 0.5˚ C before it was discharged (Bader & Roessler 1971). The effluent from the Card Sound Canal was discharged into the deeper waters of Card Sound, outside the boundary of Biscayne National Monument. The effects of thermal effluents due to the Card Sound Canal were different from those observed at Turkey Point Grand Canal (Thorhaug et al. 1979). The degradation of benthic habitat in Card Sound were summarized in Thorhaug et al. (1979) as being less severe than those in Biscayne Bay, possibly due to differences between the two locations in depth, circulation and previous canal construction. However, it still presented a significant impact. Trawl surveys conducted by Thorhaug & Roessler (1977) documented the impact of thermal effluent to epifaunal and nekton communities within near shore seagrass beds of Card Sound. Since 1968, when the thermal addition studies began, reports by Roessler & Zieman (1970), Hagan & Purkerson (1970), Bader, Roessler and Thorhaug (1970), Iversen & Roessler (1971), Roessler (1971), Thorhaug

(1974a), Thorhaug et al. (1974), Roessler et al. (1975), Zieman & Wood (1975) and Thorhaug (1979) have summarized findings in the benthic and nekton communities in the vicinity of Turkey Point and in Card Sound.

Research documenting the effects of the Card Sound Canal ultimately prompted the construction of a large-scale closed-cycle cooling canal network in 1973, which finally eliminated thermal discharge into the waters of Biscayne Bay and Card Sound (Figure 1.3). The system consists of 32 shallow cooling canals, each about 8.4 km long, approximately 1.5 m deep, providing 15.6 km^2 surface area for heat exchange and residence time for the effluent of 40 hours. Evaporative losses are made up by seepage of brackish groundwater from underneath the system (Laws 2000). The canal system does not discharge directly to fresh or marine surface waters. However, an exchange of water between the canal system and the groundwater is likely because the system is unlined (Hughes et al. 2009, SFWMD 2009). During the dry season, when the natural gradient is from Biscayne Bay and Card Sound towards the Everglades, water is pumped from an interceptor ditch surrounding the system to create an artificial gradient from the Everglades into the ditch. This is meant to prevent the flow of hypersaline water from the cooling canals towards the Everglades (NUREG-1437, 2002). Turkey Point Units 3 & 4 and associated structures and features including the cooling canal system occupy approximately 8000 acres of formerly mangrove and freshwater wetland habitat (NUREG-1437, 2002). The construction of the cooling canal system provided much needed habitat for the American crocodile (*Crocodylus acutus*) (Brandt et al. 1995) and has been a contributing force to its reclassification from endangered to the less serious category of threatened species.

Approved by the U.S. Congress as part of the Water Resources Development Act of 2000, the Comprehensive Everglades Restoration Plan, is a joint Florida state and U.S. federal effort to redesign surface water flow through the canal system of South Florida, replenish the Everglades ecosystem and restore a more natural quantity, timing and distribution of flow into Biscayne and Florida Bays. The South Florida Water Management District (SFWMD) and the U.S. Army Corps of Engineers (USACE) will implement the CERP. CERP encompasses over 60 elements and in total and is projected to cost $13.5 billion, half of which is shared by the federal government (www.evergladesplan.org). One element of the plan, the Biscayne Bay Coastal Wetlands Project, is designed to redistribute freshwater flow across a broad front, replacing lost overland flow and partially compensating for reduction in groundwater seepage (Janzen et al. 2008). The final EIS for this project was released in January 2012.

In 2010, FPL requested to amend Facility Operating Licenses and revise Turkey Point Units 3 & 4 technical specifications. The extended power uprate (EPU) would first undergo concurrent state and federal processes of environmental review. On November 4, 2011 the Nuclear Regulatory Commission issued a draft Environmental Assessment for the proposed extended power uprate project. The Florida Department of Environmental Protection included among the conditions of certification of the Units 3 & 4 EPU, that FPL must submit a Biscayne Bay Surface Water Monitoring Plan, pursuant to Chapter 62-302, F.A.C. to the FDEP Southeast District Office. The uprate project would increase the generation of the plant from 2300 megawatts thermal (MWt) to 2644 MWt resulting in an increase in temperature of the water in the cooling canal system of 2.5°F, that is, from 106.1°F to 108.6°F (FPL 2011). Increased temperature in the canals may result in increased evaporation and thus increase the salinity of water within the canal system. Certification IX of the Final Monitoring Plan includes the collection of field salinity and temperature data from stations located within Biscayne Bay to determine the impacts of proposed changes in the Turkey Point Cooling Canal System on Biscayne Bay (Appendix A, SFWMD 2009). In accordance with the Fifth Supplemental Agreement between FPL and the South Florida Water Management District, FPL must monitor for impacts of the Turkey Point cooling canal system on the water resources of the SFWMD in general, including assessment of potential impacts to surface water and groundwater, as well as wetlands in the vicinity of the cooling canal system (Appendix A, SFWMD 2009).

On June 30, 2009 FPL submitted a Combined Construction and Operating License (COL) application for two new nuclear units at the Turkey Point property. These proposed nuclear units, collectively called Units 6 & 7, are 1,117 MWt Westinghouse AP1000 model (Figure 1.5.1). The new units and supporting infrastructure would be located in the approximately 218-acre plant area (Figure 1.5.2). Units 6 & 7 would be located within the northeast corner of the industrial wastewater facility on an area adjacent to the shoreline. (FPL 2010). Including improvements to offsite areas, the total wetland impact for the project is projected to be a decrease of approximately 700 acres, and includes a 50 acre reduction in mangrove habitat largely associated with a wastewater treatment facility. Estimated total project costs are $12.1-$17.8 billion (FPL 2010). Each unit will have three mechanical draft cooling towers, which operate on a closed cycle, separate from the cooling canal system. Mechanical draft cooling towers use large volumes of water as a transfer medium to remove heat from the reactors' condensers through evaporation. Through evaporative losses, the cooling water becomes concentrated in dissolved solutes, which may corrode the equipment. Thus portions of water, known as "blow down" are drawn off periodically and replaced by new water to maintain equilibrium in total dissolved solutes. The blow down from Units 6 & 7 will be discharged via deep injection into the Boulder Zone of the lower Floridian Aquifer (FPL 2010). The proposed cooling system would use treated, reclaimed municipal waste-water from the Miami-Dade Water and Sewer Department South District Wastewater Treatment Plant (located approximately nine miles north of Turkey Point plant property), as the primary source for the closed-cycle wet cooling system. A maximum of 43,200 gal/minute of 'makeup' water to replace losses from evaporation, blow down and drift, would by supplied via pipeline to a water treatment plant on premises. Approximately ninety million gallons of water per day (mgd) would be delivered. Fifty-nine mgd would supply water needs of the proposed project with additional excess water delivered to Unit 5 (a natural gas unit) that currently draws water from the Floridian Aquifer, and the remainder of the water would be delivered to restoration sites owned by FPL (FPL 2010). As mechanical draft cooling towers operate, water droplets containing solutes can become entrained in the upward evaporative flow and deposit salts onto the surrounding environment in a process known as 'salt drift' (Miner & Warrick 1974, Shrecker et al. 1975, Talbot 1979, Lin et al. 1994). The predicted maximum salt drift from the cooling towers for Units 6 & 7 is 900 kg/ha/mo based on conservative estimates (FPL 2010). Salt deposition rates attenuate beyond the immediate vicinity of the makeup reservoir. Wetland and nearshore habitats are predicted to receive varying rates of deposition (FPL 2010). Although the Nuclear Regulatory Commission does not require a backup source to ensure the availability of water, FPL will build a secondary system that would use radial collector wells (RCW) composed of four onshore caissons with eight lateral lines to draw water from 40 feet below the bottom of Biscayne Bay to a distance approximately 900 feet from the caisson. When these wells are in operation, they will draw approximately 125 mgd. Water sourced from both Miami-Dade County reclaimed waste-water and the RCW will be treated by reverse osmosis at FPL's water treatment facility to reduce the concentration of corrosive solutes which could damage the cooling tower machinery. Based on the results of modeling provided by FPL, while the radial wells are in operation, a 0.55 ppt. maximum average salinity difference could be detected within the Bay within a predicted radius from the RCW (FPL 2010). As of May 2012, Units 6 and 7 are currently being reviewed in both state and federal processes.

1.3 Permitting Process and Stated Conditionalities

In the State of Florida, a proposed nuclear reactor must go through both state and federal processes of environmental review. Within the state process, Florida Electrical Power Plant Siting Act (F.S. 403.501-.518) is the state's centralized process for licensing large power plants (Figure 1.6.1). In the pre-application stage, the applicant files a Notice of Intent (F.S. 403.5063) to submit an application. The applicant works with reviewing agencies to determine what information should be included in the application. The Public Service Commission (PSC) reviews the need for power generated by the proposed facility in relation to the needs of Florida and issues a Need Determination (F.S. 403.519). Several federally delegated permits may be acquired separately at this time. They include Preconstruction/Prevention of Significant Deterioration/New Source

Review program (PSD/NSR), National Pollutant Discharge Elimination System/Wastewater program (NPDES), Underground Injection Control Program (UIC), Resource Recovery and Conservation Act program (RRCA).

The next stage is the site certification process. The applicant must file a Site Certification Application (SCA) with the Florida Department of Environmental Protection's Siting Coordination Office (SCO). The certification replaces local and state permits. Local governments and state agencies within whose jurisdiction the plant is to be built participate in the process. A certification grants approval for the location of the power plant and its associated facilities such as transmission lines, fuel and cooling water supply infrastructure, and the electrical grid. At this point, entities and persons affected by the proposed project can attend hearings and provide comments, typically represented by attorneys (F.S. 403.5604). After the certification application is filed, the completeness review begins (F.S. 403.5066). The SCO, with input from affected agencies determines if the application contains enough information for agencies to analyze impacts of the proposed project. The Land Use Determination (F.S. 403.5066) is the statement that gives local government the authority to make a finding regarding consistency of the proposed project with local land use plans and zoning ordinances. The applicant then puts out public notices (F.S. 403.5115) and the local government may host public meetings to receive public input (F.S. 403.50663). Each affected agency may then submit a Preliminary Statement of Issues (F.S. 403.507(1)) to the SCO and the applicant to address concerns with a proposed project. The agencies then prepare their official reports which include: an assessment of jurisdictional issues, recommendations of whether the agency would approve or disapprove of the proposal, Conditions of

Certification, an assessment of exceptions and variances required to approve certification, an assessment of issues relating to the use of agency controlled land, and a summary of public comments received (F.S. 403.507(2)). It is in this process that the agencies have the most influence. However, the Siting Board may overrule a negative agency recommendation if they determine that the project is in the best public interest. The Florida Department of Environmental Protection (FDEP) prepares an analysis of the agency report and gives an overall recommendation of whether the project should be approved or denied (F.S. 403.507(5)). If denial is recommended, corrective measures are suggested which the applicant can make before reapplying. The project then goes before an Administrative Law Judge for a Certification Hearing (F.S. 403.508(2)), unless it is exempt from such by signed stipulation (F.S. 403.508(6)). The Administrative Law Judge issues a Recommended Order, which contains the facts and conclusions on the law about matters covered in the application, along with proposed Conditions for Certification (F.S. 403.509). The Recommended Order is submitted to the FDEP for presentation to the Siting Board. The Siting Board hearing is composed of the Governor and a subset of his cabinet or by the Secretary of the Florida Department of Environmental Protection (DEP), in non-contested cases. The Siting Board determines whether the power plant and associated facilities should either be approved or denied based on reasonable assurance of public welfare and safety, and compliance with agency requirements.

The federal power plant licensing process is subject to the Atomic Energy Act of 1954, as amended in NUREG-0980, which requires that civilian uses of nuclear materials and facilities be licensed, and empowers the Nuclear Regulatory Commission (NRC) to establish and enforce standards by rule or order. In 1989, the NRC established the combined licensing process, which combines a construction permit and an operating license, with certain conditions, into a single license, the Combined Operating License (COL). The NRC may issue a COL to authorize construction of a nuclear facility (10 CFR Part 52) following the completion of the application process. The combined license includes both safety and environmental reviews (Figure 1.6.2). The National Environmental Policy Act of 1969 (NEPA) (Sec. 102 [42 U.S.C. 4332]) requires the Nuclear Regulatory Commission (NRC), as an agency of the federal government, to undertake a process of environmental review for any "major federal action significantly affecting the quality of the human environment." (10 C.F.R. Part 51). In accordance with the NEPA, NRC staff also performs an environmental review to evaluate the potential environmental impacts and/or benefits of the proposed plant (Figure 1.6.3). A typical review will include analysis of impacts to air, water, animal life, vegetation, natural resources; and property of historic, archaeological, or architectural significance. The review will evaluate cumulative, economic, social, cultural and other impacts and environmental justice. The NEPA process is designed to involve the public and gather the best available information on the proposed action so that decision makers may be fully informed. In the proposal phase of the environmental review process, an Environmental Impact Statement-Scoping Summary Report is issued. Following the completion of the report, the government may exempt an agency from the process by issuing a Categorical Exclusion (CATEX), which allows the agency to proceed with the project and omit the remaining steps. In phase two, an Environmental Assessment is issued to the EPA, wherein the proposal is analyzed in addition to the local environment with the aim to reduce the negative impacts of the development to the area. The purpose of the EA is to provide sufficient evidence and analysis for determining whether to prepare an EIS. If no significant impacts are identified within the EA, a Finding of No Significant Impact (FONSI) is issued, which allows the lead agency to proceed without having to complete an EIS. In this scenario, the EA would aid agency compliance with NEPA and help to identify better alternatives and mitigation measures. In the case that an EIS is necessary, the EA will facilitate its preparation. In phase three, the EIS is issued to the EPA and vetted.

The primary licenses that FPL must obtain in order to proceed with the Units 6 & 7 expansion are: a Site Certification Permit (SCA) from the state, a Combined Operating License (COL) from the NRC, and a Section 404 permit from the Army Corps of Engineers. The goal of the NEPA process is to avoid, minimize or mitigate undue harm to the environment in that order. In both the state and federal licensing process, reviewing agencies, often with different jurisdictional priorities, must eventually reach a consensus with regards to recommendations to improve the proposal and conditionalities of approval. The Final Environmental Impact Statement (FEIS) will identify environmental concerns related to water quality including: effluent limitations, monitoring requirements, and mitigation measures. In addition to evaluating the proposed project, the NRC must also evaluate alternatives including mitigation, “no action”, alternative locations and non-nuclear energy sources.

1.4 Present Study

The present study is an exploration of the case of the Units 6 & 7 expansion at Turkey Point Nuclear Generating Station. As the expansion undergoes federal and state review, numerous governmental, civic and non-governmental organizations are involved in evaluating the project and making recommendations to prevent undue harm to the surrounding environment. Although it is a new project, using state of the art technology, the review of Units 6 & 7 cannot fully escape associations with Turkey Point's past, or concerns for the future of Biscayne Bay. Stakeholders in the environmental review process have varying roles to play and differing degrees of influence over the review process. Ultimately, their perception of TPNGS may influence their decision-making processes, especially when confronted with the limits of science to predict outcomes. The environmental review process does not operate independently of the socioeconomic sphere; it is a multi-layered system in which both social and ecological factors interact. Indeed, Hom et al. (2009) state:

> The high potential for complex interactions and the highly uncertain scientific environment in which these socio-technical systems operate, leads to a situation in which the management of potential risk in fact becomes not only a technical and scientific issue, but a social management task.

The precautionary principle provides a framework for addressing scientific uncertainty in the minds of stakeholders, removing the burden of risk management from being placed on science entirely. In the NEPA process, the precautionary principle is employed by allowing development to occur and monitoring for potential hazards, with the condition that remedial action must be taken if an impact is anticipated (Opdam et al. 2009). However, this application relies on the ability of monitoring programs to detect impacts using ecologically relevant metrics, often at multiple spatial and temporal scales. The design and implementation of effective ecological monitoring studies are not simple tasks unless the effect of predicted impacts are large and well defined in time and space and in their nature. In the face of uncertainty, stakeholder perception of environmental risk from nuclear power projects to the coastal zone may influence the process of environmental decision-making. The use of the precautionary principle in environmental impact studies can address attitudes and perceptions (which may be driven by uncertainty) by insisting that policy decisions err on the side of environmental wellbeing. Maximizing precaution can also make monitoring programs more efficient by instituting procedures that increase the power of studies to detect impact should it occur. The role of the precautionary principle in the design of environmental impact assessments is intimately related to well-understood probabilities of errors in decisions about ecological (and many other scientific) theories based on statistical tests. Conducting a statistical power analysis prior to implementation of a monitoring program is one of many tools to maximize efficacy of impact detection (Smith et al. 1993). Thus to improve the environmental review process, there is both a need to investigate the perceptions of key stakeholders with regard to environmental risk and its effect on their decision-making processes, and a need to improve processes for obtaining empirical data to validate or repudiate those decisions.

CHAPTER II: Stakeholder Perception of Environmental Risk

2.1 Background

Reaching viable, equitable, and acceptable decisions to balance environmental management with societal needs requires involvement of a wide range of stakeholders, (National Research Council 1994, 1995; Commission on Risk Assessment and Risk Management 1997; Burger et al. 2008). Managing ecosystems is partly a social process (Norgaard 1992; Meffe & Viederman 1995), and this is particularly true for dealing with nuclear sites where both the human and environmental security spheres interact to frame stakeholder perception. Although considerable attention is devoted to environmental monitoring and assessment with respect to the status of a particular plant on the surrounding biota, less attention is devoted to assessing public attitudes about the relative environmental risks (and benefits) of different technologies. Human perception affects both decision-making processes as well as analytical studies (Gutrich et al. 2005). Perception of environmental issues influences human action to manage and protect the functionality of ecosystems. Gaps in issue-specific environmental awareness and lack of available independent information contribute to the divide between environmental risk perception and objective environmental risk (Fletcher et al. 2009, Petrosillo et al. 2009). Methods to assess risk perception include the development of cognitive maps and psychometric paradigms to explain the perception of hazards (e.g., Slovic 1992, McDaniels et al. 1995, Burger 2003, Burger et al. 2008). The environmental risk perception and accessibility of accurate and up to date ecological information by stakeholders involved in the management process is of particular relevance when new projects are being considered (Suman et al. 1999). Psychological elements, such as social and cultural values, economic realities and political factors inform the decision-making process. So do technical risk estimates provided by experts, or results gathered in risk assessment (Slovic 1992, Bechtel 1997). The establishment of management priorities depends largely on the perception of environmental risk by managers, which is in turn influenced by the diffusion of issue-specific environmental information. The incorporation of analysis of manager and stakeholder perceptions is increasingly being included as a part of the risk assessment process (Petrosillo et al. 2009).

The environmental review process for new nuclear reactors is a complex, multi-organization effort involving numerous federal, state and local agencies. Other groups, such as civic organizations, local municipal government and non-governmental organizations (NGOs), also influence the process through attendance at meetings, public education campaigns, political processes, legal action, and avenues internal to the review process.

2.2 Goals and Objectives

The goal of this study was to assess the perception of risk to Biscayne Bay from the operation of current and proposed cooling systems by a targeted group of individual stakeholders and managers. In this study, I examined the attitudes and perceptions stakeholders hold about the interaction of the Turkey Point Nuclear Generating Station with the adjacent nearshore marine environment. My overall hypothesis was that perceptions will be fairly heterogeneous within and across stakeholder groups on most topics due to multiple factors that influence decision-making.

The study examined perceptions of key stakeholders on the following topics: 1) purpose of the Units 6 and 7 expansion; 2) environmental change and threats to Biscayne Bay; 4) comparative environmental risk to the marine environment from cooling systems used at TPNGS; 5) satisfaction with and efficacy of the permitting process. The intent was to characterize convergences and divergences of perception on these topics within and between stakeholder groups.

Educational and professional background (Grimble & Wellard 1997, Burger et al. 2008), gender (Bord & O'Connor 1997, Sjöberg 2009), and jurisdictional proximity (Fort & Rosenman 1993), have been identified in the literature as external factors which may influence the decision making process. The background of each stakeholder was studied to provide insight into some of the variability of perception of environmental risk within and between stakeholder groups.

Perceptions of the purpose of the Units 6 and 7 expansion were analyzed to identify stakeholders who were categorically supportive of the expansion, those who were only conditionally supportive, and those who were against the expansion entirely. A further goal was to categorize beliefs about the need for increased energy generating capacity in the region, and the appropriateness of the expansion's location.

Although TPNGS is located on the shores of Biscayne Bay, I predicted that stakeholders who work on issues relating to TPNGS would have varying perceptions of past and present conditions in Biscayne Bay and different concepts of the environmental risk it faces. A working knowledge of the surrounding environment and history of the Turkey Point location is crucial to contextualizing environmental risk and change. One section of the interview was devoted to gauging perception of changes (both naturally occurring and anthropogenic) Biscayne Bay has undergone over time and the perception of whether those changes were ongoing or had already taken place. With an urban watershed, Biscayne Bay is subjected to a variety of anthropogenic stressors, most of which are unrelated to TPNGS. This section explores the perception of the health of Biscayne Bay by stakeholders.

To build on perceptions of the health of Biscayne Bay, a section of the interview was devoted to exploring perceptions of environmental risk to the Bay attributed specifically to TPNGS. This section does not cover perceptions about risk posed by nuclear reactor technology (spent fuel storage, radio nucleotides etc.) or catastrophic events (earthquakes, hurricanes, rapid sea level rise, acts of war etc.), but focuses on normal plant operation, specifically of the plant's cooling systems. The objective of this section was to have stakeholders rank cooling system technologies TPNGS has used in the past, continues to use, and proposes to use in the future, in terms of their potential for environmental impact to Biscayne Bay. The section further detailed positive and negative attributes of each cooling system and determined the level of consensus between stakeholder groups on this issue.

The final section of the interview explored opinion of the licensing and environmental review process itself. Questions in this section were designed to elucidate lists of positive and negative attributes related to transparency, objectivity, and function of the licensing process. The goal of this section was to determine if respondents were satisfied with the performance of the permitting process, or if they felt it needed improvement in certain areas.

This is an exploratory inquiry of an understudied, yet highly significant, area that merits further investigation. The sample of interviewees polled in this study was not meant to be a statistically representative of the entire population of stakeholders. Members of the general public were not surveyed. Inherent in this approach were certain limitations such as generalizing the results to a broader population, which would have been feasible only with statistically representative sampling. However, this study does provide insight into environmental risk as perceived by an involved and knowledgeable cross-section of stakeholders. The open-ended format allows respondents to raise issues and themes of which the interviewer may not have been previously aware.

2.3 Methods

2.3.1 Stakeholder Interviews

I examined stakeholder perceptions of the need for expansion, environmental threats to Biscayne Bay environmental risk to the marine habitat adjacent to the TPNGS property, and the environmental review process. Stakeholders were defined as the individuals or sets of individuals who have an interest in the environmental review of TPNGS because they are party to the review process and/or could have an active or passive influence on its outcome (adapted from Reed et al. 2009). The intent was to perform an in-depth analysis of stakeholder views rather than obtain a representative overview of perceptions and compare them statistically between sub-groups. Therefore, my sample was designed to collect contrasting opinions and points of view from a highly targeted group (Fischer & Young 2007, Quétier et al. 2010, Lamarque 2011). The sample size of respondents was intentionally small (21 individuals), thus conventional quantitative statistical analysis was not appropriate. First, targeted agencies were identified by a survey of publically available site certification, combined operating license documents, recorded interagency email communications, and transcripts of public meetings. Respondents from the agencies and organizations identified were carefully selected through initial inquiry to stakeholder agencies and organizations to identify those individuals with the most direct involvement in the permitting, review and vetting of the project proposal. The intent was to interview a targeted group of peer-identified 'experts' and see where perceptions converged and diverged, by investigating their rationale with in-depth, open ended questions. Multiple agencies and organizations are involved in simultaneous, parallel review processes related to TPNGS. Many of the individual representatives of these agencies work on multiple projects simultaneously and/or are only involved partially. Further study which includes statistically compliant sample sizes from each group identified here is recommended.

Through consultation with managers and stakeholders, I examined the diversity of perceptions within and between stakeholder groups. Primary research done for the risk perception analysis part of this paper was limited to representatives of certain stakeholder agencies involved in the permitting process and did not include members of the general public. There is no means of guaranteeing that respondents were being honest and it was assumed that they were not intentionally withholding relevant information. The same sampling strategy and interview guide was used for all stakeholder groups (henceforth referred to as "panels"). The panels (Table 2.1.) included a group of representatives from agencies or organizations with direct involvement in the environmental review of the expansion project (proposed Units 6 & 7), as well as individuals with technical expertise on the potential for these projects to affect the marine environment. Participants were selected by reputation or recommendations (snowball strategy). Following an investigatory inquiry with each agency involved in the review process, the representative(s) most familiar with agency's involvement in projects relating to TPNGS environmental review, as designated by the agency initial contact, was contacted. Those individuals identified as key informants by initial inquiry and by designation by their colleagues were asked to participate in semi-structured interviews. The semi-structured interview format, following the open-ended approach that is characteristic of ethnographic and qualitative research (Whitehead 2004), was used to characterize the respondents by age, gender, formal education, length of experience working in this area/ecosystem and economic activities, and the physical proximity of the individual's workplace to the TPNGS property. Semi-structured interviews were used to collect qualitative data to understand the interviewee's point of view. Open-ended questions give a medium level of freedom to interviewees to scope their opinions on a subject, but also allow interviewers to reshape questions during the interviews to go into the predefined themes in depth (Bunce et al. 2000). The open-ended aspect of these interviews encourages informants to raise relevant issues that the facilitator may not be aware of (Bunce et al. 2000).

In total, 21 interviews were conducted. Interviews lasted between 45 minutes and 2 hours, and were carried out in person or via telephone between December 2011 and March 2012. The interviews were divided into five sections to address the five objectives of the perception study: 1) Stakeholder demographics and background, 2) Stakeholder perceptions of the purpose of the Units 6 and 7 expansion, 3) Stakeholder perception of

Biscayne Bay: past and present; 4) Stakeholder comparison of cooling systems used at TPNGS, 5) Stakeholder perception of the permitting process. The interview guide, including all formal questions can be found in Appendix A.

2.3.2 Data Analysis

Interviews were individually transcribed during the interview. Following the semi-structured interview, a quality check was performed on the data and the transcripts were formatted and edited for completeness. The final transcripts were then collated and all personal identification information of the respondent was removed. The anonymous transcripts retained information to panel level. Answers were tabulated by theme allowing easy comparison across panels. A qualitative thematic discourse analysis following Lamarque et al. (2011) is presented. The coding of qualitative data entails assigning unique labels to text passages that contain references to specific categories of information (Carey et al. 1996). For this study, I developed and assigned a list of codes that corresponded to each separate belief and also larger themes held by respondents. Following Carey et al. (1996), I began by reading responses from the interviews and then compiled a list of mnemonic codes along with their definitions. The list of codes was all-inclusive and mutually exclusive. I assigned codes to each idea within each response, which facilitated the rapid thematic analysis of discourse across panels.

A qualitative analysis of divergence and convergence of perceptions within and across panels is presented with the aid of tabulations (following Lamarque et al. 2011). Several themes were explored via expanded tables recording each distinct perception expressed and how many times the perception was repeated by members of each panel.

Several of these tabulations were further analyzed through the use of summary tables and/or histograms. Results were tabulated by number of listings within each category, within each panel and pooled across panels. The number of repetitions of attributes within a category, often called "density of repetitions", a proxy for relative divergence and convergence of beliefs was separately tabulated. This qualitative metric can be expressed as the number of times any attribute within a specific category was mentioned by a respondent within a specific panel, divided by the total number of distinct attributes within that category across panels.

To supplement qualitative discourse analysis, the perceptions of respondents for key subtopics within each theme were ranked on a five point Likert scale following Alreck & Settle (1995). Attitude and perception questions elicited responses that indicated degrees of support for or opposition to statements. For this analysis, we report support/agreement with a statement, as either: Strongly Agree and Moderately Agree. Similarly, opposition/disagreement with a statement is either: Strongly Disagree and Moderately Disagree. Neutral responses and responses which indicated the individual did not feel comfortable in their knowledge base to respond to the statements were also recorded. Tables report the mean responses where the scale of responses is: 0 = not enough information, 1 = Strongly Agree, 2 = Moderately Agree, 3 = Neutral, 4 = Moderately Disagree, 5 = Disagree.

2.4 Results

2.4.1 Stakeholder Interviews

Following the analytical strategy and interview guide, I analyzed successively the role of the respondent in the issue, perceptions relating to the need for the proposed expansion, general perceptions about past and present anthropogenic influence on Biscayne Bay – the water body adjacent to TPNGS, perceptions of potential environmental impacts to the marine environment of the proposed expansion, and views on the efficacy of the permitting process.

2.4.2 Stakeholder Demographics and Background

Analytical categorizations are a set of methods in which classification of stakeholders is carried out by the researcher based on their observations of the issue in question and theoretical perspective on how a system functions (Hare & Pahl-Wostl 2002). In this study, stakeholders were grouped into panels according to role in the permitting process within different scales of governance. However, panels were not uniform. Individual managers may be influenced by factors external to their professional context such as social networks, geographic environment, previous experience, socio-economic and cultural background (Reed et al. 2009).

Age distribution of respondents within gender categories was limited (Table 2.2). The majority of panels C, D, and E, were composed primarily of men aged 50-65. The female representatives of these panels and Panel E all fell within the 25-39 age bracket. Panel A was the only panel to have a female representative in an over 40 age bracket. Panel E was the only panel to have any representative in the over 65 age bracket.

Educational and professional background varied within and between panels. Most respondents self-identified as either “technically-oriented” or “policy-oriented”. The most common formal education (includes undergraduate and graduate) degree categories were Biology, Engineering and Geology. Diversity of formal education was high within panels (Figure 2.1.1). With regards to professional experience in the public sector, the most commonly mentioned experience was environmental policy (Figure 2.1.2). No respondents from NGO's held any public-sector experience. Local respondents had the greatest within-panel diversity of public sector career experience. Career experience within the private sector was more evenly distributed (Figure 2.1.3). With the exception of Panel E, more career fields were represented in every category than the number of individuals surveyed. This indicates a high degree of occupational multiplicity.

2.4.3 Stakeholder perceptions of the purpose of the Units 6 & 7 expansion-

This section identifies and categorizes the different ways in which interviewees perceived the need for increased energy-generating capacity in South Florida in general, and how they view the Unit 6 & 7 expansion within the context of energy demand in particular. Analysis of how the interviewees explained the impetus to construct these additional nuclear units suggests a broad array of perceptions.

Although on April 11, 2008, the Florida Public Service Commission issued an affirmative Determination of Need for the construction of two additional nuclear generating units at FPL's existing Turkey Point power plant site, perceptions of the need for increasing energy generating capacity in South Florida were generally negative (Figure 2.2.1). Respondents who answered positively to this question largely supported their response by citing the Public Service Commission's Determination of Need which is issued by the state based on population growth projections (F.S. 403.519). Qualitative differences were observed between panels. Respondents from Panel A (the applicant) all answered affirmatively to the question of need, whereas members of federal, and largely, local agencies and NGO's, answered negatively. Responses from state agencies were the most diverse. Not only did respondents from the state disagree on whether there was a need for increased energy generating capacity in South Florida, they had the broadest range of explanations for this belief. The question "Is there a need for increased energy generating capacity in South Florida?" evoked spontaneous comments on the PSC, either critical or supportive of the findings of the Determination of Need. Across panels, the most commonly held perception was the belief that the population growth rate projections used by the PSC to make its determination of need are outdated. This opinion was expressed by at least one respondent from every panel except Panel A. For example:

> The PSC produced a statement of need based on economic projections during the height of the real estate boom. Their projections were off…. Economic estimations of the cost of nuclear energy were retrospective, whereas projections of demand were prospective. - Local Participant

Representatives of Panel A (the applicant) offered evidence to the contrary, stating:

> The average annual growth is 2.8%. Projections say that, despite changing economic times, we can expect to see 2-2.5% growth over the next decade. -FPL Participant

Other groups of interviewees, presenting the official agency position, declined to give their personal belief on whether the PSC's projections are appropriate:

> That question can be answered by the Public Service Commission. They decide whether the facility is needed and we proceed based on their decision. They've decided it is. Our agency does not comment on this. - State Agency Participant

From federal participants to NGO's there was a clear choice of negative response to the question of the 6 and 7 expansion being the best way to meet energy demand (Figure 2.2.2). Panel A (the applicant) was entirely in favor of the Units 6 and 7 expansion. They were joined on this belief by some respondents from state agencies. Some federal and state participants supported nuclear expansion but were uncertain about the TPNGS location. The reasons for these beliefs, according to the respondents, were: concerns about sea level rise, inability to comment prior to completion of official review of alternative sites, safety concerns about proximity to the city of Miami, and environmental concerns about proximity to a national park. Negative aspects of the location of TPNGS were generally recognized, but benefits of this location were also identified. The positive attributes of the Turkey Point site that were identified included, for example, that it is currently an operating site, therefore preferable to a greenfield site. Respondents mentioned that the infrastructure is already available and that this option has less of an environmental footprint than constructing new reactors at a pristine location (FPL and State participants). Mentioned as both a positive and negative attribute was TPNGS's proximate location to the city of Miami. Detractors held this as a safety concern, citing lack of adequate evacuation plans for the major metropolitan area. Proponents indicated that proximity to center of demand made this location more energy efficient.

> Miami-Dade is the largest population area in southern Florida. It is the epicenter of energy demand. The further away you build a plant from the load center, the larger your transmission losses. You will need to generate less energy to compensate for transmission losses when you build closer to the demand. - FPL Participant

The majority of those opposed to nuclear expansion were from local agencies and NGO's. These individuals largely favored increasing alternative energy contribution and increasing energy efficiency over construction of new reactors at TPNGS.

Despite trends for negative response to expansion at TPNGS evidenced in the previous two questions, the majority of interviewees across panels believed that the proposed expansion will proceed to construction (Figure 2.2.3). Across panels, more respondents believed that the project will be built and of these answers, respondents were fairly varied in their explanations for their belief. The most common clarification was the critical comment that the political climate has influence over whether a project is built or not. This belief was held in common by state agencies and NGOs, but not the others. Others believed the project was too economically risky, or that it would face challenges of negative public opinion. Of those who believed that the project would not be built, the most common response was that the applicant does not intend to build this project.

> They [the utility] will take the money to improve the transmission lines, and then turn around and build a natural gas generator at the site. This [Units 6 & 7] is just a pipe dream for them. - Local Participant

Within panels, the greatest diversity of response came from federal and local agencies as well as NGOs, although most panels, with the exception of Panel A (the applicant), were widely varied both in response and explanation.

2.4.4 Stakeholder Perceptions of Biscayne Bay: Past and Present

Diagnostic ecohistory of Biscayne Bay, as perceived by stakeholders was explored with the question: "How has Biscayne Bay changed over the past century?". Responses were partitioned into the categories of changes to water quality and biotic changes (Figure 2.3.1). Interviewees, from federal agencies to NGO's, listed decline in estuarine conditions and changes in species assemblage as the major changes to Biscayne Bay over the last century. Respondents were also asked to provide what they perceived to be the cause of each change they listed. All listed causes were essentially anthropogenic in origin. Causes for declining estuarine conditions included: drainage of the wetlands, water management canal construction, sea level rise, the opening of

Haulover inlet, reduced groundwater seepage, and reduction in overland sheet flow due to development. Decline in estuarine conditions was attributed to the greatest number of distinct causes. However, many respondents listed multiple causes for this change. Responses which specifically mentioned decline in estuarine conditions in Biscayne Bay accounted for more than half of all responses. Federal and state agencies provided the majority of responses which mentioned decline in estuarine conditions. Although at least two members of each panel listed decline in estuarine conditions as a change occurring in Biscayne Bay since the turn of the century, no single cause for this effect had representation in every panel. Only one cause was listed for each change related to water quality other than decline in estuarine conditions. State and local agencies (panels C and D) listed the greatest number of changes. Other changes related to water quality included: inland migration of the saltwater intrusion line due to demand of the human population for fresh water, increased nutrients and decreased water clarity; both attributed to land-based pollution.

In addition to listing changes they believe have occurred in Biscayne Bay over the past century, respondents were asked to indicate whether each change was completed or ongoing. Results show a dichotomy between changes to water quality and changes to the biology of the Bay. There was generally more consensus with regards to biotic changes: whether they were perceived as completed or ongoing, and less consensus on the status of water quality changes. For example, perceptions diverged on whether the process of decline in estuarine conditions was ongoing or complete.

> Freshwater inflow was vastly reduced by the building of the flood control canal system and the development of the shoreline. Those changes were really over and done with by the 1930's. - State Participant

> To this day, canals contribute to directing freshwater into the bay in a pulsed manner that is not consistent with the ecology of the Bay. - Local Participant

Respondents mentioned biotic changes less frequently than water quality changes overall. Within the category of biotic changes, changes to fish species assemblages accounted for more than half of all listed biotic changes. Many respondents listed more than one cause for changes to species assemblages. This change was attributed to the greatest number of different causes, which included: decline in estuarine conditions, dredging of north Biscayne Bay, and overfishing. Changes to fish species assemblages were perceived by at least one member of every panel except Panel A (FPL) to be related to decline in estuarine conditions. Some categorize this change as ongoing, while others believe it is completed and likely permanent.

> Species that can't tolerate salt are moving out, while species that can are moving in. – NGO Participant

> Estuarine species have been extirpated. We could try to re- introduce red drum, but the salinity habitat to support them just isn't coming back. –State Participant

Overall, respondents expressed multiple causes for perceived changes to Biscayne Bay over time. All of these causes were anthropogenic in origin. All perceived changes were considered by respondents to be negative, with the exception of one: an increase in the amount of larger fish and game fish in north Biscayne Bay due to increased depth from dredging, mentioned by one local participant.

Respondents were asked to name the greatest threat to the current ecosystem of Biscayne Bay. Responses were grouped into five categories: 1) water quality, 2) development, 3) overuse, 4) climate change, 3) invasive species, and 5) power plant. A sixth category, "not sure" was created for answers that indicated the respondent didn't feel they had enough information to address the question. Interviewees listed water quality, overfishing/misuse of marine resources, and environmental modification resulting from coastal development as among the major threats to Biscayne Bay (Figure 2.3.2). Although respondents were allowed to identify up to two main concerns, there was a fair amount of diversity within panels across categories of threats to Biscayne Bay. However, there was a clear trend for concern about water quality, which mirrors perceptions stated in the previous question that Biscayne Bay has experienced a decline in water quality over the past century. Stressors relating to water quality were mentioned by all panels and were the most commonly mentioned type of stressor. Lack of freshwater delivery was the most commonly mentioned stressor in not only the category of water quality, but in all categories, and was identified by at least one member of every panel (Table 2.3.1). Some respondents from FPL and state agencies mentioned "draining the wetlands", a causal factor in the attrition of freshwater delivery to Biscayne Bay, but did not make the connection between the two. They considered it a standalone problem relating to overdevelopment, but not freshwater delivery. Other respondents from federal, state and local agencies, especially those with a background in hydrology, were extremely detailed in their description of the history of anthropogenic intervention in water delivery to Biscayne Bay. Only three respondents (from state agencies and NGO's) mentioned TPNGS specifically as one of the greatest threats to Biscayne Bay (Table 2.3.2). The two effects mentioned were radioactivity and concern for hypersalinity. Hypersalinity was listed with the caveat that this perceived stressor was believed to be localized in southern Biscayne Bay.

2.4.5 Stakeholder Comparison of Cooling Systems used at TPNGS

Since Turkey Point Nuclear Generating Station first began operation in 1968, it has used two different types of cooling systems for its nuclear units: a once-through open cycle system, and a closed-cycle, recirculating system composed of cooling canals. Moving forward, the system proposed for the Units 6 and 7 expansion is another closed-cycle recirculating system. However, the proposed system will use mechanical draft cooling towers supplied with water sourced either from reclaimed municipal waste water or from underneath Biscayne Bay via a system of radial collector wells. Respondents were asked to rank the systems TPNGS has used over the course of its history of operation in terms of which system they most preferred (Figure 2.4.1) and which system they least preferred (Figure 2.4.2) with regards to risk to the marine environment. Interviewees, from federal agencies to NGO's, overwhelmingly perceived the proposed cooling system as the superior system. State and local agencies, as well as NGO based respondents cited the cooling canals as the least preferred system. Not one respondent believed the proposed system to be the worst system. There was generally greater consensus on which system was the best system than which system was the least preferred. Respondents offered the least information, whether positive or negative, for the open cycle system. This may indicate a lack of knowledge or familiarity with that system since it was replaced by the cooling canals before most respondents began to work on projects relating to TPNGS.

> I am not so familiar with the once-through system, but I suspect that if we used it in the 1960's it was probably a bad idea. – Local Participant

Respondents were more hesitant and their answers were more varied when asked to name the worst system. In general the cooling canal system was considered to be worse for the marine environment than the open cycle system it replaced.

> I think we would be better off with a once-through system. People at FPL whom I've spoken to say they know the once-through system was better than the cooling canals, but negative public opinion [of the once-through system] forced the building of the canals. – Federal Participant

> The irony is that to save several hundred acres of seagrass beds from thermal damage, they destroyed several thousand acres of mangrove wetlands to build the canals. - Local Participant

However, there were some dissenting opinions:

> This is an evolution of technology. It's not that we were less environmentally conscious in the past, it's just that we were using the best technology of the day. Once-through systems were common back then. The forced-draft towers [of the proposed system] are state of the art. –FPL Participant

The cooling canal system was also perceived as worse for the environment than the proposed system. Several respondents felt that the novelty of the proposed system attracted more attention, when the cooling canal systems may have deserved more concern.

> In some respects, concern about 6 & 7 is overshadowing the real problem which is the leaking cooling canal system. – Local Participant

> Forget about 6 & 7! The cooling canals are the real problem! - NGO Participant

To further investigate the relative merits and concerns about each cooling system, respondents were asked to list positive and negative attributes of each system (Table 2.4). A third neutral category was established for respondents who were unsure or did not have enough information to address the cooling system in question. Respondents from federal agencies to NGO's, generally attributed fewer positive qualities to all systems than negative qualities. A closer examination of the perceptions about the proposed cooling system showed that while it is perceived as having the greatest number of positive attributes (Figure 2.4.3), it also has the highest frequency of negative attributes as perceived across panels (Figure 2.4.4). Respondents who preferred the proposed system often also recognized its faults, but considered them comparatively better than those of previous systems.

> I would say the cooling towers are definitely the best option, if they did it right. There's no such thing as having a perfectly closed system. The objective is to have the least amount of interaction with the surrounding environment. The cooling towers best approximate this goal. - State Participant

In general, respondents interpreted positive and negative attributes of systems in two ways: as *absolute* attributes or attributes *relative* to the other systems. For example, a perceived absolute positive attribute of the cooling canal system is that it provides habitat for endangered American crocodiles. A relative positive attribute of the cooling canal system is the perception that this cooling system is more reliable than other systems. Attributes which are inherently negative were in some cases considered positive when compared relative to the same attribute of the other systems. The most often listed attributes, whether positive or negative, were relative attributes. For example, land usage, the impacts to wetlands associated with construction, is considered a negative attribute of all systems. However, it is a positive attribute of the new cooling towers that this system would have less of an impact to wetlands, in terms of acres of wetlands developed, than did the cooling canal system, which had the largest land-use/wetland impacts of the three systems.

> Nuclear energy is a high density power source. Units 6 & 7 will allow us to produce 2200 megawatts on 300 acres. That is incredible land use efficiency, even in comparison to previous systems used on-site. – FPL Participant

Despite the fact that the proposed system was viewed by most to be the superior system, respondents had conflicted views on potential for certain risks. Many of the attributes of the proposed system which were identified as positive by some respondents were identified as negative by others. Two such attributes were the mechanical draft cooling towers and the radial collector wells. These were the two most discussed components of the proposed system (Table 2.4). For example, salt deposition from mechanical draft cooling towers was of concern to at least one member of panels from federal agencies to NGO's, but there was a low degree of within-panel consensus on this issue.

> Salt deposition from drift will have a significant cumulative effect on the Bay over time. I can convince you of this with simple math. There are techniques to use tritium tracers to measure the effects. – NGO Participant

> A number of studies have been done on this issue. The impacts are considered to be fairly small. There has been modeling done to ensure it doesn't interfere with air quality. – State Participant

The most commonly listed positive attribute of the proposed cooling system was that the primary cooling water supply would be sourced from reclaimed municipal wastewater. This attribute was listed more times than any other attribute of the proposed cooling system, both positive and negative categories included. The term "*win-win*" was used to describe this attribute by six separate respondents across four panels from FPL to local agencies. The general explanation offered for this belief was that Miami-Dade County needs to get rid of the water anyway. These individuals generally held the belief that there was plenty of water for multiple uses due to upcoming legislation to close ocean outfalls in Florida. Several respondents from FPL and state agencies commented on the reliability of this water source citing the need for a backup system. Others, especially local government, insisted the County would be able to supply the necessary amount of water. Detractors worried that there would not be enough water for multiple uses and generally believed that the proposed cooling system would compete with Everglades restoration projects for that water source (Panels C, D, E). Some dissent occurred when discussing potential negative attributes of this water source. The most commonly listed negative perception about the cooling towers, the belief that it would contain pollutants of concern, was linked to using reclaimed wastewater. There was disagreement between groups as to whether these chemicals are regulated.

> What is of concern to me are the particles and chemical constituents such as medications that people take in the wastewater ending up in the drift and potentially in the marine environment. Florida has regulations on acceptable levels of these chemicals and we would rely on their regulations. – Federal Participant

> Salinity is less of a concern for me than the potential for environmental pollutants of concern [EPOCs] to be in the reclaimed water. These include hormones and endocrine disrupters, which could be bad for the fish. These chemicals are unregulated. You don't even need permits for them. It's also very expensive to treat wastewater to the level that you would need to remove them. – State Participant

One aspect of the proposed system that was viewed in both a positive and negative light in comparison to other systems was its novelty. The radial collector well technology has never before been used for this purpose in the state of Florida.

> The technology is new in Florida, it's state-of-the art. People haven't seen it before and they fear what they don't understand. – Federal Participant

> The radial collector wells show potential. But we should not be testing this new technology right next to a national park, especially one with pre-existing salinity concerns. - State Participant

Many interviewees expressed uncertainty about the radial collector wells, especially concerning models used to predict impact, while others were more confident in their answers.

> The model they used for the radial collector wells is based on assumptions. It's a sophomoric, steady-state, overly simplistic black box that no agency will approve. - Local Participant

> The technology is new in Florida, people haven't seen it before and they fear what they don't understand. The model is very capable of describing where the water will come from. – FPL Participant

Disagreement over the model stems from whether the RCW will pull water vertically from Biscayne Bay or laterally from the Biscayne Aquifer. This disagreement was perceived to be a hindrance to the process. The other issue of uncertainty surrounding the terms of use of the RCW is divergence of beliefs as to the number of maximum days per year the wells will be licensed to operate and whether agreements made would be honored.

> Most of the water will come from Biscayne Bay according to FPL, but [state agency] refutes this. The two groups haven't reached a point where they can even talk about it. Until they can, we're all at a stalemate. – State Participant

> The radial wells are intended to be a backup source. The number that's being thrown around is 90 days per year, maximum use. However, there's no part of any legally binding agreement that prevents the wells from being operated 365 days a year. – NGO Participant

> Using the radial collector wells is cheaper than getting waste water from the county. Being a cynic, I'm worried they'll make it [the RCW] a primary water source. - Federal Participant

Opinions were divided within panels as to whether a backup source was necessary or even required by the NRC. Among panels from federal agencies to NGO's (Panels B, C, D, and E) there were respondents within each who mentioned that the NRC doesn't require a backup source, but there were also respondents in these panels (and Panel A) who stressed the importance of a backup source. Across all panels the RCW were understood to be a backup source.

Across all systems, perceptions of environmental risk fell into three main categories: 1) land usage, 2) water quality impacts, 3) water usage/consumption. With the cooling canal systems the most often listed negative impacts were related to water quality, specifically salinity. The most commonly repeated perception, held primarily by state and local agency-based participants, was the belief that the cooling canal system is impacting the groundwater and/or Biscayne Bay surface waters. Respondents were quite detailed in their explanation of how they believe this occurs, but their beliefs were diverse.

> There is no distinct barrier between the water in the canal system and the groundwater. The cooling canals draw water from the wetlands to maintain the water level, but also the reverse happens and hypersaline water may flow out at times. – State Participant

> There are features in the karst which are basically void spaces in which water flows very fast, unlike movement through rock. The hypersaline water flows out of the canals like a river underground and materializes in the bay as a measureable plume – Local Participant

> Turkey Point is located on the interface of two habitats: Freshwater migrating eastward from the everglades system hits a seven mile long 30+ foot deep wall of hypersaline water fueled by a perpetual motion machine. The canals are a giant wall blocking the transition between the two systems. How can freshwater get to the mangroves? – Local Participant

However, several respondents implied the threat of sea level rise would eventually eliminate concerns about the canals in general.

> Only a 0.5 ft. rise in sea level would allow for partial high tide inundation of the cooling canals. The upper bound for 50 years is 2 ft. The canals will become dredge features. I don't know what their [FPL's] plan is to prepare for that. Eventually we won't be worrying about the canals interacting with the Bay through the groundwater, they'll be part of the Bay. – Local Participant

Overall, participants identified both positive and negative attributes related to each of the cooling systems evaluated. While it was certainly not unanimous, the general consensus was that despite certain flaws, the proposed system is preferable to past systems used at TPNGS.

2.4.6 Stakeholder Perceptions of the Permitting Process

Respondents were asked to rate how satisfied they were with the permitting process (both state and federal). Reactions to the statement "I am satisfied with the permitting process" revealed a divergence in opinion between panels (Figure 2.5.1). Local agencies and NGO's were unanimously dissatisfied with the permitting process, whereas the applicant (Panel A) was unanimously satisfied. Those based at federal and state agencies had the most diverse within-panel responses. No neutral views were reported and only one respondent felt too unfamiliar with the process to comment.

To further explore perceptions about the permitting process, respondents were asked to list positive and negative attributes of the process (Table 2.5). Results were grouped into three primary categories of attributes of the permitting processes: 1) Transparency, 2) Objectivity, and 3) Function. Transparency refers to the degree of information flow, objectivity relates equity and fairness within the process, and function encompasses efficacy of the process to prevent impact as well as efficiency of resources and time. Further examination revealed that for most panels, negative attributes (Figure 2.5.3) outweighed positive ones (Figure 2.5.2). Local agencies and NGO's had nothing positive to say about the permitting process, whereas the respondents representing the applicant were able to list several positive attributes within each of the categories and only one negative attribute. The greatest number of negative attributes was related to function. The category of function also had the greatest diversity and most even distribution of specific concerns. A commonly listed positive attribute related to function was that the process was thorough. Commonly listed negative attributes related to function were: inadequate scientific rigor, and that the process was not thorough enough, but also that it was too long.

With regards to objectivity, negative attributes outweighed positive ones for all panels except the applicant. Respondents from FPL as well as some federal agencies felt that the regulatory framework provided a system of checks and balances, and was effective at preventing impact. Whereas other respondents, from federal agencies to NGO's, negatively remarked that they believed decisions were based on political will and that the process favors applicant approval.

The most common complaint about the process within the category of transparency (and overall) was the perception that the process hinders interagency exchange of information. In contrast, the most commonly listed positive attribute about the process related to transparency is that it promotes communication. Despite the general consensus that information flow is critical to the process, there was disagreement between panels as to whether information flow has been sufficient thus far. FPL based participants as well as some federal and state participants felt there was good communication and information flow within the process. Whereas local respondents and some respondents from state agencies, felt information flow was poor.

> It's been a great dialogue. We enjoy excellent communication with many different agencies and the public through public meetings. It's interesting how far we've come since we first proposed it. There was a lot of preconceived notions and bad information. I think once we all sat down and talked it made everything a lot clearer. –FPL Participant

> It's frustrating that the [state agency] isn't making them [the applicant] give us the information we need to do our jobs. We can only put in so many requests for information. – Local Participant

> One example of where the process fails is communication. We had to rush through the completeness review. Granted it took over a year, but that is because [the applicant] would not provide the information we requested, so we had to formally request it many times. Now we've reached our limit on how many requests for more information we can make. You shouldn't be limited to a certain amount of asks. – State Participant

Local agencies and NGO based interviewees had comparatively more negative perceptions relating to transparency and objectivity than other panels. Many local and NGO-based respondents mentioned that they felt they didn't really have a voice in the process or that their concerns were ignored at the state and/or federal level.

> The scoping process is the only worthwhile part of the EIS process. Once the process moves beyond the earliest stages, it is in the hands of the upper bureaucrats and there is no way to stop the momentum – NGO Participant

> The process is too strict for concerned parties to get involved and have a fair voice but not strict enough in placing the burden of proof on the applicant to show no impact. – NGO Participant

Overall, perception of the licensing process by respondents was divided according to panel membership. The applicant generally held positive views about the licensing process, whereas local and NGO-based respondents generally held negative views. State and federal agencies were divided.

2.5 Discussion

The environmental review process, collaboration between state, federal and local organizations, relies on a framework of structured formal communication and inter-organizational transparency to provide objectivity. Each agency weighs in with their technical expertise to address environmental risk. These expert opinions are integrated into the formalized process. Alternative measures, conditional approvals, monitoring programs, regulatory compliance checks, remedial action or other sanctions are put in place to avoid, minimize or mitigate impact, in that order. In large, complicated licensing projects, such as the TPNGS Units 6 and 7 expansion, which require a diverse assemblage of technical knowledge; effective communication between organizations is critical. No individual can be expected to be an expert on every aspect of the licensing process and its potential ecological, cultural and socioeconomic implications. However, by working together and effectively communicating throughout their scientific processes, technical teams can draw on the expertise of others to ensure they have the most complete, up-to-date, wider picture of the process, allowing them to contextualize their results with respect to the findings of other groups. The respondents in the present study were chosen to represent the ‘experts’ of each sector of the review process. The objective in selecting this panel was to obtain a cross-section of the different types of organizations involved, represented by the people identified by the organizations themselves as being the most knowledgeable about the topic of environmental risk and the environmental assessment process. The TPNGS licensing process is intimately tied to ideological movements that ebb and flow within the socio-political arena. The respondents in the present study had diverse views on the need for energy in South Florida and the place of nuclear energy in fulfilling those needs. The perspectives gained from this cross-section of managers is valuable because it represents the interaction between technical knowledge, information dissemination within and among agencies, and the role that external factors, such as socio-political idioms, play in the determination of environmental risk.

Respondents from FPL present the point of view of industry, and stress the ways technology has improved to meet and even surpass environmental and safety regulatory standards. They bring the perspective that nuclear energy may be one of the better alternatives when it comes to meeting the reality of the nation's energy demand, especially compared to those which produce carbon emissions. It was important to include federal managers because members of this panel have the dual responsibility of considering the nation's energy needs, and protecting federal assets such as Biscayne National Park. The respondents understood the symbolic nature of TPNGS as a case study representing the balancing act the nation must face between economic causes and environmental ones. State managers bring the perspective of being those with the primary responsibility of vetting the state review process. They are also those charged with managing a watershed already taxed with multiple anthropogenic stressors, on which both the human population and the ecosystem rely. Representatives of local stakeholder groups view the licensing process through the eyes of those that will be most affected by it in their daily lives. While the state reaps the benefit of increased energy generating capacity, the locals will bear the burden of risk, both to the environment and human safety. Local respondents understood the important role Biscayne Bay plays in their local economy. Thus, from the point of view of local respondents, any potential environmental risk posed by the expansion is also an economic one. Finally, the mission of NGO's is to advocate for causes and populations they perceive to be underrepresented in the licensing process. NGO's do not have to balance economic interests with environmental ones. They are free to, from their perspective, represent the voice of the environment itself. All of these panels, with their conflicting interests, must communicate extensively for the environmental review within the licensing process to be effective. Each group has expert knowledge which must be shared with the other groups. An exploration of the perceptions of environmental risk by each of these groups provides insight into the ability of collaborative processes to identify risk objectively.

It is well established that environmental risk perception is context dependent (Hance et al. 1989; Dunlap 1991; McDaniels et al. 1995) and that differences in socioeconomic background, jurisdictional proximity and education influence risk perception (Burger et al. 2008). Burger et al. (2008) suggested that there are three steps in the process of risk perception: acquisition of information, interpretation and synthesis of different pieces of information, and understanding of that information in light of previous knowledge, perceptions or attitudes. The present study suggests that perceptions of environmental risk and the efficacy of the licensing process by managers and regional experts are highly diverse. Differences in perceptions, for example, between federal and state agencies, and between government and other stakeholders (Kamrin

1997) may partly result from differences in available information, acquisition of information, or interpretation of that information.

Even within panels, perceptions of respondents were rarely uniform. Often, members of the same panel held widely divergent views. In other cases, views were highly convergent, even across panels. Panels were chosen by dividing representatives according to the level of governing system they worked within: federal, state, local, and NGO. However, the composition of panels to some extent concealed heterogeneity of individual experience within panels. For example, although the federal government is generally thought of as being far removed from local concerns, two federal agency representatives (Panel B) were charged with the protection of national parks. These individuals, officially part of the federal licensing process, also participated in interagency meetings for the state licensing process and worked closely with NGO's. Panels were more homogeneous in terms of age range and gender makeup. The majority of respondents were middle-aged males, whereas the majority of female respondents represented a younger cohort, most in their late 20's to early 30's. The influence of age and gender on risk assessment is context specific. Gender is widely regarded to play a role in environmental risk perception, and female respondents generally express greater concern than males (Bord & O'Connor 1997, Sjöberg 2009). Further study of a greater number of individual respondents is recommended to elucidate the influence of age and gender on risk perception in this population of environmental managers and professionals.

Psychological elements, such as social and cultural values, economic realities and political factors inform the decision-making process as well as technical risk estimates provided by experts or results gathered in risk assessment (Slovic 1992, Bechtel 1997). Although panels were created to reflect scale of government, they were generally heterogeneous in terms of other factors which influence decision making and risk assessment, perhaps accounting for divergence of perception. Grouping respondents according to scale of government is one way of analytically categorizing stakeholder groups. However, other examples of analytical categorizations, popular with users in policy and development fields (Bryson et al., 2002) include those using levels of interest and influence (Lindenberg & Crosby, 1981), cooperation and competition (Freeman, 1984), cooperation and threat (Savage et al., 1991), and urgency, legitimacy, and influence (Mitchell et al., 1997).

Perception of the need for increased energy generating capacity in South Florida, varied across panels. Responses could be divided between those that supported the determination of the Public Service Commission (PSC), those who disagreed, and those who did not mention the PSC's input. Although respondents were instructed to give their personal views, it was expected that agency representatives across all panels would give the official response that they support the determination by the PSC of need for increased energy generating capacity. Surprisingly, less than half of respondents gave this response. Disagreement with the determination of the PSC was more prevalent in local and state government. One explanation for this could be jurisdictional priority. For example, the applicant likely agreed with the PSC's determination because it supported their goals. More than half of respondents who believed that there was a need for increased energy generating capacity in South Florida did not believe that Turkey Point was the best location for increasing energy generating capacity, even if they believed that nuclear energy was the appropriate fuel source. The majority of these respondents were those who lived and worked in the same county as TPNGS, potentially evidence for a "Not In My Backyard" (NIMBY) attitude (Fort et al. 1993). Many of the respondents who opposed aspects of the expansion did so because of objections to the project's location. The most common concern was that TPNGS is located in between two national parks, specifically Biscayne National Park and Everglades National Park. Fort et al. (1993) found that from a perception and cost perspective, raising the probability of an adverse consequence reduces the welfare level of the recipient population, whether or not the adverse effect actually occurs. The recipient population in this case is the national parks, and the adverse effect is environmental impact. Differences in perception might be explained by employment history and jurisdictional priority. Those charged with managing and protecting the natural resources of Biscayne Bay and the Everglades, may fear this effect will decrease the welfare level of the parks in the sense that public perception of environmental quality issues in the parks might translate into fewer visitors. However, the potential for this effect depends upon public awareness of environmental risk in the area. Further study of public perceptions of environmental risk to Biscayne National Park is recommended. Nevertheless, this is one instance in which a NIMBY effect may be at work, where the location of the risk in relation to something of value is an even more important factor than its magnitude (Fort et al. 1993). These findings stand in contrast to the findings of Burger et al. (1998) which indicated that perceived risks were smaller for those individuals who lived in proximity to nuclear energy generation sites or who worked closely with those sites. The apparent contrast can be explained by differences in the employment history of respondents referenced in the two studies. In this study, respondents who identified more environmental risks generally worked for agencies whose primary purpose is to manage or protect natural resources (i.e., groundwater monitoring, fishery resource management). Thus, they are more likely to frame potential changes in the context of environmental risk than other groups which may first consider economic or other strictly human risks and benefits. Respondents in the Burger et al. (1998) study who worked near the nuclear plant were employed by the plant and thus were found to discount environmental risks in favor of increased job security through continued activity at the site. Respondents belonging to Panel A in general perceived less environmental risks to Biscayne Bay associated with continued activity at the site. Burger et al. (1998) attributed reduced risk perception by employees of a nuclear power plant to familiarity and knowledge that employees had acquired by working with the technology for many years without apparent problems.

Perception of environmental threats currently affecting Biscayne Bay varied across panels, but displayed several convergences. Differences between environmental threats to Biscayne Bay considered important by regional experts and managers within panels appear to reflect differences in technical expertise (both knowledge and educational background) and local knowledge (generated by personal interaction with Biscayne Bay). This suggests differences in objectives or concerns across stakeholders resulting from differences in education and training (Grimble & Wellard 1997, Burger et al. 2008), which could foster divergent priorities among stakeholders for ecosystem management. Such results highlight the need to increase awareness of the different concerns facing Biscayne Bay. Some respondents were initially hesitant about listing lack of freshwater delivery, hedging their answers with the caveat that this wasn't their area of expertise.

> From what I hear, lack of freshwater reaching the Bay is a major problem. – Local Participant

This particular response also indicated some degree of information dissemination between respondents and contacts within their social or professional network. However, in general, respondents with educational and professional backgrounds in geology and hydrology were aware of water quality concerns as were those with backgrounds in ecology, whereas respondents with engineering, management or other backgrounds were less detailed in their explanation of these concerns if they listed them at all. Many respondents from all panels mentioned they worked on multiple projects simultaneously and that review of projects related to TPNGS was not their primary responsibility. Those who worked on projects relating to Everglades Restoration, such as Biscayne Bay Coastal Wetlands projects, were generally more aware of changes that had taken place in Biscayne Bay since the early 1900's. In contrast, respondents who had other duties that were not in the same area were less familiar with the ecosystem of the Bay in general. While most respondents believed the Bay had undergone some type of changes related to water quality over the past century, respondents who reported personal experience with Biscayne Bay, worked on Everglades restoration or Biscayne Bay Coastal Wetlands projects, or who had ecological or geological knowledge of the region, were better able to elaborate on the exact nature of those changes and displayed less uncertainty in response to the question. Steel et al. (2005) found that people who live in close proximity to the coast have higher levels of awareness of marine and coastal environmental management issues.

Perceptions of environmental risk specifically related to TPNGS were more divided. Respondents who were interviewed in this study showed some inconsistent and sometimes contradictory evaluations within and across panels. This contradiction might be explained by poor dissemination of information within and between agencies. Perception of environmental risk has been linked to efficacy of information dissemination and communication between stakeholder groups. In Florida, stakeholder perceptions of environmental risk, zoning strategy, design process and expected outcomes of the Florida Keys National Marine Sanctuary project were used to assess performance of information dissemination programs (Suman et al. 1999). In the present study, a common negative perception of the licensing process was that it hindered interagency exchange of information. Approximately half of all respondents believed there was good cooperation and exchange between agencies, whereas the other half of respondents complained about lack of transparency, particularly between agencies holding licensing power, the applicant, and the rest of stakeholders: consulting agencies, NGO's, local government and the public. Lack of adequate information dissemination is one explanation for the high diversity of responses across the entire survey within and between panels. The greatest variation of perception occurred within themes where there was a high degree of uncertainty. For example, of all of the cooling systems, the proposed system drew the highest diversity of responses within and between panels. This system is still in the early phases of licensing and thus is subject to change. Stakeholders have the greatest degree of control over the final implementation of this proposed system since it has not yet been built. However, the uncertainty surrounding the proposed system has resulted in general feelings of concern over lack of information dissemination. Uncertainty was believed to delay the licensing process.

> People have voiced concerns about the radial wells. It's possible they don't like the entire project and are picking on the radial wells as an easy target to stall progress. What I think is that there's a lot of uncertainty. Our models predict there will be no impact. Radial wells have been used reliably in other systems, but they have never been used in this particular area before, so we can't be 100% sure what will happen. Even if we can be 99% sure, people are uncomfortable with uncertainty. - FPL Participant

> With technical issues, you can work through them. Models are a tool to assess risk from technology that hasn't been field-tested. But once people get involved and the NGO's and the public get involved, they can kick a process into an endless cycle of review. We [federal agencies] can do this too. We can say there isn't enough information on the system to adequately address the risks. There will always be uncertainty. - Federal Participant

> I'm not sure whether this is going to be an issue. I'm not sure that's known by anyone, which makes me nervous. We will just need to continue to ask for more information. How can you approve a project when there is so much not known? – Federal Participant

> Most of the water will come from Biscayne Bay according to FPL, but [state agency] refutes this. The two groups haven't reached a point where they can even talk about it. Until they can, we're all at a stalemate. – State Participant

One explanation for the high degree of uncertainty expressed by stakeholders is that the federal environmental review process is still in the early stages. While most agencies involved in the state process have had a chance to review the information, those exclusively involved in the federal process have not. Despite this, many state participants expressed high degrees of uncertainty. Another explanation might be that many stakeholders were experts in one particular aspect of the proposed system, but were unfamiliar with other aspects. Few respondents reported familiarity with all attested attributes of the proposed system.

In view of the increased involvement of a range of stakeholders in the decision-making process it is important to understand the best methods to transmit information to audiences of diverse backgrounds. Despite the proliferation of communication tools, there is little quantitative data on effectiveness of different methods, or on the acquisition of basic ecological and exposure information necessary to make risk evaluations (Burger et al. 2008). Inconsistencies in professional and expert testimonies, even between members of the same panel, were frequently observed. Respondents were generally well informed in areas of their own specific expertise, but less well informed about other areas. Respondents generally shared the beliefs of those whom they worked closely with. The majority of respondents referenced the names of individuals who provided them with facts that informed their beliefs on a subject. The respondents were chosen because they are recognized by their colleagues to be experts on a certain topic relating to TPNGS. The concerns of these individuals, influenced by their own socio-cultural, educational and professional biases, were likely propagated throughout their professional and social networks. Thus, while increased interagency communication facilitates information dissemination, it may also increase bias. Managers may counteract such bias by obtaining information from diverse sources, thus decreasing the likelihood their perception is influenced by one biased opinion. However, even in the event that a consensus is reached, managers can only be assured of the precision of the opinions and not their accuracy. Additionally, the process requires time: many respondents in this study indicated they had multiple professional responsibilities in addition to projects relating to TPNGS. Managers may also identify popular environmental issues as higher risk in comparison to similar issues (Petrosillo et al. 2009). An in-depth social network analysis and study of information sources is therefore recommended to reveal specific pathways of information dissemination and risk awareness between individuals and groups working on this topic.

A social network analysis might also provide insight into the degree of interagency trust. When information is passed between agencies, or opinions of certain technology are relayed between stakeholders whether during formal meetings or informal communications, the degree of trust between stakeholder groups is the deciding factor in whether that information will be accepted. Burger et al. (2008) postulated that with respect to risk perceptions of environmental problems, people process information in a variety of ways, have different degrees of trust in authorities or information providers, and have different degrees of "worry," which all affect their evaluation of risk vs. benefit tradeoffs (Slovic 1992, Burger 2003). While self-interest and competition can dictate how information is received, Weber (1968) believed that people use data as support for policy positions they've already decided on, rather than processing it to arrive at a better-informed viewpoint. Understanding how stakeholders form initial viewpoints, and the degree to which perceptions are static versus dynamic, is therefore crucial to the efficacy of information dissemination programs which aim to bring risk perception closer to objective risk assessment.

In the present study, all respondents mentioned that they work closely and communicate often with many different agencies and organizations, but reported differing degrees of trust in those relationships. People who considered themselves technically oriented often doubted the ability of other agencies to understand and use key technical information.

> An impact could be occurring and it would not be recognized by the people who are supposed to recognize it. - Local Participant

The concept of epistemic trust has been established as important for risk perception (Sjöberg 2001, 2009). Those respondents who trust people and organizations, but believe that the science backing up their risk assessment is not final, or comprehensive, express epistemic distrust. In previous work, it was found that epistemic trust was more important than social trust when it came to modeling risk perception and related attitudes (Sjöberg 2001), and the effect of social trust was mediated through epistemic trust (Sjöberg 2009). The present study indicated the presence of both social and epistemic trust and distrust between organizations with relation to environmental risk from TPNGS. Respondents from local agencies and NGO's also expressed distrust in the "upper" agencies to take their concerns into account. This lack of trust was closely tied to the perception that the permitting process is too "top-down". Local and NGO based respondents were generally more emotional and personal in their responses than other panels. The emotional reactions evidenced by primarily local respondents and NGO based interviewees in the present study indicate a lack of social trust between organizations, while the cautious attitudes expressed by mostly federal agencies indicate epistemic distrust. The concept of reasonable assurance hinges on social trust. Respondents indicated that for reasons related to time and cost, environmental monitoring is not done "*to the level of science*". Stakeholder organizations in the process of environmental review cannot design and implement monitoring programs for every potential impact by themselves; they must rely on other organizations they collaborate with to provide them with reasonable assurance. However, Sjöberg (2009) suggests that it is epistemic trust, and not social trust, which contributes to precautionary attitudes among decision-makers. Through attempting to understand the underlying issues responsible for differences in trust between organizations, decision-makers may be able to address concerns more efficiently and make the process more collaborative and inclusive.

Effective risk management requires both decision-makers and managers who are well-informed and aware of environmental issues, and the involvement of stakeholders. Despite the explosion of knowledge in the environmental sciences (Ehrlich et al. 1999), studies have shown that the environmental knowledge of the public is poor (Bebbington 2005, Steel et al. 2005, Kaplowitz & Levine 2005), with little difference in the level of knowledge among stakeholders, decision-makers and managers. Consequently, most people are not sufficiently well informed on environmental issues to contribute meaningfully to management processes (Evans et al., 2008). In research carried out by Fletcher et al. (2009) on public awareness of marine environmental issues, it was found that there was significant public interest, but that there were gaps in terms of issue-specific awareness and that the availability of independent information on marine issues was limited. In this study, lack of information dissemination between agencies contributed to diverse levels of environmental risk awareness within and across panels. The Turkey Point Units 6 & 7 licensing review processes (both state and federal) are highly complex, involving multiple consulting agencies and perhaps tens of thousands of pages of technical documentation. Information comes from multiple sources, further complicated by the fact that there are two ongoing parallel licensing processes, state and federal, in addition to the Army Corps of Engineers Section 404 permitting process. Burger et al. (2008) found that ability to evaluate environmental risk was negatively correlated with complexity of information sources, defined as the number of different pieces of information required to answer a question. The present study suggests that lack of information transparency and accessibility in the licensing process makes it more difficult for managers to adequately and objectively assess environmental risk. Many respondents cited poor interagency communication as an impediment to the review process. Habermas (1984) suggested that social norms and sanctions within interactions about information narrow the gap between disputing parties. Thus, building increased interagency communication into the framework of the licensing process could help alleviate conflicts and reduce information-gap setbacks. Environmental risk posed by the TPNGS Units 6 & 7 expansion is a complex issue set in the context of a previously disturbed ecosystem and thus is mired in disagreement among scientists and policy-makers concerning uncertainty and risks. This may account for some of the discrepancies in evaluation of environmental risks (Mertz et al. 1998, Sjöberg 2001) and appropriate management. For the public, it is even more difficult to understand a complex issue, especially when decision-makers are not able to agree upon basic information. Contributing to the lack of public understanding, the majority of respondents in this study felt the licensing process was not easy for the public to follow or become involved in. At the same time, the degree of public awareness of marine and coastal issues is often difficult to discern. Much of the existing research suggests that there is a very low level of understanding of basic concepts and principles related to the marine environment (Ballantyne 2004). An informed public, able to assimilate information on spatio-temporal patterns of environmental phenomena, is essential to making decisions about protectiveness for humans and the environment (Burger et al. 2008).

Previous and current employment were predictors for specific concerns. This may be due to information flow between colleagues working in the same office, or it might be related to the priority, mission, and focus of the agency of which the respondent was an employee. It was previously discussed that those respondents who worked at agencies charged with the protection of Biscayne Bay were more detailed in their description of past and present threats to the Bay. Similarly those who were involved in the monitoring effort of the current cooling canal system for Units 3 & 4 expressed concern that the RCW operation would exacerbate the effects of the current cooling canal system's interaction with Biscayne Bay. Those who expressed this view also held two preceding beliefs: 1) the cooling canals are communicating with the groundwater, 2) the RCW are capable of drawing water laterally from the Biscayne Aquifer as well as vertically. This latter belief was expressed primarily by Panel C.

> The system either extracts freshwater from close to the shoreline or additionally there may be groundwater discharge which would be intercepted by the wells. Another concern is the cooling canal hypersaline plume. When we start pumping those wells, it lowers the hydrolic head --the pressure water is under at a specific elevation-- inducing flow towards the well, pulling that plume towards it. – State Participant

However, when respondents who held this belief were asked to comment on the spatial and temporal scale of this effect, they generally reported that the effect would be short term and localized. Similarly, respondents who believed the radial wells were of concern independent of the cooling canal structures, also described spatial and temporal scales of radial well operation as a localized impact, with the caveat that the area proposed for building these wells is highly sensitive to areas they were charged to protect.

> The effects will be physically pretty local but the area it will impact is Outstanding Florida Waters and right near Biscayne National Park. The issue is

> really more than a local one because the aquifer being affected belongs to the entire county and the park is national domain. – NGO Participant
>
> Not a big impact, but a step in the wrong direction, nonetheless. We're trying to restore estuarine conditions. Any action which could possibly increase salinity in the bay is not well advised. – Local Participant
>
> The water belongs in the aquifer: removing it would conflict with CERP objectives. Taxpayers all over the state would be paying for conflicting water usages. We pay for the radial wells to remove the fresh water and we pay for CERP to put it back in.- NGO Participant

Other respondents, employed by an organization not charged with protecting marine or groundwater resources challenged the basis of this concern.

> The water in this layer of the Biscayne Aquifer is considered a degraded source. It's not fresh water, so removing it would not conflict with other uses. – FPL Participant

In Biscayne Bay, the environmental threat most frequently listed across panels is decline in estuarine conditions. The theme of threats to water quality via decline in freshwater availability was found throughout responses to nearly all questions of environmental risk whether they were about Biscayne Bay alone, or in relation to TPNGS. Further, while numerous anthropogenic stressors contributing to the decline in estuarine conditions in Biscayne Bay that are unrelated to or predate the operation of nuclear reactors at Turkey Point have been widely studied (Light & Dineen 1994, Marshall et al. 2009), few studies have been conducted which objectively and quantitatively assess the current and future potential for interaction of TPNGS operations with the Bay (Hughes et al. 2009). Risk assessments of nuclear generating stations usually focus on valuations of the potential probability and cost of nuclear accidents and ignore the valuation of possible sublethal stressors to the environment for everyday operations (Clark and Brownell 1973). The lack of independent environmental risk assessment studies of TPNGS since the late 1970's makes it impossible to compare risk perception to objective risk analysis, or even to assess environmental risk awareness by managers in comparison to documented phenomena. Perception vs. objective assessment of environmental risk by marine resource managers has been addressed by several studies through questionnaires and series of targeted interviews (Petrosillo et al. 2009, Petrosillo et al. 2010). These studies have been used as powerful tools in improving information dissemination and environmental security (Petrosillo et al. 2009). Independent studies (i.e., those not contracted by the utility) of the potential for interaction of TPNGS cooling systems with Biscayne Bay have, for the most part, not been conducted since the closure of cooling canal system. Several post-closure studies were done (e.g., Thorhaug 1974a, 1974b, 1979, Thorhaug & Roessler 1977), but these focused on effects of the once-through cooling system. Several respondents listed the potential for interaction of the cooling canal system with Biscayne Bay through the groundwater. Despite the fact that many agency technological experts identify this as an ongoing serious risk, few independent peer-reviewed studies have been conducted to investigate the potential for interaction (Hughes et al. 2009, Stalker et al. 2009). Of these studies, most are based on modeling efforts and lack field data. A monitoring project is currently in place to quantify the potential for interaction and document its effects on the water quality and ecology of the Bay. However, several respondents commented that the monitoring program will not effectively address the impact, if one is found. Some respondents blamed inefficacy at recognizing and addressing impact scenarios on lack of technical expertise at the agencies, while others blamed it on the lack of scientific rigor required by the process itself.

> Operations will continue even if impacts occur. They might be required to mitigate, but there is no practical way they can repair this [cooling canal] system to prevent further impacts. We don't even fully understand how the cooling canals are interacting with the Bay. Impacts aren't really relevant to this process. Models may fail to predict them and monitoring plans may fail to recognize them. – State Participant

> With these monitoring plans, we often encounter the attitude from agencies that they 'can't ask people to do science'. But in reality, you need robust, hypothesis-driven monitoring and before-after-control-impact studies to effectively detect impact. We just don't have the time or resources. - Federal Participant

Other respondents echoed that sentiment, but with a different emphasis:

> We have this concept called 'reasonable assurance'-- it's a legal concept. When someone submits an application we don't review it to the level of science like a Ph.D.…that would take too long. Instead, applicants are expected to meet the minimum amount of criteria that provides reasonable assurance that the project won't do any undue harm to the environment or human population. It's not about being perfect, or even scientific, that would take too much time. – State Participant

These comments characterize the sentiment that the environmental review process would benefit from increased scientific rigor, but that financial concerns and time constraints prevent improvement. Much of current knowledge is based on modeling efforts provided by the applicant and various consulting firms such as models created to predict impacts due to the mechanical draft cooling towers and radial collector wells. A survey of relevant literature (Raghavan 1991) returned many publications on the environmental impacts of cooling towers, but only a few of these (e.g., Hunter 1976, Raghavan 1991, Perry et al. 2004) are based on actual observations at operating power plants. Of these, two (Hunter 1976, Hindawi et al. 1976) detail the effect of mechanical cooling devices at Turkey Point Nuclear Generating Station, the location of this study. Most of the studies present observations based on untested models (e.g., Roffman & Roffman 1973, Shrecker 1975, Lin et al.1994, Andrizhievskii et al. 2001, Reisman & Frisbie 2002, Meroney

2005), and lack verification against field datasets from operating plants. Less is known about radial collector well technology in this type of environment. Within the United States, most examples of this technology have been from freshwater and riverine systems. Outside of the United States, there have been several examples of RCW technology used in saltwater systems, the majority of these in use with desalinization plants (FPL 2009). The lack of precedent for this technology in this ecosystem is perhaps the source of uncertainty which leads to increased awareness and attention from agency reviewers. However, several respondents expressed the belief that, unlike previous cooling systems used at the site, it is possible to measure source contributions of the proposed system.

> The mechanical draft cooling towers are the best choice because the water that is drawn in to replace the makeup water can be measured. We can quantify withdrawal from the system and we can quantify input. The interaction of this system with the environment can be measured. Whereas the environmental footprint of the cooling canal system is unknown because the water seeps in and may leak out in a way that isn't easily measured. – State Participant

To determine the magnitude of impact, one must be able to measure or predict the source contributions and compare them to the ambient levels of the same materials. Moving forward, long-term, accurate datasets on baseline levels of ecological metrics and source contributions will be essential to adaptive management of environmental interaction with technologies proposed for use at TPNGS.

It is difficult or impossible to separate the human safety aspects of risk perception related to TPNGS from environmental security investigation. The Unit 6 & 7 expansion is a nuclear power project being reviewed in the wake of a high profile nuclear disaster at Fukushima Daiichi in Japan. Many respondents spontaneously mentioned concerns relating to nuclear safety although no question in the survey prompted them towards those subjects. Some respondents admitted to bias against nuclear power as a whole.

> I have a huge nuclear imprint on my psyche, long before I got involved in this. – Local Participant

Proponents praised the safety aspects of the project, without prompt from the facilitator to do so. The majority of respondents felt that challenges involving public perception were perhaps the biggest obstacle to proceeding with the project on schedule. Several proponents of the project suggested that detractors were attacking the project from an environmental perspective when their concerns were really about something else.

> It's possible they [reviewing agencies] are picking on the radial wells as an easy target, when really they don't like the entire project. – FPL Participant

The influence of safety fears on the perception of the public and managers of this project is an area that merits further study. Hinman et al. (1992) found that people in both Japan and America have the highest level of dread towards nuclear accidents, higher even than their dread of crime and AIDS. Whether this dread is reflective of objective risk is another question. The present study focuses only on environmental risk posed by routine plant operation. It does not explore perception of environmental risk posed by natural disasters, acts of war, or extreme sea-level rise. In these extraordinary circumstances, human safety risk and environmental risk are intertwined. Further study is recommended to investigate risk perception by stakeholders relating to non-routine or catastrophic events. In situations involving the siting hazardous of facilities, mistrust, fear, ignorance and averseness to risk on the part of the general public and professionals has lead individuals to over-weight probability of damage from policy decisions relative to more scientific assessments of such probabilities (Fort & Rosenman 1993). To properly evaluate environmental risk perception, it is imperative to separate the effects of psychological factors which possibly cross over and influence thoughts about environmental security.

This study demonstrated that with a targeted, albeit limited, sample, perceptions of environmental risk by stakeholders were highly diverse and influenced by a variety of factors including but not limited to: information flow between and within agencies, trust, and jurisdictional priority. Some factors that were not explored in this study, or could have been explored in more detail, likely played a role in this variation. These include educational and professional background, proximity to TPNGS, socio-economic factors, gender and cultural factors. Nevertheless, it seems clear that incorporating risk perception into an adaptive management framework would be an important contribution to affect a broader consensus in policy decisions than would be possible when consideration of risk perception is ignored. Adaptive management is an approach that recognizes the uncertainty that characterizes environmental systems and the incapacity of managers to predict all possible consequences of their decisions (Bennet et al. 2005). By incorporating adaptive management frameworks into the licensing process, environmental security is continuously evaluated and policy decisions are updated to reflect present conditions and future trends. Licensing processes are designed to manage the environmental, socioeconomic and human safety risks of the construction and operation of new nuclear power plants. These processes must be able to function efficiently within shifting demographic, cultural and environmental conditions. By incorporating stakeholder risk perception into an adaptive management framework, the licensing process can successfully evolve.

2.6 Conclusions

Respondents interviewed in the present study had diverse views on TPNGS and its relation to South Florida ecosystem and economy. Although stakeholders were grouped into panels by their jurisdictional role in the licensing process, membership to a panel did not preclude expressing views vastly different from others within that panel. Stakeholders came from different educational and professional backgrounds, worked in different jurisdictional proximity to the plant, and were at different stages in their career, perhaps accounting for some of the divergence. Respondents disagreed on the appropriateness of site location of the proposed expansion, whether nuclear energy was the best alternative, and even on the existence of a demand for increased energy generating capacity. Although most respondents agreed that the overall health of Biscayne Bay has deteriorated since the turn of the century and rapid development of the Miami metropolitan area, they generally disagreed on what caused those changes and whether they were still ongoing. Only a couple of respondents mentioned TPNGS when asked to list the "greatest threats Biscayne Bay faces today". With regards to the different cooling systems used at TPNGS over the course of its history, there was general consensus that the proposed system is better than previous ones. When asked to name positive and negative attributes of the system, respondents generally felt the use of reclaimed water was a positive advancement over previous technology, but they were less united on their opinions of the radial collector wells. Overall, respondents were divided on whether they were satisfied with the licensing process. Satisfaction was generally related to perceptions of transparency and equity within the process. Those who felt they did not have enough of a voice in the proceedings were most dissatisfied, whereas those who felt the process was fairly transparent were most satisfied.

This sample of 21 representatives of stakeholder organizations provides an exploratory view into the diversity of perceptions of aspects of environmental security of Biscayne Bay and its relationship to TPNGS. While the same patterns cannot be imputed for the wider public (or even the wider population of stakeholders), such diversity of opinions indicate that better communication and further scientific understanding is needed to find a common stable state among those who vet and examine the Turkey Point Nuclear Power Project Expansion Proposal.

Chapter III: Patterns of Mangrove Fish Abundance in the Vicinity of TPNGS: An Examination of Field Data Collected from Biscayne Bay

3.1 Background

Measurement and assessment of the impact of industrial operations on the environment are of great importance because the current legal and socioeconomic environment in the United States makes determination of impact crucial to regulatory assessment and compliance. Whenever a new industrial facility begins operation, the effect of the operation on the ecosystem must be assessed. However, the design and analysis of ecological monitoring studies are not simple tasks unless the effects of the potential impact are large and well-defined. The effect of change in an ecosystem can often be assessed through the use of a statistical model that incorporates the change. A commonly recommended approach for assessing the effects of an industrial power plant on the aquatic environment is to sample the environment both before and after the plant starts operation and to test for changes in biologically relevant parameters (Smith et al. 1993). A number of articles have discussed the design of ecological impact assessments (Green 1979, 1989, Hurlbert 1984, Peterman 1990, Eberhardt & Thomas 1991). While there are numerous publications dedicated to quantifying impacts of once-through cooling systems on icthyofaunal communities of coastal bays and estuaries (e.g., Langford 1983, Morin & Hirshfield 1984, Meffe 1991), there are very few studies that examine potential impacts of recirculating cooling systems (e.g., Miner & Warrick 1974, Shrecker et al. 1975, Talbot 1979, Lin et al. 1994). It has been suggested that the greatest risk to aquatic ecosystems posed by cooling systems of thermoelectric power plants is caused by continuous exposure to sublethal stressors rather than the abrupt mortality of large numbers of organisms (Clark & Brownell 1973, Laws 2000). Typically, these studies are structured around formal tests of null hypothesis and may underemphasize power analysis prior to study design, increasing the probability of failing to reject a null hypothesis (Peterman 1990). Previous studies (e.g., McCaughran 1977, Smith et al. 1993) that discussed the evaluation of the impact of nuclear power plants on riverine fish communities, found that study design and statistical power are crucial elements contributing to robustness of environmental impact assessments.

Prior to the development of Miami-Dade County, much of Biscayne Bay was bordered by mangroves, and otherwise with herbaceous wetlands (Browder & Ogden 1999). The coastal wetlands of South Florida are highly productive habitats that provide nursery, foraging and refuge areas for many bird, fish and invertebrate species. To this day, in the vicinity of TPNGS, fringing forests of red mangroves (*Rhizophora mangle,* Linnaeus), dominate the outer perimeter of protected shorelines and islands (Lugo & Snedaker 1974). Prop root habitat provided by mangrove creeks, fringe and tree islands have been demonstrated in many regions to be critical habitat for commercially and recreationally valuable species of fish (Thollot & Kulbicki 1988, Blaber et al. 1989, Morton 1990, Thollot 1992*,* Laegsgaard & Johnson 1995, Haliday & Young 1996*,* Nalgelkerken et al. 2001), including estuarine transient juveniles (Sheridan 1992, Mullin 1995). In Biscayne Bay, FL mangrove prop-root habitats are utilized by commercially and recreationally important resident and transient fish (Serafy et al. 2003, 2005, 2007). The Magnusson-Stevens Fisheries Act defined Essential Fish Habitat (EFH) as: “Those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity” (Magnuson-Stevens Act, 16 U.S.C. 1801 et seq.). The South Atlantic Fisheries Management Council (SAFMC) designates mangroves as EFH for juvenile gray snapper

(*Lutjanus griseus*), dog snapper (*L. jocu*), bluestriped grunt (*Haemulon sciurus*), spiny lobster (*Panulirus argus*), and pink shrimp (*Farfantepenaeus duararum*) (SAFMC 2009). SAFMC also identifies mangroves as Habitat Area of Particular Concern (HAPC) for several species within the snapper/grouper complex. The ontogenic and trophic roles that mangrove shoreline habitats play in supporting fish assemblages within Biscayne Bay is complex and may vary depending on location, season and fish species (Serafy et al. 2003, Faunce & Serafy 2008).

The earliest records of mangrove-associated fishes in Biscayne Bay and Florida Bay were species lists (e.g., Odum 1970, Odum & Heald 1972, Brook 1975, Hixon 1975) often limited in geographic scale (e.g., Nugent 1970, Hixon 1975, Schmidt 1979, Thayer et al. 1987). Odum et al. (1982) compiled assemblage lists of mangrove fishes from other studies throughout South Florida (e.g., Nugent 1970, Hudson et al. 1970, Odum 1970, Bader & Roessler 1971, Heald et al. 1974, Brook 1975, Hixon 1975, Holm 1977, Schmidt 1979) but did not characterize these assemblages quantitatively beyond metrics of standing crop and species richness. In more recent years, studies of mangrove fish in Biscayne Bay have concentrated on identifying long-term (>2 years) spatial and temporal patterns across larger geographic areas (> 20 sites) using a visual belt-transect method following Rooker & Dennis (1991) (Serafy et al. 2003, 2005, 2007, Faunce & Serafy 2008). Visual belt transect survey methods are a cost efficient way to rapidly survey a large number of sites. Studies, which sample a larger geographical area, may be used to make comparisons between areas or, linear shoreline segments (e.g., Serafy et al. 2003). Other studies used geographic regions as a proxy for water quality parameters such as salinity gradients across freshwater upland sloughs to downstream estuarine embayments in Florida Bay (e.g., Ley 1992, Ley et al. 1994, 1999; Faunce et al. 2004, Green et al. 2006). These more recent studies have locally characterized the influence of microhabitat variables on species composition, finding that the influence of these variables is fish species-specific (Serafy et al. 2003).

The shoreline segment adjacent to TPNGS is unique among Biscayne Bay mangrove shoreline habitats because it lies adjacent to an operating nuclear generating station, which is in the process of environmental review for expansion. Early studies in this area were largely aimed at impact assessment of thermal discharge from plant operations. Nugent (1970) surveyed macrofauna within two mangrove creeks near Turkey Point to compare areas affected with those unaffected by heated effluents, and found total fish density was significantly higher in unaffected areas in the wet season only. Since 1968, when the thermal addition studies began, reports by Bader & Roessler (1971) and Thorhaug & Roessler (1977) included areas of South Biscayne Bay in the vicinity of Turkey Point when sampling epifaunal and nekton communities within near shore seagrass beds, but the surveys did not include mangrove prop root habitat. In 2009, FPL contracted Ecological Associates Inc. to characterize fish and shellfish assemblages in Card Sound in the vicinity of TPNGS. Sampling was conducted over a one year period beginning in March 2008. The study used a 3.0 m otter trawl towed along linear transects 60-180 m from shore (EAI 2009). However, surveys of the seagrass habitat do not necessarily reflect species distribution within the mangrove prop root (Thayer et al. 1987). Later studies which did survey the mangrove fringe in the vicinity of TPNGS did not specifically describe patterns within this area, but included sites along or near the TPNGS property in their investigation of patterns across larger geographic scales (e.g., Serafy et al. 1997, 2003, 2005, 2007; Faunce & Serafy 2008). As part of the environmental review process, in a report to the Biscayne Bay Regional Restoration and Coordination Team, Serafy (2008) identified Biscayne Bay mangrove shoreline as one of the five major aquatic habitats to be monitored in order to quantify and track spatial and temporal trends in fish diversity and abundance (density and/or biomass) in the vicinity of TPNGS. A study of mangrove fish communities of Biscayne Bay that has been ongoing in this region since 1998 is the shoreline fish community visual assessment (SFCVA). The SFCVA was established under the Restoration, Coordination and Verification (RECOVER) program as part of CERP (Serafy et al. 2005). Analysis of baseline conditions of shoreline fish prior to changes implemented by CERP is crucial to documenting anticipated changes throughout the stages of restoration. Although this study occurs adjacent to the TPNGS property (Figure 3.1.1), it has never been used to specifically characterize the shoreline icthyofauna in the vicinity of Turkey Point.

3.2 Goals and Objectives

In this chapter, I explore the ability of current SFCVA protocol to capture shifts in mangrove fish communities in the vicinity of Turkey Point Nuclear Generating Station. The specific objectives are to examine empirical data on mangrove fish assemblages collected as part of a larger study of Biscayne Bay to: 1) Characterize the baseline condition of assemblages within the study area. 2) Determine whether current sampling intensity in this region is sufficient to capture change in assemblage and species level metrics at different spatial scales using statistical power analysis. Understanding statistical power provides three ways to improve environmental monitoring. First, it allows the most sensitive tests to be chosen from among those applicable to a dataset. Second, preliminary power analysis can be used to indicate the sample sizes necessary to detect an environmental change. Third, power analysis should be used after any non-significant result is obtained in order to judge whether that result can be interpreted with confidence or the test was too weak to examine the null hypothesis properly (Fairweather 1991). In the present study, I used a power analysis to determine, based on data collected from 2005-2011, if the current study design would be able to detect change in fish communities at different magnitudes and in different areas of the property should an environmental impact or improvement in environmental quality occur. Regardless of whether local shifts in fish assemblages are caused by operation and construction of the Unit 6 & 7 expansion, or whether they are the result of external factors, or even in the case that biotic communities remain undisturbed, it is essential to be able to design a protocol with the capacity to adequately capture potential shifts an ecologically significant scale.

The most compelling reason for considering power in environmental impact studies, according to Fairweather (1991), is that Type II errors can be more costly than Type I errors for environmental management. This is because "The commitment of time, energy and people to fighting a false alarm (a Type I error) may continue only in the short term until the mistake is discovered. In contrast, the cost of not doing something when in fact it should be done (a Type I1 error) will have both short- and long-term costs (e.g., ensuing environmental degradation and the eventual cost of its rectification). Thus, low power can be disastrous for environmental monitoring programs (Fairweather 1991).

3.3 Methods

3.3.1 Study Area

The SFCVA has been monitored by the Principal Investigator's research team twice annually since 1998 (Serafy et al. 2005). The spatial extent of the SFCVA spans from Northern Biscayne Bay and Oleta River to Barnes Sound, encompassing mangrove habitat on Elliot and Sands Key, northern islands of the Florida Reef Tract (Figure 3.1.1). The present study selected a portion of the SFCVA study area relevant to TPNGS. The primary study area (henceforth referred to as "SA-1") follows the boundary line of the TPNGS property to the north, extending along the mainland shoreline of Biscayne Bay southwest and ends due south of the southwest corner of the cooling canal system in Card Sound (Figure 3.1.2). This study area was chosen to maximize mangrove habitat relevant to operations at TPNGS. A total of 477 visual surveys were completed between 2005-2011 within SA-1. Two targeted study areas were chosen to evaluate the SFCVA's ability to provide baseline data for operation of two components of the cooling system of the Units 6 & 7 expansion. The two targeted study areas (henceforth referred to as "SA-2" and "SA-3") were delineated based on maps provided by Florida Power and Light Co. in the COL Application Rev. 2. (FPL 2010) and the Site Certification Application (SCA, Chapter 5, Figure 5.1.3-1) for SA-2 and SA-3 respectively. These maps were imported into ArcGIS, and georeferenced to correspond to a shoreline base layer, then exported as a map layer. The study sites within selected zones were clipped within the boundaries delineated by FPL's maps. SA-2 was created to include area within the zone of deposition of aerosol emission from proposed mechanical draft cooling towers (Figure 3.1.3). SA-3 was designed to correspond to the boundaries of salinity change from operation of the radial collector wells of modeled operational Scenario 1 (Bechtel Power Corporation 2010) (Figure 3.1.4). A total of 193 visual surveys were completed in SA-2, and 108 visual surveys in SA-3 were completed within the 2005-2011 time period.

3.3.2 Shoreline Fish Community Visual Assessment Field Methods

Visual surveys followed the SFCVA protocol (Serafy et al. 2005) further described in Serafy et al. (2003). The surveyor snorkeled 30 m-long transects parallel to the shore and recorded the species identity, number and size-structure (minimum, mean and maximum total length) of fishes observed. When identification of all individuals to the species level was not possible, identification was done to the genus or family level following Rooker & Dennis (1991). Belt transect length is 30 m and width is 2.0 m, thus the total area surveyed per transect is 60 m^2. Visual surveys were conducted between 09:00 and 17:00 to avoid poor lighting conditions. Surveys were conducted during consecutive wet and dry seasons (i.e., July to September and January to March, respectively). Microhabitat measurements of water temperature, salinity and dissolved oxygen were recorded using a multi-probe water quality instrument. Water depth was measured at each endpoint and the midpoint of each transect using a 2 m-long polyvinyl chloride pole marked at 2 cm increments.

3.3.3 Data Analysis

Using SFCVA data from the 2005-2011 time period, I generated formal assemblage lists composed of presence-absence data, percent occurrence and average density of each species, for seasonal and annual periods within each study area. To characterize trends within the 2005-2011 period that the data was collected, I generated time series charts for each study area and each season of species richness, total fish density, and frequency of occurrence of gray snapper, as well as the microhabitat variables salinity, temperature and depth. Prior to statistical analysis, fish density values were log transformed to reduce variance. A paired Student's t-test was applied to seasonal distributions of the above listed metrics within each study area to determine if observed seasonal differences were statistically significant. Following Kushlan (1981) I calculated the number of samples (N) required to provide a statistically adequate sample using the equation $N = t_{\alpha}^2 s^2/L^2$, where t is Student's statistic for the selected confidence level α, s^2 is the variance of the sample, and L is the allowable error (Snedecor & Cochran 1967). In this study, α was 0.05, and t was determined by the number of samples within each season and study area using a Student's statistic t distribution table. The power analysis was applied to species richness, and total fish density, and density of gray snapper (*Lutjanus griseus*) for each study area and each season: wet, dry and pooled across seasons. Density of individual fish species are often dominated by zero values and such was the case with density of gray snapper in the present study. Thus, power analysis of density of gray snapper returned values for minimum sampling intensity that could not be feasibly met. Frequency of occurrence of gray snapper was chosen instead to investigate the ability of the protocol to detect change at the species level, whereas the other analyses focus on the assemblage level. To assess the power of the SFCVA protocol to detect change in frequency of occurrence at the species level, I calculated the frequency of occurrence of gray snapper (*Lutjanus griseus*) for each study area within each season for the time period spanning 2005-2011, and again for 2011 alone. A binomial power function was used to compute minimum sample size within each season and across seasons, for each study area. Gray snapper were chosen because they were consistently in the top five most prevalent species within each study area and they are a species of economic importance in South Florida (SAFMC 2010). To determine if sampling within one year was more or less efficient than pooling data taken across the study period, I conducted separate series of power analyses for each metric using data pooled across the years 2005-2011 and data from the most recent year (2011) only.

3.4 Results

3.4.1 Species Assemblages

Species assemblage is the term used to describe the collection of species making up any co-occurring community of organisms in a given habitat or fishing ground. Fish assemblages are recognized as potentially sensitive indicators of habitat degradation, environmental contamination, and overall ecosystem productivity. I compiled a list of species and their presence or absence in each study area (Table 3.1.1). SA-2 and SA-3 were sub-sampled from SA-1, thus SA-1 contains the greatest number of species. SA-1 had 47 taxa, representing 27 families. SA-2 had the second greatest species richness containing 34 taxa representing 21 families, followed by SA-3, the smallest study area, which contained 25 taxa representing 16 families. Nearly half of all taxa (23 out of 47) were present in all three study areas. To create a more detailed picture of fish assemblages within each study area, separate species lists were compiled for each, detailing the frequency of occurrence and mean density of each species present within each season, depicted in tables 3.1.2, 3.1.3, and 3.1.4 for SA-1, SA-2, and SA-3 respectively. There were general differences in frequency of occurrence and mean density values for many species between seasons. Table 3.1.5 ranks species within study areas and seasons in terms frequency of occurrence and mean density, listing the taxa with the top three highest values for each metric. The same seven taxa repeatedly appeared in the top three in terms of frequency of occurrence and mean density: Gerrids (*Gerridae sp.*), small water-column fish such as silversides, herring and anchovies (*Antherinidae/Clupeidae/Engraulidae sp*.), great barracuda (*Sphyraena barracuda*), goldspotted killifish (*Floridichthys carpio*), gray snapper (*Lutjanus griseus*), and porgies --a mixture of gerrid and sparid species (*Sparidae*), and striped mullet (*Mugil cephalus*). In SA-1 and SA-2, *Gerridae sp*. mojarras, were consistently the most frequently occurring taxa across seasons. *Antherinidae/Clupeidae/Engraulidae sp*. consistently had the highest density in SA-1 and SA-2. Most taxa that ranked in the top three for frequency of occurrence in a given season and study area also ranked in the top three in terms of density. However, some species, which ranked in the top three in frequency of occurrence consistently did not appear in the top three in mean density, and vice-versa. For example, *S. barracuda* appeared in the top three in terms of frequency of occurrence in each season in each study area, but did not once appear in the top three ranked taxa in terms of density. Seasonal differences were also reflected by the assemblage ranking. For example *F. carpio* was only ranked in the top three in terms of frequency of occurrence and density during the dry season, and annual average, whereas *L. griseus* were only ranked in the top three in terms of frequency of occurrence during the wet season, and annual average. Overall, results reveal assemblages in each study area that exhibit seasonal differences, and are dominated by a few prevalent species.

3.4.2 Water Quality

To characterize temporal trends in salinity, temperature, and depth for all study areas, microhabitat variables of salinity, surface temperature and mean depth were measured at each study site prior to survey. Salinity measured at study sites (Table 3.3.1) was significantly greater ($\propto = 0.05$) in the dry season than the wet season in SA-1 and SA-3, but not in SA-2 (Figure 3.2.1), (Table 3.2.1). Surface water temperature (Table 3.3.2) was significantly greater ($\propto = 0.05$) in the wet season than the dry season in all study areas (Figure 3.2.2), (Table 3.2.1). Mean depth, the average of depth measurements taken at each endpoint and the midpoint of each survey (Table 3.3.3) was significantly greater ($\propto = 0.01$) in the wet season than the dry season in SA-1, but not in SA-2 or SA-3 (Figure 3.2.3), (Table 3.2.1).

3.4.3 Power Analysis of Fish Metrics

The SFCVA appears effective at detecting a 30% change in taxonomic richness, total fish density, and occurrence of gray snapper in all study areas (Table 3.4.1), but not within all seasons or all sampling periods. The SFCVA may be best suited for detecting change in taxonomic richness compared to the other metrics tested. At current sampling intensity, power to detect a 30% change was only unilaterally achieved for the metric of taxonomic richness. It is generally also effective at detecting a 30% change in log-transformed total fish density, with one exception in the wet season of SA-3 in 2011. The SFCVA at current sampling intensity is mostly ineffective at detecting a 30% change in occurrence of gray snapper. However, if sampling is limited to the wet season for all study areas, the current sampling intensity for the years 2005-2011 is more than adequate to detect a 30% change in this metric. A power analysis provides the minimum number of samples needed to detect a change at any given effect size. In future studies of mangrove fish communities in the vicinity of TPNGS, researchers may require the ability to detect change at a certain level of precision. Using the power analysis conducted on the SFCVA protocol with data pooled across years 2005-2011 and with data from 2011 only, I created tables to show the minimum number of samples within each study area needed to detect a change at each level listed in 5 and 10 % increments. This was done for the metrics taxonomic richness, total fish density and density of gray snapper, and generally reflects the same information reported above for the graphs, but in tabular form to provide relevant numerical information. Seasonally resolved averages of taxonomic richness from 2005-2011 are depicted at three spatial scales in Figure 3.2.4, and summarized in Table 3.3.4. Similarly, seasonally resolved averages of log transformed total fish density from 2005-2011 are depicted at three spatial scales in Figure 3.2.5, and summarized in Table 3.3.5, while seasonally resolved averages of frequency of occurrence of gray snapper from 2005-2011 are depicted at three spatial scales in Figure 3.2.6, and summarized in Table 3.3.6. This is a useful tool to inform future studies as to the sampling intensity required to detect levels of change with management or ecological relevance. Overall the SFCVA protocol's current sampling intensity was effective at detecting relevant changes in species richness, but sampling effort must be increased to detect relevant change in total fish density and occurrence of gray snapper.

3.4.4 Taxonomic Richness-

Taxonomic richness (Table 3.3.4) was higher in the wet season at all spatial scales (Figure 3.2.4). Results of paired t- tests found taxonomic richness to be significantly greater ($\propto$= 0.05) in the wet season than the dry season in all three study areas (Table 3.2.1). A power analysis was conducted on taxonomic richness data from both seasons, finding that a greater minimum number of samples was needed to detect change at a given effect size in the dry season at all three spatial scales (Figure 3.3.1) in comparison to the wet season (Figure 3.3.2). At current sampling intensity, the SFCVA protocol is more than sufficient to detect a 30% change in taxonomic richness in any of the study areas in any season (Table 3.4.1). At all three spatial scales, current sampling intensity allows the detection of a less than 12% change in the dry season and a less than 10% change in the wet season (Table 3.4.2).

3.4.5 Total Fish Density

Total fish density, the mean number of fish of all species present in each 60 m^2 survey, (Table 3.3.5) was greater in the wet season than the dry season at all three spatial scales (Figure 3.2.5). Results of paired t-tests found seasonal differences in total fish density from 2005-2011 were significant in all study areas ($\propto$ = 0.05) (Table 3.2.1). The minimum number of samples required to detect a change at a given effect size was greater in the dry season (Figure 3.3.3) than the wet season (Figure 3.3.4) at all three spatial scales. At current sampling intensity, the SFCVA protocol is generally sufficient to detect a 30% change in total fish density (Table 3.4.1). A 30% change can be detected in all seasons, in all study areas with the exception of the smallest spatial scale (SA-3) in the wet season if only data from 2011 is used (Table 3.4.1). In this case, sampling intensity must be increased during the wet season to detect a 30% change.

3.4.6 Occurrence of Gray Snapper

Frequency of occurrence of a species is a metric that provides information about the prevalence of a species. The metric represents the number of surveys in which a species is present compared to the total number of surveys. Earlier in this section, the top three species in each section were ranked in terms of frequency of occurrence and mean density (Table 3.1.5). Certain species such as *Sphyraena barracuda* were often in the top three in terms of frequency of occurrence, but not of density, suggesting this species is commonly encountered, but not in large numbers. A power analysis was conducted on frequency of occurrence of gray snapper (*Lutjanus griseus*) within each season. Occurrence of gray snapper (*Lutjanus griseus*), the number of surveys where gray snapper were present compared to the total number of surveys, (Table 3.3.6) was significantly greater ($\propto = 0.05$) (Table 3.2.1) in the wet season than the dry season at three spatial scales surveyed (Figure 3.2.6). Consequently, the power of the SFCVA protocol to detect change in occurrence of gray snapper is much greater for a given sampling intensity in the wet season (Figure 3.3.6) than the dry season (Figure 3.3.5) in all study areas. At current sampling intensity, the SFCVA meets the requirements of power to detect a 30% change in occurrence of gray snapper in the wet season in all study areas, but not in the dry season at any of the spatial scales surveyed (Table 3.4.1). Sampling intensity must be increased in all study areas in the dry season to meet the requirements for power. Given the greater relative efficiency of wet season sampling for this metric, sampling may alternatively be limited to the wet season. However, this may not be optimal if certain power plant operations, disproportionately affect the dry season.

3.5 Discussion

Environmental impact assessment and monitoring can be regarded as attempts to test the null hypothesis that some human action has no impact upon the environment. The goal of these studies is to detect an impact if one really exists. Failure to detect an impact and reject a null hypothesis, can result in poorly informed management decisions. Thus, consideration of statistical power within the context of hypothesis testing is highly relevant to the design of environmental impact assessment programs (Fairweather 1991). The objective of the present study was to assess the ability of the SFCVA protocol to detect change in mangrove shoreline ichthyofaunal communities in the vicinity of Turkey Point Nuclear Generating Station. The SFCVA protocol was not originally designed to address this question, yet the existence of a long-term dataset of mangrove fish populations in the vicinity of TPNGS presents the opportunity to determine baseline condition prior to the proposed Units 6 & 7 expansion project. Concerns for the applicability of this study as a baseline include temporal and spatial scale of sampling, choice of relevant ecological metrics, and feasibility of increasing sampling to adequate levels.

Smith et al. (1993) suggested that characterization of long-term trends in fish communities prior to the construction of an industrial power plant is critical to interpreting the results of a post-impact assessment within the context of natural background variability. However, characterization of short-term trends may also be important, depending on the nature of the impact. Certain nearshore, demersal and estuarine fish communities in South Florida are strong indicators of short-term environmental condition because of their relatively rapid response times to physicochemical changes (Haake & Dean 1983, Lorenz 1999, Lorenz & Serafy 2006). The ability of a sampling protocol to detect change of a certain magnitude in any experimental treatment or field metric is dependent upon the coefficient of variability (CV= 100[mean]/SD). Both the sample size of the current effort and the variance inherent in the dataset influence the ability to detect future change.

Power in any statistical procedure is affected by the following: variability in the measurements (power is negatively related to variance), the probability of a Type I error (power is positively related to $\propto$), amount of sampling (power is positively related to sample size), and effect size (power is positively related to effect size) (Underwood 2003). Variance in this study is influenced by the type of metric chosen, the natural variability within the study area for that metric, and whether data are pooled across years and/or across seasons.

Mensurative experiments involve the making of measurements at one or more points in space or time where space and/or time is the only experimental variable or treatment (Hurlbert 1984). Environmental impact studies can be considered mensurative experiments: while the researcher cannot manipulate aspects of the impact itself, they can control spatial and temporal components of a study designed to measure it. Sampling intensity over time and space is an important component of statistical power, but power is not the only consideration when designing a study. Spatial extent of study area may be related to predicted extent of impacts as it was in this study or correspond to ecological or management zones. Studies in Biscayne Bay, which sample a larger geographical area, have been used to make comparisons between areas, or segments of the same shoreline (e.g., Serafy et al. 2003, Faunce & Serafy 2008). Other local studies used geographic regions as a proxy for water quality parameters such as salinity gradients across freshwater upland sloughs to downstream estuarine embayments in Florida Bay (e.g., Ley 1992, Ley et al. 1994, 1999; Faunce et al. 2004, Green et al. 2006). Fish assemblages may vary in response to annual, seasonal or daily time scales. The level of monitoring selected must be appropriate for measuring changes on one of these scales. When studying larger geographic regions, seasonal sampling, a form of long-term, low level monitoring, was most often used to determine patterns related to seasonal influences and change over longer periods of time. Multi-year studies are necessary to determine levels of inter-annual variability in both the fish assemblages and their environment (Faunce & Serafy 2006). Seasonal monitoring is more cost efficient for studies that are intended to take a year or more, which have the goal of detecting larger scale patterns or detect seasonal signatures. Studies of mangrove fish communities in this region that employed high intensity, short duration monitoring (monthly surveys) usually focused on a smaller number of sites (e.g., Hixon 1975, Schmidt 1979, Thayer 1987, Ley et al. 1994). A common problem when designing surveys is that scales at which impacts may occur often unpredictable, especially in advance of a disturbance. A complete analysis should, therefore, include sampling at multiple spatial scales in hierarchical design (Green 1979, Underwood & Chapman 2003). The present study focused on three different study areas, one large and two small, to test power of the SFCVA at current sampling intensity to detect changes in various metrics. SA-2 and SA-3 were delineated based on predicted impact provided by modeling efforts. SA-2 and SA-3 were subsamples of SA-1, therefore representing hierarchical nested spatial scales, but they were also designed to be relevant at different predicted impacts. Thus, if broader impacts are observed in SA-1, it might be difficult to discern from which study area they originate or if they are relevant to another pre-existing or concurrent disturbance separate from the proposed expansion. The targeted study areas encompassed relatively low sample sizes because they were opportunistic selections from a study originally designed for a much larger area. Because sampling intensity of the SFCVA is relatively fixed and the study areas cover varying spatial extent, sampling effort varies between study sites. Sampling effort was lowest for all seasons in SA-3, and greatest in the largest study area SA-1. Power to detect change in each of the metrics was greater in SA-1 than other study areas for all seasons. Although SA-1 encompassed a larger spatial extent, and therefore had the potential for greater variance, it had a roughly proportional sampling representation. However, it is important to note that these study areas must be considered individually and cannot be considered control sites for one another.

Another component of sampling intensity is temporal scale. Impacts can cause different temporal patterns of relevant variables (Green 1979). Two major temporal classes of disturbances have been identified: press and pulse (Bender et al. 1984). Press disturbances occur where an impact persists after it starts. The impact affects the magnitude of the variable being sampled, where the average levels before the disturbance is altered to a new running average post-impact (Underwood & Chapman 2003). Pulse disturbances are short-term disturbances which then cease. The impact causes short-term fluctuations in the variables being measured causing altered rates of change in ecological variables (Underwood & Chapman 2003). A third type of impact is a press disturbance where the disturbance can cause different responses at different times because of interactions with ecological cycles, physicochemical conditions or other impacts. Here, the impact cannot be detected as an altered average of the variable measured after the disturbance starts, but impact can be inferred from increased variance among times of sampling (Underwood & Chapman 2003). It is possible for impacts to occur at several simultaneous time scales and as combinations of pulse and press. It is also possible that pulse or press disturbances could elicit pulse or press responses within the environment (Glasby & Underwood 1996). Maximizing the number of periods sampled is particularly important for pulse disturbances (Underwood & Chapman 2003).

It is unclear whether potential impacts of the proposed Units 6 & 7 would be pulse or press. With currently available information, SA-3 may be more likely to experience a pulse response since this study area corresponds to the proposed location of radial collector wells (RCWs). The RCWs are meant to be a backup system, and are likely to be restricted by conditions of licensing to how many days per year they will be operational. SA-2 corresponds to potential impacts of mechanical draft cooling towers, an essential component of nuclear unit operation and are likely to be used more continuously. Thus, potential impacts may be predicted to resemble a press response if they occur, with the caveat that only if the cooling towers are operated uniformly across time which is unusual for this technology (Talbot 1979). However, without detailed knowledge of what specific operating conditions will be, it is challenging to predict the nature of responses or their presence and magnitude in the fish communities. The SFCVA protocol is designed to survey twice a year. Although there is relatively high spatial coverage of the study areas, there is low temporal coverage on short time scales. Thus, the SFCVA at current temporal sampling intensity may not be suitable to capture pulse responses that operate on shorter than seasonal time scales.

The present study explored the relative efficiency of using data collected over a seven year period vs. using data only from the most recent year. Although number of samples is greater when pooled across all years of the study (2005-2011), variance may also be greater during that study period compared to data collected from the most recent year only (2011). Thus, in the present study, it was generally more efficient to use data from 2011 only compared to data from multiple years. Although it was demonstrated that it is more efficient to use only one year of data, rather than to pool data across seven years, in most cases the current SFCVA sampling design was able to detect more subtle changes when data were pooled across years. This is because sample size was larger when data were pooled across years, compared to cases where only one year of data is used. The present study found that SFCVA protocol at current sampling intensity is effective at detecting a 30% change in taxonomic richness in all seasons and all study areas, whether one year of data were used or data were pooled across seven years. However, this protocol was less effective at detecting change in other metrics. When total fish density data were log transformed, the SFCVA was effective at detecting changes at all three spatial scales if seven years of data was used. However, when only one year of data was used, the SFCVA would fail to detect a 30% change in total fish density in the smallest study area (SA-3), underscoring the role of inter-annual variability plays in calculations of statistical power. Using data from one year only prior to a potential impact is an attractive option when designing a study because it decreases variance, thus increasing power even at reduced sampling effort. However, using data from multiple years may be important to prevent non-treatment effects related to inter-annual background variability or seasonal plant operational changes, from intruding into the study (Smith et al. 1993).

Sampling intensity within a geographic study area may be related to relative cost or time efficiency of various sampling methods. A variety of gear types have been used in Biscayne Bay and Florida Bay to sample mangrove icthyofauna including traps (e.g., Thayer et al. 1987, Ley et al. 1994), block/enclosure nets (e.g., Thayer et al. 1987, Ley 1992, Ley et al. 1999, Lorenz et al. 1999, Green et al. 2006) and visual-belt transects (e.g., Serafy et al. 2003, 2005, 2007; Faunce & Serafy 2008). Several studies, (e.g., Thayer et al. 1987, Ley et al. 1999) compared the efficacy of different gear types for sampling within the mangrove habitat. Power analyses can be an effective tool for determining the relative efficiency of different gear types and methodologies for sampling fish populations (Kushlan 1981, Ley 1992). The SFCVA uses visual belt transects, a relatively cost effective way to survey a large number of sites (Serafy et al. 2003, 2005, 2009). Within mangrove habitat in Florida Bay, visual census methods were found to be more effective at sampling large and mid-sized roving species than enclosure net methods, but less effective at sampling small benthic forage fish (Ley 1992). Assemblage metrics (e.g., richness, total fish density), frequency of occurrence, and density of multiple species making up a community have been correlated with different environmental conditions (Lorenz & Serafy 2006) and the presence/absence of multiple indicator species, or indicator assemblages, can be used to map changes (Lorenz 1999).

The present study includes assemblage lists for each study area, detailing the presence/absence, frequency of occurrence and density of the entire assemblage of each study area within and across seasons. These lists may be useful as a historical baseline with which to compare future studies utilizing similar methodology. The present study captured 47 different species in 477 visual surveys over the course of seven years. Previous studies, such as an EAI (2009) effort to assess seagrass beds in the vicinity of TPNGS did not sample within mangrove prop root habitat. The SFCVA surveys amongst the prop roots directly along the mangrove fringe, in depths ranging from 0.3 – 2.0m. In a comparative study of sampling within mangrove habitat vs. adjacent seagrass bed, Thayer et al. (1987) found species composition of seagrass beds to be significantly different between these two contiguous habitats, although mangrove associated species may utilize multiple inshore habitats (Luo et al. 2009).

The choice of biological variables to be measured is a crucial component of any monitoring process. Variables have been chosen because they are publically or politically sensitive (e.g., rare or high profile species), are commercially and recreationally exploited (i.e., fisheries), or are assumed to indicate environmental degradation (e.g., change in species diversity in marine benthos, Keogh & Quinn 1991). The important aspect of selection of correct metrics relies on the knowledge of causal pathways allowing monitoring to target individual, population or community variables that are likely to be impacted. In previous studies causality was approached by evidencing links demonstrated in the literature (usually in other parts of the world), or on ecological theory (Keough & Quinn 1991). In the present study a survey of the literature was performed on the impact of nuclear energy projects, specifically cooling systems on the coastal zone. The most commonly identified stressors were increases in temperature for open-cycle systems (Clark & Brownell 1973, Langford 1983, Morin & Hirshfield 1984, Meffe 1991, Laws 2000) and salinity for closed-cycle systems (Miner & Warrick 1974, Shrecker et al. 1975, Talbot 1979, Lin et al. 1994). However, predictions from ecological studies are often inapplicable to different habitats or geographic areas (Underwood & Fairweather 1986). The most persuasive evidence of causality is when the human activity can be manipulated experimentally and the effects directly observed (Underwood & Chapman 2003). Even when these experiments are not feasible, Keough & Quinn (1991) suggest that impact sites themselves can provide an opportunity for assessing causal relationships through hypothesis testing; although treatments are rarely replicated. Researchers must then consider the mechanism underlying observed changes, or when choosing test metrics, they must predict likely vectors of impact.

Previous studies in Biscayne Bay have repeatedly documented the local influence of microhabitat variables of temperature (Serafy et al. 2007), salinity (Serafy et al. 1997, 2003, 2007, Faunce & Serafy 2008) and depth (Serafy et al. 2007) on mangrove fish communities. In the early 1970's, a change in temperature due to thermal effluent from the Turkey Point Grand Canal and later the Card Sound Canal impacted fish communities of seagrass beds in the vicinity (Thorhaug 1979). Anthropogenically induced variability in salinity has been implicated in changes to the structure of fish communities in proximity to water management canals (Serafy et al. 1997). Changes to, or increased variability in, habitat gradients are a potential vector of impact to mangrove fish communities. Conversely, background variability and natural fluctuations in physicochemical gradients may also confound isolation of impact effects, thus appropriately designed studies will consider background variability. Despite this, it is often impossible to predict *a priori* mechanisms of impact without making assumptions about causality based on untested and unverified theory or studies from other geographic areas that may not be ecologically representative of the target area.

In the absence of definitive studies of potential mechanisms of impact in this area, the present study chose both community level and population level metrics readily obtained from a long-term dataset to assess the ability of the SFCVA to serve as an opportunistic baseline for change at multiple spatial ecological scales. Community measurements are attempts to summarize the composition of a community. In a review of the ecological relevance of different diversity metrics, Keough & Quinn (1991) stated that taxonomic richness and diversity indices are commonly used community level indices. Previous studies in Biscayne Bay have used taxonomic richness as an indicator of environmental disturbance (Serafy et al. 1997, Faunce et al. 2004). The SFCVA is more than adequate for detecting a 10% change ($\propto$=0.05) on an annual basis for the study area of greater Biscayne Bay that it was designed to monitor (Serafy et al. 2005, 2009). The present study found that current sampling intensity within all seasons in all study areas is effective at detecting a 30% change in taxonomic richness. Variance within this metric within each test was relatively low compared to other metrics used. Taxonomic richness was found to be significantly higher in the wet season than the dry ($\propto$=0.05). Previous studies of the entire mainland shoreline of Biscayne Bay found similar seasonal signatures (Serafy et al. 2005, 2009). Although species richness is found to be the most efficiently measured by the current sampling design in terms of number of samples required to detect a 10% change, it may not be the most telling of an environmental impact. The origin of the belief that taxonomic richness is negatively affected by environmental impact comes from the idea that various kinds of anthropogenic activity can depress local populations, potentially driving some to local extinction. Another view is that making the habitat more stressful would result in a disproportionate number of opportunistic species and loss of transient species. Keough & Quinn (1991) assert that marine ecological studies demonstrating such extinctions are few, and what may be more common is a reduction in overall abundance. Further discussion of the theoretical basis of the belief that environmental impact reduces diversity is presented in Keough & Quinn (1991).

A power analysis on seasonally resolved total fish density data was used address the ability of the SFCVA at three spatial scales to capture changes within and across seasons. Total fish density has been used by studies in this region (e.g., Ley et al. 1999, Lorenz 1999, Green et al. 2006, Lorenz & Serafy 2006) to address seasonal changes to mangrove fish communities, and has been correlated with changes in temperature (Ley et al. 1999, Lorenz 1999), depth (Ley et al. 1999, Lorenz 1999), and salinity (Green et al. 2006, Lorenz & Serafy 2006). The present study found total fish density was significantly higher in the wet season in all study areas except SA-1 (when only data from 2011 was used). This relationship stands in contrast to the findings of Ley et al. (1999), which indicated that densities of demersal mangrove fish communities in NE Florida Bay were higher in the winter months (dry season). A power analysis revealed that the SFCVA at current sampling intensity is effective at detecting a 30% change in total fish density with one exception. In the case of the exception (the wet season in SA-3 when data from 2011 only is used), sampling intensity would have to be increased to detect a change of this magnitude. The metric of total fish density is substantially less cost-effective in terms of minimum number of samples needed to detect change at a given effect size change than taxonomic richness, due to its high variance. Log-transforming the data can reduce some of this variance and increase the practicality of using total fish density as a metric of community change. It is also possible that total fish density may be more sensitive to environmental change. Density metrics provide insight into abundance of fish populations and the carrying capacity of habitats at different states of environmental disturbance, whereas that information is substantially more difficult to infer from taxonomic richness (Keough & Quinn 1991). Reasons for such a high variance could include the patchy distribution of schools of small water column fishes such as silversides, herrings and anchovies. When taxon-specific density data were tallied, small water column fish were the group with the highest density in all seasons in all study areas except the dry season in SA-3. When encountered within our surveys the abundance of small water column fishes is an order of magnitude greater in many cases than the taxon-specific abundance of the next most abundant species. However, the presence or absence of small water column fish in these surveys may still be important for detecting impact depending on the nature of the disturbance. Thus, silversides and others should not be categorically excluded from total fish density metrics, but instead their exclusion might be evaluated on a case-specific basis. Alternatively, community level abundance metrics, such as biomass indicators, which take into account the relative size of the fish present, might be used in conjunction with total fish density.

Population metrics target populations of a single species, and the metrics involved are generally the abundance or size distribution of all individuals in the population. As indicators of environmental impact, two different types of species are used. Positive indicators are opportunistic species which may increase their dominance under stressful environmental conditions because less tolerant competitors and predators are removed (Keough & Quinn 1991, Vega Cendejas & De Santillana 2004). The absence or decline of a species that is normally present can be as telling as the presence of opportunistic ones: negative indicator species are those that are intolerant of specific environmental conditions. Motile fish species may engage in avoidance behavior of adverse conditions, as well as positive selection of favorable ones (Browder & Moore 1981, Peterson et al 1993, Lankford & Targett 1994, Serrano 2010). Economically important species have also been used as indicators. These are often species with a high profile because they are perceived as anthropocentrically important. Charismatic megafauna such as marine mammals, as well as species of importance to commercial and recreational fishing, usually receive high priority in marine environmental debates. Although such species cannot always be used as indicators by ecological criteria, and they may not be able to imply broader community level change; they will usually be expected by managers to be components of marine monitoring programs (Keough & Quinn 1991). Future studies may focus on any species within the assemblage as an indicator. However, gray snapper (*Lutjanus griseus*) was chosen to test the ability of SFCVA protocol to detect species-specific change in the present study, because it is both a species of commercial and recreational importance (SAFMC 2010), and it has demonstrated preference behavior in response to physicochemical gradients (Serrano 2010). In addition, it was consistently ranked one of the top five most prevalent species (in terms of frequency of occurrence) in all study areas.

The first criterion for choice of indicator species in baseline assessments should be frequency of occurrence (Smith et al. 1993). Species that are not frequently encountered prior to a disturbance are generally not useful as indicators. Here, power analyses were conducted on frequency of occurrence of gray snapper within each shoreline segment and season. The ability of the SFCVA to detect change in this metric was greater in the wet season than the dry. In no case was the current sampling intensity sufficient to detect a 30% ($\propto$=0.05) change in frequency of occurrence in the dry season. In all but one case, sampling intensity would have to be more than doubled in order to detect change at this level. Percent occurrence of gray snapper in each study area was generally greater in the wet season than the dry season, thus efficiency could be maximized by limiting sampling to the wet season. However, sampling within both wet and dry seasons increases the chance of detecting impacts that are season-specific; including those that are the result of compounding interactions of impact with seasonal patterns of background variability. Additionally, although gray snapper are more prevalent in the wet season, other important species have the opposite distribution. One example is the goldspotted killifish (*Floridichthys carpio*), which is more prevalent on the mainland shoreline of Biscayne Bay in the dry season (Serafy et al. 2007). Other taxon-specific metrics such as density require fewer samples to detect change at the same effect size. These seasonal signatures reflect those found in previous studies for gray snapper on the mainland shoreline of Biscayne Bay (Serafy et al. 2003, 2005, 2005, Serrano 2010). Previous studies in this area have included taxon-specific density measurements (Faunce et al. 2004, Serafy et al. 2005, Green et al. 2006, Lorenz & Serafy 2006, Faunce & Serafy 2008). However, even in the wet season, frequency of occurrence of gray snapper was never greater than 70%, thus in at least 30% of surveys, zero gray snapper were observed. Zeros correspond to either an absence of fish in the area at the time or an absence due to low sampling intensity (i.e., low detection ability). Since sampling intensity was equal or nearly equal across seasons compared, it most likely reflects the former. The dominance of zero catches in the dry season data can increase variance, pulling the means closer to zero, thus reducing power within that season (Smith et al. 1993). Other studies have addressed the issue of zero catch dominance by employing density metrics, which reflect both frequency of occurrence and concentration. The "delta approach" incorporates frequency of occurrence and concentration when present (exclusive of zeros) into the composite delta-density metric. This approach has been used in several studies locally to improve accuracy in the characterization of patterns of variability in mangrove fish abundance at the species-specific level (Serafy et al. 2007, 2009, Faunce & Serafy 2008, Serrano 2010). Future studies may benefit from employing the delta approach to increase power within seasons.

One component of power that is rarely discussed is the setting of effect size (Fairweather 1991). The size of effects to be examined is usually determined on a case-by-case basis and involves the consideration of past results and a consensus of applicability. In the field of environmental impact study, critical effect sizes are set on a political basis as well as an ecological one. For example, environmental regulations, legal precedents, compensation cases, limits to acceptable change, aesthetic preferences, and economic considerations may all come in to play when setting effect size in designing impact studies (Fairweather 1991). The present study does not attempt to explore the ecological or political relevance of the chosen effect size. For some biological metrics, effect size may be limited or structured by the nature of the metric itself. For certain distributions, using effect sizes set in percentages would result in a fraction of a species change, which may be less appropriate. For other metrics in this study, an effect size of a change in 30% was set as the standard by which the SFCVA was judged as effective at detecting a change. Metrics that were not effective at detecting change at 30% at current sampling intensity, may be effective at detecting a change of a higher or lower magnitude depending on regulatory constraints or thresholds set by decision-makers to minimize impact. Using current sampling effort as the planned sample size for future studies, I determined the effect size of each metric the SFCVA was able to detect. Through the use of the tables generated in this study, managers can determine whether sampling effort should be increased or decreased to meet environmental regulations. Researchers can manipulate effect size and sampling intensity when designing environmental impact studies depending on whether the potential impact is low-level and cumulative (i.e. some forms of press disturbances) or relatively dramatic and short term. Environmental impacts of the proposed expansion are predicted to be minimal for both the radial collector wells and the cooling towers (FPL 2010). In general, unlike once through systems, impacts on the environment caused by recirculating cooling systems thought to be subtle and cumulative, only evident over a long period (Clark & Brownell 1973, Talbot 1979). Of course, there is also the potential for drastic effects associated with system failure not discussed in the present study.

3.6 Conclusions

Increasingly, environmental managers attempt to incorporate precautionary principles into studies of environmental impact (Green 1979, 1989, Smith et al. 1993, Underwood & Chapman 2003). In any quantitative analysis, precaution is closely related to the power of an analysis to detect an impact. Impact assessments and post development monitoring programs that have low power are inadequate and will not meet their objectives (Green 1989, Peterman 1990, Smith et al. 1993). They could lead to poorly-informed management decisions because they would have little chance of finding statistically significant effects, even if actual effects are large. However, designing studies to detect impact is complicated by natural spatial and temporal variability as well as the nature of statistical interactions which characterize impacts (Peterman 1990, Fairweather 1991, Underwood & Chapman 2003). Power analysis is a useful tool to test the relative efficiency of various study designs to detect impact in different metrics at multiple spatial and temporal scales. The present study found that opportunistically sub-sampling data from an existing monitoring program is an effective way to detect impact at relatively low effect sizes for certain community and species-specific metrics in all seasons (species richness and total fish density) but not frequency of occurrence of gray snapper in the dry season. Recommendations for future study include the determination of appropriate ecological metrics at species-specific and community levels under scenarios of increased spatial and temporal sampling. Power analysis allows the most sensitive tests to be chosen from among those applicable to a dataset (Fairweather 1991). In general, increased spatial concentration of sampling would improve power to detect press impacts, while increasing the periodicity of temporal sampling (looking at multiple time scales) would increase power to detect pulse impacts.

Ultimately, the study design and sample sizes employed determine the cost of an adequate study. Peterman (1990) contends that an inexpensive (in terms of funds and/or effort) study runs the risk of severely compromising power. However, costs can be minimized when studies are designed to target specific questions using the appropriate metrics and effect sizes. Power analysis can be used to determine *a priori* how large an effect size would have to exist to give statistical power given the planned sample size, contributing to the overall cost effectiveness of the study (McCaughran 1977, Peterman 1990, Fairweather 1991). Future studies might include a cost-benefit analysis of continuing use of the current SFCVA protocol vs. designing a Before-After-Control-Impact (BACI) study (Stewart-Oaten et al. 1986) of mangrove fish communities specifically for the Units 6 & 7 expansion. This study would be informed by policy-defined limitations on acceptable effect size, use ecological metrics which are relevant to managers, and include the use of appropriate control sites. The present study did not explore the use of control sites for specific potential impacts. The use of multiple control sites can improve prevention of (Underwood & Chapman 2003), but not eliminate (Stewart-Oaten et al. 1986), spatial confounding of impact detection. In addition to estimates of effect sizes, estimates of variance of the variables to be sampled are key ingredients of successful study design. Specifically, the relevant variances are those that occur in the absence of potential impact, before the proposed action starts. They are: the variance among replicate units in any location at any time, the variance from time to time in any location, variation among periods that differ among control locations when there is no impact, variation among times within periods that differ from location to location, and the variance among periods when there is no impact (Underwood & Chapman 2003). In the case of the Turkey Point Units 6 & 7 expansion, the SFCVA dataset can, at the very least, serve in a pilot capacity to provide these variances necessary to determine the appropriate effect sizes and necessary sampling intensity.

The requirements of precautionary decision-making revolve around the magnitude of predicted impacts or the magnitude of an impact that had not been predicted, but if it occurs, would warrant some change in management of the development or remedial action (Underwood & Chapman 2003). The TPNGS case study illustrates some of the difficulties in ecological impact assessment, especially where predicted impacts are not well defined. The question of assessing change in field situations not only requires sound knowledge of statistical difficulties, but also of biological and political ones (Smith et al. 1993). More integration of these components would be beneficial. Sound design requires a good statistical model, the understanding of underlying biological processes in the area, and careful planning with consideration of statistical power. All of these components are critical to achieve defensible impact assessments.

Chapter IV: Summary and Conclusion

4.1 Summary and Conclusion

The demand for electric power in the United States is expected to double by the year 2050 (DOE 2008). To meet these needs, thermoelectric generating capacity is projected to increase by nearly 22% between 2005 and 2030, based on Energy Information Administration's (EIA) Annual Energy Outlook (2006). Nuclear power provides 19% of energy consumed in the United States. As of March 2012, twenty-seven new nuclear reactors are in the process of review for a combined operating license from the Nuclear Regulatory Commission, and the majority of these are located near rivers, lakes, or the coast (NRC 2012). As more nuclear reactors enter licensing, there is an increasing need to understand the human dimension of the environmental review process: specifically, how decision makers are influenced by perception of the risks associated with new nuclear projects. Despite nearly five decades of nuclear energy generation in the United States, there are surprisingly few studies in the published literature that consider statistical power in designing studies to detect environmental impact to the aquatic environment from thermoelectric power plants (McCaughran 1977, Smith et al. 1993). While the present study provides some insight into the roles of stakeholder perception and statistical power in the environmental review process for a particular case, there is still much to learn about best way to apply these research modes to Turkey Point and future projects. Previous studies have suggested that human perception affects both decision-making processes as well as analytical studies (Gutrich et al. 2005). However, it is just beginning to be considered in standard environmental risk assessment practice (Petrosillo et al. 2009).

The present study demonstrates that stakeholder perception, statistical power, and the precautionary principle intersect at the crossroads of uncertainty. Previous work has identified three sources of uncertainty which hinder environmental decision-making: *ignorance* (inadequate understanding), *unpredictability* of ecological system behavior and *ambiguity* in the science policy interface (Opdam et al. 2009). While all three sources of uncertainty are present in the TPNGS case study, Opdam et al. (2009) present that only ignorance can be solved by science alone. Respondents selected from stakeholder categories specifically for their expertise on environmental issues relating to TPNGS demonstrated in the perception study that there is more disagreement than consensus among decision-makers on this topic. For example, stakeholders generally identified increasing salinity as a primary stressor to Biscayne Bay which predates the construction of TPNGS, but may be aggravated (in their opinion) by present and future cooling system operations. However, respondents could not agree on the spatial and temporal extent of salinity impacts, the ecological implications, or even the vector by which it would act. When predicted impacts are uncertain, it is especially difficult to design studies to adequately capture them. Environmental impact study designs generally rely on baseline data of multiple ecological and physicochemical metrics taken before predicted impact occurs to establish a baseline by which change can be measured (Stewart-Oaten et al. 1986). Researchers must not only predict the impact, but its spatial and temporal extent in order to design studies which capture it with any accuracy or precision. With ecological baseline studies, researchers have the added task of anticipating the ecological implications and possible cascading effects of a physicochemical change. Researchers must design studies that capture these effects at ecologically relevant sizes above the background noise of numerous confounding factors, without knowing much about how these impacts will occur, although advancements in predictive modeling have improved this process dramatically (Underwood & Chapman 2003). Scientific information always comes with uncertainty because of limitations of data or knowledge, because of the inherent stochasticity in natural systems, and because environmental impact studies operate within the context of regulatory time and monetary constraints (Reckhow 1994, Harremöes 2003). However, Opdam et al. (2009) propose that according to the precautionary principle, science does not have to bear the responsibility for providing certainty to decision-makers.

An emerging practice of employing the precautionary principle to manage uncertainty is to allow activity to occur, while accepting a certain risk, and then to monitor for potential hazards with the condition that activity will cease if an impact is discovered (Opdam et al. 2009). This application relies on the ability of monitoring programs to effectively detect ecological signatures of disturbance. The present investigation used three study areas to probe two specific vectors of potential impact to the nearshore environment provided by respondents in the perception study. It found that an ongoing monitoring effort funded by the U.S. Army Corps of Engineers could provide baseline data to effectively detect a one-species change in average taxonomic richness on a seasonal or annual basis within each study area. However, sampling effort must be increased to detect changes in metrics prone to higher variances such as frequency of occurrence of gray snapper (*Lutjanus griseus*). The influence of salinity on taxonomic richness of mangrove fish communities has been demonstrated by previous studies in Biscayne Bay (Serafy et al. 1997, 2003). While Serafy et al. (2003) correlated increased salinity with increasing species richness on the leeward key islands of Biscayne Bay compared to the mainland shoreline, Green et al. (2006) found the opposite relationship in NE Florida Bay. Increasing salinity was not the only predicted threat. Respondents also mentioned changes in salinity variability, a factor that is negatively correlated with taxonomic richness (Serafy et al. 1997). Community level density metrics may be less sensitive to salinity changes (Ley et al. 1999, Lorenz 1999). Thus if salinity is the predicted stressor, another metric with a documented relationship to salinity, such as biomass (Lorenz 1999), may be more appropriate. Previous work suggests that the effect of salinity on mangrove fish in this region is species specific (Serafy et al. 1997, Lorenz 1999, Faunce et al. 2004, Serafy et al. 2003, Lorenz & Serafy 2006). The assemblage of species present can serve as an indicator of salinity conditions (Lorenz 1999, Faunce et al. 2004, Lorenz & Serafy 2006). Population level metrics, along with changes in taxon-specific density/abundance and frequency of occurrence, may provide more information about the nature of ecological effects of salinity changes on mangrove fish communities. Meanwhile, it is also possible that salinity changes may affect different species in complicated non-linear ways: gray snapper density and frequency of occurrence has a parabolic relationship with salinity in lab observations but a linear one was established from field observations (Serrano 2010). Even if the appropriate metric is designed in advance to measure the appropriate type of impact, there are multiple confounding factors. These factors not only include biotic interactions, physicochemical and habitat parameters that influence fish distribution, but also preexisting anthropogenic salinity alteration in Biscayne Bay. Further study in this area is recommended to determine the various causes of background variability in mangrove fish community dynamics. With that information in hand, the ecological signatures of impact may be more easily recognized. In addition, laboratory studies of the preference and tolerances of species commonly occurring in the vicinity of TPNGS may shed light on how species movement into and out of habitat is evidence of broader changes or crossed thresholds.

Turkey Point Nuclear Generating Station presents an excellent case study in the roles of perception, power and precaution in the environmental review process. The first cooling system used at the site became a textbook case study of environmental impact (Laws 2000). A high-profile investigation into thermal pollution of Biscayne Bay and later Card Sound resulted in the creation of the cooling canal system. It was a brutal tradeoff: To deal with the problem of damage to several hundred acres of seagrass bed, 8000 acres of mangrove and wetland habitat were leveled to build the cooling canal system. At the time, recognition of the ecological importance of seagrass bed habitats was on the rise, while the value of mangrove habitats was yet to be widely studied (Laws 2000). An unexpected benefit of the cooling canal system was that it provided critical habitat for endangered American crocodiles (*Crocodylus acutus*) and is partially responsible for saving this iconic species from the brink of extinction. Today, as Everglades Restoration prepares to implement $1.6 billion in projects to restore Biscayne Bay's coastal wetlands to their formerly estuarine condition (CERP 2011), the environmentalist and environmental professional community is perhaps more aware of salinity changes that have taken place over the past century in Biscayne Bay. The cooling canal system, which was designed in the late 1960's, is unlined and the surrounding substrate is highly porous. This results in uncertainty as to whether this hypersaline system is communicating with groundwater and impacting the surrounding wetlands and Biscayne Bay (Hughes et al. 2009, SFWMD 2009). The lack of formal studies evaluating the potential for this effect has led to uncertainty among stakeholders. A socio-political/regulatory environment in which there is lack of scientific consensus but high risk is ripe for the propagation of worry and precautionary attitudes (Sjöberg 2009). While worry might be considered counterproductive, precautionary attitudes may actually make a review process more thorough. Petrosillo (2009) found that the more different types of environmental risk managers were aware of, the more active they were in risk prevention. Stakeholders in the perception study expressed concern that current and future operations at TPNGS have the effect of increasing salinity in Biscayne Bay, feeding a trend that Everglades restoration projects are meant to reverse. This uncertainty has led to a major multi-organizational monitoring effort which includes assessment of the potential for salinity impacts to Biscayne Bay from the cooling canal system (SFWMD 2009). Additionally, the land-use aspects of the system itself are large enough to generate concern that the canal system may present a physical barrier to freshwater flow in the upper layers of the aquifer into Biscayne Bay. However, this effect has not been formally evaluated. It is within this context of previous environmental impact and uncertainty of the potential for current environmental impact that FPL is proposing to build two new nuclear units at the Turkey Point site. Concern about the potential for environmental risk from aspects of the expansion to the cooling system of Units 6 & 7 was reflected in the perception study despite the fact that cooling system technology has achieved considerable advancements over the past few decades in the area of impact prevention. In particular, high efficiency drift eliminators have become the industry standard on all new mechanical draft cooling towers (Lucas et al. 2009). However, the mechanics of cooling tower drift impact and prevention were not widely understood by respondents. It is possible they may not realize the TPNGS expansion project has several important improvements over previous projects. For example, FPL has contracted with Miami-Dade Water and Sewer district to have their primary water source to be reclaimed municipal waste-water, an alternative that most survey respondents were in favor of. However, despite these improvements, the majority of respondents felt that the greatest challenge the expansion project would face was one of public and stakeholder perception.

The requirements of precautionary decision-making revolve entirely around the magnitude of predicted impacts or the magnitude of an impact that has not been predicted but, if it occurs, would warrant some change in management of the development (or some remedial action). Making this clear to environmental decision-makers is not always easy. Getting them to respond with appropriate quantitative estimates of effect-sizes is even more difficult (Underwood & Chapman 2003). Faced with this difficult task, many monitoring efforts fail to thoroughly consider factors such as statistical power and the ecological relevance of metrics and effect sizes in their study design (Smith et al. 1993). Not only can a properly applied power analysis increase the cost-efficiency of a study (Peterman 1990), but the cost of not doing one can also be great (Underwood & Chapman 2003). Ultimately, the relative costs of a Type I vs. Type II error must be weighed by environmental managers. The probabilities of making mistakes of each kind are therefore important in attempting to reach a sound decision. Type I errors may lead to a costly search for a non-existent effect (Simberloff 1990). The cost incurred in the interim might be the halting or modification of operation, and possibly the loss of development or economic opportunity altogether for the producer (Fairweather 1991). However, a Type

II error puts the burden of cost on the consumer: the false sense of security created by non-significant results while environmental degradation continues may lead to extensive damage and elevated recovery costs. Possible spillover effects to other areas is another component of the greater public cost of Type II errors (Underwood & Chapman 2003). But when environmental monitoring is industry-funded, producers may discount the future cost of eventual environmental recovery over the current benefits of forgoing the extra step of doing a power analysis (Underwood & Chapman 2003). Another cynical view on the lack of power analysis in environmental impact studies suggests that it is in the interest of developers and environmental regulators to obtain non-significant results in environmental impact assessments (Hayes 1987). This may lead to the use of very weak tests by unscrupulous researchers at the behest of their financiers (Fairweather 1991). Alternatively, the absence of power analysis in environmental studies can be explained by lack of understanding of its benefits (Peterman 1990). All sources of uncertainty in environmental studies are either inevitable for practical reasons or inherent to the systems studied. Participants in a decision-making process must be transparent about how uncertainty is dealt with (Funtowicz et al. 2000). Power analysis contributes to transparency by identifying sources of uncertainty in ecological information.

In environmental impact studies, often a lack of clear and logistically consistent definitions of precaution leads to contradictions in practical attempts to implement precautionary decision-making (Underwood & Chapman 2003). Particularly, there is confusion about the roles (or lack of roles) of science in legal decisions about precaution (Bazelon 1981, Bodansky 1981). Although the objective evaluation of these perceptions as they relate to true environmental risk is beyond the scope of this study, the precautionary principle states that if an action or policy has a suspected risk of causing harm to the public or to the environment, in the absence of scientific consensus that the action or policy is harmful; the burden of proof that it is not harmful falls on those taking the action. Agencies may place conditions of certification on the applicant, which stipulate that if an impact is found once operation commences, they can be held accountable for mitigation. The review process strives to avoid, minimize and mitigate impacts in that order. The consulting agencies work with the applicant to predict impacts and find solutions so that they may be avoided or at least minimized. With the knowledge that not all impacts can be predicted or avoided, monitoring programs are the final "safety net" for the environment. If a monitoring program identifies an impact has occurred, remedial action may be taken to change some aspect of the operation to minimize that impact. The applicant may also be held accountable for the cost of the mitigation. Of course, all of this depends on the ability of monitoring programs to detect impact. The environmental review process is ultimately designed to allow consulting agencies to give scientific opinion on whether any proposed action would cause undue harm to the environment. The applicant then works with the consulting agencies and the lead agencies to make improvements to the proposal and answer requests for additional information from the agencies. This continues until there is a consensus of "reasonable assurance" that the proposed action will not cause undue harm. The present study found that at this stage in the TPNGS environmental review process, uncertainty and divergent perceptions of environmental risk, caused in part by lack of adequate information dissemination, have both impeded progress and left many stakeholders without reasonable assurance. However, it is also possible that the apparent lack of consensus may be a natural stage of the still-evolving review process.

While science cannot rule out all kinds of uncertainty, it can cooperate with policy to find ways to address it. The precautionary principle has been widely and internationally accepted (e.g., in the Treaty on the European Union, the CBD and the Rio Declaration; Foster et al. 2000) as a framework for managing uncertainty due to inadequate scientific understanding (Harremös 2003). Applying the precautionary principle means that uncertainty in significance determination is recognized explicitly (Lawrence 2007) giving way to uncertainty management instead of prevention. Within the precautionary principle, measures do not have to aim at zero risk, but instead promote risk reduction measures (Opdam et al. 2009). Residual risks have to be tolerated by everyone as a socially fair distribution of burden. Determination of what is an acceptable level of risk is ultimately a political responsibility (Opdam et al. 2009). The final threshold to be crossed would be to develop the predictive science that would enable calculation of risk probabilities at the point that decisions are actually made, rather than in analyses of what happens after a decision is made (Underwood & Chapman 2003). This could occur through the creation of risk-analysis models, which in turn would inform stakeholder perception, increasing the relevance of epistemic trust relative to social trust. Here, the concept of adaptive management would be useful to construct a cooperative learning process built on the precautionary principle (Opdam et al. 2009). Thus, bringing together risk perception (Slovic 1992), risk-analysis (Suter, 1993, 1996) and sampling designed to effectively evaluate the various options would be a great step forward in the process of environmental review.

5. Figures

5.1 Chapter I Figures

Figure 1.1. Turkey Point Nuclear Generating Station (TPNGS): view from Biscayne Bay.

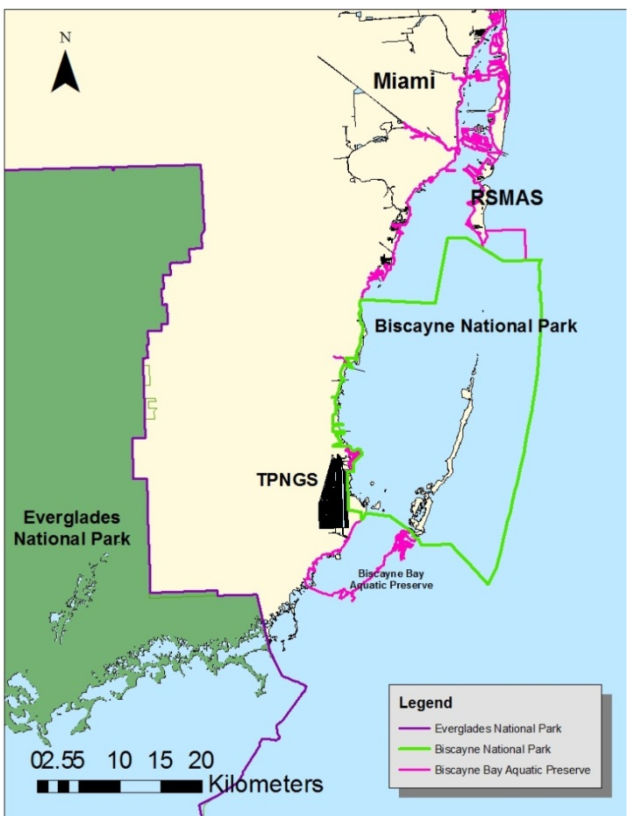

Figure 1.2. Location of TPNGS relative to Everglades National Park, Biscayne National Park, Biscayne Bay Aquatic Preserve, the city of Miami, and the Rosenstiel School of Marine and Atmospheric Sciences, University of Miami (RSMAS).

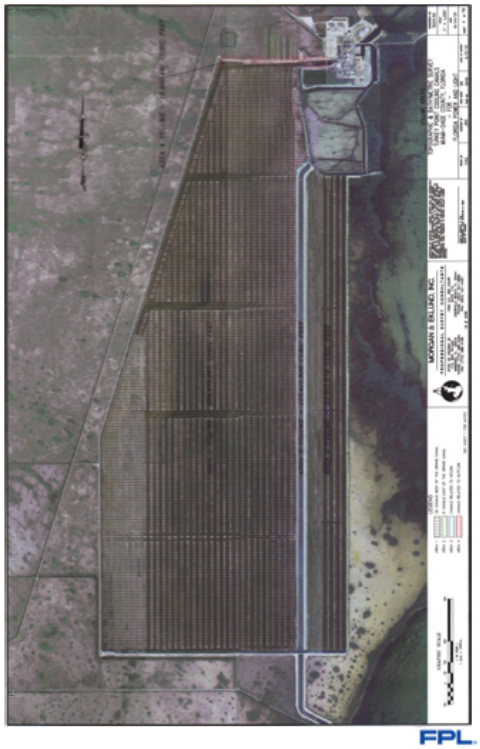

Figure 1.3. Present day aerial view of Turkey Point (FPL 2009).

Figure 1.4.1. Present day aerial view of Turkey Point.

Figure 1.4.2. Aerial view of Turkey Point ca.1938. (U.S. Department of Agriculture Soil Conservation Service *via* Peter Harlem, Florida International University, *pers. comm.*).

Figure 1.5.1. Graphic representation of Units 6 & 7 expansion. (FPL 2011).

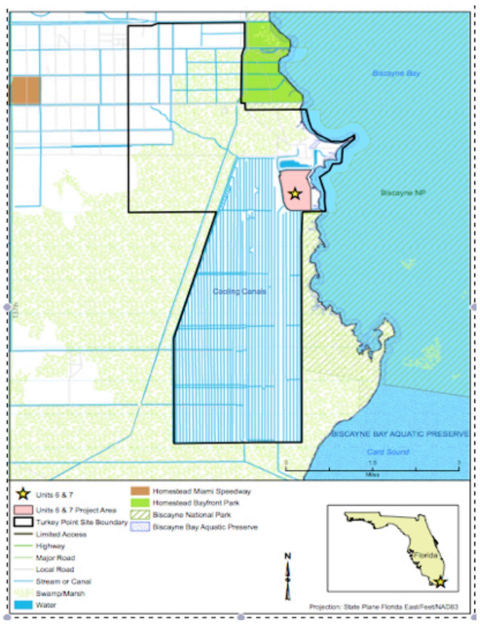

Figure 1.5.2. Location of Units 6 & 7 expansion. (COL Application, Rev. 2. Part 3. Figure 2.1-1. FPL 2009).

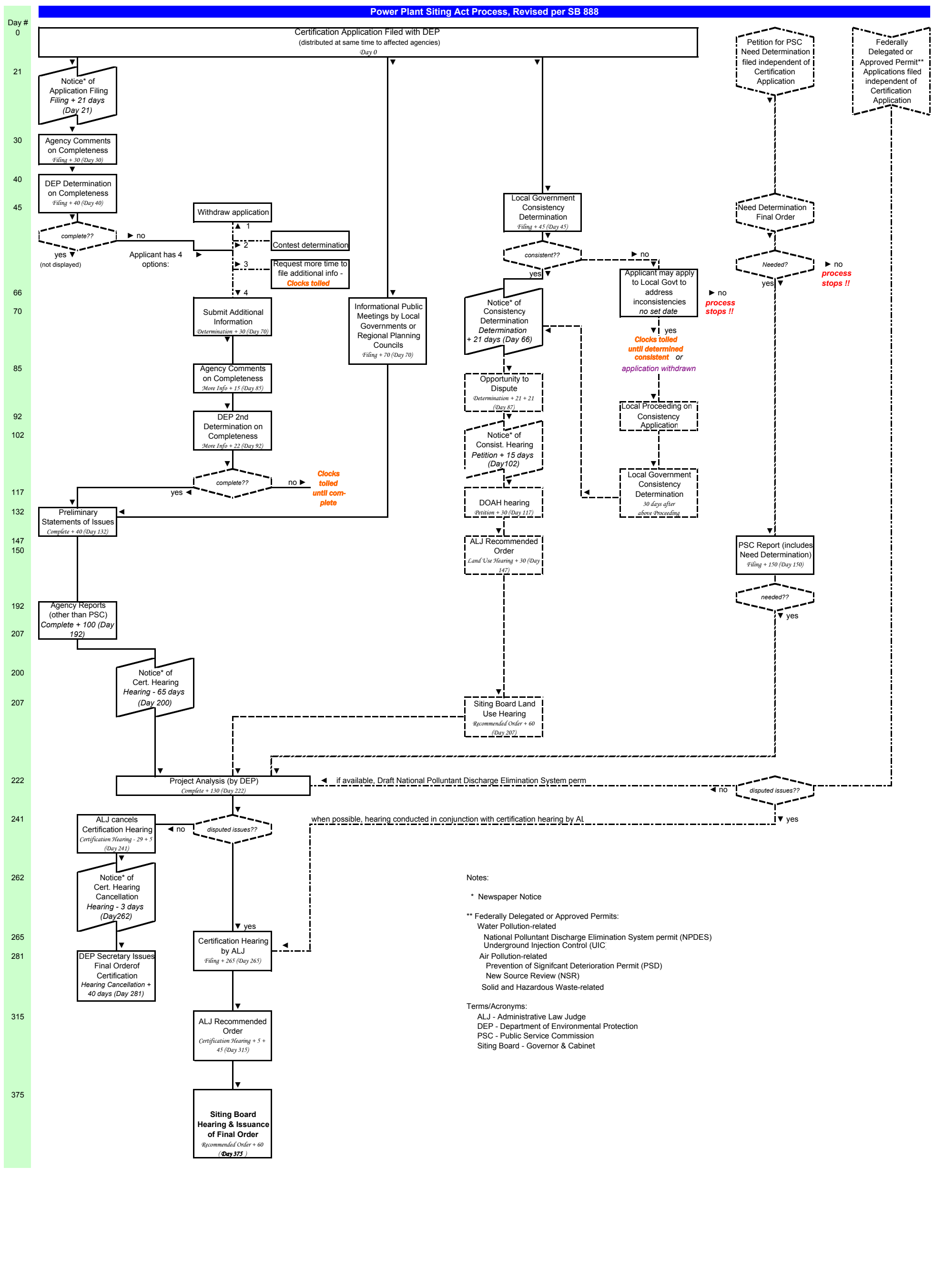

Figure 1.6.1. Flowchart of the Power Plant Siting Act process. Source: www.dep.state.fl.us/ Accessed: March 2, 2012.

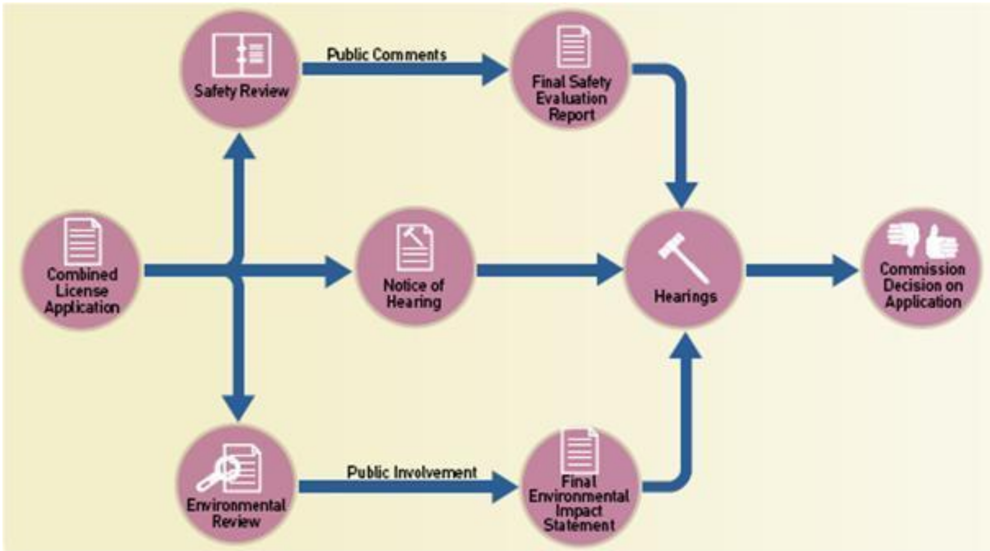

Figure 1.6.2. Flowchart of the combined licensing process. Source: www.nrc.gov Accessed: March 2, 2012.

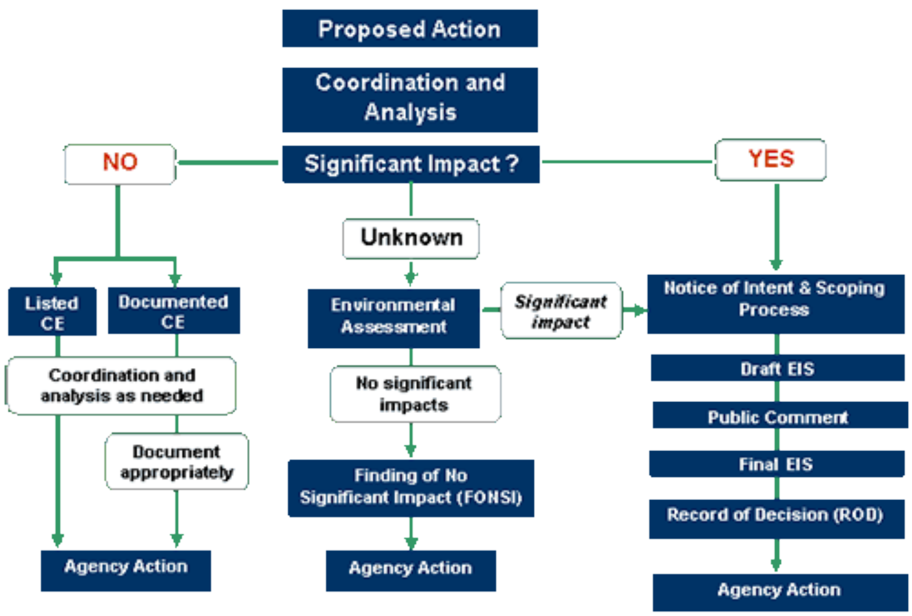

Figure 1.6.3. Flowchart of the NEPA process. Source: www.epa.gov Accessed: March 2, 2012.

5.2 Chapter II Figures

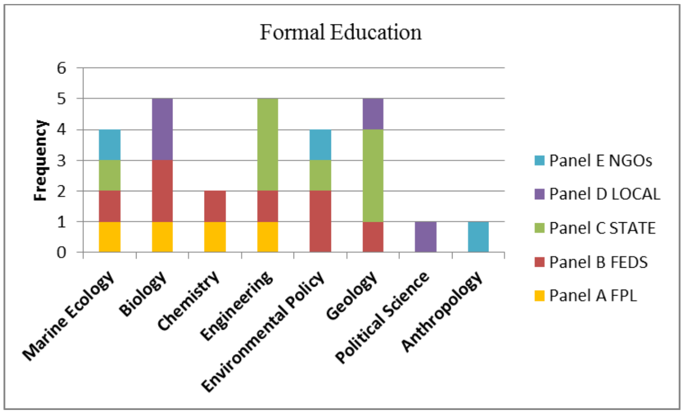

Figure 2.1.1. Formal education of respondents by panel. Multiple listings per respondent are due to multiple degrees or majors.

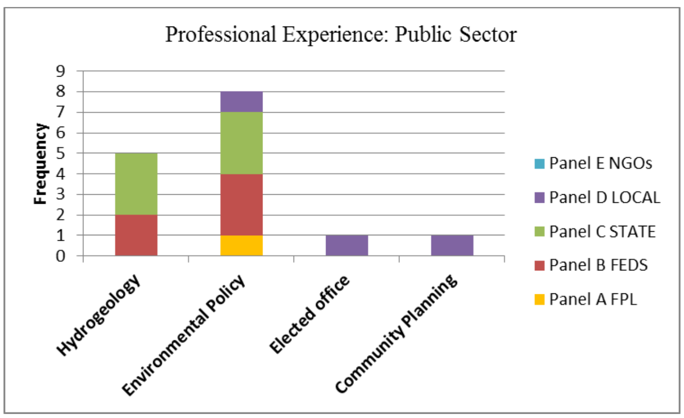

Figure 2.1.2. Public sector professional experience of respondents by panel. Multiple listings per respondent are due to multiple work experiences.

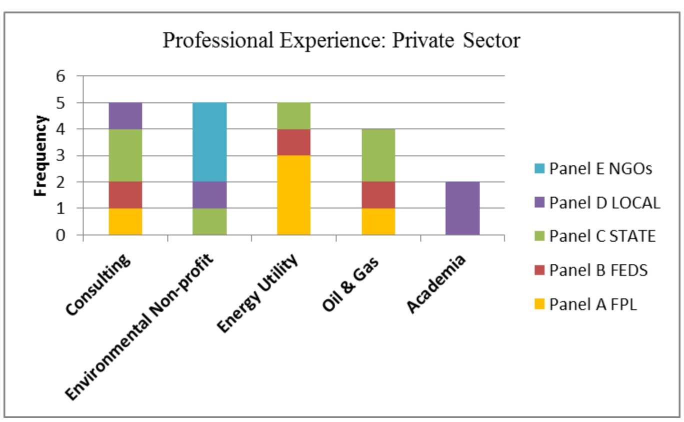

Figure 2.1.3. Private sector professional experience of respondents by panel. Multiple listings per respondent are due to multiple work experiences.

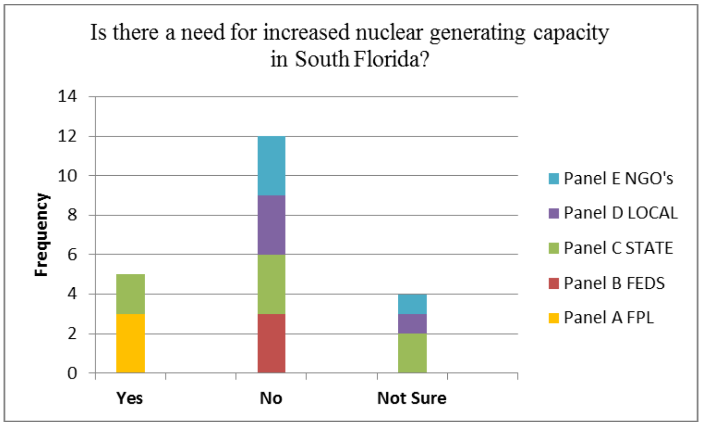

Figure 2.2.1. Perceptions of need for increased energy generating capacity in South Florida.

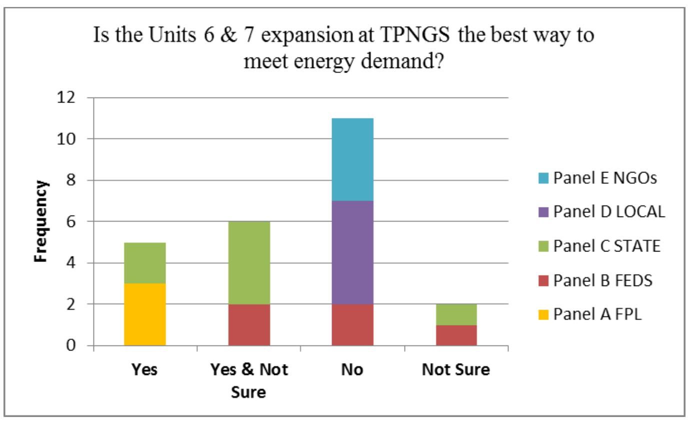

Figure 2.2.2. Perceptions of need for the Turkey Point Units 6 and 7 expansion. * The response "Yes & Not sure" refers to those respondents who believe that nuclear energy is the best way to increase energy generating capacity, but who are not sure that TPNGS is the best location for nuclear expansion.

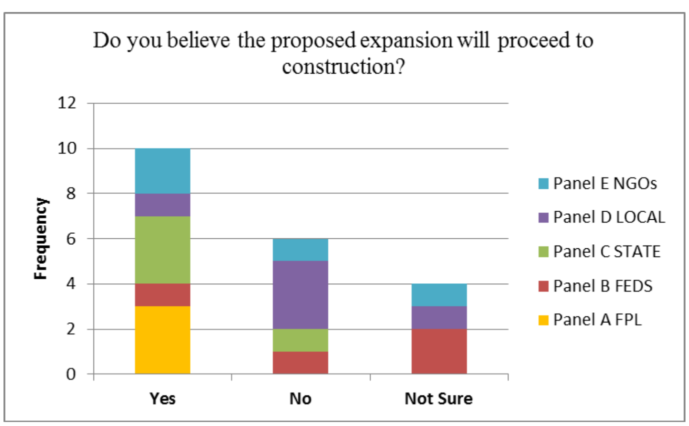

Figure 2.2.3. Perceptions of the future of the proposed Units 6 and 7 expansion.

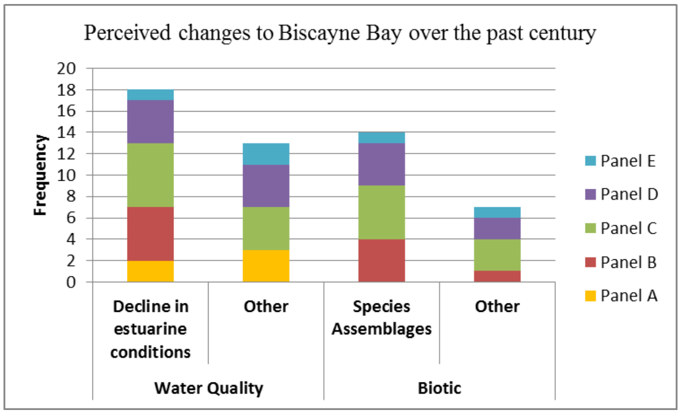

Figure 2.3.1. Perceived changes to Biscayne Bay over the past century.

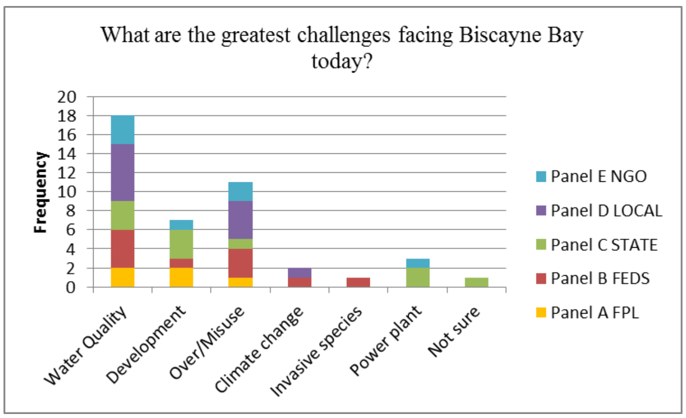

Figure 2.3.2. Stressors to Biscayne Bay perceived to be of greatest concern to stakeholders.

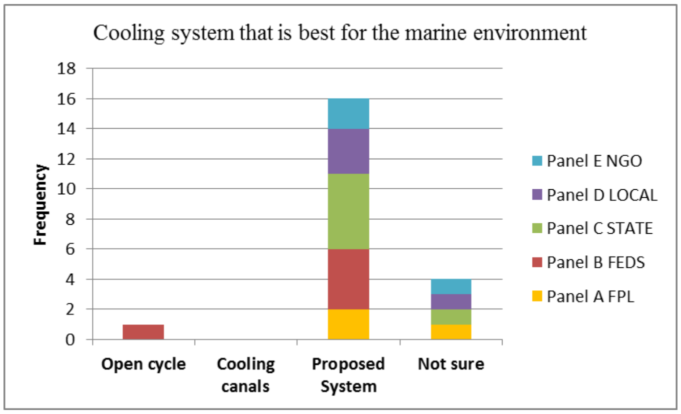

Figure 2.4.1. Cooling system preferred by respondents when asked to rank the cooling systems used by Turkey Point Nuclear Generating Station since 1968 in terms of their relative risk to the marine environment. The "proposed system" refers to the combination of mechanical-draft cooling towers and their primary and secondary water source described in the combined operating license application for nuclear units 6 & 7. (Note: Unit 5, a natural gas generator located at the TPNGS site, uses cooling towers but is not included in this study). The "once-through" system is the first open-cycle system used from 1967-1973. The cooling canals are a closed cycle system which have operated from 1973-present.

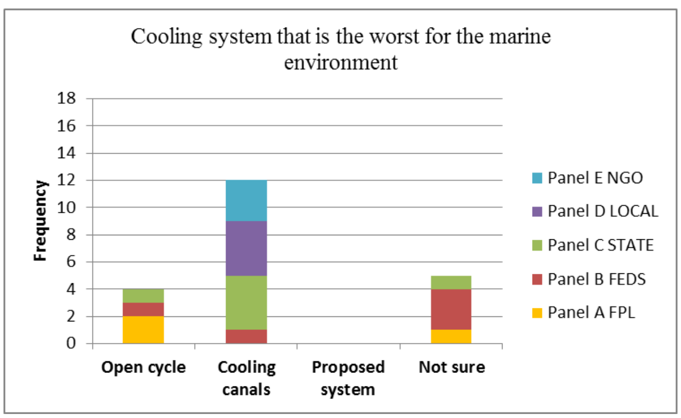

Figure 2.4.2. Cooling system least preferred by respondents when asked to rank the cooling systems used by Turkey Point Nuclear Generating Station since 1968 in terms of their relative risk to the marine environment.

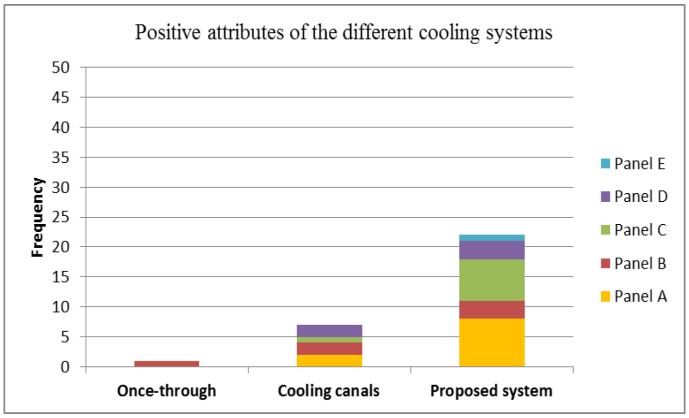

Figure 2.4.3. Number of positive attributes of each of the different cooling systems used at Turkey Point Nuclear Generating Station since 1968 according to stakeholders.

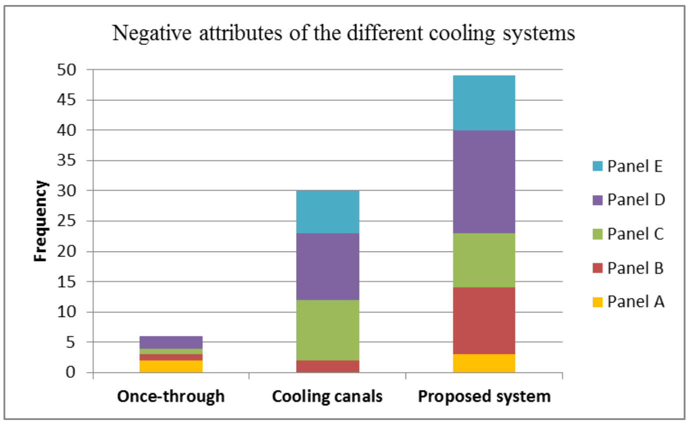

Figure 2.4.4. Number of negative attributes of each of the different cooling systems used at Turkey Point Nuclear Generating Station since 1968 according to stakeholders.

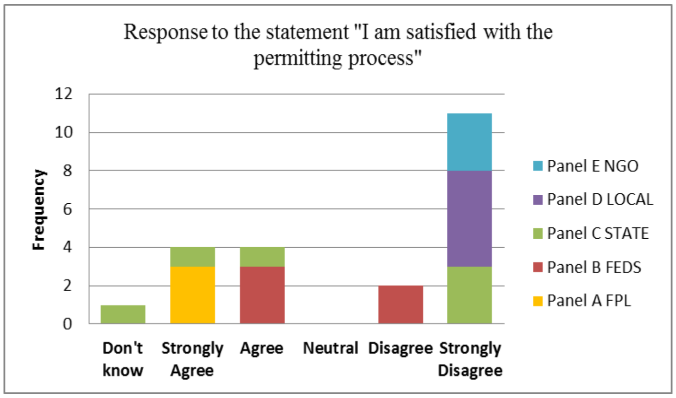

Figure 2.5.1. Response to the statement “I am satisfied with the permitting process” converted from a five-point Likert scale.

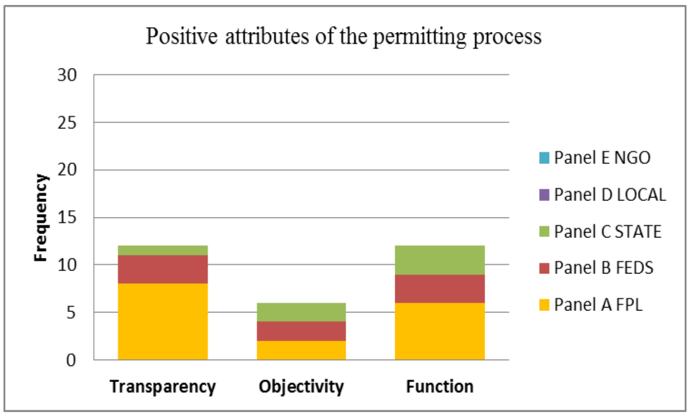

Figure 2.5.2. Positive attributes of the permitting process listed by respondents relating to transparency, objectivity or function.

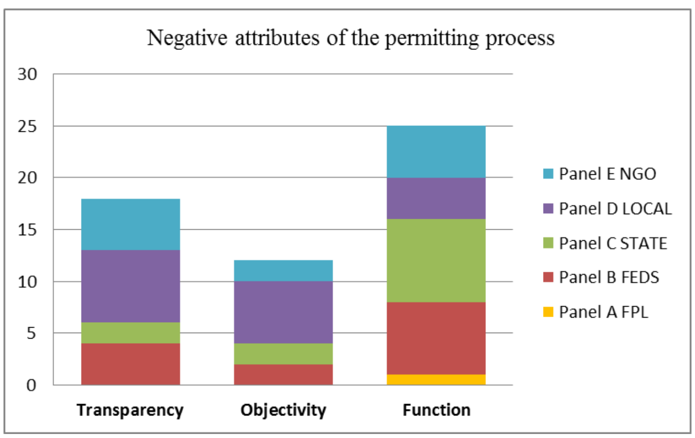

Figure 2.5.3. Negative attributes of the permitting process listed by respondents relating to transparency, objectivity or function.

5.3 Chapter III Figures

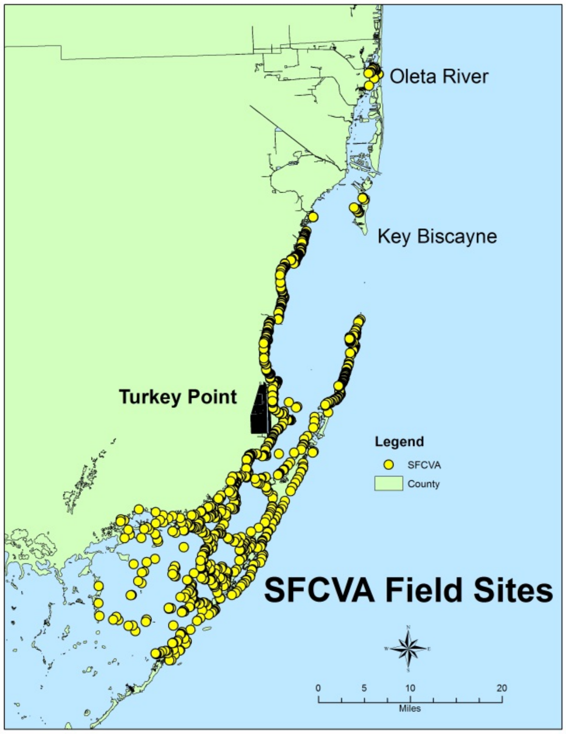

Figure 3.1.1. Map of SFCVA study area 1998-2011

Figure 3.1.2. Map of SA-1 study sites, including boundaries of Biscayne National Park and Biscayne Bay Aquatic Preserve.

Figure 3.1.3. Location of SA-2 study sites. The colored polylines represent the percentage of maximum cooling tower drift deposition modeled for the area within (FPL 2009).

Figure 3.1.4. Location of SA-3 study sites. The red polyline delineates the extent of a 0.55 ppt. maximum average salinity increase (FPL 2009).

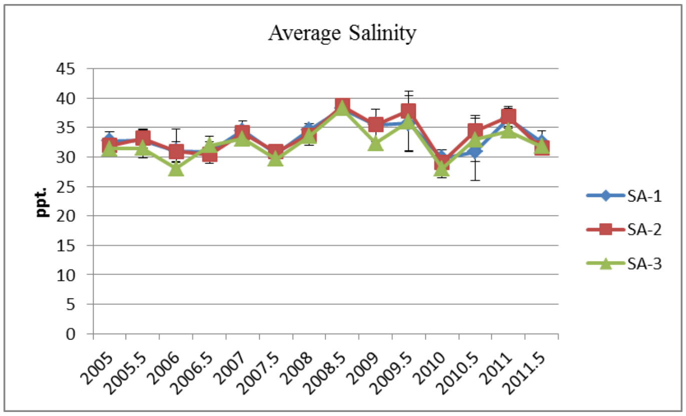

Figure 3.2.1. Average salinity in all study areas. Whole numbers and fractions correspond to dry seasons and wet seasons respectively.

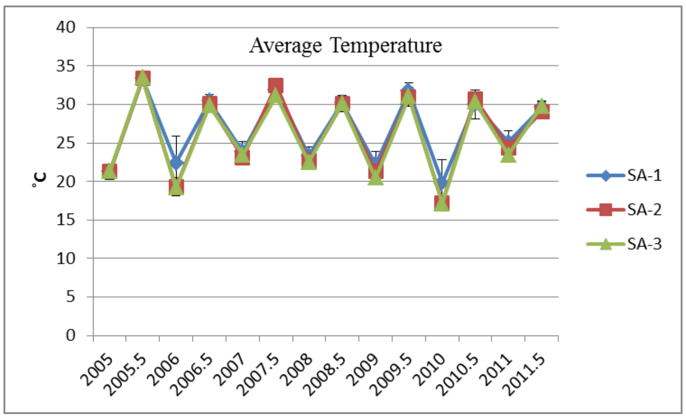

Figure 3.2.2. Average sea surface temperature in all study areas. Whole numbers and fractions correspond to dry seasons and wet seasons respectively.

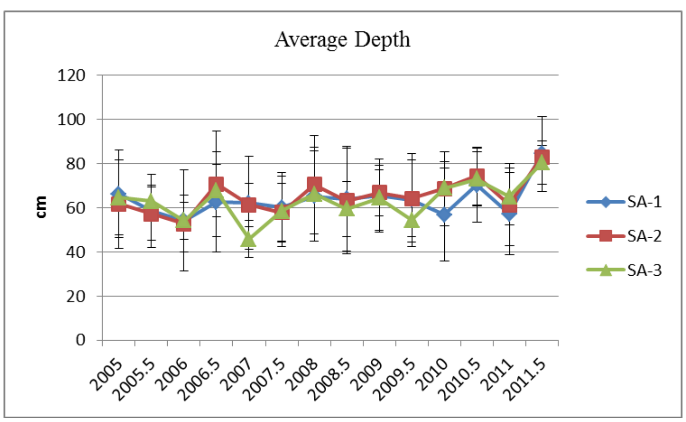

Figure 3.2.3. Average depth in all study areas. Whole numbers and fractions correspond to dry seasons and wet seasons respectively.

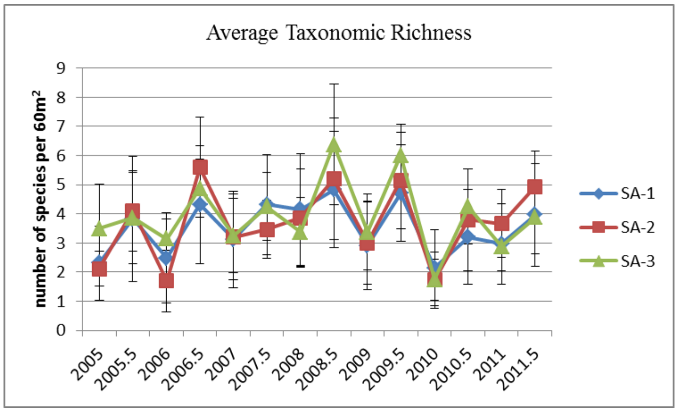

Figure 3.2.4. Average taxonomic richness in all study areas. Whole numbers and fractions correspond to dry seasons and wet seasons respectively.

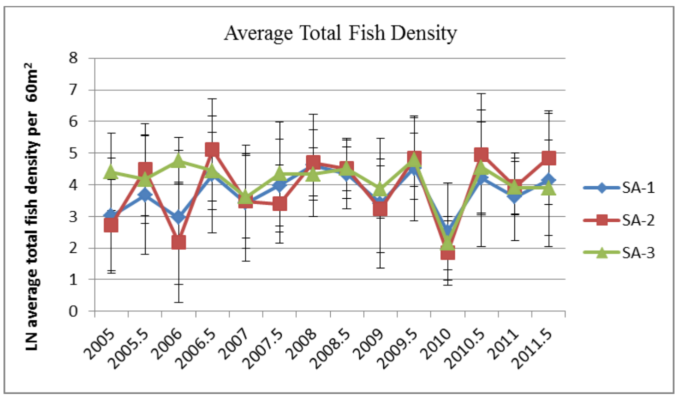

Figure 3.2.5. Average number of fish per survey (natural log transformed) in all study areas. Whole numbers and fractions correspond to dry seasons and wet seasons respectively.

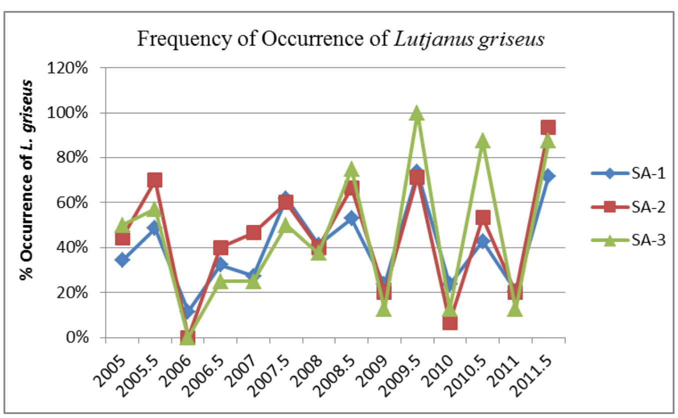

Figure 3.2.6. Frequency of occurrence of gray snapper (*Lutjanus* griseus) by season in all study areas. Whole numbers and fractions correspond to dry seasons and wet seasons respectively.

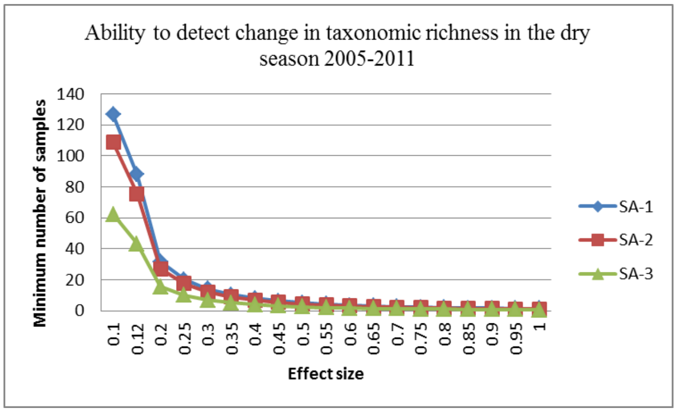

Figure 3.3.1. Minimum number of samples needed in the dry season to detect change in taxonomic richness at effect size L, in all study areas.

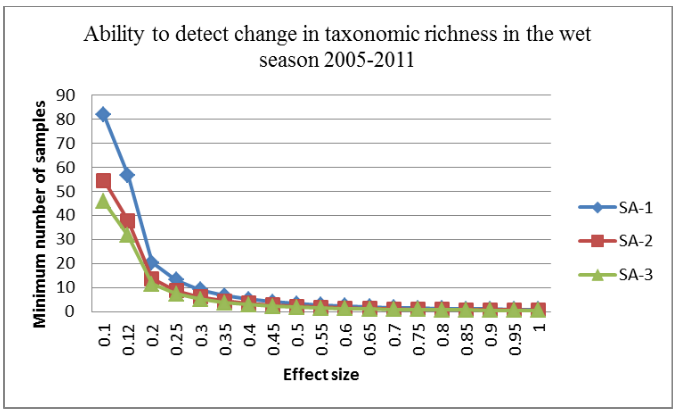

Figure 3.3.2. Minimum number of samples needed in the wet season to detect change in taxonomic richness at effect size L, in all study areas.

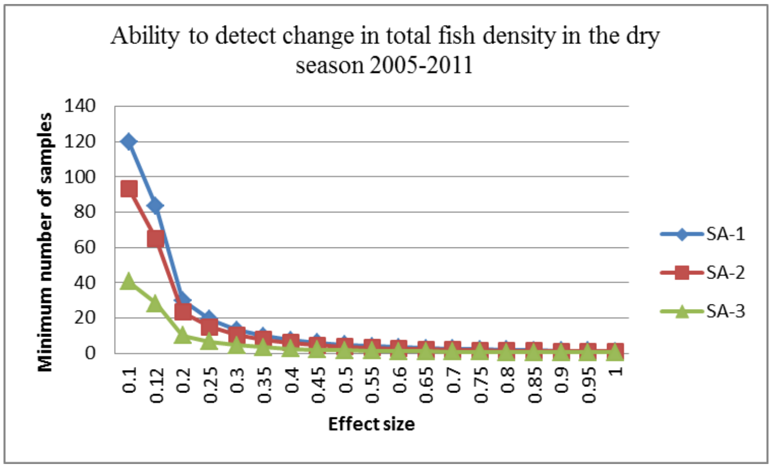

Figure 3.3.3. Minimum number of samples needed in the dry season to detect change in total fish density at effect size L, in all study areas.

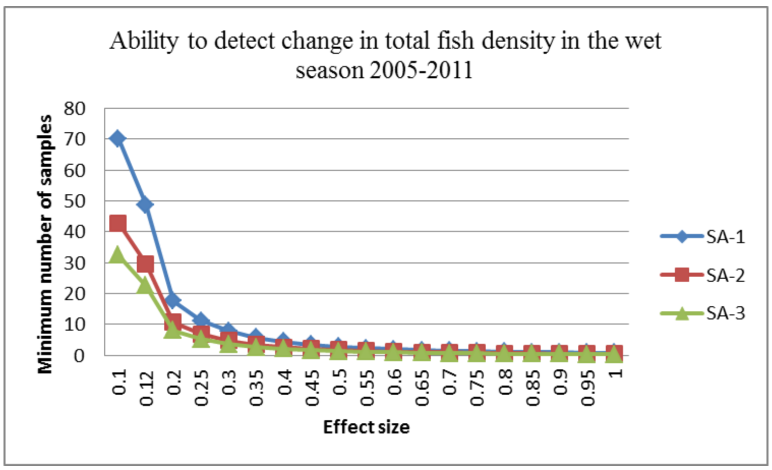

Figure 3.3.4. Minimum number of samples needed in the wet season to detect change in total fish density at effect size L, in all study areas.

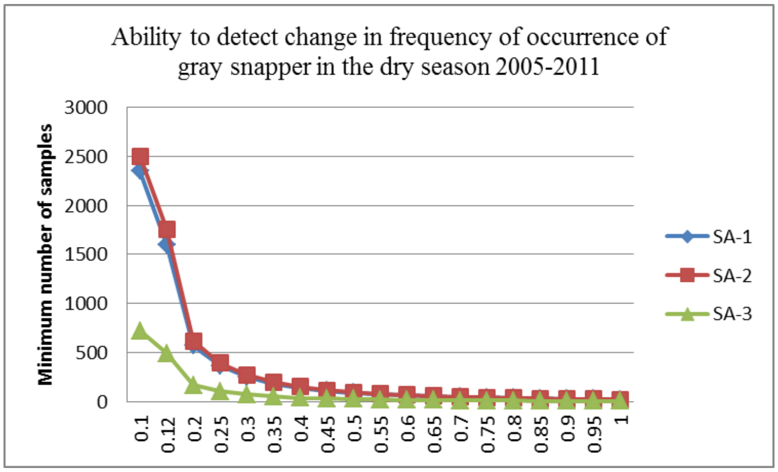

Figure 3.3.5. Minimum number of samples needed in the dry season to detect change in frequency of occurrence of gray snapper (*Lutjanus griseus*) at effect size L, in all study areas.

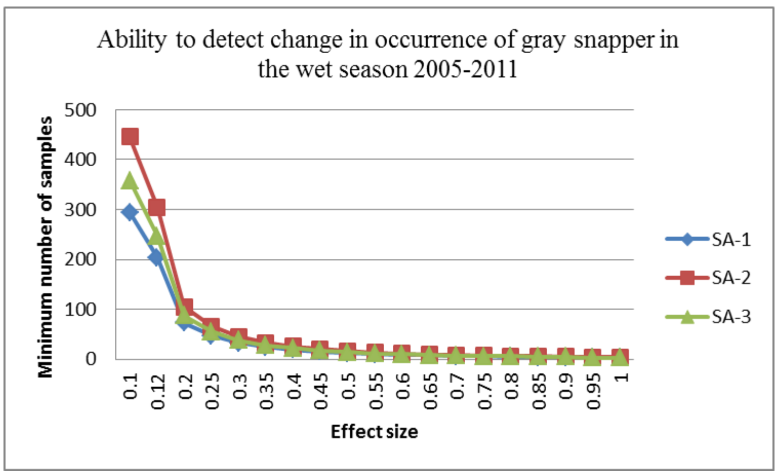

Figure 3.3.6. Minimum number of samples needed in the wet season to detect change in frequency of occurrence of gray snapper (*Lutjanus griseus*) at effect size L, in all study areas.

6. Tables

6.1. Chapter 1 Tables

Key Milestones	Completion Date Actual - A Target - T
Application Tendered	06/30/09 - A
Acceptance Review	
Acceptance Review Start	06/30/09 - A
Docketing Decision Letter Issued/Acceptance Review Complete	09/04/09 - A
Review Schedule Established/Schedule Letter Issued to Applicant	05/28/10 - A
Safety Review	
Phase A - Requests for Additional Information (RAIs) and Supplemental RAIs	05/27/11 - T*
Phase B - Advance Final safety evaluation report (SER) without Open Items	05/12 - T*
Phase C - ACRS Review of Advance Final SER	09/12 - T
Phase D - Final SER	12/12 - T
Environmental Review	
Phase 1 - Environmental impact statement (EIS) scoping summary report issued	12/10 - A
Phase 2 - Draft EIS issued to EPA	10/11 - T
Phase 3 - Final EIS issued to EPA	10/12 - T
Hearing	
Commission or ASLB hold mandatory hearing	
License	
Commission decision on issuance of COL application	

Table 1.1. Scheduled timeline for the COL application for the Units 6 & 7 expansion. Source: www.nrc.gov Accessed: November 15, 2011.

6.2. Chapter 2 Tables

Panel	composition	N
Panel A	FPL	3
Panel B	Federal agencies	5
Panel C	State agencies	6
Panel D	Local agencies	4
Panel E	Non-governmental organizations	3

Table 2.1. Composition of panels

	Panel	Panel A FPL		Panel B FEDS		Panel C STATE		Panel D LOCAL		Panel E NGOs		Total	
Age	Gender	M	F	M	F	M	F	M	F	M	F	M	F
	> 25											0	0
	25-39				1				1	1	1	1	**3**
	40-50	2		1			1	1				4	1
	50-65		1	3		5		2				**10**	1
	> 65									1		1	0
	All	2	1	4	1	5	1	3	1	2	1	16	5

Table 2.2. Age and gender of respondents.

Category	Change	Cause	A	B	C	D	E	All
Water quality	Decline in estuarine conditions	Drainage of the wetlands	1			2		3
		Water management canal construction	1	1	2			4
		Sea level rise		1				1
		Opening cuts in N. Biscayne Bay		1		1		2
		Reduced groundwater seepage		1	3			4
		Reduction of sheet flow due to development		1	1	1	1	4
	Inland migration of the saltwater intrusion line	Demand of population for freshwater			2			2
	Pulsed salinity events	Water management canals	1		1	1	1	4
	Increased nutrients	Urban runoff	2		1	2	1	6
	Decreased water clarity	Land based pollution				1		1
Biotic	Fish species assemblages	Decline in estuarine conditions		2	2	1	1	6
		Dredging of North Biscayne Bay		1	1	1		3
		Overfishing		1	2	2		5
	Deteriorating fish health	Land based pollution.			1			1
	Mangrove removal	Coastal Development		1				1
	Invasive macroalgae	Nutrient overloading			1			1
	Ghost traps	Marine debris			1			1
	Reduced wetland habitat	Urbanization				1		1
	Change in seagrass communities	Propeller scarring				1		1
		Increased salinity					1	1
Not sure				1			1	2

Table 2.3.1. Perceptions of changes to Biscayne Bay that have taken place over the past century.

Category	Stressor	A	B	C	D	E	All
Water Quality	Lack of freshwater delivery	1	3	2	3	3	**12**
	Land based pollution	1	1		2		4
	Lack of funding for CERP			1	1		2
Development	The draining of the wetlands	1		1			2
	Urbanization	1		2		1	4
	Mangrove removal		1				1
	Dredging			1			1
Overuse	Fishing Pressure		1		2		3
	Sea grass scarring		2			1	3
	Coral reef damage			1			1
	General	1			2	1	4
Climate Change	Global Warming		1				1
	Sea level rise				1		1
Invasive species	Lionfish		1				1
Power Plant	Hyper salinity			2*			2
	Radioactivity					1	1
Not sure				1			1

Table 2.3.2. Present day stressors to Biscayne Bay of greatest concern to respondents * Only occurring in southern Biscayne Bay (south of the Rickenbacker Causeway).

System	Attributes	Description		A	B	C	D	E	All
Open cycle	+	Less land usage.			1				**1**
	-	Thermal pollution	General		1	1			2
			Seagrass bed impact	2			2		**4**
	Neutral	Not Sure		1					1
Cooling canals	+	Provide habitat for endangered crocodiles		2	2		2		**6**
		Reliability				1			1
	-	Interaction of cooling canal	with Biscayne Bay		1	2	1	3	7
			with groundwater		1	4	4	3	**12**
		Extraction of groundwater resources for makeup				1			1
		Wetland impacts of construction – spatial footprint				1	3		4
		Canals block freshwater wetland transition to coast				1	3	1	5
	Neutral	Not sure		1		1			2
Proposed System	+	Use less water overall		2			1		3
		Re-use municipal waste water		3	2	4	2		**11**
		Land usage, smallest wetland impacts.		1	1			1	3
		Discharge blow down into the boulder zone		1		2			3
		Water intake and output is measureable.		1		1			2
	-	Water usage	Amount	1	1	1	3	1	7
			Conflicting with CERP			1	2	1	4
		Cooling tower drift	General	1			1	1	3
			Salt		2	1	2	2	7
			Pollutants from wastewater		2	1	3	2	**8**
		Radial collector wells	Drilling, sinkhole creation		2		1		3
			Increased salinity		1	4	2	2	**9**
			Entrainment of organisms		1	1	1		3
		Land use- spatial footprint			1		2	1	4
		Uses more electricity to operate		1					1
		Deep well injection of blow down into the aquifer			1				1
	Neutral	Not Sure			1	1			2

Table 2.4. Positive and negative attributes of three different types of cooling system used by Turkey Point Nuclear Generating Station since 1968. Attributes listed by the respondents were grouped by which cooling system they referenced, and further grouped by whether they were positive, negative or neutral. Number of listings of attributes was tabulated by panel.

	Category	Attribute	A	B	C	D	E	Total
Positive attributes	Transparency	Promotes agency communication.	3					**5**
		Promotes public participation.	2					3
		Good transparency	3					4
	Objectivity	Good objectivity						1
		Good oversight, checks & balances		2				**3**
	Function	Works to improve projects						2
		Thorough	3	2				**6**
		Structured	2					3
		Fast						1
Negative attributes	Transparency	Hinders interagency exchange of information		4	2			**8**
		Difficult for public to follow/get involved				3	3	6
		Lack of transparency				3		4
	Objectivity	Not enough distance between regulators and the regulated				2		2
		Decisions based on political will			2			**5**
		Process favors applicant approval				3		**5**
	Function	Not scientifically rigorous enough		2				**4**
		No process to adequately address impact scenario						2
		Marginalizes consulting & local agencies: too "top-down"				2		**4**
		Not enough appropriately trained technical personnel at consulting						3
		Not thorough enough			2			**4**
		Discourages dissent			2			2
		Too long		3				**4**
		Does not include principles of adaptive management.						2
Neutral		Not familiar with permitting process						1

Table 2.5. Positive and negative attributes of state and federal licensing process grouped by whether they were positive, negative or neutral and further grouped into three categories according to which of three core aspects of the licensing process they referenced: 1) Transparency, 2) Objectivity, 3) Function.

6.3. Chapter 3 Tables

Table 3.1.1. List of species occurring in all study areas from 2005-2011 and their presence/absence within each study area. Dark gray shaded cells represent presence.

Family	Taxon	Common name	SA-1	SA-2	SA-3
Antherinidae/ Clupeidae/Engraulidae	*Antherinidae/ Clupeidae/Engraulidae sp.*	Silverside/herrings/ anchovies	x	x	x
Belonidae	*Strongylura notata*	Redfin Needlefish	x	x	x
Caragidae	*Caranx hippos*	Crevalle Jack	x	x	
	Caranx ruber	Bar Jack	x	x	
	Naucrates ductor	Pilotfish	x	x	
Carcharhinidae	*Carcharhinus leucas*	Bull Shark	x	x	
	Carcharhinus limbatus	Blacktip Shark	x		
	Negaprion brevirostris	Lemon Shark	x	x	x
Centropomidae	*Centropomus undecimalis*	Common Snook	x	x	x
Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead Minnow	x	x	x
	Floridichthys carpio	Goldspotted Killifish	x	x	x
Dasyatidae	*Dasyatis americana*	Southern Stingray	x	x	x
Diodontidae	*Chilomycterus schoepfi*	Striped Burrfish	x		
Fundulidae	*Fundulus confluentus*	Marsh Killifish	x		x
	Lucania parva	Rainwater Killifish	x	x	x
Gerridae	*Gerres cinereus*	Yellowfin Mojarra	x	x	x
	Gerreidae sp.	Gerrid sp.	x	x	x
Ginglymostomatidae	*Ginglymostoma cirratum*	Nurse Shark	x	x	
Gobiidae	*Gobiidae sp.*	Goby sp.	x	x	
	Lophogobius cyprinoides	Crested Goby	x		x
Haemulidae	*Anisotremus virginicus*	Porkfish	x		
	Haemulon melanurum	Cottonwick	x		
	Haemulon parra	Sailor's Choice	x	x	x
	Haemulon sciurus	Bluestriped Grunt	x	x	x
	Haemulon sp.	Grunt sp.	x	x	
Lutjanidae	*Lutjanus apodus*	Schoolmaster	x	x	x
	Lutjanus griseus	Gray Snapper	x	x	x
	Lutjanus jocu	Dog Snapper	x	x	x
Megalopidae	*Megalops atlanticus*	Tarpon	x		
Mugilidae	*Mugil cephalus*	Striped Mullet	x		x
Ostraciidae	*Lactophrys quadracornis*	Scrawled Cowfish	x		
Poeciliidae	*Gambusia sp.*	Mosquitofish	x	x	x
Pomacentridae	*Abudefduf saxatulis*	Sergeant Major	x	x	x
Scaridae	*Scarus guacamaia*	Rainbow Parrotfish	x	x	
Sciaenidae	*Sciaenops ocellatus*	Red Drum	x		
Serranidae	*Epinephelus itjara*	Goliath Grouper	x	x	
Sparidae	*Archosargus probatocephalus*	Sheepshead	x		
	Archosargus rhomboidalis	Sea Bream	x	x	x
	Calamus calamus	Saucereye Porgy	x		
	L. rhomboides / A. rhomboidalis	Pinfish/Seabream	x	x	x
	Langodon Rhomboides	Pinfish	x	x	x
Sphyraenidae	*Sphyraena barracuda*	Great Barracuda	x	x	x
Sphyrnidae	*Sphyrna tiburo*	Bonnethead	x		
Synodontidae	*Synodus foetens*	Inshore Lizardfish	x	x	
	Synodus intermedius	Sand Diver	x	x	
Tetraodontidae	*Sphoeroides spengleri*	Bandtail Puffer	x	x	x
	Sphoeroides testudineus	Checkered Puffer	x	x	x

SA-1			% Occurrence			Density		
Family	**Taxon**	**Common name**	**Dry**	**Wet**	**Annual**	**Dry**	**Wet**	**Annual**
Antherinidae/ Clupeidae/Engraulidae	*Antherinidae/ Clupeidae/Engraulidae sp.*	Silversides/herrings/anchovies	27%	48%	38%	275.2	410.4	361.6
Belonidae	*Strongylura notata*	Redfin Needlefish	8%	15%	12%	10.1	15.5	13.6
Caragidae	*Caranx hippos*	Crevalle Jack		1%	0.4%		1.0	1.0
	Caranx ruber	Bar Jack		0.4%	0.2%		2.0	2.0
	Naucrates ductor	Pilotfish		0.4%	0.2%		1.0	1.0
Carcharhinidae	*Carcharhinus leucas*	Bull Shark	0.4%	0.4%	0.4%	1.0	1.0	1.0
	Carcharhinus limbatus	Blacktip Shark		0.4%	0.2%		1.0	1.0
	Negaprion brevirostris	Lemon Shark	1%	1%	1%	1.0	1.0	1.0
Centropomidae	*Centropomus undecimalis*	Common Snook	7%	4%	5%	3.2	1.5	2.5
Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead Minnow	4%	2%	3%	8.7	2.0	6.8
	Floridichthys carpio	Goldspotted Killifish	46%	27%	36%	31.9	19.3	27.3
Dasyatidae	*Dasyatis americana*	Southern Stingray	1%	0.4%	1%	1.0	1.0	1.0
Diodontidae	*Chilomycterus schoepfi*	Striped Burrfish		0.4%	0.2%		1.0	1.0
Fundulidae	*Fundulus confluentus*	Marsh Killifish	0.4%		0.2%	15.0		15.0
	Lucania parva	Rainwater Killifish	10%	1%	5%	3.9	1.5	3.7
Gerridae	*Gerres cinereus*	Yellowfin Mojarra	15%	24%	19%	5.8	4.7	5.1
	Gerreidae sp.	Gerrid sp.	60%	79%	69%	34.5	14.1	22.9
Ginglymostomatidae	*Ginglymostoma cirratum*	Nurse Shark	1%	2%	1%	1.0	1.3	1.1
Gobiidae	*Gobiidae sp.*	Goby sp.	0.4%		0.2%	1.0		1.0
	Lophogobius cyprinoides	Crested Goby	0.4%		0.2%	1.0		1.0
Haemulidae	*Anisotremus virginicus*	Porkfish		0.4%	0.2%		1.0	1.0
	Haemulon melanurum	Cottonwick	0.4%		0.2%	6.0		6.0
	Haemulon parra	Sailor's Choice	1%	10%	5%	2.0	6.9	6.5
	Haemulon sciurus	Bluestriped Grunt	3%	8%	6%	10.3	7.7	8.5
	Haemulon sp.	Grunt sp.	1%	2%	2%	3.7	2.6	3.0
Lutjanidae	*Lutjanus apodus*	Schoolmaster	1%	11%	6%	1.3	4.3	4.0
	Lutjanus griseus	Gray Snapper	26%	55%	40%	22.3	16.5	18.4
	Lutjanus jocu	Dog Snapper		1%	0.4%		1.0	1.0
Megalopidae	*Megalops atlanticus*	Tarpon	0.4%	0%	0.4%	8.0	1.0	4.5
Mugilidae	*Mugil cephalus*	Striped Mullet	0.4%	1%	1%	3.0	29.5	20.7
Ostraciidae	*Lactophrys quadracornis*	Scrawled Cowfish	0.4%	0.4%	0.4%	1.0	1.0	1.0
Poeciliidae	*Gambusia sp.*	Mosquitofish	2%		1%	3.0		3.0
Pomacentridae	*Abudefduf saxatulis*	Sergeant Major	0.4%	5%	3%	1.0	2.6	2.5
Scaridae	*Scarus guacamaia*	Rainbow Parrotfish	2%	1%	1%	1.5	3.0	2.1
Sciaenidae	*Sciaenops ocellatus*	Red Drum		0.4%	0.2%		4.0	4.0
Serranidae	*Epinephelus itjara*	Goliath Grouper		1%	0.4%		1.0	1.0
Sparidae	*Archosargus probatocephalus*	Sheepshead	1%	0.4%	1%	1.0	1.0	1.0
	Archosargus rhomboidalis	Sea Bream	3%	8%	6%	12.1	13.3	13.0
	Calamus calamus	Saucereye Porgy		0.4%	0.2%		1.0	1.0
	L. rhomboides / A. rhomboidali	Pinfish/Seabream	6%	9%	8%	26.4	61.9	48.1
	Langodon Rhomboides	Pinfish	11%	24%	17%	17.0	18.8	18.2
Sphyraenidae	*Sphyraena barracuda*	Great Barracuda	27%	63%	45%	2.7	2.8	2.8
Sphyrnidae	*Sphyrna tiburo*	Bonnethead		0.4%	0.2%		1.0	1.0
Synodontidae	*Synodus foetens*	Inshore Lizardfish		0.4%	0.2%		1.0	1.0
	Synodus intermedius	Sand Diver	1%	0.4%	1%	1.0	1.0	1.0
Tetraodontidae	*Sphoeroides spengleri*	Bandtail Puffer	2%		1%	1.0		1.0
	Sphoeroides testudineus	Checkered Puffer	8%	4%	6%	1.8	2.0	1.8

Table 3.1.2. List of all species occurring in SA-1 from 2005-2011 and their frequency of occurrence and average density values for each season and across seasons. Gray shaded cells represent species within the top three highest mean frequency of occurrence and density (light gray and dark gray shading respectively).

SA-2			% Occurance			Density		
Family	Taxon	Common name	Dry	Wet	Annual	Dry	Wet	Annual
Antherinidae/ Clupeidae/Engraulidae	*Antherinidae/ Clupeidae/Engraulidae sp.*	Silversides/ herrings/anchovies	22%	56%	39%	142.90	490.64	394.55
Belonidae	*Strongylura notata*	Redfin Needlefish	12%	16%	14%	11.91	9.00	10.19
Caragidae	*Caranx hippos*	Crevalle Jack		1%	1%		1.00	1.00
	Caranx ruber	Bar Jack		1%	1%		2.00	2.00
	Naucrates ductor	Pilotfish		1%	1%		1.00	1.00
Carcharhinidae	*Carcharhinus leucas*	Bull Shark	1%	1%	1%	1.00	1.00	1.00
	Negaprion brevirostris	Lemon Shark	1%	2%	2%	1.00	1.00	1.00
Centropomidae	*Centropomus undecimalis*	Common Snook	5%	4%	5%	1.40	1.50	1.44
Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead minnow	5%	1%	3%	8.80	2.00	7.67
	Floridichthys carpio	Goldspotted Killifish	45%	29%	37%	23.93	18.24	21.61
Dasyatidae	*Dasyatis americana*	Southern Stingray		1%	1%		1.00	1.00
Fundulidae	*Lucania parva*	Rainwater Killifish	12%	1%	6%	3.09	2.00	3.00
Gerridae	*Gerres cinereus*	Yellowfin Mojarra	11%	25%	18%	6.50	3.60	4.43
	Gerreidae sp.	Gerrid sp.	57%	83%	70%	25.22	12.52	17.57
Ginglymostomatidae	*Ginglymostoma cirratum*	Nurse Shark		3%	2%		1.33	1.33
Gobiidae	*Gobiidae sp.*	Goby sp.	1%		1%	1.00		1.00
Haemulidae	*Haemulon parra*	Sailor's Choice		9%	5%		2.89	2.89
	Haemulon sciurus	Bluestriped Grunt		10%	5%		5.20	5.20
	Haemulon sp.	Grunt sp.		4%	2%		1.25	1.25
Lutjanidae	*Lutjanus apodus*	Schoolmaster	1%	6%	4%	2.00	3.17	3.00
	Lutjanus griseus	Gray Snapper	26%	65%	46%	10.75	17.34	15.55
	Lutjanus jocu	Dog Snapper		1%	1%		1.00	1.00
Poeciliidae	*Gambusia sp.*	Mosquitofish	3%		2%	4.33		4.33
Pomacentridae	*Abudefduf saxatulis*	Sergeant Major		4%	2%		1.25	1.25
Scaridae	*Scarus guacamaia*	Rainbow Parrotfish	1%	2%	2%	1.00	2.50	2.00
Serranidae	*Epinephelus itjara*	Goliath Grouper		2%	1%		1.00	1.00
Sparidae	*Archosargus rhomboidalis*	Sea Bream	4%	13%	9%	17.75	12.69	13.88
	L. rhomboides / A. rhomboidalis	Pinfish/Seabream	10%	9%	9%	16.11	33.00	24.56
	Langodon Rhomboides	Pinfish	15%	35%	25%	15.64	17.77	17.16
Sphyraenidae	*Sphyraena barracuda*	Great Barracuda	33%	71%	52%	2.74	2.49	2.56
Synodontidae	*Synodus foetens*	Inshore Lizardfish		1%	1%		1.00	1.00
	Synodus intermedius	Sand Diver	1%		1%	1.00		1.00
Tetraodontidae	*Sphoeroides spengleri*	Bandtail Puffer	3%		2%	1.00		1.00
	Sphoeroides testudineus	Checkered Puffer	12%	5%	8%	1.18	2.60	1.63

Table 3.1.3. List of all species occurring in SA-2 from 2005-2011 and their frequency of occurrence and average density values for each season and across seasons. Gray shaded cells represent species within the top three highest mean frequency of occurrence and density (light gray and dark gray shading respectively).

SA-3			% Occurrence			Density		
Family	**Taxon**	**Common name**	**Dry**	**Wet**	**Annual**	**Dry**	**Wet**	**Annual**
Antherinidae/ Clupeidae/Engraulidae	*Antherinidae/ Clupeidae/Engraulidae sp.*	Silversides/ herrings/anchovies	23%	51%	37%	18.38	99.11	59.49
Belonidae	*Strongylura notata*	Redfin Needlefish	4%	16%	10%	1.06	1.82	1.44
Carcharhinidae	*Negaprion brevirostris*	Lemon Shark		4%	2%		0.04	0.02
Centropomidae	*Centropomus undecimalis*	Common Snook	6%	5%	6%	0.09	0.11	0.10
Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead Minnow	2%	4%	3%	0.19	0.05	0.12
	Floridichthys carpio	Goldspotted Killifish	60%	36%	48%	13.60	7.89	10.69
Dasyatidae	*Dasyatis americana*	Southern Stingray	2%		1%	0.02		0.01
Fundulidae	*Fundulus confluentus*	Marsh Killifish	2%		1%	0.28		0.14
	Lucania parva	Rainwater Killifish	6%	4%	5%	0.11	0.05	0.08
Gerridae	*Gerres cinereus*	Yellowfin Mojarra	13%	29%	21%	1.04	0.98	1.01
	Gerreidae sp.	Gerrid sp.	77%	78%	78%	32.75	10.80	21.57
Gobiidae	*Lophogobius cyprinoides*	Crested Goby	2%		1%	0.02		0.01
Haemulidae	*Haemulon parra*	Sailor's Choice		11%	6%		0.53	0.27
	Haemulon sciurus	Bluestriped Grunt		5%	3%		0.16	0.08
Lutjanidae	*Lutjanus apodus*	Schoolmaster	2%	16%	9%	0.02	0.51	0.27
	Lutjanus griseus	Gray Snapper	21%	69%	45%	2.91	8.80	5.91
	Lutjanus jocu	Dog Snapper		2%	1%		0.02	0.01
Poeciliidae	*Gambusia sp.*	Mosquitofish	4%		2%	0.21		0.10
Pomacentridae	*Abudefduf saxatulis*	Sergeant Major		2%	1%		0.04	0.02
Sparidae	*Archosargus rhomboidalis*	Sea Bream	9%	15%	12%	1.17	1.36	1.27
	L. rhomboides / A. rhomboidalis	Pinfish/Seabream	6%	20%	13%	1.36	14.25	7.93
	Langodon Rhomboides	Pinfish	25%	27%	26%	4.85	4.58	4.71
Sphyraenidae	*Sphyraena barracuda*	Great Barracuda	30%	82%	56%	0.91	1.82	1.37
Tetraodontidae	*Sphoeroides spengleri*	Bandtail Puffer	4%		2%	0.04		0.02
	Sphoeroides testudineus	Checkered Puffer	6%	4%	5%	0.08	0.05	0.06

Table 3.1.4. List of all species occurring in SA-3 from 2005-2011 and their frequency of occurrence and average density values for each season and across seasons. Gray shaded cells represent species within the top three highest mean frequency of occurrence and density (light gray and dark gray shading respectively).

		Dry		Wet	
Study Area	Rank	Occurrence	Density	Occurrence	Density
SA-1	1	*Gerridae sp.*	*Antherinidae/ Clupeidae/ Engraulidae sp.*	*Gerridae sp.*	*Antherinidae/Clupeidae/ Engraulidae sp.*
	2	*F. carpio*	*Gerridae sp.*	*S. barracuda*	*L./A. rhomboides /rhomboidalis*
	3*	*Antherinidae /Clupeidae/ Engraulidae sp.*	*F. carpio*	*L. griseus*	*M. cephalus*
	3*	*S. barracuda*			
SA-2	1	*Gerridae sp.*	*Antherinidae/ Clupeidae/ Engraulidae sp.*	*Gerridae sp.*	*Antherinidae/Clupeidae/ Engraulidae sp.*
	2	*F. carpio*	*Gerridae sp.*	*S. barracuda*	*L./A. rhomboides /rhomboidalis*
	3	*S. barracuda*	*F. carpio*	*L. griseus*	*F. carpio*
SA-3	1	*Gerridae sp.*	*Gerridae sp.*	*S. barracuda*	*Antherinidae/Clupeidae/ Engraulidae sp.*
	2	*F. carpio*	*Antherinidae/ Clupeidae/ Engraulidae sp.*	*Gerridae sp.*	*L./A. rhomboides /rhomboidalis*
	3	*S. barracuda*	*F. carpio*	*L. griseus*	*Gerridae sp.*

Table 3.1.5. Summary list ranking species within study areas and seasons in terms of top three highest frequency of occurrence and mean density values. *In SA-1, *Antherinidae/Clupeidae/Engraulidae sp.* and *S. barracuda* both rank third at 27% occurrence in the dry season.

Paired Student's T-test: Dry season vs. wet season pooled across years 2005-2011			
	SA-1	SA-2	SA-3
	p	*p*	*p*
Species richness	<0.0001	<0.0001	<0.0001
Total fish density	<0.0001	<0.0001	<0.0001
Occurrence of *L.griseus*	0.0036	0.0019	0.0070
Salinity	0.0124	0.3128	0.0293
Temperature	<0.0001	<0.0001	<.0001
Depth	0.0035	0.5435	0.0901

Table 3.2.1. Results of Student's t-tests comparing wet season vs. dry season distributions pooled across years (2005-2011) for the above listed metrics. Grey shaded cells contain statistically significant values ($\alpha = 0.05$).

Paired Student's T-test: Dry season vs. wet season 2011			
	SA-1	SA-2	SA-3
	p	*p*	*p*
Species richness	0.0089	0.0033	0.0331
Total fish density	0.2109	0.0263	0.0178
Density of *L. griseus*	0.0297	0.0099	0.0217
Salinity	<0.0001	0.0001	<0.0001
Temperature	<0.0001	<0.0001	<0.0001
Depth	<0.0001	0.0011	0.0526

Table 3.2.2. Results of Student's t-tests comparing wet season vs. dry season distributions of 2011for the above listed metrics. Grey shaded cells contain statistically significant values ($\alpha = 0.05$).

Salinity (ppt.)					
Study Area	Study Period	Dry		Wet	
		2005-2011	2011	2005-2011	2011
SA-1	n	239	34	238	32
	Mean	33.57	36.42	32.84	32.58
	Std. dev.	3.04	1.70	4.17	2.31
	Variance	9.22	2.90	17.41	5.36
SA-2	n	94	15	99	15
	Mean	33.45	36.74	33.86	31.44
	Std. dev.	2.84	1.74	3.40	0.95
	Variance	8.08	3.03	11.59	0.89
SA-3	n	53	8	55	8
	Mean	31.63	34.35	33.08	31.76
	Std. dev.	2.57	0.50	3.94	0.39
	Variance	6.626	0.25	15.53	0.15

Table 3.3.1. Summary of salinity data.

Sea Surface Temperature (˚C)					
Study Area	Study Period	Dry		Wet	
		2005-2011	2011	2005-2011	2011
SA-1	n	239	34	238	32
	Mean	22.46	25.27	31.12	29.80
	Std. dev.	2.79	1.62	1.76	0.84
	Variance	7.79	2.61	3.08	0.71
SA-2	n	94	15	99	15
	Mean	21.47	24.43	30.92	29.07
	Std. dev.	2.55	1.16	1.55	0.43
	Variance	6.51	1.36	2.39	0.19
SA-3	n	53	8	55	8
	Mean	21.10	23.43	30.76	29.69
	Std. dev.	2.37	0.26	1.41	0.62
	Variance	5.64	0.07	2.00	0.38

Table 3.3.2. Summary of temperature data.

Depth (cm)					
Study Area	Study Period	Dry		Wet	
		2005-2011	2011	2005-2011	2011
SA-1	n	239	34	238	32
	Mean	57.92	54.45	63.40	81.38
	Std. dev.	20.27	18.95	21.29	18.97
	Variance	410.96	359.07	453.30	359.76
SA-2	n	94	15	99	15
	Mean	64.39	63.13	67.12	83.56
	Std. dev.	17.83	19.09	19.59	5.66
	Variance	317.82	364.52	383.69	32.08
SA-3	n	53	8	55	8
	Mean	59.84	62.29	64.82	82.00
	Std. dev.	16.23	14.24	15.58	10.91
	Variance	263.45	202.79	242.65	118.98

Table 3.3.3. Summary of depth data.

Taxonomic Richness					
Study Area	Study Period	Dry		Wet	
		2005-2011	2011	2005-2011	2011
SA-1	n	239	34	238	32
	Mean	2.87	2.97	4.16	3.97
	Std. dev.	1.63	1.38	1.91	1.77
	Variance	2.67	1.91	3.63	3.13
SA-2	n	94	15	99	15
	Mean	2.85	3.67	4.63	4.93
	Std. dev.	1.50	1.18	1.72	1.22
	Variance	2.36	1.38	2.95	1.50
SA-3	n	53	8	55	8
	Mean	3.02	2.88	4.8	3.88
	Std. dev.	1.18	0.83	1.61	1.25
	Variance	1.40	0.70	2.61	1.55

Table 3.3.4. Summary of taxonomic richness data.

Total Fish Density					
Study Area	Study Period	Dry		Wet	
		2005-2011	2011	2005-2011	2011
SA-1	n	239	34	238	32
	Mean	3.36	3.61	4.416	4.41
	Std. dev.	1.87	1.39	1.77	2.10
	Variance	3.48	1.92	3.13	4.41
SA-2	n	94	15	99	15
	Mean	3.24	3.94	4.56	4.85
	Std. dev.	1.58	0.91	1.48	1.46
	Variance	2.48	0.82	2.28	2.26
SA-3	n	53	8	55	8
	Mean	3.82	3.91	4.39	3.89
	Std. dev.	1.21	0.83	1.24	1.51
	Variance	1.46	0.68	1.55	2.27

Table 3.3.5. Summary of total fish density data.

Occurrence of *L. griseus*			
Study Area	Study Period	Dry	Wet
		2005-2011	2005-2011
SA-1	n	239	238
	Mean	26 %	55 %
	Std. dev.	0.10	0.15
	Variance	0.01	0.02
SA-2	n	94	99
	Mean	25 %	65 %
	Std. dev.	0.19	0.17
	Variance	0.04	0.03
SA-3	n	53	55
	Mean	21 %	69 %
	Std. dev.	0.17	0.26
	Variance	0.03	0.07

Table 3.3.6. Summary of gray snapper occurrence data. * There is no data for gray snapper frequency of occurrence for the year 2011 only because there is only one value for each season, thus descriptive statistics were not computed for 2011 only.

Segment	Season	Sampling period	Taxonomic Richness	Total Fish Density	Occurrence of *L. griseus*
SA-1	Dry	2005-2011	X	X	--
		2011	X	X	--
	Wet	2005-2011	X	X	X
		2011	X	X	--
SA-2	Dry	2005-2011	X	X	--
		2011	X	X	--
	Wet	2005-2011	X	X	X
		2011	X	X	X
SA-3	Dry	2005-2011	X	X	--
		2011	X	X	--
	Wet	2005-2011	X	X	X
		2011	X	--	--

Table 3.4.1. Power analysis overview. The ability of the SFCVA to detect a 30% change in the above listed metrics within each study area for each season and sampling period. Shaded cells populated with "X" represent sampling intensity sufficient to detect a 30% change

Segment	Season	Sampling period	N_0	Taxonomic Richness		Total Fish Density		Occurrence of *L. griseus*	
				$N_{L=.30}$	L_0	$N_{L=.30}$	L_0	$N_{L=.30}$	L_0
SA-1	Dry	2005-2011	239	14	0.07	13	0.07	253	0.31
		2011	34	10	0.16	7	0.13	340	0.96
	Wet	2005-2011	238	9	0.06	8	0.05	33	0.11
		2011	32	9	0.16	12	0.18	33	0.31
SA-2	Dry	2005-2011	94	12	0.11	10	0.10	270	0.50
		2011	15	5	0.18	3	0.13	358	1.52
	Wet	2005-2011	99	6	0.07	5	0.05	45	0.20
		2011	15	3	0.14	5	0.17	10	0.23
SA-3	Dry	2005-2011	53	7	0.11	4	0.09	72	0.34
		2011	8	5	0.24	3	0.18	789	2.99
	Wet	2005-2011	55	5	0.09	4	0.08	38	0.25
		2011	8	6	0.27	9	0.32	17	0.44

Table 3.4.2. Power analysis summary. $N_{L=.30}$ is the necessary number of samples to detect a 30% change. N_0 is the number of samples in the current study for the given sampling period. L_0 is the effect size of the current study.

Dry Season Taxonomic Richness						
	SA-1		SA-2		SA-3	
L	2005-2011	2011	2005-2011	2011	2005-2011	2011
10%	126	90	109	47	62	47
12%	88	62	75	33	43	33
20%	32	22	27	12	16	12
25%	20	14	17	8	10	8
30%	14	10	12	5	7	5
35%	10	7	9	4	5	4
40%	8	6	7	3	4	3
45%	6	4	5	2	3	2
50%	5	4	4	2	2	2
55%	4	3	4	2	2	2
60%	4	2	3	1	2	1
65%	3	2	3	1	1	1
70%	3	2	2	1	1	1
75%	2	2	2	1	1	1
80%	2	1	2	1	1	1
85%	2	1	2	1	1	1
90%	2	1	1	1	1	1
95%	1	1	1	1	1	1
100%	1	1	1	1	1	1

Table 3.5.1. Minimum number of samples needed to detect change in dry season taxonomic richness at effect size *L,* in all study areas (rounded to the nearest whole sample).

Wet Season Taxonomic Richness						
	SA-1		SA-2		SA-3	
L	2005-2011	2011	2005-2011	2011	2005-2011	2011
10%	82	83	54	28	46	58
12%	57	57	38	20	32	40
20%	20	21	14	7	11	14
25%	13	13	9	5	7	9
30%	9	9	6	3	5	6
35%	7	7	4	2	4	5
40%	5	5	3	2	3	4
45%	4	4	3	1	2	3
50%	3	3	2	1	2	2
55%	3	3	2	1	2	2
60%	2	2	2	1	1	2
65%	2	2	1	1	1	1
70%	2	2	1	1	1	1
75%	1	1	1	1	1	1
80%	1	1	1	1	1	1
85%	1	1	1	1	1	1
90%	1	1	1	1	1	1
95%	1	1	1	1	1	1
100%	1	1	1	1	1	1

Table 3.5.2. Minimum number of samples needed to detect change in dry season taxonomic richness at effect size *L,* in all study areas (rounded to the nearest whole sample).

Dry Season Total Fish Density						
	SA-1		SA-2		SA-3	
L	2005-2011	2011	2005-2011	2011	2005-2011	2011
10%	120	61	93	24	40	25
12%	83	42	65	17	28	17
20%	30	15	23	6	10	6
25%	19	10	15	4	6	4
30%	13	7	10	3	4	3
35%	10	5	8	2	3	2
40%	7	4	6	2	3	2
45%	6	3	5	1	2	1
50%	5	2	4	1	2	1
55%	4	2	3	1	1	1
60%	3	2	3	1	1	1
65%	3	1	2	1	1	1
70%	2	1	2	1	1	1
75%	2	1	2	1	1	1
80%	2	1	1	1	1	1
85%	2	1	1	1	1	1
90%	1	1	1	1	1	1
95%	1	1	1	1	1	1
100%	1	1	1	1	1	1

Table 3.5.3. Minimum number of samples needed to detect change in dry season total fish density at effect size *L,* in all study areas (natural log transformed and rounded to the nearest whole sample).

Wet Season Total Fish Density						
	SA-1		SA-2		SA-3	
L	2005-2011	2011	2005-2011	2011	2005-2011	2011
10%	70	107	43	43	32	84
12%	49	74	30	30	23	58
20%	18	27	11	11	8	21
25%	11	17	7	7	5	13
30%	8	12	5	5	4	9
35%	6	9	3	4	3	7
40%	4	7	3	3	2	5
45%	3	5	2	2	2	4
50%	3	4	2	2	1	3
55%	2	4	1	1	1	3
60%	2	3	1	1	1	2
65%	2	3	1	1	1	2
70%	1	2	1	1	1	2
75%	1	2	1	1	1	1
80%	1	2	1	1	1	1
85%	1	1	1	1	1	1
90%	1	1	1	1	1	1
95%	1	1	1	1	1	1
100%	1	1	1	1	1	1

Table 3.5.4. Minimum number of samples needed to detect change in wet season total fish density at effect size *L,* in all study areas (natural log transformed and rounded to the nearest whole sample).

Dry Season Occurrence of *L. griseus*						
	SA-1		SA-2		SA-3	
L	2005-2011	2011	2005-2011	2011	2005-2011	2011
10%	2350	3000	2500	3055	723	7070
12%	1600	2089	1755	2140	492	4920
20%	570	759	617	789	168	1772
25%	365	487	391	511	105	1136
30%	253	340	270	358	72	789
35%	185	250	197	265	52	580
40%	140	192	150	204	39	445
45%	111	152	118	162	31	352
50%	90	124	95	132	25	285
55%	74	102	78	110	20	236
60%	62	86	66	93	17	198
65%	53	74	56	79	14	169
70%	46	64	48	69	12	146
75%	40	56	42	60	11	127
80%	35	49	37	53	9	112
85%	31	43	32	47	8	99
90%	28	39	29	42	8	89
95%	25	35	26	38	7	80
100%	22	32	23	35	6	72

Table 3.5.5. Minimum number of samples needed to detect change in dry season frequency of occurrence of gray snapper at effect size *L,* in all study areas (rounded to the nearest whole sample).

Wet Season Occurrence of *L. griseus*						
	SA-1		SA-2		SA-3	
L	2005-2011	2011	2005-2011	2011	2005-2011	2011
10%	294	296	446	77	358	128
12%	204	205	305	55	247	91
20%	73	74	105	21	87	35
25%	47	47	66	13	55	24
30%	33	33	45	10	38	17
35%	24	24	33	7	28	13
40%	19	19	25	6	22	10
45%	15	15	20	5	17	8
50%	12	12	16	4	14	7
55%	10	10	13	3	11	6
60%	9	8	11	3	10	5
65%	8	7	9	3	8	4
70%	6	6	8	2	7	4
75%	6	6	7	2	6	3
80%	5	5	6	2	6	2
85%	4	4	6	2	5	2
90%	4	4	5	2	5	2
95%	4	4	4	1	3	2
100%	3	3	4	1	3	2

Table 3.5.6. Minimum number of samples needed to detect change in wet season frequency of occurrence of gray snapper at effect size *L,* in all study areas (rounded to the nearest whole sample).

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8. Appendix A

Interview Guide*:*

Preface:

I'm a graduate student at the University of Miami in Marine Affairs and Policy. I'm conducting research on mangrove fish communities in the vicinity of Turkey Point Nuclear Generating Station and on stakeholder perceptions about the facility and its proposed expansion. Through this interview, I hope to understand perceptions of the TPNGS expansion project from all of the stakeholders. I am interested in your role as a stakeholder in the expansion project/manager of natural resources and your thoughts and opinions of the environmental review process for the project. If you feel strongly about not answering the question, simply say "next question" and we will move on. The information you give will not be connected to you by name or by the name of your organization. I am hoping you will be able to provide me with further contacts for interview and survey. I welcome your suggestions and input on how I could further my knowledge of this issue. I will send you a copy of the final report. Thank you for your participation.

Part I: About the role of the respondent in the issue.

1. Tell me a little bit about yourself and how you got into this business.
    a. Where are you from?
    b. What is your training in?
    c. How did you become involved in this business?
2. How long have you been working in your current job?
    a. Where is your office located?
    b. What did you do before you worked here?
3. How long have you been involved in the TP units 6 & 7 expansion?
4. What is the role of your agency/group in the expansion?
    a. Do you give consultations?
    b. Do you issue any permits?
    c. Under what laws/regulations does your agency/group derive its involvement in the expansion proceedings?
    d. do you do any monitoring? Where?
5. What is your role in the expansion?
6. Did you participate in any public meetings?

Part II: About the Units 6 & 7 expansion (proposed)

** The EIS is currently in the draft stage which has not yet been submitted.*

7. Is there a need for increased energy generating capacity in South Florida?
    If yes →

If no →

b. What do you think would be alternate ways to meet energy demands?

9. What do you see as the greatest challenge (if any) that the project will face in order to proceed according to schedule?

a. Do you think this project will be built?

b. Why or why not?

Part III: About the ecology of Biscayne Bay (past and future)

10. How familiar are you with the ecology of Biscayne Bay?
11. What does Biscayne Bay mean to you?
12. Please list what in your opinion are the greatest challenges facing the ecosystem (fish populations- mangrove habitats, water quality standards) in Biscayne Bay?

a. Why?

13. How do you think Biscayne Bay has changed over time? (If at all).

a. Please list all changes and state whether they are ongoing or completed.

b. What may have caused these changes?

Part IV: About the potential environmental impacts of the proposed plant (if permitted)

15. Of all the cooling systems Turkey Point has used over the years and will use in the future,[once-through, cooling canals, and now the cooling towers] which do you think is the best choice with regards to the marine environment and why?

a. Please rank the systems.

b. Please list the positive and negative attributes of the systems used.

16. Let's talk a little bit about the cooling system for the new units? Are you familiar with the system?

If yes → a. What are your thoughts about the proposed cooling system?

b. What are the potential environmental concerns (if any) you have about mechanical draft cooling towers?

17. Do you think salt drift be an issue with the new cooling system?

a. Why or Why not?

If yes → What do you think will be the spatial/temporal extent of salt drift resulting from these cooling towers?

a. Is the environment able to absorb an effect of this magnitude?

18. Let's talk a little bit about where the cooling water is going to come from.

a. How do you feel about using reclaimed municipal wastewater?

b. How do you feel about the radial collector wells?

19. Do you think there is potential for impact to Biscayne Bay? r

If yes → a. Will the effects be localized or widespread?

b. Will they be short or long term?

Part V: Overall opinion of the environmental review and licensing process.

20. What has your experience been so far with the permitting process and the projects you've been involved with?
    a. Please list positive and negative attributes of the licensing process.
    b. How have these findings influenced your expert view about the expansion?
21. Please rank how much you agree or disagree with the following statement on a scale of 1-5. "I am satisfied with the permitting process." 0 = I don't know enough about this particular question to speak to this, 1= Strongly Agree, 2 = Agree, 3 = Neutral, 4 = Disagree, 5 = Strongly Disagree
    a. How do you feel about the process?
    b. Is the process too strict/not strict enough?
22. What other groups/agencies do you work closely with?
    a. How is your relationship with these groups?

Part VI: **Demographic Information**

23. Where do you live?
    a. How long have you lived there?
24. Age range:
    a. <25
    b. 25-39
    c. 40-50
    d. 50-65
    e. > 65
25. Gender:
    a. Male
    b. Female