Journal of the Minnesota Academy of Science

Volume 46 | Number 3 Article 6

1980

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ABSTRACT—Observations of environmental conditions and biota in four depressed spots, called "vernal ponds", within the Northwoods Audubon Center near Sandstone, Minnesota, are reported for the period March 15 to September 4, 1977. Life cycle dynamics and utilization of the pond areas are considered in relation to time, days of the month, moisture-dryness, and species; but are lumped together for reporting as if the four locations were a single pond entity. Hypotheses as to the role of these ponds in the surrounding ecosystem and questions for possible further investigation are suggested.

In the woods and fields of Northwoods Audubon Center there are many depressions that fill with water following spring melt and heavy rains. The depressions are created by the root systems of fallen trees (cradle knolls), land moving operations such as shallow gravel pits, and irregular deposition of glacial till. The latter type holes are predominant in vernal pond formation.

The term "vernal pond" refers to the pond's normal cycle following melt water and summer dryness. This pattern has been observed over six months, but the weather of 1977 produced an irregular pattern due to the severe soil dryness resulting from the drouth of 1976 and ended in a deluge of rain during August and September. The ponds remained filled with water from early August throughout the fall and then froze.

Concern for these ponds is related to their ecological role in the life of our forests, and this report concentrates on observable phenomenoa rather than chemical analysis and microscopic work. The role of the ponds is discussed through things that anyone could observe if time were taken and relate to a naturalist's curiosity.

In regular visits pond depths were measured, and records were made of temperature, tracks, observable vertebrates and invertebrates on the surface, and sampled invertebrates within the pond taken with a nylon-stocking plankton net. Four ponds were chosen for comparison purposes, as follows:

Pond number 1 is circular in shape and is on a hill, draining to a larger pond below. The drainage pattern for this pond is very small and, therefore, it depends on great snow accumulation. The basin is humus, but lacks herbaceous plants. Hardwoods dominate the surrounding land. The highest elevation around the pond is 10 feet above the shallowest point. The furthest point of drainage is 240 feet from the center, but the average drainage distance is only 88 feet, with no apparent drainage channels.

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Pond number 2 is also a woodland pond. Its drainage area is very flat and broad. The highest point over the basin bottom is 6 feet above and 100 feet away. The drainage area is hard to estimate.

Vegetation includes blue flag iris, sticktights, sedge (species unknown), sarsaparilla, and lady and sensitive fern. Surround ing this pond are three large toothed aspens, three black ash, nine red maple, two paper birch, four balsam and one red oak. Saplings (less than 3 inch DBH) were dominated by poplar but included three ash and two oak. The balsams had 80 percent of their needles over the pond, which demonstrates the pond's influence on the vegetative growth.

The rocks and old root hummocks were covered with moss. Hair cap *(polytrichum)* and tree moss *(climacium)* dominated the ground and hedwigia covered the rocks.

Pond number 3 is a small depression in a fallow field that is dominated by blue grass (poa) and brome grass in the flat areas and canary reed grass in the lower spots. The area that collects water has Virginia speedwell, marsh St. Johnswort, ragweed and unidentified sedges as the dominant basin plants. Canada goldenrod is also common. A clump of leafy bulrush is also a good indicator of the wet conditions.

The drainage area is limited to 6 feet from the east and 60 feet in other directions.

Pond number 4 is in the same field as number 3 but is located on exposed gravel in a cut that was made for road fill. The basin has a bottom of clay washed in from the steep side banks. It lacks the leaves and decaying grass of the other three ponds. On three sides this pond has steep 45-60 degree banks with no other drainage. On the south there is a 125-foot gradual slope that does not rise more than two feet from the lowest point.

The banks are lined with canary reed grass, with brome and bluegrass above it. On the edge of the pond are beaked rush *(rhynocarus)* and lake bank sedge *(carex lacustris)*. Scattered foxtail, barnyard grass and glyceria are the collecting basin grasses. Purslane speedwell (veronica peregrina), clovers (alsike, white, red and sweet), ragweed and fleabane are the dominant basin flowering plants. Canada goldenrod is also common and knapweed and chicory bloom on the banks above the water line. Balsam poplar and willow are the woody plants that are establishing themselves in the pond.

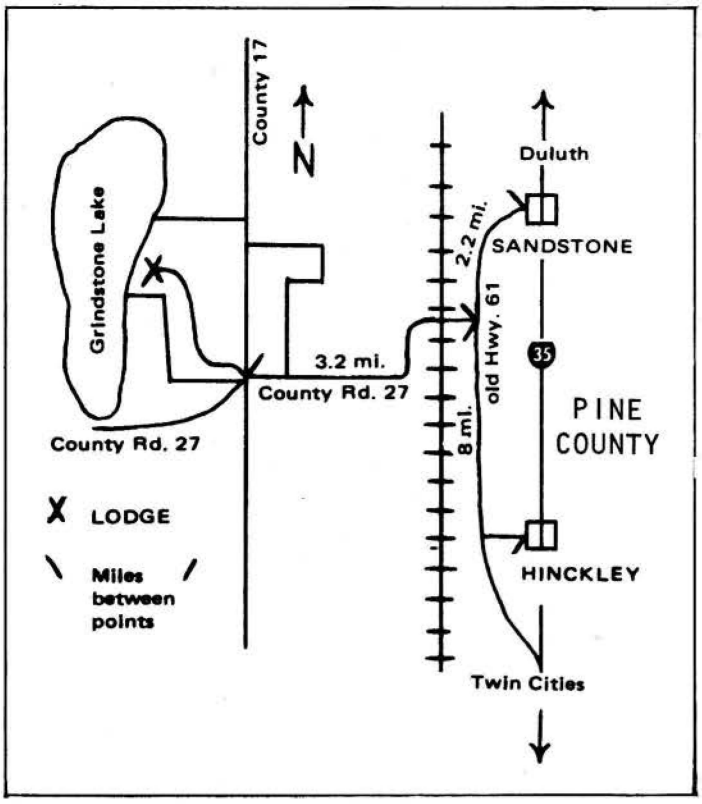

Figure 1. — The Northwoods Audubon Center is located in Pine County, Minnesota, west of the town of Sandstone.

Physical Factors Pertinent to Observations

The area receives 570 mm of rain from March 20 to September 4 in typical years. During this time rain fell 31 days from March 20 to August 7. During the remainder of August there were 12 rain days.

For the 134 days from March 20 to August 1 pond number 1 held water for 3 days (2.2 percent), pond 2 for 45 days (33.6 percent), pond 3 for 31 days (22.4 percent), and pond 4 for 74 days (55.2 percent). Table A shows rain days and pond depths.

The pattern for water holding is very erratic. Initially pond 3 was the only one to hold water, being in the field where the sun melted more snow than in the woods. Pond 4 had water percolate between the curled plates of clay and through the sand until the clay was sufficiently wet to cover the entire basin.

From the end of March through mid-June the impermeable clay held water in pond 4 while all the others were dry. The increased drainage in pond 3 is hypothesized as the result of ground ice elimination.

In mid-April pond 2 in the woods began to hold water, as did pond 4. This seemed to indicate that ground moisture which had been tremendously low was then becoming closer to normal and percolation was slowed as a result.

Pond 4 was the only active June water body until a July 4 downpour, and ponds held water from then on through July 22, with the exception of pond 1, which held water for only two days.

Pond 4 was more exposed to sun and wind than ponds 2 and 3, but seemed to have good staying power despite its broad, shallow, unshaded basin. Perhaps the percolation rate of the other basins offset the evaporation rate of pond 4 while its clay soil almost eliminated percolation.

Life that could be observed beneath the ice, and periodic temperature readings were taken to understand the conditions in which life existed. The data is summarized in Table B. A fascinating reading was on March 21, when temperature varied from zero celsius for the air and the surface ice to a +7 degrees celsius 95 mm below the ice.

The dark humus and the ice lens worked like a solar collector and provided the small invertebrates with a place to live before other organisms could enjoy the benefits of spring. Later this was not as dramatically beneficial. In some cases the air was even warmer, but the important factor was the pond's ability to retain heat. The midnight readings of April 22 indicate that the water does not fluctuate in temperature as rapidly as the air, which might be an important factor in the life of the pond creatures.

Large Animal Life Around and In the Pond:

Pond 1. During the preliminary mapping of the pond three buck rubs were noticed on saplings growing in the basin. Each woodland pond in the area supported some sapling growth, and in many ponds there was evidence that these saplings seldom reach maturity. The pond areas may be a consistent source of food and buck rubs.

A grey squirrel and chipmunk were active around the ponds the latter setting up residence in a stump near the center of the basin. A vireo nest was near. Pileated woodpeckers, hairy woodpeckers and blue jays could be heard in the area.

Most of the period during which other ponds held water, pond 1 had wet humus. There were skunk pawing marks, which might indicate that skunks were seeking grubs or insects in the damp soil.

The only day that water was present, fingernail clams were abundant, as were snails. A water scavenger beetle was active and so was an unidentified spider.

At pond 2 skunk tracks in the melt period indicated digging in the mud and leaves. Subsequent flooding showed that this pond had a high population of angleworms. Under water the population that was apparent from surface observation was 12-15 per square foot. Others may have been under the leaves. When the water dissipated, worms were not observed.

Large invertebrates in the pond water included diving beetles, water scavenger beetles and, in July, whirligig beetles. Mammals that were sighted at the pond included fox squirrels, grey squirrels, white-tailed deer, porcupine, and flying squirrels. None was observed actively drinking or hunting.

Chickadees tended to frequent the trees around the pond more than any other bird. A wood frog near the pond and a garter snake swimming in the water were the remaining vertebrate observations.

At pond 3 invertebrates in the water were predacious diving beetles, water crawling beetles, and water scavenger beetles. A fisher spider worked the surface and red mites were observed in the water. A ground squirrel and leopard frog were observed ashore during the summer and grasshoppers, crickets and leaf hoppers were common in the grasses.

Pond 4 offered a great number of observations because it held water more than the others and the clay bottom retained tracks better. Diving beetles and water scavenger beetles were most numerous and were observed whenever water was in the pond. The diving beetles would line up along the shore under overhanging grasses, remaining totally immersed. Red mites and water boatman were frequently seen. The boatman population would fluctuate from the dominant position to almost none.

Snails (*bulimnea and physa)* were observed in large numbers, frequenting the pond vegetation. In one instance many

were observed floating mouth upward, as though gasping for air or feeding on the neuston. This observation was made on July 22.

Grasshoppers were common along the pond edge and would often jump into the water when approached. Crickets and leaf hoppers also were numerous. In June butterflies visited the pond. Among them were tiger swallowtails, checkerspots and sulfurs.

Diving beetles were dropping our of the air into the water at this pond in June.

The first dragonflies to be observed over the water were seen on July 2. There were four species and nine individuals. They increased in number and were observed mating, feeding, and egg laying. Surface insects also first appeared in July, including water striders and whirligig beetles.

Amphibians were not part of the spring observations. A chorus frog was first seen in the water on June 30 and seven tadpoles were seen July 11. Unfortunately the pond dried up July 15. A leopard frog and wood frog were observed on September 4.

Garter snakes were seen swimming on one occasion and resting in a clay depression on another.

Mammals were night visitors to the pond and left their impressions cast in the clay. Deer were the most frequent visitors. Tracks which could be determined as new occurred on 16 days. Since it was possible for deer to approach without leaving tracks and there were days when the pond was not checked, it is possible that they were present more often. After the rain the clay would be soft, but two days of sun would bake the earth and make it much too hard for impressions, so it is significant that the tracks were found on 44 percent of the days visited with water in the pond. The greatest number of deer indicated for one evening was three. This was noted quite often, which probably indicates a doe and two fawns.

Other mammal or track observations included mink on two days and coyote, raccoon, fox, ground squirrel, or mouse, one day each.

Birds were observed in the field, but did not appear to interact with the pond until summer. A kingbird sat on a thistle stalk on the north end of the pond and flew hunting sorties over the pond and back. On one occasion the bird broke the surface of the water while in flight. It is unknown if the bird was taking a surface insect or a drink, but the first seems more probable.

Other songbirds observed near the pond were a grasshopper sparrow, tree swallow and goldfinch.

A killdeer was observed walking on the ground in the basin, but other actions were not seen. A snipe was heard in its mating performance in the same field.

The most unusual observations were tracks. A mouse track was observed terminating at the pond's edge, where owl tracks were evident. The source of liquid for one was, apparently, meat for another.

A number of holes measuring 3 to 4 mm in diameter and 10 mm long were scattered in the clay near the water. These were usually 15 to 35 mm deep and were at an angle. They appeared to be probing marks, but foot prints were not seen.

Small Invertebrates, Larva and Algae:

The ponds were able to fill with life within 24 hours of rain. Many organisms probably were dormant in the soil between rains, others flew to the ponds or possibly fell to the earth with the rain.

Ponds that were dormant tended to start up at the same point as active ponds when rain filled the basins. This could be accounted for by interstitial life in the damp soil or some organisms could be passed over in the cycle. For example pond 2 and a pond outside of the four study sites had daphnia the first week of May, while the rest of the ponds were dry then and never had daphnia.

Pond 1 is another example. Having water only two days during the year, instead of beginning its aquatic period with abundant copepods it began with seed shrimp, which were dominant in other ponds at that time of year.

Fingernail clams were seen initially on

A Fingernail clams were seen initially on April 22 in both ponds 2 and 4. Pond 3, dry then, never had any.

Phantom midges appeared in both pond 2 and 3 for the first time on July 21.

Pond 1 had water only July 4 and 5. The dominant species were mosquito larva and clam shrimp (eubranchiopod), with midges and cyclops (copepods) being the only other species.

Fairy shrimp appeared in only one pond for three days, but the clam shrimp, also a eubranchiopod, were long-duration summer occupants. Seed shrimp (ostracods) were also short-duration dwellers.

Algae Observations in the Ponds

Zygnema, a long filamentous algae, was the most abundant and appeared in all four ponds. In pond 4 it left the red clay green in color after the water evaporated or percolated away. From June 15 on, the algae was thick and increased in amount. Midges seemed to use this for refuge and many animals were observed feeding on it.

Volvox were apparent from early spring through the summer. Pond 4 had an April peak and a mid-June resurgence. Pond 3 had volvox consistently with a May 31 peak. The woodland ponds 1 and 2 did not have volvox.