ABSTRACT: Florida state law mandates that water use is regulated through a permitting process which requires the protection of wetlands greater than 0.20 ha. The wetlands' permitting criteria is being scrutinized for effectiveness in protecting wetland functions. Hydrologic alteration can adversely impact wetland ecosystems. Detecting an ecological response to hydrologic alterations, especially resulting from groundwater withdrawals, can be subtle and difficult to quantify. To test wetland protection criteria, a hydrologically sensitive indicator species was needed. Native crayfish species, trophically critical elements of Florida wetlands, were selected. Mesocosm studies are being performed to ascertain the survival threshold of crayfishes to hydroperiod alterations. This index will be applied within the permitting process to modeled water usage to determine if the requested water allocation will cause impacts that could negatively affect wetland function.

KEY TERMS: indicator species, crustaceans, ecological assessment, groundwater, wetlands.

INTRODUCTION

Background of Regulatory Issues

In southern Florida, water use is regulated by a permitting process through a state agency, the South Florida Water Management District (SFWMD). Chapter 373 of the Florida Statutes mandates that permitted water use should not cause harm to wetland resources. Typically, the evaluation of the effects of proposed water use requires a drawdown analysis. Currently, the existing permit criteria standard states that under a 90-day period of no recharge (rainfall), consumptive water use shall not cause a drawdown of the groundwater table greater than 1.0 foot at the edge of any wetland. While all water resources may be potentially affected by consumptive water use permits, of particular concern are small, depressional, isolated wetlands. Because of documented harm to isolated wetlands influenced by excessive groundwater withdrawals elsewhere in Florida (Rochow 1994), in 1997 the SFWMD implemented a research program to better ascertain the relationship between hydrology and isolated wetland ecology. While obtaining hydrologic data was straightforward, linking hydrology with ecology and formulating a regulatory criteria from these linkages was not as apparent. This paper describes how the researchers' use of an indicator species in criteria development provided a vehicle for integration of science into the public policy process.
Ecological Setting

Florida's isolated wetlands are known for their seasonal nature. The surface water in these isolated wetlands is, in effect, a surface expression of the groundwater table. During the dry season, groundwater levels drop, and the wetland experiences a drydown where surface water levels are either greatly reduced or absent. The wetlands are not inundated until the groundwater rises above land surface in the early wet season. Florida's diverse wetland types are classified according to their hydroperiods, or approximate amount of time each year that the wetland has surface water (Myers and Ewel, 1990). Generally, marshes and wet prairies have a hydroperiod of 90-180 days, while cypress domes and sloughs have a hydroperiod of 180-365 days. The biota associated with these isolated wetlands are adapted to the seasonally fluctuating nature, with hydroperiod specific life histories. The result is a unique assemblage of species that differs from more permanent water bodies, such as lakes and ponds (Moler and Franz, 1987, Kushlan 1989, Hart and Newman, 1995).

Methods

Hydrologic Data

Hydrologic data were collected at 38 wetland sites throughout central and southern Florida. These wetlands were chosen to represent the diversity of isolated wetland conditions, and include cypress (*Taxodium distichum*) and tupelo (*Nyssa aquatica*) swamps, graminoid and broad leaf marshes, wet prairies, and hydric hammocks. Study sites included wetlands in preserves and parks, agricultural lands, and in proximity to public water use well fields, rapidly developing residential areas, and mining operations. Wetlands within nature preserves and parks were used as control sites as they are not influenced by consumptive water use; other wetlands were specifically chosen because they are near areas influenced by groundwater withdrawals from agriculture and public water supply utility operations. Each wetland was equipped with a Campbell Scientific® CR10X continuous data logger that measured surface and groundwater levels at 15 minute intervals; climatic events were also recorded at weather stations set up within the study areas. Data were collected and the instruments were calibrated on a monthly basis. Observations made from 1997-2001 led to the conclusion that the consumptive water use's main effect on wetlands translated into changes in wetland hydroperiod. These changes could be incurred two ways; surface water could be reduced in overall volume so that the wetlands would get dry earlier, reducing hydroperiod at the end of the wet season, or groundwater would be drawn to such deep levels in late dry season, that the onset of wetland rehydration is delayed as it would take a longer time for groundwater levels to rise above land surface. Average hydroperiod of different isolated wetland types were determined; research is currently underway to determine how various causal factors, such as climate and consumptive water use, can influence changes in wetlands hydroperiods.

Selection of an Indicator Species

The hydrologic data told much about the water levels in the wetlands under a variety of settings, but nothing about how the wetland ecosystems were responding to or influenced by hydrologic alteration. To decipher the imprint that hydrology left on the wetlands' biota, an indicator species was required. Indicator species are often used as effective ecological measures of a potential stressor's effect upon the environment. The researchers developed criteria to detect which isolated wetland biota would be suitable indicator species. These criteria were:

- a potential indicator species' life history obligated it to the use of isolated wetlands,
- this plant/animal had a measurable life history trait influenced by hydrology,
- preferably, the influence of hydrology upon the indicator species was discernible on a short time frame (<1 year),

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preferably, the indicator species would have an influential (i.e., key) position within isolated wetland ecosystems.

It was determined that native crayfish species (Procambarus alleni, Procambarus fallax) fit all these criteria. Crayfish area known as a key species (Momot and Jones, 1978, Huner 2000), and their presence has a profound effect within their ecosystems (Momot and Jones, 1978, Weber and Lodge, 1990 Gamradt and Kats, 1996, Nystrom et al., 1996, Taylor and Redmer, 1996, Gamradt and Kats, 1997, Guan and Wiles, 1997, Gutierraz-Yurrita and Montes, 1998). These decapod crustaceans are ubiquitous within Florida's intact wetland ecosystems, and are one of the most abundantly available food resource for many wetlands predators (Hobbs, 1942, Hendrix and Loftus, 2000). Crayfish are prey for many higher order predators such as wading birds, reptiles, amphibians, sport fish, and mammals. Many species, such as the white ibis (Eudocimus alba), crayfish frogs (Rana aerolata), crayfish snakes (Regina spp.) and otter (Lutra canadensis) specialize in feeding on crayfish (Kushlan and Kushlan 1979, Kushlan 1979, Ashton and Ashton, 1988, Conant and Collins, 1991, Choate et al., 1994, Tennant, 1997, Huner 2000). Crayfish also assist the energy flow through wetland food webs as they convert stored energy in detrital matter to a usable form (Momot and Jones, 1978, Lodge and Kershner, 1994, Nystrom et al., 1996, Whiteledge and Rabeni, 1997). As voracious herbivores, they can also alter a wetlands' macrophytic structure and associated fish and microinvertebrate species both positively and negatively (in the case of introduced crayfish species). A field study by the research staff in 1999-2000 revealed that there is a significant, strong correlation (r=0.93) between the fluctuating groundwater levels and crayfish behavior. Instead of dispersing to deeper waters, P. alleni responds to falling wetland water levels by excavating survival burrows. P. alleni continue to deepen their burrows as the groundwater falls further below land surface, suggesting that the crayfish are following the groundwater table as it moves down through the soil, and are seeking an optimal environment to survive the dry season. Surviving the dry season interred in burrows is crucial for the sustainability of the crayfish population within each wetland. (Huffman, 2001). Because of its important trophic position, declines in crayfish populations could translate negatively throughout the wetland ecosystem. These negative effects could include a shift in the trophic balance of the wetland, a build-up of detrital matter, which could lead to eutrophication of the ecosystem (Lodge and Kershner, 1994, Nystrom et al., 1996, Whiteledge and Rabeni, 1997), and a decline in those species that specialize in feeding on crayfish.

While the field study revealed that P. alleni may potentially be vulnerable to hydrologic alterations, little has been published about the tolerances of P. alleni and P. fallax to hydrologic change. To effectively use crayfish as an environmental assessment tool, a strong linkage must be made between hydrologic alteration and crayfish's ability to survive in an altered system. To pinpoint the level at which hydroperiod loss becomes lethal for crayfish, a laboratory mesocosm experiment was designed to simulate a stressful condition (lack of surface water) in varying degrees to determine at what level hydroperiod reduction induces a large pulse in mortality for both P. alleni and P. fallax. The goal of the research experiment was to determine the maximum drydown duration that represents the survival threshold for each species. From this drydown duration threshold the corresponding hydroperiod can be calculated. This hydroperiod, represented in numerical terms, can be used as the basis for the permit criteria for the groundwater drawdown analyses associated with water use permit applications. These analyses will be used to interpolate an expected change upon the hydroperiod of any wetland systems nearby and determine if the requested allocation would induce a hydroperiod loss greater than the survival thresholds of the wetlands' extant crayfish populations.

Mesocosm Drawdown Survivor Threshold Study

The drawdown experiment used the corresponding amount of dry time of various hydroperiods (e.g. 120 day hydroperiod=245 day dry condition) to represent drawdown stress at different levels. Test mesocosms were delineated as control (no drawdown, permanently flooded),
and from 30 up to 240 days of drydown, divided into 30 days increments. One species was used for each mesocosm, and each treatment level was replicated twice per species.

Clear acrylic mesocosms (122cm x 47cm x 47cm) were constructed using non-toxic aquarium sealants. Each mesocosm was lined with 0.003 mm plastic garbage bag for added leak protection. PVC wellscreen piezometers with 10-slot, 5.1cm x 152.4cm screen were inserted in the middle of the mesocosm and the mesocosms were filled to a wet sand level of 96cm with masonry sand, which is approximately the same grain size as the sands found within Florida's isolated, depressional wetlands. Control tanks were equipped with corner filter-aerators as they were to remain inundated for the experiments duration. Test tanks were equipped with airstones. All mesocosms were filled to a depth of 122cm with water treated with detoxifying reagents. Submerged aquatic plants collected at crayfish capture sites were added to the tanks. Each tank was inoculated with 6 crayfish. The crayfish were allowed to acclimate to their tanks for a week. All tanks, while inundated, received equal amounts of commercial crustacean food pellets and dosing of biological waste detoxifying solutions three times a week. Using a small pump and hose, tanks were subjected to artificial drawdown through the piezometer weekly until their surface water levels reached zero. This was considered the starting point of the test. The tanks were then allowed to stay dry for a specified amount of time, or treatment level. Sub-surface water levels and crayfish observations were made three times a week after complete drydown. Once a treatment's time allotment had passed, the tanks were re-flooded. Hidden surviving crayfish usually emerged from the sand within a few hours. The percentage of crayfish surviving the dry period was calculated after several days, to allow enough time for deeply burled crayfish to emerge. Preliminary results indicate that P. fallax has a very low tolerance to complete lack of surface water, with a mortality rate of 90%, while P. alleni, sheltering in burrows they create after all surface water is removed, have a survival rate of 80% at 60 days. All tests will be completed by October 2002, with the expectation that there will be a level of drydown above which there is 100% mortality. This drydown level, after re-testing, will be used as the survival threshold in developing the permit criteria.

SCIENCE AND POLICY INTEGRATION

Quantifying the ecosystem's basic needs for water resources is a first step in understanding how human water use can affect a harmful change. Using an indicator species that is common throughout the ecosystem, at or near the base of the food web, and sensitive to the presence of the targeted stressor allows two benefits over using rare and higher order indicator species. First, much ambiguity and questions about multi-faceted causation created when studying rare or higher order indicator species is eliminated, and secondly, a potential stressor's effect upon an ecosystem becomes apparent before it reaches the top of a foodweb.

Using quantifiable measures, such as key species' demands of a specific resource, to gauge an ecosystem's essential needs, allows humans to maximize the performance and efficiency of decisions used in the planning, design and implementation of public policies. Water resource managers are faced with the increasingly difficult task of recognizing and accommodating the needs of both the public interests and the environment. Developing innovative solutions and compromises in environmental policy is the challenge of natural resource management. Using applied scientific research that targets the mechanistic understanding of an ecosystem's response to natural stressors is an assessment tool that allows the integration of science in the development of sustainable resource management policy. This approach is a collective attempt by scientists and policy makers to positively affect long term ecosystem and public health while allowing for the needs of resource consumers.

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