LEVEL III AND IV ECOREGIONS OF NEW JERSEY

by

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INTRODUCTION

Ecoregions denote areas of general similarity in ecosystems, and in the type, quality, and quantity of environmental resources. They are general purpose regions that are useful for structuring and implementing ecosystem management strategies across political boundaries (such as state lines) and across agencies (Omernik and others, 2000). Ecoregions stratify the environment according to its probable response to disturbance, and recognize the spatial differences in the capacities and potentials of ecosystems (Bryce, Omernik, and Larsen, 1999).

Ecoregion frameworks are useful for 1) inventorying and assessing national and regional environmental resources, 2) setting regional resource management goals, 3) establishing geographical research frameworks, and 4) developing regional biological criteria and water quality standards (Arkansas Department of Pollution Control and Ecology, 1988; Bazata, 1991; Environment Canada, 1989; Gallant and others, 1989; Heiskary and Wilson, 1989; Hughes, 1989b; Hughes and others, 1987, 1990, 1994; Larsen and others, 1986; Lyons, 1989; Ohio Environmental Protection Agency, 1988; Plotnikoff, 1992; Rohm and others, 1987; U.S. Environmental Protection Agency, Science Advisory Board, 1991; Warry and Hanau, 1993; Whittier and others, 1988).

Ecoregion frameworks have been developed for several countries, including the United States, Canada, New Zealand, and the Netherlands (Bailey, 1976, 1983, 1995; Bailey and others, 1985, 1994; Biggs and others, 1990; Ecological Stratification Working Group, 1995; Klijn, 1994; Omernik, 1987, 1995a; Omernik and Gallant, 1990; U.S. Environmental Protection Agency, 2005; Wiken, 1986). The first compilation of ecoregions in the conterminous United States by the U.S. Environmental Protection Agency (U.S. EPA) was performed at a relatively cursory scale (1:3,168,000), and was published at a smaller scale (1:7,500,000) (Omernik, 1987). Subsequently, this ecoregion framework was expanded to include Alaska and all of North America, revised, and made hierarchical (Gallant and others, 1995; Omernik, 1995b; U.S. Environmental Protection Agency, 2005).

Level I is the coarsest level in the ecoregion hierarchy; it divides North America into 15 ecological regions. Level II divides the continent into 50 regions. At level III, the continental United States contains 104 ecoregions, whereas the conterminous United States has 84. Level IV ecological regions are further subdivisions of level III ecoregions. The exact number of ecological regions at each hierarchical level is still changing slightly as the framework undergoes development at the international, national, and state levels.

Detail resolution on Omernik's (1987) ecoregion map of the conterminous United States was necessarily limited by its rather small scale of 1:7,500,000. Subsequently, many larger scale, collaborative, state projects refined Omernik's original ecoregion map, and subdivided its level III ecoregions into level IV ecoregions. Completed level IV ecoregion projects cover Alabama, Arkansas, Colorado, Delaware, Florida, Georgia, Idaho, Illinois, Indiana, Iowa, Kansas, Kentucky, Louisiana, Maryland, Mississippi, Missouri, Montana, Nebraska, Nevada, North Carolina, North Dakota, Ohio, Oklahoma, Oregon, Pennsylvania, South Carolina, South Dakota, Tennessee, Texas, Utah, Virginia, Washington, West Virginia, Wisconsin, and Wyoming. Other state level IV ecoregion projects are in the draft phase including Connecticut, Massachusetts, Minnesota, New Mexico, and Rhode Island. These level IV ecoregion projects have involved state agencies, U.S. EPA regional offices, and the U.S. EPA–National Health and Environmental Effects Research Laboratory, Western Ecology Division in Corvallis, Oregon. Projects have included participation by the U.S. Department of Agriculture–Natural Resources Conservation Service and the U.S. Department of Agriculture–Forest Service as part of an interagency effort to develop a common framework of ecological regions.

In this paper we refine the level III ecoregions of New Jersey, subdivide them into more detailed level IV subdivisions, and provide descriptions for each ecoregion in the state. New Jersey has 5 level III and 17 level IV ecoregions; nearly all level IV ecoregions continue into ecologically similar parts of adjacent states (Woods and others, 1996; Woods and Omernik, 1996).

The procedures used to define New Jersey ecoregions are consistent with those that were used in preceding U.S. EPA ecoregion studies of neighboring states (Woods and others, 1996; Woods and Omernik, 1996). They are based on the premise that ecological regions can be identified through the analysis of biotic and abiotic characteristics that affect or reflect differences in ecosystem quality and integrity (Omernik, 1987, 1995a; Wiken, 1986). Spatial pattern, composition, and spatial correspondence of physiography, natural vegetation, soil, surficial and bedrock geology, climate, land use, land cover, wildlife, and fish were considered as part of the process. The relative importance of each biotic and abiotic characteristic varied from one ecological region to another regardless of the ecoregion hierarchical level. Expert judgment was employed throughout the selection, analysis, and classification of data to define the ecoregions. Information from the literature and input from state and regional experts were very important to this project, as well as the earlier ones in neighboring states. Ecoregion lines were compiled at 1:250,000-scale onto 1:250,000-scale topographic base maps. More detailed explanations about the methods, materials, rationale, and philosophy for the ecoregionalization process can be found in Gallant and others (1989), Omernik (1995a), and Omernik and Gallant (1990).

Evaluation of the ecoregion framework presented in this paper is a necessary future step. U.S. EPA ecoregions have been evaluated extensively in the past, and the most meaningful of these efforts have involved the use of measures of water quality and indices of biotic integrity (IBI's) (Hughes, 1989a; Larsen and others, 1986, 1988; Whittier and others, 1987; Yoder and Rankin, 1995). A better tool would be a more encompassing index of ecological integrity (IEI) (Omernik, 1995a, 1995b); although an IEI is not available yet, there is considerable interest in at least two states to begin its development. Verification of ecoregions cannot be done by considering individual ecosystem components; this is because the ecoregion framework was not intended to show regional patterns specific to either the flora or fauna of terrestrial ecosystems, nor was it intended to reflect distributions of fish or aquatic macroinvertebrates.

REGIONAL DESCRIPTIONS

58 NORTHEASTERN HIGHLANDS

- Partly glaciated highlands that are typically cored by metamorphic crystalline rocks, and often forested. Open high hills and lakes occur in glaciated northeastern areas. Low mountains are found in southwestern and central portions that were not covered by Wisconsinan-age ice.
- Uplands are characteristically underlain by resistant, Precambrian gneiss, whereas valleys are composed of much less resistant Paleozoic limestone and shale. Nearby ecoregions 62, 64, 67, and 84, including all other parts of New Jersey, lack metamorphic crystalline rock, as well as its associated physiography and soils.
- Gneissic soils are typically nutrient-poor, and clay- and iron-rich.
- Upland native vegetation is mixed oak forest. On slopes underlain by gneiss and shale, red oak predominates along with white, black, scarlet and chestnut oaks. On drier, high elevation slopes and ridgetops, both pitch pine-scrub oak and chestnut oak forests occur, and often intergrade. On moister sites, hemlock-mixed hardwood forest grows in ravines and on lower, north-facing steep slopes over gneiss. On more fertile sites, sugar maple-mixed hardwood forest occurs.
- Kuchler potential natural vegetation is Appalachian oak forest (dominants: white oak and northern red oak).
- Today, forests, general farmland, and rural residential developments are common. Forests are generally more extensive than in Ecoregion 64 or the valleys of Ecoregion 67.
- Ecoregion 58 has broader ridges, more rock outcrops, different rocks, and narrower valleys than the structurally different Ridge and Valley (67), and has considerably more surface irregularity and much less human population than the Northeastern Coastal Zone (59). It is higher and more rugged and has much less agriculture and population than the lithologically distinct Northern Piedmont (64), and has different rocks, soils, and native vegetation than the lower and less rugged Pine Barrens (84b).

58h Reading Prong

- Low mountains and high hills that are characteristically cored by gneissic rocks. More than 90% of Ecoregion 58h in New Jersey is driftless. The rest is mantled by highly weathered and leached, Pre-Wisconsinan Drift. Elevations are higher, terrain is more rugged, and forests are more extensive than in nearby Ecoregions 64a, 64e, 67a, and 67b. Ridges are broader, rock outcrops are more common, and valleys are narrower and steeper than in Ecoregion 67. Lacks the numerous lakes, relatively unleached Wisconsinan glacial deposits, and associated soils of the Glaciated Reading Prong (58i).
- Uplands in both Ecoregions 58h and 58i are characteristically cored by resistant, Precambrian gneiss, whereas valleys are underlain by less resistant Paleozoic limestone and shale; surrounding Ecoregions 64 and 67 lack metamorphic crystalline rocks and their associated soils.
- Slightly acidic soils derived from underlying metamorphic crystalline rock are common. Gneissic soils are clay- and iron-rich, and are typically well-drained to xeric. Red yellow podzolic soils cover driftless uplands underlain by gneiss, and red yellow podzols are found on Pre-Wisconsinan drift; soils are markedly different from those of Ecoregion 58i.
- Mixed oak forest is native.
- Today, forest is common on more rugged, stony, or elevated sites. Elsewhere, general farmland, woodlots, and rural residential development occur; forest is now less dense than in the Trap Rock Ridges and Palisades (64b).

58i Glaciated Reading Prong

- Open, high hills cored by metamorphic crystalline rock, and characterized by numerous glacial lakes, many wetlands, and Wisconsinan glacial deposits. Lake density is far greater than in Ecoregion 58h, which was never covered by Wisconsinan ice. Elevations are higher, terrain is more rugged, and forests are more extensive than in nearby Ecoregions 64e, 64f, 67j, and 67k.
- Many rock outcrops are found in Ecoregion 58i. In addition, discontinuous, Wisconsinan till is common, in contrast to Ecoregion 58h, which is either driftless or covered by Pre-Wisconsinan till. Wisconsinan glacial drift is much less leached than the Pre-Wisconsinan drift of Ecoregion 58h.
- Uplands in both Ecoregions 58h and 58i are characteristically cored by resistant, Precambrian gneiss, whereas valleys are underlain by less resistant Paleozoic limestone and shale; surrounding Ecoregions 64 and 67 lack metamorphic crystalline rocks and their associated soils.
- Brown podzolic soils are found on acid Wisconsinan drift, and gray brown podzolic soils occur on alkaline or near-neutral glacial deposits; soils are markedly different than those of Ecoregion 58h.
- Mixed oak forest is native. A few northern species that grow in Ecoregion 58i are not found in Ecoregion 58h.
- Today, forest is common on rugged, stony, or elevated sites. General farmland, woodlots, and rural residential development occur elsewhere. Many lakes have been acidified by sulfur from upwind industrialized areas.

63 MIDDLE ATLANTIC COASTAL PLAIN

- Low, nearly flat coastal plain underlain by unconsolidated Quaternary gravels, sands, and silts. Characterized by an ocean-modified climate, a long growing season, and swampy, marshy, and frequently flooded areas. Terrain is flatter than in the Atlantic Coastal Pine Barrens (84) and the lithologically distinct Northern Piedmont (64).
- Upland vegetation cover is predominantly loblolly-shortleaf pine forests; it contrasts with longleaf-slash pine forests of the warmer Southern Coastal Plain (75) and the pine barrens of Ecoregion 84b.
- Undrained coastal lowlands and tidally influenced river margins support tidal marshes, swamps, floodplain forests, and pocosins. Wetland habitats often contain, or are dominated by, southern species that are absent from corresponding habitat in northern New Jersey (i.e., Ecoregions 58, 62, 64, and 67).
- Kuchler potential natural vegetation is mostly oak-hickory-pine forest (dominants: hickory, longleaf pine, shortleaf pine, loblolly pine, white oak, and post oak), southern floodplain forest (dominants: oak, tupelo, and bald cypress), and pocosin (dominants: shrub and forest bogs, Atlantic white-cedar, and some loblolly pine); the potential natural vegetation of Ecoregion 63 is distinct from the northeastern oak-pine forest (dominants: pitch pine, scarlet oak, and black oak) of the nearby Pine Barrens (84b).
- In New Jersey, wetlands dominate Ecoregion 63; only about 15 percent the upland area is in cropland.

63a Delaware River Terraces and Uplands

- Marshy, nearly level, low elevation terraces along the Delaware River and Delaware Bay. Wetlands are much more extensive than in Ecoregions 84d and 84b in New Jersey, and Ecoregions 63f and 65n in Delaware.
- Saline marsh deposits, alluvial and estuarine sand and silt, tidal marshes, and tidally-influenced, sluggish, meandering streams are common.
- In New Jersey, salt marshes occur along Delaware Bay from Cape May to Salem County. Brackish marshes are found from Salem County to Trenton. Upstream of saltwater or brackish marshes are freshwater tidal marshes.
- Marshes are dominated by saltmarsh cordgrass and, in higher areas, by salt-meadow grass. Shallow, very saline depressions with very harsh conditions occur on the high marsh; other than glassworts, they support few plants.
- Large tracts of tidal wetlands have been impacted or destroyed by erosion, pollution, dredging, draining, filling, and embankment construction; however, the Wetlands Act of 1973 greatly reduced subsequent wetland losses.
- Hydric soils and flooding are common in areas that have not been artificially drained.

64 NORTHERN PIEDMONT

- Partly glaciated, irregular plains and low hills that have been extensively cleared for farms or suburban-urban developments; in addition, large old glacial lake beds are found near the Wisconsinan terminal moraine, and scattered, forested, rocky ridges occur on diabase and basalt intrusions. Overall, physiography and lithology contrast with the low mountains of the Northeastern Highlands (58), the Ridge and Valley (67), and the flat coastal plains of Ecoregions 63 and 84.
- In New Jersey, Triassic brownish red, shale, sandstone, and argillite are extensive; these sedimentary rocks are much less resistant to erosion than the metamorphic crystalline rocks that form the core of the adjacent Northeastern Highlands (58). In northern New Jersey, Wisconsinan drift blankets the Triassic sedimentary rocks.
- Climate is humid continental, with cold winters, and hot summers; climate is colder that in the Middle Atlantic Coastal Plain (63) and Atlantic Coastal Pine Barrens (84).
- In New Jersey, native vegetation is mixed oak forest on well-drained upland sites over sandstone, shale, diabase, and basalt. On drier slopes, chestnut oak forests are native. In moister valleys, ravines, and on steep, lower, north-facing diabase ridges, hemlock-mixed hardwood forests are native. On more fertile sites, sugar maple-mixed hardwood forests are native.
- Kuchler potential natural vegetation is mostly Appalachian Oak Forest (dominants: white oak and northern red oak); it contrasts with the oak-hickory-pine forests of the Piedmont (45) and the northeastern oak-pine forest (dominants: pitch pine, scarlet oak, and black oak) of the Pine Barrens (84b).
- Soils are generally deep, well-developed, and have moderate to high base saturation. Alfisols are common. Differences in rock types, and the presence or absence of glacial drift, result in different soil types.

64a Triassic Lowlands

- Undulating plains underlain by Triassic-age sedimentary rock, and characterized by a mosaic of farms and suburban-urban development. Most of the landscape has sufficient local relief to prevent ponding, but impeded drainage sometimes occurs on broad flats.
- Underlain by brownish red, Triassic shale, sandstone, argillite, and siltstone.
- Reddish, residual soils are common. Soils derived from reddish shale are usually only slowly permeable. Soils that developed from gray sandstone are deep, well-drained, and acidic. Soils from argillite are clayey, poorly drained, and have hardpans in lower horizons. Locally, soils developed from loess, or in the north, from Pre-Wisconsinan drift; relatively unleached Wisconsinan till is absent unlike in the Glaciated Triassic Lowlands (64e) where it is common.
- On New Jersey's mesic uplands, mixed oak forest is native; red oak, white oak, black oak, hickory and chestnut were originally abundant. On soils derived from loess, forests dominated by oak, poplar, beech, ash, maple, and hickory are native. On poorly drained, clayey soils with hardpans that were derived from argillite, native vegetation is a mosaic of red maple, swamp hardwoods, and mixed oaks, including pin oak.
- Today, a mosaic of farms and houses has largely replaced the native vegetation. Urbanization increases northward towards New Brunswick.

64b Trap Rock Ridges and Palisades

- Stony, steep, mostly wooded ridges, hills, and palisades that are composed of highly resistant diabase, basalt, or heat-altered sedimentary rock. Outcrops of highly weathered rock are common. Lithology, woodland density, topography, and landuse are distinct from the rest of the Northern Piedmont (64) in New Jersey. Ecoregion 64b protrudes above adjacent ecoregions.
- Partly glaciated. Thin, rocky, discontinuous Wisconsinan-age glacial till is found north of the terminal moraine on the Palisade Sill and on the northern Watchung Mountains. Pre-Wisconsinan glacial drift is usually absent south of the Wisconsinan terminal moraine, although limited Kansan-age till occurs, particularly on the southern Watchung Mountains and on Basking Ridge.
- Molten diabase and basalt (i.e., "trap rock") intruded shales, argillites, conglomerates, and reddish sandstones along the scattered sills and dikes of Ecoregion 64b during the Triassic Period. In the process, adjacent sediments were heat-altered into harder, denser, and less porous material. The level of induration in the nearby sediments increases toward the trap rock.
- Characteristically, soils are thin or absent; elsewhere in the Northern Piedmont (64), soils are deeper and rock outcrops are less common. Stony, non-acidic, fine-textured soils with a heavy clay subsoil are common over diabase; they are hard to till and best suited for forest or pasture. Well-drained to xeric conditions are common, but poorly drained sites occur in depressions and on flats. On steep ridges, soils derived from basalt or diabase are often unstable; they tend to creep downslope, creating shallow, ledgy soils on upper slopes, and deeper, wetter gley soils on lower slopes near the bases of ridges.
- On diabase and basalt ridge slopes, mixed oak forests are found; red oak, white oak, and black oak are most common, and sugar maple, chestnut oak, black birch, white ash, and tulip tree occur. On highest ridges, including Cushetunk Mountain, ridgetops and on upper slopes support chestnut oak forests (dominants: chestnut oak and red oak). In ravines and on steep, lower, north-facing slopes, hemlock-mixed hardwood forests occur. Native vegetation is distinct from the Passaic Basin Freshwater Wetlands (64f) and Hackensack Meadowlands (64g).
- Black birch, tulip tree, white ash, basswood, sugar maple, and shrubs are most common on north-facing slopes, whereas dogwood is most abundant on south-facing slopes. Everywhere, trees are larger on north-facing slopes than on drier south-facing slopes. Acid loving plants are absent from diabase and basalt areas.
- In New Jersey, Ecoregion 64b includes Rocky Hill, the Palisades, and Cushetunk, Watchung, and Sourland mountains.

64e Glaciated Triassic Lowlands

- Glaciated, undulating plains that are dominated by urban activity, underlain by Triassic sedimentary rock, and covered by Wisconsinan-age drift. Ecoregion 64e is physiographically and lithologically distinct from Ecoregion 64b, 64f, and 64g. Wisconsinan-age till is absent from the Triassic Lowlands (64a).
- Till and stratified drift are extensive, with the former being thickest and most continuous on lower areas. Two types of till occur: 1) acidic red sandstone and shale till derived from Triassic sediments of the Northern Piedmont (64), and 2) gneissic till derived from Precambrian crystalline metamorphic rocks of the Northeastern Highlands (58). Gneissic till is limited to the northwestern part of Ecoregion 64e.
- Stratified drift, in the form of outwash plains, deltas, kames, and moraines, fills main stream valleys.
- Soils are mostly derived from Wisconsinan-age till and stratified drift, not residuum as in Ecoregion 64a.
- Native vegetation was probably mixed oak, sugar maple, and northern hardwoods, but it has been totally removed and replaced by urbanization.

64f Passaic Basin Freshwater Wetlands

- Large, nearly flat, former glacial lake containing freshwater marshes, swamps, and peatlands, and composed of lacustrine clays, fluvial sands, and till. Slowly permeable soils, high water tables, frequent flooding, sluggish streams, and swampy conditions are common. Physiographically, lithologically, and botanically distinct from the Triassic Lowlands (64a), Trap Rock Ridges and Palisades (64b), and Glaciated Triassic Lowlands (64e).
- Freshwater marshes are typically found next to ponds, rivers, and streams, where water stands during spring and early summer. Swamps occupy former glacial lakes. Bog and fen peatlands are found in glacier-scoured basins or in valleys blocked by glacial drift. The Passaic Basin Freshwater Wetlands (64f) lacks the salt and brackish marshes of the Hackensack Meadowlands (64g).
- In swamps, red maple is very common, and American elm, pin oak, swamp white oak, sour gum, sweet gum, white ash, and silver maple are abundant. Reeds and sedges also occur. Yellow birch is less common, and pin oak, swamp white oak, and silver maple are more common than in swamps within the Northeastern Highlands (58) and Ridge and Valley (67).
- In fens and bogs, sphagnum moss, ferns, and sedges are common.
- Wetlands lack many southern plant species that are found in the Middle Atlantic Coastal Plain (63) and Atlantic Coastal Pine Barrens (84).
- Includes the Great Swamp and Troy Meadows.

64g Hackensack Meadowlands

- Large, low elevation, former glacial lake containing a mix of brackish, salt, and freshwater marshland that has been heavily impacted by humans. Varved, lacustrine clays overlain by fluvial sands and peat deposits are common. Physiographically, lithologically, and botanically distinct from the Triassic Lowlands (64a), Trap Rock Ridges and Palisades (64b), and Glaciated Triassic Lowlands (64e).
- Originally a mosaic of Atlantic white cedar swamps, floodplain forests, and cattail marshes.
- Soils are mostly of blue mud or clay, but peaty soils occur in former cedar swamps, and contain many logs, roots, and stumps.
- Current plant communities include marshes dominated by phragmites, forests, meadows, and plants growing on refuse ground.
- The Hackensack Meadowlands has been severely depleted and altered. Diking, damming, filling, logging, embanking, dumping, burning, building development, and pumping have heavily impacted the meadowlands. Much of the original organic mat has been deeply buried by fill, causing subsidence. In addition, the ecoregion has been extensively burned, fueled by trash and peat. Land use is a contrast to the Passaic Basin Freshwater Wetlands (64f) as well as other ecoregions in the Northern Piedmont (64).
- Today, most of Ecoregion 64g is used for industrial purposes, including refuse disposal. The remaining marshland is largely dominated by phragmites, but saltmarsh cordgrass occurs along the edge of tidal creeks. Species diversity is now far less than it was before settlement. The last Atlantic white cedars died in 1939.
- At the crossroads of several Atlantic Flyway migration routes. Critical stop over area for migratory birds.
- Provides habitat for 275 plant species, 50 species of fish, 25 species of reptiles, and 24 species of mammals. 25 species are state-listed as threatened or endangered.
- Now listed as an "Area of Critical Concern" by the state, a "priority wetland site" under the Emergency Wetlands Resources Act, and an "Aquatic Resource of National Importance" by the United States Environmental Protection Agency.

67 RIDGE AND VALLEY

- Diverse, folded, and faulted, partly glaciated ecoregion with northeastwardly trending, forested ridges and agricultural valleys; structurally distinct from the flat-lying rocks of Ecoregion 62.
- Mostly underlain by Paleozoic sedimentary rock, but some metamorphic rocks like slate, quartzite, and marble also occur; overall, Ecoregion 67 is lithologically distinct from Ecoregions 58 and 64.
- Surface morphology is influenced by lithological characteristics. Ridges are cored by resistant sandstone or conglomerate; they often parallel each other, but locally, where strata has been compressed into plunging folds and later eroded, they zigzag. Valleys cut into limestone and dolomite are smoother, and have more karst and a lower drainage density than the more rolling shale valleys.
- Soil type and thickness are influenced by lithologic differences. Ridge soils tend to be stony, shallow, acidic, and not very fertile. Valleys soils derived from limestone, shale, or glacial till tend to be well-drained, well suited to agriculture, and deeper and more fertile than ridge soils. Soils derived from shale have a much lower agricultural potential than limestone soils, unless the shale is calcareous. Alfisols are common in limestone valleys. Inceptisols and Ultisols occur in shale valleys and on ridges cored by sandstone or conglomerate.
- Native vegetation of valleys, slopes, and hilltops, particularly over shale, is mixed oak forest dominated by red, white, and black oaks.
- Native vegetation on cooler and moister sites on sandstone, shale, or conglomerate is hemlock-mixed hardwood forest; hemlocks are very common in ravines and on steep, lower, north-facing slopes, but black birch, yellow birch, sugar maple, basswood, and a sparse understory also occur.
- Native vegetation in fertile areas, such as limestone valleys, is sugar maple-mixed hardwood forest; sugar maple is abundant, and grows with white oak, black oak, red oak, white ash, tulip tree, black birch, yellow birch, red maple, basswood, American beech, hickories, and a well developed understory.
- Kuchler potential natural vegetation and climate both vary from north to south. Both growing season and precipitation increase towards the south. From the northern limit of Ecoregion 67 in New York to near its border with Maryland, the potential natural vegetation is Appalachian oak forest. Southward, oak-hickory-pine forest is common to about the James River, whereupon Appalachian oak forest returns.
- Today, ridges are largely forested, and valleys are usually dominated by agriculture. Productive farming is most common on the rich soil and gentle terrain of limestone valleys. Poultry farms can be economically important.
- Diverse aquatic habitats and fish assemblages occur in Ecoregion 67, and are partly the result of the ecoregion's extensive latitudinal range, variable lithology, and fluctuating stream gradients. High-gradient streams are found in watergaps and on ridge slopes; elsewhere, gentler gradient, warmer, and more meandering streams are abundant. Trellised stream networks are common. Springs and caves often occur in limestone valleys.

67a Northern Limestone/Dolomite Valleys

- Broad, undulating, low-relief agricultural valleys south of the Wisconsinan terminal moraine that are underlain by cavernous carbonate rock and characterized by karst topography and fertile soils. In areas that are immediately south of the Wisconsinan limit, outwash terraces and kames may occur. Relief is typically less than in the Northern Shale Valleys (67b) and Northern Glaciated Shale and Slate Valleys (67k), and the terrain is typically smoother than in the Northern Glaciated Limestone Valleys (67j).
- Sinkholes and underground streams have developed in the underlying carbonate rocks. Drainage density is low, but where streams do occur, they tend to have gentle gradients, plentiful perennial flow, and distinctive fish assemblages.
- In New Jersey, Cambrian-age limestone is extensive, and often interbedded with other rocks including shale, thereby promoting topographic and soil diversity. Alluvium is found on the fluvial terraces along the Delaware River. Discontinuous deposits of Pre-Wisconsinan till and stratified glaciofluvial drift occur. Stratified glaciofluvial drift typically occurs on outwash terraces and kames.

- The border between Ecoregions 67a and 67j is coincident with one of the most distinctive soil boundaries in the state. Mesic Alfisols are common in the New Jersey portion of Ecoregion 67a. Here, soils that developed over stratified glaciofluvial deposits are coarser-textured and deeper than soils in Ecoregion 67j. Soils derived from Pre-Wisconsinan till are more leached of carbonates, have more *in situ* clay formation, and are generally deeper than soils from younger Wisconsinan till and limestone in Ecoregion 67j.
- Sugar maple-mixed hardwood forest is native.
- Today, native vegetation has been mostly cleared for agriculture, but scattered woodlands still occur in steepest areas.

67b Northern Shale Valleys

- Rolling shale valleys and scattered low hills south of the Wisconsinan terminal moraine. Lithologically and physiographically distinct from the limestone valleys and karst of Ecoregions 67a and 67j.
- Relief, drainage density, average stream size, surficial runoff, and soil erosion potential are greater than in the limestone valleys of Ecoregions 67a and 67j. Resultant stream turbidity and stream habitat impairment from siltation are also greater than in Ecoregions 67a and 67j.
- Underlain in New Jersey by folded and faulted Ordovician Martinsburg Shale; this slaty shale is slightly more erosion resistant than the limestone underlying Ecoregions 67a and 67j.
- Northern parts were covered by pre-Wisconsinan, not Wisconsinan, ice. Its pre-Wisconsinan drift is more oxidized than the Wisconsinan drift of Ecoregion 67k; buried rocks and bedrock are redder, and the joints and the matrices between rock fragments are more silty and clayey than in Ecoregion 67k.
- Shallow, well-drained, Inceptisols and Ultisols are common in Ecoregion 67b in New Jersey, and developed from slaty shale or pre-Wisconsinan drift. Soils are typically less base-rich and, thus, less naturally fertile, than those of neighboring Ecoregion 67a, which were derived from weathered limestone and pre-Wisconsinan glacial drift.
- Today, small grain, corn, hay, and general farming predominates, with woodlands growing on steeper sites.

67j Northern Glaciated Limestone Valleys

- Broad, glaciated, rolling to uneven, agricultural valleys north of the Wisconsinan terminal moraine that are underlain by cavernous limestone, and contain knolls, karst topography, and thin, fertile soils. Lithologically and physiographically distinct from the more irregular shale valleys of Ecoregions 67b and 67k, and the sandstone ridges of Ecoregion 67m.
- Cambrian-age limestone is extensive, and is often interbedded with other rocks including shale, thereby promoting topographic and soil diversity. Sinkholes and underground streams have developed in the carbonates, thereby reducing surficial drainage density. Where surface drainage does occur, streams tend to have gentle gradients, plentiful year around flow, and distinctive fish assemblages.
- Shallow soils, thin and discontinuous Wisconsinan-age till, many rock outcrops, and a few erratics occur; glacial drift is younger and not as leached than Ecoregion 67a.
- The border between Ecoregions 67j and 67a is coincident with one of the most distinctive soil boundaries in the state. Mesic Alfisols are common. Soils derived from Wisconsinan till in Ecoregion 67j are not as coarse nor as deep as the soils from stratified glaciofluvial deposits in Ecoregion 67a. Soils that developed over Wisconsinan till in Ecoregion 67j are less depleted in carbonates, more fertile, have less *in situ* clay formation, and are generally shallower than the soils developed from pre-Wisconsinan till in Ecoregion 67a.
- Sugar maple-mixed hardwood forest is native on Ecoregion 67j’s characteristically fertile soils.
- Native vegetation has been mostly cleared for agriculture, but scattered woodlands still occur in steepest areas.

67k Northern Glaciated Shale and Slate Valleys

- Broad, irregular rolling to hilly valleys north of the Wisconsinan terminal moraine underlain by slaty shale and fine-grained sandstone and covered by Wisconsinan-age glacial drift. Scattered knolls and lakes occur. Lithologically and physiographically distinct from the sandstone ridges of Ecoregion 67m and the older, more diverse rocks of Ecoregion 67l. Not as agriculturally-dominated as the karst-rich, limestone valleys of Ecoregions 67a and 67j.
- Relief, drainage density, average stream size, surficial runoff, and soil erosion potential are greater than in the limestone valleys of Ecoregions 67a and 67j. Resultant stream turbidity and stream habitat impairment from siltation are also greater than in Ecoregions 67a and 67j.
- Underlain in New Jersey by folded and faulted Ordovician Martinsburg Shale; this slaty shale is slightly more erosion resistant than the limestone underlying Ecoregions 67a and 67j.
- The Wisconsinan drift is younger and less oxidized than the pre-Wisconsinan drift of Ecoregion 67b; buried rocks and bedrock are not as red, and the joints and the matrices between rock fragments are less silty and clayey than in Ecoregion 67b.
- Shallow, well-drained Inceptisols and Ultisols are common, and have developed from slaty shale and Wisconsinan drift; many boulders occur. Soils are not as base-rich or as naturally fertile as those of the neighboring Northern Glaciated Limestone Valleys (67j).
- Native vegetation is mixed oak-sugar maple-northern hardwood forest. Native to shallow soils are chestnut oak, black oak, red oak, hickories, and yellow poplar. Native to deeper soils are white oak, hickories, and red maple.
- Today, small grain, corn, hay, and general farming predominates, with woodland growing on steeper sites; forest cover is much less than in the nearby, more rugged Northern Glaciated Ridges (67m).

67l Northern Glaciated Limestone Ridges, Valleys, and Terraces

- A diverse area on the western edge of the Ridge and Valley (67) containing glaciated valleys, folded and faulted ridges, and fluvial terraces. Mixed rock types, scattered karst, and various landuses occur. The Delaware River forms the western boundary Ecoregion 67l, and is almost 800 feet below the plateau surface of the adjacent Low Poconos (62b).
- Underlain by Silurian limestone and shale, as well as Devonian limestone, sandstone, and shale. Mantled by stratified glacial drift, till, and, sometimes, by loess or alluvium. The lithologic and physiographic mosaic of Ecoregion 67l is distinct from that of the more rugged Northern Glaciated Ridges (67m), the glaciated and lake-studded plateau of Ecoregion 62b, the Northern Glaciated Shale and Slate Valleys (67k), and the Northern Glaciated Limestone Valleys (67j).
- Includes Minisink Valley, Flatbrook Valley, Wallpack Ridge, and the terraces of the Delaware River. Minisink Valley contains karst, is underlain by Devonian limestone, and is covered by thick glacial drift. Flatbrook Valley is underlain by sandstone, limestone, and other rocks, and is almost completely covered by glaciofluvial sediments dominated by gravels and partly indurated gravels. Wallpack Ridge is composed of northwesterly dipping limestone, sandstone, and dark shale, and is covered by thin glacial drift. The Delaware River terraces are composed of alluvial sands, alluvial gravels, and lacustrine silts, and are locally mantled by loess; they rise to about 100 feet above the river.
- Kuchler potential natural vegetation is Appalachian oak forest.
- Today, forest cover is much less than in the neighboring Ecoregions 67m and 62b. In Flatbrook Valley, native vegetation on well-drained sites is generally oak-northern hardwoods, and includes sugar maple. On Wallpack Ridge, native vegetation consists of a mixed oak-northern hardwood mosaic, and includes sugar maple.
- Alfisols and Inceptisols are common.

67m Northern Glaciated Ridges

- High, glaciated, steep-sided forested ridges north of the Wisconsinan terminal moraine. Its glaciated ridgetops are less sharp, and much more lake-studded than those of its lithologically similar, but unglaciated, neighbor in Pennsylvania, the Northern Sandstone Ridges (67c).
- Ecoregion 67m is more rugged and has higher crestal elevations than other level IV ecoregions in New Jersey's Ridge and Valley (67). Includes the highest point in New Jersey, 1,803 feet above sea level.
- Cored by folded and faulted, interbedded Silurian sandstone, conglomerate, and quartzite. Less resistant rocks, such as shale, may underlie the slopes. Rock outcrops are common, especially on high elevation glaciated ridges, where soil cover is lacking and very dry habitats occur.
- Covered by ice during the Wisconsinan; there are end moraines, eskers, and numerous glacial lakes. Discontinuous glacial drift also occurs; it is thickest between Kittatinny Mountain and Paulins Kill where till composed of sandstone and quartzite completely covers the underlying Ordovician slaty shale. Drift is largely absent from the escarpment on the southeastern side of Kittatinny Mountain, thin on top of the mountain, and somewhat thicker on its western side.
- Soils are mostly Inceptisols and Ultisols that were derived from residuum, colluvium, or glacial till. They are typically shallow, sandy, discontinuous, and low in fertility. On stable, well-drained sites where continuous soil cover occurs, particularly on the top of the Kittatinny Mountain, acid brown forest soils are present. On deep till, soils are impoverished. In coves and depressions, strongly-acid gley soils with indurated horizons occur.
- Pitch pine-scarlet oak forests, pitch pine-scrub oak forests, cove forests, and bogs occur. Pitch pine-scarlet oak forests are well suited to sites with thin, dry, infertile, and silica-rich soil; pitch pine is better adapted than scarlet oak to ridgetops that are exposed to winter snow and ice storms, and are fire-prone during the summer. Pitch pine-scrub oak forests are found on more protected sites, and include pitch pine, chestnut oak, scarlet oak, white oak, and red maple; tree species are more abundant in these protected sites than on more exposed ridgetops. Cove forests contain hemlock, tulip poplar, white oak, and sweet birch. Acid, mountain cedar-type bogs occur, and contain peat up to 12 feet deep.
- High-gradient streams flow off the ridges into narrow valleys; they do not have as much buffering capacity as those of the Northern Dissected Ridges (67d) in Pennsylvania, and are subject to acidification. Calcium, magnesium, and potassium concentrations in drainage waters are much lower than in the Northern Glaciated Limestone Valleys (67j).
- Today, forests and rock outcrops are common.

84. ATLANTIC COASTAL PINE BARRENS

- Low, undulating part of the Atlantic Coastal Plain that is underlain by unconsolidated sediments, and distinguished by extensive pine-oak woodlands. Wetlands, agricultural lands, and urban areas also occur. The terrain is more irregular than in the Middle Atlantic Coastal Plain (63), but less irregular than the Northeastern Coastal Zone (59). Elevations are lower, and relief is generally less, than in Ecoregions 58, 64, and 67.
- Plains, terraces, cuestas, sandy hills, beaches, dunes, and barrier islands occur.
- Xeric soils are extensive; they are largely composed of quartz sand, are acidic, have limited nutrient availability, and are most common in the Outer Coastal Plain where they are concentrated in Ecoregion 84b. Hydric soils dominate low, poorly drained parts of the Outer Coastal Plain, primarily Ecoregion 84c. Mesic soils are concentrated on the uplands of the Inner Coastal Plain (84d).
- Underlain by clays, silts, marls, sands, gravels, and shell beds that are lithologically distinct from the rocks of Ecoregions 58, 64, and 67. The Inner Coastal Plain (84d) is primarily made up of Cretaceous-age sediments, whereas the Pine Barrens (84b) ecoregion is mainly composed of Tertiary-age deposits, and the Barrier Islands - Coastal Marshes (84c) ecoregion is comprised of Quaternary-age deposits.

- Pine-oak woodlands are native to the Outer Coastal Plain in Ecoregion 84b, and are adapted to frequent fire and xeric, acidic soils with limited nutrients.
- Mixed oak forests and beech-oak forests are native to the mesic uplands of the Inner Coastal Plain (84d); sugar maple and red oak trees are rare or absent in these forests, but are common in the mesic upland forests of Ecoregions 58, 64, and 67.
- Salt marshes, swamps, and floodplain forests are native on hydric soils of low sites along tidally-influenced rivers.
- Freshwater marshes are native to regularly flooded depressions, particularly on the clayey soils of the Inner Coastal Plain (84d), and in dune swales.
- A transition zone between northern and southern plant species; many species of northern affinity reach their southern range limit in Ecoregion 84, where they are joined by southern species. Many of these species were uncommon or did not exist in the Northern Piedmont (64). 475 species of the 1373 native plant species found on Inner and Outer Coastal Plains of New Jersey in 1910, were rare or not found in Ecoregion 64.
- Kuchler potential natural vegetation is a mix of northeastern oak-pine forest (dominants: pitch pine, scarlet oak, and black oak), Appalachian oak forest (dominants: white oak and northern red oak), and northern cordgrass prairie (dominants: saltgrass and salt marsh cordgrass); the mosaic is distinct from that of Ecoregions 59 and 63. Northeastern oak-pine forest is common on the sandy, xeric, fire-prone uplands of the Outer Coastal Plain, whereas Appalachian oak forest once dominated the less sandy, more fertile soils of the Inner Coastal Plain. Northern cordgrass prairie occurs along tidal channels in the Outer Coastal Plain.
- Ecoregion 84 is the northern limit of many southern plant species.
- Normal January temperatures tend to be much warmer than in northern New Jersey. Away from the coast , temperature differences are greater in winter than in summer.
- Plant growth begins earlier in spring and extends later into the autumn than in northern New Jersey; the growing season (43˚+ mean temperature) is up to 5 weeks longer than in northern New Jersey.
- Today, cropland is extensive in the Inner Coastal Plain (84d), whereas pine-oak woodland dominates the much larger Pine Barrens (84b). Low, poorly drained areas that have not been artificially drained are wetlands.

84b Pine Barrens

- Gently undulating, low-elevation coastal plain composed of unconsolidated sediments, and distinguished by sandy, droughty, infertile soils, frequent fires, and extensive pine-oak woodlands. Land use, soils, native vegetation, and lithology are distinct from those of the neighboring Inner Coastal Plain (84d) and Barrier Islands - Coastal Marshes (84c).
- Tertiary sedimentary deposits are common, but are locally overlain by patches of Pleistocene sands and gravels. Ecoregions 84d and 84b are generally underlain by different ages of sediments, and are separated by a belt of low cuestas that are composed of partially indurated sands and gravels.
- Geology and vegetation boundaries roughly coincide. However, soil and vegetation borders are an even better fit.
- Most soils are dominated by quartz sand, and are acidic, xeric, and have a very limited nutrient supply; they are coarser, drier, less fertile, and less suited to agriculture than the mesic soils of Ecoregion 84d. However, poorly drained sands and a few peat deposits up to six feet thick also occur, and interfinger with well-drained sites.
- Sluggish streams occur, and are fed by a large aquifer of fresh water that is fed by precipitation. There is almost no overland flow, due to excessively drained soils and limited relief.
- Surface water is acidic, low in hardness, and high in humic compounds. Summer stream temperatures are cool and constant. In winter, streams rarely freeze. Fertilizers, manure, and sewage have degraded water quality locally.

- Over a thousand small wildfires affect this ecoregion annually. Pines are well adapted to fire; mature trees have thick, fire-resistant bark and can send up shoots from the base if the top is killed by fire. Fire also creates suitable conditions for establishing pine seedlings by consuming forest litter, thereby exposing the sandy soil surface. Fire, together with clearcutting, favors pine over oak. If fire was excluded, oak would become strongly dominant in Ecoregion 84b.
- Uplands are covered by pine-oak forests. Botanical diversity is low because many species are not adapted to the prevailing dry, sandy, infertile soils and frequent fires. Pitch pines typically comprise 50 to 60% of the upland forests; shortleaf pines, black oaks, post oaks, white oaks, scarlet oaks, chestnut oaks, and blackjack oaks are also present. Where more frequent fire and stronger winds occur, dwarf pine forests are found and, typically, contain a few blackjack oaks and, sometimes, post oaks.
- Low-lying areas, depressions, and water courses are commonly swampy, and support, closed-canopy Atlantic white cedar swamps, swamp hardwoods, pitch pine lowlands, and mineral-poor fens. Most of New Jersey's remaining cedar swamps are now found in the Pine Barrens (84b); these swamps have been heavily and repeatedly logged, and are now much less common than they were a century ago. Large areas once covered by lowland forests have been leveled, diked, ditched, and dammed for blueberry and cranberry cultivation.
- Includes twelve northern plant species at their southern range limit or their southernmost Coastal Plain range limit. Over a hundred plants of southern affinity reach the northern limit of their range in Ecoregion 84b.
- Kuchler potential natural vegetation is northeastern oak-pine forest. It is distinct from the Appalachian oak forest that dominated the mesic uplands of Ecoregion 84d, and the northern cordgrass prairie that occurs along tidal channels in Ecoregion 84c.
- Today, forestry, cranberries, highbush blueberries, and residential developments are major economic pursuits in the Pine Barrens. The pine-oak woodlands of Ecoregion 84b constitute 45% of New Jersey's present total forest area, and are managed by controlled burning. Repeated cutting and frequent fires have impacted the structural appearance and species composition of forests in all parts of Ecoregion 84b.
- The Pine Barrens has been internationally recognized by the United Nations as an International Biosphere Reserve. More than one million acres is in the federal New Jersey Pinelands National Reserve. In addition, there are state parks and forests in the ecoregion.

84c Barrier Islands - Coastal Marshes

- Beaches, dunes, spits, hooks, low terraces, lagoons, and barrier islands composed of unconsolidated Quaternary sediments, and characterized by extensive salt marshes along tidal channels; vegetation, soils, and land forms are distinct from other parts of Ecoregion 84.
- Surficial sediments include: a) beach, dune, and near shore marine sand; b) saline marsh deposits; and c) marine silt, sand, clay and peat. These Quaternary deposits contrast with the Cretaceous sediments of Ecoregion 84d and the primarily Tertiary deposits of Ecoregion 84b.
- Dunes are most common on barrier islands and on Sandy Hook; in no other ecoregion in New Jersey are dunes, and corresponding habitat, as abundant, although a few dunes also occur in the Pine Barrens (84b). Dunes in Ecoregion 84c support only a few species of grasses and other xerophytic herbaceous plants: 1) In the primary dune zone just inland of the beach, there is a sparse cover of dune grass and other members of its community, such as sea rocket, dusty miller, saltwort, and seaside spurge; 2) immediately inland, beach heather, together with a few members of the dune grass community, grow in swales and on flats; 3) further inland, in the secondary dune zone, is a low, shrub thicket primarily composed of bayberry, beach plum, shadbush, and highbush blueberry, with some low red cedar and scrub oak; and 4) in moist, protected hollows and swales of the secondary dune zone there are dune woodlands composed of American holly, black cherry, red cedar, red maple, pitch pine, hackberry, and sassafras.

- Salt marshes are dominated by saltmarsh cordgrass and salt-meadow grass. Saltmarsh cordgrass occupies low areas near water that flood daily, whereas salt-meadow grass dominates more elevated sites that are only flooded during higher tides. On yet less flooded, higher marshland, salt-meadow grass is intermixed with spike grass and black grass. Glassworts are adapted to the prevailing, harsh conditions of salt pannes. Coastal marshland in New Jersey, as well as in other states, has suffered severely from human actions; marshes have been extensively filled for housing and industrial use, and most of them have been polluted.
- Freshwater marshes are found along streams, at river mouths, and in dune swales.
- Barrier islands are dynamic, fragile, and contain many unique and important wildlife habitats. They protect the mainland from erosion by oceanic storms, but have been eroded on their seaward side by wave action and breached by hurricanes. In New Jersey, they are being pushed landward a couple of feet per year. Barrier islands serve as important nesting sites for several state-endangered birds, including the piping plover, black skimmer, and least tern. Loggerhead turtles use the barrier island beaches as nest sites.
- Kuchler potential natural vegetation is northern cordgrass prairie; it is distinct from the northeastern oak-pine forest of xeric, fire-prone uplands in the Outer Coastal Plain of Ecoregion 84b, and the Appalachian oak forest of mesic uplands in the Inner Coastal Plain (84d).
- Ecoregion 84c is equivalent to the Barrier Islands - Coastal Marshes (63d), but in the Atlantic Coastal Pine Barrens (84) instead of the Middle Atlantic Coastal Plain (63).

84d Inner Coastal Plain

- Undulating plain primarily underlain by Cretaceous unconsolidated sediments that was once covered by mixed oak and beech-oak forests, but now dominated by agriculture, urban development, and transportation infrastructure; land use and potential natural vegetation, are distinct from the Pine Barrens (84b) and Barrier Islands - Coastal Marshes (84c).
- Underlain primarily by Cretaceous unconsolidated gravels, sands, and clays. However, partially indurated sands and gravels also occur, and form a belt of low cuestas that separate Ecoregion 84d from the mainly Tertiary sediments of Ecoregion 84b. Ecoregion 84d is lithologically distinct from the reddish shale, sandstone, argillite, and siltstone of the neighboring Triassic Lowlands (64a). It has older deposits than Ecoregion 84b and 84c.
- Soils usually have a larger proportion of clay, and are more moist, more fertile, and better suited to agriculture than the soils of the Pine Barrens (84b), which are often xeric and dominated by quartz sand.
- Native upland vegetation is probably mixed oak forests and beech-oak forests; white and black oaks along with American beech, pignut and mockernut hickories, black walnut, tulip tree, and red maple once occurred.
- Kuchler potential natural vegetation is Appalachian oak forest. It is distinct from the northeastern oak-pine forest that dominates Ecoregion 84b, and the northern cordgrass prairie that occurs in Ecoregion 84c.
- Today, very little mature upland forest remains. Nearly all of Ecoregion 84d has been cleared, settled, and converted to agriculture or urban uses. Extensive corn, wheat, soybean, vegetable, dairy, and poultry farming occurs. Only the wettest lowlands still retain extensive tracts of natural vegetation. Scattered, wet, clayey depressions support marsh vegetation such as phragmites, cattails, and wild rice; wild rice is much more common than in the marshes of northern New Jersey in Ecoregion 58, 64, and 67.

SOURCES FOR NEW JERSEY ECOREGION INFORMATION

Primary Sources For New Jersey Ecoregion Information

The New Jersey ecoregion delineations were based on several criteria: 1) physiography, 2) natural vegetation, 3) soil, 4) surficial and bedrock geology, 5) climate, 6) land use and land cover, and 7) regional biogeography.

The main sources for ecoregion delineations and descriptions were Forman (1998), Robichaud Collins and Anderson (1994), Tedrow (1986), and Woods and others (1996). Sources for specific topics are listed below. A complete list of sources is included at the end of this report.

1) Physiographic information was gathered from Fenneman (1938), Tedrow (1986), Richards and Judson (1965), and Woods and others (1996).

2) Natural vegetation information was obtained from several sources, including Braun (1950), Buell and others (1966), Forman (1998), Robichaud Collins and Anderson (1994), McCormick and Buell (1968), Pearson (1961), Stone (1973), Tiner (1985), and Lutz (1934). Potential natural vegetation information came from Kuchler (1964).

3) Soil information was gleaned from many sources, including the Tedrow (1986), State Soil Geographic (STATSGO) digital map (Natural Resources Conservation Service, no date), official soil descriptions (Natural Resources Conservation Service, on-line resource), and county soil surveys (Natural Resources Conservation Service, various dates).

4) Surficial and bedrock geology information came from Fullerton (1992), Lewis and Kummel (1910-1912), Richmond, Fullerton, and Weide (1987), and Widmer (1964).

5) Climate information, including growing season, precipitation, and temperature data, came from the Office of the New Jersey State Climatologist (on-line resource).

6) Land use and land cover information came from several sources, including the land use classification of Anderson (1970), the 2002 Census of Agriculture (National Agricultural Statistics Service, on-line resource), county soil surveys (Natural Resources Conservation Service, various dates), and the seasonal land cover map by Loveland and others (1995).

7) Regional biogeographic information was derived from sources including Keys and others (1995), Forman (1998), Robichaud Collins and Anderson (1994), Omernik (1987), Woods and others (1996), and Woods and Omernik (1996). Lists of threatened and endangered species in New Jersey came from the New Jersey Division of Fish and Wildlife (on-line resource).

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