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Ecological Status of the Everglades: Environmental and Human Factors that Control the Peatland Complex on the Landscape

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2.1 Introduction

The Everglades was an almost impenetrable wall of sawgrass "plains" and reptile-infested waters according to the early Spanish and American explorers (Ives 1856; Lodge 1994). Its name may have come from the term "Never Glades" as first used by Vignoles (1823). Originally called Pa-hay-okee ("grassy lake") by the resident Native Americans, the Everglades was later popularized and put forward as a threatened environment that needed federal protection by Marjory Stoneman Douglas's seminal 1947 book *The Everglades: River of Grass*. Her wonderful "river of grass" metaphor has unfortunately led to a simplistic view of the complexities of the Everglades ecosystem, how it functions on the landscape, and how its diversity of communities should be managed to sustain this subtropical wetland (McCally 1999). It is often referred to as the "Everglades marsh or swamp" by local residents, biologists, and engineers; however, it is correctly identified as a fen (Richardson 2000; Keddy 2000; Rydin and Jeglum 2006; Grunwald 2006). In more generic terms, the entire wetland would be referred to as a peatland by wetland ecologists in North America or as a mire by those in Europe. A mire is a wet terrain dominated by living peat-forming plants and is often used in botanical and ecological investigations of vegetation types. "Peatland" is a more universal term used to define a terrain covered by peat, usually to a minimum depth of 30–40 cm. Even if the site is drained, it is still a peatland, but if it loses its original peat-forming plants it is no longer considered a mire (Sjors 1948; Rydin and Jeglum 2006). The terms peatland and mire are therefore not used interchangeably by peatland ecologists in Europe and North America. Here we use "peatland" to generally represent the complex diversity of community types found on peat soils in the Everglades and "fen" in a more strict sense to represent alkaline peat or calcium mineral-based ecosystems found over vast portions of the Everglades landscape. Future detailed research on groundwater flows and geochemistry will be needed to distinguish which specific locations within the Everglades function as true groundwater-influenced fens vs. peatland types with surface- or rainfall-dominated inputs (discussed later in Sect. 2.5). Thus, the Everglades should not be classified as a swamp because it is not a forest-dominated wetland, and it is not technically a marsh because marshes are characterized by standing or slow-moving water with submerged, floating-leaved, or emergent plant cover rooted primarily in mineral soil with nutrient-rich overlying waters (Rydin and Jeglum 2006). These are important distinctions when one considers how different marshes and swamps are from peatlands in terms of their hydrologic controls, biogeochemistry, rates of peat accretion, plant and animal communities, and successional development. To maintain some continuity of terms in this volume with historic usage we do use the word marsh to refer to specific community types like cattail marsh. Nevertheless, the terms "Everglades peatland" or "fen" by themselves do not reveal the vital and multifaceted hydrologic connections and nutrient sources that historically existed between the Everglades and surface water runoff coming from Lake Okeechobee via the Kissimmee River, the close connections of groundwater and surface waters in the region due to the karst limestone underlying the wetlands, and most importantly the seasonal influence of the key water source – rainfall (Parker et al. 1955; see Chap. 7).

The Everglades peatland complex was created by blocked drainage due to development of limestone substrata of various porosities overlain on a flat basement rock and confined by sandy ridges that developed from sea level rise and fall about 5,000 years before present (YBP) (Gleason and Stone 1994). The thin layer layers of porous rock that formed during earlier glacial periods absorbed, stored, and transmitted water at different rates, a characteristic crucial to the formation of a myriad of different plant communities found in the Everglades mire even today (McCally 1999). For example, the landscape, while dominated by sawgrass, is interlaced with periphyton-rush sloughs, wet prairies, and ponds, and it is dotted with tree islands and willow heads. The proportion of each community type varies greatly along a north-to-south hydrologic gradient (see Chaps. 4, 7–9, and 12). Most of these plant community associations evolved under low phosphorus (P) concentrations because the main source of water was rainfall with extremely low P concentrations (Redfield and Urban 1997). The exception to communities evolving under low P concentrations are tree islands and the vegetation around alligator holes (Davis 1943; Loveless 1959; Steward and Ornes 1975b; Craft and Richardson 1993a; Sklar and van der Valk 2002) as well as plant communities adjacent to Lake Okeechobee with its high historical TP concentrations $>30\,\mu g\ l^{-1}$ (Walker 2000). Another factor maintaining P limitations in the Everglades, unlike northern peatlands or fens, is the nitrogen-fixing blue-green algae community, or periphyton, found in open-water sloughs. Because of the periphyton community's high rates of nitrogen fixation, Everglades soils are exceptionally high in nitrogen (2–4% by weight); thus, very high N:P ratios (>100) exist, further driving the system to severe P limitations (Richardson et al. 1999).

To fully understand the Everglades ecosystem, it is necessary to understand how human interventions over the last one hundred years have dramatically altered the natural Everglades development processes that started more than 5,000 years ago. Thus, the objectives of this chapter are to provide the reader with a basic foundation for understanding how the Everglades ecosystem complex has developed and to provide an analysis of factors controlling ecosystem functions in the Everglades today. It is not our intent to review in detail the geological formations and processes that have led to the development of the Everglades, as so many great articles and volumes have been written on this topic (e.g., Brooks 1968; Gleason 1974a; Perkins 1977; Gleason and Stone 1994). To accomplish our goal and help interpret the specific research and restoration lessons presented in the chapters that follow we (1) present a brief review of Everglades peatland formation and characterize the wetland processes that led to development of this vast peatland complex, (2) provide a proper classification of the Everglades system that might help in the development of a more appropriate restoration management framework, (3) review the factors controlling ecosystem structure and succession of communities found within the peatland complex today as compared to historical conditions, and (4) compile and synthesize historical and current data on some key elements of precipitation trends, hydrologic shifts, and nutrient inputs on a landscape scale.

2.2 Formation of the Everglades: The Historical Everglades Prior to Major Anthropogenic Impacts

One of the key benefits of examining the long-term history of the Everglades is that it is possible to learn about natural variations in the system prior to the industrial era as well as determine what environmental factors controlled the formation and development of the Everglades. Knowledge of the rates and magnitudes of change, as well as of recovery rates from disturbances, is critical to future restoration plans. Restoration plans that incorporate natural variation and known responses to disturbance are also likely to be more ecologically and economically feasible.

The Everglades mineral substrate formed a large basin or trough during the Pleistocene, and shallow marine sediments were deposited, primarily during the Sangamon interglacial stage 125,000 YBP (Davis 1943; Parker and Cooke 1944; Gleason 1984). The retreat of the northern U.S. glaciers 18,000–16,000 YBP, blockage of drainage from the Everglades due to rising sea level, a change to a subtropical climate, and the concurrent increase in rainfall allowed for the development of the Everglades as we know it. Three limestone formations underlie the Everglades. The Miami Formation is found in the southern Everglades National Park (ENP) region; the Anastasia Formation, comprised of sandy calcareous sandstone, is found in the northeast area; and the Fort Thompson Formation, which underlies the northern half to a depth of 50 m, is mostly marine and freshwater marls, limestone, and sandstone (Enos and Perkins 1977).

A geological study of the bedrock that underlies the Everglades shows a differentiation in permeability from north to south. Low-permeability limestone underlies the northern portion of the Everglades basin around Lake Okeechobee and extends into the northern half of WCA-3 and into the western portions of WCA-2. In the southern section of WCA-3 and the southeastern section of WCA-2B, there is an abrupt shift to highly permeable limestone (Gleason et al. 1974; Perkins 1977). This has important ramifications for the movement and storage of water, peat development, and the establishment of plant communities. Moreover, construction of any water storage areas in the lower eastern part of the Everglades would be subject to severe water loss unless extensive and expensive efforts were made to line the reservoirs due to the high permeability of the underlying bedrock. According to Gleason et al. (1974), bedrock configuration established the drainage directions prior to peat deposition in the Everglades. For example, Lake Okeechobee flowed through a channel eastward to the area now known as WCA-1, and a deep depression bisected the lower Everglades and created a southwest flow gradient toward Florida Bay (Fig. 2.1). These patterns appear to have changed little over the course of time. For example, Gleason et al. (1974) note that tree island orientation is correlated with drainage directions expected from bedrock topography. The only detailed vegetation map of the Everglades came from early survey work of Davis (1943) and was based on his extensive field observations in the late 1930s (Fig. 2.2). Although, the mapping was done prior to any massive increase in farming in the Everglades Agriculture Area (EAA), many of the large canals had been dug and peat subsidence had started according to his field notes. His map provides distributions

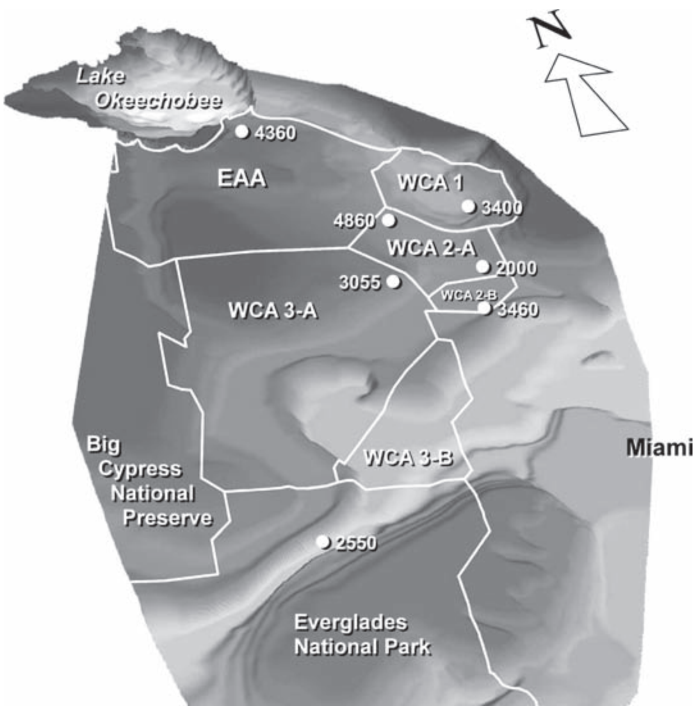

Fig. 2.1 Bedrock map of the Everglades prior to peat development based on kriging of USGS depth measurements and isopleths maps (Parker et al. 1955; Parker and Cooke 1944). *Darker shades* represent higher regions (bedrock plateau south of Lake Okeechobee, etc.) and *lighter shades* represent depressions or troughs in the bedrock (e.g., in WCA-1 and in lower WCA-3A, WCA-3B and in the northern portion of the ENP where Taylor slough is now found). Also shown are basal dates of peat from ^{14}C measurements (McDowell et al. 1969; Gleason et al. 1974; Craft and Richardson 1998)

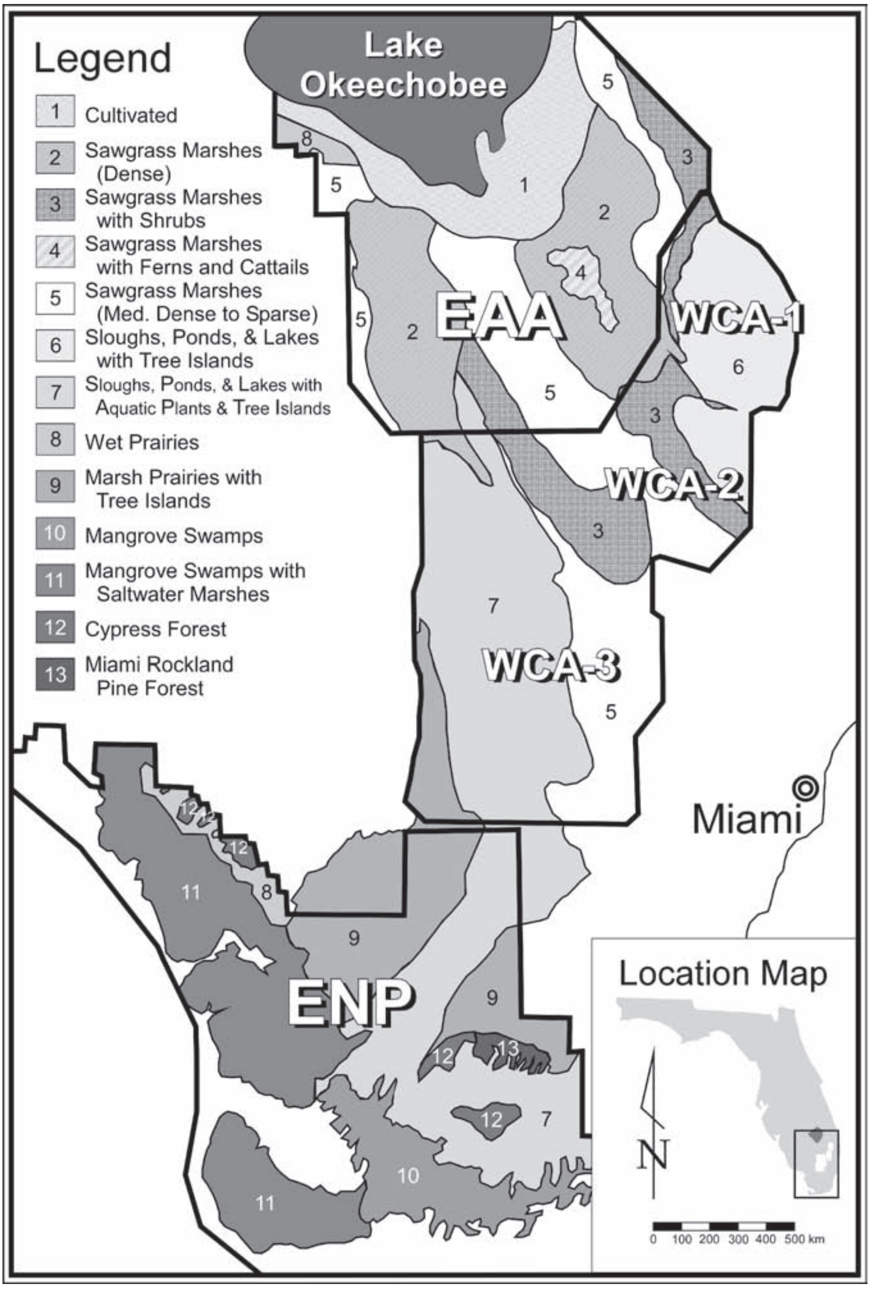

Fig. 2.2 Historic map of the vegetation communities in the Everglades based on the map of Davis (1943). The map has been redrawn and simplified from the original map, and the boundaries of the current Water Conservation Areas (WCA-1, WCA-2A, and WCA-3A), the Everglades National Park (ENP), and the Everglades Agricultural Areas have been added

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