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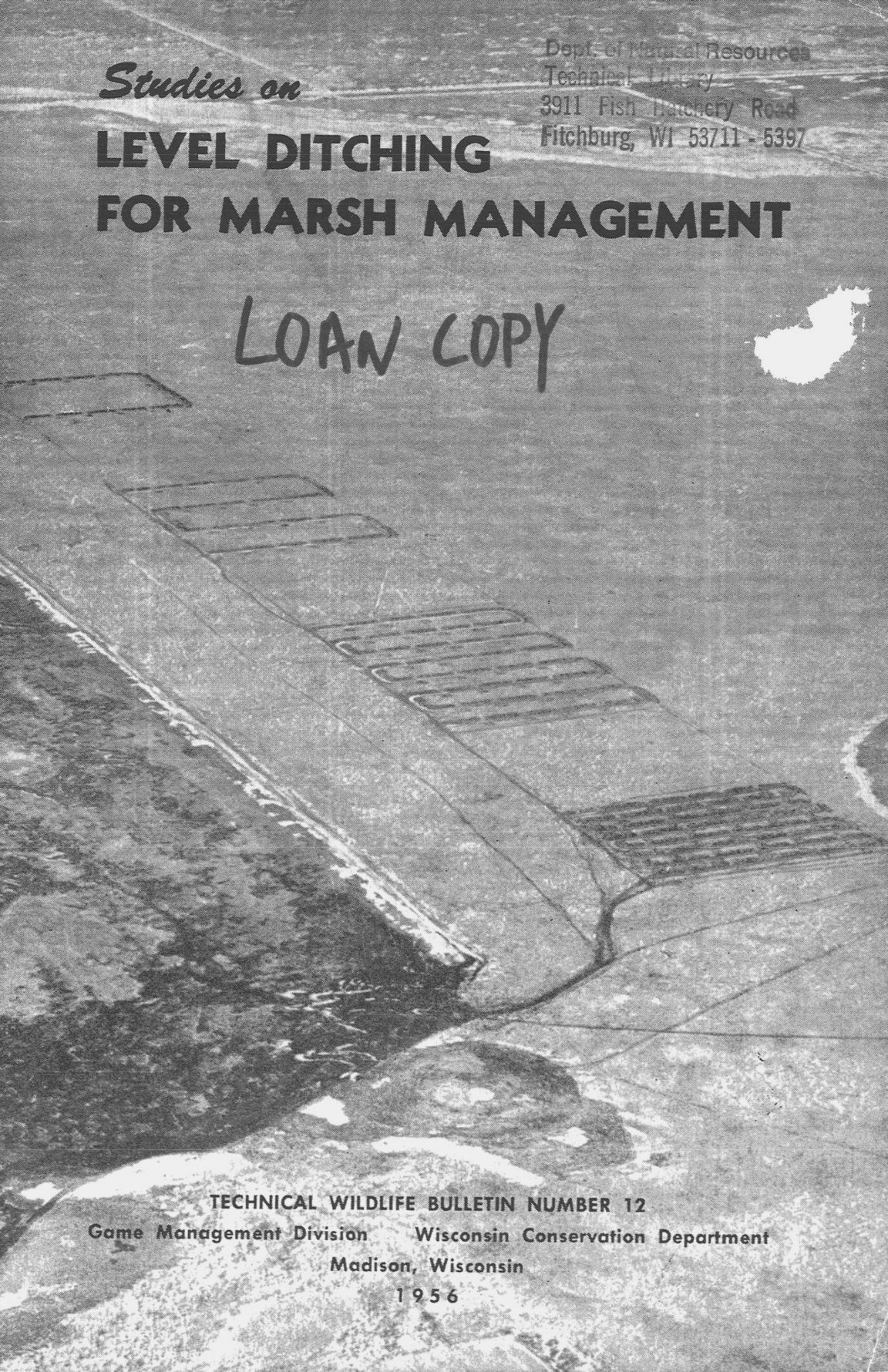

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STUDIES ON LEVEL DITCHING FOR MARSH MANAGEMENT

by

HAROLD A. MATHIAK and ARLYN F. LINDE

Final Report

Pittman—Robertson Project — 15-R
(Revision of Technical Wildlife
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Photographs were taken by Staber Reese (aerial photos) and by the authors.

Note: Three years' work (1949–1951) on the experimental ditches was reported in Technical Wildlife Bulletin Number 5 (1953). A bulletin was published at this time because of the demand for a progress report on the level ditching experiment, even though the study was not complete. Developments in the ditching study during the succeeding three years (1952–1954) have been added in the present report. Major changes in the findings which have occurred as a result of six years of work include variations in harvest, duck usage of the ditches and the loss of water depth.

Edited by Ruth L. Hine

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ABSTRACT

In order to determine what level ditch spacings result in the maximum production of muskrats, the economics involved, and the benefits of level ditching to other species of wildlife, four series of experimental level ditches were dredged in a "dry marsh" portion of the Horicon Marsh Wildlife Area.

The benefits to muskrats of level ditches are many. In this portion of the marsh, there often is not enough water to allow muskrats to obtain food throughout the critical winter period. The deeper water of the ditches, however, makes it possible for muskrats to obtain food more easily throughout the critical winter period, and the high spoilbanks offer more protection from freeze-outs than the average size muskrat house constructed of marsh vegetation. During summer drouth periods when other surface water is not available, the open water of the ditches helps hold muskrats in a marsh. In high flood periods, spoilbanks benefit muskrats and other wildlife by offering dry resting sites, feeding places, and shelter. They provide excellent nesting sites for waterfowl. Furthermore, level ditches facilitate transportation for hunting or trapping.

Dredging was superior to blasting as a method of ditch construction, for it was far more economical and produced a more desirable type of ditch. Studies of a series of blasted ditches similar to the dredged ditches were abandoned because of the prohibitive costs of dynamiting. The four ditches were constructed with a dragline at a cost of 10 cents per cubic yard, or $2,338 for 13,298 lineal feet of ditch 13 feet wide at the top and 5 feet deep. The ditching treatment varied in cost from $25 to $156 per acre for spacings of 400 feet and 50 feet between ditches respectively.

Over the six-year period during which the dredged ditches have been in existence, deterioration of the spoilbanks was slow because of the heavy bluejoint and canary grass cover. Siltation of the ditches themselves progressed faster than expected largely because of the extensive tunneling habits of the high muskrat populations. Excavated materials were generally deposited in the ditches. Ditch D4 was completely filled with muck during the low water period of 1953. As a result, the experimental ditches at Horicon remained highly productive for muskrats about six years. The ditches will, however, benefit muskrats at certain times of the year, and waterfowl and upland game for a much longer period.

Muskrats began to move into the ditches in the first few weeks following construction, and the population continued to increase for the next three years. Live-trapping and ear-tagging studies showed populations of over 600 muskrats in the ditches in 1951 and 1952. For the 35 acres in ditched plots, this represents a population of about 18 muskrats per acre. Disease drastically reduced the harvest in 1953 and the population had not built up again by 1954.

The harvest per acre from the ditched plots was from 4 to 10 times higher than the harvest from the surrounding bog. The greatest number of muskrats were harvested per acre in the ditch with the 50-foot spacing (15.3 muskrats per acre), while the ditch with the 400-foot spacing was low with only 5.8 muskrats per acre per year. Average annual returns per $100 invested in ditching were highest in the ditches with the 200- and 400-foot spacings, 21.0 and 22.8 muskrats being harvested respectively. The 200-foot spacing is recommended for future ditching because it gave a higher yield of muskrats per acre than did the ditch with the 400-foot spacing.

Muskrat movement away from the ditches was relatively slight except during one period of high density in spring. The inadequate harvest of muskrats from the ditches in the fall of 1951 resulted in a higher residual population in the spring of 1952, and this in turn resulted in greater movement away from the ditches during the breeding season. One of the important factors in the management of the ditches for muskrat production will be to regulate trapping pressure so that a large enough proportion of the population (approximately 75 per cent) is harvested to prevent the egress of resident muskrats.

Along with providing more stable water levels for muskrats, level ditches were also beneficial to other furbearers, fish and to waterfowl primarily during the nesting season. Twenty-four mallard and blue-winged teal nests were found on the spoilbanks in 1952 and 51 nests were found in 1953.

Perhaps the greatest value of level ditching is its influence in promoting the management of semi-dry marshes for wildlife production, rather than their drainage for relatively unneeded agricultural crops.

The capital which has been invested in ditching can be expected to be recovered in about four years. On the basis of the Horicon experiment, the production of muskrats justified the cost of level ditching. However, considering the shrinking waterfowl range, for both production and hunting, the value to waterfowl management from ditches might under some circumstances be even greater than the value received from the increased muskrat production.

INTRODUCTION

The muskrat is the most important wild furbearer in the United States and also in Wisconsin. For the past ten years, approximately 540,000 muskrats have been taken in Wisconsin annually with an average value of $687,000.

Landowners and game managers, therefore, are interested in further knowledge of ways to perpetuate or increase this valuable resource which is not only of considerable importance in itself, but also vitally related to other wildlife. Good muskrat-producing areas are usually good waterfowl-producing areas. Ducks and geese are quick to take advantage of habitat changes resulting from the feeding and house-building activities of muskrats. Areas managed for muskrats very often benefit also upland game, deer, and other furbearers largely through the creation of "edge effect", the value of which has long been recognized in wildlife management.

Although many muskrats will be produced in some years by letting these animals take care of themselves, management is often needed to insure a harvestable surplus each year. This is particularly true in "dry marsh" areas, where in most years there is not enough water to allow muskrats to obtain food throughout the critical winter period. In winter, a large number of houses built in shallow water may freeze up (Aldous, 1947). Errington (1939) found that there is increased mortality from intraspecific strife, predation, and random wandering in habitats which are drying out. The drier marshes are also in most danger of being drained under present agricultural land-use policies.

Many investigators have recognized that water control is one of the important features of marsh management (Gashwiler, 1948; Williams, 1950; and others). Fur farmers have been constructing dikes and ditches for years. Many of the earlier ditches were constructed to make trapping easier through use of boats. Quite often marsh management of muskrats is a vital factor in the operation of duck shooting establishments. Knowledge of ways to improve marshes for fur production may be most widely used in states where special laws allow fur farmers almost complete control of their fur harvest. Licensed fur farmers in Wisconsin, for example, are not dependent upon a general trapping season to harvest their crop. They may take their muskrats under permit even though the home county has a closed season on furbearers. Under our fur farm laws the licensee purchases the muskrats from the state and the muskrats then become his personal property.

The Wisconsin fur farm laws have, therefore, encouraged a very large number of habitat improvement projects for furbearers by private individuals.

Level ditching is one of the more practical means of improving a marsh for muskrats where flooding by means of dikes or dams is not feasible because of physical conditions (soil types or water supply), financial limitations, or legal restrictions (rights of adjoining landowners or of the public). Level ditches are dug in a marsh to create deep water areas. No drainage occurs because there are no outlets to a drainage system, or, if there is a connection to such a system, bulkheads may be used to prevent drainage at certain times of the year or to permit flooding at other times.

In a study of three Wisconsin marshes where level ditching had been installed, Anderson (1948) found that the catch of muskrats on these lands was increased by the ditching operations. Level ditches held water of sufficient depth in the winter to prevent "freeze-outs" and the subsequent loss of runner muskrats. They also provided muskrats with good cover on the spoilbanks and food in the ditches themselves.

Anderson's report opened the way for a comprehensive analysis of ditching in relation to muskrat production where studies could be started at the time the ditches were created. There was also a need for information on the most practical types of ditches and the best spacing of them for raising muskrats. The present experimental study was set up to investigate the productivity of ditches with different spacing designs for muskrats, the economics involved, and the benefits of level ditching to other species of wildlife. These facts and figures are needed in order to sell effectively the best type of level ditching program to increase the value of marshes for wildlife production. Much marshland which has been drained has proven itself poorly suited to the production of agricultural crops. Other marshes may already be dedicated to wildlife production but actually are poor producers of wildlife due to density of cover or lack of water.

Furthermore, muskrats are important to marsh management, regardless of their pelt values. Through level ditching it may be possible to better manage muskrats, and indirectly the marsh itself, for maximum efficiency.

Steadily increasing hunting pressures on public lands have stimulated the purchase of wild areas for private shooting grounds. Level ditching may be used to improve wildlife production and the hunting opportunities on such areas with no end cost to the new owners. Current stress on the value of strategically located wetlands to over-all wildlife productivity makes this an opportune time to present the benefits of level ditching which may help stimulate the "save the wetlands" program.

STUDY AREA

In order to evaluate the productivity of different ditch spacings, a dry marsh area of submarginal muskrat habitat was chosen in which to carry on the ditching study. The experiment was set up in 1948 in Unit 26 of the state-owned portion of the Horicon Marsh Wildlife Area, Dodge County. This unit embraces about 500 acres of semi-dry marsh, with a water level below the minimum level requisite for muskrat survival. Clark's ditch forms the southern boundary. Peat is mostly over 5 feet in depth in this area. The vegetation of this section of the marsh at the beginning of the experiment was predominately sedge (*Carex sp.*) and bluejoint (*Calamagrostis canadensis*). At the time the state conservation department began to manage the muskrat harvest in 1943, practically no muskrats were taken from this area except from Clark's ditch. Hay cutting operations adjacent to the ditches in 1948 illustrate the dryness of the area. Muskrat houses found in the dry bog away from the ditch were limited in number and so widely scattered that they were not worth trapping.

The area in which the ditches are located characteristically dries out in late summer, and muskrats have been frozen out in many winters because of the lack of water. Only when considerable snow is present to insulate the bog during the coldest periods are the muskrats able to survive the winter. Ideal snow conditions existed in the winter of 1950–51 and to a lesser degree in 1951. Several thousand muskrats were forced out of their houses on part of the Horicon Marsh when thick ice formed during the winter of 1953–54.

Water levels in the marsh were being gradually raised until sudden deterioration of aquatic vegetation beds in 1950 necessitated a change in management. From 1951–1953, summer draw-downs of water levels of eight-tenths of a foot were practiced in order to restore the desired balance between emergent vegetation and open water areas in the lower and central portions of the marsh. Without the draw-downs, a large, shallow, lake-like area would have developed which was not desirable from the standpoint of puddle duck usage or of the hunter since such open areas will support much less hunting pressure than a balanced marsh. An increase in the production of such valuable waterfowl food plants as smartweeds and millets was a secondary benefit of the draw-downs.

At the same time the emergent vegetation was deteriorating in the older flooded sections of the marsh, the higher water levels were increasing the proportion of good food plants in the drier portions of the marsh. Several control burns and one accidental fire in the ditched area, by lowering the marsh floor somewhat, undoubtedly hastened the growth of deeper water aquatics in the ditches. Thus by the summer of 1951, many of the bluejoint stands had disappeared, usually being replaced by sedge. Sedge stands were thinned out and invaded by cattail (*Typha latifolia*), bur reed (*Sparganium eurycarpum*) and bulrushes (*Scirpus* sp.). Higher fall and winter water levels caused continuing changes in vegetative cover so that by 1954 there were large blocks of narrow-leaf cattail (*Typha angustifolia*) in the ditched area. The narrow-leaf cattail in this semi-dry bog commonly reaches heights of 7–8 feet, making summer travel to the ditched plots difficult until paths are formed.

Although the combination of higher water levels and better food plants has resulted in greatly improved conditions for muskrats, and consequently increased summer populations, there is little chance for winter survival without continuous snow cover. Ordinarily when there is no snow on the marsh, only one week of sub-zero weather is needed to freeze-out most of the dry-bog muskrats. At the maximum legal limit of 75.3 feet there is only about 1–4 inches of water over the bog in the experimental ditch area. (The water level of Horicon Marsh is controlled by manipulation of the Horicon dam within limits prescribed by the Wisconsin Public Service Commission. Excess or deficiencies in precipitation sometimes result in a water level higher or lower than that desired for management purposes.)

Trapping such areas is very difficult and is usually deferred until ice permits easier walking or better yet, transportation of equipment by light car. Too often, travel conditions are not favorable over a long enough period to permit an adequate harvest.

LEVEL DITCHES

Construction

In December of 1948 and January of 1949 four series of ditches were dredged with spacings of 50, 100, 200, and 400 feet (referred to in this report as D5, D1, D2 and D4 respectively). The 50-foot series consisted of eight ditches in a five-acre plot. The other ditches were located in 10-acre plots 544.5 feet by 800 feet. The shape of the ditches and their location in relation to Clark's ditch are shown in Figure 1. All ditches were made 13 feet wide at the top and 5 feet

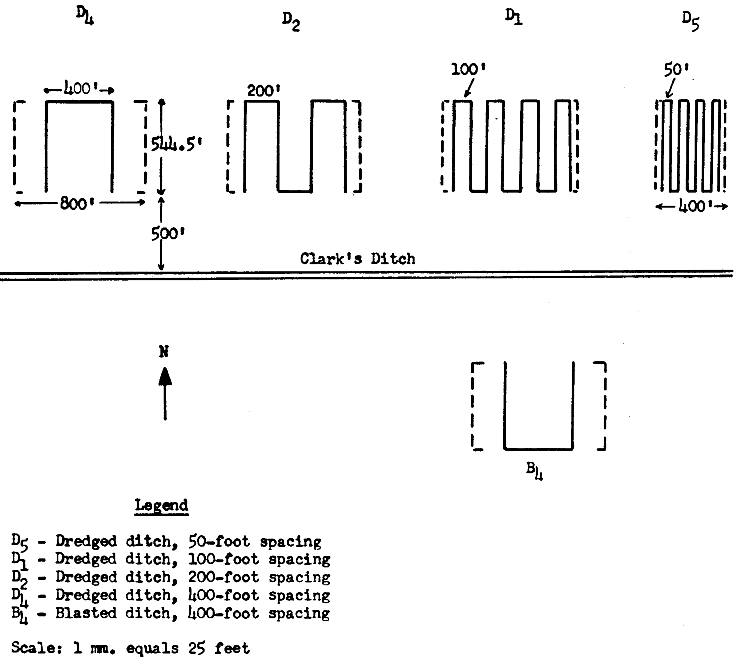

Figure 1. Experimental ditches, Horicon Marsh, Wisconsin.

deep. For convenience of travel by boat, the ends of the ditches were connected so as to form one continuous ditch within each plot. The excavated material was deposited on the north and west sides of the ditches to create spoilbanks. Gaps were created in the banks at 100-foot

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Aerial view of the experimental ditches with 100- and 50-foot spacings, showing the design of the ditches and the placement of the spoilbanks.

intervals by placing a few buckets of peat on the opposite side of the ditch. Numbered signposts were erected at 200-foot intervals along each ditch to facilitate accurate record-keeping.

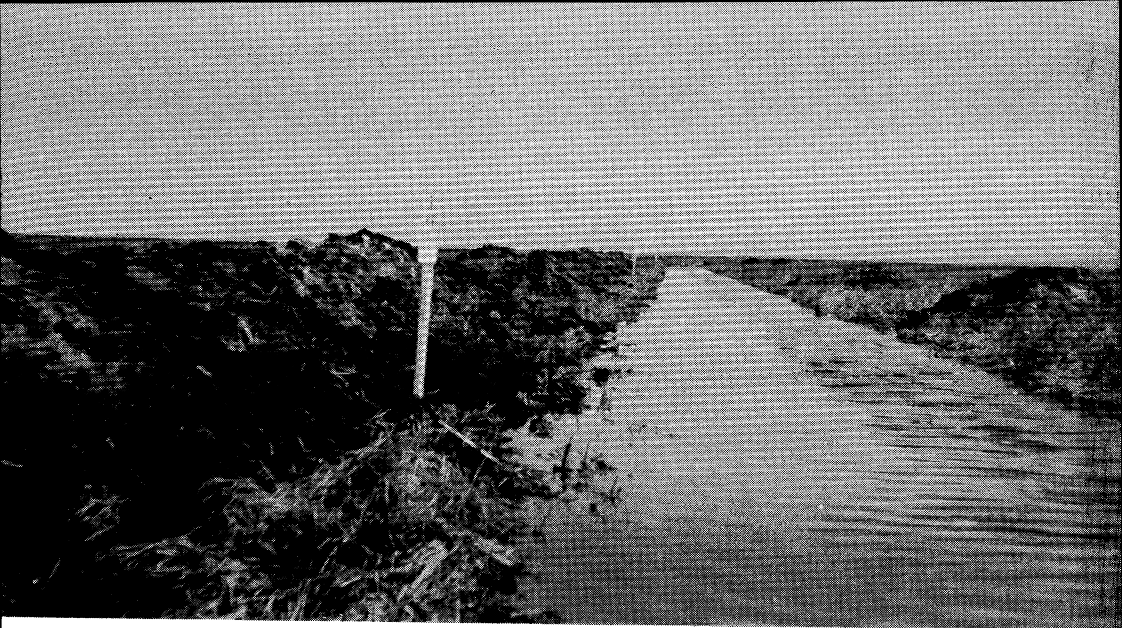
The ditches were dredged by a local dragline operator at a contract price of 10 cents per cubic yard. (Subsequent dredging costs at Horicon Marsh have ranged from 12–14 cents per cubic yard.) A three-quarter yard dragline with a one-cubic yard perforated bucket was used for the dredging. Although the frost was thick enough to support the machine when moving from plot to plot, mats were needed during the actual dredging operations. It was not necessary to use an iron ball to break through the frost at any time. The costs of each series of ditches are presented in Table 6, and will be discussed later in this report.

It was the original intention to dynamite a companion series of four ditches in order to compare dynamiting versus dredging as a means of ditch construction. Two ditches 400 feet apart were blasted in December of 1949. Four sticks of standard 50 per cent ditching dynamite placed every two feet appeared to give the best results. The location of the blasted ditch in relation to the dredged ditches is shown in Figure 1.

Biologists and engineers agreed that the ditch produced by blasting was far inferior to the dredged ditches. The blasted ditch was at least a foot shallower than the dredged ditches. Large amounts of loosened muck along the edges of the ditch proved to be highly susceptible to wave and rain erosion before protective vegetation developed. The lack of high spoilbanks desired for dens and rapid siltation drastically reduced the value of the ditch as furbearer habitat in the winter—the limiting period for muskrats in this area. Material blown from the ditch was deposited along both sides, mostly within a 50-foot space. It was sufficient to raise the level of the bog slightly but not high enough to provide dry nesting sites for waterfowl during spring floods. Furthermore, the cost of the dynamite and labor was more than twice as much as the total costs of dredging a ditch of the same length. The cost of dynamite alone at four sticks every two feet was $337.00. The entire cost of dredging the same length of ditch was only $252.00.

Provost (1948) found that blasting in a marsh to create interspersion of cover and water greatly improved the habitat for muskrats. His Iowa studies showed, however, that blasted holes were of much greater value in the deep-water emergent vegetation than in shallow-water areas.

Due to the excessive cost of blasting and the undesirable type of ditch produced in the Wisconsin study, plans to dynamite the other



View of portion of ditch following dredging.

ditches were abandoned. Productivity studies of the dynamited ditch were dropped since it is difficult to see where, under present economic conditions, dynamiting could be justified for muskrat management. The four dredged ditches will show the comparative value of various ditch spacings.

Ditch Longevity

One of the most important considerations in respect to level ditching as a management technique is the length of time the ditches remain useful to muskrats and other wildlife. At the time of dredging, the ditches averaged 5 feet in depth. An uncontrolled fire in the ditched area in December of 1949 consumed much of the emergent vegetation. As a result of the loss of the windbreaking action of the plant cover, sizable waves were produced during the flood period of the following spring. Spoilbanks not protected by patches of unburned vegetation were undercut by the waves, and the general elevation was lowered as the soil settled to form new slopes. Erosion was most serious on ditches D4 and D2 where more vegetation was burned and the wider-spaced banks allowed greater wave action. Measurements showed an average loss of depth due to wave erosion of one-half foot in D4 and D2, but only a one-tenth-foot loss in D1 and D5.

At the end of 1951, two years following dredging, the ditches were approximately 4 feet deep, which is sufficient for both summer and winter muskrat requirements. There was adequate vegetation on the banks to prevent further wave or rain erosion. However, some filling-in was becoming noticeable along the north and south sections of the ditches. Small deltas of fine vegetable remains were formed in the ditches as flood waters moved across the ditched area, the suspended materials being dropped where the deeper water of the ditches reduced the speed of the currents. The slow decomposition of organic matter further hastened the filling-in of the ditches.

From 1951 to 1954, depth losses of unexpected magnitude occurred, caused apparently by bank burrowing of the very high resident muskrat populations. On the average it required only 39 feet of ditch to produce one muskrat per year in the harvest (Table 6). Practically all the ditch muskrats resided in bank dens, which were apparently preferred to built-up houses. Materials excavated from the spoilbanks in the construction of the numerous dens were largely deposited in the ditches. Even the bog along the ditches was tunneled extensively by the muskrats, resulting in more material being deposited in the ditches. Tunneling of the bog probably occurs in the winter as the muskrats seek new food supplies. This type of feeding can be expected to become progressively more important as the water depths in the ditches decrease to the point where winter food supplies in the ditches become unavailable for longer periods due to thick ice formation. Eventually the ditch muskrats will have to depend entirely on the bog for food during periods of thick ice. The habits and survival will then correspond to the house-dwelling muskrats in adjacent bog areas. The critical point for semi-dry bog muskrats is reached when the ice and frost is about 12 inches thick. With ice depths over 15 inches, most of the food is sealed in the ice or frozen muck and unavailable to muskrats causing them to leave their homes to become winter runners.

Ditch D4 was so filled with materials excavated by muskrats that during the water draw-down and later fall drouth of 1953, the muck in the ditch actually extended one or two inches above the lowered water table. Boat travel was impossible. The muck settled somewhat over winter and the water depth in D4 was approximately 12 inches in 1954. Water depths in the other ditches ranged up to 36 inches except at places where deltas had been formed. Under-ice feeding in these ditches is still possible, at least in the deeper sections. Winter survival in future years will depend somewhat on ice depths which in turn vary according to the amount of snow cover during the coldest periods.

Ditch depths would have remained greater for a longer time if the muskrat population had not built up so rapidly. However, it was more

Delta present at the southwest end of Ditch D2 during the low water period of 1953. The activities of a high muskrat population hastened the filling in of the ditches.

desirable to have a large muskrat population and greater opportunities for large harvests as soon as possible in order to have a rapid liquidation of the ditching investment.

The question has arisen as to whether or not the ditches should be re-dredged. The cost of cleaning out the ditches by dragline would probably be more than the cost of constructing entirely new ditches. Cleaning-out is not recommended because of the cost involved, and also because the ditches improve the summer range for muskrats as long as there is any open water left, transportation is easier for harvesting, the high spoilbanks provide greater winter protection, and the value of the ditch-spoilbank combination for waterfowl is still at its peak. There is a possibility, however, of developing a cheap, portable pumping device which a marsh owner might economically operate in his spare time if labor costs were not considered.

Fur farmers have found that level ditches generally remain productive for muskrats for about ten years. Although the experimental ditches at Horicon remained highly productive for muskrats only about six years, the spoilbanks and even shallow water will continue to be of value to muskrats at certain times of the year and will certainly benefit waterfowl and upland game for a much longer period. Larger harvests can be expected from the ditched area than from an equal area of nearby bog, but the very large harvests of the first years after ditch construction will probably not be realized again.

The length of time the ditches last will vary in different localities, depending upon the soil type, erosion rate of the banks, tunneling activities of muskrats, and such human activities as trampling on banks or operation of motor boats in the ditches.

Vegetation

The establishment of vegetative cover on the spoilbanks is a vital factor in maintaining the useful life of the ditches. A rapid, heavy growth of grasses as soon after dredging as possible is desirable. Grasses are sod builders and thus are soil binders which make the banks firm, prevent erosion, retard bank freezing, and furnish ideal nesting cover for waterfowl. In many marshes the amount of residual seed in the peat is sufficiently great to give a heavy growth of vegetation the first year after dredging. There was little volunteer growth the first year on the experimental ditches, probably because the area was too wet for the drier types of vegetation (except for bluejoint, *Calamagrostis* sp.). After the completion of dredging operations and before the frost had left the ground, the banks were seeded to yellow sweet clover (*Melilotus officinalis*), canary grass (*Phalaris arundinacea*), and smartweed (*Polygonum* sp.). Because of the rough nature of the spoilbank, it was not economical to attempt to prepare a seed bed, so the seeds had to germinate without any effort being made to cover them.

Sweet clover grew well the first summer and reached maturity in the second summer. This growth retarded soil bank erosion and provided food for muskrats and cover for nesting waterfowl. Because of its rapid growth the planting was considered worthwhile even though it was replaced by other plants in the third year.

Canary grass was not conspicuous in the first summer, but increased each succeeding year until in 1955, along with bluejoint, it is the principal bank vegetation. The dense matting of blades and stems provides excellent cover for waterfowl nesting, affords spring and early summer muskrat food, and its intertwining root system gives stability to the bank.

The smartwood seeding apparently was a failure as there was as much smartweed on unplanted portions of the bank as there was on the planted area. Therefore, most of the growth can probably be attributed to volunteer growths.

By the third summer, other plants had appeared. Jewelweed (*Impatiens biflora*), thistles (*Cirsium* sp.), mints (*Mentha* sp.), nettles (*Urtica* sp.) and a scattering of other dryland species were present.

These plants were found growing mostly along the very top of the banks where the grasses made only scattered growths; bluejoint and canary grass covered the sides.

The importance of the canary grass and bluejoint cover on the ditch banks cannot be overstressed. They are now the dominant species and have given a permanent stability to the ditch banks. Where the grasses are in heavy stands it is possible to walk the banks without fear of breaking through into muskrat dens and thus further decreasing the useful life of the ditches. It was mostly in bluejoint and canary grass that the duck nests were found during the nesting studies. Banks of new ditches should be seeded to grass as soon as possible after dredging. Seeding to canary grass before the banks have a chance to dry out would be insurance against a possible lack of residual seeds of the right plant species. Addition of some white sweet clover seed would provide an early cover while the slower growing canary grass is becoming established.

Spot plantings of submerged aquatics were made on alternate ditches in the latter part of July, 1949. Coontail (*Ceratophyllum demersum*), waterweed (*Elodea canadensis*), bladderwort (*Utricularia* sp.), milfoil (*Myriophyllum* sp.) and duckweed (*Lemna* sp.) were transplanted from Clark's ditch covering approximately 50 per cent of each ditch. Wind action eventually distributed these plants to the unplanted portions of the ditches. Bladderwort and duckweed were already present in small quantities, having moved in from the surrounding bog.

In general the first summer's growth of submerged aquatics was not very conspicuous. Since then, however, these plants increased steadily until at the present time they completely choke the ditches by midsummer, making it difficult for boat travel. Most of this heavy growth is coontail but bladderwort, milfoil and waterweed are present in smaller amounts. Coontail is an important winter and early spring food for muskrats when other aquatics are used up or lacking. With the great increase in submergents has developed an annual "bloom" of green algae in the late spring and early fall. This bloom does not completely cover the ditches but occurs in separated patches. Planting of submerged aquatics is not considered necessary since they can be expected to invade ditches rather quickly and are a hindrance to boat travel at times.

The vegetative cover of the bog area in the ditched plots is constantly changing. In the summer of 1949 following dredging, the dominant species were sedge (*Carex* sp.) and bluejoint, with occasional patches of cattail (*Typha* sp.), bur reed (*Sparganium* sp.), and scattered traces of round-stem bulrush (*Scirpus* sp.), river bulrush (*Scirpus fluviatilis*), sweetflag *(Acornus Calamus)*, and reed grass *(Phragmites maxima)*. Average summer water levels increased from a reading a 74.4 at the dam in 1944 to 75.1 in 1949, an increase of seven-tenths of a foot. In 1950, late spring and summer floods brought the average up to 75.4. This brought a great increase in sedge in areas that were formerly bluejoint, and an increase in cattail stands in former sedge areas.

In the early spring of 1955 bur reed, cattail and sedge became the dominant species. Several areas formerly supporting cattail and bur reed had become small open water areas. A combination of higher water levels and muskrat feeding activities probably accounted for the opening-up process. The distribution patterns of the emergent aquatics in this area will always be in a state of change because of the great water level fluctuation during the course of each year. Water level changes as small as one or two inches may completely alter the species composition and distribution, especially where the water table is close to the surface of the bog.

MUSKRAT POPULATION

Methods of Study

Live-trapping and ear-tagging of muskrats in the ditches were scheduled each fall to facilitate analysis of population trends, the efficiency of the harvest, and movements. Live-trapping was largely confined to the months of September and October. Spring live-trapping was conducted only in 1950; in most years transportation difficulties in spring prevented this operation until well into the breeding season.

Live-trapping techniques were modified somewhat during the study until procedures were standardized as follows: Heavy pre-baiting was carried on for three scattered nights (sliced carrots placed inside traps with the doors wired open). No covering was placed on the traps, but a small amount of submerged aquatics was laid on the floor of each trap. Traps were wired on floats (two per float) spaced at 200-foot intervals in the ditches. Trapping could have been undertaken on the banks, but the floats reduced interference from other animals and also made it possible to operate entirely from a boat. Traps were set for one night on each ditch and a week or two later the process was repeated. A crew of two men was most efficient for conducting the tagging operation. One man administered the ether and recorded data while the other man sexed, aged and applied the ear-tags. Captured muskrats were transferred to cream cans and a small amount of ether added. Since an occasional large muskrat was able to jump out of a cream can, the cover was slipped over the can as the empty trap was being removed. Individual muskrats were tagged with numbered fingerling ear-tags fastened to the right ears (Aldous, 1946).

Harvesting was accomplished in the fall and early winter by means of share-trappers assisted by research personnel. Steel traps were placed on the same floats, and a few additional traps were set along the banks. Starting in 1953, live traps were used by the share-trapper instead of steel traps. They tended to shorten the harvest period since there were no wring-offs and very few snaps-offs. Live-traps were more effective in this case only because the muskrats were already accustomed to taking carrots out of the traps.

All muskrats taken on the state marsh during the trapping season were examined daily for ear tags when they were brought into the headquarters checking station so that movements away from the ditches could be detected. Muskrats taken on the experimental ditches, however, were examined immediately in order to record the exact point of capture of ear-tagged muskrats.

Live traps wired onto floats were used each fall to capture muskrats for ear-tagging.

Population Estimates

Of particular interest to game managers and fur farmers are the length of time required for muskrats to move into newly-established ditches and the rate of population increase. A brief discussion is presented below indicating the trend of the muskrat population during each year of the study. Lincoln Index calculations of the total population have not been made for each year because of the many variables involved, such as weather, ear-tag loss, movements, etc. which cannot always be uniformly evaluated. For the purpose of this paper, we felt that such an attempt to give precise population estimates was not necessary.

In the first few weeks following construction, several winter runners moved into the new ditches, and fresh muskrat sign appeared in all parts of the ditches as soon as the ice was gone in the spring of 1949. This was not unexpected since spring floods and the advent of the breeding season accelerates muskrat movements. Sign appeared so plentiful in the first fall following ditching that trapping was undertaken and a harvest of 121 muskrats achieved in 1949 (Table 6). The population increased during the next year and the harvest rose to 225.

An estimate of the population of muskrats using the ditches in 1951 was calculated using the Lincoln Index formula:

$$\frac{\text{No. Returns}}{\text{Total Tagged}} = \frac{\text{Total Harvest}}{\text{Total Population}}$$

There were 47 returns during the trapping season of muskrats ear-tagged in 1951. Five more animals had notched ears which were believed to represent lost tags, thus increasing the total returns to 52. The total number of tagged animals was 152, and the total harvest was 218. The formula then reads:

$$\frac{52}{152} = \frac{218}{\text{T.P.}} = 637$$

The total population of 637 muskrats represented 18 muskrats per acre in the ditched area of 35 acres.

Evaluation of the muskrat population in the ditches in 1952 is complicated by the fact that muskrats kept moving into the ditches during the trapping season. The tagging studies showed that these extra muskrats were not residents of nearby houses which habitually used the ditches. Rather, they were probably transient animals moving because of extreme drouth conditions and were slated to soon die of natural causes unless they happened to move into some area with water which was being actively trapped. Only through use of the ear-tagging data is it possible to estimate how many muskrats existed in the ditches prior to the trapping season and whether or not there was an influx of muskrats during the trapping season. A daily account of the 1952 harvest data is presented in Table 1. Although the final calculated population according to the Lincoln Index formula is 1025, examination of the per cent of tagged animals in the daily catch shows a marked decline in the tag returns after the 9th of November. Apparently the tagged muskrat population was about exhausted at that time and the subsequent catch was composed mostly of incoming animals. From this it is estimated that the true population of the ditches was about 750, as indicated by the November 9 population figure, and possibly as low as 631. Presumably the untagged resident muskrats were also about exhausted in the harvest by November 9.

Table 1

1952 Muskrat Population Calculations

Date	*Daily Catch*	*Cumul. Catch*	*Daily Tag Returns*	*Cumul. Tag Returns*	*Total Population**	*% Return in Daily Catch*	*% of Tags Returned Daily*	*Cumulative % of Tag Returns*
Oct. 29	99	99	30	30	657	30	15	15
30	76	175	32	62	562	42	16	31
31	61	236	19	81	580	31	10	41
Nov. 1	71	307	22	103	593	31	11	52
2	42	349	11	114	609	26	6	57
3	51	400	12	126	632	24	6	63
4	44	444	14	140	631	32	7	70
5	52	496	8	148	667	15	4	74
6	28	524	3	151	691	11	2	76
7	30	554	2	153	721	7	1	77
8	31	585	8	161	723	26	4	81
9	37	622	4	165	750	11	2	83
10	38	660	1	166	791	3	1	83
11	31	691	0	166	828	0	0	83
12	27	718	1	167	856	4	1	84
13	30	748	2	169	881	7	1	85
14	16	764	0	169	900	0	0	85
15	24	788	0	169	928	0	0	85
16	24	812	0	169	956	0	0	85
17	22	834	2	171	971	9	1	86
18	13	847	0	171	986	0	0	86
19	20	867	0	171	1,009	0	0	86
20	14	881	0	171	1,025	0	0	86

*Calculated from the formula:

$$\text{Total Population} = \frac{\text{No. Tagged (199) X Total Catch}}{\text{Total Tag Returns}}$$

In the late summer of 1953, muskrat sign in the ditches was again heavy and it looked as if another big harvest was in prospect. Indications of impending trouble, however, first were noted during the live-trapping operations. Trap mortality was conspicuously higher than in previous years and one or more freshly dead muskrats were found on every trip around the ditches. Some of the muskrats which were tagged in September were found dead during the October live-trapping. The seriousness of this die-off can be seen in the drop from 86 per cent returns in 1952 to 36 per cent returns in 1953 (Table 3). The total catch in the same years dropped from 881 to 442. Disease losses were noted in other portions of Horicon Marsh and were largely associated with dried-out bog conditions. Fortunately, trapping on the marsh was started on October 25. If late trapping, such as a mid-November or later opening had been in effect, it is certain that many more muskrats would have been lost through disease. The early trapping removed many animals before they could die and also reduced the spread of infection by progressively lowering the density of the residual population. Losses were caused by a disease of hemorrhagic nature, often referred to as Errington's disease.

With such a rapid die-off in progress, it is difficult to show the population trend from 1952 to 1953. That populations were similar in both years prior to the harvest can be shown by a Lincoln Index calculation using the results of the first day of trapping. By this means the 1952 population was estimated at 657 muskrats and the 1953 population at 609. Nearly 200 muskrats were live-trapped and ear-tagged each year with about the same ease, further indicating similar population levels.

The following year the muskrat population did not recover from the die-off of 1953. The population was so low that only 134 muskrats were ear-tagged and 147 taken in the harvest. The total population according to a Lincoln Index calculation was only 243. Failure to note evidence of a continuance of the die-off gives promise of an increased harvest in 1955.

Movements

Movement studies were made in order to determine the amount of movement within and away from the ditches. The possibility of the loss of muskrats from ditches due to natural dispersal and conditions causing such egress are important points to be considered in an evaluation of the ditching technique.

Ear-tagging provided definite information on muskrat movements. The distances moved are presented in Table 2. When a muskrat was rehandled several times through live-trapping, the distance moved was calculated from the point of previous capture, and was figured for the most likely route of travel. A few muskrats travelled between the experimental ditches and Clark's ditch. But of the 603 movements recorded in this study, 91 per cent were 400 feet or less. Trapping was carried on throughout the marsh so that movements of tagged muskrats from the ditched area would have been picked up.

Generally, when the spring density of muskrats was relatively low, little movement away from the ditches was believed to have occurred. In the spring of 1952, however, there was a high residual population in the ditches and greater movement away from the ditches took place. During the April 1–15, 1952 trapping season, five muskrats ear-tagged in the ditches the previous fall were recovered far away from the ditches—two at least 1¼ miles to the southeast and three at least ¼ mile from the ditches, but probably a mile in an easterly direction. Two other long movements of 2100 feet each were found in the fall of 1952, also originating from the underharvested 1951 muskrat crop. These returns suggest a rather heavy exodus of muskrats from the ditches. Thus the 1951 ditch population contributed the seven largest movements in Table 2. Adequate trapping is the best insurance to keep

Table 2

Movements of Muskrats Tagged in Experimental Ditches, 1949–1954

Movement in Feet	*D5*	*D1*	*D2*	*D4*	*Total*
0– 100	61	119	74	48	302
110– 200	61	74	33	7	175
210– 300	15	8	6	4	33
310– 400	18	12	7	--	37
410– 500	8	4	---	--	12
510– 600	9	4	2	--	15
610– 700	---	2	---	2	4
710– 800	1	4	2	--	7
810– 900	2	---	---	--	2
910–1000	1	---	---	--	1
1010–1100	---	---	1	--	1
1110–1200	---	---	---	--	---
1210–1300	1	---	---	--	1
1310–1400	---	1	---	--	1
1410–1500	1	2	---	--	3
1510–1600	---	---	---	--	---
1610–1700	---	---	---	--	---
1710–1800	1	---	1	--	2
1810–1900	---	---	---	--	---
1910–2000	---	---	---	--	---
2010–2100	---	---	2	--	2
1320 plus	1	1	1	--	3
6600 plus	---	---	2	--	2
Total	180	231	131	61	603

muskrats from moving during the breeding season and being lost to some other area or perhaps to natural enemies. These spring movements are apparently due to the muskrats' intolerance of crowding during the early part of the breeding season. However, a few individuals of an uncrowded population may also move and contribute natural restocking of suitable but vacant habitat.

Apparently most of the muskrats tagged in the ditches were residing in the spoilbanks, because many of the adjacent houses were trapped without recovering a single muskrat which had been tagged in the ditches. Likewise, those muskrats living in these houses were seldom taken in the ditches. From one litter of muskrats tagged in a house between D2 and D4 in 1949, three recoveries were made over a mile to the west while none were recovered in the experimental ditches themselves. Forty-one kits were litter-tagged in houses near D2 and D4 in 1952. Size and location of the litters are shown in Figure 2. Despite the intensive trapping effort of 1952, only one of these kits was taken in the ditches while two were taken at houses near the tagging sites (arrows, Fig. 2).

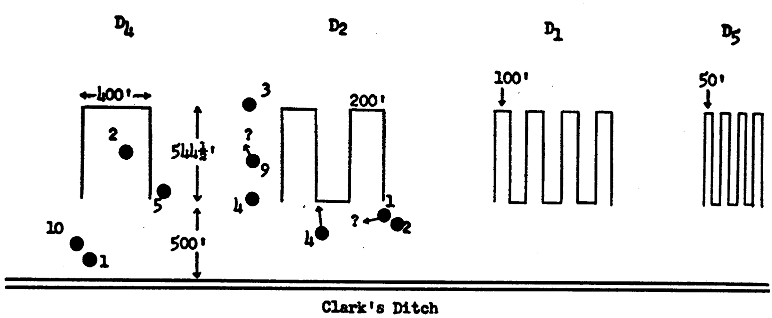


Figure 2. Location and size of litters tagged in houses in 1952. Only one of these kits was taken in the ditches while two were taken at houses near the tagging sites (see arrows). (Numbers beside each dot represent the number tagged in each litter.)

Other authors have also found that muskrats normally cover a relatively small area in their wanderings. Aldous (1947) reported that 171 recaptures of tagged muskrats showed that 54.4 per cent did not move from the place where they were last released, and that only 15.2 per cent moved more than 31 rods. In an Idaho study, 75 per cent of 84 recoveries were taken within 50 yards of where they were first tagged (Williams, 1950).

As has been shown in this study and by Errington (1943) and other investigators, drouth or freeze-up conditions or intraspecific strife resulting from overpopulation may cause rather extensive movement. This often subjects muskrats to the hazards of weather and predation. Muskrats in favorable habitat, such as that created by level ditches, then, will not suffer large losses from movement, since these animals tend to live in a relatively small home range. But overcrowding, caused for example by undertrapping, may even force ditch muskrats to move.

These observations show the great need for sufficient harvests each year. This is particularly important considering the possibility of disease outbreaks in high density areas. Muskrats moving from such areas may be disease carriers and may affect muskrats in other sections of the marsh.

Harvest

The harvest of muskrats from the ditches was undertaken by share-trappers in fall and early winter. At first an attempt was made to subject each ditch to the same trapping pressure by allotting two traps for each station spaced at 200-foot intervals. However, after ice conditions had terminated trapping in the ditches in December of 1951, the trapper was able to take an additional 67 muskrats from small houses in plots D2 and D4. Because many more muskrats could have been taken also from D1 and D5 if equal trapping pressure had been applied to all plots, these 67 muskrats have been omitted from the harvest analysis. A truer comparison of the 1951 values of the four ditch spacings is better shown when only the harvest figures from November 1—December 12 are used (Table 6). During this period the ditches were subjected to approximately equal trapping effort. Fifteen muskrats taken in early spring of 1952 from D5 are likewise disregarded in the harvest figures. Eventually the trappers began using more than the two traps per station whenever fresh muskrat activity was noted between the floats. A *saturated trapping pressure* was thus maintained and the density of traps varied with fresh sign on each ditch. The main idea was to take the crop as quickly as possible before adverse weather complications set in.

The returns on muskrats tagged in the experimental ditches may reflect efficiency of the harvest independently of the population size and are shown in Table 3. Only first-year returns of tagged muskrats are presented in order to evaluate the yearly trapping pressures. Thus of the 152 muskrats tagged in 1951, an additional 22 were taken in the year 1952, raising the total recovery rate from 31 to 45 per cent. Second-year recoveries for the other years were negligible.

About a 60 per cent return of late-fall-tagged muskrats can be expected from the ditches when such factors as weather and disease do not present major complications. In three of the six years of trapping, 1949, 1950 and 1954, returns of from 50 to 66 per cent were obtained, which indicate an average harvest for these years. The low return of 1951 (31 per cent) reflects the very unfavorable trapping conditions for that year. Ice formed on October 31, the night before trapping started, which prevented muskrats from reaching shallow-set traps and kept the trapper from properly attending his trapline. The application of the Lincoln Index showed a total population of 637 muskrats in the ditches in 1951. With a harvest of 218, this means that only 35 per cent of the population was taken. Under good management practices, approximately 75 per cent of the population could have been taken.

Table 3

Muskrats Tagged and Recovered in Experimental Ditches, 1949–1954

Year	*Number Tagged*	*Number Recovered*	*Per Cent Recovered*
1949	50	33	66
1950	57	29	50
1951	152	47	31
1952	199	171	86
1953	197	70	36
1954	134	81	60
	789	431	55

Other workers have shown that the harvest of muskrats in deep water ditches is greatly influenced by weather conditions. Dozier *et al.* (1948) and Dozier (1950) have pointed out that trapping success is to a very great extent dependent upon weather. Ice formations and deep snows may seriously hamper or delay trapping or even make it impractical.

Low returns were also obtained in 1953, but disease rather than ice was the reason that only a 36 per cent return was realized. A muskrat die-off occurred in the ditches and surrounding bog from late August until the freeze-up and many tagged muskrats died prior to the trapping season. Others died even during the season before they could be trapped.

In 1952, there was an exceptionally high return of tagged muskrats in the ditches. This was accounted for by the fact that ice did not interfere until the 23rd day of trapping, allowing a long trapping period. Drouth conditions caused muskrats to move into the ditches, and it was profitable for the trappers to continue their intensive trapping efforts. There was, therefore, a large harvest and a high return of tagged animals.

After the spring break-up in 1950, 33 muskrats were live-trapped, and 9 of these were later recovered by steel-trapping in the ditches during the regular fall trapping season (Table 4). None were retaken in other portions of the marsh. This is a relatively low recovery rate when compared to fall trapping returns in Table 3. Natural mortality during the warm summer months probably accounted for the low rate of return. Spring live-trapping was not feasible in other years.

Table 4

Spring Live-trapping of Muskrats in Experimental Ditches, 1950

Ditch Number	*No. Muskrats Ear-tagged*	*Number Recovered*	*Per Cent Return*
D5	7	3	43
D1	12	3	25
D2	13	3	23
D4	1	0	0
	33	9*	27

*All muskrats taken in 1950 except for two recovered from D1 in 1951.

A comparison of the harvest from the experimental ditches and the harvest from the surrounding bog of Trapping Unit 26, in which the ditches lie, is presented in Table 5, and shows the increased muskrat productivity resulting from the ditch construction. From 1949–1954, an average of 9.7 muskrats per acre per year was taken from the ditched plots while an average of only 1.5 muskrats per acre per year was taken from the remainder of Unit 26. (Muskrats taken in the bog during the special spring seasons are not included in Table 5 since the ditched plots were not trapped during these periods. If the ditches had been trapped intensively in spring, the total harvests would have been considerably greater, especially in the spring following the poor harvest of 1951.)

The figures presented in Table 5 represent what we might call an average harvest from the ditches. Although there was saturated trapping pressure on each ditch (in accordance with the size of the muskrat population), the ditches still contained a good potential breeding population for the next year. After the population was reduced, the law of diminishing returns set in and it no longer was profitable for the trappers to continue their effort. There was, therefore, an underharvest due to declining trapping effort and to weather conditions (in 1951). However, this tended to compensate for the fact that the ditch muskrats were known to range and feed outside the 35 acres of ditched plots, which increased to some extent the total area under consideration.

Table 5

Comparison of Muskrat Harvest from Experimental Ditches and Surrounding Marsh of Unit 26, Horicon Marsh

	Experimental Ditches			*Surrounding Bog (Unit 26)*		
Year	*Harvest*	*Acres*	*Harvest per Acre*	*Harvest*	*Acres*	*Harvest per Acre*
1949	121	35	3.5	188	500	.4
1950	225	35	6.4	109	500	.2
1951	218	35	6.2	760	500	1.5
1952	881	35	25.2	2289	500	4.6
1953	442	35	12.6	870	500	1.7
1954	147	35	4.2	208	500	.4
Average	339	35	9.7	737	500	1.5

COST VS. BENEFITS

What are the dollars and cents values of the different ditch spacings? The facts and figures concerning the cost of the ditches and the muskrat harvest from them from 1949–1954 are presented in Table 6. The economics of the ditching technique may be evaluated by considering (1) the cost of ditching, (2) the harvest of muskrats per acre, and (3) the return per $100 invested. If it can be shown that the production of muskrats by itself justifies the costs of level ditching, then the less tangible values such as water conservation and benefits to waterfowl, fish and other wildlife would make the level ditching technique all the more desirable.

The cost of a unit of ditch length was the same regardless of the spacing of the ditches. The costs per acre, however, increased with closer ditch spacings, since there was more dredging required per unit area. On any particular parcel of marsh, then, the closer the ditches, the higher the initial investment. The cost per acre figures in Table 6 will vary with the size of the ditching operation, but will serve here to indicate the relative costs of different ditch spacings.

The harvest of muskrats per acre also increased with closer ditch spacings, for on a given unit of land more ditches provide more favorable habitat and consequently more muskrats. In other words, the closer the ditches, the more muskrats produced. True values cannot be determined in this respect, however, since the muskrats ranged beyond the boundaries of the ditched plots. Much larger blocks would have to be ditched with the various spacings in order to minimize the variable of feeding outside the plots. There is probably the most error in calculating population size in connection with the 50-foot spacing where much of the marsh vegetation within the plot was covered by spoil-banks. As has been discussed earlier, any error introduced through muskrats ranging outside the ditched plots to feed, which would make the plot larger than 35 acres total, is probably offset by a partial underharvest in these plots. Actually, the 50-foot spacing (D5) is not a practical one, for there is too little vegetation left between the ditches.

Table 6

Evaluation of Muskrat Harvest in the Experimental Ditches, 1949–1954

Ditch Spacing (Feet)	*50 (D5)*	*100 (D1)*	*200 (D2)*	*400 (D4)*	*Total*
Acres in ditched plot	5	10	10	10	35
Actual length of ditches in feet	4,433	4,783	2,647	1,435	13,298
Cost	$ 779	$ 841	$ 465	$ 253	$2,338
Cost per acre	$ 156	$ 84	$ 47	$ 25	
Muskrats trapped in:					
1949	20	53	36	12	121
1950	37	77	76	35	225
1951	63	74	51	30	218
1952	224	213	272	172	881
1953	70	169	119	84	442
1954	45	57	32	13	147
Total	459	643	586	346	2,034
Av. yearly harvest per acre	15.3	10.7	9.8	5.8	9.7
Av. yearly harvest per $100 invested in ditching	9.8	12.7	21.0	22.8	14.5

In contrast, the harvest of muskrats per $100 invested was greater in the ditches with the wider spacings since there was more adjoining habitat per unit of ditch length, and since the cost of dredging was less in these plots. The 200-foot and 400-foot spacings had nearly equal harvests per $100 invested, indicating that there was no advantage to spacings greater than 200 feet. This is understandable when one observes the tremendous quantities of food available to musk-rats within 100 feet of either side of the ditches in D2. Theoretically, if length of ditch were the only limiting factor on muskrat production, the harvest per unit length of ditch (or per $100 invested) should be the same for any ditch. Actually, however, with ditches spaced closely together (e.g. 50 feet), fewer muskrats were found along the length of any one ditch due to less food present, overcrowding, etc. Food is probably the main consideration, but there could well be fighting between muskrats in the breeding season in adjacent legs of a ditch in the case of the 50-foot spacing.

On the other hand, 400 feet or larger spacings may be only partially efficient because of lack of movement across the bog between the ditches.

In a consideration of level ditching for muskrats by fur farmers, game managers, or by private individuals who might buy a marsh for hunting and trapping if they could improve the area by ditching, both the return for the money invested and the return per unit area will be important. Together they give an idea of the total production of the ditched area. For example, according to the results of this study (Table 6), the ditches with the 200- and 400-foot spacing both gave a high return per $100 invested, but the production per acre (or gross income from any marsh) was about 70 per cent greater with the 200-foot spacing.

The significance of the relationship between the cost of the operation and the return on the investment for the different ditch spacings is best illustrated by an example. Let us assume that muskrat pelts are worth $1.50 apiece. The following is a comparison of the economics of a 50-foot (D5) and 200-foot (D2) spacing:

	Yearly Muskrat Harvest/Acre	*Yearly Return/Acre*	*Ditching Cost/Acre*
D5	15.3	$22.95	$156.00
D2	9.8	14.70	47.00
Difference	5.5	$ 8.25	$109.00 (over a six-year period = $19.66 per acre per year)

For the harvest of 5.5 more muskrats per acre from D5 than from D2, the landowner is receiving $8.25 more per acre. However, his initial investment for dredging D5 is $109.00 higher than for D2. If the ditch life were assumed to be six years (as far as high muskrat production is concerned), he is paying $19.66 more annually for ditching per acre for D5 and is receiving an annual return of only $8.25 more per acre in fur on his investment. Thus, although ditches with a 50-foot spacing produce more muskrats per acre, they are not necessarily as worthwhile an investment. A ten-year ditch life which is probably more representative of Wisconsin ditches would bring the annual extra costs of a 50-foot spacing down to $10.90 which is more in line with the $8.25 extra return associated with the 50-foot spacing. The disparity between the values of the two ditch spacings increases as the pelt value decreases since the costs per acre remain constant.

The total cost of a ditching operation by a private marsh owner will depend upon several factors, such as the size and value of the land unit, and whether or not the money for dredging is borrowed. The above discussion presents a cost analysis in its simplest form for purposes of comparing the relative costs of two different ditch spacings. Anyone contemplating ditching may extend the calculations, taking into consideration such items as interest payments, labor, etc.

The return per $100 invested is a more vital consideration than the productivity per acre when pelt prices are low, for the added income resulting from ditching must pay the interest and liquidate the investment before the ditches lose their value for muskrats. If pelt prices remain high over a period of many years, it might be possible to dredge with the idea of getting the higher returns per acre associated with close ditch spacings. Probably few dredging projects carried out solely for muskrat production could be justified when pelt prices are as low as they were in 1953 and 1954. However, a lack of trapper interest and a general reduction of the muskrat crop due to extensive drouth conditions have caused pelt prices to swing upwards again. Fortunately the dredging field is in such a competitive position that dredging costs have not risen in recent years comparable to the rise in cost of most other goods and services. Low-cost dredging is most easily obtained during the winter months when there is a slack in construction work and dredge operators are willing to work at a low margin of profit.

Actual monetary returns are not given in Table 6 because of the variation in pelt values in different years and also in different habitats in the same year. Market fluctuations can also cause considerable price change within a few weeks' time in the same year. Pelt care and quantity of pelts offered for sale at one time are other factors affecting the selling price by as much as 25 cents per pelt. Production in D2 and D4 was so high that the 684 muskrats taken by the end of the fourth year would equal the ditching cost of $718 if the average pelt price was only $1.05. These same ditches at the end of the sixth year produced 832 muskrats, or more total pelts than the number of dollars ($718) invested in the ditching. Ditch trapping by boat is relatively easy during open water periods so that it is possible to complete the harvest in a few days if there is no limit to the number of traps which may be used. This is an important economic feature of ditch trapping, for parts of wildlife crops often remain unharvested because they are inaccessible to man.

As an example of the type of monetary return per acre which might be expected from a ditched marsh, we might consider the costs of and the harvest from D2 (Table 6).

No. acres	10
Length of ditch	2,647 feet
Cost of ditching	$ 465
Muskrat harvest (6-year period)	586
Av. pelt price	$ 1.50
Value of pelts	$ 879.
Profit per year	$ 879-$465÷6=$69.00
Profit per acre per year	$ 6.90

Thus on the basis of the Horicon experiment, ditching a 10-acre plot of marsh with ditches spaced at 200-foot intervals would yield a profit of $6.90 per acre per year, *just on the basis of muskrat production.* However, this is presented here as an example—not as a final analysis of the value of level ditching. In the first place, there are so many variables involved (pelt prices, trapping conditions, etc.) that a calculation based on data from one area will almost certainly not fit another area. Secondly, and most important, there are other values of ditches that cannot be as easily translated into dollars and cents. For example, potential waterfowl production on the ditches is extremely high, and ditches will certainly be of value to waterfowl long after they have become unproductive for muskrats.

OTHER WILDLIFE VALUES

Waterfowl

Several duck nests were found on the spoilbanks the first spring after dredging. These were located in the few clumps of bluejoint and sedge which were accidentally transplanted intact to the bank during dredging operations. It was not until 1952, however, that any intensive search was made to find nests. At this time, periodic checks were begun during the last week in April and continued into the first week of July. A total of 24 nests was found, but only 11 of these were successful (Table 7).

Muskrats tunneling into the banks weakened them making it extremely difficult to walk without breaking through into the dens. To prevent this, snowshoes were worn, but as the season progressed vegetative growth firmed up the banks and it was possible to walk them without snowshoes if caution were used.

In 1953 a nesting study was again conducted. This time the check began the first week in May and continued through the first week in July, when the last brood was brought off. The ditches were checked once a week during this period using a skiff and "flushing pole." The

Mallard nest on a ditch spoilbank, located next to an overturned float.

flushing pole consisted of a long fish pole with a bell, improvised from a metal can fastened by a short length of wire to the thin end of the pole. By alternately using the heavy end of the pole to push the skiff and then extending the thin end out over the bank, so that the bell dragged in the vegetation, a relatively rapid and easy method of flushing birds was effected. Its efficiency decreased somewhat as the new growth of vegetation became taller and denser. In order to find nests abandoned or destroyed by predators, the bank was walked occasionally. Blue-winged teal tended to "sit tighter" than mallards, probably because their nests were better concealed and located in thicker clumps of vegetation. As the new growth of vegetation became taller and thicker later in the season, it was difficult to flush the incubating teal unless the nesting site itself was struck with the pole. Mallards, on the other hand, nested close to the top of bank, usually in sparse clumps offering poor concealment.

There was an apparent selection of nesting sites, with a preference shown for island nesting (Table 7). One-half of the nests in 1952 were found on the islands opposite the breaks in the main spoilbanks; in 1953 about half as many nests were found on the islands as were found on the banks. However, there was about six times the potential nesting area available on the main spoilbanks as there was on the islands. In 1952 nests appeared to be concentrated more at the ends of the banks, but in 1953 there was almost equal usage of all parts of the bank. There appeared to be little correlation between species and the choice of nest sites on the bank. However, as was mentioned before, teal apparently do nest in denser cover.

The density of nests and their relative positions along the ditchbanks and island are illustrated in Figure 3.

Table 7

Location of Duck Nests on Ditchbanks, 1953

	Mallard	*B-W Teal*	*Total*
Main bank nests			
Successful	0	8	8 (24%)
Unsuccessful	10	16	26 (76%)
Total	10	24	34
Island nests			
Successful	0	2	2 (12%)
Unsuccessful	3	12	15 (88%)
Total	3	14	17

The concentration of duck nests on the experimental ditch area amounted to a minimum figure of 1.5 duck nests per acre in 1953—a considerably higher concentration than any other known area on the marsh. A comparison of the 1952 and 1953 check is presented in Table 8. A total of 51 nests was found during the 1953 nesting season, of which 38 (75 per cent) were blue-winged teal. This total was more than double the total number of nests (24) found in 1952. Blue-winged teal in 1952 accounted for only 8 or 33 per cent of the total nests. This shift from a predominance of mallard nests to a predominance of teal nests was more or less expected, as early in the spring a great increase in the teal population occurred in the general area of the ditches, while the mallard population remained about the same.

Water levels during the peak period of nest construction for each species could well influence the proportion of nests being constructed on spoilbanks or adjacent bog. When the surrounding bog is free of surface water, larger numbers of nests could be expected to be found away from the spoilbanks than when the surrounding bog is covered with flood waters. The spoilbanks and ditches, by providing loafing sites and water, may still influence the distribution of duck nests. Bennett (1938) found in his study that the average distance of blue-winged teal nests from water was 41.5 yards.

Although the nesting population greatly increased, the nesting success showed an opposite effect. Mallards were entirely unsuccessful in bringing off any broods in 1953, even though there were three more nests than there were in 1952 when the successful hatch amounted to 38 per cent. The number of blue-winged teal in 1953 increased five times over 1952, yet nesting success dropped from 63 per cent in

1952 to 26 per cent in 1953. Over-all nesting success in 1952 amounted to 46 per cent, but dropped to 20 per cent in 1953. Since all the unsuccessful nests, except for five nests which were abandoned, were destroyed by predators it is apparent that there must have been a large increase in predator activity.

An attempt was made to determine the predator responsible for each nest destruction by using the method of Rearden (1951) which is based on the manner of shell fracture and nest destruction. While identification methods are reasonably accurate, they are not without some error.

Egg shells, without evidence of a nest, were found in several instances. These may have come from previously unlocated nests, may have been brought in from destroyed nests on adjacent spoilbanks, or may have been from eggs laid at random before nest construction was started.

Table 8

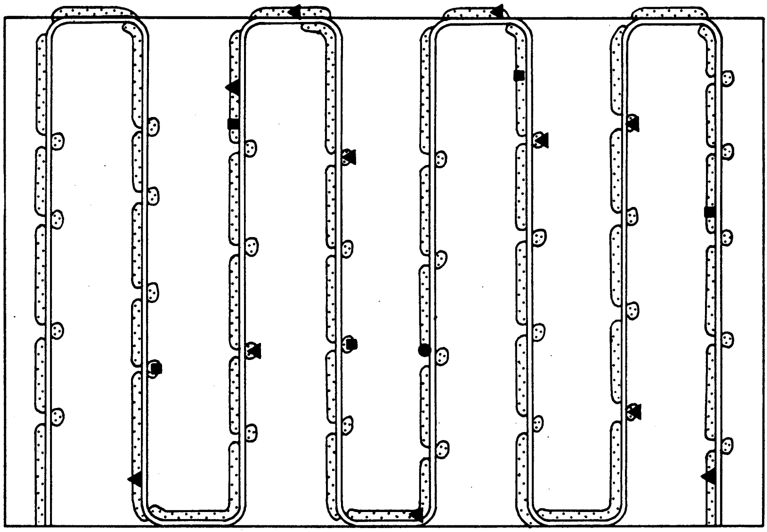
Duck Nesting Success on the Experimental Ditches, 1952–1953

	1952				*1953*			
	Mallard	*B-W Teal*	*Total*	*Per Cent of Total*	*Mallard*	*B-W Teal*	*Total*	*Per Cent of Total*
No. nests	16 (67%)	8 (33%)	24	--	13 (25%)	38 (75%)	51	--
Nests hatched	6	5	11	46	0	10	10	20
Nests destroyed	--	--	13	54	13	28	41	80
Raccoon	--	--	(9)	(37)	(11)	(15)	(26)	51
Mink	--	--	(1)	(4)	(0)	(10)	(10)	20
Other causes	--	--	(3)	(13)	(2)	(3)	(5)	10

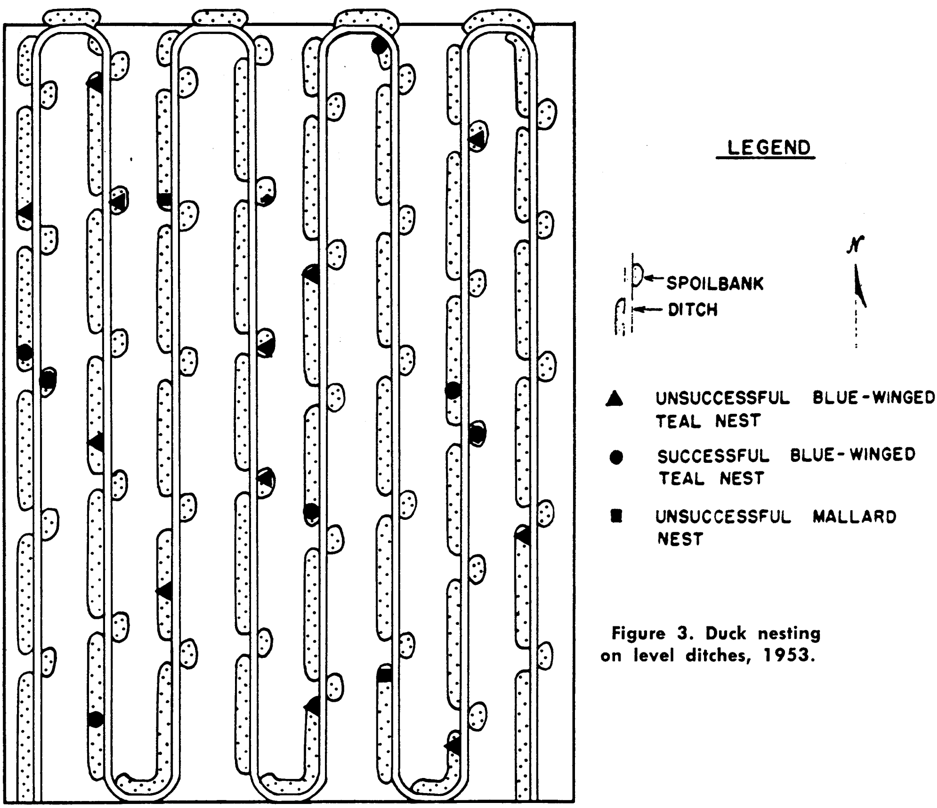
During the late winter of 1952 and early spring of 1953, occasional checks revealed considerable mink activity on the ditches. The population had increased as a result of the lowered trapping effort and very small take of mink during the 1952–53 season. Nest predation by mink increased from 4 per cent in 1952 to 19 per cent in 1953 of the total nests destroyed.

By far the most important predator on the ditches appeared to be the raccoon, which accounted for destruction of 51 per cent of all the nests found in 1953. In one unusual instance, a raccoon apparently killed a blue-winged teal sitting on a nest of 11 eggs.

The main predators, then, appeared to be raccoon and mink; other predators were not much in evidence. Opossum were known to be in the area, but no predation by these animals was detected. Crows were never seen around the ditches probably because of the lack of trees nearby. Great blue herons and black-crowned night herons were only

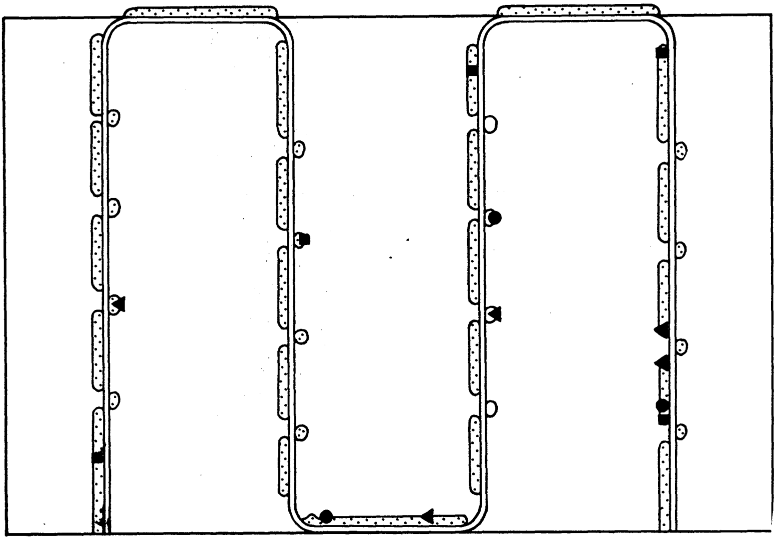


D1



D5

Figure 3. Duck nesting on level ditches, 1953.



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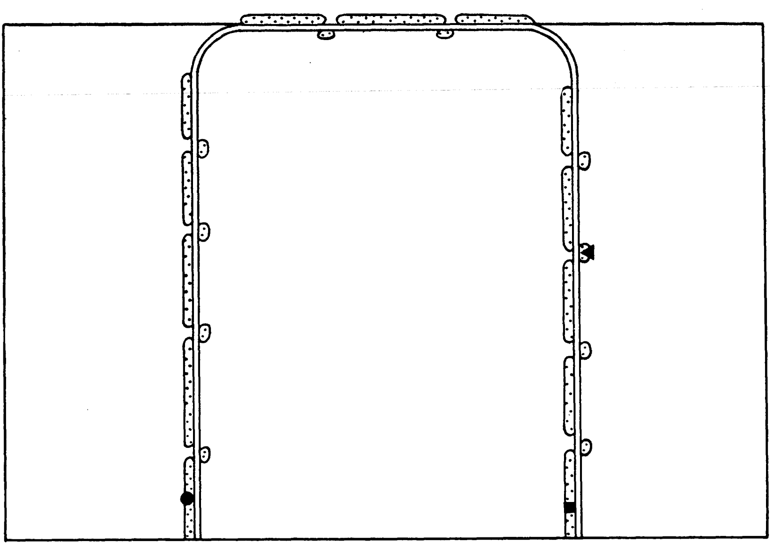


D4

occasionally seen along the ditches, but no evidence of nest destruction on their part could be ascertained.

Nest predation is not always completed in one night; there were nine cases where predators partially destroyed nests and later these nests were visited by the same or a different predator and more eggs were destroyed. In three cases (two teal and one mallard) the hen returned and continued to sit on the remainder of the eggs. One blue-winged teal actually brought off a brood after losing 5 out of her 10 eggs to predators. It is quite likely, judging from the maximum number of eggs observed in each instance, that the hens were incubating at the time of predation. The nests would probably have been abandoned if incubation were not in progress. Three nests (two teal and one mallard) were found abandoned with no signs of predation evident.

Some form of predator control seems desirable on ditches such as these when the predator harvest does not fully utilize annual reproduction. It may be, however, that the situation was somewhat aggravated by the extremely dry season and low water levels in 1953 which dried out the bog and allowed easy predator travel from one section of the bank to another. In 1952 the water levels were higher and much of the surrounding bog was flooded, thus breaking up the travel lanes somewhat and perhaps giving the nesting ducks a better chance for a successful hatch. It may be that alternate spoilbanks on either side of the ditch would decrease predation during times of relatively high water by breaking up predator travel lanes, but when the bog is comparatively dry it is doubtful if this method of bank construction would materially influence predator movements.

The fact that 24 per cent of the main bank nests were successful while the success of the island nests was only 12 per cent (Table 7) may be an indication that the island nests were more subject to predation. These islands are comparatively small, not more than 15 feet across in most cases, and are widely spaced. It would be easy for a predator to stumble upon a nest quite accidentally. The main banks, on the other hand, are about 100 feet long and offer more of an obstacle toward locating nests. It might be advisable in future ditching to have all spoilbank sections at least 40 feet in length and eliminate all *small* islands. Spoilbanks could be constructed alternately on either side of the ditch, which would tend to give the island effect the ducks apparently prefer.

The number of nests found on the experimental ditch banks makes it apparent that level ditching can be an important tool in waterfowl production as well as in muskrat management. The chief use of the ditch by waterfowl appears to be for nesting, as only small numbers of waterfowl are seen on these areas late in the summer and early in the fall even though the ditches are closed to hunting and there is no outside disturbance. Only blue-winged teal and mallards have been found nesting on the experimental ditches. With the exception of pied-billed grebes and an occasional coot, other waterfowl were seldom seen in this area. Geese sometimes use the banks briefly during their migration periods.

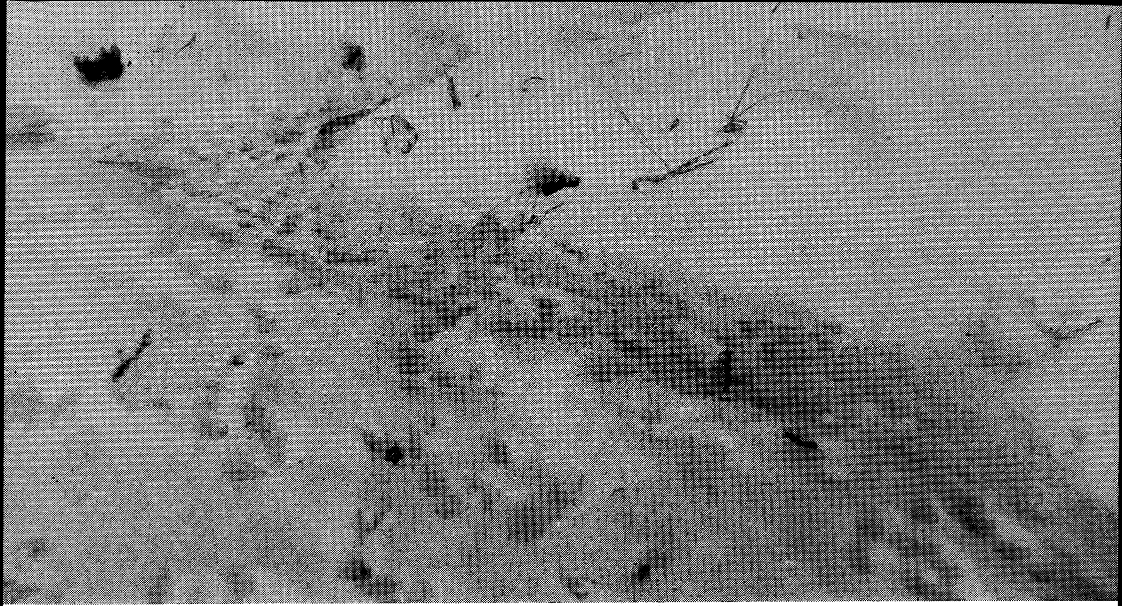
Level ditching can be made to pay for itself out of the returns realized from increased muskrat production. However, on the basis of waterfowl production alone, dredging would be justified because the banks will provide nesting sites for years after their usefulness to muskrats has ended. The clearing of existing islands of brush and other woody growths for waterfowl nesting has occasionally been advocated in the past, but the cost per duck produced is likely to be much less and the results longer lasting if new islands are created through level ditching. Cutting woody growths only encourages resprouting and the initial cost of clearing is relatively high, even when chemical controls are utilized.

In some cases, however, new spoilbanks are invaded by dense growths of willow or other light-seeded woody plants. Chemical control of these woody species while still small would help prevent deterioration of the banks as duck nesting habitat.

Fish

Annual flooding of the bog in spring and sometimes at other seasons of the year prohibits the study of fish production in the ditches, for free movement of fish from one ditch to another or to other portions of the marsh is possible during the high water period. Northern pike frequently spawn in shallow-water areas of the marsh that become dry during the summer, and in some years many pike fry find protection in the ditches during receding water levels where they are secure until the next flood period. A few large carp and northern pike of catchable size have been observed in the ditches. Mud minnows seem to be the most abundant fish of the ditches year after year; other types of minnows have been seen in very small numbers.

Ditches from which fish cannot escape might well be used for the commercial production of minnows or other fish where state laws so permit. Initial ditching costs can be justified more easily when multiple commercial uses are involved, especially in the case of private lands.



There was a heavy concentration of mink sign near the ditches as long as a few holes remained unfrozen . . .

Other Furbearers

Due to the short period of trapping in the ditches very few mink and raccoon have been taken. They cannot be considered in the economic evaluation of the ditches for mink and raccoon were commonly found in the area before the construction of the ditches. The cruising ranges of these animals are so great that 10-acre plots are inadequate for productivity studies. Nevertheless, ditching undoubtedly makes the area more suitable for other furbearers by increasing their food supply and providing denning opportunities. More mink and raccoon activity was found near the ditches than in adjacent marsh and skunks have been observed denning in the spoilbanks on several occasions.

In December of 1949, mink were feeding extensively on northern pike fingerlings. Fifty-eight young pike were found dead on the ice, each bitten in back of the head by mink. There was a heavy concentration of mink sign near the ditches as long as a few holes remained unfrozen and the mink could get at the fish, which ranged from 8–12 inches in length.

Other Game

During the last two winters a small group of deer consistently used the ditched area and deer tracks were often seen along the spoilbanks when snow was present. However, many deer tracks can also be found over a large section of the nearby marsh and some use of the area is made even in summer.

An occasional pheasant and cottontail visited the ditches, but there was not sufficient food on the banks to attract and hold upland game. More use by other game would undoubtedly have occurred if the ditches had not been quite so isolated from upland areas. In small marshes, the spoilbank-ditch combination would materially improve small game habitat by providing variety in food and cover conditions. Cottontails could easily be encouraged by the planting of small patches of shrub willow, raspberries, or other woody cover.

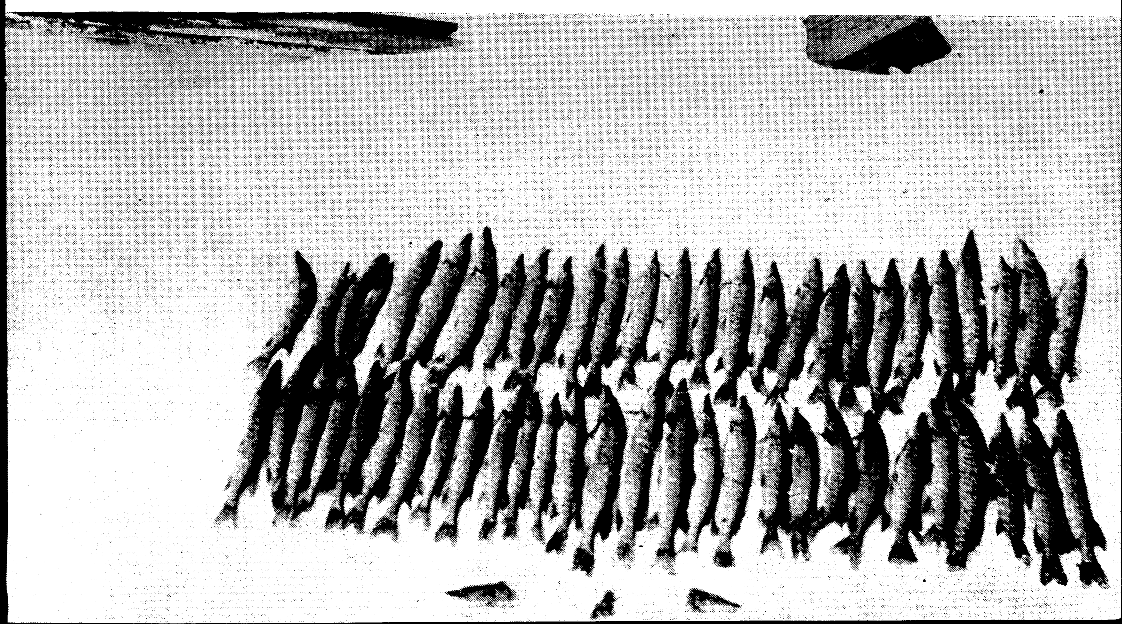
SUGGESTED MODIFICATIONS OF THE DITCHING DESIGN

Experience gained so far from the experimental ditching project has pointed to several modifications of the design used in this study which will further increase the value of the ditches for muskrats and other wildlife. A new design, with ditches spaced at 200-foot intervals, is shown in Figures 4 and 5. Some of the modifications are:

1. There should not be more than 300 feet of ditch in a straight line in order to make boat travel safer and easier during high winds. Smooth curves can be substituted for the sharp angles illustrated in Figure 4.

2. Make spoilbanks extra high at the ends of each straight section of ditch to provide a windbreak, at locations as shown in Figure 4.

. . . and the mink could get at fish. Here are young pike found dead on the ice, each bitten in the back of the head by mink (December 1949).



3. Where a broken spoilbank is possible, cut a short channel into the bog at the breaks in the spoilbanks. This will encourage muskrat utilization of the bog on the side away from the banks, and discourage humans from walking on the banks.

4. In areas in which burning is not necessary, construct spoilbanks 40 feet long on alternate sides of the ditch with 10-foot gaps between the ends of the banks so that there are two banks for each 100 feet of ditch (Figures 4-B and 5). Enlarge the ends of each spoilbank.

5. In peat marshes subject to drying, place spoilbanks so that alternate areas can be control-burned without endangering the banks or allowing peat fires to get out of control (Figure 4–A). Repeated burning of dry marsh may lower the marsh level enough to permit the growth of the aquatics desired for muskrat production.

6. When ditching in semi-dry marsh where the vegetation consists largely of sedges and grasses, it would be wise to excavate a strip 6 feet wide and one foot deep adjacent to the ditch to encourage the growth of muskrat food plants such as cattail, bulrushes, and bur reed. Such shallow excavation would be practical only when there was little or no frost in the ground.

7. Water control structures, such as drop inlet culverts, can often be utilized to regulate the flow of water into or out of a ditching system.

8. Where a small amount of ditching is planned for a large marsh, it is advisable to ditch one section with a 200-foot spacing rather than put the same amount of ditch over the entire area and have a distance of 400 feet or more between the ditches. Concentration of the muskrat population in one section of the marsh will tend to stabilize production from year to year and permit orderly development of the remainder of the marsh in future years.

9. Special considerations. (a) Small marshes that serve as habitat for upland game could be ditched to benefit waterfowl and muskrats. Although the yield would not be great, it would nevertheless further justify keeping such areas as wetlands.

(b) Ponds or short wide ditches may be desired just to provide or improve duck hunting opportunities with no concern about muskrat production. Such ponds would be most effective along major migration routes such as the Rock River system. High banks would not be wanted on a pond built for shooting. Construction might be best accomplished through use of a bulldozer during dry soil conditions, with the excavated materials being levelled out around the pond. Conditions should be kept as open as possible around the ponds in respect

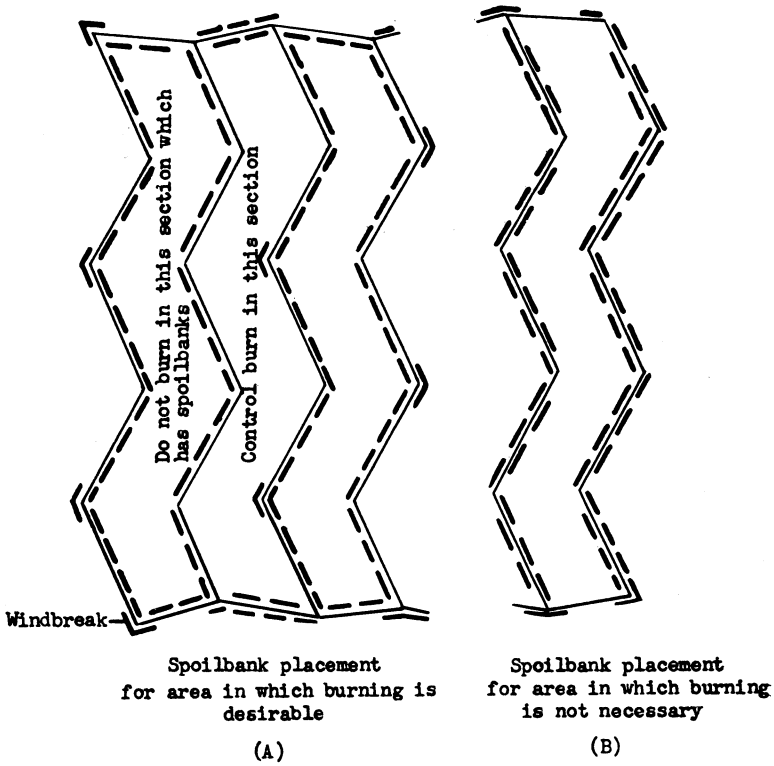


Figure 4. Proposed ditching lay-outs and spoilbank placement.

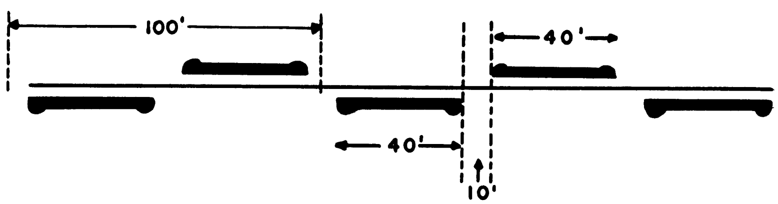


Figure 5. Enlargement of ditchbank showing proposed spoilbank placement.

to banks, trees, heavy tall growths of cattail, etc. Stubble fields or picked corn fields near the ponds increase the likelihood of developing shooting opportunities.

(c) A continuous ditch around the outside of a marsh with the spoilbank placed on the inside may aid in trespass control by creating water too deep to wade. It may also serve as a fire break by preventing marsh fires from jumping into adjacent uplands. Although a small ditch may not stop a fire during a high wind, it may be used as a starting point for back-firing or controlled burning operations.

MANAGEMENT PRINCIPLES

Numerous questions will arise in the minds of fur farmers, game managers and other individuals who are interested in using the ditching technique. The findings of the experimental ditching study will therefore be summarized in the form of questions and answers, with the hope that these will point up some of the more important aspects of level ditching as a management tool.

When is level ditching useful in the management of a marsh for fur production?

Level ditches provide deeper water areas in a "dry marsh" when flooding by means of dikes or dams is not possible or practical. Ditching provides insurance against a "dry year". The deep water and high spoilbanks are a protection against freeze-outs, make food available during the winter period, and may hold muskrats during a dry period.

Scattered cattail plants may often be used as an indicator of a satisfactory water level where ditching may prove beneficial.

What are some of the main advantages of level ditches?

Ditches increase the production of not only muskrats, but also of waterfowl, fish, and other furbearers.

The concentration of muskrats in the ditched area and the relative ease of boat travel make trapping conditions less difficult. The trapper can also get into the ditches sooner to trap. In an unditched marsh, for example, walking may be too difficult until the marsh freezes; by that time, however, the trapper runs the risk of too much snow or the rapid formation of thick ice which may make trapping impractical.

What creates the better type of ditch, dredging or blasting?

The dredging cost was much less than dynamiting, hence it was a much more practical method of ditch construction. Even if the costs of the two methods were comparable, it would be better to dredge from the muskrat's point of view. The high spoilbanks and the less rapid filling in observed in the dredged ditch in the Horicon experiment made dredging far superior to blasting as a means of creating furbearer habitat and providing good waterfowl nesting sites during flood periods.

What are some of the more important considerations in dredging a ditch?

Ditches should not be dredged in a straight line. Boat travel will be safer and easier during high winds if not more than 300 feet of ditch are dredged in a straight line.

Spoilbanks should be about 40 feet long and staggered on alternate sides of the ditch with two 40-foot banks for each 100 feet of ditch. This will reduce the chances of fire sweeping down the length of the bank, discourage walking on the banks, and create better conditions for duck nesting.

Optimum dimensions seem to be 5 feet in depth and 13–15 feet in width.

How long do level ditches last?

The experimental ditches at Horicon remained highly productive for muskrats about six years. However, they will continue to be of value to muskrats at certain times of the year and will certainly benefit waterfowl and upland game for a much longer period. Most ditches, particularly in areas in which the density of muskrats is somewhat lower than is found at Horicon, should remain productive for about 10 years.

The length of time the ditches last will vary in different localities, depending upon the soil type, erosion rate of the banks, tunneling activities of muskrats, and such human activities as trampling on banks or operation of motor boats in the ditches. Early development of grass cover on the banks will hold bank erosion to a minimum.

When can controlled burning be used in the ditched area?

Strips of vegetation between ditches may be burned as long as the plant cover on the spoilbanks is not endangered. Repeated burning of "dry marsh" vegetation may lower the marsh floor enough to permit the growth of aquatic plants desired for muskrat food.

Should the spoilbanks be planted following dredging?

Banks of new ditches should be seeded to grass as soon as possible after dredging. Seeding to canary grass before the banks have a chance to dry out would be insurance against a possible lack of residual seeds of the right plant species. Addition of some white sweet clover seed would provide an early cover while the slower growing canary grass is becoming established.

Planting of submerged aquatics is not considered necessary since they can be expected to invade ditches rather quickly and are a hindrance to boat travel at times.

What are the pros and cons of close ditch spacings?

More muskrats were harvested per acre in the plots with ditches more closely spaced (50 and 100 feet) than in those with wider-spaced ditches (200 and 400 feet). However, the closer the ditches, the greater the cost of construction per acre and the lower the fur return per $100 invested.

What are the pros and cons of wide ditch spacings?

Fewer muskrats were harvested per acre in the ditches with wide spacing (200 and 400 feet) than in those with narrow spacing (50 feet). However, since the cost per acre of these ditches was much less, the harvest of muskrats on the basis of each $100 invested was greater than in the more closely spaced ditches. This is an important consideration particularly during a period of low fur prices.

Which ditch spacing provides the greatest return for the money invested?

Over a six year period, the 400-foot spacing has produced slightly better than the 200-foot spacing per $100 invested in the ditching. Nevertheless, the 200-foot spacing is recommended for new ditching because of the much higher yield per acre.

How soon can the capital which has been invested in ditching be recovered?

In the Horicon experiment, production in the ditches spaced at 200- and 400-foot intervals averaged over 21 muskrats per year per $100 invested. The money invested would thus be recovered in four years if the average pelt price was $1.20.

How does the muskrat population in ditched marsh compare with that in similar but unditched marsh?

The ditched marsh can be expected to produce from 4–10 times as many muskrats per acre. The population in the ditched marsh will tend to be more stable due to the benefits of spoilbanks combined with deep water.

Furthemore, in dry years the ditches permit the harvest of muskrats from the unditched portion of the marsh.

How far do muskrats move from the ditches?

Muskrats in favorable habitat, such as that created by level ditches, generally will not move far, since these animals tend to live in a relatively small home range. Most of the movements were found to be 400 feet or less.

What are some of the conditions causing muskrats to move?

Unusual drouth or freeze-up conditions or overcrowding may force muskrats out of their home territory, even in good habitat, and subject them to the hazards of weather and predation.

Overcrowding will result from undertrapping a high population.

How can a large marsh be best developed for muskrats and other wildlife?

It is better to develop one end of a large marsh with ditches spaced at 200-foot intervals rather than to spread a few ditches throughout the entire area. In this way the muskrat population will be concentrated as a unit in one part of the marsh. It will be easier to trap, and if sections are overtrapped, the blanks will be quickly filled in. The remainder of the marsh then may be ditched in an orderely fashion in future years.

A ditch around the outer edge of the marsh may provide both fire and trespass control.

What other species of wildlife are benefited by ditches?

The spoilbanks provide excellent nesting sites for waterfowl. A total of 51 mallard and blue-winged teal nests were found on the spoilbanks in 1953. There is no other comparable concentration of duck nests on Horicon Marsh.

Fish production is usually increased because of the deep water in the ditches. In most marshes, the spoilbanks benefit upland game species through the production of additional food.

What are the major problems raised through this study which need further investigation?

A better understanding of the value of level ditching for wildlife management would result through the use of a much larger plot. For instance, the variable of muskrats feeding outside the plots would be greatly reduced if one plot of 100–160 acres were level ditched at the recommended spacing of 200 feet. The relation of duck nesting density to ditches and spoilbanks could also be clarified in the larger plot.

A predator control study is needed to see how many predators of various species can be taken from the ditched area and what effect the removal will have in improving nesting success. Finally, a cheap, light-weight pumping device should be developed which will efficiently clean out the ditches and thus greatly prolong their usefulness for muskrats.

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