Dissolved Oxygen Dynamics in Charlotte Harbor and Its Contributing Watershed, in Response to Hurricanes Charley, Frances, and Jeanne—Impacts and Recovery

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ABSTRACT: On August 13, 2004, Hurricane Charley came ashore in the Charlotte Harbor watershed. Surface winds at the time of landfall were estimated at 130 knots. The track of the hurricane roughly followed the floodplain of the Peace River, causing massive defoliation and mortality of native vegetation and planted citrus groves, as well as substantial damage to human habitation and various infrastructure elements. Eight days after landfall, a water quality monitoring effort documented hypoxic (< 2 mg l⁻¹) to nearly anaerobic (< 0.5 mg l⁻¹) dissolved oxygen (DO) values throughout the vast majority of the Peace River’s c. 6,000 km² watershed. Low DO values appeared to be related to high values of both dissolved organic matter and suspended materials. Hypoxic conditions in Charlotte Harbor itself occurred within 2 wk of landfall. Approximately 3 wk after the landfall of Hurricane Charley, Hurricane Frances struck the east coast of Florida, causing further wind damage and bringing substantial amounts of rain to the Charlotte Harbor watershed. Three weeks later still, Hurricane Jeanne caused similar damage to the same area. In response to the combined effects of these three hurricanes, DO values in the Peace River did not recover to pre-hurricane levels until approximately 2–3 mo later. The spatial and temporal pattern of DO fluctuations appeared to be related to the proximity of sampling locations to the path of the eyewall of the first of the three hurricanes. Within the Harbor itself, the duration of hypoxic conditions was less than that recorded within the Peace River, perhaps reflecting greater dilution of oxygen-poor waters from the watershed with less-affected water from the Gulf of Mexico.

Introduction

On August 13, 2004, the first of three hurricanes to affect the watershed of Charlotte Harbor made landfall at Cayo Costa, Florida (Sallenger et al. 2006). The first of these three, Hurricane Charley, was a category 4 storm on the Saffir-Simpson scale, with surface winds at landfall estimated at 130 knots. Hurricane Charley was the most powerful hurricane to hit the United States since Hurricane Andrew in 1992 (Pasch et al. 2005). Hurricane-force winds were experienced along the storm’s entire pathway across peninsular Florida, from Cayo Costa to Ormond Beach (Sallenger et al. 2006). Nine tornadoes were associated with Hurricane Charley’s passage through Florida (Pasch et al. 2005). The initial track of Hurricane Charley closely followed the course of the Peace River, the largest source of freshwater inflow to Charlotte Harbor. Within 6 wk, two additional hurricanes, Frances and Jeanne, struck the east coast of Florida, causing further wind damage and bringing substantial amounts of rain and flooding to the Charlotte Harbor watershed.

Several days after the passage of Hurricane Charley, numerous complaints of foul smelling water in the Peace River were received from the public. Concerns about the quality of water in the Peace River were received from officials at numerous public water supply utilities. Surface water withdrawals from the Peace River are one of the primary sources of drinking water for a population of c. 750,000 people in southwest Florida.

In response to the potential health and environmental issues apparent after the passage of Hurricane Charley, additional efforts were undertaken to supplement existing water quality monitoring efforts in the Peace River watershed. These efforts were designed to increase the monthly monitoring frequency to weekly sampling and to add water quality parameters that might prove useful for determining the basis for observed problems with dissolved oxygen (DO) values in the Peace River. Ongoing water quality sampling efforts in Charlotte Harbor were continued to determine the spatial and temporal extent of hypoxic conditions (DO < 2 mg l⁻¹) in the Harbor.
Materials and Methods

A comprehensive water quality monitoring program for the Peace River watershed has been in place since 1997. This effort replaced a series of informal monitoring programs for the watershed that had been in place since the 1950s. At a series of fixed sites, field parameters (e.g., temperature, DO, pH) are recorded, and water samples are collected for various laboratory-derived parameters (e.g., nutrients, turbidity). Samples are normally collected on a monthly basis.

In response to concerns with DO values in the Peace River, regularly visited stations (on a monthly frequency) were sampled out-of-cycle on August 22, 2004, 8 d after the landfall of Hurricane Charley. Sampling frequency for these sites was increased to weekly visits, with the intent of dropping back to monthly sampling when DO values recovered to pre-disturbance levels. The locations of these sites are shown in Fig. 1. Using storm track information supplied in Pasch et al. (2005), the distance between the sample locations and the path of the eyewall of the hurricane was estimated.

Field parameters for Peace River samples were collected with standard water quality probes that were calibrated prior to deployment. At the end of the day, all probes were checked against known standards to ensure data reliability. All probes passed all post-sampling data checks.

For laboratory parameters for Peace River sites (turbidity [NTU], total suspended solids [TSS, mg l\(^{-1}\)], color [PCU], and biological oxygen demand [BOD, mg l\(^{-1}\)]), samples were brought back to the Tampa laboratory of the Florida Department of Environmental Protection for processing. All laboratory data met all relevant requirements for sample collection, holding times, and analytical techniques specified for the National Environmental Laboratory Accreditation Program.

In the open waters of Charlotte Harbor, a series of stations has been visited on an irregular basis to study various aspects of stratification-induced hypoxia. A model examining the physical and biogeochemical factors contributing to the development of hypoxia in Charlotte Harbor was developed using data from these stations (Camp, Dresser, and McKee, Inc. 1998). Data from these stations were also used to calibrate a historical reconstruction of hypoxia in Charlotte Harbor by Turner et al. (2006). The open waters of Charlotte Harbor itself are sampled via an ongoing water quality monitoring program conducted by the Florida Fish and Wildlife Conservation Commission (FFWCC). On a monthly basis, staff from the FFWCC visit five randomly selected sampling locations within each of several strata within Charlotte Harbor and the lower reaches of the Peace and Myakka Rivers. For this report, DO data from 0.2 and 2.0 m below the surface were analyzed from the strata Upper Charlotte Harbor.

Results

The temporal patterns of DO values in the Peace River watershed varied spatially. In the upper portion of the watershed, DO values at Bartow in the upper portion of the watershed are regularly hypoxic (DO < 2 mg l\(^{-1}\); Fig. 2), and the data do not support a hurricane-related DO crash at this site. At Fort Meade, DO values appear to have been affected by Hurricane Charley, and DO values took approximately 3 mo to recover to pre-hurricane levels. In the middle portion of the Peace River, DO values appeared to have dropped to hypoxic levels in response to the passage of Hurricane Charley.