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birds from a refuge in Michigan, 14 species of parasites were found; while in 17 goslings from a Utah refuge, only five species occurred.

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EXPERIMENTS AND OBSERVATIONS DESIGNED TO SHOW CARP DESTRUCTION OF AQUATIC VEGETATION

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It is contended that carp (*Cyprinus carpio*) are extremely destructive to aquatic vegetation, but the evidence for such a statement is generally circumstantial. In southeastern Wisconsin, where the carp problem is most acute, the necessity of demonstrating such destructiveness under natural conditions became urgent both for research purposes and for education of the public. Experiments performed in 1951 and 1952 were conclusive enough to permit making a preliminary report.

There are a number of references in the literature which relate the scarcity of aquatic plants to carp. In Wisconsin, Cahn (1929) diagnosed the destruction by making observations on a drawn-down mill pond which was completely barren of vegetation. Black (1946), in 1944, was the first to carry out a controlled experiment. He divided a small

pond which had grown up to vegetation, introducing carp into one half and leaving the other half as control. Decided destruction of aquatic vegetation was evident after 51 days in the experimental half of the pond. Anderson (1950) described considerable improvement in the growth of aquatic vegetation in a pond in Ohio following removal of rough fish, where, prior to control of rough fish, turbid water and only occasional sprigs of vegetation were found.

The first evidence in this investigation that carp destroy aquatic plants was accidentally noted following the installation of a carp trap across the narrow neck of water leading out of a bay in Beaver Dam Lake, Dodge County, Wisconsin. With exclusion of carp from this bay, a dense stand of coontail (*Ceratophyllum demersum*) developed along with a minor stand of sago pondweed (*Potomageton pectinatus*). Nowhere else in the lake was there an equivalent stand of aquatic vegetation. In a repetition of observations in 1951 and 1952, it was found that carp were abundant and vegetation completely lacking. Essentially this same situation was repeated by excluding carp from a shallow bay in Lake Mason, Adams County. Here, again, the main basin of the lake had little vegetation, whereas it was abundant in the protected area.

These rather superficial observations were grounds to test more thoroughly the hypothesis that, given protection from carp, aquatic vegetation will prosper. Accordingly, in 1951, seven circular exclosures of chicken wire, each with a diameter of 16 feet, were constructed and installed in three lakes, Buffalo Lake, Lake Puckaway, and Lake Koshkonong, and again in 1952 in Lake Koshkonong. In addition, an entire bay of Lake Koshkonong was fenced off with chicken wire and observations made on changes in aquatic vegetation.

Circular exclosures were placed in the three locations in Lake Koshkonong and two localities in each of the other two lakes on July 5, 1951 (Table 1). The locations were chosen for having various conditions such as no vegetation, abundance of carp, mud bottom, sand bottom, exposure to and protection from wave action. Furthermore, chicken wire was used in the construction to minimize dissipation of wave action.

Inspection of these areas on August 7,

TABLE 1.—LOCATIONS AND DESCRIPTIONS OF CARP EXCLOSURES BUILT IN THREE WISCONSIN LAKES, JULY 5, 1951

	Lake	Location	Bottom type	Depth	Vegetation	State of rough fish problem
1.	Koshkonong	Revfik's Bay	Muck	3′	Sago pondweed	Acute
2.	Koshkonong	Thiebeau Pt.	Sand	2′	Floating leaf pondweed	Acute
3.	Koshkonong	Olson's Bay	Soft sand and muck	2′	Sago pondweed	Acute
4.	Buffalo	Outlet	Sand	3′	None	Acute
5.	Buffalo	Midlake Bay	Muck	18″	None	Acute
6.	Puckaway	Dredge bank	Muck	2′	Whitestem pondweed + 7 other species	Moderate
7.	Puckaway	Sandy Pt.	Sand	2′	Wild celery—scarce	Moderate

and September 11, of the same year yielded contrasting results. Those in Buffalo Lake had no vegetation before installation and none developed afterward. In Lake Puckaway there was no difference in the vegetation inside and outside the structures. At Lake Koshkonong the Olson's Bay structure, inside which there was no vegetation at the start, still had no vegetation inside, but there were beds outside. In the Revfik's Bay structure the vegetation inside the exclosure had disappeared while outside there were still scattered stems visible. Only in the Thiebeau Point structure was there a decided difference. Here there was more vegetation, namely floating-leaf pondweed (*P. americanus*), inside the structure than outside.

Although these results appear inconclusive at first glance, it was found that from three to nine inches of silt had been deposited inside the exclosures located in Buffalo Lake and Lake Koshkonong. Since all exclosures were located in reasonably protected locations where little wind action could be expected, activity of fish in roiling the bottom was held responsible for the deposition of silt. Possibly the deposit of 7 inches of silt smothered out plants in the Revfik's Bay location and prevented establishment elsewhere.

Under protection from fish, floating-leaf pondweed thrived at Thiebeau Point. To substantiate this, the same location was enclosed in 1952 on May 4, and another exclosure built beyond it in 34 inches of water where the bottom was soft mud. The in-shore exclosure over the sand bottom again enclosed floating-leaf pondweed and in addition scattered stems of sago. The outer exclosure contained only scattered stems of sago pondweed.

On July 3, both had dense stands of vegetation inside as well as outside. On August 15, most sago stems had wilted following fruiting and only a tangled mass of stems lay on the bottom. In the outer exclosure over soft bottom there appeared to be a slightly greater quantity of vegetation inside than in an equal area outside.

Although the sago disappeared, the floating-leaf pondweed prospered into September at the inner location. However, unlike the previous year there was a good stand of vegetation both inside and outside. When measurements of depth were taken, it was found that the depth was four inches less than surrounding areas at the inner location and eight inches less at the outer. The definite improvement in the growth of the vegetation can be associated with lessened carp activity, as indicated by the decreased catch per unit effort for carp fishermen, a decline from 18,862 pounds to 10,667 pounds. Even though there was sufficient fish activity to have caused deposition of silt similar to that the year before inside the exclosures plants were apparently thriving. Thus, it became apparent that silt was not necessarily a deterrent to growth of established plants as suggested by earlier observations.

As mentioned earlier, a chicken-wire fence was stretched across the entire mouth of Bingham's Bay, one of several comparable bays in Lake Koshkonong, a distance of approximately 1,600 feet. This fence was constructed on July 3, with a "V" leading lakeward to allow the escape of any fish which may have been entrapped in the 75 acres of water

enclosed by the fence. At time of construction, vegetation (mainly sago pondweed and a trace of coontail) was abundant both inside and outside the fence and the water was generally turbid.

The first inspection on July 9, showed early signs of improvement despite the fact that part of the fence had been disturbed. A Secchi disk reading of 26 inches was taken inside the fence while outside it was only 13 inches. Already, coontail had largely disappeared outside the fence whereas it was common inside.

In another inspection on August 15, turbidity was sufficient to blot out the Secchi disk at 15 inches in the lake. Inside the fence the bottom was clearly visible at three feet, there was no sign of turbidity, and there was a blanket of aquatic vegetation so dense it was impossible to run an outboard motor through it. Species observed were as follows: coontail, very abundant; floating-leaf pondweed, common; leafy pondweed (*P. foliosus*), common; flatstem pondweed (*P. zosteriformis*), common; and sago pondweed, common. In no other bay on the lake was there a stand of vegetation which approached that in Bingham's Bay in density or species composition.

The fence was removed on August 29, because high waters had reduced the effectiveness of the barrier. Vegetation was still very dense in the upper two-thirds of the bay and was comprised of essentially the same species along with some additions. A trace of wild rice (*Zizania aquatica*) was evident, naiad (*Najas flexilis*) common, and water weed (*Anacharis canadensis*) abundant. On all the inspections two small clones of yellow water lilies (*Nuphar*) were present.

In the lower third of the bay, where carp had access, vegetation was already greatly thinned and water muddied. It appeared as though carp were progressively browsing their way into the interior of the bed of vegetation.

Carp are apparently so closely associated with vegetation in their ecology in shallow waters that any major decrease in their numbers is quickly demonstrated by a recovery of vegetation. They appear not greatly unlike swine in their activities and succeeded in roiling water sufficiently to deposit as much as nine inches of silt on a protected area during a two-month summer period. Turbidity was increased sufficiently to decrease by one-half or more the distance light penetrates in the water.

Closing off an entire bay demonstrated the prolific nature of the vegetation and the destructive and grazing potential of carp. With protection, the vegetation developed into blanket proportions within only a part of one season while only barren waters lay outside the protected areas. The carp's approach to a new pasture of aquatics consisted of working the edge and opening the bed gradually. Should one be looking for signs of carp abundance, openings in the vegetation rather than the depletion of individual species of aquatic plants appear to be a good indicator. Fencing off a bay was successful enough to say that the practice has promise in protecting the vegetation of shallow bays for waterfowl.

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THE EFFECT OF CARP EXCLOSURES ON GROWTH OF SUBMERGED AQUATIC VEGETATION IN PYMATUNING LAKE, PENNSYLVANIA [1]

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Numerous workers have noted an association between a high population of carp and a low population of submerged, rooted aquatic vegetation. Ricker and Gottschalk, (1940), found that removing coarse fish resulted in an increase in extent and density of vegetation in Bass Lake, Indiana. The mechanism behind this association varies in kind and degree according to the ecological conditions presented by the body of water in which carp and vegetation occur. The bulk of experimental evidence that carp reduce vegetation has been derived from artificial ponds and other small bodies of water. Since this association exists in Pymatuning Lake to an unusual degree, it was decided to use fenced quadrats as a means of determining the effect produced by exclusion of carp during the growing season on vegetative growth.

Furthermore, quantitative studies of rooted submerged aquatic plants are scarce, as pointed out by Wilson (1939).

Pymatuning Lake is an impounded body of water on the border between Pennsylvania and Ohio. The upper portion known as Sanctuary Lake, lies entirely within a waterfowl sanctuary administered by the Pennsylvania Game Commission. It is separated from the rest of the lake by a dam that maintains it at a level at least two feet above that of the lower portion. The level is maintained throughout the year except when drawn down a foot in the summer by the Game Commission so that more shore area is exposed for vegetative growth. Sanctuary Lake contains about 2500 surface acres and has an average depth of six feet with a maximum depth of nine feet.

The temperature of the lake varies from 32°F. in the winter to 88°F. in the summer. During the winter the ice cover is not constant for more than a few weeks at a time. Light penetration during the growing season is relatively slight due to more or less constant blooms of blue-green algae, and to silt and detritus, stirred from bottom and shores by wave and animal activities. Light extinction as measured with a

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