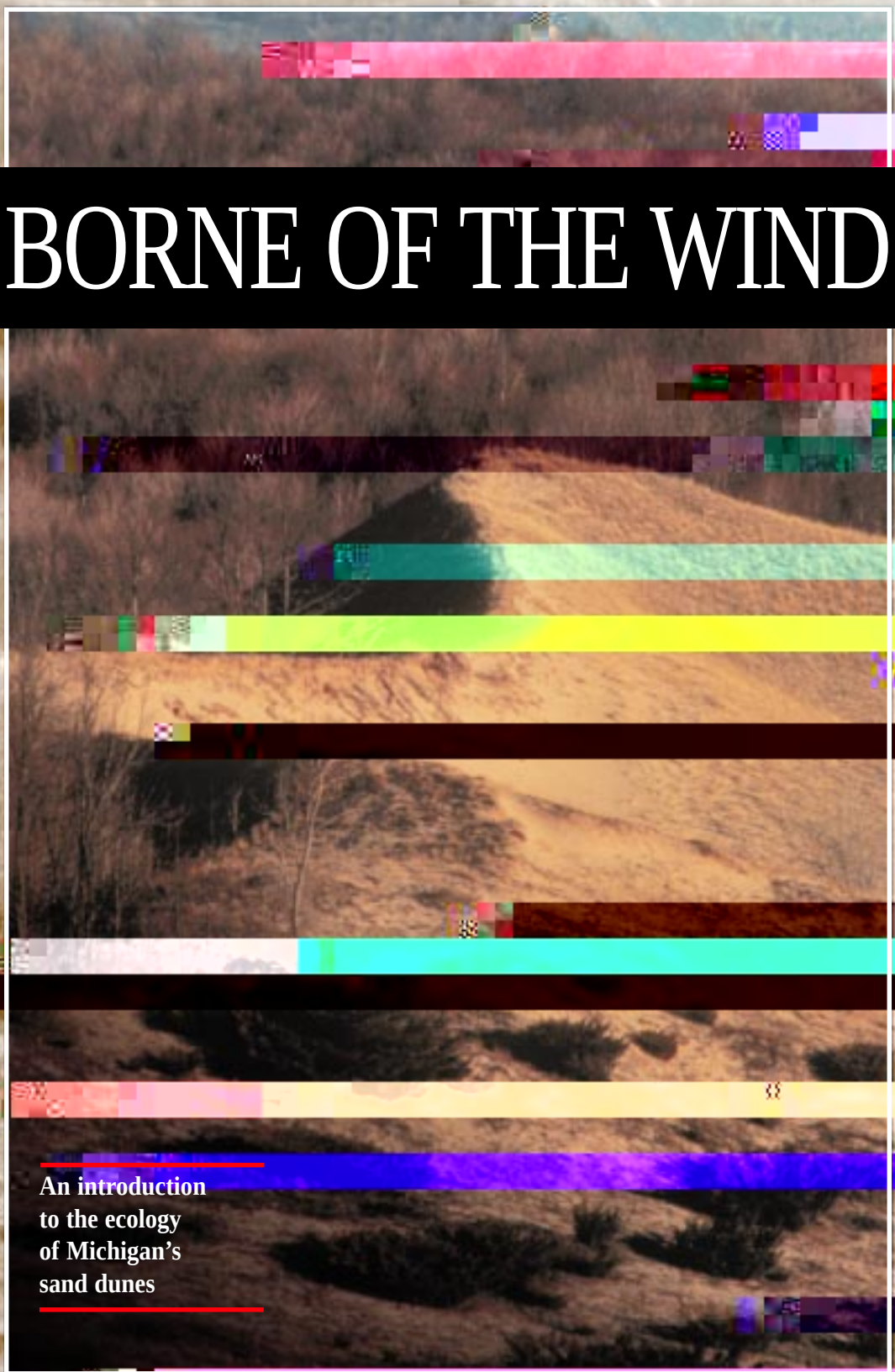
BORNE OF THE WIND



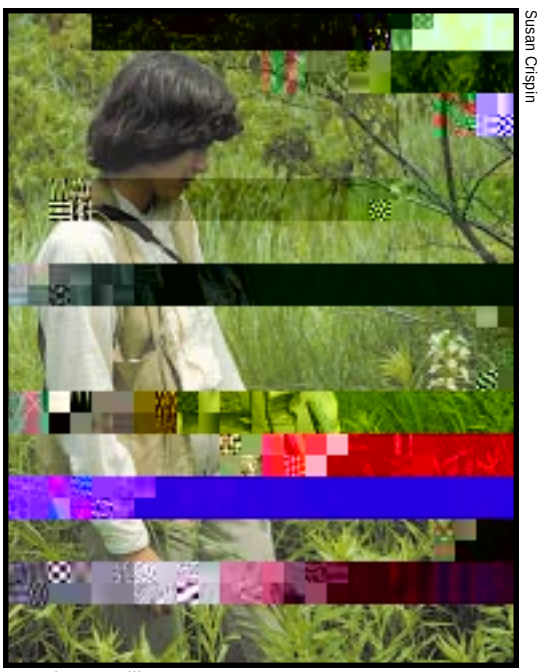
An introduction to the ecology of Michigan's sand dunes

DEDICATION

To Dr. Warren Wagner, Jr., who inspired many of us to become biologists and inspired many more to love and value the beautiful world of nature…

Susan Crispin

Dr. Warren H. Wagner, Jr.



Susan Crispin

Wendy O'Neill

…and to Wendy O'Neill, who spent her short life inspiring those around her to acquire and protect lands for conservation.

Borne of the Wind: An Introduction to the Ecology of Michigan's Sand Dunes

GREAT LAKES COASTAL DUNES

The high sand dunes are among the most rugged and beautiful natural features of the Lake Michigan and Lake Superior shorelines. Great Lakes dunes comprise the most extensive freshwater dunes in the world, so vast that they are visible to astronauts from outer space. In terms of the plants and animals, the coastal dunes are also rich, supporting more endemic species than any other Great Lakes ecosystem.

Some of the earliest European explorers and settlers in Michigan commented on the rugged character of the dunes. Bela Hubbard, a member of the 1840 survey of the Grand Sable dunes, described them as "a miniature Sahara." Many of Michigan's most visited state parks and national lakeshores showcase these thrilling natural features. Michigan contains more dunes than any other Great Lakes state, however, significant coastal dunes are also found along the shorelines of all Great Lakes states, and on the Ontario shoreline as well.

The high coastal dunes familiar to many Michigan residents are not the only kind of dunes. In fact, other types of dunes may be found along the shoreline as well as in the interior of the state. Here we discuss some of the more common dune types and their significance to a wide variety of plants and animals.

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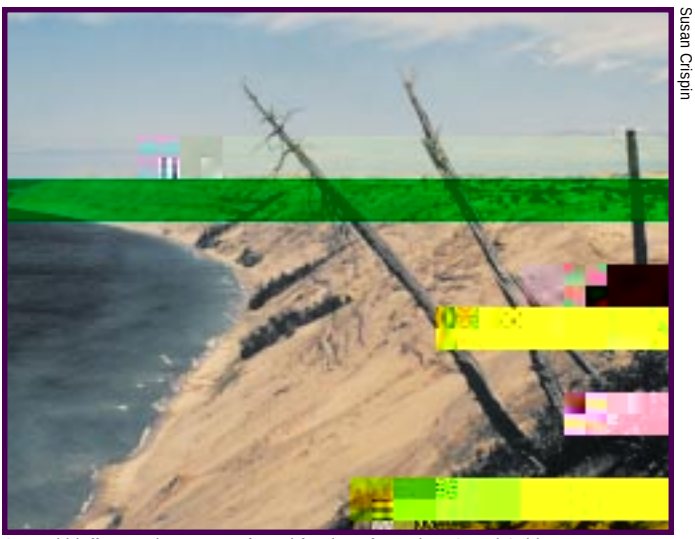
SAND SOURCE

The most basic factor in dune formation is the presence of abundant sand.

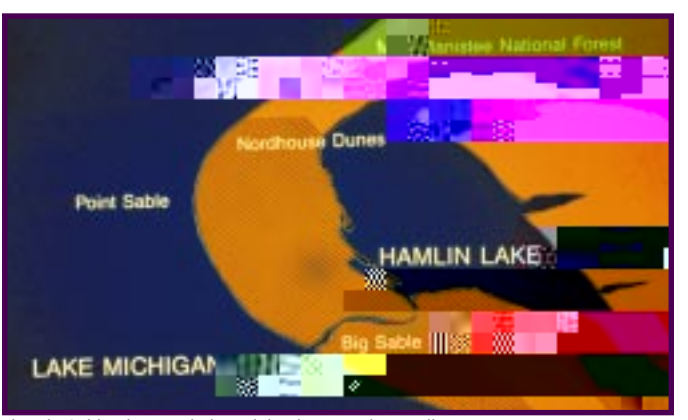


Susan Crispin

Coastal bluffs, a major source of sand for dune formation. Grand Sable Dunes.

Within the Great Lakes basin, continental glaciers covered the landscape for over one million years, providing the major source for sand and other sediments. Meltwater streams flowing from the glaciers' flanks carried tremendous volumes of sand and gravel that settled along extensive sandy plains or in narrow stream channels. Another source of sand was glacial till, a mixture of sand, silt, and clay that was deposited along the margins of the glaciers or dropped as the glacial ice slowly melted. Not only did the glaciers provide sediments rich in sand, they also scoured out the broad, deep basins that the Great Lakes now occupy.

These glacial sediments are concentrated in two sources that provide sand for coastal dunes: rivers and coastal bluffs. Large volumes of sand are carried into the Great Lakes by river systems, which is why many of our dune complexes are located at the mouths of large rivers like the Grand, Kalamazoo, Muskegon, and Pere Marquette. High coastal bluffs, which are continually being eroded by winds and waves, are another important sediment source, as seen at Sleeping Bear Dunes National Lakeshore, along northern Lake Michigan, or at Grand Sable Dunes along the south shore of Lake Superior. These sediments are



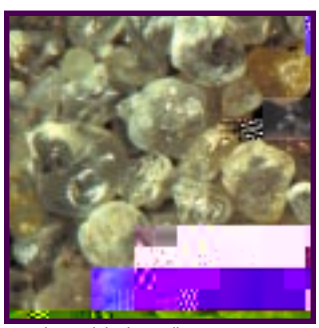
The Big Sable River carried sand that became the Nordhouse Dunes.

moved along the shoreline by offshore currents and eventually get redeposited along the shoreline to form sand beaches or foredunes. When conditions are right, these sands can be carried inland by strong winds to form interior dunes.

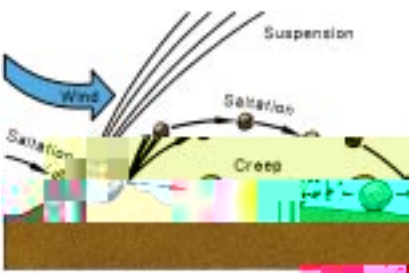
While water deposits particles on the beach that range in size from pebbles to very fine sands, wind-formed dunes consist largely of medium and fine sands. Large volumes of medium and fine sands bounce along within a meter of the ground, in a process called **saltation** (see diagram at right). Saltation is responsible for most sand movement on the dunes. Coarse sand is too large to be readily moved by the wind, and its movement consists of short distance "surface creep" resulting from collisions with moving fine and medium sand particles. Finer silt and clay sized particles are carried in suspension far beyond the coastal dunes.

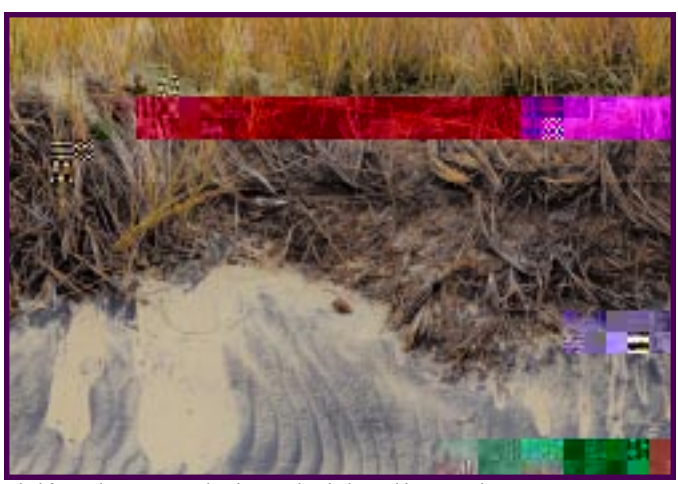
Beach or dune sand consists largely of quartz (87-94%), with lesser amounts of feldspar (10-18%), magnetite (1-3%), and traces of other minerals such as calcite, garnet, and hornblende. Sand particles are rounded and frosted by continuous collisions with other sand grains. Quartz grains range from very coarse to very fine sands. In contrast, magnetite, which is twice as heavy as quartz, consists primarily of fine and very fine sand grains, although larger particles can be found. As a result of this size and density difference, gently moving water or light winds cause the heavier, smaller magnetite to settle out into dark bands overlain by lighter, larger quartz. Gentle summer winds accelerate the separation of magnetite from quartz, but the sorting is quickly undone by fall and winter storm winds and waves.

Moving sand is very abrasive, as demonstrated by **ventifacts**, stones that have flattened facets polished smooth by the sand. Similarly, the colorful label of a soda can left on the dune is soon sandblasted to a dull gray. An interesting, rare phenomenon in the dunes is the fusion of sand grains by lightning strikes, forming fragile tubes called **fulgerites.**


David Wisse

Beach sand (enlarged).




Dennis Albert

Wind-formed patterns on the dunes. The dark sand is magnetite.

WIND

Strong winds blowing in a relatively consistent direction are a second factor critical for dune formation.

Wind-blown sand on snow.

For the Great Lakes, prevailing winds are typically from the southwest. As a result, the greatest concentration of large dunes is along the eastern and northern shorelines of Lake Michigan, with the largest dunes along the eastern shoreline. Dune formation is a dynamic and cyclic process. On an annual scale, sand movement and dune formation are greatest from late autumn through early spring, when prevailing winds are strongest and leaves are absent from deciduous shrubs and trees growing on the dunes. Ice accumulation along the shoreline, called an **ice foot**, can reduce the amount of wave erosion of the beach during the winter. During cold years when a large ice foot forms and remains in place throughout much of the winter, there is reduced sand movement and dune formation.

Ice foot along Lake Michigan shoreline.

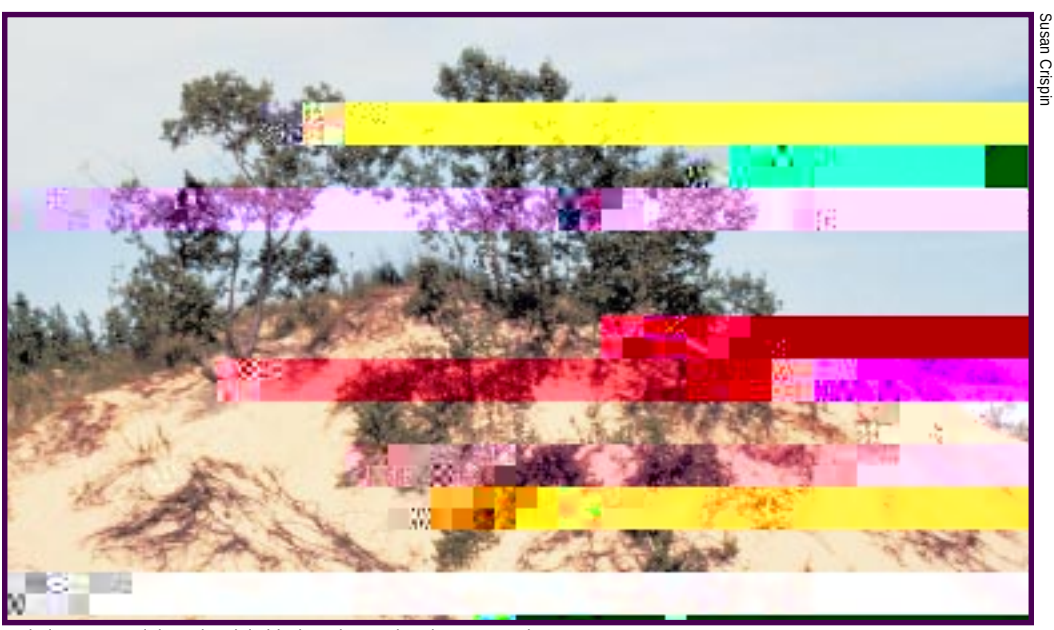
VEGETATION

A final factor, vegetation, traps and stabilizes sand.

Without periodic entrapment, sands cannot accumulate vertically to create high coastal dunes. Most plants are not adapted to the constant burial and abrasion that characterizes the dune environment.

Donald Petersen

Narrow spikes of marram grass *(Ammophila breviligulata)* and broad spikes of sand reed grass *(Calamovilfa longifolia)* colonize open sand.



Susan Crispin

Buried cottonwood *(Populus deltoides)* produces abundant root suckers.

Marram grass (*Ammophila breviligulata*), typically the first species to establish on the bare dune sands, is one of the species most adapted to survival on the dunes. Not only can marram grass tolerate being buried by sand, studies have shown that it requires burial for optimal growth. When the wind encounters marram grass or other dune vegetation, its velocity is reduced, causing sand to accumulate. As dune sands bury the marram grass, it continues to form new growth above the sand, while its roots and rhizomes continue to grow and stabilize the sands.

Donald Petersen

Marram grasses slows the wind, causing sand to accumulate.

Most of the common herbs, shrubs, and trees of the dunes are tolerant of sand burial. Grasses most tolerant of sand burial include marram grass, sand reed, and little bluestem. Shrubs tolerant of burial include red osier dogwood and sand cherry. In southern Michigan, cottonwood shows considerable tolerance to sand burial, as does balsam poplar further to the north. When buried, both cottonwood and balsam poplar produce root suckers from buried stems, resulting in clumps of small trees on the partially stabilized dune. Roots form just below the sand surface, where moisture is most available.

As vegetation of the dunes is stabilized, herb and shrub diversity increases and forests eventually establish. With the establishment of a forest canopy, dune pioneering plants like marram grass and sand cherry rapidly disappear and are replaced by plants more tolerant of the reduced light conditions in the forest understory.

Dennis Albert

Little bluestem
(Schizachyrium scoparius).

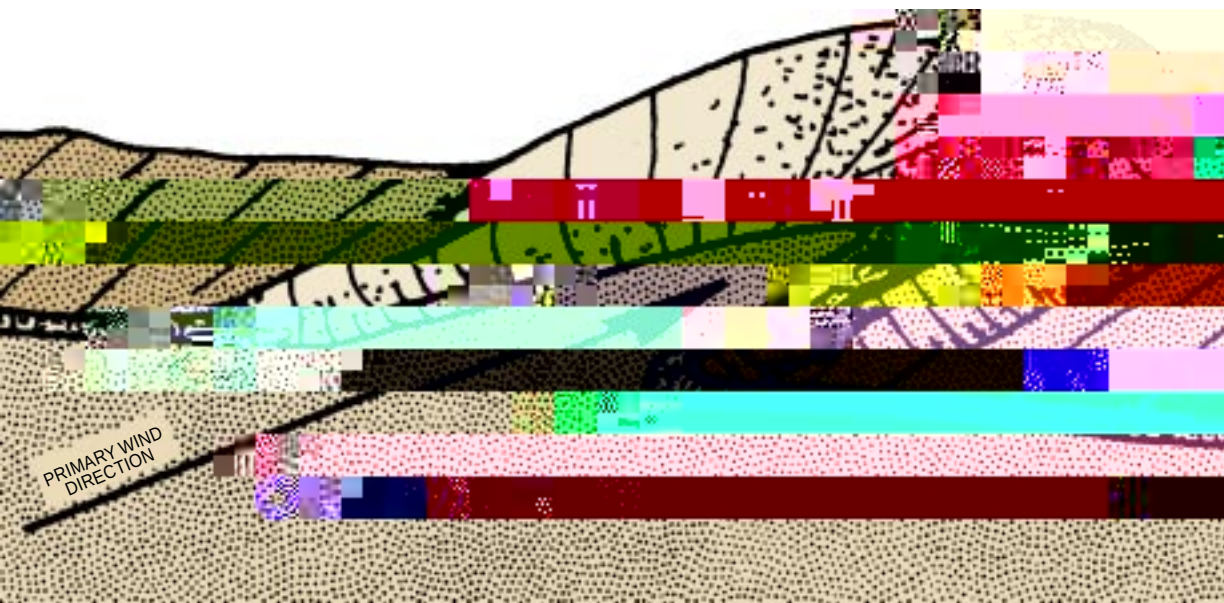
PARABOLIC DUNES

Parabolic dunes, defined by their distinctive U-shape, are found only in moist environments, where extensive vegetation cover often stabilizes the dunes.

R. Torresen

Parabolic dune at Hoffmaster State Park extends into the surrounding forest.

Parabolic dunes occur in several large complexes along the eastern Lake Michigan shoreline. In the Lake Michigan basin, the sand source for the parabolic dunes is broad sand terraces that formed along the lake margins 11,000 to 13,000 years ago. Parabolic dunes probably formed when the forested sand terraces were destabilized during high lake levels, resulting in the formation of U-shaped blowouts. Dune destabilization occurred at intervals several hundred or thousand years apart, when lake levels were high. Strong winds result in migration of the dunes inland, while marram grass and other vegetation cause the sand to accumulate vertically. The end result is the formation of parabolic dunes 250 to 300 feet high.



PERCHED DUNES

These dunes are perched atop glacial moraines that have bluffs 90 to 360 feet above the present lake level.

Perched dunes are restricted to the northeastern shore of Lake Michigan and to Lake Superior. They are nourished largely by sand blowing off bluff faces, rather than sand from the beach. Perched dunes themselves are often much smaller features than the bluffs upon which they rest. Foredunes, perched along the upper edge of bluffs, are quite dynamic. Among the most famous perched dunes are Grand Sable on Lake Superior and Sleeping Bear dunes on northeastern Lake Michigan.

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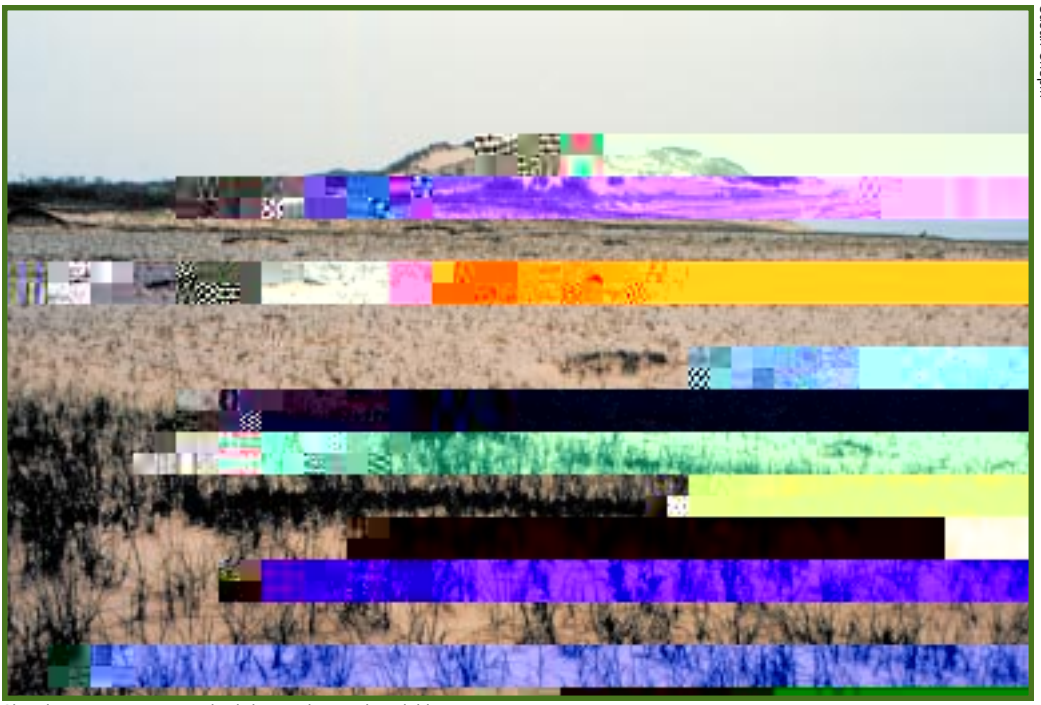
Grand Sable Dunes, perched dunes along Lake Superior.



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Sleeping Bear Dunes, perched dunes along Lake Michigan.

Gary Reese

A lag zone of pebbles and cobbles along the bluff-top at Grand Sable Dunes.

The sediments of bluff faces are quite variable. Clay banding can result in moist seepages on the bluffs. Strong winds remove clay, silt, and sand, leaving pebbles and cobbles, called a **lag zone**, either on the face of the bluffs or along the upper edge. Along the lakeshore, the beach is often quite narrow.

LINEAR DUNES

Large complexes of linear dunes form the shoreline along numerous Great Lake bays.

5000 years ago. Since this time, Great Lakes water levels have been gradually dropping over the long-term. The water levels also have an irregular short-term cycle of lows and highs. As the water level drops, a new beach ridge (foredune) forms along the lakeshore, usually separated from the previously formed ridge by a swale. The largest beach ridges in a dune and swale complex record periods of high water level. When the water level rises high enough, beach ridges and swales formed at lower water levels will be destroyed, leaving no record of their short existence.

The large dune and swale complex at Indiana Dunes National Lakeshore on Lake Michigan in Indiana, contains upwards of 150 dune ridges, forming a four-mile wide complex that was deposited over roughly 4000 years. Along northern Lake Michigan, at Michigan's Wilderness State Park, a two-mile-wide complex of 108 ridges was created over a similar time period. Unlike the parabolic dune complexes, most dune ridges in the dune and swale complexes are low features,

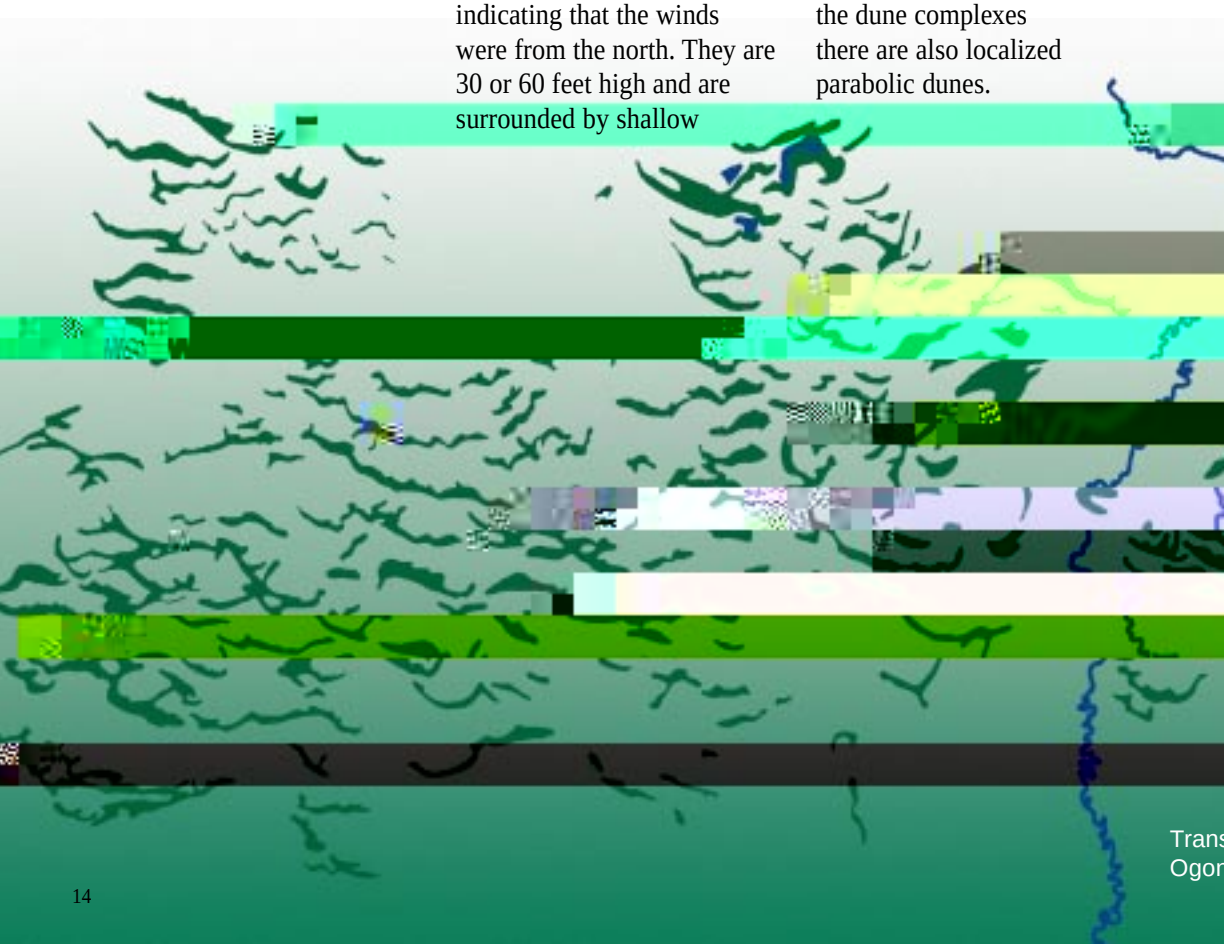
enough to destabilize the small dunes, forming small groups of parabolic dunes within the larger parallel dune and swale complex.

Along the shoreline, plant

TRANSVERSE DUNES

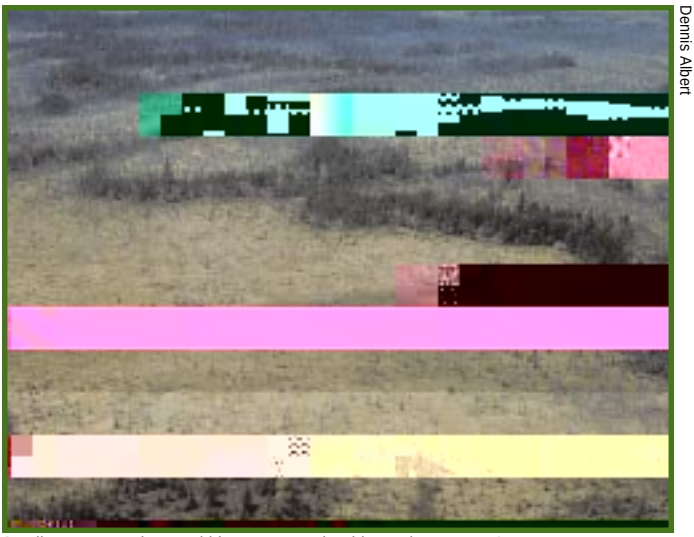
In the Upper Peninsula of Michigan, large abandoned bays of glacial Great Lake Algonquin from approximately 11,000 years ago contain transverse dunes and an occasional parabolic dune.

Transverse dunes, linear to scalloped in shape, are believed to have formed in shallow bays along the edge of the glaciers. Sand carried by glacial meltwater streams was abundant along the margins of the bays. Strong winds blew off the glaciers, forming this sand into a series of long, linear dunes, all oriented roughly perpendicular to the wind. The dunes have steep south faces, indicating that the winds were from the north. They are 30 or 60 feet high and are surrounded by shallow peatlands. Many of the Algonquin-aged bays were large, greater than 5 miles across, and contain several dozen dunes. Similar complexes of transverse dunes are also known from portions of northern Europe. Some scientists still debate the origin of these sand ridges, thinking that these dune features are actually sandspits that formed in shallow water. Within the dune complexes there are also localized parabolic dunes.



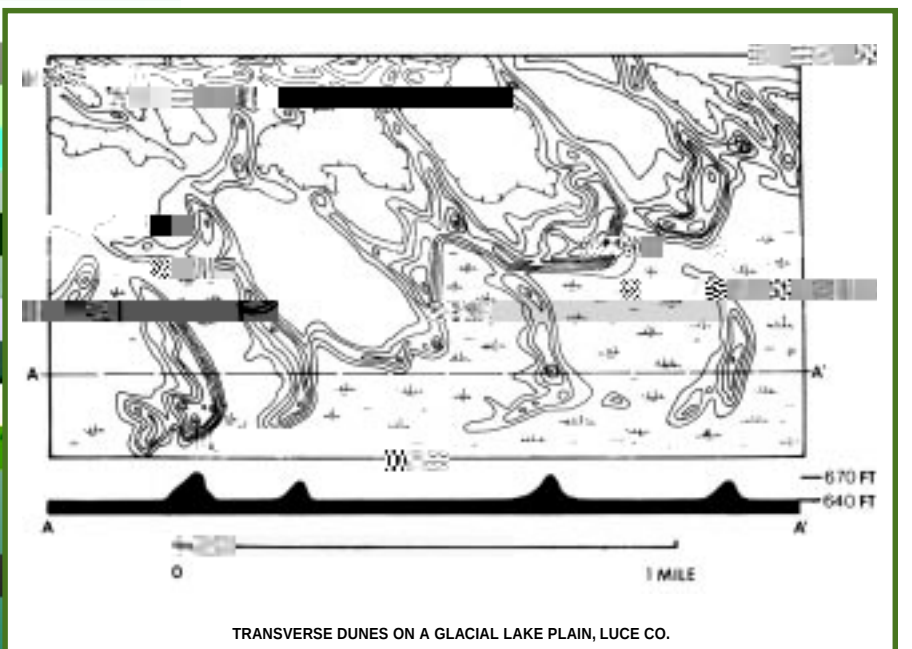
Trans
Ogon

For several thousand years after the glaciers retreated, the climatic conditions were dry enough that pine forests grew on the flat sands of the dried-up bays, but about three to four thousand years ago, the climate became cooler and moister, allowing wetland plants to expand across the bays, replacing pines with aquatic sedges and sphagnum mosses and creating peatlands that now have thin peat deposits, 2 to 3 feet thick.



Dennis Albert

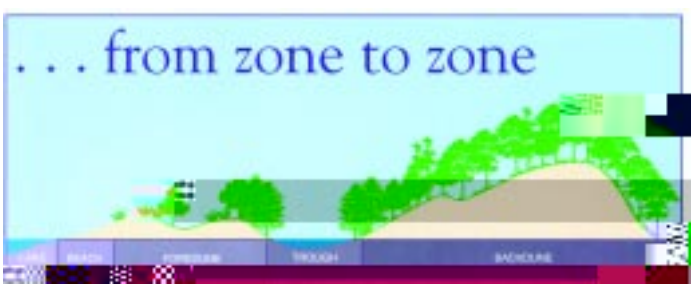
Small transverse dunes within a vast peatland in northern Luce County.



TRANSVERSE DUNES ON A GLACIAL LAKE PLAIN, LUCE CO.

sverse Dunes,
ntz Bay, Delta County.

Many animals visit the beach to feed. Shorebirds, including gulls, sanderlings, sandpipers, and plovers, feed on drowned insects and dead fish along the beach, espe-



Occasionally groups of butterflies, like the white admiral, can be seen puddling (another term for drinking) near the shoreline, where evaporation causes minerals to concentrate in the moist sand. Minerals are lost by butterflies during breeding and the moist beach sands provide the butterflies with a nutrient-rich moisture source.

Many species of tiger beetle are found along sand beaches of the coastal dunes. During migration, thousands of ladybird beetles can be found clustered together on debris along the shoreline. These are but a small sample of the insects that use the beach.

Further up on the beach, where storm waves seldom reach during the summer months, plants tolerant of the strong winds and extreme temperatures can establish. These include sea rocket, beach pea, bugseed, and seaside spurge, most of which are annuals adapted to a harsh, changing environment. Digger wasps are also found in this zone.

Where the back beach has abundant pebbles, piping plover, a federally endangered shorebird, creates a nest of pebbles to raise its young. Piping plover was once common along Great Lakes beaches, with 30 nesting pairs once counted along two miles of southern Lake Michigan beach. Market hunting in the late 1800s greatly reduced its populations, but more recently it has again been threatened by increased human development along the shoreline. Raccoons and unleashed dogs both destroy plover eggs and kill juvenile birds.

Powell Cottrille

White admirals *(Limenitis arthemis)* and tiger swallowtails *(Papilio glaucus)* puddling on beach.

FOREDUNE

The foredune is the zone where pioneering grasses cause sand to begin accumulating.

It can consist of a distinctive, low dune feature, or merely a low landward continuation of the beach. The most important pioneer-

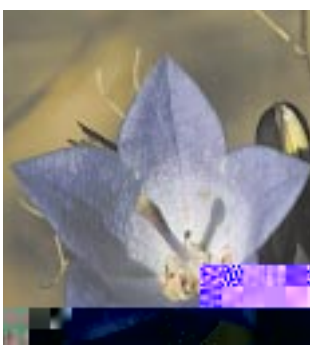


Photo courtesy of The Nature Conservancy.

Pitcher's thistle *(Cirsium pitcheri)*.

David Wisse

Antlions (Family *Myrmeleontidae*) are typically hidden beneath the sand.

native) plants that effectively stabilize the dune sand.

During the summer, temperatures at the sand surface regularly reach 120° F (50° C), locally reaching 180° F (80° C). Such extremes cause many of this zone's inhabitants, such as Fowler's toad, the eastern hognose snake, spider wasps (also called digger wasps), sand spiders, burrowing spiders, and wolf spiders to burrow during the day to reach cooler temperatures. When temperatures are extreme, they are active at the surface only during cooler morning, evening, and nighttime hours. The antlion is another insect that spends its life under the sand, waiting for ants and other small insects to slip into its unstable funnel-shaped sand trap.

The harmless eastern hognose snake is one of the most intriguing residents of the dunes. When surprised, the hognose snake rises up defiantly, flattening its head into a cobra-like hood and hissing loudly. If this threatening posture fails, it will writhe, convulse, and finally turn over on its back and feign death, only to flip over again and continue on its way once danger has passed. Toads are a favorite food of the hognose snake. Another large and extremely fast snake occasionally sighted sunning itself on the dunes or in low shrubs, is the blue racer.

A rare insect of the foredune is the Lake Huron locust. This locust exposes its yellow wings and clicks distinctively during flight,

Photo courtesy of The Nature Conservancy.

Hairy puccoon *(Lithospermum caroliniense)*.

Earl Wolf

Wolf spider (Family *Lycosidae*).

Photo courtesy of The Nature Conservancy.

Sand cherry *(Prunus pumila)*.

Earl Wolf

Eastern hognose snake *(Heterodon platirhinos).*

providing means of easily recognizing an otherwise indistinctive insect. The locust feeds on wormwood, a common plant on the dunes. Wormwood is also the host for a rare plant of the dunes, clustered broom rape, which is partially parasitic on wormwood. A rare moth found only on the foredune is dune cutworm, whose larvae feed on dune grasses. Song sparrow, vesper sparrow, field sparrow, and the eastern bluebird forage on insects of the foredune, as do eastern kingbird and chipping sparrows when scattered trees are present. Prairie warbler, a rare breeding bird in Michigan, is known to nest among

Earl Wolf

Eastern hognose snake
(Heterodon platirhinos).

Ken Jacobsen

Red anemone *(Anemone multifida).*

Gary Reese

Lake Huron tansy *(Tanacetum huronense).*

Photo courtesy of The Nature Conservancy.

Sterile rosette of Pitcher's thistle (Cirsium pitcheri).

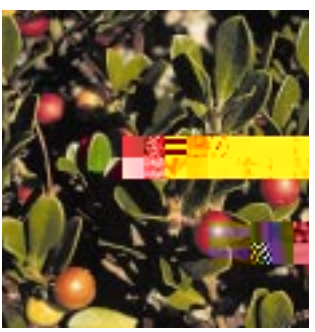
the shrubs on and in the lee of the foredune, as far north as Sleeping Bear Dunes along Lake Michigan and Rogers City on Lake Huron. Colonies of bank sparrows nest in the low, steep cliff face of the foredune, formed by erosion during winter storms, and both bank swallows and tree swallows are often seen feasting on the abundant flying insects of the dunes.

The foredune is continually being buried by sand or eroded by strong winds. It is colonized by the beach grasses, along with other herbs and shrubs tolerant of sand burial, but its environment is typically too extreme for the successful establishment of most tree species. A few eastern cottonwoods, balsam poplar, and oaks can be found on the most protected portions of the foredune. All of these trees, especially the eastern cottonwood and balsam poplar, tolerate burial by sand, but the strong winds and occasional burial result in short stature and poor growth.

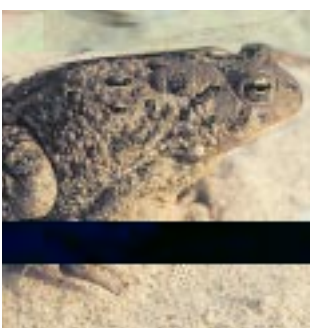
Dune cutworm *(Euxoa aurulenta).*

Butterfly weed *(Asclepias tuberosa).*

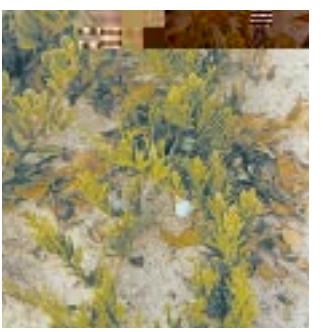
Spider wasp *(Pompilidae).*



Bearberry

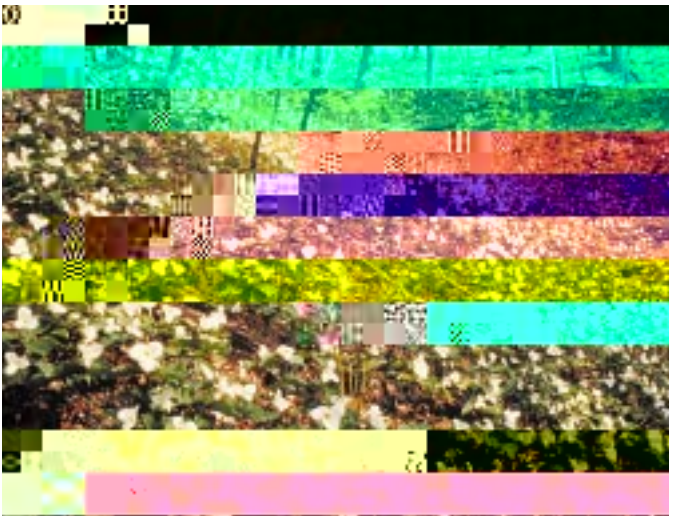


Fowler's toad *(Bufo fowleri).*

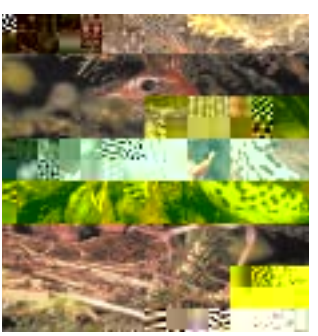


Ground juniper *(Juniperus horizontalis).*

of broad-winged hawks
gliding from one warm air



canopy reduces the summer
heat and moisture loss.



Earl Wolf

Solomon's seal
(Polygonum pubescens).

Earl Wolf

Bunchberry *(Cornus canadensis).*

Earl Wolf

Prairie phlox *(Phlox pilosa).*

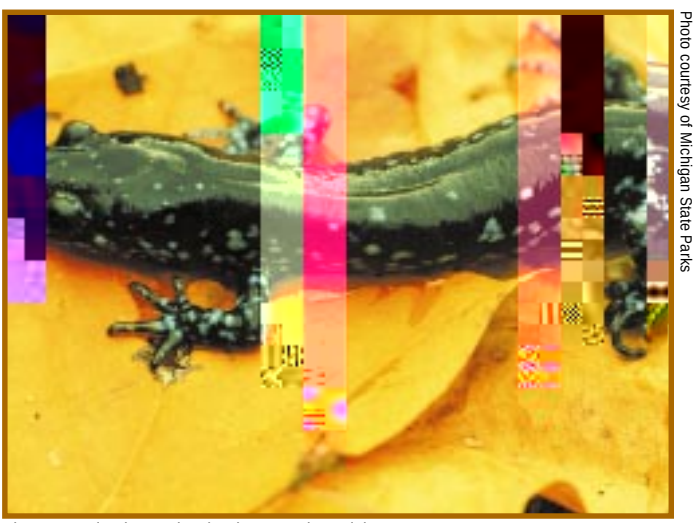


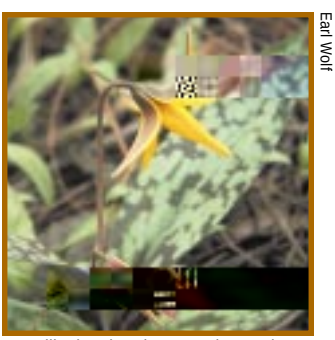
Photo courtesy of Michigan State Parks

Blue-spotted salamander *(Ambystoma laterale).*

include black-throated green warbler, black- and-white warbler, scarlet tanager, wood thrush, ovenbird, eastern wood pewee, rose-breasted grosbeak, veery, American redstart, yellow-billed cuckoo, black-billed cuckoo, and red-eyed vireo. This abundance of songbirds attracts many raptors, such as sharp-shinned, red-shouldered, and Cooper's hawks. The eastern box turtle can also be encountered ambling

Donald Petersen

Canada anemone
(Anemone canadensis).



Earl Wolf

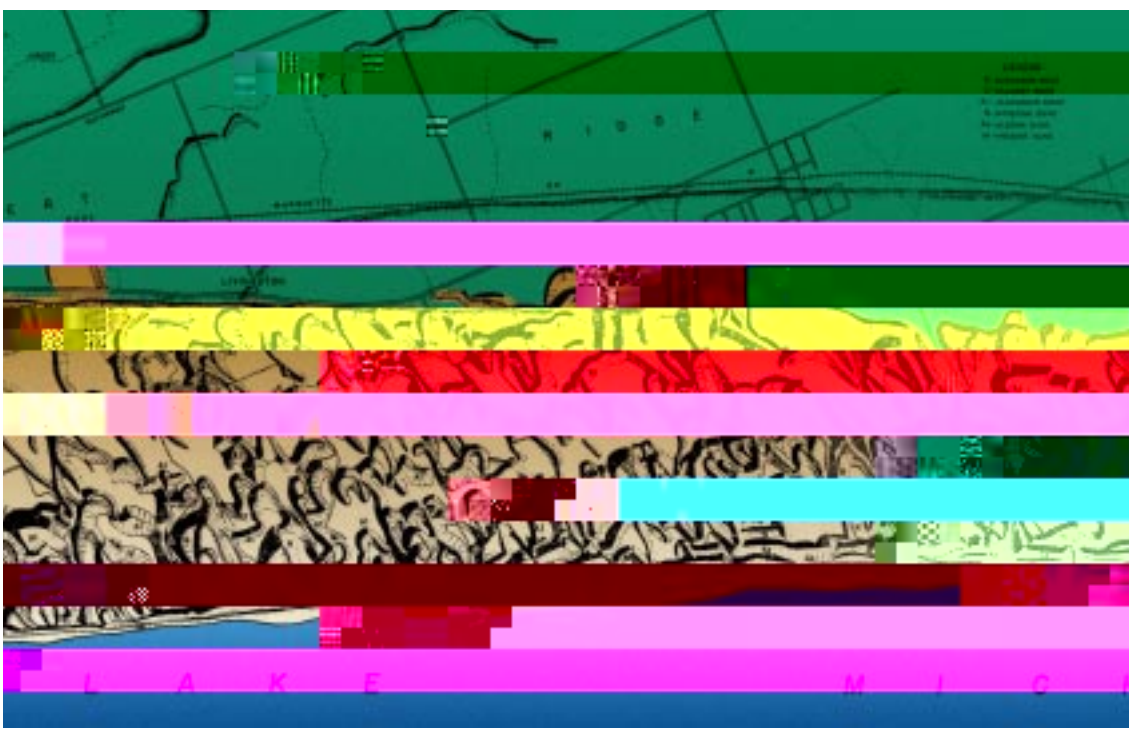
Trout-lily *(Erythronium americanum).*

Earl Wolf

Squirrel-corn *(Dicentra canadensis).*

on the forest floor, and careful investigation beneath logs and leaves will sometimes uncover the delicate red-backed salamander. The casual visitor seldom encounters more than a few red-backed salamanders during a visit, but this small salamander may be more important to the forest than many realize. Studies have shown that from 200 to 3600 salamanders can live in an acre of forest. The salamander feeds on a broad range of insects and soil organisms, as well as being eaten by birds, turtles, and small mammals of the forest. The black rat snake is also a localized inhabitant of the mesic backdune forest along southern Lake Michigan.

While the backdune forest is the most protected habitat on the dunes, it can also undergo dynamic change. Its location along the shoreline results in exposure to infrequent, but extreme storm events. Such coastal storms during the spring of 1998 destroyed backdune forests at Hoffmaster State Park and Wilderness State Park in


L A K E M I C

Earl Wolf

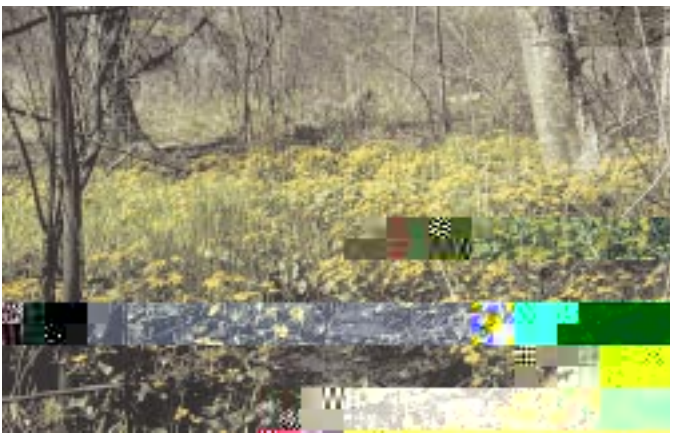
Learn to recognize the three part leaf of poison-ivy *(Toxicodendron radicans)*.

Studies show that there have been several periods during the last 4,000 years when environmental conditions resulted in extensive blowouts within the dunes. These periods are closely linked with Great Lake high-water levels.

Dune grasses partially stabilize the blowouts resulting in vertical accumulation of sand within the blowout. As the sand migrates inland, it buries and kills the forest. Sand migration is greatest during the fall and winter months, when vegetation cannot effectively reduce the wind velocity. Most of the plants and animals characteristic of foredunes are also found on blowouts.

Pitcher's thistle can be found growing throughout the bowl of a blowout and is often quite abundant near the upper, landward edge, where there is abundant open sand. Lake Huron locust can be abundant here as well. Poison ivy can be especially troublesome along the lee edge of the blowouts, where it sometimes forms a formidable, waist-high wall between the forest and the blowout.

The shallow ponds are rich in aquatic insects like dragonflies and damselflies. Spring peepers, Fowler's toads, garter snakes, mink, and muskrats are among the other inhabitants of the ponds. Along southern Lake



Dennis Albert

Mosses and earth stars (*Geastrum* sp.) growing on open dunes, Grand Sable Dunes.

Dennis Albert

Wormwood *(Artemisia campestris).*

Mosses appear to play a role in dune stabilization on some northern dunes. This is most evident on the Grand Sable dunes along Lake Superior, in the Upper Peninsula of Michigan, where cooler, foggy conditions are more favorable to mosses and lichens. Studies in the Grand Sable dunes showed that *Polytrichum piliferum*, a moss, was able to survive burial by over two inches of sand.

The perched dunes themselves are by no means stable. The largest perched dune at Sleeping Bear Dunes National Lakeshore, the "Bear", was completely forested and rose 234 feet above the plateau in 1906. Erosion began in the 1920s, and by 1961, the majestic giant had been reduced to only 132 feet in height. Studies on Grand Sable Dunes indicate that both vehicle use and heavy foot traffic have led to increased erosion on grass- and herb-dominated portions of the dunes.

Interdunal swales are much less common than within the parabolic dunes. They also differ, as their water table is not determined by fluctuations in Great Lakes water levels, since they are perched far above the Great Lakes.

Beaches associated with perched dunes, lying beneath steep, eroding bluffs, are often much narrower than their parabolic dune counterparts. During periods of high Great Lakes water levels, the lake's water can be directly eroding the bluffs. Even though the beaches can be quite narrow, piping plovers are known to nest on the beaches below the perched dunes, as at Sleeping Bear Dunes National Lakeshore.

Michael Penskar

Dunewort *(Botrychium campestre*).

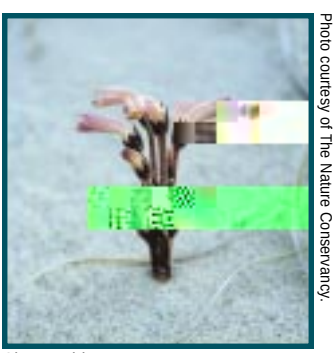


Photo courtesy of The Nature Conservancy.

Clustered broom rape
(Orobanche fasciculata).

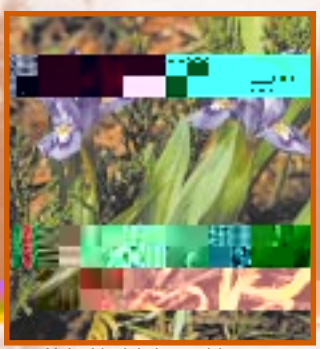
ERODING BLUFF

Steep eroding bluffs of till form the base from which the perched dunes rise.

For both the Grand Sable dunes on Lake Superior and the Sleeping Bear dunes on Lake Michigan, the bluffs are responsible for roughly 300 feet of elevation, while the perched dunes formed on the bluff are only half that height. The bluff faces of perched dunes are quite variable. At both Grand Sable and Sleeping Bear dunes, the bluff faces are very sandy, supporting dune plants, but fine-textured bands of clay or loam are also encountered. On some bluff faces fine-textured banding results in numerous seepages. Trees and shrubs establish on the bluff faces, but continual erosion of the bluff base results in widespread instability. Fallen trees are common on forested portions of the bluffs.

Both clustered broom rape and dunewort commonly

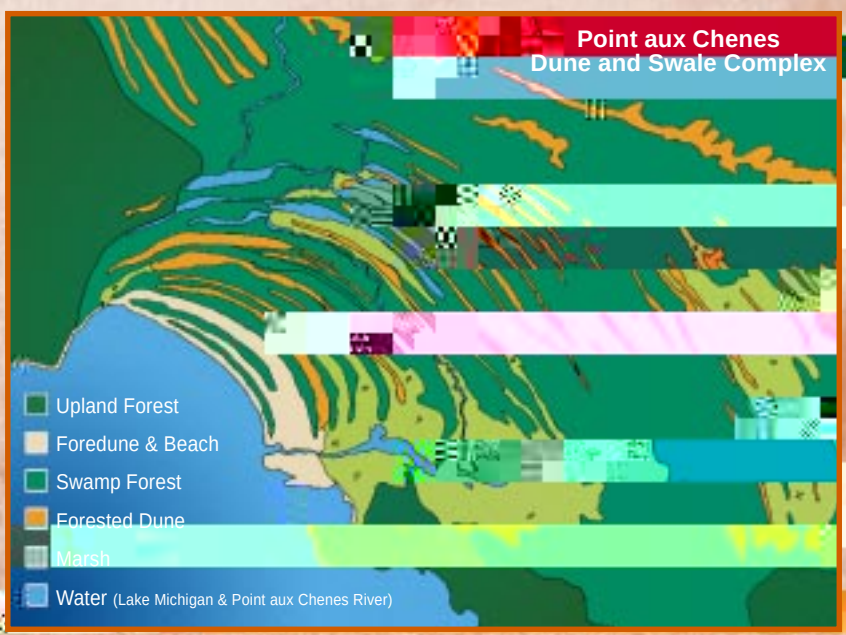
Zonation of Dune & Swale



Harold Malde

Dwarf lake iris *(Iris lacustris)*.

Dune and swale complexes have four distinct, alternating zones. These are the **beach and foredune**, the **open interdunal swales**, the **forested dune ridges**, and the **forested swales**. Dune and swale complexes can be quite extensive; one of the largest is the 40 mile long Tolston Beach complex along the southern Lake Michigan shoreline in Indiana and Illinois.



Dennis Albert

BEACH AND FOREDUNE

The beach zone of dune and swale complexes and parabolic dune complexes share many processes, plants, and animals.

In contrast, there is reduced sand availability on the foredunes of most dune and swale complexes. As a result,

OPEN INTERDUNAL SWALES

The wetness of interdunal swales near the present lakeshore is determined by the Great Lakes water level.

Dennis Albert

Shallow marly swale at Pointe aux Chenes dune and swale complex.

When water levels are high, several swales near the shoreline may be flooded. Swales farther from the shoreline can also be flooded, but these swales are typically flooded because of ground-water flow or seepage, not due to the lake's water level. Aquatic vegetation in the swales can be quite diverse, including aquatic or emergent grasses, sedges, herbs, and shrubs. In some complexes, there can be several open, sedge- or alder-dominated swales separated by forested ridges before the swales become consistently forested.

Aquatic insects are likewise abundant in these shallow, warm swales, along with leeches. Several populations of Hine's emerald dragon-flies, a federally endangered species, have recently been discovered within the marly swales near St. Ignace, on northern Lake Huron. Woodcock and common snipe commonly nest in the brushy swales, found where the open swales along the shoreline transition to forested swales.

The moist swale margins in the Straits of Mackinac, along the northern Lake Huron and Lake Michigan shoreline, are the primary habitat for a rare Great Lakes endemic plant, Houghton's goldenrod. During high Great Lakes water levels, Houghton's goldenrod

Harold Malde

Butterwort *(Pinguicula vulgaris).*

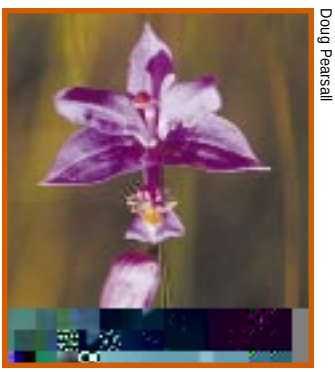
Susan Crispin

Houghton's goldenrod *(Solidago houghtonii).*

populations can decrease drastically and sometimes the plant may appear to be absent from a site. When water levels drop, the number of stems around a swale can increase dramatically, sometimes even occupying the entire bottom of moist swales. Houghton's goldenrod is occasionally found growing on the drier low dunes as well. The marly swales in the Straits area provide habitat for another showy rare plant, butterwort, which can be locally abundant along the moist margins or within the shallow waters of the swale. The size of butterwort populations can likewise fluctuate greatly in response to water level changes.

Harold Malde

Pitcher-plant *(Sarracenia purpurea).*

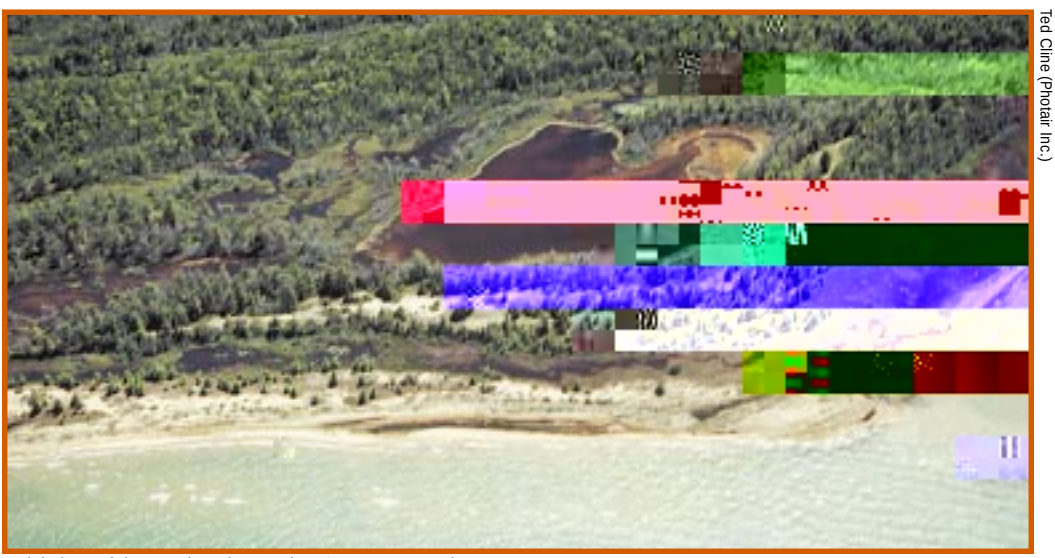


Doug Pearsall

Grass pink *(Calopogon tuberosus).*

The Nature Conservancy

Indian paintbrush *(Castilleja coccinea).*



Ted Cline (Photair Inc.)

Aerial photo of dune and swale complex, Grass Bay on Lake Huron.

FORESTED DUNE RIDGES

Succession on the dune and swale complexes is much more rapid than succession on the higher parabolic dunes, probably because of reduced sand accumulation in the dune and swale complex, thus allowing trees to establish without being buried.

Michael Penskar

Shallow swale with aquatic plants, surrounded by conifer-dominated dunes, Gulliver, northern Lake Michigan.

Stabilization of the dunes by trees also results in relatively rapid soil development, with increased nutrient and moisture availability. This results in continual forest dominance, but replacement of pine forests by more mesic hardwood forest types appears to be very slow on dune and swale complexes, with conifers maintaining dominance for over 2,000 years. This is in strong contrast to many of the parabolic dune complexes, where hardwoods commonly dominate the more protected inner portions of the dunes. This continued dominance by pines, balsam fir, and early successional hardwoods, such as oaks, balsam poplar, and aspen, may result from regularly occurring wind storms. Both from the original surveyors' notes and from recent records, it is apparent that wind storms occur often near the shoreline, creating the large openings required for establishment of pines and other early successional tree species.

Large white and red pine on the ridges provide nest trees for bald eagles and ospreys, both of which feed either in the nearby lake or within the larger, open swales. During the summer months, ground-nesting northern harriers are encountered gliding gracefully above the open swales. Following large wind storms or major insect infestations, woodpeckers forage for insects and nest in standing, dead trees. Dwarf lake iris can form dense colonies growing beneath both open and closed-canopied conifer forests just back from the shoreline, but in this habitat it seldom flowers, except when the forest canopy is opened by a storm. Dwarf lake iris may persist on shady, forested ridges as much as a mile from shore.

Betty Cottrille

Black-backed woodpecker *(Picoides arcticus).*

FORESTED SWALES

The establishment of forests within the swales is much more gradual than the establishment of forests on the ridges.

While herbaceous vegetation often completely dominates only the 3 or 4 swales closest to shoreline, shrubs can be prevalent well into a complex. The shrubs are gradually replaced by swamp conifers as one proceeds further from the shoreline and as the swales become drier. In southern Michigan, common shrubs are buttonbush, Michigan holly, meadowsweet, and willows, while further north, speckled alder, sweet gale, mountain holly, and shrub-sized black spruce, northern white cedar, and tamarack become increasingly dominant. On Lake Superior, where organic materials decompose slowly because of the cold climate and where the soils are more acid, bog vegetation dominates these shrub swamps, including bog laurel, cranberries, bog rosemary, leatherleaf, and Labrador-tea.

Further from the shoreline, swamp conifers become the dominant vegetation. Groundwater-fed streams enter most of the dune and swale complexes. In the oxygen-rich waters near these streams, cedar, speckled alder, and hardwoods, such as paper birch and trembling aspen are abundant. In portions of the swales with restricted groundwater influence, black spruce, tamarack, and acid-tolerant shrubs are prevalent. Organic soils accumulate in most forested swales, but are seldom greater than three feet deep.

These dense conifer swamps provide extensive habitat for orchids and other plants requiring sheltered, cool, shady conditions. Among the rare plants known from these complexes is Lapland buttercup, a state threatened plant with a mostly boreal distribution, and round-leaved orchid, which also requires the cool protected habitat.

Faunal surveys of the dune and swale complex have been much less intensive than the plant surveys. Some relatively common users of this protected habitat are snowshoe hare, common snipe, red fox, and whitetail deer.

Zonation of Transverse Dunes Within Glacial Embayments

Betty Cotrille

Common snipe *(Gallinago gallinago).*

There has been less detailed study of the dune fields within the glacial bays of the Upper Peninsula of Michigan than in any other dune type. Yet, even with this paucity of information, it is clear that these dune complexes are extremely important for maintaining Michigan's plant and animal diversity.

Dennis Albert

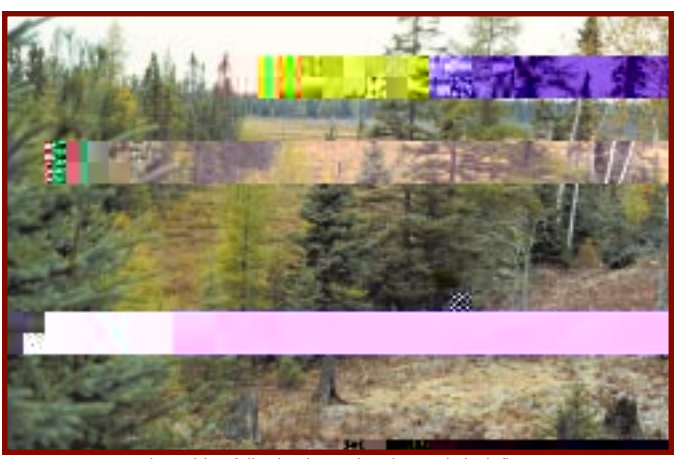
Red pine and white pine growing on low transverse dune ridges within extensive peatland, Barfield Lakes.

DUNE FORESTS

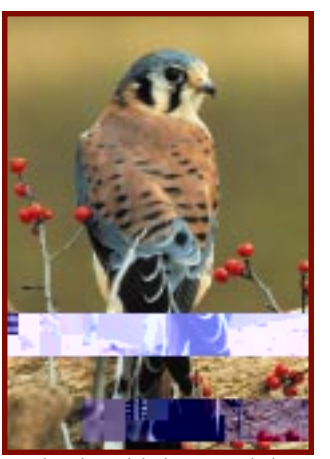
The original surveyors' notes from the mid-1800s described vast peatlands, often flooded by beaver dams, and broken by narrow white pine- and red pine-capped ridges.

Low white-pine dominated transverse dunes within a shallow, sedge-dominated peatland, Barfield Lakes.

While white pine and red pine were common dominant trees, the surveyors also made reference to aspen and jack pine. In a few places, eastern hemlock grew with white pine, creating a majestic forest. A few examples of this forest type still remain, as at Swamp Lakes and portions of Barfield Lakes. Many of the ridges were at least partially burnt, as were the surrounding peatlands. Following settlement, winter logging was conducted on most of the bays, and fires often followed logging, sometimes resulting in the loss of pines and replacement by aspen. Plant surveys of the ridges have resulted in no rare plant finds. Bracken fern, blueberries, huckleberries, poverty grass, and Pennsylvania sedge are among the most common plants. It is also common to encounter bald-faced hornet nests, either in the loose sand or hanging from bracken fern, and in the twilight, one may be serenaded by bobolinks. The upland conifer forests remain important for birds like the pine siskin, Blackburnian warbler, and other songbirds requiring mature conifers for nesting.



Open, transverse dune ridge following heavy logging and slash fires.



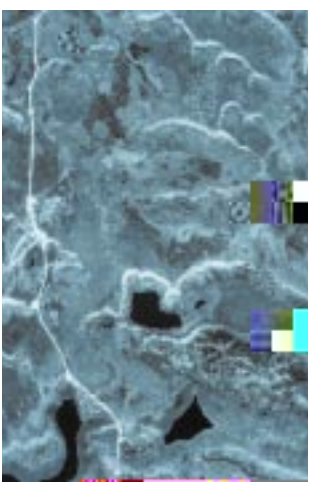
American kestrel *(Falco sparverius).*

The peatlands surrounding the transverse dunes form an intriguing, diverse habitat. At the margins of many peatlands, there is typically a zone with groundwater influx, where a narrow band of northern white-cedar grows.

Cedar quickly gives way to black spruce and tamarack, sometimes followed by stunted jack pine in the center of the peatland. Tree growth is slow because of the harsh, frost prone micro-climate and low nutrient availability. As a result of these extreme conditions, a 1-inch diameter tamarack may be 75 to 100

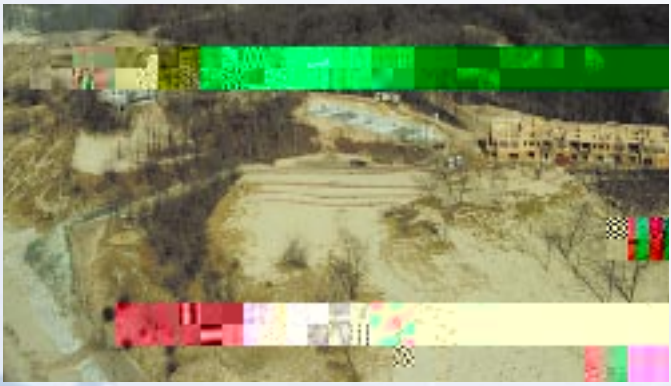
bird common to this complex
of dunes and wetlands.

Merlins, a small falcon



Dune Threats

Both the ecological importance and recreational value of Michigan's sand dunes are well recognized. Unfortunately, there are also numerous threats to the dunes, ranging from degradation of the dunes by residential and recreational uses to complete elimination by mining. Among the threats identified along Michigan's coastal dunes, the following are among the most wide spread or severe:



- Exotic (introduced non-native) plants and animals.
- Off-road vehicles (ORVs)
- Pedestrian recreational overuse

EXOTIC PLANTS & ANIMALS

Exotic plants are a widespread threat to dunes.

Walter Loope

Bladder campion *(Silene vulgaris).*

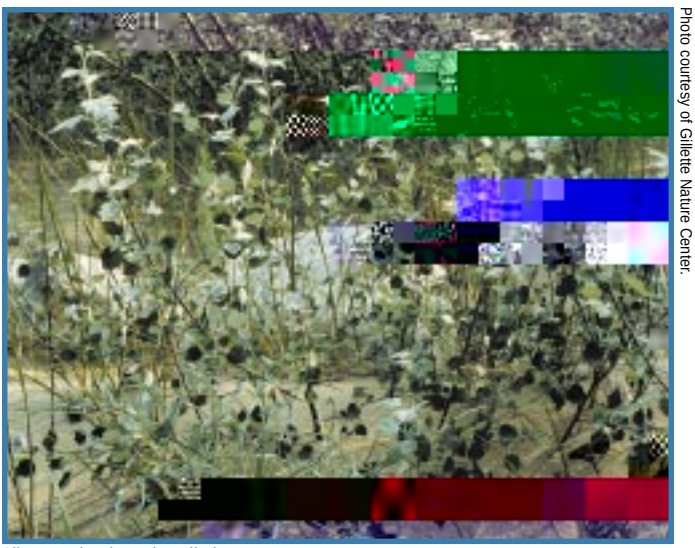


Photo courtesy of Gillette Nature Center.

Silver poplar *(Populus alba).*

One widespread exotic plant is spotted knapweed, which colonizes open habitat, often spreading along roadway corridors. It forms dense patches, resulting in stabilization of blowing sand, thus reducing habitat for rare species like Pitcher's thistle, which requires open, moving sand for its establishment and survival. Another plant that similarly stabilizes open sand dunes is baby's-breath. Both of these plants can be extremely difficult to eliminate once they have established, since their seed can persist in the sand, gradually germinating over several years. Baby's-breath forms large taproots, up to several feet long, making manual removal difficult. Other herbaceous plants commonly invading the open dunes include bouncing bet, bladder campion, Canada bluegrass, autumn olive, scots pine, and smooth brome grass.

Still other plants have been purposely planted on the dunes by land owners to stabilize the dunes, especially black pine, Lombardy poplar, and white poplar. Black pine has begun to reproduce by seed on some of the state parks, causing a costly management problem. Both Lombardy and white poplar reproduce vegetatively, producing open clones in the case of Lombardy poplar, and very dense clones for white poplar. Once trees have established on the dunes, the general public is sometimes opposed to their removal, even though these exotics may threaten populations of rare endemic dune plants.

To date, there are many less exotic animals than plants adversely impacting the dune environment. A recent arrival to the sandy shoreline is the zebra mussel. In bays of the Great Lakes, zebra mussel

has been reported to cause chemical changes, resulting in increased levels of blue-green algae. While the effects on the sand beach have not yet been fully evaluated, the tremendous numbers of shells cannot help but alter some aspects of the dune ecosystem. These colorful shells often form windrows on the beach following storms, and can result in severe lacerations to the bare feet of beach-goers, especially children.

Another potential exotic threat is a beetle that has been introduced to control an exotic species of thistle. There are indications that the beetle may also feed on federally-threatened Pitcher's thistle.

Samara Hamze

Baby's-breath *(Gypsophila paniculata).*

Dennis Albert

Lombardy poplar *(Populus nigra var. italica).*

ORVS & OVERUSE

Degradation: ORV's and Recreational Overuse

Earl Wolf

A visually pleasing boardwalk reduces the erosion at Hoffmaster State Park's Gillette Nature Center.

The effect of off-road vehicles and, in some cases, overly heavy pedestrian use have been well documented on the dunes. Probably the most dramatic example of off-road vehicle use is Silver Lake State Park, where extreme levels of use have eliminated almost all vegetation from a large portion of the dunes, creating conditions that we associate with the most barren, extreme desert environments. Studies done using aerial photos taken over a period of fifty years document the effect of off-road vehicles at both Sleeping Bear Dunes National Lakeshore and Grand Sable Dunes (Pictured Rocks National Lakeshore). The Great Sleeping Bear dune lost over half of its height from heavy vehicle use. Similarly, studies have shown that the amount of unvegetated sand increased dramatically at Grand Sable dunes as a result of vehicle and pedestrian uses.

Extreme pedestrian use has led to the development of boardwalks at some of the most heavily used parks. Boardwalks have been successful in reducing recreational erosion at several Michigan parks, including Hoffmaster and Warren Dunes State Parks.

Human degradation to the dunes takes many forms. Garbage and debris are widespread. Not only does refuse detract from the scenic beauty of the dunes, it can also be dangerous to wildlife. For example, shore birds can become entangled in plastic 6-pack holders or swallow the colorful remains of helium balloons and their attached ribbons. Helium balloons, purposefully or accidentally released along the shorelines from as far away as Wisconsin, are probably the most common debris found on the beach.

Dave Kenyon

Dune buggy, Silver Lake State Park.

Photo courtesy of Michigan State Parks.

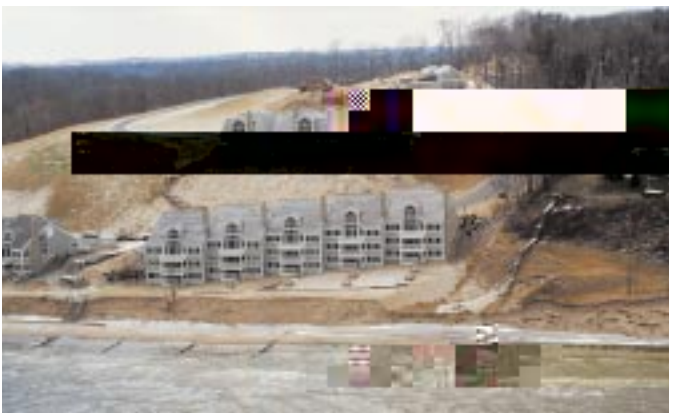
The “dune climb” at Sleeping Bear Dunes National Lakeshore. Heavy pedestrian traffic has resulted in almost complete elimination of vegetation.

Dennis Albert

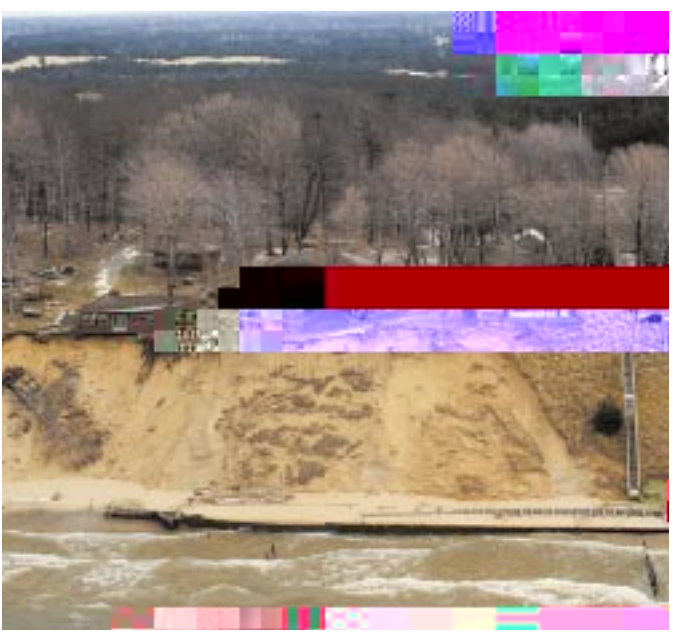
A sample of balloon ribbons picked up along a short section of beach, Warren Dunes State Park.

RESIDENTIAL DEVELOPMENT

There is probably no more attractive place to drink morning coffee than from one's dining room perched atop a coastal dune, yet, in terms of the coastal environment, homes built within the dunes cause numerous problems.



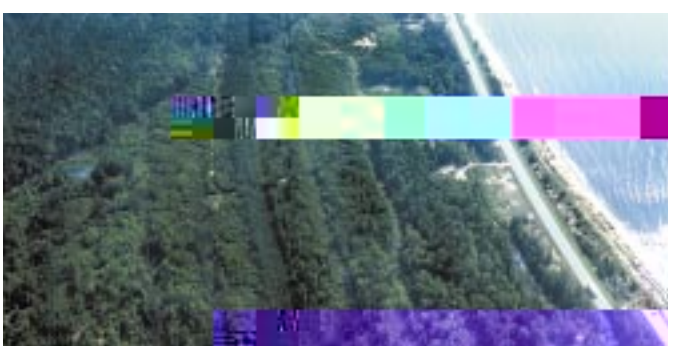
the home is built, the open sand which was only slightly objectionable when tracked onto the picnic blanket, becomes a major irritation,

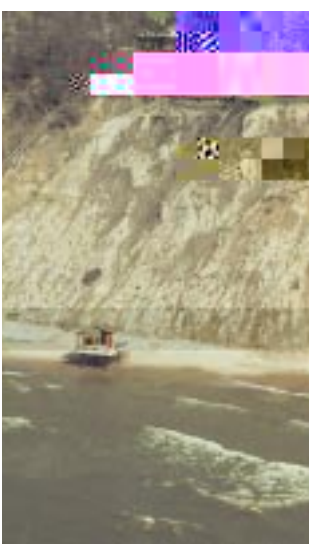


and a lawn is soon planted. Soon, blue grass, other lawn grasses, and accompanying weeds such as dandelion and smooth brome, become troublesome exotic pests on the open dune. When the sand begins burying the deck, swimming pool, or living room windows, the lawn is followed by a protective barrier of black pine or Lombardy poplar,

Home construction on sand dunes can be a risky and an expensive venture. Sand dunes are by definition unstable. Increased activity, either in the form of human disturbance to dune plants or climatic disturbances, can result in rapid destabilization of the dunes, resulting in rapid sand movement. It is not unusual during a study of coastal residential areas to encounter homes whose foundations have been eroded by bluff erosion or homes, swimming pools, or driveways buried by sand. Even the forested dunes can be a very risky place to build, as was demonstrated by a windstorm in late spring of 1998. The storm caused extensive property damage within the dunes near Muskegon, when thousands of uprooted trees destroyed roofs, blocked roads and driveways, and damaged cars. There have been recent, severe storms along the northern Lake Michigan shoreline as well, with large white pine and red pine especially prone to wind damage.

Residential development can also seriously degrade linear dune (dune and swale) complexes. To access the shoreline, where most residential development occurs within these complexes, a series of driveways





OTHER DEVELOPMENT

In the recent past, coastal dunes were an extremely important source of sand for industrial uses.

Presently, one of the first dune restoration projects is underway at a sand mining site adjacent to Grand Mere State Park, near Bridgeman. Other sand mining sites have been stabilized rather than restored, using the ponds or lakes created during mining operations as focal points for golf courses or condominium complexes.

Golf course development linked to luxury homes or condominiums often destroys the ecological integrity of sand dunes. Most golf

The Sand Dunes Protection and Management Program, as part of the Natural Resources and Environmental Protection Act, 1994 PA 451, is in place to protect dunes from residential, commercial, and industrial uses.

Sand dune regulations were enacted by the state of Michigan to protect dunes that were not publicly owned from indiscriminate development. Seventy thousand acres of shoreline along Lake Michigan and Lake Superior were designated and mapped by the Michigan Department of Natural Resources as "critical dune areas". These areas are mapped in the Atlas of Critical Dunes (1989). Critical dune areas include, but are not limited to, all barrier dunes along the shoreline, both open and forested dunes. Parabolic, perched, and linear dunes are included within the "critical dune areas" designation.

Not only do the sand dune regulations identify the dunes being regulated, they also restrict certain activities within the dunes. Construction of structures, roads, and driveways is now restricted on steep slopes (over 33%) to reduce dune destabilization. Before the regulations were enacted, construction of homes on steep slopes and unstable, open dunes was common.

Home or condominium construction along the shoreline periodically results in the loss of structures, especially during high-water periods, when dune and shoreline bluff erosion can be quite rapid. The loss of structures can be quite costly to the landowner. Attempts to save homes by building jetties or other shoreline structures result in the disruption of a long-shore currents and sediment transport, sometimes negatively affecting nearby properties.

While current regulations have resulted in reduced degradation of Michigan's sand dunes, development pressure remains high. The density of development in many dune areas has been

SAND DUNES ON PUBLICLY-OWNED LANDS OR PRIVATE NATURE PRESERVES IN LOWER MICHIGAN

	Dune & Swale Complex (Linear Dunes)							
	South	North	South	North	South	North	South	North
1. Grand Beach	X							
2. Warren Dunes State Park			**X**					
3 Grand Mere State Park			X					
4 Van Buren State Park			X					
5 Saugatuck State Park			**X**					
6. Holland State Park			X					
7. Rosy Mound State Park			X					
8. Hoffmaster State Park*			**X**					
9. Muskegon State Park*			X					
10. Duck Lake State Park			X					
11. Meinert County Park				X				
12. Benona Township Park				X				
13. Silver Lake State Park				X				
14. Charles Mears State Park				X				
15. Ludington State Park*				X				
16. Nordhouse Dunes Wilderness Area (USFS)				**X**				
17. Orchard Beach State Park				X				
18. Sleeping Bear Dunes National Lakeshore*		**X**				**X**		
19. Manitou Islands; Sleeping Bear Dunes N. L.		**X**				**X**		
20. South Fox Island						X		
21. Leland Municipal Beach		X		X				
22. Leelanau State Park				X				
23. Fishermans Island State Park		X						
24. Petoskey State Park				X				
25. Beaver Island (MI DNR)		X		X				
26. High Island (State Wildlife Research Area)						X		
27. Garden Island (MI DNR)		X						
28. Hog Island (MI DNR)		X						
29. Wilderness State Park		**X**		**X**				
30. Trail's End Bay (Twp. Park)		X						
31. Lakeport State Park	X							
32. Vassar and Tuscola State Game Areas								X
33. Gratiot-Saginaw State Game Area								X
34. Au Sable State Forest								X
35. Port Crescent State Park	**X**							
36. Albert E. Sleeper State Park	**X**							
37. Fish Point Wildlife Area	X							
38. Tobico State Game Area	X							
39. Pointe Au Gres (MI DNR)		X						
40. Tawas Point State Park		X						
41. Negwegon State Park		**X**						
42. Misery Bay (MI DNR)		X						
43. Thompsons Harbor State Park		X						
44. Hoeft State Park		X						
45. Cheboygan State Park		**X**						
46. Point Catosh, Bois Blanc Island (MI DNR)		X						

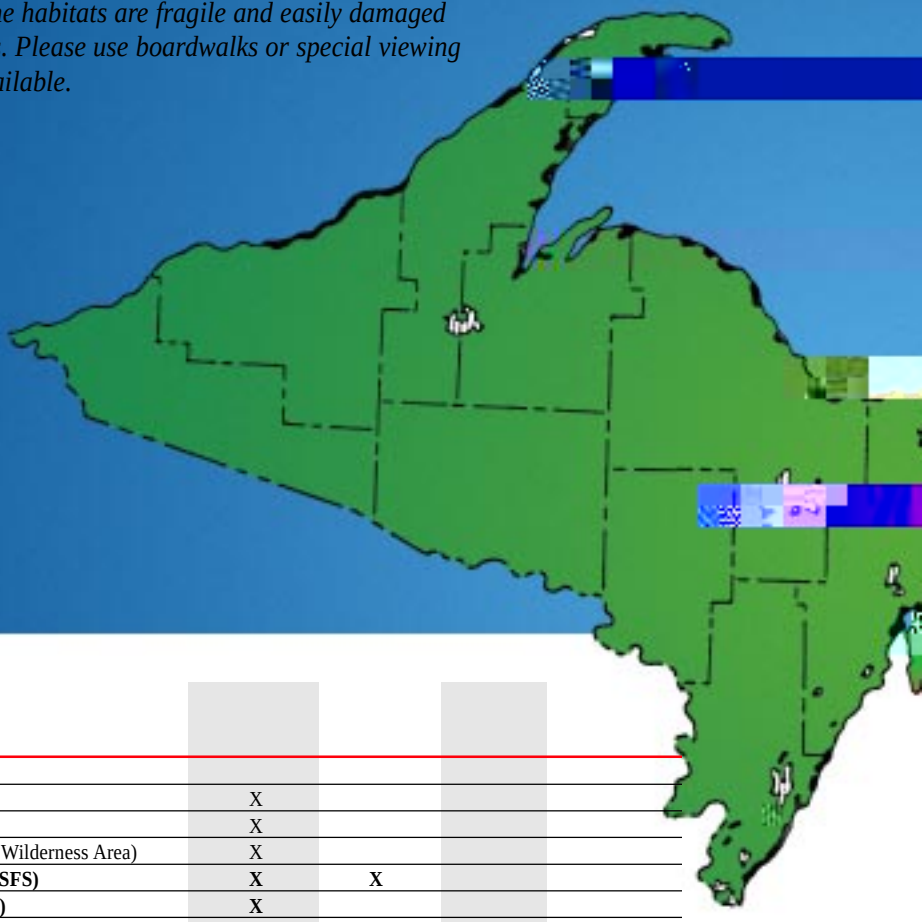
Codes:

Bolded sites are excellent examples of dune types with easy access.

* Interpretative Services Available.

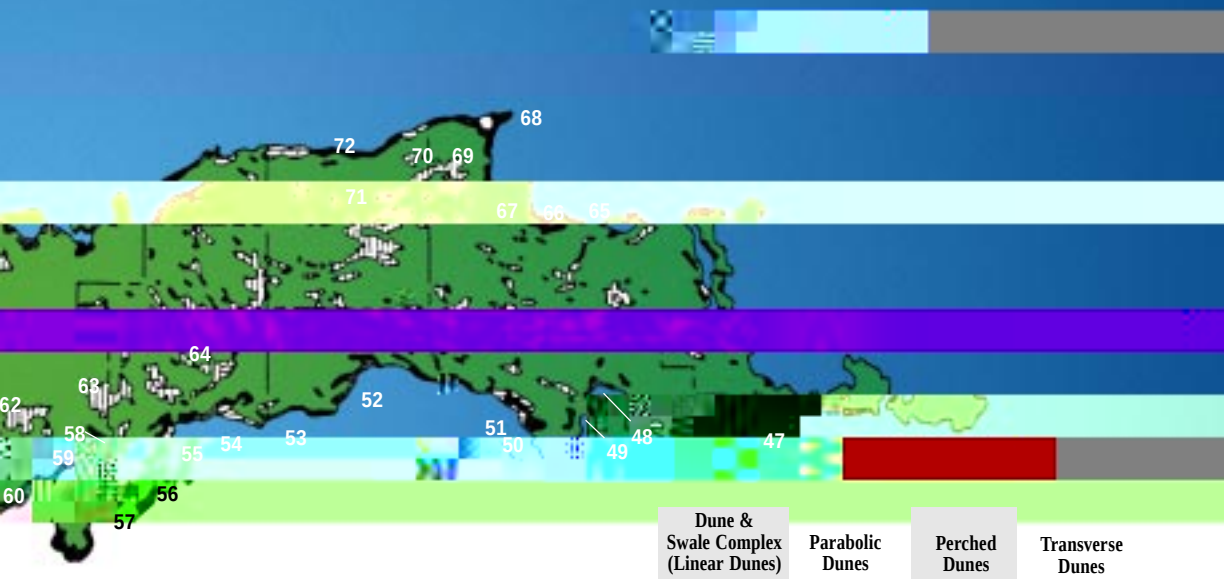
DUNES IN MICHIGAN - UPPER PENINSULA

Remember that dune habitats are fragile and easily damaged by human activities. Please use boardwalks or special viewing platforms when available.



47. De Tour State Park	X		
48. St. Martin Bay (USFS	X		
49. Horseshoe Bay (USFS Wilderness Area)	X		
50. Pointe aux Chenes (USFS)	**X**	**X**	
51. Brevoort Lake (USFS)	**X**		
52. Big Knob State Forest Campground	**X**		
53. Seiners Point to Point Patterson (MI DNR)	X		
54. Seul Choix Point West (MI DNR)	X		
55. Thompson State Roadside Park (MI DNR)	X		
56. Portage Bay (MI DNR)	X		
57. Sucker Lake (MI DNR)	X		

SAND DUNES ON PUBLICLY-OWNED LANDS OR PRIVATE NATURE PRESERVES IN UPPER MICHIGAN



	Dune & Swale Complex (Linear Dunes)	Parabolic Dunes	Perched Dunes	Transverse Dunes
69. Tahquamenon Falls State Park	**X**			**X**
70. Swamp Lakes (Preserve: The Nature Conservancy)				X
71. McMahon Lake(MI DNR and Nature Conservancy Preserve)				X
72. Two-Hearted River Mouth	X	X		
73. Muskallonge Lake to Grand Marais (MI DNR)	X			X
74. Grand Sable Dunes (Pictured Rocks Nat'l. Lakeshore)*				**X**
75. 12-Mile Beach (Pictured Rocks Nat'l. Lakeshore)	X			
76. Grand Island (USFS Federal Recreation Area)	**X**			
77. Au Train Bay (USFS and MI State Roadside Park)	X			
78. Little Presque Isle (MI DNR)	X			
79. Pequaming (MI DNR and TWP. Park)	X			
80. Baraga State Park	X			
81. Traverse Bay County Park	X			
82. Eagle Harbor (Michigan Nature Association Preserve)	X	X		
83. Great Sand Bay (Michigan Nature Association Preserve)			X	
84. F. J. McLain State Park	X			
85. Sleeping Bay and Misery Bay (MI DNR)	X			

Codes:

Bolded sites are excellent examples of dune types with easy access.

* Interpretative Services Available.

REFERENCED SPECIES: COMMON AND LATIN

Amphibians	
Blanchard's cricket frog	*Acris crepitans blanchardi*
Blue-spotted salamander	*Ambystoma laterale*
Fowler's toad	*Bufo fowleri*
Northern leopard frog	*Rana pipiens*
Red-backed salamander	*Plethodon cinereus*
Spring peeper	*Pseudacris crucifer crucifer*
Arthropods - Spiders	
Wolf spider	*Lycosidae* (Family)
Birds	
American bittern	*Botaurus lentiginosus*
American kestrel	*Falco sparverius*
Bald eagle	*Haliaeetus leucocephalus*
Black tern	*Chlidonias niger*
Black-and-white warbler	*Mniotilta varia*
Black-backed woodpecker	*Picoides arcticus*
Black-billed cuckoo	*Coccyzus erythropthalmus*
Black-throated green warbler	*Dendroica virens*
Blackburnian warbler	*Dendroica fusca*
Bluebird, eastern	*Sialia sialis*
Broad-winged hawk	*Buteo platypterus*
Common loon	*Gavia immer*
Common snipe	*Gallinago gallinago*
Cooper's hawk	*Accipiter cooperii*

RARE PLANTS & ANIMALS

RARE PLANTS OF THE DUNES AND ASSOCIATED WETLANDS

Common Name	***Latin Name***	**South**	**North**	**South**	**North**	**South**	**North**	**South**	**North**
Alga pondweed	*Potamogeton confervoides*								**X**
American dune wild-rye	*Elymus mollis*		**S**		**S**		**S**		
American shore-grass	*Littorella uniflora* var. *americana*		**S**						X
Auricled twayblade	*Listera auriculata*		**S**						
Bald-rush	*Psilocarya scirpoides*			M					
Beauty sedge	*Carex concinna*		M,H						
Black-fruited spike-rush	*Eleocharis melanocarpa*			M					
Blue wild-rye	*Elymus glaucus*						S		
Butterwort	*Pinguicula vulgaris*		**M,H**						
Calypso	*Calypso bulbosa*		**M,H,S**		M,S		M,S		
Canada rice-grass	*Oryzopsis canadensis*								**X**
Carey's smartweed									

RARE ANIMALS OF THE DUNES AND ASSOCIATED WETLANDS

Common Name	*Latin Name*	Dune & Swale Complex (Linear Dunes)		Parabolic Dunes		Perched Dunes		Transverse Dunes	
		South	North	South	North	South	North	South	North
AMPHIBIANS									
Blanchard's cricket frog	*Acris crepitans blanchardi*			M					
BIRDS									
Bald eagle	*Haliaeetus leucocephalus*	H	**M,H,S**		**M,S**		**M,S**		**X**
Black tern	*Chlidonias niger*		S						
Black-backed woodpecker	*Picoides arcticus*		M,H,S						X
Common loon	*Gavia immer*								**X**
Merlin	*Falco columbarius*						S		X
Osprey	*Pandion haliaetus*		S,M,H						X
Peregrine falcon	*Falco peregrinus*						M		
Piping plover	*Charadrius melodus*		M,H,S	M	**M**		**M,S**		
Tern, caspian	*Sterna caspia*				M		M		
Tern, common	*Sterna hirundo*	H	H		M		M		
Tern, Forester's	*Sterna foresteri*	H							
Warbler, cerulean	*Dendroica cerulea*				M				
Warbler, prairie	*Dendroica discolor*			**M**	M		M		
INSECTS - BUTTERFLIES AND MOTHS									
Aweme borer	*Papaipema aweme*		M						
Dune cutworm	*Euxoa aurulenta*			M					
Frigga fritillary	*Boloria frigga*		S						X
Grizzled skipper	*Pyrgus centaureae wyandot*		**H**						
INSECTS - CICADAS AND HOPPERS									
Spittlebug									

RECOMMENDED DUNE LITERATURE

Atlas of Critical Dunes. Michigan Department of Natural Resources Land and Water Management Division. 1989. (now in Michigan DEQ)

A Field Guide to Great Lakes Coastal Plants. Walter J. Hoagman. Michigan Sea Grant Extension. 1994.

Discovering Great Lakes Dunes. Elizabeth Brockwell-Tillman and Earl Wolf. Michigan State University Extension, Michigan Sea Grant, and Gillette Natural History Association. 1998.

Dune Country: A Hiker's Guide to the Indiana Dunes. Glenda Daniel. Swallow Press. 1984.

Dune Type Inventory and Barrier Dune Classification Study of Michigan's Lake Michigan Shore. William R. Buckler. Report of Investigation 23, Geological Survey Division, Department of Natural Resources. 1979.

Geology of Michigan. John A. Dorr, Jr. and Donald F. Eschman. University of Michigan Press. 1970.

Great Lakes Dune Ecosystems. Michigan State University Extension. 1998.

Grand Mere. Grand Mere Association. Kalamazoo Nature Center. 1973.

Michigan's Sand Dunes. Steven E. Wilson. Pamphlet 7, Michigan Department of Natural Resources, Geological Survey Division.

Michigan Coastal Dunes: a heritage worth saving. Natural Heritage Program. Michigan Department of Natural Resources. Poster.

Sand Dunes of the Great Lakes. Edna and C. J. Elfont. Sleeping Bear Press. 1997.

Up and Down the Dunes. Emma Pitcher. Shirley Heinze Environmental Fund. 1987.

ACKNOWLEDGMENTS

Funding