COASTAL WATERSHED CONDITION ASSESSMENT OF FORT PULASKI NATIONAL MONUMENT

Caroline McFarlin[1] and Merryl Alber[2]

AUTHORS: Graduate Student[1] and Assistant Professor[2], Dept. of Marine Sciences, University of Georgia, Athens, GA 30602
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Abstract. We recently completed an assessment of Fort Pulaski National Monument for the Water Resources Division of the National Park Service. The report provides information on park resources, water quality and impairments, and other issues of concern. Although there are no real sources of pollutants at Fort Pulaski itself, both point and nonpoint sources of pollutants can be found nearby that have the potential to affect its water resources. We identified nutrients and contaminants as currently existing problems. A majority of nutrient samples were classified as either fair or poor, and there is evidence for elevated contaminants (primarily arsenic and PAHs) in sediment and animal tissue taken from both tidal creeks and the main channel of the Savannah River. Dissolved oxygen was identified as a potential problem due to the amount of organic material and nutrients associated with industrial activity. Fecal bacteria concentrations are low and not considered a problem. Continued water quality monitoring at the Park is particularly important in order to note any change occurring with the Savannah Harbor Expansion Project. The report provides a list of recommendations for additional observations that would allow us to better evaluate coastal water resources.

INTRODUCTION

Fort Pulaski National Monument is located 15 mi. east (and downstream) of Savannah, GA and is comprised of a series of small islands surrounded by salty, tidally-influenced river channels and creeks. The Park extends from the mouth of the Savannah River to about 7 mi. upstream. Salt marsh and open water habitat constitute the majority of the Park's total area (~5,000 of 5,623 ac.) (Meader, 2003; NPS, 2004). Although there are [currently] no major sources of pollutants within the Park, its water resources are influenced by numerous upstream industrial and municipal facilities, as well as by alterations (deepening and dredging) to the River and the container ship traffic associated with the Port of Savannah. In addition, water resources near the Park may be affected if the Harbor (from Fort Pulaski to just above Kings Island Turning Basin, ~36 mi.) is deepened an additional 6 to 8 ft as proposed by the Harbor Expansion Project.

A watershed assessment of Fort Pulaski was completed for the National Park Service in 2005 (McFarlin and Alber, 2005). The purpose of the report was to evaluate water quality in and around the Park itself, compile information on pollutant sources in its watershed, and identify potential threats to water-dependent resources and habitats. This paper summarizes the information on water quality that was compiled as part of the report and provides recommendations for further work.

METHODS

Our assessment of water quality conditions at the Park included information on nutrient concentrations, dissolved oxygen, bacterial indicators, and contaminants. In all cases we focused on data from stations immediately adjacent to Fort Pulaski (Fig. 1).

Most of the recent water quality data (since 2000) reported here is from the Coastal Resources Division (CRD)

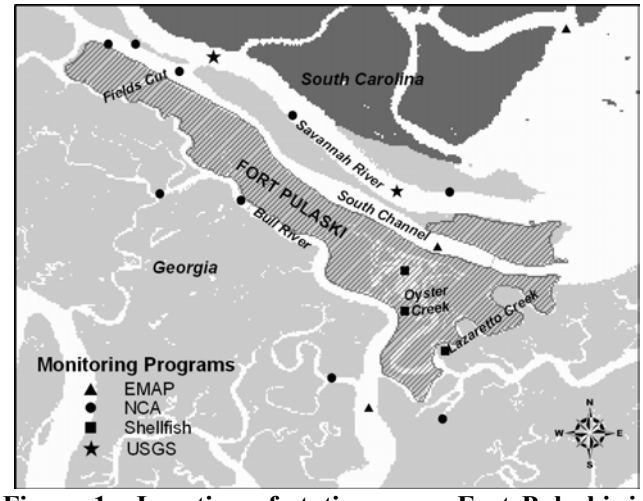

Figure 1. Location of stations near Fort Pulaski, including those that were part of the U.S. EPA Environmental Monitoring and Assessment Program (EMAP), both the National Coastal Assessment (NCA) and Shellfish Monitoring stations sampled by the GA DNR-CRD, and stations sampled as part of a USGS study (Hyland et al., 1998; USGS, 2005).

of the GA Dept. of Natural Resources (DNR). CRD collects samples near Fort Pulaski as a part of two ongoing programs: the State's shellfish monitoring and EPA's National Coastal Assessment Program (NCA). CRD samples 4 shellfish stations immediately adjacent to Fort Pulaski monthly, and another 1-3 randomly selected sites are sampled once during the summer as part of the NCA program (n=9 sites total, 2000-2003). Measurements include dissolved nutrients (total dissolved nitrogen (TDN); ammonium (NH_4); nitrate + nitrite (NO_3+ NO_2); total dissolved phosphorus (TDP); orthophosphate (PO_4)), dissolved oxygen (DO) concentrations, bacterial indicators (fecal coliform) and contaminants (metals and priority pollutants in sediment and animal tissue).

Additional sources of water quality data are from the NSF-sponsored GA Rivers Land Margin Ecosystem Research (LMER) Program at the University of GA (Wiebe and Sheldon unpublished data) and USGS sampling (USGS, 2005). Observations of contaminants in sediment and organisms comes from the EPA Environmental Monitoring and Assessment Program (EMAP) (Hyland et al., 1998); the 1998 EIS Savannah Harbor Expansion Feasibility Study (GPA, 1998); studies conducted for the Park Service by investigators at Savannah State University (Richardson and Sajwan, 2001 and 2002); and an independent study by Loganathan et al. (2001).

RESULTS

Dissolved Nutrients. Average dissolved inorganic nutrient concentrations near Fort Pulaski are summarized in Table 1. The measurements from the various programs show quite a range: average DIN concentrations (the sum of NH_4, NO_3 and NO_2) were lowest in the GA-CRD data set and highest in the GA Rivers LMER observations, and average PO_4 concentrations were lowest in the NCA observations and highest in the USGS sampling. Station locations, sampling dates, and analytical methodology varied among the different programs, but these observations are in keeping with nutrient concentrations reported for South Carolina open waters and tidal creeks in summer 2000 (Van Dolah et al., 2002).

There are no EPA standards for dissolved nutrient concentrations, so we compared the observations to the criteria developed for the National Coastal Condition Report II (NCCRII) (U.S. EPA, 2004). For nitrogen, DIN concentrations less than 0.1 mg N L^{-1} are considered "Good;" those between 0.1 and 0.5 are considered "Fair;" and those above 0.5 are considered "Poor." By these criteria, 51% of the total DIN observations in the Fort Pulaski region of the Savannah River (n = 167) are Good and 49% are Fair (none are Poor). For phosphorus, dissolved inorganic phosphorus (DIP) concentrations less than 0.01 mg

Table 1. Nutrient concentrations (mg L^{-1}) reported by various programs at stations adjacent to Fort Pulaski, GA and in South Carolina tidal creeks and open water. Nitrogen species as listed; DIN is Dissolved Inorganic Nitrogen; TDN is Total Dissolved Nitrogen; TDP is Total Dissolved Phosphorus. Data are means ± standard deviation.

Program	GA Rivers LMER	USGS	GA-CRD Shellfish Monitoring	NCA Monitoring	South Carolina
# Stations	Transect, ~RM 0-8	2	4	6	60
Dates of Observations	year-round (1994-1996)	year-round (2002-2003)	year-round (2001-2003)	summer (2000-2002)	summer (1999)
Nitrogen (mg N L^{-1})					
NH_4 (# obs)	n=15	n=48	n=578	n=6	n=53
mean ± SD	0.072 ± 0.025	0.049 ± 0.033	0.044 ± 0.028	0.064 ± 0.035	0.051 ± 0.064
min-max	0.014 – 0.105	0.015 – 0.14	0.007 – 0.131	0.022 – 0.103	0 - 0.280
NO_2 + NO_3 (# obs)	n=15	n=48	n=98	n=6	n=57
mean ± SD	0.131 ± 0.054	0.103 ± 0.049	0.035 ± 0.026	0.110 ± 0.121	0.035 ± 0.049
min-max	0.023 – 0.194	0.025 – 0.23	0.001 – 0.130	0.004 – 0.291	0 – 0.305
DIN (# obs)	n=15	n=48	n=98	n=6	n=50
mean ± SD	0.203 ± 0.072	0.152 ± 0.066	0.079 ± 0.044	0.174 ± 0.124	0.094 ± 0.087
min-max	0.079 – 0.294	0.045 - 0.31	0.008 – 0.211	0.065 – 0.349	0.006 – 0.380
TDN (# obs)	n=10	---	---	---	n=59
mean ± SD	0.391 ± 0.062	---	---	---	0.594 ± 0.146
min-max	0.282 – 0.471	---	---	---	0.361 – 0.950
Phosphorus (mg P L^{-1})					
PO_4 (# obs)	n=15	n=48	n=578	n=2	n=60
mean ± SD	0.027 ± 0.010	0.073 ± 0.040	0.023 ± 0.011	0.014 ± 0.001	0.023 ± 0.034
min-max	0.013 – 0.042	0.03 – 0.19	0.003 – 0.072	0.014 – 0.021	0 – 0.209
TDP (# obs)	---	---	n=572	---	n=60
mean ± SD	---	---	0.035 ± 0.020	---	0.039 ± 0.035
min-max	---	---	0.018 – 0.100	---	0.006 – 0.255

LMER (Wiebe and Sheldon, unpublished data), USGS (USGS, 2005), and South Carolina (Van Dolah et al., 2002).

P L^{-1} are considered "Good;" those between 0.01 and 0.05 are considered "Fair;" and those above 0.05 are considered "Poor." By these criteria, 77% of the total DIP observations (n = 163) are Fair; 4% are Good, and 19% are Poor. These results indicate that nutrient concentrations warrant continued observation in this area.

Dissolved Oxygen. Observations of DO concentrations in surface water come from samples collected by GA CRD for the Shellfish Monitoring Program. These measurements were generally taken at mid-day and thus do not reflect the daily minimum (which usually occurs just before dawn). Surface DO measurements ranged from 2.7 to 10.7 mg L^{-1} and averaged 5.8 ± 1.7 mg L^{-1} from Mar 2000 – Apr 2004. Concentrations less than the GA EPD Recreational Water Quality Standard of 4 mg L^{-1} occurred 16% of the time (31 of 196 observations), with 6 of the observations falling below 3 mg L^{-1}. There was a distinct seasonal cycle in DO concentrations, with summertime minima and wintertime maxima (Figure 2). All observations of low DO occurred between May and Oct (these were nearly equally distributed across the 4 stations).

Information on DO concentrations throughout the water column come from samples taken by GA CRD for the NCA Program. Oxygen concentrations were measured at 1-m intervals during the late summer (either in Aug or Sept), when DO minima occur. DO concentrations during 2000, 2002, and 2003 ranged from 3.32 to 5.23 mg L^{-1}, with surface water (<1 m) averaging 4.38 ± 0.57 and bottom water (the lowest measurement in a profile) averaging 4.03 ± 0.62. Two stations near Elba Island Cut (~RM 6 in the North Channel) and two near the intersection of Turners Creek and the Bull River had average concentrations below 4 mg L^{-1}.

Bacterial Contamination. Fecal coliform concentrations were measured at the four CRD Shellfish stations located in Oyster Creek, which is the only approved site for shellfish harvest in Chatham Co. Of the 584 monthly observations taken between 1991 and 2004 (n =145-147 at each station), only 9 were above the GA criterion for coastal recreational water (100 CFU/100 ml). In order to evaluate similar monthly sampling, Van Dolah et al. (2002) considered 43 CFU/100 ml as representative of marginal conditions and >400 CFU/100 ml as degraded conditions. In the CRD data set, 18 observations (3.1%) are considered marginal and 7 extremely high observations (1.2%), taken from June 1991 to July 2000, are considered degraded. Nearly half of these observations were at the most upstream station (#1222), which may reflect reduced flushing at this site. However, more recent measurements (2002-present) were ≤5 CFU/100 ml, indicating improved conditions at this location.

Contaminants. According to the Environmental Impact Statement (EIS) done for the GA Ports Authority (GPA 1998), four heavy metals (cadmium, chromium, copper, and arsenic) were elevated (above effects range low (ERL) values), and butyltin and PAHs were enriched in channel sediments near Fort Pulaski in 1996 and 1997. However, associated toxicity and bioaccumulation tests for both heavy metals and organic contaminants indicated little to no effects on organisms. The EIS also provided information on contaminants found in the water: River reaches just above and below Fort Pulaski exceeded GA Water Quality Standards for copper (>2.9 mg L^{-1}) and nickel (>8.3 mg L^{-1}); ammonia (max. 34,000 µg L^{-1}) and manganese (max. 2,130 mg L^{-1}) were elevated to levels previously found to cause toxic affects in marine organisms; and arsenic was elevated (~6.6 µg L^{-1}) but well below the GA Water Quality Standard.

Other studies conducted at the Park also showed some evidence for elevated contaminants in sediment and animal tissue. We compared sediment contaminants from the EMAP and NCA programs to ERL values and found no exceedances in either metal or organic contaminant concentrations, and all sediment toxicity tests were negative. However, arsenic was enriched in sediment at one NCA site (GA00-0030 had a concentration of 7 ppm, compared to the ERL value ~8 ppm). Loganathan et al. (2001) also reported concentrations of DDT (2.11 ppb) in North Channel sediments above ERL values. The EMAP/NCA program also conducted analyses of shrimp tissue. A total of 47 contaminants were detected between the two programs. Although none of these were above FDA guidelines (action or tolerance levels), arsenic and PAHs were elevated in comparison to EPA Risk Guidelines. Richardson and Sajwan (2001, 2002) also reported elevated concentrations of arsenic and PAHs in oyster tissue. It should be noted that tissue contaminant concentrations did de-

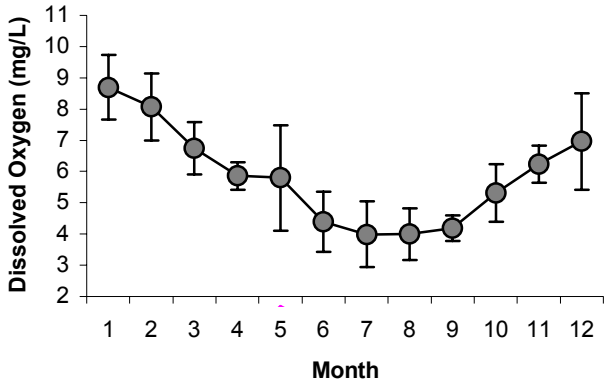

Figure 2. Seasonal variation in mean dissolved oxygen averaged across 4 GA DNR-CRD Shellfish stations in Oyster Creek. Data from March 2000 - April 2004.

crease between EMAP (sampled in 1995) and NCA (sampled in 2000): arsenic decreased from 0.26 to 0.04 ppm and total PAHs decreased from 0.15 to 0.008 ppm. However, these sites would still be rated "poor" according to the NCCRII criteria. Finally, Loganathan et al. (2001) reported elevated levels of PCBs in fish tissue (spot, silver sea trout, Atlantic croaker, and Atlantic menhaden).

DISSCUSSION AND RECOMMENDATIONS

The watershed assessment of Fort Pulaski provided us with information that we used to assess the potential for impairment to the various water resources of the park. We classified nutrients and contaminants as existing problems, and DO as a potential problem based on the water quality data compiled for the report. Fecal coliform, in contrast, were not considered a problem. Below we provide the reasons for making these judgments and offer recommendations for improved sampling in the future.

Nutrients were identified as an existing problem at Fort Pulaski. Although nutrient observations were extremely limited, nearly half of the DIN and over half of the DIP measurements taken for the NCA and USGS programs were classified as fair or poor, which suggests that continued observation is important. It would also be useful to obtain measurements of dissolved organic nitrogen (DON) for the region. Long-term measurements at Skidaway Island, just outside the study area, show evidence of linear increases in DON concentration over the past 10 y, along with smaller, less obvious increases in DIN (Verity, 2002). Given that DON comprises approximately 80% of total dissolved nitrogen, additional measurements of DON would be informative.

Although neither the EMAP nor the NCA analyses yielded any contaminant that exceeded standards, these were considered an existing problem based on elevated concentrations of arsenic and organic contaminants in samples taken near the Park. In addition, the EMAP/NCA program did report slightly elevated PAH concentrations in shrimp tissue and there is also evidence for elevated concentrations of PCBs in fish tissue. The Park is also close to several potential sources of contaminants. There is a dredge spoil site located directly across from the Park, and several heavy metals (including arsenic) have been detected in sediments associated with other dredge disposal sites in close proximity to the area (Winger et al., 2000). In addition, numerous industries (including 20 Superfund sites) located upstream release contaminants to the groundwater, soil, or air. Both organisms and sediment should be tested for the compounds that have been reported or are known to be released in the area. Sediment toxicity tests would also be helpful. Lastly, it might be useful to test for emerging pollutants such as pharmaceuticals and hormones.

Dissolved oxygen was identified as a potential problem at Fort Pulaski based on observations of low DO in the tidal creeks and estuary. Concentrations are even lower just upstream of Fort Pulaski: mean DO decreased to less than 4 mg L^{-1} below a depth of only 2 m for all 21 NCA stations that span the Savannah Harbor. Although some areas in the GA rivers are naturally low in oxygen, the low DO observed in the Savannah is likely due to discharges of organic matter and/or nutrients associated with industrial activity. In a study conducted for the GA Ports Authority, the lowest mean DO concentrations were shown to occur at about RM 15, adjacent to the GA Ports Authority Ocean Terminal and downtown Savannah (ATM, 2000). Ten major point source dischargers were identified in the Harbor, 6 of which occurred between RM 13 and 20; 85% of the total point source discharges came from a single source located between RM 16.6 and 18.7 (ATM, 2004). There is also recent evidence for coast-wide decreases in DO that is likely caused by increased nutrient loading to the area (Verity et al., 2006). Based on these observations, we recommend taking some diel measurements of oxygen, as well as taking measurements in both surface and bottom water. Observations of DO are particularly critical during summer when concentrations generally reach their minima. If there were an indication of a real problem, it would be important to tie this information to observations of the distribution of organisms: are nekton leaving the area? are low oxygen concentrations affecting benthic organisms?

Fecal coliform bacterial concentrations sampled in Oyster Creek were generally low and are not considered a problem. Shellfishing is currently permitted in the area. However, it might be useful to collect additional samples in and around the Park to provide a more complete picture of bacterial contamination.

Water quality observations at the Park are ongoing. In addition to the CRD shellfish and NCA programs described above, the NPS established a fixed station in Aug 2006 at the Lazaretto Fishing Dock to record physical and water quality characteristics including DO and nutrient concentrations (following National Estuarine Research Reserve protocols). The Park Service is also scheduled to initiate a probabilistic survey in summer 2007 at 30 stations along a hydrographic profile in or adjacent to the Park boundary. Water quality (ph, DO, temp salinity and secchi depth) will be sampled every 5 y, and sediments (total organic carbon, grain size, and the full suite of EPA recommended priority and non-priority pollutants) will be sampled every 10 y, both of which will be useful for monitoring conditions at Fort Pulaski over time. Continued observations near Fort Pulaski will be particularly important if the proposed deepening of the main channel of the River occurs, as monitoring activities such as those described here will be necessary for documenting any future changes in the region.

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