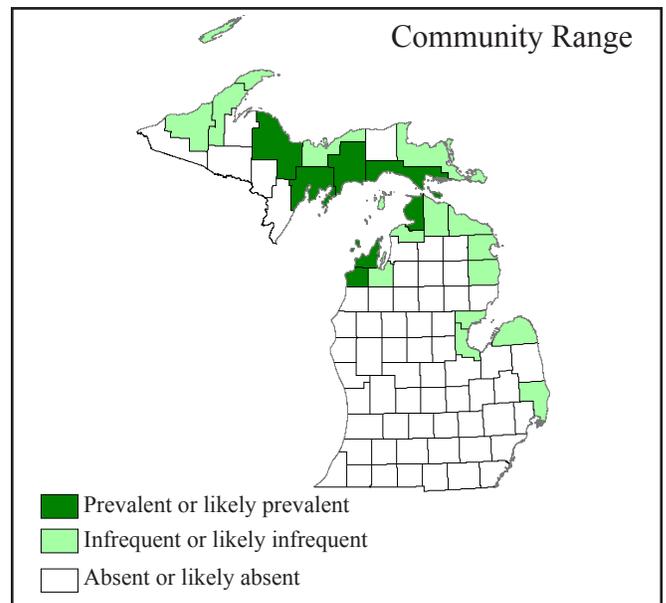




Photos by Joshua G. Cohen



Global and state rank: G3/S3

Common name: Great Lakes wooded dune and swale

Range: This complex of wetland swales and upland beach ridges (dunes) is found in embayments and on large sand spits along the shoreline of all of the Great Lakes. These complexes are documented from Minnesota, Wisconsin, Michigan, Illinois, Indiana, Pennsylvania, Ohio, and the province of Ontario.

Rank justification: Wooded dune and swale complexes are restricted to the Great Lakes shoreline (Homoya et al. 1985, Comer and Albert 1991, 1993). Although there are features of similar geological origin along the shorelines of most oceans and seas as well, the biota of the marine systems is distinctly different (Wiedemann 1984). Residential and recreational development has resulted in disrupted hydrological conditions and wetland destruction. Currently, about 95 dune and swale complexes have been identified in the Great Lakes, with 70 located in Michigan. Michigan's 44 highest quality dune and swale complexes total about 77,616 acres (31,410 hectares) in area.

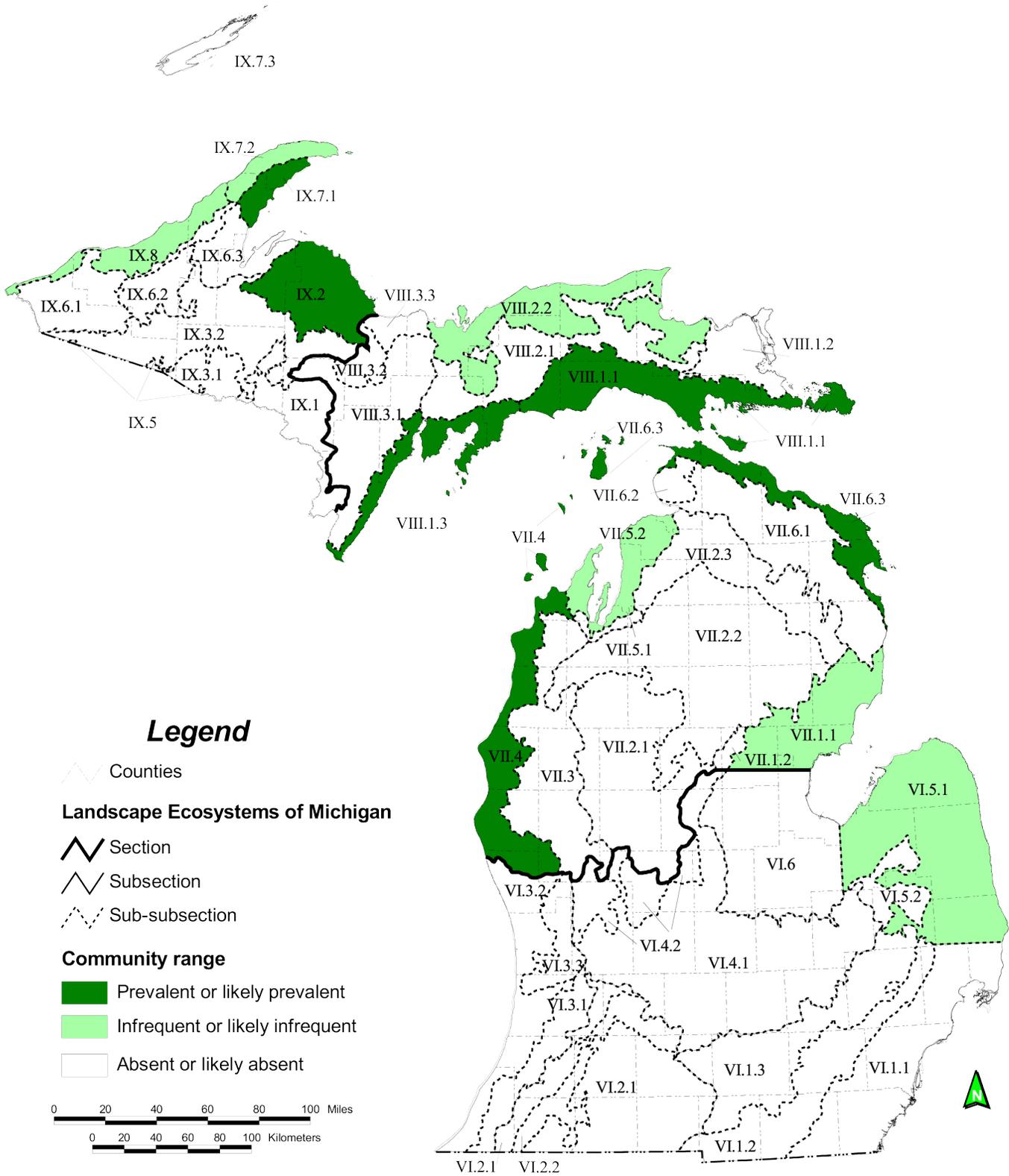
Landscape context: Many complexes began forming when the Great Lakes were at glacial Lake Algonquin levels, approximately 12,000 years ago (Dorr and Eschman 1970, Comer and Albert 1993), but in the southern Great Lakes, some of the large complexes are younger, approximately 6,000 years old (Chrzastowski and Thompson 1992, Thompson 1992). Receding lake levels deposited a series of sandy beach ridges ranging from 0.5 m to 4.0 m high. From the air, these ridges appear as a series of arcs generally parallel to the shoreline, and often extending up to two miles inland (see photo, page 2). The dune ridges can be quite numerous, with 150 ridges forming over 6,000 years near Gary, Indiana (Thompson 1992) and 108 ridges form-

ing over 3,500 years in northern Lower Michigan (Lichter 1998).

Natural processes: These complexes are best developed where streams provide a dependable sand source. The combination of along-shore currents, waves, and wind form foredunes along the shoreline. With gradual long-term drops in water level, combined with post-glacial uplifting of the earth's crust, these low dunes gradually rise above the direct influence of the lakes, and new foredunes replace them. Over several thousand years, a series of ridges and swales is created. For most complexes, the flow of surface streams and groundwater maintain the wet conditions in the swales. Along the Lake Superior shoreline, where post-glacial uplift is greatest, many of the complexes consist primarily of dry, forested swales (Comer and Albert 1993). The number and size of the dune ridges and swales differs depending on fetch and the amount of sediment available.

Vegetation description: Because they contain a unique assemblage of physiographic, soil, and vegetative components, and provide a high quality habitat for numerous shoreline animal species, the Wooded Dune and Swale Complex is considered a distinct natural community in Michigan (Kost et al. 2007). Classic ecological studies have identified distinctive successional zones within the sand dune portion of the complexes, determined on the basis of several factors, including distance from the lake, amount of soil development, and available light (Olson 1958, Cowles 1899). Lichter's (1998) recent study of dune and swale complexes at Wilderness State Park in northern Lower Michigan has identified similar successional trends. He found that, at the Lake Michigan shoreline, young dunes had 1) stronger winds, 2) more sand burial and erosion, 3) higher levels of sunlight, 4) higher rates of evaporation, and 5) lower available nitrogen and phosphorus than older beach ridges farther inland, resulting in an open





Ecoregional map of Michigan (Albert 1995) depicting distribution of wooded dune and swale complex (Albert et al. 2008)



herbaceous-dominated plant community along the shore. Farther inland, with greater protection from sun and wind and with greater soil development, there was succession from open dune, first to grassland, then to shrubs, and finally to forests, with mesic northern hardwoods increasing in dominance on beach ridges farther from the shoreline.

Both swales and upland dune ridges were studied by MNFI (Comer and Albert 1991, 1993). Of the 17 sites where elevations were measured from the shoreline inland, only 3 sites contained swales where the sandy bottoms of all or most of the swales lay below the current Great Lakes water levels. This suggests that, except for a few examples, the influence of Great Lakes water-level fluctuations is probably limited to the first few swales inland from the shoreline. For most of the complexes, the water occupying the swales comes from streams flowing from the adjacent uplands or from groundwater seepage.

The foredunes of most dune and swale complexes are commonly 1-2 meters high, with beach grass (*Ammophila breviligulata*), dune grass (*Calamovilfa longifolia*), autumn willow (*Salix serissima*), dune willow (*S. cordata*), and balsam poplar (*Populus balsamifera*) most common. Within their ranges, federally-threatened Pitcher's thistle (*Cirsium pitcheri*) and state-threatened Lake Huron tansy (*Tanacetum huronense*) are also found on the foredunes.

Immediately behind the foredune, where lake-influenced, calcareous sands are most common, a shallow swale often contains twig-rush (*Cladium mariscoides*), sweet gale (*Myrica gale*), shrubby cinquefoil (*Potentilla fruticosa*), blue joint grass (*Calamagrostis canadensis*), Kalm's lobelia (*Lobelia kalmii*), false asphodel (*Tofieldia glutinosa*), and grass-of-Parnassus (*Parnassia glauca*). Less commonly, in the Straits of Mackinac area, federally-threatened Houghton's goldenrod (*Solidago houghtonii*) is found in the swales behind the foredune.

The swale immediately behind the foredune is influenced by short-term variation in lake levels and can be partially or occasionally completely filled by dune sands following major storm events. Species common to this first swale include the rushes (*Juncus balticus*, *J. pelocarpus*, *J. nodosus*), spike rush (*Eleocharis acicularis*), and threesquare (*Scirpus americanus*).

A low dune field with more advanced plant succession often follows the first open dunes and swales. Jack pine (*Pinus banksiana*), white pine (*P. strobus*), and red pine (*P. resinosa*) often form a scattered overstory canopy, while ground juniper (*Juniperus communis*), creeping juniper (*J. horizontalis*), bear berry (*Arctostaphylos uva-ursi*), beach grass, and June grass (*Koeleria macrantha*) form a scattered ground layer.



Aerial photo of wooded dune and swale complex on north shore of Lake Michigan. See close-up images of open swale and red pine-forested dune on cover. Photo source: MNFI 1998 Digital Orthophoto County Mosaics.



Following the dune-field zone, both dunes and swales are typically forested. Moist swales are often forested and soil organic material has often begun to accumulate. Northern white cedar (*Thuja occidentalis*), speckled alder (*Alnus rugosa*), willows (*Salix* spp.), and red maple (*Acer rubrum*) dominate the partial overstory canopy and understory. In northern Lake Michigan and Lake Huron, where these swales are better drained, and northern white cedar forms the overstory, federally-threatened dwarf lake iris (*Iris lacustris*) may be found in large non-flowering populations.

In contrast to the dry or moist swales, in those swales where standing water is present through most of the year, sedges (*Carex aquatilis* and *C. stricta*), twigrush, marsh marigold (*Caltha palustris*), swamp candles (*Lysimachia terrestris*), and swamp cinquefoil (*Potentilla palustris*) commonly dominate the ground layer.

Forested beach ridges, with soils of medium to coarse sand, tend to be dominated by species common to dry-mesic and mesic northern forest (Kost et al. 2007). Soil moisture conditions appear to change dramatically with slight elevational changes and are reflected in the development of soil organic material and changing plant species. On higher, drier ridges, soils often have less than 3 cm of organic material. Red pine, white pine, and red oak (*Quercus rubra*) are often co-dominant, while paper birch (*Betula papyrifera*), bigtooth aspen (*Populus grandidentata*), balsam fir (*Abies balsamea*), and red maple are sub-dominant or understory species. Bracken fern (*Pteridium aquilinum*), black huckleberry (*Gaylussacia baccata*), blueberry (*Vaccinium myrtilloides*), bunchberry (*Cornus canadensis*), and wintergreen (*Gaultheria procumbens*) occur in the shrub and ground layers.

On lower ridges, where soils are moister, soil organic material accumulation is greater (4-25 cm). White pine may still dominate the overstory, but often white spruce (*Picea glauca*), black spruce (*P. mariana*), red maple, balsam fir, northern white cedar, and occasionally tamarack (*Larix laricina*) are co-dominant. Canada honeysuckle (*Lonicera canadensis*), mountain holly (*Nemopanthis mucronatus*), twinflower (*Linnaea borealis*), dwarf blackberry (*Rubus pubescens*), Canada mayflower (*Maianthemum canadense*), and starflower (*Trientalis borealis*) are common in the shrub and ground layers.

Complexes located in embayments protected from prevailing winds tend to be formed entirely of low, water-lain beach ridges. As a result, even the beach ridges within these complexes support wetland vegetation. An example is Ogontz Bay, in the eastern Upper Peninsula of Michigan. Here swales ranged from 1-30 m wide and 0.5-3.0 m deep. Narrow, shallow swales are forested with northern white cedar, black spruce, and red maple, with speckled alder and willows in the understory and shrub layers, and sedges (*Carex disperma*, *C. trisperma*, *C. leptalea*, *C. interior*, *C. cryptolepis*, *C. flava*, *C. intumescens*), blue joint grass, fowl

manna grass (*Glyceria striata*), water horehound (*Lycopus uniflorus*), and Sphagnum mosses (*Sphagnum* spp.) in the ground layer.



Photo by Joshua G. Cohen
Forested swale dominated by rich conifer swamp.

Wider, deeper swales are more often unforested, with chokeberry (*Aronia prunifolia*), red osier dogwood (*Cornus stolonifera*), bog birch (*Betula pumila*), and speckled alder forming a shrubby ecotone, while sedges (*Carex lasiocarpa*, *C. oligosperma*, *C. aquatilis*, *C. stricta*) and woolgrass (*Scirpus cyperinus*) form a mat within which marsh fern (*Thelypteris palustris*) and horned bladderwort (*Utricularia cornuta*) also occur. Where a sedge mat is not well developed, bur-reed (*Sparganium minimum*), pond-lily (*Nuphar variegata*), and pondweeds (*Potamogeton berchtoldii* and *P. natans*) are commonly found.

Organic material gradually accumulates in the swales over time; organic material in swales reaches a depth of 30-75 cm within 300 meters of the lake's edge. Vegetation in swales reflects the more acid conditions of the older thickets as peat accumulates. Leatherleaf (*Chamaedaphne calyculata*), bog rosemary (*Andromeda glaucophylla*), Labrador tea (*Ledum groenlandicum*), bog laurel (*Kalmia polifolia*), large cranberry (*Vaccinium macrocarpon*), cottongrass (*Eriophorum virginicum*), pitcher-plant (*Sarracenia purpurea*), Sphagnum mosses (*Sphagnum centrale*, *S. wulfianum*, *S. warnstorffii*, *S. magellanicum*, and *S. squarrosus*) are commonly found in the thick peat soils of the swale behind the shoreline.

An even stronger pattern of increased organic matter accumulation occurs farther north along Lake Superior. For example, at Grand Traverse Bay in Keweenaw County, very low beach ridges and swales have thick accumulation of acid organic matter, with bog-like vegetation in the first swale of the shoreline.





The swales of wooded dune and swale complexes support a variety of wetland types with open wetlands (above) more common near the shoreline and forested and shrub wetlands (below) more prevalent further from the Great Lakes. Photos by Joshua G. Cohen.



A PRELIMINARY CLASSIFICATION OF MICHIGAN WOODED DUNE AND SWALE COMPLEXES

North-south patterns in plant distributions are clear in both the uplands and wetlands of Michigan's wooded dune and swale complexes. Extremes are seen between the complexes along Saginaw Bay, with southern species, and those of the Keweenaw Peninsula, with more northern or boreal species (Comer and Albert 1993). Along this north-south gradient, complexes were broken into five sub-types based on a combination of geographic location and processes of beach ridge formation, which have resulted in significantly different assemblages of plant species. The five sub-types identified include the Southern Lake Huron, the Northern Lake Huron/Lake Michigan-Low Dune, the Northern Lake Michigan-High Dune, the Lake Superior-High Dune, and the Lake Superior-Low Dune sub-types.

Even within complexes of each sub-type, there are relatively low percentages of similar species. This reflects the highly variable nature of these complexes. There are, however, major floristic differences between the northern and southern sub-types; for example, while 50% of the species are shared by two northern complexes, as little as 19% of plant species are shared by physically similar northern and southern complexes.

The Southern Lake Huron complexes cannot be divided into distinctive landform sub-types, primarily because few intact examples remain. This sub-type is best distinguished by its southern species, including cottonwood (*Populus deltoides*), black walnut (*Juglans nigra*), and buttonbush (*Cephalanthus occidentalis*).

Complexes within the Northern Lake Huron/Lake Michigan-Low Dune sub-type are commonly found in embayments with little exposure to prevailing westerly winds. As a result, the low beach ridges (0.5-1m) of these complexes are almost entirely water-lain. They generally support wetland vegetation, both in the swales and on many of the ridges. All complexes along the Northern Lake Huron shoreline fall into this category. Along the Northern Lake Michigan shoreline, complexes of this sub-type are found in portions of Mackinac, Schoolcraft, and Delta counties, where embayments are protected from westerly winds. Because the sandy soils along these shorelines are partly derived from limestones and dolomites of the underlying Niagaran Escarpment, plant species associated with moist, calcareous conditions, including Great Lakes endemics such as Houghton's goldenrod and dwarf lake iris, are commonly found close to the shoreline.

The Northern Lake Michigan-High Dune sub-type is distinguished by high, often irregular dune ridges formed by prevailing westerly winds. Clear distinctions can be made between the upland vegetation of the high dune ridges (2-5 m) and the wetland vegetation of the swales. Dune ridges are dominated by white pine, red pine, red oak, and paper birch, while the swales contain the widest variety of plant communities of any sub-type. Wetland plant communities

include emergent marsh, intermittent wetland, bog, northern wet meadow, northern shrub thicket and rich conifer swamp. This sub-type is most common in Benzie, Leelanau, Emmet, Mackinac, and Schoolcraft counties; Sturgeon Bay is a typical example (see Appendix IV in Comer and Albert (1993)).

The Lake Superior sub-type is dominated by plant species of distinctly northern character. This sub-type, represented by relatively few examples concentrated in Marquette and Luce counties, typically contains few swales with wetland vegetation. This is due to well-drained conditions resulting from high, wind-sorted dune ridges (1-3 m), and by adjacent rivers that effectively drain much of the complex. An example is at the mouth of the Iron River in Marquette County, where the first swale lies below current Lake Superior water levels, but all other swales are above the lake and well drained. These complexes are characterized by dry northern forest with jack pine and red pine.



Photo by Joshua G. Cohen

Dry northern forest dominating dunes and dry swales in Marquette County along the Lake Superior shoreline.

Complexes of the Lake Superior-Low Dune sub-type are typically found where embayments are not directly exposed to prevailing westerly winds. The resulting low, water-lain beach ridges often support swamp forests of white and black spruce, tamarack, and balsam fir. The wet swales contain vegetation characteristic of acid peatlands and bogs. A good example of this type is Grand Traverse Bay, in Houghton and Keweenaw counties.

Characteristic vegetation of open foredune

<u>Strata</u>	<u>Most abundant</u>
Tree canopy	<i>Populus balsamifera</i> (balsam poplar)
Short shrub	<i>Salix serissima</i> (autumn willow), <i>S. cordata</i> (dune willow), <i>Juniperus communis</i> (ground juniper), <i>J. horizontalis</i> (creeping juniper), <i>Arctostaphylos uva-ursi</i> (bear berry)
Herbaceous	<i>Ammophila breviligulata</i> (beach grass) <i>Calamovilfa longifolia</i> (dune grass)



Characteristic vegetation of open swale

<u>Strata</u>	<u>Most abundant</u>
Tree canopy	
Short shrub	<i>Myrica gale</i> (sweet gale), <i>Potentilla fruticosa</i> (shrubby cinquefoil), <i>Betula pumila</i> (bog birch), <i>Aronia prunifolia</i> (chokeberry), <i>Cornus stolonifera</i> (red osier dogwood)
Herbaceous	<i>Carex stricta</i> , <i>C. aquatilis</i> , <i>C. lasiocarpa</i> , <i>C. oligosperma</i> (sedges), <i>Eleocharis rostellata</i> , <i>E. acicularis</i> (spike-rushes) <i>Cladium mariscoides</i> (twig-rush), <i>Scirpus acutus</i> , <i>S. americanus</i> (bulrushes), <i>Calamagrostis canadensis</i> (blue joint grass), <i>Juncus balticus</i> , <i>J. pelocarpus</i> , <i>J. nodosus</i> (rushes), <i>Scirpus cyperinus</i> (woolgrass), <i>Thelypteris palustris</i> (marsh fern), and <i>Utricularia cornuta</i> (horned bladderwort)

Characteristic vegetation of forested dune

<u>Strata</u>	<u>Most abundant</u>
Tree canopy	<i>Pinus banksiana</i> (jack pine), <i>P. strobus</i> (white pine), <i>P. resinosa</i> (red pine), <i>Quercus rubra</i> (red oak), <i>Betula papyrifera</i> (paper birch), <i>Populus grandidentata</i> (bigtooth aspen), <i>Acer rubrum</i> (red maple), <i>Abies balsamea</i> (balsam fir)
Short shrub	<i>Gaylussacia baccata</i> (black huckleberry), <i>Vaccinium myrtilloides</i> (blueberry)
Herbaceous	<i>Pteridium aquilinum</i> (bracken fern), <i>Cornus canadensis</i> (bunchberry), <i>Gaultheria procumbens</i> (wintergreen)

Characteristic vegetation of forested swale

<u>Strata</u>	<u>Most Abundant</u>
Tree canopy	<i>Thuja occidentalis</i> (northern white cedar), <i>Picea mariana</i> (black spruce), <i>Acer rubrum</i> (red maple)
Short shrub	<i>Alnus rugosa</i> (speckled alder), <i>Salix</i> spp. (willows)
Herbaceous	<i>Carex disperma</i> , <i>C. trisperma</i> , <i>C. leptalea</i> , <i>C. interior</i> , <i>C. cryptolepis</i> , <i>C. flava</i> , <i>C. intumescens</i> (sedges), <i>Calamagrostis canadensis</i> (blue joint grass), <i>Glyceria striata</i> (fowl manna grass), <i>Lycopus uniflorus</i> (water horehound), and <i>Sphagnum</i> spp. (Sphagnum mosses)

Michigan indicator species: The community is too widespread to identify a small group of representative species.

Other noteworthy species: Rare animals associated with wooded dune and swale complexes include *Haliaeetus leucocephalus* (bald eagle, state special concern), *Char-*

adrius melodus (piping plover, state endangered), *Canis lupus* (wolf, state threatened), *Accipiter gentilis* (northern goshawk, state special concern), *Buteo lineatus* (red-shouldered hawk, state threatened), *Falco columbarius* (merlin, state threatened), *Euxoa aurulenta* (dune cutworm, state special concern), *Trimerotropis huroniana* (Lake Huron locust, state threatened), *Sistrurus c. catenatus* (eastern massasauga, state special concern), *Lanius ludovicianus migrans* (migrant loggerhead strike, state endangered), and *Pandion haliaetus* (osprey, state special concern).

Rare plant associates include *Cirsium pitcheri* (Pitcher's thistle, state threatened), *Solidago houghtonii* (Houghton's goldenrod, state threatened), *Stellaria longipes* (starwort, state special concern), *Iris lacustris* (dwarf lake iris, state threatened), *Calypso bulbosa* (calypso, state threatened), *Pterospora andromedea* (pine-drops, state threatened), *Tanacetum huronense* (Lake Huron tansy, state threatened), *Cypripedium arietinum* (ram's head lady's-slipper, state special concern), *Orobanche fasciculata* (broomrape, state threatened), *Carex albolutescens* (greenish-white sedge, state threatened), *Ranunculus lapponicus* (Lapland buttercup, state threatened), *Armoracia lacustris* (lake cress, state threatened), *Leymus mollis* (American dune wild-rye, state special concern), *Salix pellita* (satiny willow, state special concern), and *Crataegus douglasii* (Douglas' hawthorn, state special concern).

Invasive, non-native species such as *Lythrum salicaria* (purple loosestrife), *Phalaris arundinacea* (reed canary grass), and *Phragmites australis* (giant bulrush) can also invade the wet swales.

Conservation/management: Protecting hydrology is important in the maintenance of vegetative structure in wooded dune and swale complexes. Road development across the swales, even with culverts, typically modifies the hydrology. Marinas, typically requiring dredging and other major modification of the wetlands, have been constructed in some complexes. Golf courses have also been built on complexes and unsuccessfully proposed for others. Intensive use as deer yards has greatly altered the wetlands in the Upper Peninsula, where regeneration of northern white cedar has been eliminated or greatly reduced. In some deer yarding areas, conversion of the ridges to aspen has also been proposed. Residential development has resulted in major alteration of several dune and swale complexes, due to several factors, including road and driveway construction, wetland filling, and septic leakage. Nutrient addition from leaking septic tanks and drain fields is suspected of contributing to the dominance of invasives such as *Typha angustifolia* (narrow-leaved cat-tail), giant bulrush, and purple loosestrife.

Similar communities: The dune and swale complexes contain several plant communities, including Great Lakes marsh, emergent marsh, intermittent wetland, northern wet meadow, southern wet meadow, southern shrub carr, north-



ern fen, poor fen, interdunal wetland, rich conifer swamp, poor conifer swamp, hardwood-conifer swamp, bog, dry northern forest, and open dune.

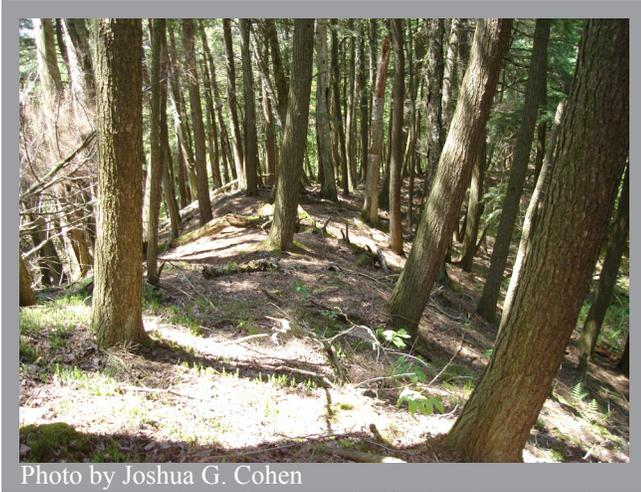


Photo by Joshua G. Cohen

Dry-mesic northern forest typically dominate the dune ridges of wooded dune and swale complexes.

Other classifications:

Michigan Natural Features Inventory Presettlement Vegetation (MNFI): includes upland forest types: red pine/white pine, hemlock, red pine, white pine, oak/pine barrens, black oak, jack pine, aspen, beech/sugar maple, red pine/jack pine; swamp forest types: black ash, American elm, northern white cedar, tamarack, lowland conifer, balsam fir, black spruce, red maple, white birch, balsam poplar, trembling aspen, speckled alder, shrub swamp; herbaceous: Great Lakes marsh, open dune, emergent marsh, and lake.

Michigan Department of Natural Resources (MDNR): Several DNR cover types occur within the dune and swale complexes, including lowland brush, marsh, tamarack, paper birch, aspen, cedar, swamp hardwoods, spruce-fir, hemlock, jack pine, marsh, balsam poplar and swamp aspen and swamp white birch, mixed swamp conifer, oak, red pine, black spruce swamp, tamarack, white pine, sand dune, and water.

Michigan Resource Information Systems (MIRIS): The following MIRIS cover types occur within dune and swale complexes: aspen-birch, upland hardwoods, lowland hardwoods, upland conifer, lowland conifer, shrub, emergent, aquatic bed, and open water.

National Wetland Inventory (NWI): Several wetland types would be mapped within the wooded dune and swale complex, including: *palustrine system*: aquatic beds, emergent, scrub shrub, and forest classes; *lacustrine system*: unconsolidated shore, emergent, and open water classes.

The Nature Conservancy National Classification:

Code: CECX002000: Great Lakes dune-swale complex vegetation.

Alliance: This complex contains over 40 different alliances in different parts of its Great Lakes range.

Related abstracts: open dunes, Great Lakes marsh, southern wet meadow, interdunal wetland, rich conifer swamp, poor conifer swamp, hardwood-conifer swamp, dry northern forest, dwarf lake iris, pitcher's thistle, lapland buttercup, piping plover, and prairie warbler.

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Wooded dune and swale complex, Emmet County, Michigan. Photo by Joshua G. Cohen.

