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Research article

How could discharge management affect Florida spring fish assemblage structure?

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ABSTRACT

Freshwater bodies are increasingly affected by reductions in water quantity and quality and by invasions of exotic species. To protect water quantity and maintain the ecological integrity of many water bodies in central Florida, a program of adopting Minimum Flows and Levels (MFLs) has begun for both lentic and lotic waters. The purpose of this study was to determine whether there were relationships between discharge and stage, water quality, and biological parameters for Volusia Blue Spring, a first magnitude spring (discharge > 380,000 m^3 day^{-1} or 100 mgd) for which an MFL program was adopted in 2006. Over the course of fourteen years, we assessed fish density and diversity weekly, monthly, or seasonally with seine and snorkel counts. We evaluated annual changes in the assemblages for relationships with water quantity and quality. Low discharge and dissolved oxygen combined with high stage and conductivity produced a fish population with a lower density and diversity in 2014 than in previous years. Densities of fish taxonomic/functional groups also were low in 2014 and measures of water quantity were significant predictors of fish assemblage structure. As a result of the strong relationships between variation in discharge and an array of chemical and biological characteristics of the spring, we conclude that maintaining the historical discharge rate is important for preserving the ecological integrity of Volusia Blue Spring.

1. Introduction

Globally, freshwater systems are threatened by changes in water availability and timing of inputs, reductions in water quality and changes in nutrient recycling rates, changes in watershed land use, and introductions of invasive species (Dudgeon et al., 2006; Geist, 2011). These threats are likely to be most severe in areas of water scarcity or high human population density (Postel, 2000; Kummu et al., 2010; Cooley et al., 2014), two conditions that may or may not co-occur (Kummu et al., 2010). Water scarcity and high population density produce societal need for water, which in turn produces political will to support the societal need; these two factors stand in the way of maintaining historic water levels and flow rates (Postel, 2000; Katz, 2006). In areas that rely heavily on groundwater, water withdrawals from aquifers for domestic, agricultural, or industrial uses can cause water scarcity in areas where it previously did not exist or exacerbate the problem in areas where it did exist (van der Kamp, 1995; Postel, 2000; Custodio, 2002; Kummu et al., 2010). Limitations on water recharge to aquifers may compound the problem of groundwater withdrawals in developed areas.

To help reduce the conflict over water availability between water users and ecological function, hydrologic models can provide quantitative estimates of seasonal and annual variation in water availability, and the impact of consumptive use on this available water (Poff et al., 2003; Richter et al., 2003; Arthington et al., 2006). Early hydrologic approaches for water management focused on minimum stream flows only, whereas more sophisticated modern approaches have incorporated the timing and the duration of high/low flow events and the rate of change of these events (Poff et al., 1997; Richter et al., 1997, 2003; Arthington et al., 2006; Dudgeon et al., 2006). High and low flow events can drastically affect the viability of freshwater fish and invertebrate populations and, therefore, the composition of these assemblages (Poff et al., 1997; Bunn and Arthington, 2002; Arthington et al., 2006; Dudgeon et al., 2006). For example, in some streams and rivers, high flow events can scour organisms from the substrate or submerge riffles; in others, high flows can inundate productive reproductive habitat, allowing organisms to complete their life cycles in flooded forest

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(Poff et al., 1997; Bunn and Arthington, 2002). Poff et al. (1997) and Bunn and Arthington (2002) provide more detailed overviews of the wide range of possible effects of changing flow rate and periodicity on stream and river assemblages. Thorough hydrologic modeling in consultation with ecologists can allow water managers to evaluate how management plans will affect the needs of human use and freshwater conservation (Dudgeon et al., 2006).

Florida provides an interesting case study for this type of conflict between water use and conservation as it is among the fastest growing states in the US (https://www.census.gov). Although freshwater appears plentiful in Florida, the majority of the water used by the population of Florida originates in the Floridan Aquifer (Marella and Berndt, 2005). The Floridan Aquifer is relatively shallow and recharges easily relative to deep aquifers, like the Ogallala Aquifer that underlies the Great Plains (Sophocleous, 2005; Toth and Katz, 2006). However, increases in water withdrawals and reductions in water recharge associated with the increase in impervious surfaces during land development threaten the continued maintenance of water pressure in the Floridan aquifer (Spechler and Halford, 2001). Discharge from Florida's iconic springs depends upon maintaining aquifer pressure.

The fresh water of Florida, including that discharged from springs, is managed by five Water Management Districts that are charged with finding the balance between water supply and ecological integrity (Munson et al., 2005). The St. Johns River Water Management District (SJRWMD) manages all of the waters within the St. Johns River watershed, which includes all or part of several large metropolitan areas (Jacksonville, Orlando, and Daytona) in east central and northeast Florida. The water demands in this region, as is true of most of Florida, are great. To help manage demands on water quantity, the Florida Water Resources Act of 1972 charged the water management districts with developing Minimum Flow and Level programs (MFL) for major water bodies in the state (Munson et al., 2005). The purpose of these MFL programs is to help make determinations about the impact of new and existing consumptive use permits on spring and river flows and on lake levels (Neubauer et al., 2008). Each of the MFL programs adopted by the SJRWMD incorporates the magnitude and rate of change of flow as well as the duration, timing, and return intervals of high and low flow events to predict the effect of consumptive use on spring flow and to prevent “significant harm” to the ecosystem. Each MFL program is specific to a system and represents the hydrologic condition over long periods (possibly 50 years). The original language of the legislation was vague on the biological criteria for preventing “significant harm” (Munson et al., 2005), so the criteria can focus on species, communities, or processes (Neubauer et al., 2008). .

Volusia Blue Spring is one of the large first magnitude springs of Florida (Scott et al., 2004) and a major winter refuge for Florida manatee (Laist and Reynolds, 2005). This spring, like most in central Florida, has experienced a triad of disturbances, with decreases in water supply concurrent with increases in nutrient loading and pressure from exotic species (Shafland, 1996; Katz, 2004; Phelps et al., 2006; Stevenson et al., 2007; Work et al., 2010). To maintain water supply in this system, an MFL program was established in 2006. The primary ecological goal of this MFL program was to maintain winter warm-water refuge habitat for the endangered Florida manatee, the population of which was modeled as growing exponentially (Rouhani et al., 2007). By the time of the adoption of this MFL, the spring discharge had declined below the historic mean of 4.45 $m^3\ s^{-1}$ or 157 cfs (cubic feet per second) of the period of record of 1933–2006 (Fig. 1). Discharge ranged from approximately 4.4 $m^3\ s^{-1}$ or 155 cfs to 4.7 $m^3\ s^{-1}$ or 165 cfs until the early 1980s, after which the discharge declined sharply to near 3.7 $m^3\ s^{-1}$ or 130 cfs in 1990; Rouhani et al. (2007) attributed the decline to a long period of relatively low rainfall from 1970 to 1990. Since 1990, the discharge has been variable, but overall the trend has been a decline in discharge over the period of record from 1932 to 2013 (Holland and Bridger, 2014). Under the MFL plan, the spring discharge is to be restored to its historic mean over the course of fifteen years (2009–2012 = 3.88 $m^3\ s^{-1}$ or 137 cfs, 2014–2019 = 4.02 $m^3\ s^{-1}$ or 142 cfs, 2019–2024 = 4.19 $m^3\ s^{-1}$ or 148 cfs, after 2024 = 4.45 $m^3\ s^{-1}$ or 157 cfs). These discharge goals were based on maintaining the “warm-water useable habitat” for manatees and avoiding catastrophic 50-year events, such as combinations of low discharge, low stage, and low river temperature that would last 3 or more days and increase the likelihood of cold stress for manatees. During this period of discharge increase, the MFL program mandated monitoring the spring at five year increments to ensure that primary producers, invertebrates, fish, turtles, and manatees all maintained healthy populations. The first survey of the Volusia Blue Spring under the Minimum Flow and

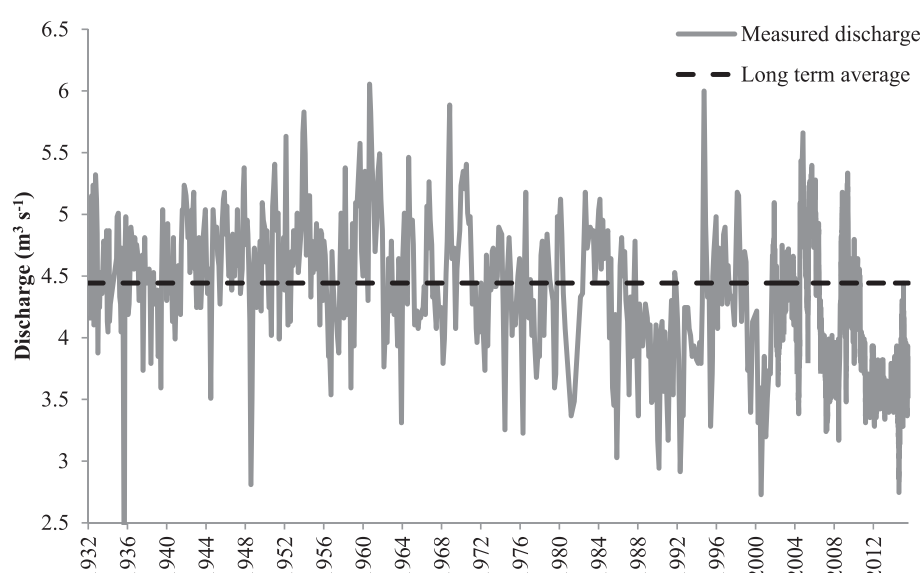

Fig. 1. Long-term trends in discharge for Volusia Blue Spring (1932–2015). Data were provided by SJRWMD and US Geological Survey (USGS).