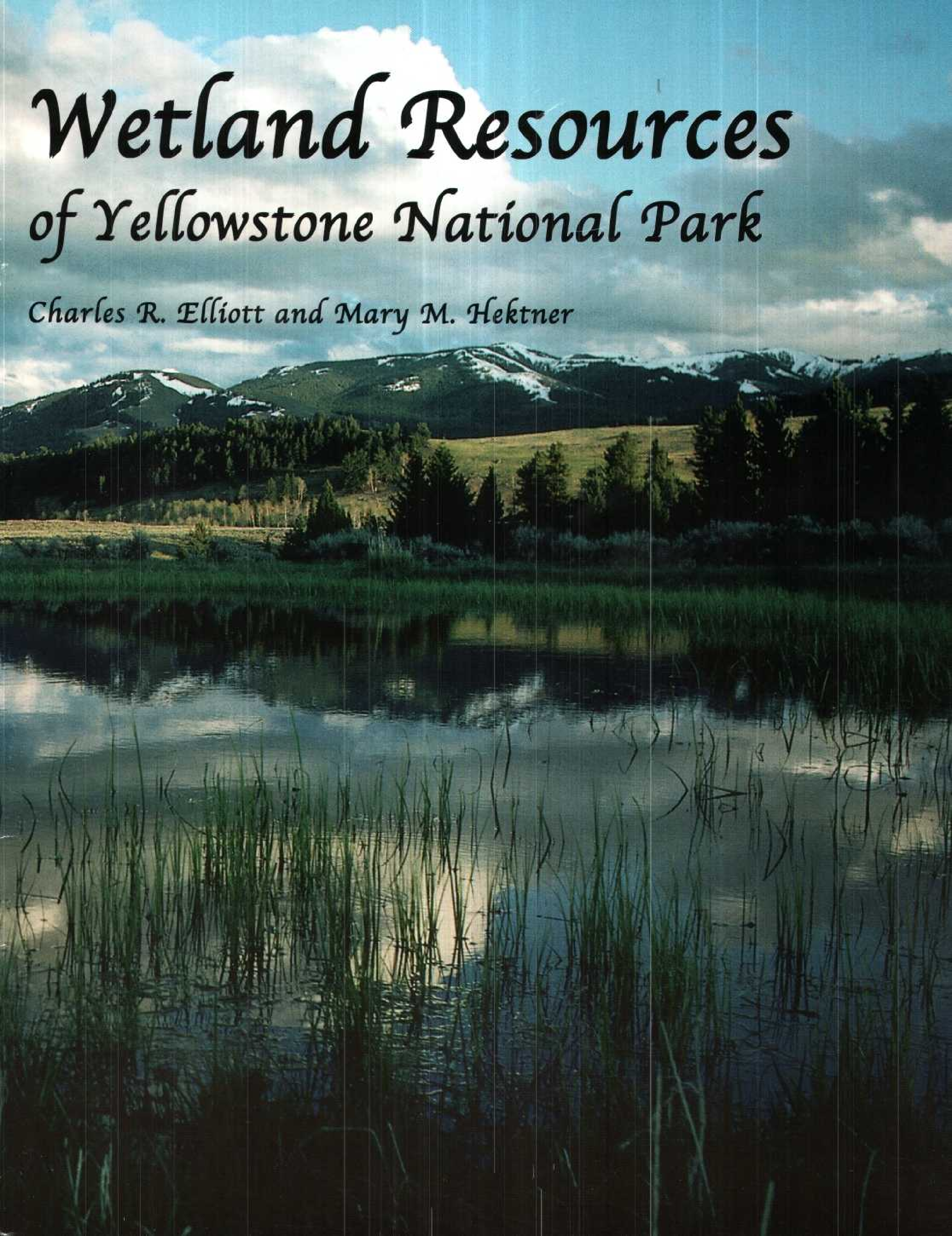
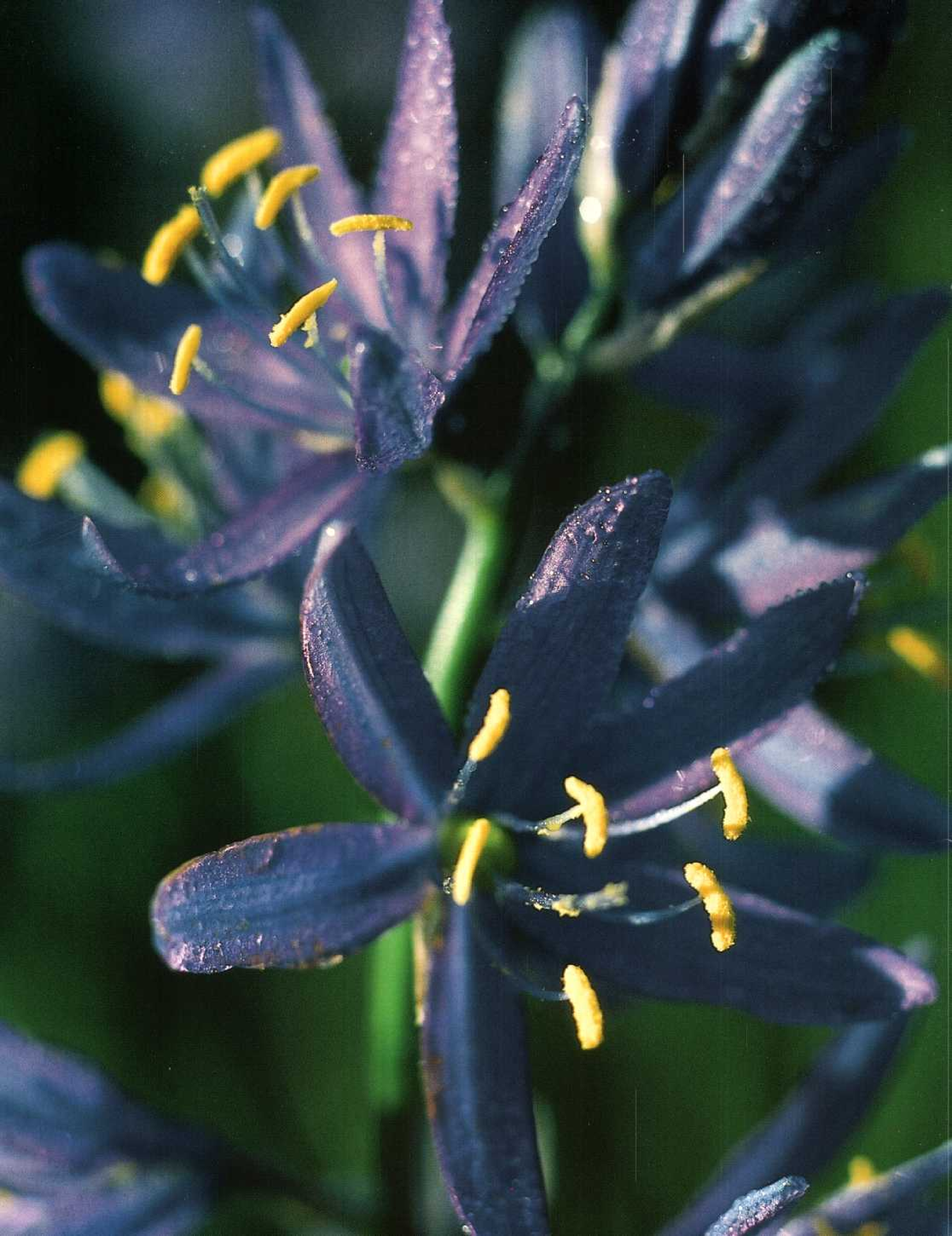
Wetland Resources
of Yellowstone National Park

Charles R. Elliott and Mary M. Hektner





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Copies may be obtained from:

U.S. Fish and Wildlife Service
National Wetlands Inventory
Denver Federal Center
P.O. Box 25486
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National Park Service
Yellowstone National Park
Yellowstone Center for Resources
P.O. Box 168
Yellowstone National Park, Wyoming 82190

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Cover photo: Lamar Valley. Left: camas. Above: trumpeter swans. (All by Jennifer Whipple.)

Foreword

Wetlands are a cornerstone of Yellowstone's majestic qualities. Riverways have always provided the primary routes used by visitors to the region. Two centuries ago, John Colter, a member of the Lewis and Clark expedition, was probably the first Euroamerican to explore what is now Yellowstone National Park. He traveled upstream along the Yellowstone River, probably seeing his first thermal features along the banks below Tower Falls.

Later exploratory parties kept better records and, fortunately, documented the park's wonders with photographs and paintings to help disbelievers become believers. In 1869, David Folsom and two other private citizens journeyed across the Yellowstone plateau. Near present-day Bridge Bay on Yellowstone Lake, Folsom wrote:

> "We came to a small grassy opening upon the opposite side of which was a beautiful little lake, separated from the main lake by only a sandbar, which the surf had thrown up across the narrow neck which formerly connected them. . . . Large flocks of geese and ducks were feeding near the shore or floating gracefully on its smooth surface. Beyond the lake the timber was tall and straight and to appearances as thick as cane in a southern swamp. This was one of the beautiful places we had found fashioned by the practised [*sic*] hand of nature, that man had not desecrated" (Haines 1996).

The accounts of early explorers make clear that they were awed by the array of waters, geologic wonders, meadows, forests, and wildlife they found, all of which contributed to the United States Congress' decision to enact the world's first national park in 1872. Due to its unique environment and early protection, Yellowstone retains the almost unbelievable features and ambience found by its first visitors. Today, the park's sensational wetland resources continue to be identified by visitors as highlights of their stay. If we do our job well, the Yellowstone experience will survive for future generations of explorers, young and old, to enjoy.

M.V. Finley

Michael V. Finley
Superintendent, Yellowstone National Park

Left: Hayden Valley from near Grizzly Overlook (Renée Evanoff). Above: Stevenson Island (Sue Consolo Murphy).

Introduction

Wetlands exist in bewildering variety, from thermal algae mats to cattail lake margins to spray wash from towering waterfalls, and they produce a magnificent showcase of natural resources. They are the most productive habitats on Earth. (Productivity is measured by the total weight of plant and animal material produced per unit area.) Wetlands cover only 6.4 percent of the Earth's surface, yet they account for 24 percent of total global productivity (Kesselheim et al 1995). Neither forests, grasslands, nor irrigated agricultural lands produce more plant and animal material than wetlands.

Bison at thermal pool on Geyser Hill. Top right: Dewdrop Lake.

Wetlands serve as crucial habitats for a tremendous diversity of plants and animals. While only 5 percent of the land area of the United States is wetland (Dahl 1990), 31 percent of all known U.S. plants are wetland plants (P. B. Reed, USFWS, pers. com.). Countless birds, fish, and wildlife species use wetlands for food, shelter, spawning, breeding, nesting, migration, and wintering areas. One third of threatened and endangered plant and animal species in the United States are wetland-dependent. Wetlands also help to control flooding, prevent coastal erosion, and protect water quality by serving as important natural filters of contaminants, pollutants, and other toxic materials.

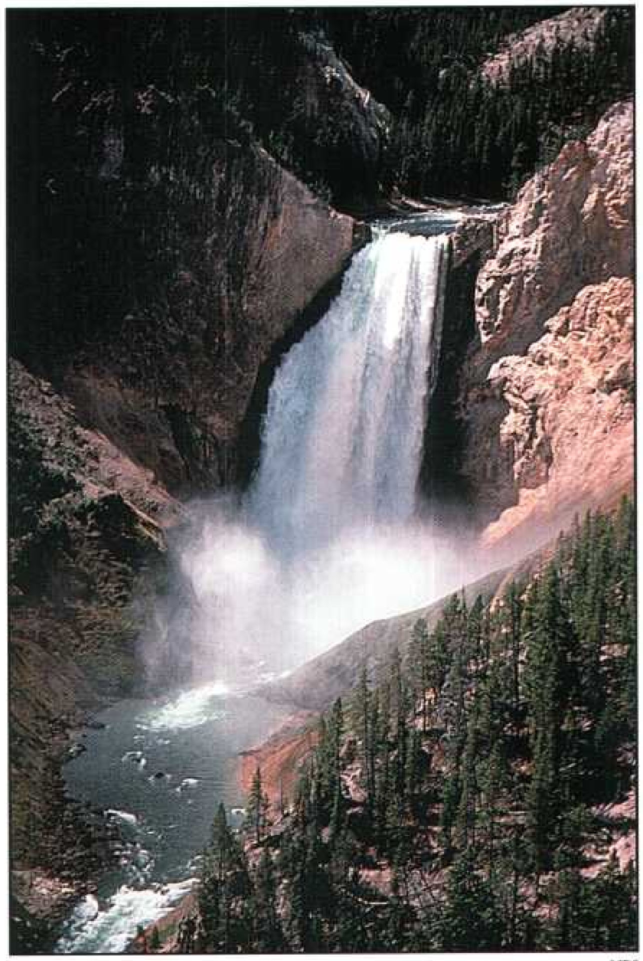
At the time of European settlement, about 10 percent of what would later become the coterminous United States was wetlands (Dahl 1990). By the mid-1980s, more than half of the nation's wetlands had been drained, mostly for agriculture. As public understanding of the importance of wetlands in maintaining water quality and wildlife habitat increases, so does legal protection. In the meantime, however, the loss of wetlands continues, especially on private lands.

National parks, on the other hand, stand as a commitment and testimony of the American people to preserve portions of our natural resources. Yellowstone encompasses 2,219,791 acres, considerably larger than the states of Rhode Island and Delaware combined, and its wetlands total 228,766 acres—a dynamic and productive 10.3 percent of the park.

Yellowstone is a place of extremes. The park's geologic history ranges from catastrophic volcanic eruptions 1,000 times greater than that of Mt. St. Helens to periods of glaciation that supported ice fields more than 3,000 feet thick. Elevations in the park range from 5,282 feet in the northwest, where the Gardner River drains, to 11,358 feet in the southeast, at the summit of Eagle Peak. Precipitation ranges from as low as 10 inches per year in the north near Gardiner, Montana, to nearly 80 inches per year in the park's southwest corner. Temperatures ranging from -66°F to 103°F have been recorded. These volatile geologic and climatic factors produce a dynamic setting for Yellowstone's wetlands.

Wetlands form through the combined characteristics of an area's soil, topography, hydrology, and climate. The primary influences on the nature, distribution, and extent of Yellowstone's wetlands are the location and water-holding capacity of their associated soils. Wetlands emerge as lakes, rivers, ponds, marshes, bogs, streams, seeps, wet meadows, thermal pools, and geysers found on high mountain slopes, in valleys, and along lower-elevation rivers. Lakes, rivers, and geysers are not always considered wetlands; however, they must be considered in an ecological approach to the park's management. Therefore, in this booklet the term "wetlands" is used generically to include both wetlands and deepwater habitats.

Yellowstone's wetlands range in size, depth, and availability of water. Some are temporarily flooded lands with seasonal water sources that provide an influx of water from snowmelt or rain in the spring only to shrink or dry up later in the season. These wetlands can be several inches deep and less than 0.1 acre in size. Other wetlands are permanently flooded with perennial water sources, such as Yellowstone Lake, which is at least 400 feet deep and over 100 square miles in surface area. Shallow wetlands produce invertebrate life that feeds the smallest minnows, whereas Yellowstone Lake supports the largest remaining native inland cutthroat trout population in the world. The wetlands that exist between these two extremes include an aquatic diversity perhaps unrivaled anywhere in the world.



Lower Falls of the Yellowstone River. NPS

Shoshone Lake from the geyser basin. J. Whipple

Fen north of Biscuit Basin. J. Whipple

Hardy Species: Wetland Plants

J. Whipple

Wetland plants exhibit a variety of special adaptations that allow them to exist in waterlogged or saturated soils under anaerobic (without oxygen) conditions that exist for several weeks during the growing season to year-round. Plants that are able to survive and reproduce under these harsh conditions are commonly referred to as hydrophytes. Morphological and physiological adaptations allow hydrophytes alternate metabolic pathways that contribute to successful oxygen exchange and, therefore, tolerance of otherwise toxic environments. Upland plants simply cannot survive extended periods of anaerobic conditions, so hydrophytes become the dominant species. Common wetland plants include duckweed, bulrushes, cattails, sedges, willows, and cottonwoods, as well as showy flowers such as elephant's head, fringed gentians, and marsh marigolds. Wetlands can be identified through the plants that occur on the site, as well as through the soils that result from specific hydrologic conditions.

Approximately 38 percent of Yellowstone's 1,200 plant species are associated with wetlands, and 11 percent (species such as water lilies, water buttercup, spikerush, and cattails) grow only in wetlands. Such species are called obligates because they occur in wetlands 99 percent of the time.

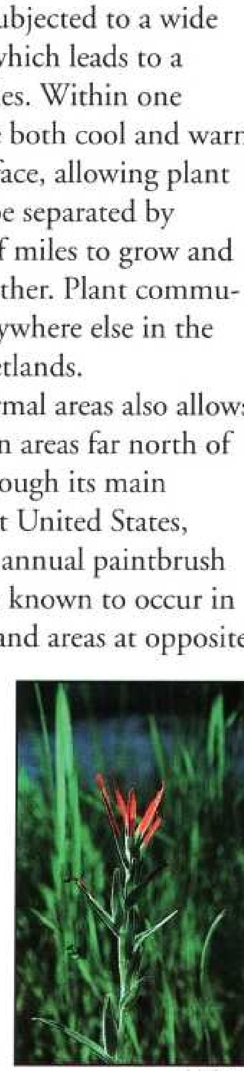
Yellowstone's wetlands are home to many unusual plants. Of the 90 rare plant species known to occur in the park more than half are associated with wetlands.

J. Whipple

Elephant's head. Top right: water lily.

In Yellowstone, wetlands are subjected to a wide range of water temperatures, which leads to a fascinating array of plant species. Within one wetland complex, there can be both cool and warm water springs rising to the surface, allowing plant species that would otherwise be separated by hundreds or even thousands of miles to grow and reproduce adjacent to one another. Plant communities that are not recorded anywhere else in the world exist in Yellowstone's wetlands.

The heat generated in thermal areas also allows some plant species to survive in areas far north of their typical distribution. Although its main distribution is in the southwest United States, *Castilleja exilis*, a red-flowered annual paintbrush that blooms in early August, is known to occur in two thermally influenced wetland areas at opposite ends of the park.



Paintbrush. J. Whipple

Two greater Yellowstone wetland endemics (plant species that grow nowhere else in the world) are especially interesting. Yellow spikerush (*Eleocharis flavescens*) typically occurs in tropical and subtropical America; outside of Yellowstone, the closest population is in Mississippi. A special variety of this species, warm spring spikerush (*Eleocharis flavescens* var. *thermalis*), has developed in Yellowstone. It grows primarily as floating mats on warm thermal water, vanishing if the water temperature becomes too hot or too cold. Warm spring spikerush is totally dependent on warm water; it never occurs in water that is cold to touch.


Globeflower. J. Whipple


Bladderwort. J. Whipple

Tweedy's rush (*Juncus tweedyi*) is also highly restricted in its distribution, occurring primarily within the park's boundaries with just a few populations beyond. This wetland plant is often associated with thermal areas, especially in areas that are quite acid in composition. Sometimes Tweedy's rush will be the only obvious plant in portions of a thermal area.


Tweedy's rush. J. Whipple

Other Yellowstone wetland plants, species such as green keeled cotton-grass (*Eriophorum varidicarinatum*), False uncinia sedge (*Carex microglochin*), mud sedge (*Carex limosa*), and lesser panicled sedge (*Carex diandra*), are more typically found in the boreal (northern) zone of Canada and Alaska. These plants are often found in peatlands—wetlands with large accumulations of dead plant material (peat) that have formed around cold-water springs. In Yellowstone, plants from northern Canada and Alaska grow alongside others typical of the Rocky Mountains of Wyoming and Montana.


Sundew. J. Whipple


Cotton-grass near Norris. J. Whipple

Vital Habitats: Wetlands and Wildlife

J. Whipple

Yellowstone offers visitors a rare opportunity to observe animals interacting in a natural setting, and much of the best viewing is near wetlands. The quality of wetland environments as habitat for birds, fish, and other wildlife is one of their most visible and popular attributes. An estimated 80 percent of Wyoming's native animals rely on wetlands, especially the areas along rivers and creeks (Consolo-Murphy and Murphy 1999). Wetlands serve as both home and "supermarket" for innumerable species, many of which depend upon wetlands during some part of their daily, seasonal, or life cycles. Some species, such as beavers, tiger salamanders, and American dippers, are year-round wetland residents.

Yellowstone is home to a vast array of native animals—more than 400 types of aquatic insects, at least 300 birds, 100 butterflies, 60 mammals, 12 fishes, and 10 reptiles and amphibians. The majority of these species have some association with wetlands during their lives, whether for food, water, shelter, breeding, nesting, spawning, migration, wintering areas, or predatory opportunities.

Aquatic insects are a vital part of wetlands and, like reptiles and amphibians, are good indicators of overall ecosystem health. Each species requires certain attributes in the system it inhabits, and if that system is changed, the species will change in response. Aquatic insects are abundant both in species and total number, contributing to ecosystem biodiversity. They have important roles in the nutritive relationships within wetlands, serving as food for birds and fish. Their presence, absence, kinds, and numbers can tell us about the survival chances of fish and the kinds of fish we can expect in an area (Roemhild 1982). Water fleas and other filter-feeding aquatic invertebrates also help to maintain the water quality of lakes by removing algae. Aquatic invertebrates may play an important role in wetland nutrient cycling. They can regenerate as much as 35–60 percent of their own nutrient content each day, helping fuel algal growth and influencing algal competition by altering nutrient ratios (Duffy 1999). Aquatic insects depend upon wetland environments in all degrees—the larvae of horse flies thrive in mud, mosquito eggs require a few days in water to develop into adults, immature caddisflies and mayflies live in water for a few months, and water boatmen and backswimmers spend all of their lives in water.

Mosquito. J. Whipple

Moose eating aquatic vegetation. Top right: chorus frog. NPS

Common snipe. J. Whipple

Birds also occupy all of Yellowstone's wetland environments. More than 50 percent of the park's resident breeding bird species—including rare trumpeter swans and the nation's own bald eagles—are associated with wetlands, which provide them with ideal food and nesting habitat. A similar percentage of migratory bird species, such as yellow-headed blackbirds, stop in wetlands along flyways to rest, breed, and eat. Although deep-water lakes and amphibious environments, such as shores, streambanks, and ephemeral marshes, are home to a diversity of birdlife, they cannot compare with shallow water wetlands and marshes for bird species richness and abundance. The complexity of these habitats offers a variety of food, nest sites, and shelter to birds of all sizes.

Butterfly diversity is correlated with plant diversity, which makes wetlands the perfect habitat for many of these winged species. Butterflies are commonly found in Yellowstone's wet meadows. The Yellowstone checkerspot, for example, is a species that typically prefers wet sedge meadows

Beaver lodge and dam. NPS

Grizzly on elk carcass. NPS

and will lay its eggs on a shrub called black twinberry—but only if the shrub is in a wet meadow. Other moisture-loving species are the painted lady and the western meadow fritillary, whose host plants include willows, violets, and legumes (Debinski 1996).

Large mammals are perhaps the most recognized wetland residents. In summer, moose move tranquilly through shoulder-deep water eating aquatic plants, and beavers cut willows to eat and to build lodges. In spring, bears fish for spawning trout in shallow streams. Winter visitors may see wolf tracks imprinted in the snow-covered frozen marshes. River otter may be seen fishing and swimming in summer and sliding down snowbanks in winter. All mammal species visit wetlands for water, offering predators various feeding opportunities.

Eighteen fish species, 12 native and 6 introduced, inhabit Yellowstone's waters. This number is small by most standards; some river systems in the Midwest have more than 200 species, and some in South America have thousands (Varley and Schullery 1998). There are many reasons for Yellowstone's small number of fish species. Until relatively recent geologic times the park was covered by glaciers, so not much time has elapsed for fish to arrive or evolve. The headwaters of five major river systems are either in or just upstream from the park, and more than 200 waterfalls form barriers to the upstream movement of aquatic life. More than two-thirds of Yellowstone's lakes are naturally fishless (Varley and Schullery 1998). Many waters are not suitable for fish due to shallow depth or water chemistry and temperature, especially those receiving great quantities of heat and minerals from hydrothermal features. When fish stocking began in Yellowstone in 1890, fish were planted in almost all lakes and ponds, with little knowledge as to whether the transplants could survive. In many cases, they did not, due mainly to a lack of spawning habitat and to winterkill (Pierce 1987). Some plantings did succeed, changing the balance of life in many of the park's lakes and stream systems.

Nevertheless, Yellowstone is considered a sport fishing and fish-watching mecca, due largely to early habitat preservation measures. The park was heavily over-fished in early years, but the habitat remained largely undisturbed from development. With recent changes in fishing regulations, such as mandated "catch-and-release fishing," fish populations have rebounded and park waters have become world-renowned as examples of intensively used yet healthy fisheries. Today, Yellowstone contains 91 percent of the remaining habitat for

Cutthroat trout jumping LeHardy Rapids. NPS

Garter snake. J. Whipple

the Yellowstone cutthroat trout population, most of which is in Yellowstone Lake. A typical stream in Yellowstone may support as much as 40 pounds of fish per acre of water (Varley and Schullery 1998). Unfortunately, the park is not immune from introduced species, and lake trout, whirling disease, and New Zealand mud snails currently threaten to change aquatic systems.

Six reptile species and four amphibian species are known to occur in Yellowstone. Three of the reptile species (the wandering garter snake, sometimes called a "water snake"; valley garter snake; and rubber boa) and all four amphibian species, (the blotched tiger salamander, boreal toad, boreal chorus frog, and spotted frog) are associated with wetlands. They are often significant elements of the food chain. Many species consume large quantities of insects, other invertebrates, and both aquatic and terrestrial vertebrates. For example, the wandering garter snake regularly catches and eats fish, and the valley garter snake depends heavily on amphibians. Rubber boas often feed on small mammals that are commonly found in grass and shrub habitats along streams and wetlands (Koch and Peterson 1995). Many reptile and amphibian species also provide food for predators such as trout, sandhill cranes, great blue herons, red-tailed hawks, otters, and other mammals.

Although reptiles and amphibians seldom receive as much attention as some of the park's more popular and visible inhabitants, they are believed to be good indicators of an ecosystem's health. They are sensitive to pressures from land and water development by humans, and to the effects of pollution. Amphibians have sensitive skin and two different stages in their life cycle—one larval, aquatic stage and one terrestrial, adult stage—making them very vulnerable to environmental changes. Larvae may be exposed to waterborne contaminants such as acid rain. When adults prey on insects that harbor sublethal amounts of toxic pollutants, they accumulate these pollutants in their tissues; this can eventually impair normal development and reproduction or even kill the creature. Eggshell thinning caused by such an accumulation of toxic pollutants in the tissues of predators nearly caused the extinction of bald eagles and peregrine falcons.

Presently, many amphibian populations appear to be in decline throughout the world. Scientists are not yet sure what to make of this; it may be that populations fluctuate naturally in response to natural events such as drought, or human-influenced changes in global processes—warming of the earth, ozone depletion, increased ultraviolet radiation, or acid precipitation. Other activities that may harm amphibian populations include habitat alteration, such as draining or filling wetlands, introduction of contaminants to an area, and introduction of exotic species.

River otter eating cutthroat trout. NPS

In Yellowstone, amphibians may be in better shape than in some other areas, but we lack the long-term population data necessary to determine the status of the park's populations. Unless we determine what is causing the world's amphibian populations to decline, amphibians in this region may encounter trouble in the future—if they haven't already.

Bison and elk along the Firehole River. J. Whipple

Misunderstood Landscapes: Wetlands and People

Up until the 1970s, wetlands were considered useless, unhealthy wastelands. Laws and policies encouraged their draining and dredging. Farmers were paid to turn wetlands into croplands, and sprawling cities dredged and filled wetlands to accommodate new roads, factories, and housing developments. It's estimated that by the mid-1980s, more than half of the original wetlands in the lower 48 states had been lost due to human activities (Dahl 1990).

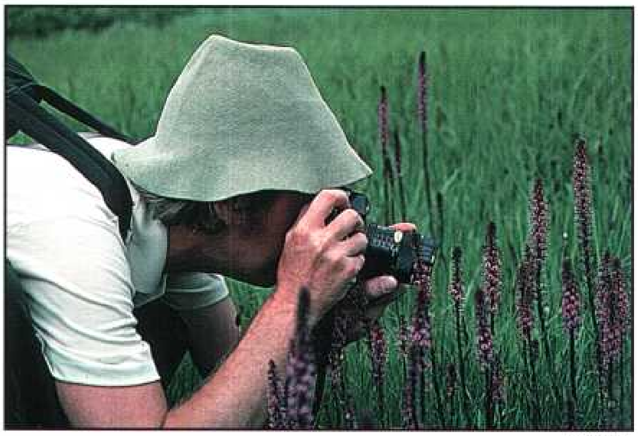
Fortunately, due to Yellowstone's designation as a national park, Yellowstone's wetlands have been spared many impacts. Less than 2 percent of park land has been developed, yet those roads and developments that do exist were historically placed in or near the more easily traveled and most scenic places—wetlands. Riparian corridors were always the easiest travel routes for early explorers and mappers. Today, when possible, the park is moving such developments out of wetlands and attempting to restore them to more natural conditions. Wetland areas that have the potential to be affected by new projects are now mapped and inventoried so that the projects can be designed to avoid or minimize adverse impacts.


J. Whipple

Warm spring spikerush growing over the road in Gibbon Canyon.

Developments are not the only influence on Yellowstone's wetland resources. Exotic organisms, such as New Zealand mud snails and whirling disease, are recent accidental introductions, probably brought in on fishermen's footwear and equipment. These exotic species have the potential to change the composition of the community—the existing array of native aquatic insects and mollusks—and quite possibly cause declines in fish populations. The degree to which these uninvited arrivals will affect the park's aquatic systems is currently unknown.

Undoubtedly an intentional illegal introduction, non-native lake trout were discovered in Yellowstone Lake in 1994. A much larger and voracious fish than the cutthroat trout, lake trout pose a great threat to the future of the lake's native fish, and the effects ripple. Scientists estimate that the fates of at least 42 species of birds and mammals are to some extent tied to the Yellowstone cutthroat (Varley and Schullery 1995). These



J. Whipple

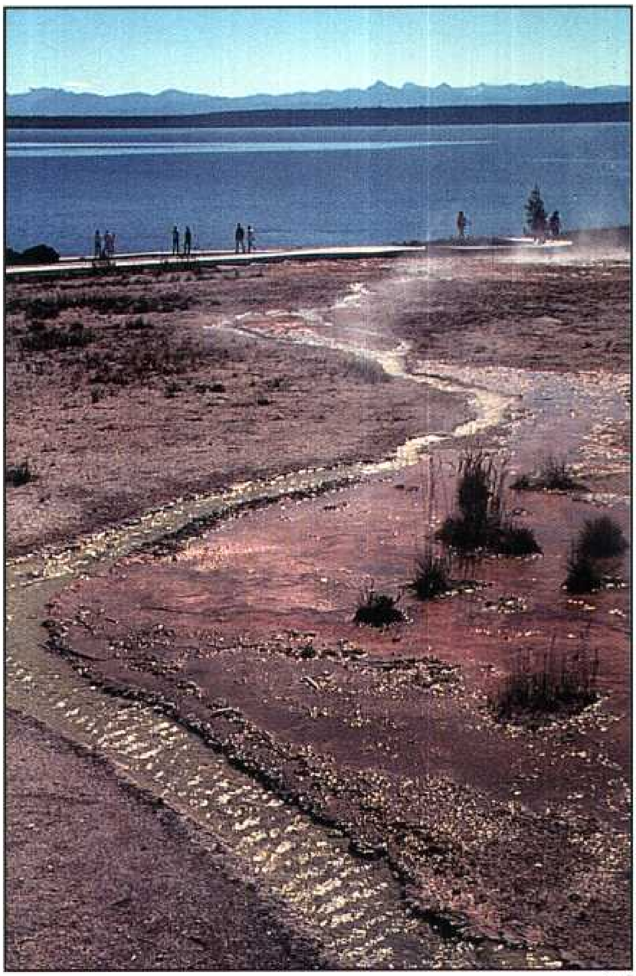
Photographing elephant's head.

include the osprey, bald eagle, black bear, grizzly bear, river otter, mink, marten, short- and longtail weasel, pelican, merganser, California gull, loon, kingfisher, and dozens more. Some of these species eat fish only occasionally, while others—both scavengers and predators—depend on them heavily. Unless lake trout numbers are controlled, they will severely reduce cutthroat trout numbers, affecting the entire food chain.

While wetlands have been bad-mouthed in the past (think of such expressions as *bogged* down in details or *swamped* with work), scientists and the American public are beginning to appreciate how wetlands help to maintain a healthy environment. Scientists now know that wetlands are vital natural filters of contaminants, pollutants, and other toxic materials. Wetland soils and vegetation impede the incoming flow of water, act as natural carbon filters, and send on the outgoing water in a much cleaner condition. Wetlands also trap metals from natural sources. In Yellowstone's wetland sediments, researchers have found high levels of metals, such as arsenic, uranium, mercury, zinc, and other toxic and nutrient trace metals, that are natural components of hydrothermal waters (Otton 1997). Without the natural filtering wetlands provide, rivers such as the Firehole and Gibbon, which receive large infusions of runoff from hot springs and geysers, would probably be chemically unsuited to support the high productivity of life found there today.

Wetlands have also been called a window on the Earth's past. Wetlands evolve through time, and scientists learn how they have changed by looking at wetland soil cores and studying the sediments, pollen, diatoms, and other elements found in them. Such evidence provides information about past climates and environments. For example, researchers working to reconstruct the park's past fire frequency and its vegetational history use wetland core pollen records that span the last 14,000 years. Scientists can also obtain information necessary for predicting future climate change by studying the carbon cycle in wetlands, which store carbon as peat and release it as carbon dioxide and methane.

Today, wetlands are also recognized for the numerous and incredible recreational opportunities they provide. Visitors to Yellowstone enjoy sightseeing, bird and wildlife watching, fishing, canoeing, and motor boating. Without wetlands, Yellowstone's landscape simply would not be the park Americans know and cherish.



NPS

West Thumb Geyser Basin.

Very Special Places: Thermal Wetlands

J. Whipple

Yellowstone National Park has the largest, most undisturbed, and most famous concentration of geothermal features in the world. More than 300 major geysers—including such often predictable giants as Grand, Castle, Daisy, and, of course, Old Faithful—and some 10,000 brilliantly colored hot springs, bubbling mud pots, and steaming fumaroles combine to make Yellowstone a place unlike any other in the world.

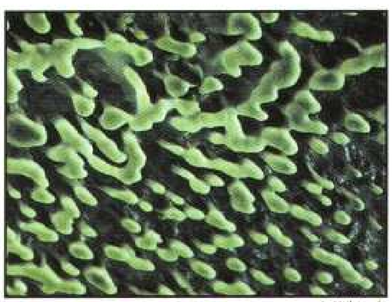
What might, at first glance, seem to be an uninhabitable place is actually teeming with life. The temperatures of the hot springs vary tremendously, from cool springs with only a little thermal influence to effervescent superheated springs that are actually a few degrees hotter than the boiling point, about 199°F at the park's average elevation of 7,500 feet above sea level. Even at this temperature, far above the upper temperature limit for photosynthesis, there are hardy heat-loving microorganisms known as thermophiles, visible only with microscopes.

The ability of thermophiles to reproduce in boiling water was discovered in 1967, when microbiologist Thomas Brock determined that there were organisms in almost all of the hot springs. This discovery of life forms, known as "extremophiles," that live in such conditions has led to industrial and medical applications reaching far beyond the park. Subsequent research has identified and cloned an enzyme from one thermophile, *Thermus aquaticus*, first isolated from a hot spring in Yellowstone. This enzyme has made possible the process of DNA fingerprinting, which is applied to investigations of crime scenes, identification of birth defects, and biotechnical research. The search for other thermophiles is not confined to planet Earth. Scientists have used the Yellowstone hot springs as a model for predicting life on other planets, and speculate that life could be present even in the extreme environment that exists on the planet Mars.

J. Whipple

Abyss Pool. Top right: monkeyflowers growing near a hot spring.

Most hot springs owe their color to the bacteria and algae growing in the water, though minerals color some unusual hot springs. If a feature is extremely hot, well over 180°F, only microscopic thermophiles are present and the water will appear blue, just like any other body of water. (Water absorbs most colors except for blues and blue-greens, which are reflected back. If any other material is present in the water, its tint is added to the blue.) As the water cools to below 167°F, thermophilic cyanobacteria (commonly referred to as blue-green algae, though it is a photosynthetic bacteria and not a plant at all) will begin to appear, first bright yellow and then brilliant



Cyanobacteria. J. Whipple

Brine flies. J. Whipple

orange. Dark browns and true greens appear when the water temperature drops to 120–130°F—still much hotter than it is safe for humans to touch. (The water temperature in a hot tub is usually around 100°F, and in a bathtub around 90°F.) True algae can survive in areas with acid runoff, appearing bright green. Other runoffs support a mixture of cyanobacteria and algae, producing yet a different color scheme altogether.

Vascular plants are able to grow and reproduce in thermal areas when the temperature drops below 113°F (Brock 1994). One of the showiest plants found near thermal areas, yellow monkey flower (*Mimulus guttatus*), has been found blooming as early as February, when the adjacent ground is still in winter's grip. The heat allows the plants to grow through the winter on thermally warmed ground and along snow-free hot spring channels. During winter, the stems are short and leaves grow close to the warm ground. As soon as the weather warms, the stems grow quickly and the plant begins to bloom.

Although the upper temperature limit for animal life is also about 113°F, there are large areas where the thermal waters have cooled enough that animals can live. The most common hot spring animals are brine flies and their larvae that feed on the cyanobacteria mats. These flies, in turn, are food for larger predators, such as dragonflies, spiders, tiger beetles, wasps, and mites. These predators often attract even larger animals like mountain bluebirds, killdeer, and insect-eating rodents.

Geothermal areas in the winter are some of the best places to view concentrations of wildlife. When winter buries the park in snow and ice, bison and elk congregate near thermal areas where snow is not as deep, feeding and resting on the geothermally warmed ground. The warm influx from thermal features also keeps rivers like the Firehole and Madison from freezing, providing habitat for ducks, geese, and swans. The thermal influence in the Firehole River has also altered rainbow trout spawning time from spring to fall, as fish eggs would otherwise cook in the high temperatures—60°F to 80°F—found in spring and summer.

Hot spring at the Chocolate Pots. J. Whipple

The National Wetlands Inventory in Yellowstone

Yellowstone's wetlands have been mapped as part of the U.S. Fish and Wildlife Service's National Wetland Inventory, a Congressionally mandated program to identify, classify, and map all wetlands in the United States—information that has never been available before. The wetland maps are available to park managers for use in the development of resource management strategies, environmental impact assessments, natural resource inventories, habitat surveys, and site-specific project planning.

National Wetland Inventory (NWI) maps consist of wetland boundaries added to a black and white version of a 1:24,000-scale, 7.5-minute U.S. Geological Survey topographic base map (Figure 1). Wetlands are identified and classified according to guidelines found in "Classification of Wetlands and Deepwater Habitats of the United States" (Cowardin et al. 1979), which defines wetlands as:

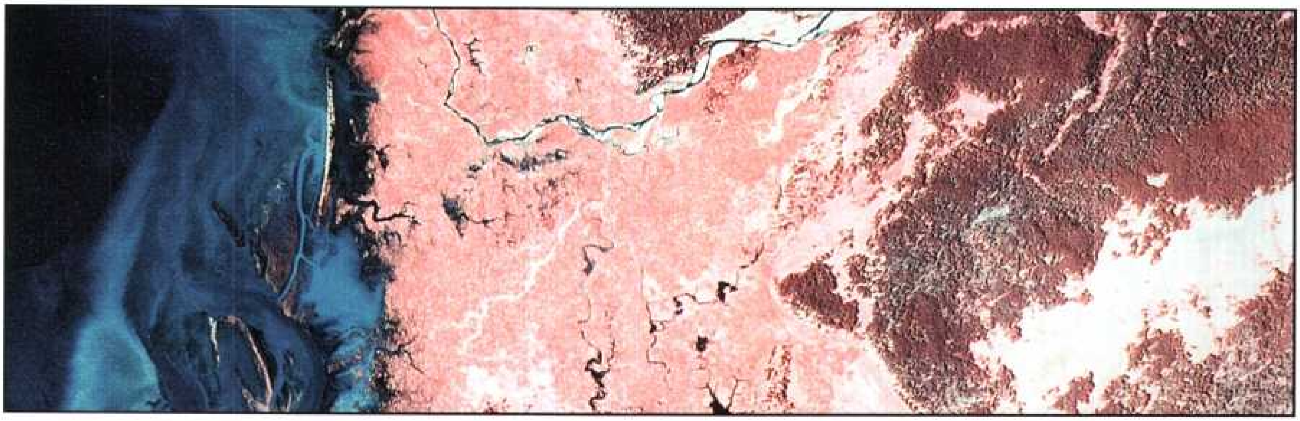
> ". . . lands transitional between terrestrial and aquatic systems where the water table is usually at or near the surface or the land is covered by shallow water. For purposes of this classification wetlands must have one or more of the following three attributes: (1) at least periodically, the land supports predominantly hydrophytes [wetland plants], (2) the substrate is predominantly undrained hydric soil, and (3) the substrate is nonsoil [does not support vegetation] and is saturated with water or covered by shallow water at some time during the growing season of each year."

The Cowardin classification system and the NWI maps include deepwater habitats—permanently flooded lands where the water depth in the deepest part of the basin exceeds 6.6 feet at low water. Throughout this booklet, the term "wetlands" is used generically to include both wetlands and deepwater habitats.

The procedures used to map the wetland resources of Yellowstone National Park were the same procedures used throughout the country. This process ensured that Yellowstone's wetland data are consistent with and comparable to wetland data collected elsewhere. The production of accurate wetland maps is dependent upon the availability of good aerial photography (Figure 1), field reconnaissance, photointerpretation, review of draft maps, production of final maps, production of a digital data base, and many quality-control steps.

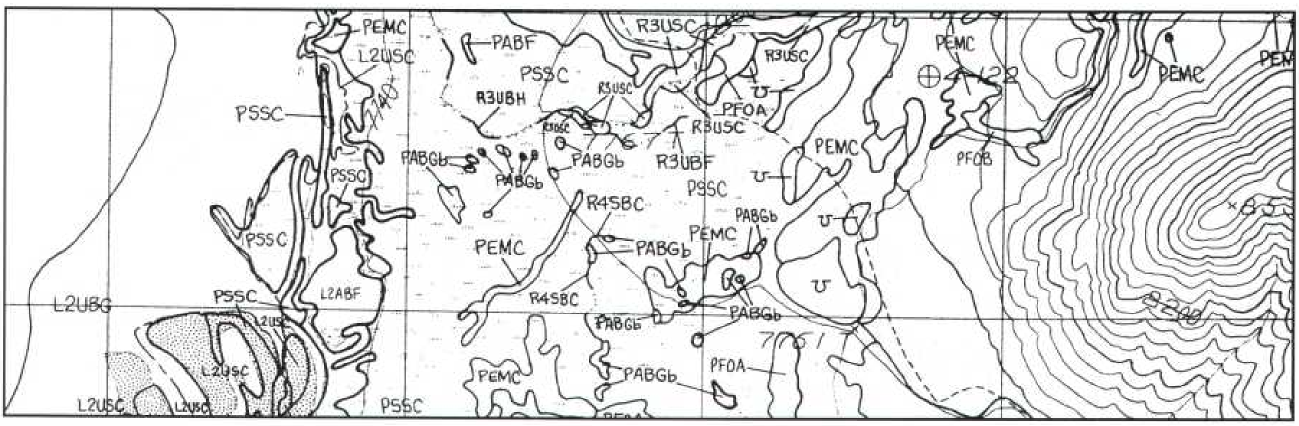
Wetland identification and classification were produced through stereoscopic interpretation of 1:58,000-scale color infrared photography taken primarily in August and September of 1982, 1983, and 1984. Field reconnaissance was performed prior to photo interpretation to correlate photographic signatures with different landscape features and habitats on the ground. Technicians identified wetland habitats by vegetation and soil types using input from park personnel. Collateral information, including topographic maps, SCS soil surveys, and USGS water resources data, was also used to ensure accurate delineation. The wetland classifications are shown as a series of number and letter codes that are identified in a legend at the bottom of the map (Figure 2).

The USFWS produced draft maps, then conducted a second field review to correct errors, such as wetland omissions, upland inclusions, and incorrect classifications, made during initial



A. Undelineated photo.

B. Delineated photo.



C. National Wetlands Inventory final map.

Figure 1. Color infrared aerial photography before (A) and after (B) photointerpretation, and the resulting National Wetlands Inventory final map (C).

SYSTEM	SUBSYSTEM	CLASS
RIVERINE	LOWER PERENNIAL	Rock bottom Unconsolidated bottom Aquatic bed Rocky shore Unconsolidated shore
	UPPER PERENNIAL	Rock bottom Unconsolidated bottom Aquatic bed Rocky shore Unconsolidated shore
	INTERMITTENT	Streambed
LACUSTRINE	LIMNETIC	Rock bottom Unconsolidated bottom Aquatic bed
	LITTORAL	Rock bottom Unconsolidated bottom Aquatic bed Rocky shore Unconsolidated shore Emergent
PALUSTRINE		Rock bottom Unconsolidated bottom Aquatic bed Unconsolidated shore Moss-lichen Emergent Scrub-shrub Forested

WATER REGIMES		SPECIAL MODIFIERS
A. Temporarily flooded	G. Intermittently exposed	b. Beaver
B. Saturated	H. Permanently flooded	d. Partially drained
C. Seasonally flooded	J. Intermittently flooded	h. Diked/Impounded
F. Semipermanently flooded	K. Artificially flooded	x. Excavated

Figure 2. National Wetlands Inventory map legend used for Yellowstone National Park.

photointerpretation. The corrected final paper maps were completed in 1997. Maps were digitized to transfer the data into an electronic database. The information was then placed in geographic information systems (GIS) for computerized data analysis, such as the calculation of statistics on wetland types and acreages (see Appendix), and production of a variety of ancillary products such as color-coded maps.

The National Wetland Inventory classifies all wetlands in the United States into five major systems. Three of these are found in Yellowstone: lacustrine (lakes, reservoirs, and large or deep ponds), riverine (rivers and streams), and palustrine (wet meadows, swamps, marshes, potholes, fens, bogs, and small shallow ponds) (Figure 3). Each system is divided into subsystems and then into classes that describe the general appearance of the wetland in terms of hydrologic characteristics, dominant vegetative form, and composition of the substrate. It is these descriptive classifications that are found on the NWI maps.

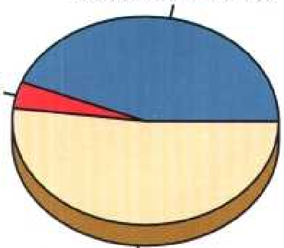


Figure 3. Yellowstone's wetlands are identified as lacustrine, riverine, or palustrine.

Because of scale limitations on NWI maps, individual plant names and dominance types are not used. For example, one cannot tell from an NWI map what species of shrubs are present in the scrub-shrub dominated wetland. That type of information must be obtained elsewhere, such as from descriptions or maps of the park's vegetation (Despain 1990).

The National Wetland Inventory identified 57 categories of wetlands occupying over 228,766 acres or 357 square miles (10.3 percent) of Yellowstone (see Appendix). Yellowstone's *lacustrine wetlands,* lakes and ponds (defined as being greater than 20 acres in size or having a water depth exceeding 6.6 feet at low water), occupy 100,888 acres or 4.5 percent of the park, and constitute 44.1 percent of the park's wetlands. Lacustrine wetlands are classified as either littoral or limnetic based on the water depth (Figure 4). In general terms, the littoral zone is that part of the lake or pond that is less than 6.6 feet deep, and the limnetic zone is that part that is more than 6.6 feet deep. The littoral zone is often the most productive area of the aquatic system because it includes the area of maximum light penetration and therefore supports the greatest amount of aquatic life.

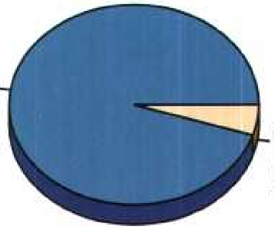


Figure 4. Nearly all of the park's lacustrine wetlands are limnetic. Yellowstone Lake is 90% of the total acreage.

Riverine wetlands (Figure 5) occupy 9,350 acres or 4.1 percent of the park's wetlands. Streams in the riverine system may be intermittent, flowing part of the year and leaving a dry creek bed at other times of the year. Other streams are perennial and have continuous water in channels classified as lower perennial, which are meandering and slow moving, or upper perennial, which are rapidly flowing and display cascading whitewater conditions. Eighty-eight percent of Yellowstone's streams are upper perennial. While all upper perennial streams do not display whitewater conditions, they

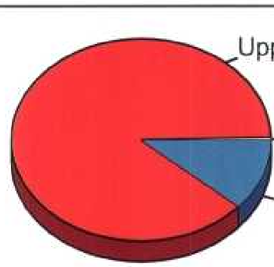


Figure 5. Yellowstone's river systems (upper and lower perennial and intermittent) form an intricate pattern of water movement throughout the park.

still maintain characteristics such as being highly oxygenated and maintaining high velocity, and are characterized by either gravel or rocky substrates.

The third category of wetlands found in Yellowstone is *palustrine wetlands*. While most vegetated wetlands are included in the palustrine system, lacustrine and riverine systems can also be vegetated, with the most dominant life form being the nonpersistent "emergents," the herbaceous grasses and forbes (Figure 6). Palustrine wetlands are described by either the dominant life form (trees, shrubs, emergents, mosses and lichens, or aquatic plants) where vegetation covers 30 percent or more of the substrate; or the physiography and composition of the substrate (rock bottom, unconsolidated bottom, or unconsolidated shore) where there is less than 30 percent vegetative cover. Palustrine wetlands occupy 118,528 acres of the park, 51.8 percent of the park's wetlands.

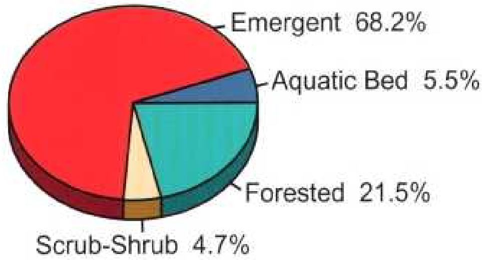


Figure 6. Vegetated wetlands are distributed throughout the park, with the emergent class the most dominant.

The NWI maps further describe wetlands by the water regimes present (Figure 7). Water regimes range from saturated soils, with little or no standing water, to flooded soil conditions lasting a few weeks during the growing season, to water bodies that contain open water throughout each year. Water depth may be a few inches located in a small catchment basin to several hundred feet, in the case of Yellowstone Lake. The water regime often determines the type of aquatic vegetation that dominates a specific site. Due to the variety of its water regimes, Yellowstone supports an array of aquatic vegetative species ranging from dwarf spikerushes and sedges to towering cattails and bulrushes. Wetlands with greater water depth support rooted and floating pondweeds and beautiful expanses of lily pads.

Paper copies of Yellowstone's wetland maps may be acquired by contacting the Regional Map Distribution Center in Brookings, South Dakota, at (605) 688-5890. Digital data can be downloaded through the NWI home page on the Internet at http://www.nwi.fws.gov.

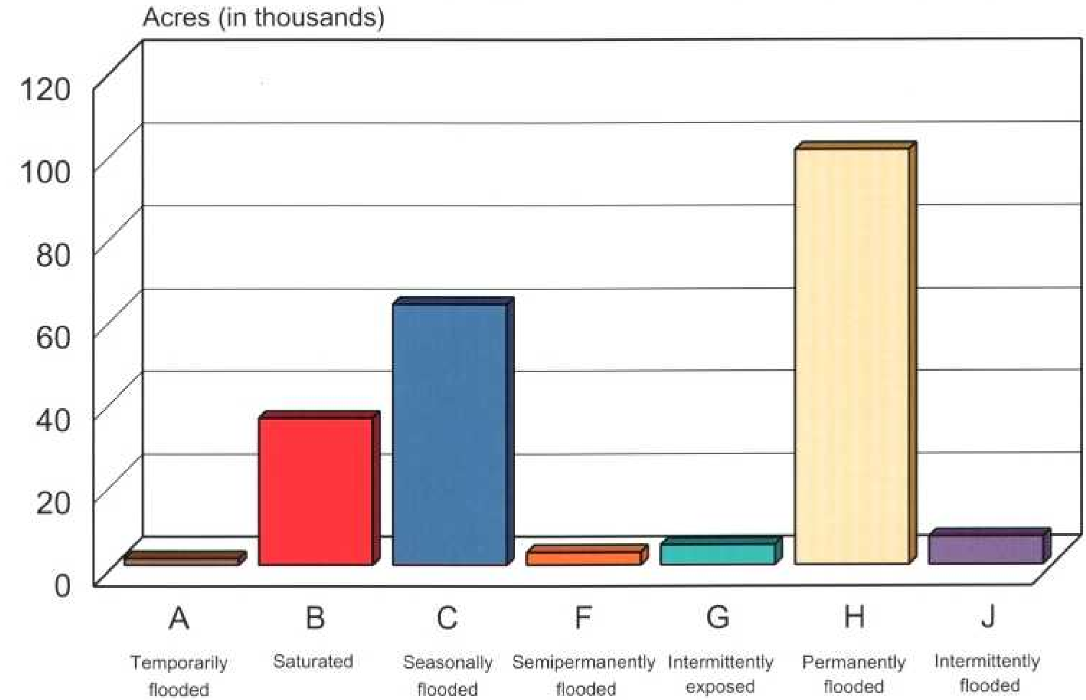


Figure 7. Water regimes in Yellowstone range from temporarily flooded to permanently flooded.

Right: waterfall in backcountry thermal area (J. Whipple).

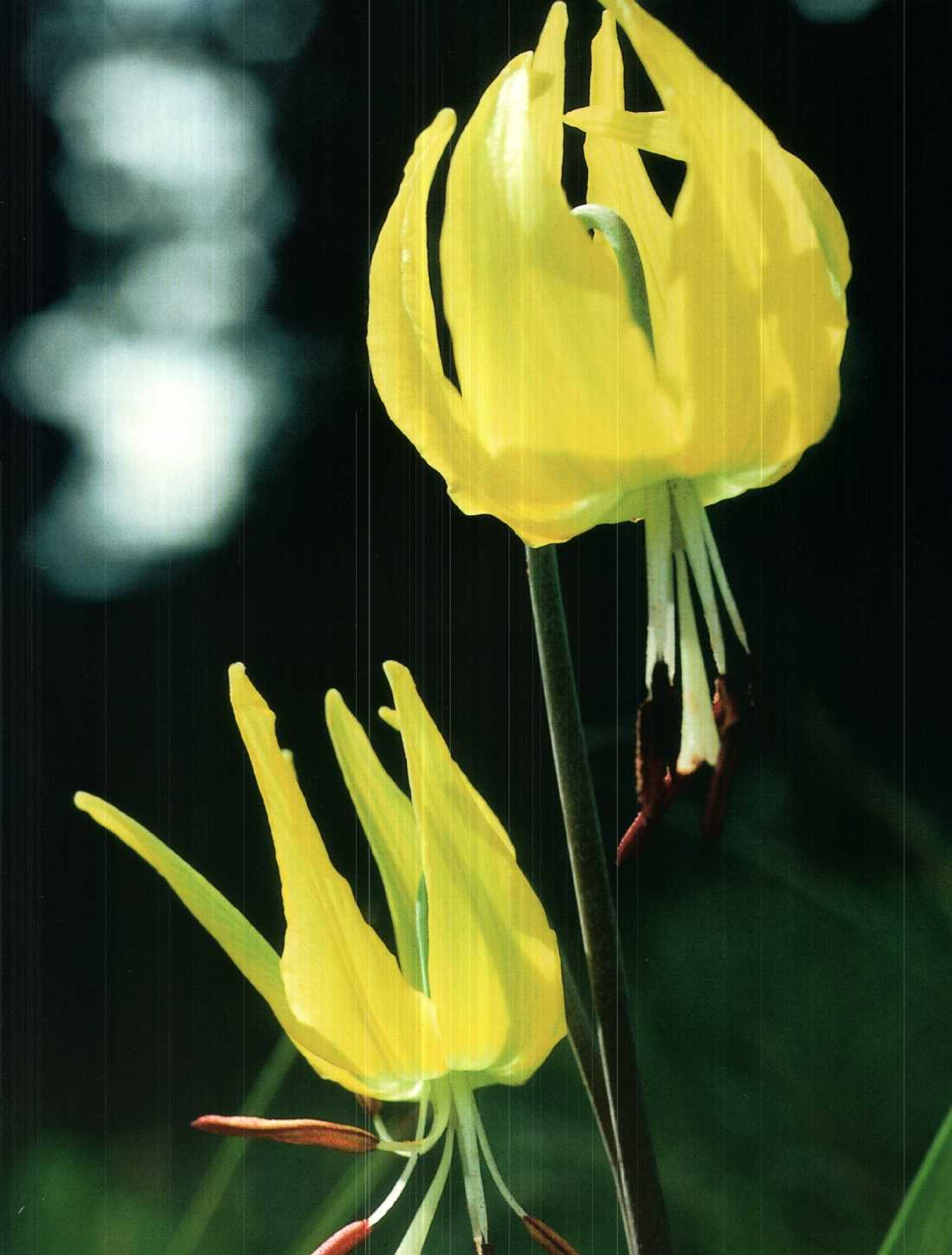
In Closing

Yellowstone National Park exists today in perhaps as pristine a state as any area can be in twenty-first century society. The Yellowstone and other powerful rivers still flow undammed through grasslands and towering forests. Yellowstone Lake remains a formidable body of water, dominating the landscape and influencing the ecology of the entire ecosystem. Yellowstone's wetlands—in all their diversity and complexity, in all their grandeur and wonder—still support waterfowl, fish, amphibians, and plant communities that nineteenth-century explorers would recognize.

Yellowstone's wetlands are essential to the survival of hundreds of magnificent creatures. While extinction may be a fact of evolution, the accelerated rate of species decline in today's world is contrary to evolutionary processes. Any endangered species may say to us, "Be careful of me my friend, for if you drive me to extinction, another heaven and earth must pass before you see me again."

Yellowstone National Park is a sanctuary for many plants and animals and their habitats, largely because of the variety of wetland resources it preserves. Here, humans find the opportunity to see and enjoy a landscape and associated species that have thrived for thousands of years. May it always be so.

The southeast arm of Yellowstone Lake. Top right: caterpillar on willow. Right: glacier lily. (All by J. Whipple).



Appendix: Yellowstone National Park's Wetland Classifications and Acreages

The National Wetlands Inventory identifies wetlands by a coding system that is a series of letters and numbers. These codes are technically referred to as alphanumerics or attributes. For example, Yellowstone Lake is classified as an L1UBH where (L) lacustrine, (1) limnetic, (UB) unconsolidated bottom, and (H) permanently flooded, specifically identify deep lake habitat. Each of these four terms, *i.e.,* lacustrine, limnetic, unconsolidated bottom, and permanently flooded, is identified in the Cowardin *et al.* (1979) wetland classification system. In addition, these terms are identified on every wetland inventory map.

For a more detailed explanation of the NWI map codes, consult the U.S. Fish and Wildlife Service's 1993 publication "NWI Maps Made Easy: A User's Guide to National Wetlands Inventory Maps of the Mountain-Prairie Region."

Wetlands are delineated cartographically on every map as one of three features: (1) polygon, (2) linear, or (3) point. A polygon is a wetland large enough that a photointerpreter can delineate an entire boundary around the wetland. A linear feature is a wetland so narrow that a single dashed line is used to delineate it. A point is a wetland so small that a single dot delineates it.

For area measurement, polygon wetlands are measured during the digitizing process. Linear and point wetlands are measured on the assumption that linear wetlands average 10 feet wide, and points average 0.1 of an acre.

"Frequency," as used in this appendix, does not identify individual basins, rather it identifies the number of times that a particular wetland classification is used. For example, a single wetland basin may consist of a deep central zone classified as PABF (palustrine, aquatic bed, semipermanently flooded) with a shallower periphery of PEMC (palustrine, emergent, seasonally flooded) and an even shallower periphery of PEMA (palustrine, emergent, temporarily flooded). In this example, there is only one wetland basin, but three wetland classifications and, therefore, three frequencies.

Pelicans on Yellowstone Lake. NPS

Yellowstone National Park Wetland Acreage Statistics

Attribute	Feature	Frequency	Acres
LACUSTRINE			
L1ABH	Polygon	2	12.1
L1UBH	Polygon	134	96,015.4
L2ABF	Linear (0.10 miles)	1	0.1
L2ABF	Polygon	4	44.7
L2ABG	Linear (16.13 miles)	95	19.6
L2ABG	Polygon	135	3,927.3
L2ABGb	Polygon	1	25.9
L2ABH	Polygon	1	40.1
L2UBF	Polygon	18	8.5
L2UBG	Linear (113.06 miles)	221	137.0
L2UBG	Polygon	3	551.9
L2UBH	Linear (0.99 miles)	4	1.2
L2USA	Polygon	1	0.5
L2USC	Polygon	14	103.9
Subtotal		**634**	**100,888.2 acres**
PALUSTRINE			
PABF	Linear (7.06 miles)	87	8.6
PABF	Point	14	1.4
PABF	Polygon	3,077	2,048.0
PABFh	Polygon	6	4.6
PABG	Polygon	59	330.9
PABGb	Polygon	81	35.3
PABKx	Polygon	12	16.1
PEMA	Linear (7.11 miles)	27	8.6
PEMA	Point	1	0.1
PEMA	Polygon	454	1,559.2
PEMAx	Polygon	1	0.5
PEMB	Linear (3.43 miles)	56	4.2
PEMB	Point	12	1.2
PEMB	Polygon	5,153	20,592.6
PEMBb	Polygon	5	47.3
PEMC	Linear (759.38 miles)	4,304	920.5
PEMC	Point	50	5.0
PEMC	Polygon	15,854	54,347.3
PEMCh	Polygon	2	1.3
PEMCx	Linear (0.49 miles)	6	0.6
PEMF	Linear (4.56 miles)	32	5.5
PEMF	Polygon	109	320.8
PEMH	Linear (3.45 miles)	32	4.2
PEMJ	Linear (1.06 miles)	6	1.3

PEMJ	Point	1	0.1
PEMJ	Polygon	417	3,563.3
PFOA	Linear (27.79 miles)	141	33.7
PFOA	Polygon	2,584	10,953.0
PFOB	Linear (0.12 miles)	1	0.2
PFOB	Polygon	2,111	14,598.0
PFOC	Polygon	7	56.0
PFOJ	Polygon	20	53.1
PMLB	Polygon	1	2.8
PSSA	Linear (5.63 miles)	28	6.8
PSSA	Polygon	53	72.6
PSSB	Linear (0.08 miles)	2	0.1
PSSB	Polygon	99	277.8
PSSBb	Polygon	2	3.0
PSSC	Linear (1.54 miles)	12	1.7
PSSC	Polygon	616	5,303.7
PSSCx	Linear (0.22 miles)	1	0.3
PUBFx	Polygon	2	0.4
PUBH	Point	2	0.2
PUBH	Polygon	298	88.1
PUBKx	Polygon	1	2.7
PUSA	Polygon	30	31.8
PUSC	Point	3	0.3
PUSC	Polygon	85	63.8
PUSCx	Polygon	1	0.1
PUSJ	Linear (0.50 miles)	5	0.6
PUSJ	Polygon	1,096	3,149.0
Subtotal		**37,059**	**118,528.3 acres**

Riverine

R2UBH	Linear (2.53 miles)	33	3.1
R2UBH	Polygon	5	6.9
R2USC	Linear (0.25 miles)	2	0.3
R2USC	Polygon	5	25.0
R3ABH	Linear (0.87 miles)	8	1.1
R3ABH	Polygon	20	101.3
R3RBH	Linear (4.27 miles)	27	5.2
R3RBH	Polygon	10	157.8
R3UBF	Linear (505.89 miles)	1,915	613.2
R3UBF	Polygon	4	10.0
R3UBG	Linear (143.98 miles)	630	174.5
R3UBH	Linear (972.61 miles)	9,464	1,178.8
R3UBH	Polygon	93	3,955.5
R3UBHx	Linear (0.19 miles)	1	0.2
R3USA	Linear (2.13 miles)	18	2.6
R3USA	Polygon	452	564.1
R3USC	Linear (10.69 miles)	124	13.0
R3USC	Polygon	647	1,468.0
R4SBA	Linear (182.97 miles)	212	221.8
R4SBC	Linear (635.83 miles)	1,240	770.7
R4SBC	Polygon	6	75.8
R4SBCx	Linear (0.41 miles)	4	0.5
R4SBF	Linear (0.42 miles)	5	0.5
Subtotal		**14,925**	**9,349.9 acres**

Total		**52,618**	**228,766.39 acres**

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Mt. Ash tributary. Top left: thermal spider. Top right: dipper.

J. Whipple

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Top: pond near Lewis Lake. Mid-page: arrowhead and horsetail. Right: dragonfly on cattail. (All by J. Whipple.)