WILD-RICE

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FOREWORD

Wild-rice is the only cereal crop that grows wild in Canada. Its wide distribution and relative abundance along waterways from the Atlantic Ocean to Manitoba provided food for Indians, explorers, fur traders, and other early inhabitants of the area. Often they took the grains with them and established new plantings along their travel routes. Today Indians still use wild-rice for food, and it has also become a source of revenue for them. It is harvested from its natural habitats and later appears as a specialty food at fancy prices on the shelves of modern supermarkets.

In view of the historical, sociological, and economic interests attached to wild-rice, it is surprising that little factual information is available. This publication, then, will be welcomed by historians, agriculturists, foresters, and others who are interested in the past and future development of Canadian resources. The consumer will find here interesting information about the source of his favorite side dish for wild duck or pheasant. Here in one volume is an accurate account of the plant — its botany, distribution, habitat requirements, and utilization.

Dr. Dore has brought to this work the specialized training of a grass taxonomist and many years of experience. His special interest in the subject gives his treatment the flavor of not only the practical botanist but the true naturalist as well.

J. L. Bolton
Research Coordinator (Forage Crops)
Research Branch

INTRODUCTION

Wild-rice is our only native cereal. Of the wild grasses in Canada it is the only one that grows from seed each year and produces a grain of sufficient size to be used as food by man.

The other cereals, wheat, oats, barley, rye, and corn, are "tame" grasses in the sense that they are completely dependent on the farmer's care and attention for survival in our climate. These crop plants had their origin in foreign lands, and for many centuries they have been so modified by selection and cultivation that they are now quite unlike their wild progenitors. In contrast, wild-rice is essentially the same plant today that it was when the first explorers found certain Indian tribes of the interior using it as a main food.

In the past, many other names have been used for wild-rice: Indian rice, Canadian rice, water oats, water rice, tuscarora, and manomin. The last two were derived from names of Indian tribes. The early French explorers called the plant *folle avoine*. This name and, less often, direct translations of the English, *riz sauvage* and *zizanie,* are still used in writings in French. However, *folle avoine* is also used for a very troublesome weed, wild-oats (*Avena fatua*), and this dual use is confusing. It is encouraging to note that many producers of wild-rice, as well as discerning naturalists and sportsmen who wish to be precise about the plant, use the name *zizania*. It is written without a capital letter and in ordinary print, but otherwise the word is identical with the Latin name of the genus to which all species of wild-rice belong. As such usage conforms with botanical principles of priority, zizania is clearly understood internationally.

The two-word and uncapitalized name wild rice often seen in print today has led to a certain amount of confusion in parts of the world where rice (*Oryza sativa*) is the chief cereal crop. All the native species of *Oryza* of Asia, as well as weedy strains of *O. sativa* such as the red rice that infests the fields in the southern States, are appropriately called wild rice, that is, rice that grows wild. In this publication the name is hyphened, and it is consistent in meaning with the generic name *Zizania*. The proposed use of the single word wildrice has similar merit and is gaining acceptance among American writers.

Several rivers and lakes in the North Central States and Canada have received their names from the presence of stands of wild-rice. Rice Lake near Peterborough, Ont., is perhaps the largest and best known of these in Canada. Recently a lake, at 50° 31′ N 93° 31′ W, about 70 miles northeast of Kenora, has been named Zizania Lake.

THE WILD-RICE PLANT

Wild-rice is found mainly along the shores of rivers and streams in shallow water, where stands often form dense and continuous beds. In lakes, where it is usually less abundant, stands are generally concentrated at sites near the inlet and outlet, where the current is more or less constant. Its lighter green color usually distinguishes wild-rice from bordering stands of cattails and other shallow-water plants, but close examination is always necessary to establish identity.

LIFE CYCLE

Wild-rice is an annual. It must grow from seed each year. In the spring the seeds germinate, but it is not until about the middle of June that stalks appear above the water. During this establishment period, firm roots penetrate the muddy bottom to provide the anchorage necessary to support the stems, which eventually grow several feet above the surface. In early August, a loosely branched panicle is produced at the top of the stem. Each panicle bears two kinds of flowers. On the stiff upper branches female flowers are produced, and these remain attached until the seed is ripe. On the lower and more flexible branches the male flowers are formed; these drop off a day or two after they shed their pollen.

As soon as fertilization has taken place, the ovary quickly enlarges and soon fills the space inside the hull. At maturity, the hulls with enclosed grains fall into the surrounding water and sink quickly to the bottom. All seeds do not mature at the same time, but ripen and shatter over a period of a week or two. However, by mid-September all will have fallen. The plant body then dies and, even before freeze-up, the old stems break down into the water. The seeds lodged in the soil remain dormant over the winter.

Wild-rice forms thick productive beds in some small rivers in southern Ontario if these rivers have rushing floodwaters in the spring. In midsummer, stands occupy all the shallow water, leaving only a narrow mid-river channel. A patch of perennial plants, including cattails and pickerelweeds, is at the right of this picture, taken near Dalrymple, Victoria County, Ont. (Photo by W. J. Cody)

In Stony Lake, Peterborough County, Ont., wild-rice grows only in a shallow bay at the mouth of Jack River. Wild-rice seems to benefit from currents and from fine sediments deposited on the bottom each year.

STRUCTURE OF THE PLANT PARTS

Wild-rice, like most other herbaceous seed plants, is composed of stems, roots, leaves, flowers, and fruits. In the following description of these components, attention is directed particularly to those features that distinguish wild-rice from other species of grass, and also from plants that resemble grasses, such as rushes, sedges, and bulrushes, which inhabit the same shoreline sites. The fine details of structure that serve to distinguish one variety of wild-rice from another, however, are given in the taxonomic review (page 16).

STEM The stem is the elongated supporting axis that bears the leaves and flowers. In grasses, the term stem also includes the closely enveloping leaf sheaths that surround the axis, or culm. In wild-rice, the stems are ordinarily erect and rather slender. They reach a height of 2 to 10 feet, depending on the variety, the depth of water in which the plants grow, and other environmental factors. Stems in the midst of a bed are usually uniform in height, but those near the margins of the bed, both on the deep-water and shoreward sides, are shorter. Branch stems, or tillers, arise low on the plant, and they are usually shorter than the main stem.

The culm, the central cylindrical portion of the stem, possesses the typical bandlike joints, or nodes, characteristic of all true grasses. The presence of well-marked nodes is one feature that distinguishes wild-rice from all other grass-like plants. The nodes are densely felted with very small hairs, a feature not present in many other Canadian grasses. The nodes, solid within the culm, mark the points where the leaves and branches, and even the roots and flowers, arise. Growth in length takes place in the soft tissue immediately above the nodes. The straight sections of culm between the nodes, the internodes, are about a foot long, completely smooth, and usually constant in number within one variety. Below the water, the unsheathing leaves soon decay and the culm is left naked and smooth. Other marsh plants often have rough stems or are angular in cross section.

The internodes of the culm are hollow, as in most grasses, but in wild-rice they have a rather large air-filled cavity. This cavity is divided at more or less regularly spaced intervals by thin parchmentlike partitions. These cross partitions, or diaphragms, are readily seen when the culm is carefully sliced lengthwise, but they are not easy to detect by casual observation. In all species of *Zizania* the presence and structure of these partitions are unique, although similar dividing walls, or septa, characterize some species of rushes. The diaphragms can sometimes be seen by viewing the fresh culms against strong sunlight or by crushing the culm gently between the fingers.

In writing about wild-rice no one has previously given attention to the mode of formation and function of these in-

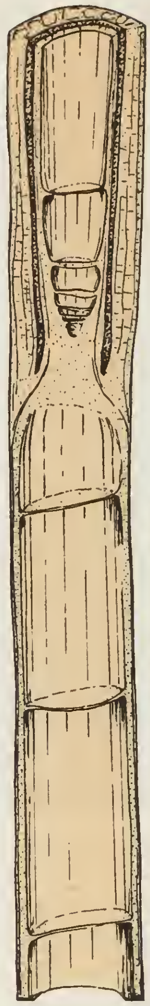
Parts of the wild-rice plant: A, *base of stem, with roots embedded in bottom mud, and prop roots descending from submerged nodes (× 0.27).* B, *flowering panicle with staminate florets on lower branches, pistillate florets on upper branches (× 0.27).* C, *a single staminate floret with its two scales, lemma and palet, diverged to expose the six stamens (× 2.16).* D, *a single pistillate floret, showing its lemma prolonged into a bristly awn, and two feathery stigmas protruding from the base of the clasped palet (left of letter, × 2.16; right of letter, natural size).* E, *mature grain, showing long embryo, and sheared-off stigmas at tip (right of letter, × 2.16; below letter, natural size).*

ternal partitions. The structures are remnants of the pith. They originate in the living tissue immediately above a node and draw apart as the internode above elongates. These partitions lack all vascular and strengthening tissue and do not contribute any structural support to the culm. Their cells are star-shaped and thin-walled and have minute air spaces between the walls. The partitions, therefore, are very porous and do not impede the diffusion of gases up and down the stem. In a short-lived aquatic plant, good aeration must extend to the base of the stem if the roots are to grow actively in a deeply submerged bottom. Although these diaphragms are soft and porous, they do not absorb water. They may act as air locks, and by this means prevent the whole interior of the culm from becoming flooded if a break occurs.

The chambers inside the culm, as well as the many smaller air spaces interspersed throughout the living tissues, even root tissues, make the whole plant particularly buoyant. In contrast to stems of other grasses, the stems of wild-rice, at least in their underwater portion, have a very weak structure. They could not maintain themselves well in an upright position in the water if it were not for their acquired buoyancy. Uprooted plants float quickly to the surface and never regain a roothold.

ROOTS The roots grow into the mud diagonally and anchor the plant firmly against the lifting force of waves and side currents. A gentle pull is enough to dislodge the complete root system, with usually a large clod of heavy mud attached. The roots have several short horizontal rootlets, to which the substrate clings. The root system is quite unlike that of other plants. True root hairs, microscopic and unicellular, which are always present on land plants and other grasses, are lacking in wild-rice.

The roots, which cluster at the base of the stem, are rather straight, spongy, thickish, and generally whitish, but often rust-tinged by iron deposits on their surface. On plants in deep water or soft ooze, side roots often develop from

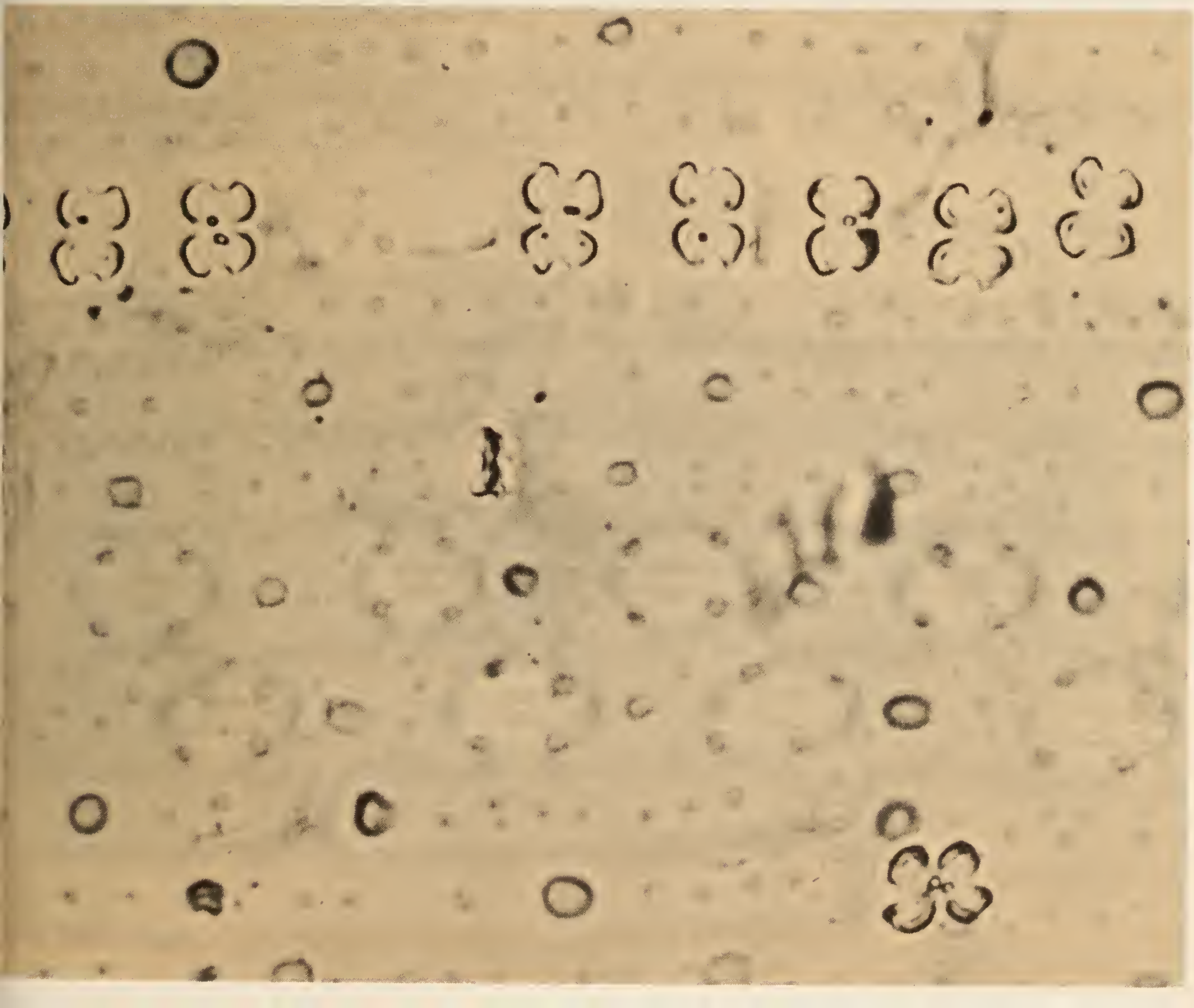


Left: *Lengthwise section of stem through one node, showing parchmentlike cross-partitions (× 4.2).* Right: *In the seedling stage the leaves of wild-rice float limply on the water's surface. Erect stems come up later from the bottom.*

higher nodes. These roots are similar to the prop roots of corn.

LEAVES The leaves have slender blades, which, as continuations of the sheaths, stand at a close angle to the stem, then spread away and usually lop over towards the tips. The width of the blades varies from ¼ inch to 1½ inches, depending on the variety. The midrib does not run directly up the center of the blade, but is a little to one side. The midrib is much more prominent on the lower surface. The scalelike appendage, or ligule, situated at the junction of the blade and sheath, is a useful feature to distinguish grasses. In all species of *Zizania* the ligule is membranous, rather

Microscopic view of a leaf, from which the epidermis has been removed, specially treated to show the diagnostic butterfly-shaped silica casts, which line up in the cells over a vein. One cast has been dislodged to lower right. Ghosts of other cells with wavy walls, stomata, papillae, and cuticular pegs also show faintly (× 125).



firm at the base, thin and usually frayed at the top, and up to ½ inch long.

The first two or three leaves of the seedling never grow above the water. They are soft, weak, and ribbonlike, quite different from the leaves that form on the mature plant. They closely resemble the leaves of eel-grass *(Vallisneria)*, a common weed in water and one often found growing in the same habitat. A young wild-rice plant, however, can be distinguished quickly by the presence of the old seed husk, which invariably remains attached at its base. Eel-grass leaves will not pull up, but instead, they break off at a perennial runner. Usually, the juvenile leaves eventually reach the surface of the water, and float with their upper surface in contact with the air. It seems necessary for the leaves to reach this stage before a flowering stem can be produced. If the water is too deep and the first young leaves do not reach the surface, no flowering stem is produced. On exposed mud, the long soft leaves do not develop.

The outer, or epidermal, cells of the leaves have several microscopic, peglike projections of cuticle, a diagnostic feature by which an expert can recognize wild-rice, even from a very small fragment. These projections probably aid in the shedding of water, particularly from the upper side of the seedling leaves. Silica casts of a butterfly shape, visible by a suitable technique and formed in specialized cells of the epidermis, provide another sure diagnostic feature.

FLOWERS The flowers are borne in a branching panicle about the end of July or early August. The individual flowers, or florets, are rather large, about the size of oat florets. They are unisexual. The staminate, or male, florets are situated on the lower branches of the panicle, and the pistillate, or female, on the upper. Such segregation of the sexes is found in very few other grasses, corn being perhaps the most familiar example. In corn, however, the staminate florets are in the tassel at the top of the stem, and the pistillate florets are in the ears along the side. This arrangement is just the opposite of the one in wild-rice. Separation of the flowers promotes cross fertilization, which in wild-rice is further ensured by the earlier blooming of the pistillate florets.

The staminate florets are usually ¼ to ½ inch long, and variable in color: yellow, greenish, and pink or sometimes dark red. Unlike the pistillate florets, the staminate florets hang down on threadlike stalks from spreading panicle branches. Each floret consists of two soft and similar scales, the lemma and palet, which contain the stamens. The two outer scales, or glumes, that are found in most grasses are lacking or rudimentary in *Zizania*. The number of stamens, six, is unique among Canadian grasses, three being the regular number. The anthers are always bright yellow, large, and easily counted with the naked eye. The flowers open in the forenoon, usually about 2 hours after sunrise, and by evening the male florets with spent anthers will have fallen off. All the male flowers in a panicle complete blooming within a few days, but those in secondary panicles or on plants in deeper water come into bloom later than the uppermost flowers. The flowering of all plants in a bed may therefore continue for several weeks.

The pistillate florets are strikingly different from the staminate in structure and duration. They are borne on short firm stalks in an erect position held close to the panicle branches. Each pistillate floret has a long rough bristle, or awn, at the tip. As the florets push up above the leaf sheath they put out two white feathery stigmas, one on either side of the floret near its base. The lemma and palet are interlocked and do not spread widely apart at flowering time as they do in the staminate flower. They separate at the base by a slit only wide enough to allow the stigmas to protrude. Soon after the stigmas are pollinated, the ovary begins to enlarge, and within a few days it completely fills the space within the two floral scales. In varieties of wild-rice that have thin-textured scales, the plaited lemma and palet expand, so that at maturity the ovary is closely covered

Like corn, but unlike most other grasses, wild-rice bears separate male and female flowers. Left: *Of the male flowers at the lower part of the panicle, those at the bottom just emerging from the leaf sheath are not yet open, those in the middle are in bloom and shedding their pollen, and others at the top have been spent and have fallen off (× about 0.6).* Right: *The female flowers at the top of the panicle are in full bloom, and their feathery stigmas are exposed to trap pollen borne on the air. The stigmas shrivel as soon as the pollen tubes penetrate them and fertilize the ovary, but they will remain receptive for several days if they are not pollinated (× about 0.6).*

by the stretched scales. If the grain does not develop, the scales remain slender and shrunken. In varieties with firm-textured lemma and palet, there is a vacant space between the scales at flowering time, and after fertilization the grain fills this space. In these varieties, therefore, there may be no noticeable difference in size or appearance between barren and fertile florets.

The lemmas are generally pale yellow or green, but in some plants they may be yellowish brown or tinged deeply with red. On approaching maturity the lemmas all turn straw-colored or light brown, and they are often quite shiny. When ripe, or nearly so, they break away from their funnel-topped stalks at a point situated below what remains of the glumes, which form a hard smooth flange around the basal scar. Only the slightest disturbance is required to dislodge the mature florets and cause them, together with the enclosed grain, to fall into the water. The long, roughened, flexible awns seem to play an important part in the dislocation of the fertile lemmas. They rasp against the bending panicle branches and cause the ripe florets to spring off from their stalks. The awns, however, are not considered an aid for dissemination, even though they may serve in this way on the seeds of some other plants. The seeds, by which is meant the disseminated reproductive structures, are quite slippery, and they do not adhere to moving objects. Indeed, they easily and quickly fall out of a hand that is attempting to gather them.

GRAIN The grain is light green in the firm-dough stage, but while still in this stage it turns olive brown; and, finally, in the hard-kernel stage, it becomes dark brown or black. Most seeds are shed when the grain is in the firm-dough stage, the hard stage not being attained until they have been allowed to dry for several days.

When the seed strikes the surface of the water it plummets quickly to the bottom, directed in its course by its rudderlike bristle. Consequently, it lodges fairly close to the parent plant. Seeds of most aquatic plants, however, generally possess inflated or buoyant structures, by means of which the seeds are widely dispersed. Even in fast-flowing water, wild-rice seeds are not carried far by the current. After they reach the bottom, the seeds become fixed against the current; because their heavy bases slope forward, the seeds hold their position and are not washed out into deep water.

The grain itself contains an embryonic plant, or germ, which extends the whole length of the grain along the grooved side, and also contains a large store of starchy cells, or endosperm. The grain is closely surrounded by a thin, but impervious, coat, or pericarp. The grains of wild-rice are longer than those of any other native grass in Canada and longer than most varieties of cultivated cereals. The weight of a kernel, however, is less than that of the average grain of corn, wheat, oats, or barley. As grain is not attached to the lemma and palet, it can be threshed completely clean from the hull. Its slenderness and relative brittleness when dry make it susceptible to breakage when it is threshed by mechanical means.

Comparison of wild-rice (center) with grains of the common cereals. Upper, left to right: *oats (hulled), oats (dehulled kernels), and wheat;* lower, left to right: *barley (hulled), barley (milled kernels), and corn (all* $\times$ *about 4.2).*

A TAXONOMIC REVIEW OF THE GENUS, SPECIES, AND VARIETIES

Zizania, the genus to which all wild-rice species belong, was formally established by Carolus Linnaeus in 1754 (*Genera Plantarum,* Edition 5, page 427). The name had been used earlier by J. F. Gronovius (*Flora Virginica,* Part 2, page 189, 1743) for the plant of eastern North America. The following are the main characters of this genus.

Flowers unisexual, on separate branches of the same panicle; glumes obsolete or absent; stamens 6; lemma and palet of the pistillate flower flanged together and separating only at the base at flowering time when stigmas protrude, closely surrounding but not adhering to the grain at maturity, the lemma prolonged into a coarse awn; grain elongate and cylindrical, the embryo extending its full length; stellate pith diaphragms present in culm cavity; leaf epidermal cells with low papillae, studded cuticle, and X-shaped silica casts.

Four species constitute the genus *Zizania* as it is currently understood, but the validity of one, *Z. texana,* is controversial. The names of the species and their varieties, and distinguishing characters follow.

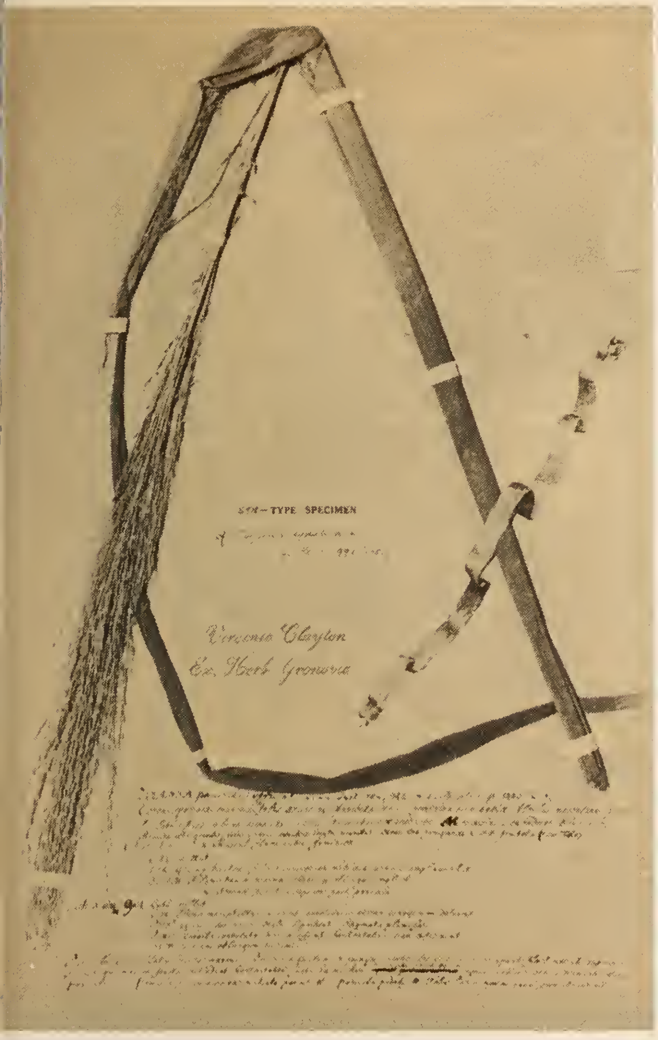
1. ZIZANIA AQUATICA

This species was named in 1753 by Linnaeus (*Species Plantarum,* Edition 1, Volume 2, page 991). It was based on a description by Gronovius (*Flora Virginica,* Part 2, page 189, 1743), which cites a specimen, No. 574, collected by John Clayton in "Virginia." The specimen is preserved in the Gronovian Herbarium at the British Museum of Natural History.

Plants annual, upright, killed by frost in autumn (in Canada); staminate and pistillate florets borne on stalks completely smooth at their summit; hull of grain thin, papery, dull, and minutely roughened on the surface. Two varieties are recognized.

1a. ZIZANIA AQUATICA var. AQUATICA

SOUTHERN WILD-RICE, SOUTHERN ZIZANIA This is the typical variety of the species.



The original specimen collected in Virginia by John Clayton, as No. 574, and sent to Gronovius in Leyden for him to describe. The full description as published in Flora Virginica, *1739, has been copied onto the sheet by hand. In 1753, Linnaeus provided the binomial specific name* Zizania aquatica *for the plant; consequently, this Clayton specimen is the nomenclatural type of the species. It is preserved in the Gronovian Herbarium at the British Museum of Natural History.*

An authentic specimen of Zizania aquatica *L. preserved in the Linnaean Herbarium, London, the source of much nomenclatural confusion. It consists of several complete plants, thin-stemmed and narrow-leaved, folded together and pasted on the sheet. Linnaeus himself wrote on the sheet only "1 aquatica" and the symbol ♈ for Gronovius. The depauperate plants look so different from the large plant, the Clayton specimen in the previous picture, that several subsequent authorities thought that Linnaeus must have made a mistake, intending to mark it "palustris". Microscopic examination of the florets, however, completely confirms the original identification by Linnaeus.*

Plants usually 6 to 8 feet tall; stalks often 1 inch thick at base; leaf blades 1 to 2 inches broad, pale green, usually drooping outwards at the top; panicles large, usually 10 to 20 inches long, many branched, with numerous florets; pistillate florets with an awn usually 1 to 3 inches long. On muddy shores of streams in southern Ontario and Quebec, southward to Florida and Louisiana.

1b. ZIZANIA AQUATICA var. BREVIS

Estuarine wild-rice, Estuarine zizania This variety

The type specimen of Zizania aquatica *var.* brevis *Fassett collected by its author, Norman C. Fassett, on the rocky tidal flat of the St. Lawrence River at Levis, opposite Quebec, in 1923. The varietal name* brevis *refers particularly to the short awn on the grain-bearing spikelets (which have all fallen from the specimen and are enclosed in the envelope seen above the label on the sheet), but* brevis *applies also to the low stature of the plant and to the grains and spikelets, which are shorter than those in other varieties. The name estuarine wild-rice is given because the plant is confined solely to those shores influenced by freshwater tides, known as the estuary. The estuarine shores of the St. Lawrence, however, are very broad and extend for many miles above and below Québec City. The specimen is now preserved in the Gray Herbarium, Harvard University.*

was named by Norman C. Fassett in 1924 (*Rhodora,* Volume 26, page 157) on the basis of specimens that he and H. K. Svenson collected at Levis, Que.

Plants 1 to 3 feet tall, with slender flexible stalks; leaf blades usually less than ½ inch broad, dull green. Panicles usually 4 to 10 inches long, few branched and with few florets. Pistillate florets with an awn less than ½ inch long. On tidal flats of St. Lawrence River estuary.

2. ZIZANIA PALUSTRIS

This species was named by Linnaeus in 1771 (*Mantissa Plantarum Altera,* page 295) on the basis of plants grown in his garden at Uppsala from seed sent from America by Pehr Kalm, his student. Linnaeus took only the upper stalk of one stem to preserve in his herbarium and this portion has been selected as the type.

Plants annual, upright, dying after maturation of grain (in October in Canada); staminate and pistillate florets borne on stalks completely smooth at the summit; hull of grain firm and leathery, shiny and smooth on the surface but scabrous in the furrows. Two varieties are recognized

2a. ZIZANIA PALUSTRIS var. PALUSTRIS

NORTHERN WILD-RICE, NORTHERN ZIZANIA This is the typical variety of the species, but in most modern works it is given under the combination *Z. aquatica* var. *angustifolia* Hitchcock.

Stems usually extending 2 to 4 feet above the water surface, rather slender; leaf blades ¼ to ½ inch broad; panicle slender and few flowered, the staminate florets usually numbering less than 15 on a branch, the pistillate

The classical specimen of Zizania palustris *L. is preserved in the Linnaean Society Herbarium, Burlington House, London. On it, Linnaeus wrote only "Zizania" at the left of the base of the stalk and "H U" at the right. From the initials we know the plant was grown in his garden, Hortus Upsalensis, at Uppsala, Sweden, and from other sources we know that the seed was collected near Montreal by his student, Pehr Kalm, in 1749. The other annotation faintly showing on the sheet was made later by the authority, J. E. Smith:* "palustris vix ob aquatica diversa" (palustris, *scarcely different from* aquatica), *an opinion that led later students to doubt the specific distinctness Linnaeus wished to designate.*

This specimen of Zizania palustris *var.* interior *was collected at Armstrong, Emmet County, Iowa, in 1897, and made the type for the variety by N. C. Fassett in 1924. It is most important that such specimens exemplifying a name be preserved for future reference. This sheet is held in the Gray Herbarium, Harvard University.*

usually only 2 to 6 on a branch. In water up to 4 feet deep in rivers and some lakes; widespread in southern Canada from New Brunswick to Manitoba (extended by planting), southward into the northern states.

2b. ZIZANIA PALUSTRIS var. INTERIOR

Interior wild-rice, Interior zizania This variety was first described by Fassett in 1924 (*Rhodora,* Volume 26, page 158) as a variety of *Z. aquatica.* He cited a specimen from Armstrong, Iowa, as the type. This variety is here transferred to the species *Z. palustris* in the new combination *Z. palustris* var. *interior* (Fassett) Dore.

Stems usually 4 to 8 feet tall; leaf blades ½ to 1½ inches broad; panicles ample, branches generally divergent and many flowered, the staminate florets numbering over 30 on a branch, the pistillate 10 to 30 on a branch. On muddy shores and in water up to 1 foot deep along rivers; southeastern Manitoba and adjoining Ontario (scattered at various points by being planted, from New Brunswick to Manitoba), more abundant in the adjoining North Central States.

3. ZIZANIA TEXANA

Texas wild-rice, Texas zizania This species was named by A. S. Hitchcock in 1933 *(Journal of Washington Academy of Science,* Volume 23, page 454) from speci-

The coarse Manchurian wild-rice, Zizania latifolia, *is growing in a muddy paddy at Ottawa. This broad-leaved Asiatic species is perennial, but when grown outside or indoors in the greenhouse it has never produced flowers. The three clumps, grown from small rhizome fragments set out the previous fall, have stems over 5 feet high and they have enlarged rapidly. In the Orient, the underground runners, when swollen by fungal infection, are prized as a vegetable. In France and Russia this species is grown as a forage plant on wet land.*

mens and information sent by W. A. Silveus from San Marcos, Texas.

Plants described as perennial, prostrate, with surface-rooting stems, otherwise similar to *Z. aquatica* var. *aquatica* in foliage, flower, and fruit characters. This dubious species is known only in the San Marcos River at the type locality, San Marcos, where it is considered to be endemic. There is reason to believe that its "perennial" nature is due to the constant year-round temperature of the artesian waters in which it grows, and flowers even in the winter months. The prostrate habit of the plant is undoubtedly caused by the force of the current, which holds down the stems, restricting panicle formation and maturation of grain. The status of "*Z. texana*" as a species distinct from *Z. aquatica*, therefore, requires careful field appraisal. It is possible that some confusion has resulted from collectors mistaking the heavy rhizomes of another grass, *Zizaniopsis miliacea*, which grows at the same site, for perennating structures of the *Zizania*.

4. ZIZANIA LATIFOLIA

Manchurian water-rice, Manchurian zizania This species was first named by Turczaninow in 1838 (Bulletin de la Société des Naturalistes de Moscou, page 105) on Asiatic plants, but the name was not properly founded until 1909 by Otto Stapf (*Kew Bulletin*, Number 9, pages 385–390).

Plants perennial, spreading by coarse subterranean runners; staminate and pistillate florets borne on stalks having a row of microscopic hairs at the tip, a corresponding crown of hairs present at the base of the hull of the floret; hull of grain thin, papery, dull, and rough as in *Z. aquatica*. A native grass of Manchuria, Korea, Japan, Burma, and northeastern India.

In parts of the Orient some stands of *Z. latifolia* are sterile because of infection by a systemic fungus. The swollen shoots of such plants are highly prized as a vegetable. This species also has potentialities as a forage grass, and it has been planted for grazing purposes in other countries of Asia and in Europe. Flowering plants grown at the Royal Botanic Gardens at Kew provided the material from which Dr. Stapf prepared the first detailed description and made a comparison with the North American *Z. aquatica*. In the botanic garden and greenhouse at the Plant Research Institute, Ottawa, however, this species has never flowered, although it has continued to grow vegetatively from seeds from Urawa, near Tokyo, Japan, originally sent by Tetsuo Koyama in 1954. At the Patuxent Reserve, near Washington, where the species was first introduced for testing by Charles E. Chambliss in the 1920s, the plants always flower, but in some seasons too late to ripen seed.

DISCUSSION OF TAXONOMIC CATEGORIES

Of the species outlined above, only the two that occur in Canada, *Z. aquatica* and *Z. palustris,* each with two varieties, are treated in the following pages. This treatment differs from that in two of the standard botanical manuals currently in use, *Gray's Manual of Botany* by Fernald, 1950, and *The New Britton and Brown Illustrated Flora* by Gleason, 1958, in which the four varieties are included as one species, *Z. aquatica.* The treatment in these manuals follows the concept of Fassett as presented in his critical monograph, "A Study of the Genus *Zizania,*" in 1924. In his *Manual of the Grasses of the United States,* 1951, Hitchcock does not, of course, mention var. *brevis,* because this variety does not occur in the United States.

The recognition of two species of *Zizania* in America (exclusive of "*Z. texana*") is not new. It was the original concept of Linnaeus, if we interpret his classical works correctly. Linnaeus proposed two names in *Zizania,* at different times and without cross reference, but later European authorities have not agreed with him on the application of these names, even their separate validity. In America, when Professor Hitchcock reviewed the genus in the seventh edition of *Gray's Manual,* 1908, he accepted Linnaeus' names as representing two distinct species, but, unfortunately, applied the names in reverse order. This error, appearing in a manual of such wide recognition, accounts for the confusion that continues to arise whenever reference is made to records or specimens accumulated between 1908 and 1924. Fassett's revision appeared in 1924. In the United States Department of Agriculture publication in 1922, *Wild Rice,* Charles Chambliss follows Hitchcock's treatment.

Wiegand and Eames in their *Flora of the Cayuga Lake Basin, New York,* 1925, used the two names correctly, but their treatment was ineffective because Fassett's recognition of a single species, coming out in print almost concurrently, obviated the need for two names. However, in an article in *Rhodora,* Volume 29, pages 228 and 229, 1927, Fassett considered it necessary to reiterate his concept and to explain that, in his opinion, var. *interior* in its morphology completely bridged the gap between the two supposed species. The state of indecision will undoubtedly persist until a thorough biosystematic investigation is made of the supposed entities. Meanwhile, a classification into four varieties divided between the two original species, and based simply on morphological and geographical features, is preferred. Fuller knowledge of the underlying genetic relationships might provide justification of distinct species status for var. *brevis,* so characteristic are its features of short awn, small grain, and small height, which are perpetuated under cultivation. Such treatment would not be out of line with the view of the first collector of this dwarf plant, Col. William Munro ("the most accomplished agrostologist of our day," according to Asa Gray), who, in 1858, indicated that a specimen gathered at Quebec was a species different from tuscarora.

When the distinctions between varieties are considered, an intergradation of characters resulting from infraspecific crossing can be expected. Geographic separation is the chief factor that keeps varieties distinct. When they occur at the same place, intermediate individuals are usually found. Some authors call such geographic varieties subspecies, an equivalent category. Plants intermediate between var. *palustris* and var. *interior* are often found. The intermediates between var. *aquatica* and var. *brevis* are comparatively very few, and their occurrence is hard to explain because they grow where one parent variety is lacking.

Further difficulty in classification is caused by variations that are due to environment: variations in vigor of the plants expressed in size of stem, breadth of leaves, and ampleness of inflorescence. For example, specimens of var. *interior* growing in a crowded stand can become so depauperate as to be indistinguishable from plants of var. *palustris;* and there is the classic example of Linnaeus' pot-bound *Z. aquatica* being mistaken for *Z. palustris* by Hitchcock.

Within varieties, individual plants have inherent morphological variations of a minor nature. These variations include differences in color of the plant body and florets, length of the floret bristle, size and shape of the grain, and number of grains to a branch. Such variations, genetic in nature, could be classified and named as separate botanical forms, but so far no forms have been designated for wild-rice in America. If any of these forms prove to be agronomically significant, they might be designated cultivars.

OCCURRENCE OF WILD-RICE VARIETIES IN CANADA

Wild-rice occurs naturally over a large portion of eastern North America extending from New Brunswick westward across southern Canada to eastern Manitoba and southward to Massachusetts and Nebraska. It also extends southward along the Atlantic slope to Florida and to southern Louisiana. Within the limits of this broad range, there are large sections where wild-rice has always been absent and other areas where it is sparsely scattered, because of either a lack of suitable habitats or the presence of certain physiographic and biological barriers to migration. On the other hand, wild-rice is known to grow at stations well outside the above-stated limits, but in these localities its occurrence is certainly the result of intentional planting. In these outlying stations, the plant grows well, often better than within its natural range, maintaining itself from year to year. Such evidence indicates that the potential range is very great, probably encompassing the temperate and tropical portions of all continents, wherever suitable conditions occur.

No routine survey has been made across Canada, so all the places where wild-rice grows and does not grow have not been recorded. However, our knowledge of localities in southern Ontario, eastern Manitoba, and parts of New Brunswick is quite complete. It has been possible, then, to indicate by stipple on distribution maps the general area where stands of probably natural origin occur.

On these maps, which follow in this chapter, a solid circle denotes an approximate locality where one or more specimens have been collected; these specimens are preserved in various herbaria and museums. Records of proven locations do not allow great details on the maps. In fact, naturalists and others familiar with their local countryside will probably know additional places where wild-rice grows. An open circle represents a location for which there is no substantiating specimen. An open or solid circle not in a stippled area, represents a locality where the variety grows as the result of known or presumed planting. Place names marked by a circled dot are for orientation only.

Conclusions regarding climatic requirements cannot easily be arrived at from the distribution maps. Wild-rice migrates slowly and has not reached the ultimate limits of its range. Unlike the seeds of many other plants, seeds of wild-rice are not scattered widely by the wind. The plant must have water in which to grow, and flowing water is the main agent for the dissemination of its seeds. If a few plants got into the upper reaches of a river, wild-rice could be expected to spread eventually throughout the whole downstream system. There seems to be no natural means by which grains can move upstream or get over land to another water system, hence nearby streams or tributaries of main streams may completely lack wild-rice.

Seeds are often carried by birds, either internally or on their bodies. But, because the grains of wild-rice are smooth, they do not adhere, and it is unlikely that they would be carried on the feathers or feet of birds. Since grains of wild-rice are thin-shelled and highly digestible, it is also inconceivable that they could pass unharmed through a duck's crop and digestive tract. Beavers, however, might carry wild-rice grains for short distances in the mud they use for building dams.

The activities of the aborigines must

be emphasized. Wild-rice was important to them as a food plant, and its grain was gathered in quantity, stored for winter use, and undoubtedly carried on long trips by canoe. It is probable that seeds, if not intentionally planted near new tribal grounds, may have been accidentally dropped along the travel routes. It would be the grains from the fresh harvest that would be effective in new sites. To understand the present-day irregular occurrence of wild-rice, all such factors must be considered. Only recently, since man has developed an ardent interest in hunting and wildlife conservation, has wild-rice been introduced to the hundreds of sites far remote in the wilderness that have been made accessible by plane, car, and motorboat.

Extensive beds of northern wild-rice, Zizania palustris *var.* palustris, *occupy the shallows along the shifting course of this stream in southern Ontario. The grain provides much food for wildfowl but it is not known to be harvested here by humans. Seeds fall to the bottom in September and replenish the beds year after year. The position of the beds depends on the conformation of the alluvial deposits.*

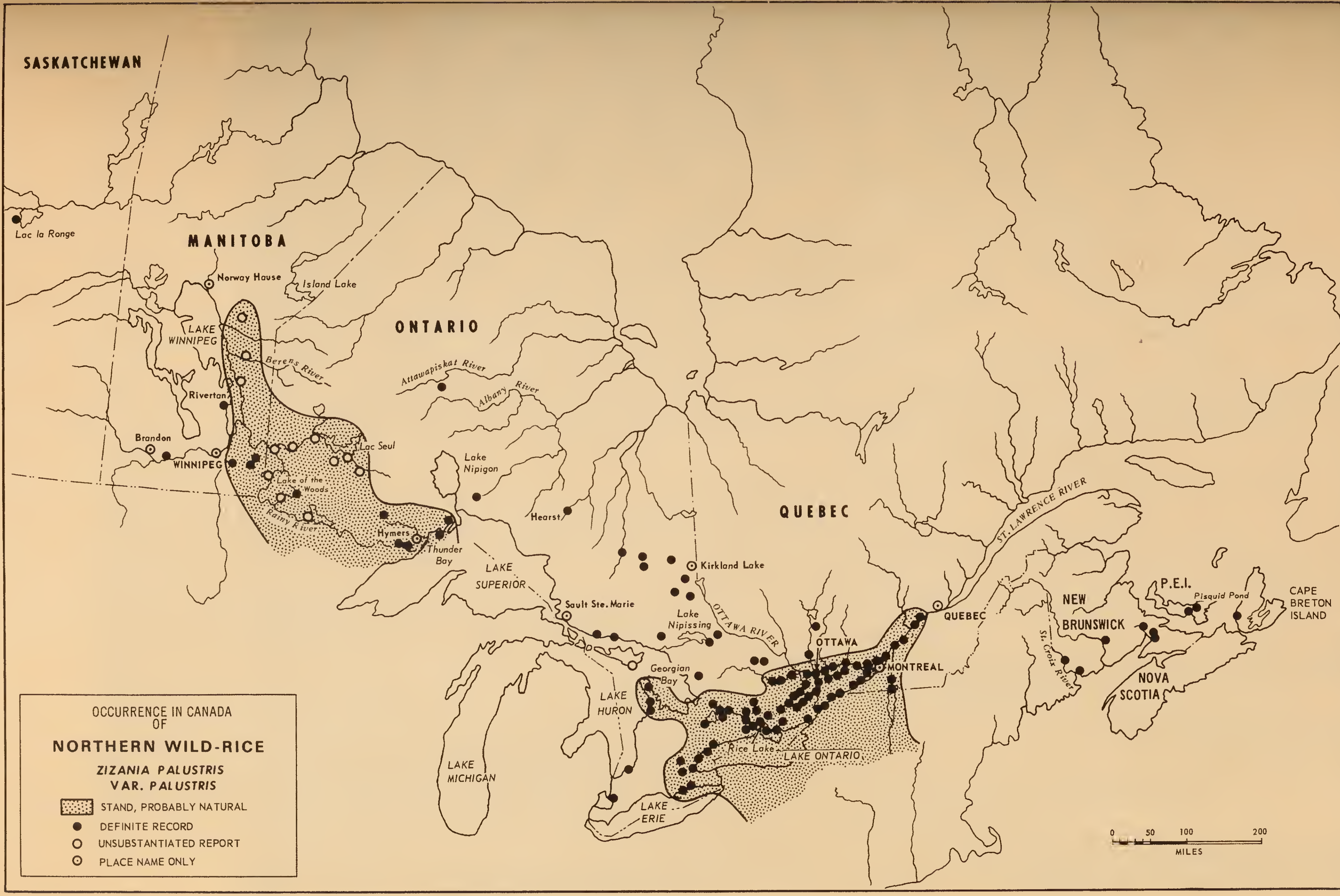
NORTHERN WILD-RICE

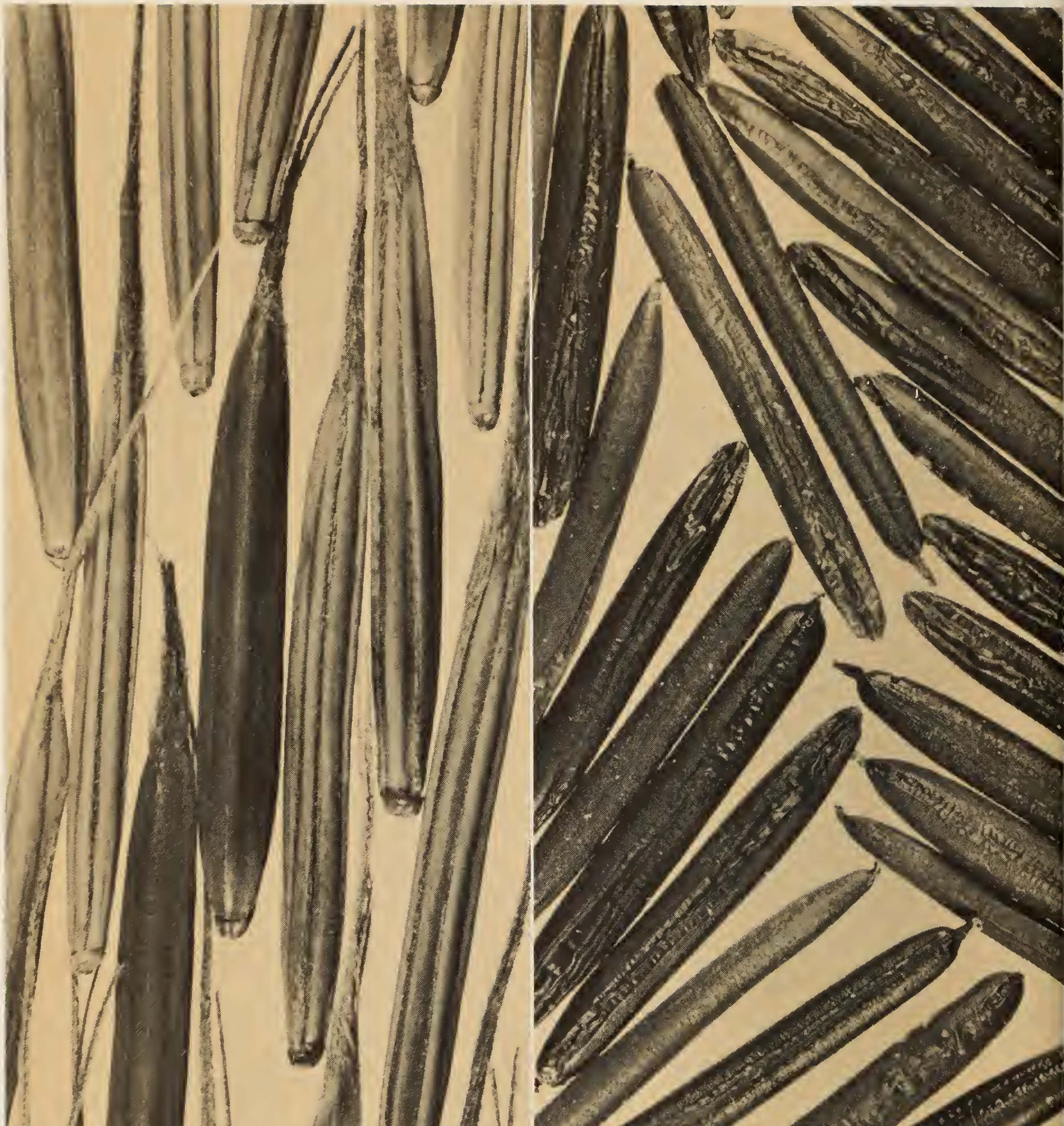
The most common variety of wild-rice in Canada, northern wild-rice *(Z. palustris* var. *palustris*) is also the variety of greatest commercial importance. It grows in extensive beds in the shallow brown waters of the many rivers, or their lakelike expansions, in the Precambrian area of eastern Manitoba and adjoining Ontario. Some stands are so reliable that the rice has been harvested in an organized way for many years. Northern is also the variety abundant in the rivers and streams of southeastern Ontario, where, however, the rice is harvested only on a limited scale for seed to be used for planting. It is not, however, the wild-rice that is the subject of several authors who know only wild-rice as it grows in the eastern seaboard states. The distinction between the two types is important.

Northern wild-rice has the largest grain of all the varieties, and consequently it is the most desirable for the market. At one time it was promoted as "giant wild-rice," especially by producers and handlers in Wisconsin. Seed sold under this name, however, has been found by test to produce plants with grains no larger than those average for the variety. The grains certainly are large in comparison to those of southern wild-rice in the Atlantic States, so assertions in advertisements have been legitimate. Within the botanical variety itself there are, of course, certain natural strains that inherently produce a grain somewhat larger than average. These strains are found wherever the variety occurs, but they are more frequent in certain localities, notably in the Kenora district, where they are highly regarded for their superior quality. However, northern wild-rice sets fewer grains in each head than some of the other varieties, so it is not as productive as might be desired.

In Manitoba, the producing areas of northern wild-rice are all east of Lake Winnipeg, extending as far north as about latitude 53°, which is within about 50 miles of Norway House. It is not known just how far this northward range extends in adjoining Ontario, and the particular shape of the lobe shown on the map is not at all definite. No specimens are available from this general area, and it was only in 1961 that Alfred Rogosin, in an unpublished report, stated that it was var. *palustris* that occurred

Northern wild-rice grows sparsely when it is crowded by other aquatic plants, as it often is in many small streams in Ontario. Left: *The plants extend from the muddy shore, near the drift-log on which the man is standing, out into water about 2 feet deep in midsummer.* Right: *Plants of northern variety are seen to have a slender panicle of appressed florets at the top of each stem. The stems, however, increase in number when the plants have plenty of space.*


SASKATCHEWAN
Lac la Ronge
MANITOBA
Norway House
Island Lake
LAKE WINNIPEG
Berens River
Riverton
Brandon
WINNIPEG
Lake of the Woods
Rainy River
Lac Seul
Hymers
Thunder Bay
ONTARIO
Attawapiskat River
Albany River
Lake Nipigon
Hearst
LAKE SUPERIOR
Sault Ste. Marie
Kirkland Lake
Lake Nipissing
OTTAWA RIVER
Georgian Bay
LAKE HURON
LAKE MICHIGAN
LAKE ERIE
Rice Lake
LAKE ONTARIO
OTTAWA
MONTREAL
QUEBEC
QUEBEC
ST. LAWRENCE RIVER
St. Croix River
NEW BRUNSWICK
NOVA SCOTIA
P.E.I.
Pisquid Pond
CAPE BRETON ISLAND
0 50 100 200
MILES
OCCURRENCE IN CANADA OF
NORTHERN WILD-RICE
ZIZANIA PALUSTRIS VAR. PALUSTRIS
STAND, PROBABLY NATURAL
DEFINITE RECORD
UNSUBSTANTIATED REPORT
PLACE NAME ONLY



Northern wild-rice. Left: *Grains as harvested; hulls are smooth, shiny. and corrugated lengthwise. their sharp hairs confined to the grooves and base of the coarse awn.* Right: *The inner kernels after the hulls are removed; the kernels are dark brown or black. and wrinkled up the side of the germ (× 4.2).*

there. The only previous information was in an ethnological account by A. I. Hallowell acquired during visits in the early 1930s to the tribes of Indians in eastern Manitoba. Hallowell learned that wild-rice grew in abundance within the territory of the Salteaux Indians at latitude 52° N and for a distance of some 60 miles up the Berens River, but that none grew north of Norway House at latitude 54°, and none grew on the canoe route eastward from Norway House to Island Lake, about 175 miles away. In the account, he mentions the occurrence of wild-rice in several other rivers to the south, which flow into Lake Winnipeg. On the map of *Z. palustris* var. *palustris* these locations are denoted by open circles because there are no specimens on which to base an identification.

Agents licensed by the Crown in Manitoba buy wild-rice from the Indians and bag the fresh grain at designated clearing points. Two of the main points are Lac du Bonnet, about 55 miles east-northeast of Winnipeg, and Pointe du Bois, near the western limit of the Whiteshell Provincial Park, about 75 miles east-northeast of Winnipeg. The records of sales from these and other franchises are the basis of the productivity figures given in Table 1. The franchises fall roughly into three blocks. The area east of the northern half of Lake Winnipeg is the most remote and the amount of wild-rice yielded here is not great; the region of rivers and lakes east of the southernmost part of Lake Winnipeg is an important area of production; the Whiteshell Provincial Park farther to the south produces the bulk of raw grain, about 70 percent of the total annual crop in Manitoba.

Occurrences outside these areas are known, but the plant is almost completely absent from the myriad of rivers, sloughs, and lakes elsewhere in Manitoba and Saskatchewan. At Riverton, Man., wild-rice grows in the Icelandic River, the point where shipments are received from the north and west. At Sewell Lake, isolated in the Spruce Woods Reserve east of Brandon, it has been known for many years, according to word I have received from Dr. R. D. Bird.

In Lac La Ronge, Sask., stands are doing well near the Indian reservation; good stands also occur in localities (not shown on the map) north of Prince Albert, Sask.

Large quantities of raw grain are brought to Kenora, in Ontario near the Manitoba border, and the rice is shipped to Winnipeg by truck or to other points more convenient by railroad. However, the Manitoba authorities do not keep records of the amount entering the province from Ontario. There is also a shipping center at Fort Frances on the Rainy River, whence the bags of fresh grain go direct to points in Minnesota for processing. From the highways in the Lake of the Woods and Rainy Lake areas northern wild-rice can be seen at several places, but the stands are scattered and sparse. Wild-rice of fine quality is known to be regularly harvested by the Indians within the jurisdiction of the Sioux Lookout Agency, over 100 miles east of Kenora. In this same general area, west of Lac Seul, Zizania Lake and Zizania Creek were officially named in 1924. Although it is evident that the best beds are located intermittently in the vast network of waterways in the Kenora district, there is a strong possibility that seed was brought intentionally or inadvertently by the Indians, once the reserves had been designated to them. At any rate, from our present knowledge it seems that the stands must run out completely at some line north and east of Sioux Lookout, on Lake Seul. In 1857 members of the Palliser Expedition, traveling westward by canoe from Thunder Bay, noticed wild-rice first at Rainy Lake and from there to the Red River settlement (Winnipeg). In early times wild-rice was probably very scarce or absent in most of the tract extending west from the head of Lake Superior, except for the southwestern part of Kenora, and stands now present in the English River, in the Kenora district, and in Round-table, Sandstone, and Whitefish lakes in the Thunder Bay district and are likely the result of intentional planting.

No evidence is available for the occurrence of wild-rice in the many lakes and streams that drain into Lake Superior from the north. Some wild-rice grows, however, in a bay of that lake at the base of the Silby Peninsula. An interesting record is provided by a specimen collected by Abbé Lepage in 1952 at Lake Hail, some 200 miles north of Lake Superior on the divide between the Albany and the upper Attawapiskat rivers. Despite the discoverer's opinion, expressed to me in a letter, it seems as if this stand was established by intentional planting, but it is not known why wild-rice would have been planted at so remote a location. No specimens were obtained by botanists of the University of Toronto during extensive investigations along the north shore of Lake Superior between 1935 and 1939.

According to a more recent verbal report, there are two or three lakes, unspecified, east of the Nipigon River where wild-rice now grows. This occurrence is quite likely, but is seems certain that no natural stands originally occurred between Lake Nipigon and Sault Ste. Marie. An old record from Hearst is accompanied by information on planting.

An interesting record is from Lake Huron east of Sault Ste. Marie, where a specimen, still preserved, was collected by Robert Bell in 1860 from a "marsh at the mouth of the Mississaugi [sic] River." This is one of the earliest Canadian collections and it can be considered to be from an original or at least a pre-settlement stand. Bell's brother John (1870) reported wild-rice from nearby Drummond Island, Mich., in 1866 and, although no subsequent collections have been made at either locality, the old stands and possibly others isolated in that general area, such as one in Cheboygan County, Mich., probably still exist. The Serpent River site located some miles east of the Missisagi, however, was not detected until 1949. Because of this late date, the location of the stand near the highway and an old homestead, and the presence of another, definitely alien, aquatic grass (*Glyceria maxima*), this site is certainly an artificial one. The single stand on Manitoulin Island, represented by a preserved collection from South Baymouth made in 1958 by Hugh Dale, is considered to be of similar origin.

It is entirely likely that, originally, the plant was lacking from all the area north of Lake Huron and Lake Nipissing. Several reports from this region have been made in recent years. Some stands have been sown by officials of the Ontario Department of Lands and Forests, whereas others have been privately planted by sportsmen. The stands in the series of lakes connected by Grassy River, 25 miles northeast of Gogama, are considered to be of natural origin. Much seed from these lakes has been used for planting in lakes around Swastika and Kirkland Lake, some distance to the east. In most cases, the stands resulting from seedings in this northern area are thin, and their establishment is not very reliable or persistent. Baldwin (1958) reported several localities in the Clay Belt and expressed doubt of any being natural stands. The conditions in the Grassy River lakes must be particularly favorable for the stands to persist there from the seed brought in a long time ago, presumably by ancestors of the Indians now in the reservations nearby.

Krotkov (1940) reported wild-rice as "somewhat rare" on the Bruce Peninsula, as he collected it at only three points. In the counties south of this peninsula its absence may be due to the rivers being small and often temporary. The occurrence near Port Franks along the lower part of Lake Huron is undoubtedly the result of planting.

The main stands of the variety in Ontario, therefore, are not found in the wilderness of lakes and streams in the north but in the waters of the Trent system and rivers flowing into the Ottawa from the west and south. The stands that made Rice Lake famous in the early days of settlement are perhaps the best known in all Canada. Catherine Parr Traill, in her lucid description of the natural history of Peterborough County in *Studies of Plant Life in Canada,* 1885, dwelt at some length on the Rice Lake beds and the methods used by the Indians in their harvesting. The great antiquity of aboriginal culture in that part of the province and the high state of development it attained could well have been the result of a sufficient and reliable supply of wild-rice. It is quite likely that seed was carried into the Trent River system by the earliest of the aboriginal inhabitants, presumably from areas in New York State, since archaeological evidence indicates commerce in that direction.

The present poor status of the Rice Lake beds, restricted to a few acres in protected bays along the north shore in the vicinity of the mouth of Indian River, cannot be taken as a measure of their former extent. Reduction of the old stands seems to have taken place since the beginning of the present century, and it is now profitable to harvest them. Nickels (1952) reported a similar decline at Buckhorn Lake, in the Kawartha Lake system. Stony Lake, some 25 miles north of Rice Lake, probably never had similar continuous stands along its shores, or Mrs. Traill, who knew that lake just as well as Rice Lake, would have mentioned them. In 1952, stands a few acres in extent were present in Stony Lake, at the northeast near the mouth of a large entering stream known as the Jack River. Recently pictographs have been discovered on the rock in this area. Stands of variable dimension, from stray plants to vast beds, may be found in almost every other lake expansion and connecting stream of the Trent system from Lake Ontario to Georgian Bay, with the strange exception of Lake Simcoe.

Much planting, apparently of seed from outside sources, has taken place in this central portion of southern Ontario and there is an admixture of tall broad-leaved types that are intermediate to the interior variety. In the Rice Lake area a distinction is even made between "lake rice" and "river rice," the latter being the larger and more productive plant present in the Indian River and the marsh at its mouth. At one time, Mr. G. S. Taylor, the general merchant at Keene, engaged in the wild-rice seed trade. The "river rice" could have been brought in from Minnesota, where a similar seed industry had developed earlier.

Whatever the origin and source of the mixed stands in this part of eastern Ontario may be, it is quite clear that there were no original stands north of the southern boundaries of the Muskoka, Haliburton, and Nipissing districts before settlement. In 1953, in an unpublished report of a survey of aquatic plants made in seven lakes of the Muskoka district, J. K. Shields stated that wild-rice was absent from all but one, where it was known to have been planted a few years previously. A small stand in the Mattawa River at Pimici Bay was planted in 1945; one in Bass Creek where it enters Lake Nipissing from the southeast, collected in 1929, is undoubtedly of the same origin.

In the Ottawa drainage, extensive and almost continuous stands are present along the Mississippi and Rideau rivers, throughout their major parts. Stands are also known in the South Nation, Bonnechere, and Petawawa rivers, but none are reported for their smaller tributaries or for the intervening Madawaska. Scattered patches are present in the waters of the Ottawa itself, from Renfrew downwards. To what extent these have been planted by interested sportsmen is not definitely known, but it may be that some, perhaps all, have resulted from sowings. For example, there is the story that the late Bill Beaver, a pure-blooded Indian of Marmora, brought the first wild-rice seed to the upper reaches of the Mississippi some 90 years ago, and all stands now present down the Mississippi may constitute the progeny of that early introduction. In the slow-flowing Jock River, a tributary of the Rideau near Ottawa, the stands start abruptly at a point about eight miles above its mouth, where a planting must have been made but a few decades ago.

No tributaries flowing into the Ottawa from the north side have yielded records of wild-rice, and its original absence is quite certain in that part of Quebec province. The two locations shown on the map north of the Ottawa River represent a small experimental planting in Danford Lake in 1949 and a localized establishment near Mont Laurier in the Lievre River recorded in 1941. Since the climate is suitable, the absence of wild-rice from tributaries north of the Ottawa can be accounted for by the inability of the plant to disperse upstream.

It is safe to assume because of the wide gap eastward from Ontario that all stands of wild-rice in the Maritime Provinces are the result of planting. Some facts are available to support this assumption. At Aulac, N.B., a single stand, obviously planted from a bridge, was present in 1945 in a ditch on the marsh. At nearby Long Lake, N.S., an official of the Canadian Wildlife Service made a seeding shortly before 1935. In Prince Edward Island the stand in the muddy Pisquid Pond has persisted since about 1900, but one at Southport planted with Wisconsin seed in 1928 was destroyed by muskrats after only 3 years. In a pond in Cape Breton wild-rice planted with seed from Wisconsin about 1948 developed very poor growth, but other more successful stands are said to exist in Nova Scotia. At Maquapit Lake, N.B., there was a fairly large and vigorous stand in 1957, but it was quite isolated; at McAdam repeated plantings have been unsuccessful and the last one died out in 1957; in an artificial pond at Tower Hill, a planting was made in 1960. Since the plant is absent from numerous water bodies in the Atlantic Provinces well known to botanists, including the Magaguadavic and St. Croix rivers, which are the nearest rivers to the natural stands in the Penobscot River in Maine, it is quite certain that the few occurrences of which we have record are the result of planting also.

Between the years 1910 and 1945, the Division of Botany at the Experimental Farm at Ottawa, in response to public requests, gave considerable attention to wild-rice and even supplied small lots of viable seed, free of charge, for planting. The seed was harvested locally from the

Northern wild-rice grows well amid human competition, as shown here, along the Indian River near Keene, Ontario.

Rideau River or from a stand in the Arboretum lagoon established from seed from Hymers, Ont. Many seed samples were also sent abroad. During the last two decades requests for seed have continued to be received, but these have been directed to suppliers in eastern Manitoba and Wisconsin.

INTERIOR WILD-RICE

Natural stands of the interior variety (*Z. palustris* var. *interior*) occur only in the southernmost portion of Manitoba. It has been introduced, however, as far east as New Brunswick, and it is very abundant in the lower St. John River.

Interior wild-rice is closely related to northern wild-rice, var. *palustris*, and the two varieties are often difficult to distinguish when conditions do not allow their full development. The grains are somewhat shorter than those of the northern variety, but they are produced in greater abundance. Thus, they get into the commercial harvest in Manitoba and also, undoubtedly, into the viable seed distributed for planting. The grain is plump

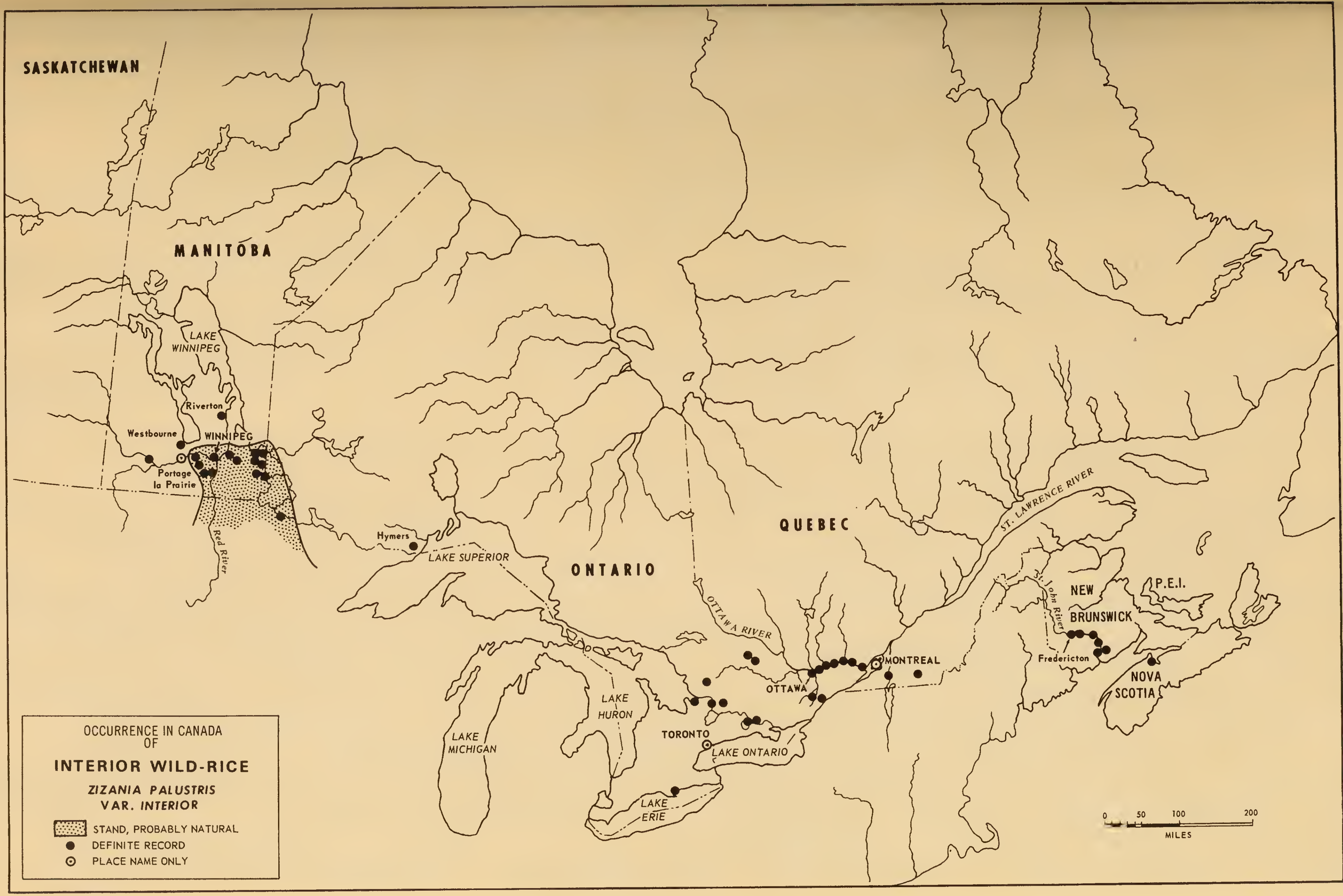
Interior wild-rice, Zizania palustris *var.* interior. Left: *Interior wild-rice grows abundantly for miles in the soft muds of the Sale River channel, southwest of Winnipeg. As the water dries up, the stand becomes lush and continuous, but the substrate makes it impossible to harvest it from canoe or on foot.* Right: *Interior wild-rice is locally known as river-rice in southeastern Manitoba because it lines the banks of rivers like the Whiteshell, shown here.*

Interior wild-rice. Left: *The plants grow 6 feet high on the mud flats and among the waterlilies of the lower Ottawa River. In the spring, floodwaters rise 4 to 10 feet over these flats, but in the fall the mud becomes bare and hard enough to walk on.* Right: *On the tidal beaches of the lower St. John River, N.B., the stands of interior wild-rice are subject to daily flooding. Some damage is done by floating logs and debris.*

and suitable to be grown for sale, but because of an arbitrary preference for a very long grain it is not favored by producers.

In general. interior wild-rice is a plant of stream banks and shallow waters. It inhabits shores from which the water retreats in the summer, leaving flats of muddy alluvium or ooze. In experimental ponds of constant depth interior variety flowers slightly later than northern variety, but in natural habitats on the warm muds of shallow streams it flowers and ripens earlier. It is possible, therefore, to harvest it earlier than other varieties and to do so on foot. In fact, it is almost impossible to harvest this interior variety from a canoe or boat. A broad basket or carton strapped to the waist makes a good collecting receptacle, the heads being easily drawn over by hand and rapped against the inside to dislodge the ripe seed.

When fully developed, the plants are 5 to 8 feet tall, are rather sturdy in the stalk, and have quite broad, pale-green leaves that lop over at the top. New

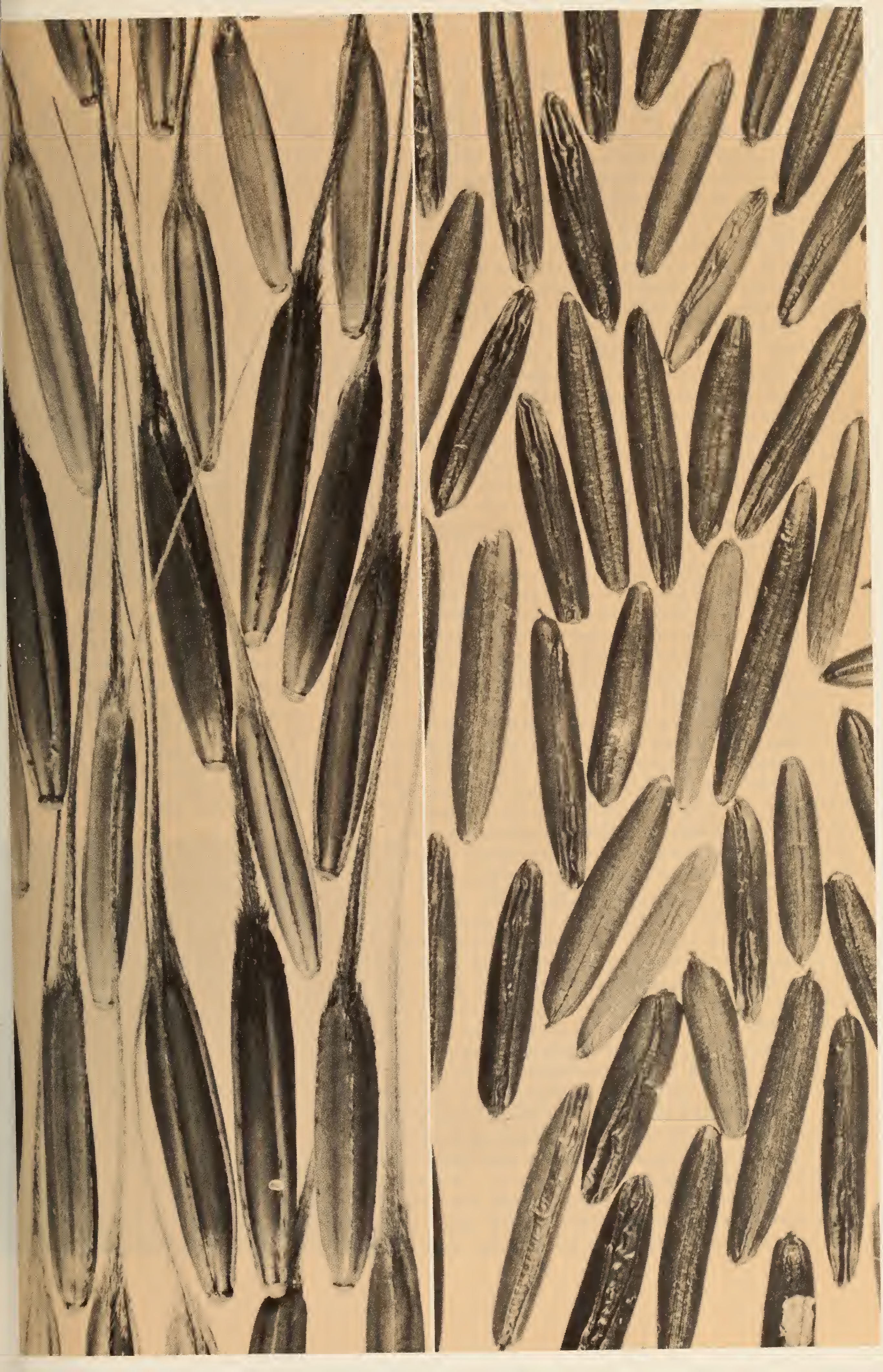

SASKATCHEWAN
MANITOBA
LAKE WINNIPEG
Riverton
Westbourne
WINNIPEG
Portage la Prairie
Red River
Hymers
LAKE SUPERIOR
ONTARIO
QUEBEC
ST. LAWRENCE RIVER
OTTAWA RIVER
OTTAWA
MONTREAL
TORONTO
LAKE ONTARIO
LAKE HURON
LAKE MICHIGAN
LAKE ERIE
St. John River
NEW BRUNSWICK
Fredericton
P.E.I.
NOVA SCOTIA
0 50 100 200
MILES
OCCURRENCE IN CANADA OF
INTERIOR WILD-RICE
ZIZANIA PALUSTRIS VAR. INTERIOR
STAND, PROBABLY NATURAL
DEFINITE RECORD
PLACE NAME ONLY

shoots tillering out from the base soon thicken up a sparse stand on an exposed riverbank. When Fassett (1924) recognized interior variety as distinct, he did not report it for Canada, but stated its distribution as "Lake Michigan to North Dakota and Nebraska; Texas." The Canadian records as now known are given in detail in the following paragraphs and are shown on the map.

In the Sale River, southwest of Winnipeg, interior wild-rice reaches its characteristic development and almost clogs the muddy course of the river during low water. A nearly continuous stand runs from Elie near Portage la Prairie down to the junction with the Red River, a distance of about 30 miles, but it does not extend into the Red itself. Elsewhere in the plains area of southern Manitoba, interior wild-rice is sporadic and of less typical growth. Such sites are in the Whitemud River at Westbourne, where a mixture of color forms are present; in Sturgeon Creek on Portage Avenue, Winnipeg; in Cooks Creek near Gleason; and in the Brokenhead River near Beausejour.

Interior variety is plentiful in the Whiteshell Provincial Forest, which until recently was called the Whiteshell Forest Reserve. The Forest occupies almost all of the Whiteshell Provincial Park. This park is some 70 miles east of Winnipeg and borders on Ontario. Wild-rice is abundant on the shores of Whiteshell and Rennie rivers and on oozy borders of their lakelike expansions, such as Rice Lake and Lone Island Lake. It is here that it grades imperceptibly into northern wild-rice, and the two varieties are hard to tell apart. In crowded stands the plants are stunted, more slender, and more sparsely panicled, and they look like poorly developed specimens of northern variety, which grows in the same waters. Presumably the two varieties hybridize in such localities, but they can be distinguished by the gatherers and buyers. The tall plants that grow in the soft muds along the shore are here known as "river rice." Seeds of these plants are usually left by the gatherers, partly because the plants are inaccessible and partly because

Interior wild-rice. Left: *Grains as harvested; the hulls are smooth and firm, like those of northern wild-rice, but slightly shorter.* Right: *The black grains removed from their hulls (× 4.2).*



they bear shorter grains. In contrast, the large-grained plants of northern wild-rice are known as "lake rice." The plants assigned to interior variety in the Whiteshell Provincial Forest are not quite as broad-leaved as those in the Sale River, and not as uniformly pale green. Shades of pink and purple suffuse their panicles and create a duller green in the foliage. Other specimens identifiable as interior variety are from scattered sites such as Treesbank, where a planting was made by Norman Criddle in 1910; Ile-à-la-Crosse in northern Saskatchewan, planted before 1949; and the Icelandic River above Riverton, Man.

Several sites of this variety are known in Ontario, and all are undoubtedly intentional plantings made during the past few decades. The seed obtained from Hymers, Ont., and multiplied at Ottawa for distribution, seems to have been of interior variety, if the illustration given by Faith Fyles (1920) is correct. The stand at Hymers, southwest of Fort William, was probably intentionally established. There is therefore considerable mixing, both mechanically and by hybridization, in the planted stands and it is difficult to find pure and characteristic stands of interior wild-rice in Ontario and eastward. The alluvial flats of the Ottawa River from the city of Ottawa down to where the river meets the St. Lawrence provide favorable habitats for the interior variety. Most of the plants are left on the exposed mud at low-water in mid-August, and the seeds can be collected on foot. The density of the stands varies greatly from year to year, but when conditions are good the set of seed is very high.

Several isolated stands in Quebec and the Maritime Provinces, excepting those in the lower St. John River, are of small extent, and their time of establishment is definitely known in some instances. Near Sherbrooke, Que., for example, seed of American source was planted about 1935. In the Canard River, N.S., plants of interior variety appeared for the first time in the province in 1939.

The stands in the St. John River, N.B., merit fuller comment because of their great extent and ideal accessibility for

Southern wild-rice, Zizania aquatica *var.* aquatica. Upper: *The grass reaches its typical development as a tall broad-leaved plant with large plumelike panicles in deltaic marshes at the mouths of small streams such as Dedrick Creek where it enters Lake Erie.* (Photo by Ontario Department of Lands and Forests) Lower: *When in full bloom in the latter part of July, the bright-yellow staminate florets are very conspicuous in the open panicles. Pollen is shed for a period of only one day. This photograph was taken on the Napanee River, Ont.*

exploitation. On this river, the northernmost occurrence is at McKinley Ferry, about 10 miles above Fredericton, and stands are found continuously downstream for about 70 miles, until brackish water occurs. Banks 50 to 100 feet wide grow along both shores, as well as along the various meandering side channels and lagoons influenced by the tidal waters. In this low-gradient stretch of the St. John, periodic high floods prevent the establishment of permanent vegetation and make conditions favorable for a lush development of semiaquatic and aquatic herbs. Slackening of the current twice a day causes a continual deposition of silt and creates open flats favorable to annual species.

On the higher parts of the mud beaches of the St. John River, wild-rice plants grow much taller and develop the broad leaves and full panicles so characteristic of the interior variety. Smaller and more depauperate plants occur on the lower beach and out into water a foot or two deep at ebb tide. Such plants resemble northern wild-rice. In deeper water, seedlings cannot survive because of extreme muddiness.

The early history of these St. John River stands is obscure. Zizania was not reported for the province until 1883 (Fowler, 1885) although lists of grasses were published before that date. Early botanists exploring the banks around Fredericton could not have failed to notice such a conspicuous and abundant grass if it had been there at the time. Consequently, the stands must have been introduced from some unknown source in the 1880s and must have spread to all parts of the estuarine water.

SOUTHERN WILD-RICE

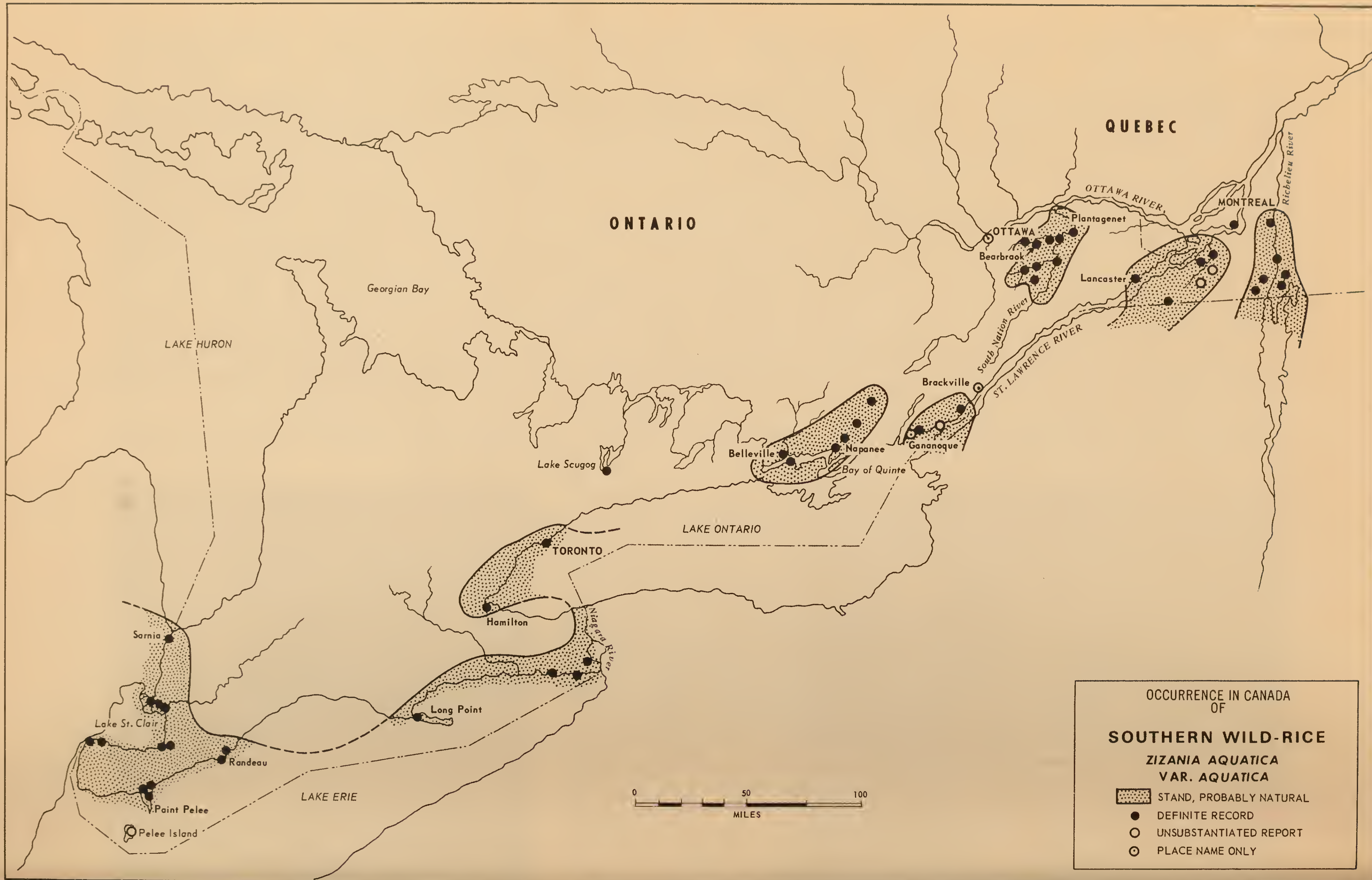
The southern variety (*Z. aquatica* var. *aquatica*) is widely distributed and is the chief species in the eastern states, but it is present in Canada only along the Great Lakes in southern Ontario and in the low lands of southwestern Quebec. There has been little interest in establishing this variety from seed, so the places where it is now found in Canada are probably the ones where the plant occurred when the areas were first settled.

Southern wild-rice is a handsome, ornamental plant, and it is taller than any other native grass species. For some reason not clearly understood, most of its many florets are sterile, but the plant sets enough seeds to sustain stands. The grain is rather slender and thin compared with that of northern wild-rice. It seems to do best on rich mineral alluvium at the mouths of sluggish streams, which otherwise remain barren and become caked when the water dries up in midsummer.

When Fassett (1924) made his revision of the genus, he cited only one specimen of southern wild-rice from Canada, from Pelee Island in Lake Erie, barely within Canadian territory. There were, however, at least six other specimens available from Canada at that date: from Sandwich, Amherstburg, Hamilton, Belleville, Casselman, and Montreal. Today we have specimens from many more places and our knowledge of its total presence and absence is better known.

The stands in Lake St. Clair are along the channels of the delta, in slow-moving creeks entering the lake from other directions than that of the southward-flowing St. Clair River, and on protected mud flats in the lake itself. A statement by Dodge (1915) that the plant was abundant in Sarnia Bay and in shallow water along the St. Clair River may indicate a former continuous extension to the foot of Lake Huron, although this cannot now be verified. From below Lake St. Clair, in the Detroit River, there is a very early specimen, marked "swampy area, Amherstburg, C.W., August 1848," preserved in the herbarium at the Edinburgh Botanical Garden. No subsequent specimens from the river have been collected.

Along Lake Erie, erosion of the shoreline creates unfavorable conditions for southern wild-rice and it occurs only where protection is afforded by long sand bars or spits, such as those at Point Pelee, Rondeau, Long Point, and Point Abino. The stands at Point Pelee were at one time extensive and they formed the main marsh for a considerable distance off


OCCURRENCE IN CANADA OF
SOUTHERN WILD-RICE
ZIZANIA AQUATICA
VAR. AQUATICA
STAND, PROBABLY NATURAL
DEFINITE RECORD
UNSUBSTANTIATED REPORT
PLACE NAME ONLY
0
50
100
MILES
QUEBEC
ONTARIO
OTTAWA RIVER
Richelieu River
MONTREAL
Plantagenet
OTTAWA
Bearbrook
Lancaster
South Nation River
ST. LAWRENCE RIVER
Brockville
Gananoque
Napanee
Belleville
Bay of Quinte
Lake Scugog
Georgian Bay
LAKE HURON
LAKE ONTARIO
TORONTO
Hamilton
Niagara River
Long Point
Sarnia
Lake St. Clair
Randeau
Point Pelee
Pelee Island
LAKE ERIE

Southern wild-rice. Left: *Grains as harvested; the hulls are dull and thin, rough, with minute bristles, and prolonged into a very fine awn.* Right: *The grains are long but fairly slender in this variety (× 4.2).*

shore. Now, however, plants are very scarce here, and the marsh consists mainly of cattails and perennial reeds. Usually, too, the stands extend up the slow-moving parts of entering streams for a mile or two from the lake. Those behind Long Point, for example, may be said to be actually in the deltaic courses of Big Creek and Dedrich Creek. The stands in Welland County at the east end of Lake Erie are all in slow streams that flow into Lake Erie or the Niagara River, away from the lake shore proper.

Similarly, along Lake Ontario, the stands are away from open shores and confined to secluded marshy bays and stream mouths. Some of these stands are gradually disappearing. No plants have been reported from Hamilton Bay since 1898, and until recently none were collected from the Bay of Quinte, where, in 1867 on a specimen label, John Macoun recorded them as abundant. It was not until 1951 that southern wild-rice was again collected in the Bay of Quinte area. The collection was made at Huff Island across the bay from Belleville, by Soper and Heimberger, and a specimen has been preserved. In 1956 it was found in several of the slow creeks nearby, but was absent from the vast tracts of marsh at other places. The plant may have escaped detection in isolated stream beds, but at present it has declined in abundance in the other extensive habitats around the Bay of Quinte. The reason for decline is not known, but perhaps changes in the level of Lake Ontario, industrial pollution, or feeding by introduced carp are responsible.

In the Napanee River, at the eastern end of the Bay of Quinte, the plant grows well for a distance of some 15 miles above the town of Napanee, where a high dam has been constructed. In the broadening mouth of the river below the dam wild-rice is absent, even from the shallow muddy waters that would ordinarily be expected to support flourishing stands. According to verbal reports, wild-rice, presumably of the same variety, occurs in Odessa Lake and Sydenham Lake, in a drainage system east of the Napanee River.

A well-known stand occurs inland along the causeway at the south end of Lake Scugog, some 25 miles north of the Lake Ontario shore, and samples have often been collected from it. None of these samples, however, antedate 1929, so seeds must have been intentionally planted there.

Eastward along the St. Lawrence River, in an area observed quite intensively, southern wild-rice stands have been seen at only four points, all in the mouths of tributary creeks or rivers, three near Gananoque, the other in a sluggish stream east of Lancaster, which is much farther down the St. Lawrence. Such stands have periods of luxuriance and decline. In 1949 George M. Stirrett observed and photographed a dense, tall growth in a creek east of Gananoque, but in 1962 no plants remained. In 1950 many plants occurred in the mouth of Jones Creek, near Brockville, but they were not noted again on several subsequent inspections. Plants were abundant near Lancaster in 1949, but they were not seen in 1958. Insect depredation may be the cause of periodic reduction of seed.

North of the St. Lawrence, stands are known only in the lower reaches of South Nation River and its tributaries, Bearbrook, and the South Castor River, and in Scotch River, which, like the South Nation, drains into the Ottawa River. In these streams wild-rice plants are numerous, essentially continuous, and easily accessible from the roads near Marionville, Bear Brook, Leonard, Pendleton, Bourget, and Plantagenet. Although isolated some 40 or 50 miles north of the general limit of the variety, they are considered to have started naturally many years ago. Plants in this area are scarce in some years. There is also considerable morphological variation among individuals. Some patches are made up of plants that indicate a transition to estuarine wild-rice var. *brevis*, which is found mainly in the estuary of the St. Lawrence, about 100 miles to the east.

In southwestern Quebec, southern wild-rice occurs in the northward-flowing St. Louis and Chateauguay rivers and in Oak Creek and English River, which are tributaries of the Chateauguay. It is also present in the drainage of the Richelieu River, but seldom in the main channel itself. An extensive stand, considered to be the largest one of this variety in Canada, occurs on the impenetrable muddy morass that forms the bed of "South River," an overflow of the Richelieu. East of the Richelieu this variety of wild-rice has never been collected. The 1895 preserved collection by H. B. Cushing from "St. Pierre River, Montreal," the earliest from Quebec province, came from a habitat now buried under the pavement of downtown Montreal. It was probably an introduction.

In summary, the limited and interrupted distribution of southern variety in Canada suggests that it lacks aggressiveness and is unlikely to extend northward under present climatic conditions.

ESTUARINE WILD-RICE

Estuarine wild-rice (*Z. aquatica* var. *brevis*) is so named because it grows in the estuary of the St. Lawrence River. Here tides occur twice a day, but the water is fresh rather than salty. Since the plants do not tolerate salty water, their range is rather well defined at the lower limit. The estuary of the St. Lawrence, however, is very extensive, and stands of estuarine wild-rice cover many miles of estuarine flats.

The farthest upstream occurrence now known is at Grondines, about 50 miles above Quebec City. From Grondines the stands extend almost continuously down to Trois Saumons, about 50 miles below Quebec on the south shore, and to Ste. Anne de Beaupré and the northeastern tip of the Isle of Orleans, about 20 miles downstream from Quebec, on the north shore.

Estuarine wild-rice is the only variety of *Zizania* that occurs in this part of Canada, and it is a variety not known from other estuaries on the Atlantic coast. A logical conclusion, then, is that it has evolved in the present or former estuary of the St. Lawrence and is endemic there.

A large number of specimens of var. *brevis* have been collected over the years by professional botanists. Perhaps the earliest specimen is the one collected by Col. William Munro, a British army officer stationed at Quebec and an accomplished agrostologist, who obtained the plant in September 1858 on the "shores of the Island of Orleans near Quebec." On the specimen sheet in the Royal Botanic Gardens, Kew, is Munro's annotation: "probably an undescribed species of *Zizania* . . . very different in general appearance from Tuscarora." This is a significant taxonomic comment, made 66 years before the plant was formally described by Fassett (1924).

The stations for estuarine wild-rice shown on the map are mainly those that happened to be convenient for sampling by botanists; if all occurrences of the plant were plotted, a continuous line of stations would result. The 67 specimens examined came from 38 locations. At places such as Neuville, Cap Rouge, Lotbinière, and Montmagny, the plant has been collected many times.

The type locality is Levis, directly opposite Quebec City. The location, described as "rocky tidal flats of the St. Lawrence," by H. K. Svenson and N. C. Fassett, who found the plant on August 9, 1923, is now one of the most congested commercial sites along the river. Visitors may like to know of another site, more favorable and secluded, where they may see this fascinating variant. It is not far away, at the village of Cap Rouge, on the north side of the river just 2 miles above the Quebec Bridge. Here, a narrow road runs down the cliffs and leads to the red shaly beach fronting an abundant stand of the plants. At the proper time of day, estuarine wild-rice may be watched as it becomes progressively inundated by the tide. The plants offer no resistance to the onrushing current; rather, their stems lean forward with the flood as if hinging from a flexible knee joint at the base, presenting a rather astonishing performance for any erect-stemmed plant. The plant becomes completely submerged, then repeats the performance as the tide flows out. Drifting bits of debris and algae become caught in the panicle and a thin veneer of mud is left on the whole plant. Any annual species that under such conditions can establish, remain in place, flower, and produce seed in season is certainly a wonder of nature.

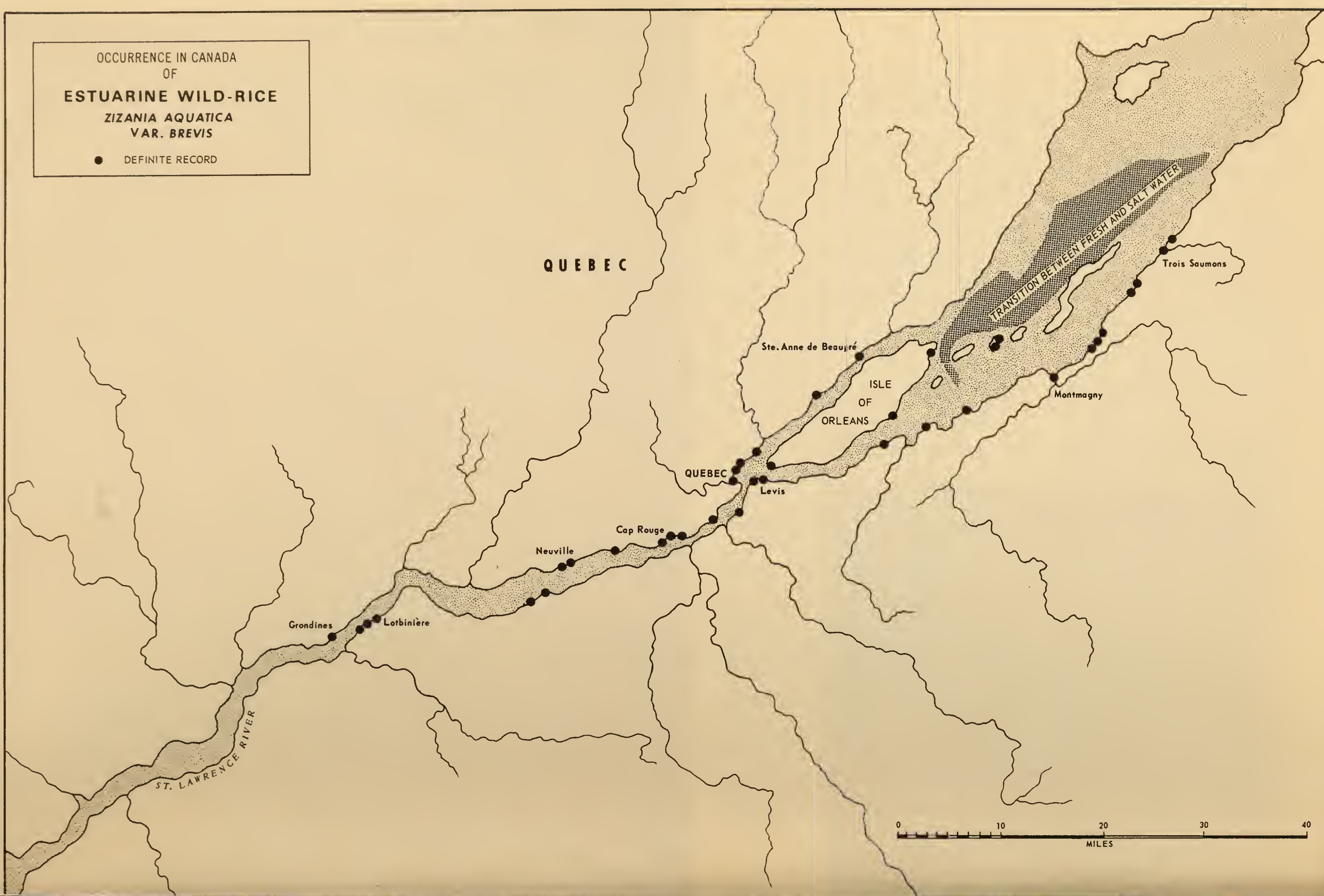
The plants reach their best development and bloom earlier on the shoreward portion of the flats, where, when the tide is in, they are submerged for a shorter time. Some are completely inundated only at times of high spring tides. Farther out, the plants are smaller, have sparser panicles, and bloom later. No doubt the low temperature of the water and the longer interval of submergence have something to do with their delayed development. Consequently, ripening of seed takes place over an extended period. This is one reason why the grains of estuarine wild-rice have never been harvested commercially. They are also not desirable because of their rather small size. Nevertheless, the plant provides a valuable crop of food for migratory birds and other wild fowl that flock to the tidal flats each year.

Another field characteristic, not seen in dried specimens, is shown by plants growing at the lower limit of the estuary, where the tidal waters become periodically brackish. The fresh stems and leaves have a somewhat succulent or rubbery texture not found in plants upstream. The plants also grow remarkably tall for the variety and develop long, stiff, and spreading panicle branches. The anatomical basis for these intervarietal differences have not been investigated, but presumably the differences are due to environment rather than heredity.

At one time there was reason to believe that the dwarf plants of the estuary were merely ecologically modified forms. However, plants from seeds and from seedlings, both obtained from the Quebec tidal flats, grown in water of constant depth in artificial pools at Ottawa had

much the same characteristic form. They were about half as high again as the wild tidal-habitat plants, and their panicles were slightly fuller; but the florets, short awns, and small grains remained the same. This experiment also showed that fluctuating tidal water was not a necessity for their well-being and survival and incidentally, led to the question of why this variety should remain confined to an inhospitable estuary of a single river.

Estuarine wild-rice, Zizania aquatica *var.* brevis. Upper left: *Wild-rice of the estuary of the St. Lawrence is part of the cover of the tidal flat opposite the Isle of Orleans. This marsh is completely submerged when the tide is in.* Below: *Plants half-submerged by the tidal water at Cap Rouge, Que. The panicles in bloom were photographed on 8 August.* Lower left: *For most of the day plants of estuarine wild-rice are completely exposed on the level mud flats, but their foliage carries a thin film of mud, which gives them a gray color. Some algae remain caught on the stiff panicle branches of these plants at Trois Saumons, Que.* (Photo by A. Hamel)


OCCURRENCE IN CANADA
OF
ESTUARINE WILD-RICE
ZIZANIA AQUATICA
VAR. BREVIS
DEFINITE RECORD
QUEBEC
TRANSITION BETWEEN FRESH AND SALT WATER
Trois Saumons
Montmagny
Ste. Anne de Beaupré
ISLE
OF
ORLEANS
QUEBEC
Levis
Cap Rouge
Neuville
Lotbinière
Grondines
ST. LAWRENCE RIVER
0
10
20
30
40
MILES

Estuarine wild-rice. Left: *Grain as gathered; the hulls are thin and rough, and they usually have a thin coating of silt; the awn is rather short; the two scales often become spread apart by the enlarged grain.* Right: *The kernels are much smaller than those of other varieties (× 4.8).*

HABITAT REQUIREMENTS

Little exact information on the requirements of wild-rice for water, soil, temperature, light, and nutrients has been published. However, many observations have been made on the plants in the wild and on factors such as depth of water in which they grow, the condition of the bottom mud or substrate, the presence of fungi and predacious insects and animals, and the quality of the seed sown. In the following pages an attempt is made to assess this information and to draw tentative conclusions.

DEPTH OF WATER

A suitable depth of water is probably a prime requirement of wild-rice. The northern variety is usually found in water as deep as 2 to 3 feet. In deeper water the plants do not grow or they tend to be very slender, single-stemmed, widely spaced, weaker, and later-flowering. As a consequence, they are much less productive than those in shallower water. Shoreward in the bed, where the water may be only 6 to 12 inches deep in midsummer, the plants grow densely together, have several tillers from each root, and produce ample panicles. Plants close to the shore are often shorter, but they fruit equally well. As the water gradually recedes during the summer, these shoreline plants rapidly finish their growth on the completely exposed mud.

Presumably, the depth of water that exists in the early part of the season when the seedlings are starting to grow is of greatest importance. As mentioned earlier, the seedling plants are completely aquatic and require free water deep enough for development. This depth may be only 1 or 2 inches, merely enough to cover the young plants. The seedling leaves are soft and limp and have no structural tissues to allow them to grow erect or to withstand drying in the air. These soft leaves grow rapidly in length until they reach the surface, where they float until a water-repellent upper side is developed. Aerial stems and permanent leaves are then produced from the base of the plant, but they are not formed if the water is so deep that the seedling leaves do not reach the surface. The speed at which these leaves reach the surface also determines the form of the mature plant. Those that come to the surface early in shallow water result in a flowering plant with short internodes, numerous tillering branches, and clusters of lateral roots, all of which form a sturdy and productive plant. Popular accounts that wild-rice grows in water 6 to 7 feet deep are undoubtedly exaggerated. The highest waterline measured on sturdy specimens is 3 feet 3 inches.

Interior wild-rice does better in shallow water, not over 2 feet deep in the spring and diminishing to a few inches or none at all in midsummer. Southern wild-rice, however, needs very shallow, warm water for germination, and thereafter develops best on wet mud, where it is able to withstand sudden and irregular inundations of its roots during the latter part of the season. Estuarine wild-rice is more remarkable in that it will withstand inundation with water several feet deep twice daily during the whole course of its growing cycle. However, this variety has been found to grow well, actually better, under water constantly 2 to 3 inches deep.

Stability of water level after the aerial stems have once been formed is very important. Severe losses of stands of northern wild-rice have resulted from flooding in midsummer. This situation has caused great concern and has been a source of grievance among Indians dependent on the annual harvest of the grains in Manitoba and adjoining Ontario, particularly if the flooding was thought to have been caused by dam construction or other man-produced disturbance. Once the plants have completed growth, any increase in water level allows waves and currents to batter the stems, tangle the leaves and panicles, and cause much damage to the seed crop. On the other hand, a sudden drop in water level in midseason often causes the plants to topple over and lodge, and to make many of the culms actually become broken and permanently kinked. A graduate decline in water level during the summer, which is normal in most Canadian lakes and rivers, seems to be a natural sequence to which the development of wild-rice has adjusted.

KIND OF WATER BODY

The type of water body in which northern wild-rice grows most extensively in Canada is not the lake, as so many accounts would lead us to believe, but the river and stream, where there is always a certain flow of water. The so-called "lakes" are usually lakelike broadenings of otherwise regular river channels. When beds of thrifty wild-rice are found in a water area that can be classified as a lake, these beds are restricted to particular positions adjacent either to the mouth of an entering stream or to the outlet, and not along quiet-water shores or in dead bays. The presence of extensive beds of wild-rice in Lake Erie, far out into the open water of quiet bays such as the bay at Long Point, may seem to be exceptional. Until the site is inspected, however, it is not realized that over the shallows of the lake there are circulating currents of such force that a boat has to be anchored against them. In summer, the growth of wild-rice marks out the course of these channels quite well. It is obvious, then, that a constant and fairly vigorous movement of water is related to the presence of wild-rice. Small land-locked lakes, bog-margined lakes, and still ponds are seldom locations of wild-rice, and attempts to grow it in such places often result in failure.

In rivers and streams where wild-rice is found, the stands are usually along the shores, and their width depends on the gradient of the bottom. Beds out in the middle of the channel are always dissected into elongated, tapering or sinuous stands that correspond in shape to the pattern of the silt bars below. In general, rivers that flood violently in the spring and carry much alluvium, then retreat to a normal summertime flow that allows the silt deposits to come near the surface provide ideal sites for the establishment and growth of wild-rice.

The delta at the mouth of a stream entering a lake provides similar conditions. It appears, however, that it is only when the alluvium of the delta is freshly deposited each year or when it is shifted around from year to year, that wild-rice grows well and persists. On stabilized deltaic alluvium, perennial aquatic species soon take over and form a solid and permanent marsh. The periodic erosion and redeposition of bottom sediments, therefore, create the necessary habitat favorable for an annual plant like wild-rice. Such sediments are, in fact, a counterpart of cultivated crop land for the growth of grain. Furthermore, it appears to be the lack of plant competition rather than the force of water that accounts for the presence of wild-rice. The remarkable ability of seeds of wild-rice to hold their position on the stream bottom against the force of strong currents has already been mentioned. It is a feature not possessed by the seeds of most aquatic plants. The importance of this feature can now be appreciated, both in relationship to the establishment of seedlings and to the persistence of stands of wild-rice in waters where the current, at least at some periods of the year, is sufficient to have a strong abrading effect on the shores and channel.

Interior wild-rice is found in similar water bodies, but, in contrast to northern wild-rice, it usually inhabits the shallower water portions of the shore, growing on alluvium that may be worked free of other vegetation by heavy, drifting objects, such as logs or ice in the spring. Consequently, in lakelike expansions of streams where both varieties grow, interior wild-rice is found forming the band closer to the shore or on the muddy strand. The southern variety in Canada occurs along the shores of fluctuating streams or their deltas, where deep muddy alluvium left by sudden floods buries all other vegetation. In the rivers of the Atlantic States it thrives under similar tidal conditions. Estuarine wild-rice grows in a special location, where tidewater occurs, even where strong erosional or depositional forces are present. Actually, these forces account for the freedom from overcrowding by perennial plants, hence for the survival of the estuarine species in a habitat that would otherwise appear to be inhospitable.

NATURE OF SOIL UNDER THE WATER

People interested in wild-rice often consider the nature of bottom sediments to be of great importance. This belief is related to their experience in gardening or farming, because in their pursuits the texture and nature of the soil, its fertility, and moisture-holding properties are so obviously important to the cultivated crop. For the growth of wild-rice, however, it seems to make little difference whether the soil under the river is mud, sand, or gravel. Under natural conditions, wild-rice plants may be found even where the bottom is bare and rocky, just as long as there are spaces between the boulders or small crevices in the bedrock floor for the seeds to lodge and the seedling roots to penetrate and hold on. It is true that in most instances the densest beds are found in such soft-textured sediments as silts, muds, and oozes, but the presence of a substrate of particular textural and physical properties does not seem to be important. The total amount of moisture in a submerged soil has little relationship to texture; likewise, fertility is just as much related to the quality of the supernatant water as to that of the substrate particles.

In many lakes and ponds possessing a thick deposit of rich-looking mud or ooze, no wild-rice grows. Often wild-rice is absent not only in small, landlocked lakes

Wild-rice does not grow in the brown waters of bog-margined lakes in the Precambrian region, as shown here at Jordan Lake, Hastings County, Ont., and a planted stand would probably not survive.

but in the shallower bays of large lakes and rivers. The bottom may also be essentially free of other aquatic plants and if freedom from competition is so important, it would seem that here would be an ideal habitat for wild-rice. Yet a few trials have shown that here wild-rice fails to flourish even when intentionally planted. It is likely that in these deep, oozy sediments there is a complete deficiency of dissolved oxygen, particularly if the sediments contain much organic material. The accumulation of organic sediments and the lack of available oxygen are associated with the process of building up the bottom of dead-water lakes, and as more detritus is added the more intense become the anaerobic conditions. It can be assumed that wild-rice, more than some other aquatics, must have an ample supply of oxygen in the substrate to assure rapid development of the root system required to form the annual flower-producing plant and to support it to maturity within one season. Anything that might disturb or "cultivate" the bottom sediments should increase the amount of oxygen, particularly if that disturbance also destroys the living roots of established perennial plants. Thus, when the floating ice of spring drags out the old plants by their roots, and mud is pulled up in clods and redeposited in a more loosely arranged manner, aeration is improved. Captain Bill Holden, well-known bush pilot and reliable observer of wild-rice in Manitoba, tells the story of how he "buzzed" a large moose feeding in a lush bed of aquatics and watched it take off, with much churning and splashing, across the muddy waters of a lake. The next year, so he states, a strip of wild-rice clearly marked out in green the path the frightened animal had "cultivated."

CHEMICAL COMPOSITION OF THE WATER

Natural waters differ in their content of dissolved salts, acids, and gases. In regions of limestone rock, streams and rivers containing deep, loose soil are well supplied with mineral salts and other elements of value to plants. Waters of such regions are particularly fertile, and if wild-rice is present it grows vigorously and extensively. Also, in settled and agricultural areas, the streams receive fertility from the manures and chemicals applied to surrounding farmland and from domestic and municipal wastes. On the other hand, from the rocky granitic wilderness of the Precambrian Shield flow streams and rivers of soft water, which is low in mineral salts and is also mildly acidic. Plants growing in this water are widely scattered and they lack vigor.

Successful plantings of wild-rice in northern acidic waters show that acidity in itself is not detrimental. The absence of wild-rice in northern streams, or its failure to establish, is in most cases probably due to some other more significant factors such as low aeration of substrate or competition from other plants. In the prairies of Western Canada, however, the water in most small streams and temporary ponds and sloughs is high in salts. In very dry seasons the salts may become so concentrated that halophytic vegetation develops, or the growth of all vegetation is prevented. In an experiment, Moyle (1944) showed that a concentration of sulfates in excess of 50 parts per million prevented the growth of wild-rice. Concentrations of this moderate amount are probably prevalent in many sloughs, or the small streams draining them, in the grassland area of Western Canada.

In brackish water that contains so much salt that it may be detected by taste wild-rice does not grow. The distribution of estuarine variety in the lower St. Lawrence River is limited by the content of sea water. On the seacoast it is undoubtedly the concentration of salts that prevent the growth of wild-rice in tidal marshes and lagoons. Plants said to be established in the coastal marshes of the Chignecto Isthmus are actually situated in the fresh water of streams issuing from the upland. The absence of wild-rice from the many other rivers of the Atlantic provinces near the seashore, however, cannot be attributed to salinity. There seems to be no reason for wild-rice not growing in these streams.

Water may be charged with sewage and industrial wastes that prevent the growth of all aquatic plants. Although the cause has not been definitely ascertained, wild-rice has completely disappeared from some streams in settled areas the last fews years since detergents have come into extensive use. To such cleansing agents the delicate floating seedling leaves of wild-rice are more sensitive than other aquatic plants.

Wild-rice does not grow well in competition with (lower right) *perennial aquatics.*

PLANT INDICATORS AND COMPETITION

Good beds of wild-rice in rivers are usually situated in the zone just outside the belt of tall reeds and cattails that fringes the shores. There the water becomes too deep for the reeds. Very few wild-rice plants grow intermixed with cattails and bulrushes, even though the water is of a more suitable depth. Apparently, the crowding or competition from perennial reeds prevents its survival.

The actual wild-rice zone is often marked by floating leaves of water lilies, under which the bottom is often devoid of submerged aquatic plants. Evidently, the shade cast by the lily pads in midsummer does not allow completely submerged waterweeds to grow. Wild-rice plants, the seeds of which have a large supply of stored food and germinate early, develop a large enough area of leafage before the water-lily leaves have expanded and formed a complete canopy over the surface. Once the aerial stems rise above the surface, the wild-rice is no longer at a competitive disadvantage. If water lilies are absent and the site then becomes filled with a dense growth of perennial waterweeds, most of which propagate by runners or underground shoots, the establishment of the wild-rice seedlings may be precarious. Even though the physical conditions for plant growth appear good, the biological conditions created by the permanently established plants prevent the incursion of new individuals. If this competitive growth could be destroyed and the physical conditions of the aquatic habitat left the same, it should be possible to establish wild-rice seedlings.

Undoubtedly, competition from perennial aquatic plants accounts for the absence of good wild-rice growth in many water areas. Conversely, lack of competition accounts for the unexpected presence of wild-rice in locations where strong water currents and a heavy deposition of silts might appear inimical to proper growth. Actually, eroding currents and heavy deposits of alluvium indirectly have a favorable action, either by removing competitive perennial weeds or by burying them deeply.

Plant competition is a complicated subject that is concerned with "open" and "closed" communities. In closed habitat the component species are in balance with the environment and it is very difficult or impossible for another individual to invade and become established. In open habitat this balance has not been achieved or it is being continuously disturbed. Because wild-rice must start from seed each year, it can only succeed and persist in a habitat that is regularly kept open by recurring events. Obviously these conditions occur infrequently in natural terrain, and they are confined to special locations. Consequently, wild-rice appears in only spotty or sporadic stands over extensive water areas.

LIGHT

The intensity of sunlight is important, because light energy is basic for the nutrition and growth of all green plants. Aquatic habitats are seldom overshadowed by trees or other obstructions. It is only along narrow streams where overhanging trees cast heavy shade that wild-rice beds are suppressed by inadequate light. Like almost all other green plants, wild-rice grows best in full sunlight. The very high light intensities obtained over open-water surfaces do it no harm.

Light intensity in the underwater habitat, however, can become a limiting factor and it can affect the plant in the seedling stage. Deep water, and especially deep turbid water, or a continuous cover

Lily pads produce river-bottom shade that inhibits growth of wild-rice.

of floating algae, scum, or debris, greatly reduces the amount of light that penetrates to the bottom. In general, wild-rice seedlings are better fitted than most plants to manage under such conditions, because of the very large amount of food stored in the grain.

TEMPERATURE

The aquatic habitat of wild-rice ensures that the plant is exposed to a fairly uniform temperature throughout the year. This uniformity is particularly present in the underwater habitats, where changes of temperature are gradual, never go to wide extremes, seldom show the diurnal fluctuations present in fields, and occur with predictable regularity year after year.

Seeds of wild-rice in water that does not freeze completely to the bottom are subjected to temperatures no lower than about 40° F during the winter months. If the water freezes to the bottom, the temperature of the mud drops to 32° F or slightly lower, but does so very gradually. Further lowering of temperature is seldom harmful to living plant organs and seeds that survive the initial freezing. Despite this well-known fact, certain early observations gave rise to the belief that the seeds of wild-rice were killed by freezing and it was thought that wild-rice was absent from northern lakes and streams because the water froze completely to the bottom each winter. However, in experiments at Ottawa seeds maintained full viability when stored outdoors in barrels or tubs of mud frozen throughout the winter. Indeed, this is now the practical method recommended for the storage of the seed for spring planting. It has also been possible to obtain viable grains of shallowly buried rice in March from riverbanks, just after the snow has melted, in places where the soil has been subjected to extremes of alternating freezing and thawing during the winter.

Some contradictory evidence on winter-killing comes from tests performed by workers of the United States Department of Agriculture at Washington and recounted by Güssow (1911). It is possible that these results were obtained on southern wild-rice, which would be the most readily available variety near Washington. The Ottawa observations were made on northern and interior varieties. The difference in observation may be valid if different botanical varieties were used, and the information would establish facts useful in interpreting the different geographic occurrences of the varieties.

At the warm extreme, summer temperatures in Canada never get hot enough to restrict the growth of any variety. If, of course, summer heat causes the particular habitat to dry up completely, the plants will die. It is important, however, that the summer season be warm enough and long enough to allow the growth cycle to be completed. Continuation of wild-rice, unlike perennials, could not be expected in far northern latitudes where the growing season is too short for maturation.

BIOLOGICAL CONSIDERATIONS

There are certain aspects of seed setting, inheritance of characters, and hybridization that must be given first attention if wild-rice is ever to be exploited fully and intelligently. The problems involved, however, have not yet been given serious attention and the following discussion can only be a summary of the scanty information at hand and of suggested lines to follow.

SEED SETTING

To those who have harvested wild-rice it is well known that all pistillate florets in the panicle do not produce good grains; usually some florets remain as empty hulls. The amount of sterility varies and may be as high as 80 percent as, for example, in southern wild-rice. The causes of sterility have not been studied, but they may be associated with both pollination and fertilization. Although the plant is ideally fitted for cross-pollination, because of the unisexual nature of the florets, bagging experiments and plants grown in isolation in the greenhouse show that wild-rice can set seed by self-pollination.

In numerous anthers examined microscopically, pollen grains have always been abundant, and they have been normal in appearance. Factors in the environment that interfere with the shedding of this pollen or with its transference to receptive stigmas could, of course, be important. Hot dry weather just at the time of flowering might cause failure of pollination, presumably by shriveling the stigmatic hairs. A spell of wet weather, on the other hand, could prevent the free drifting of the pollen grains or cause their plasmolytic bursting. Also, the very first pistillate florets to open might not get pollinated if stamens were not exposed until a few days later. Secondary panicles

Wild-rice growing in shallow paddies at Ottawa. For this experiment, seed to provide these plants was gathered in several localities in Canada.

produced late in the season might also have less chance of being pollinated.

INTERVARIETAL HYBRIDIZATION

Certain plants possess characteristics intermediate between the recognized varieties, and they may be varietal hybrids. The northern and interior varieties appear to be closely related, and apparent hybrids between them occur frequently. Also, there are unusual plants, some with the general features of southern varieties but with short awns, localized in Bear Brook near Ottawa, and others with the general features of estuarine variety but taller, which occur only in the lower part of the St. Lawrence estuary from L'Anse à Gilles to St. Jean Port Joli. These types may have also resulted from intervarietal hybridization. An interpretation of the origin of such intermediate plants must await the results of experimental crossings and comparison of resulting plants. The same number of chromosomes, $2n = 30$, has been counted in the root-tip cells of all the varieties. The chromosomes of the Asiatic *Z. latifolia* number $2n = 34$, and this plant produces sterile hybrids when crossed with *Z. palustris* (Bondar, 1958).

Germinating seeds. Seedlings sprout rapidly in the spring after storage in a barrel of frozen soil. The primary root soon withers and permanent roots develop from the first node above the seed. (Photo by Faith Fyles)

SELECTION AND BREEDING

Much of the success and value of cereal crops is due to the use of specialized strains selected for desirable characteristics such as high yield, disease resistance, and climatic adaptation. As yet, the recognized techniques of breeding and selection have not been applied to the improvement of wild-rice. It should not be construed that planned selection went into the development of the "giant wild-rice" sold in Wisconsin; samples show that its grains are of all sizes. In most wild-rice stands, however, there are individual plants with inherently larger grains than others, and it seems logical that these individuals could be selected and multiplied, and other desirable features imparted into hybrids with them.

For example, strains with a greater number of florets to the panicle, with more uniformity of ripening, or with delayed shattering of mature grains would be valuable breeding objectives. In some varieties the hull is very thin and more easily removed, and in estuarine variety the grain even protrudes from the hull at maturity. Such a feature worked into a high-yielding, large-grained strain, would greatly facilitate its threshing.

If artificial cross-breeding were attempted, the wild-rice plant should prove a favorable subject for experimentation, because it possesses several features that would ease manipulation. The individual florets are unisexual, making the need for emasculation unnecessary; the sexes are segregated, making the control of pollination by bagging almost as simple as with corn; the florets are large and single, and easy to measure and count; the plant is annual, allowing a new generation, even two generations, to be obtained during a year. In addition, the variability inherent in the wild populations makes the prospect of selection very promising.

SEED GERMINATION AND VIABILITY

The percentage germination of wild-rice grains is high when they are allowed to lie in their natural position in the bottom of the river over winter, or when stored in containers under conditions of similar saturation and low temperature. Tests conducted by Fyles (1920) showed that when grains fully ripened on the stalk were placed in mud and submerged in water over the winter, they germinated 100 percent the next spring. A grain lot that had been stored in a spring-fed reservoir and received by Leggatt (1923) after some seeds had already begun to sprout was found, on test, to have a germination ranging between 57 and 74 percent. It is known, however, that seeds incompletely matured on the stalk do not possess the same high degree of germination.

Seeds fully ripened on the stalk have a definite dormancy of long duration and will not germinate for at least 3 months after ripening (Simpson, 1966), even if temperature, moisture, and substrate are satisfactory for growth. They must pass through an afterripening period under freezing or near-freezing temperatures before the embryo will break this dormancy and continue development into a new seedling plant.

There are conflicting opinions about the number of years wild-rice grains will remain dormant in the bottom of a body of water. It has been maintained that plants will suddenly reappear in a pond after 2, 3, or several years of absence, but such reappearance has yet to be substantiated.

It is known that when seed is stored dry, germinability is lost rather rapidly. Several tests have been performed to show the rate at which the power to germinate declines. One test on grains in dry storage, reported by Fyles (1920), gave after 4 weeks 45 percent, after 6 weeks 14 percent, and after 7 weeks 1 percent. This test proves that it is possible to keep the grain in dry storage for only a short time after harvest. As might be expected, complete failure always results from the planting of processed seed. Packaged wild-rice, as sold in grocery stores, will not germinate.

NATURAL ENEMIES OF WILD-RICE

INSECTS

Two kinds of small caterpillars attack the wild-rice plant; one feeds mainly on the developing grains, the other mainly on the pith inside the stalks. They do much damage to the plants, and at times the amount may be extreme. The periodic famines suffered in the historic past by the Indian tribes in the Minnesota area, as recorded by Jenks (1901), were likely caused by severe insect depredation of wild-rice. Steeves (1952) stated that in Manitoba whole beds have been wiped out by insect attack. In 1957, a large number of insects were noticed on the plants in the Whiteshell Provincial Forest, and by 1959 the plants were so sparse that only a negligible amount of grain was harvested (Melvin, 1960). However, unusually high water levels in 1959 made it difficult to interpret the decline clearly as a cyclic parasite – host phenomenon. Melvin (1960) has summarized other accounts of insect damage in Ontario.

Perhaps the more serious of these two pests is the noctuid moth *Apamea apamiformis* (Guenée), identified by D. F. Hardwick and discussed by MacKay and Rockburn (1958). Although the occurrence of the larvae is widespread and their importance has long been known, the specific identification of the pest was delayed by the difficulty of trapping and rearing adults to prove their relationship to the larvae actually doing the damage.

The life history of *A. apamiformis* is now fairly well known. The moths mate in early July and lay their eggs inside the pistillate florets during the brief moment when the scales of the hull are slightly separated at the base to allow the stigmas to protude. The eggs are therefore deposited in a position well hidden from view. Their shadows can be seen if the heads of the florets are viewed against

In some years caterpillars of a night-flying moth, Apamea apamiformis, *severely damage the wild-rice heads. The late-instar larvae shown here have come out of the florets to feed on the grains from the outside (× about 2).*

the bright light of the sky. The pearl-like eggs soon hatch, and the newly emerged larvae start to feed on the grain developing in the hull. When the grain is eaten, the larvae cut a hole in the hull and emerge to feed on other grains in the head. At this stage the larvae bind the panicle together with fine weblike strands that prevent the ripening spikelets from falling off. The larvae grow until they are about the same size as the wild-rice hulls, and change from a pale green to a brownish color. They are longitudinally striped in all instars except the first and last, and so match closely the color of the ripening wild-rice heads. The later stages also feed in the leaf sheaths, and bore into the stalk, usually in the upper half. Larvae of another species are often found near the crown in the same stalk. It is not certain where pupation takes place, but apparently the mature larvae fall to the water and find their way to shore or to floating masses of debris, where they pass the winter, and pupate in the spring. Damage to the plant can be effectively prevented by applying an insecticide at flowering time. (At a later date the eggs and larvae gain protection inside the hull.)

Larvae of the rice stalk borer, *Chilo plejadellus* Zincken, enter the stem and move up or down inside it, eating out the pith partitions and the lining pith, and according to Melvin (1960), so weakening the stems that they may break prematurely during periods of high wind. The creamy-white eggs are laid in early July on the flat surface of the leaves in clusters of about 25 eggs. The young larvae feed for a short time on the leaf tissue before they enter the stems. Older larvae may also burrow out of the stems and ascend the plant to feed on the grain. The larva grows to be a yellowish-white caterpillar, about an inch long, with a dark-brown head and with four vague purple longitudinal stripes. The mode of overwintering is not fully understood, but Melvin found both living larvae and living pupae in dead plant material gathered in April when ice still covered the lake. The larvae subsequently pupated in his laboratory. The adult is a whitish-yellow nocturnal

Egg masses of Apamea *are revealed inside the seed chamber when the opaque hulls are "cleared" in the laboratory; ordinarily, the eggs are completely hidden from view (× 3).*

moth with wings almost an inch across.

Aphids are sometimes very abundant on wild-rice plants, but their damage is apparently negligible. Those collected at Crowe Lake in Hastings County, Ont., were *Rhopalosiphum niger* Richards (1960), belonging to the "apple–grass" group. These aphids hibernate on apple and hawthorn trees and make their appearance on grass plants during the summer. Presumably they must fly or be blown to the wild-rice plants from trees along the shore. Aphids of the same genus and similar habits have been reported (Adams, 1945) on wild-rice in the St. John River, N.B., where they "were so abundant that every randomly collected stalk was coated with the insect." Heavy infestations have also been noted (Melvin, 1960) in the Whiteshell Provincial Forest. As may be expected, predacious beetles have been found feeding on the aphids. Numerous other insects have been collected on or around wild-rice plants, but their presence seems only incidental and not connected with any damage to the plants.

A leafminer, *Phytobia incisa* (Meigen), attacked all varieties in experimental plots at Ottawa in 1962, but it has not been noticed on plants in the wild.

A nematode, *Radopholus gracilis* (de Man, 1880) Hirschmann, 1955, has been isolated from the cortex of the roots (Sanwal, 1957), but it has not been noticed to cause serious damage.

Damage caused by caterpillars (× 2.5).

Damage to leaves by the leaf-miner insect, Phytobia incisa *(natural size).*

FUNGI

The two most important fungal diseases of the wild-rice plant are ergot and smut.

The ergot *Claviceps zizaniae* (Fyles) Pantidou, well described by Maria Pantidou (1959), develops as a mass of fungal tissue inside the pistillate floret at the expense of the grain. The fungal mass, or sclerotium, is a firm, irregularly oblong, purplish-gray body, three or four times the diameter of the normal grain. The large size of the fungus forces the lemma to spread at a wide angle, and so makes detection easy. The mature sclerotia remain on the panicle long after uninfected grains are shed, presumably until the plants themselves break down at the approach of winter. As they are buoyant, they float among plant debris and drift to the shore, where they complete their development. Capitate spore bodies are produced the following summer, about the time the plants come into bloom. The spores are blown to the wild-rice flowers and they infect the young ovaries. The first sign of infection is a sticky droplet oozing from the lemma; the droplet is an exudate of the fungus that is growing inside the ovary. The sticky substance, or honeydew, also contains spores. It is possibly transported by insects to other florets developed the same season.

Ergot of wild-rice is by no means prevalent in Canada. From time to time sclerotia have been detected at widespread localities on both northern and interior varieties, but not on southern variety. In Ontario in 1952, slight infection was found at five different localities in Peterborough County and adjacent parts of Hastings County. Ergot apparently occurs more regularly in Wisconsin (Brown and Schofield, 1903) and in Manitoba, and special precautions are then taken to remove the sclerotia from the harvested grain (Steeves, 1952). Wild-rice ergot has also been reported from Prescott County and the Thunder Bay district of Ontario (Fyles, 1915, 1920), from Fredericton, N.B., Shediac, N.B., and Amherst, N.S. (Wehmeyer, 1950). A particularly heavy infestation occurred in 1957 at Sheffield, N.B. (Pantidou, 1959), where panicles were actually weighed down by the ergot bodies.

The common ergot, *Claviceps purpurea* (Fr.) Tul., has always been of public concern, not because of its damage to the host plant, which is negligible, but because of the often fatal poisoning of people and livestock eating contaminated cereals. Ergotized rye flour is the usual food that poisons people, and many fatalities from its consumption occurred in France in 1950. However, when purified and controlled, the poisonous compound provides a potent drug of great benefit to the medical profession. The

Ergot, Claviceps zizaniae, *on wild-rice. The sclerotia develop in place of the grains and expand the floral scales. The ergots adhere long after the uninfected grains have fallen (× about 0.7).*

A heavy infection of ergot may cause the wild-rice panicles to bend over. The picture shows interior wild-rice at Sheffield, N.B., 9 September 1957. (Neotype specimen, Dore 17042, designated by Pantidou, 1959).

potential pharmaceutical value of the ergot of wild-rice, a different fungal species, is not known.

The smut disease commonly affecting the stems and leaves of wild-rice is caused by *Entyloma lineatum* (Cke.) Davis. The affected areas appear as black circular patches or elongated spots, which may coalesce and cover many parts of the plant. The black color, which changes to a leaden tint on drying, is due to firmly packed spores situated immediately below the epidermis. The fungus undoubtedly weakens the plant, but there is no evidence that it kills the immature plant.

Other parasitic fungi of wild-rice, listed by Weiss (1950), are: *Diplodia oryzae* Miyake, on dead culms; *Doassansia zi-*

A black smut, Entyloma lineatum, *attacks the sheaths and culms but does little damage (× 1.2).*

zaniae J. J. Davis, causing a stem smut; *Helminthosporium oryzae* B. de Haan, causing a leaf spot; *Mycosphaerella zizaniae* (Catt.) I. Miyake, causing a leaf spot; *Ophiobolus oryzinus* Sacc., causing a culm rot; and *Sclerotium zizaniae* J. J. Davis, causing a culm rot.

FISH, MAMMALS, AND BIRDS

The carp, *Cyprinus carpio* L., a coarse omnivorous fish that may weigh as much as 20 or 30 pounds, frequents warm shallow waters, where wild-rice grows well. This fish has the habit of thrashing about in the water and roiling the muddy sediment; in the process it dislodges loosely rooted aquatic vegetation. Sportsmen and naturalists who have noticed masses of uprooted wild-rice plants have been quick to blame the damage on the carp. The dwindling stands of wild-rice in such areas as Rice Lake and Buckhorn Lake (Nickels, 1952) have been said to be due to this cause, and their reestablishment would seem impossible as long as these fish prevail. Carp entered Ontario waters early in the century and they have continued to spread and increase rapidly. There are no definite incriminating records, but there are strong indications that the progressive decline in abundance of wild-rice in Lake Ontario, in the St. Lawrence River, and in numerous connecting rivers and lakes, coincides with the rapid spread of carp. On the other hand, some naturalists think the decline in wild-rice in Lake Ontario is due to a rising water level, and others have observed places where wild-rice has continued to persist along with a large population of carp. Powerboats in fishing areas, the oil they discharge, and the waves they create also damage and dislodge wild-rice and other shoreline plants, so the case against the carp is not clear-cut.

Muskrats are particularly fond of the growing shoots of wild-rice, and by nipping them off at the waterline they prevent subsequent flowering and fruiting. Muskrats have been blamed for failures in establishing wild-rice in ponds in Prince Edward Island, and their presence could be an important factor in the elimination of the plant in other areas. The larger grazing animals, such as the moose and domestic cattle, also find the foliage very palatable and they will eat all plants within their reach. It is thought, however, that they could not exterminate the plant from large areas.

Some of the small birds, especially red-winged blackbirds and sparrows, are avid feeders on the grain. In late August and early September large flocks of blackbirds in their southward migration settle on the wild-rice beds. They alight directly on the stems and eat the grains from the panicles. Their weight, however, causes many of the loose grains to fall off into the water, and though their depredations do not threaten continued establishment of the plant, much of the crop is lost and this becomes a serious matter for persons interested in the harvest.

Ducks do most of their feeding on grains that have been shed and have sunk to the bottom, but they have been observed to reach up from the water and pick grains from low-growing or bent-over plants. By the time the main flocks arrive from the north, the ripe grain is mainly shed from the panicles. It has been thought that large numbers of ducks, particularly the diving ducks, might so deplete the seed supply from the bottom that nothing would be left to produce a stand the following year, but this scarcely seems possible. In 1909, W. J. Bean reported that in Britain the difficulty in developing wild-rice stands may have been due to sparrows taking the ripe seeds in the fall and waterfowl, of which there is a large resident population, "worrying" the weak plants in the spring.

Carp damage. Left: *Carp are blamed for destroying this wild-rice bed in a shallow stream. Notice that the stems are broken above the waterline and that plants are undamaged among the deadheads along the shore. Carp are abundant in this stream, but it is more likely that fishermen and outboard motors did the damage.* (Photo by J. M. Gillett) Right: *Dead stems lifted from the bottom of the pond are said to have been uprooted by carp. It is more likely that these are the remains of last year's plants, but it is often hard to assess such evidence conclusively.* (Photo by G. H. Hammond)

Muskrats relish wild-rice stems. By eating them off at the waterline, they restrict growth, prevent seeding, and usually eliminate the stand.

PRODUCTION AND USE

The precise date when wild-rice first came into use as food may never be known with certainty. It would coincide closely with the time when aboriginal man first noticed the plant, that is, when he moved eastward into central North America after the Pleistocene glaciation, about 10,000 years ago. Nomadic man, omnivorous and subsisting on whatever he could gather from the land, would quickly learn the value of wild-rice grains and settle down where a supply was adequate. The eminent ethnologist, A. E. Jenks, writing in 1900, considered that "no other section of the North American continent was so characteristically an Indian paradise as far as spontaneous vegetal food is concerned, as was this {wild-rice} territory in Wisconsin and Minnesota." According to Eva Lips (1956), by the time the first historical accounts were written, starting with Marquette's journal about 300 years ago, some tribes had long lost their nomadic habits and developed a fully sedentary way of life that depended on the wild-rice harvest.

The first European explorers to penetrate the wilderness, the early traders, missionaries, and pioneering settlers, quickly learned the value of wild-rice from the Indians. In 1766, Carver (in Jenks, 1901), recognizing its provident value, confidently predicted that "in future periods it will be of great service to the infant colonies as it will afford them a present support until in the course of cultivation other supplies may be produced." And Alexander Henry, in his *Travels* written in 1775, believed that without the large quantity of wild-rice he obtained in the Lake of the Woods area his voyage northwestward beyond the Saskatchewan River could not have been completed.

The original harvesting method. The person in the stern of the canoe draws the stems over the gunwale with one stick, and with another he taps the ripe seeds off into the bottom of the canoe. (Photo by National Film Board)

The artificial exploitation of wild-rice was also strongly urged by Timothy Flint as early as 1828. Writing in his famous *Geography and History,* he said, "It is astonishing, amidst all our eager and multiplied agricultural researches, that so little attention has been bestowed upon this interesting and valuable grain. It has scarcely been known, except by the Canadian hunters and savages, that such a grain, the resource of a vast extent of country, existed. It surely ought to be ascertained if the drowned lands of the Atlantic country will grow it. It is a mistake that it is found only in the northern regions of the Mississippi valley." But despite his expression of concern and all that has been said by later conservationists and development-minded persons, wild-rice has not yet attained the status of a cultivated cereal, to be sown, cropped, and exploited on an agricultural scale.

ORIGINAL METHODS OF HARVESTING AND PROCESSING

Harvesting of the grain by the Indians was entrusted to the older members of the tribe. A man sat in the front of the canoe to propel it with paddle or forked stick; a squaw sat in the back to draw the stalks in over the side with one stick and tap the ripe grains off into the canoe with another. Unripe grains that still adhered to the panicles were left for a later harvesting. Much care was taken not to damage the stalks, so that the harvesting could be completed later. Two or three gatherings were made during the harvest season, extending over a period of 10 to 14 days.

Several ethnobotanists have described another and more intricate method of harvesting, one seemingly not used by tribes resident in Canada. The standing heads were drawn together and tied securely with native twine made from basswood bark. This was done when the grains were quite immature, in the milk stage, and before there was any chance of their being dislodged by handling. The panicles were wound from the base upward to the tip; the tops were then bent over and fastened in a loop. This binding, when done in a distinctive manner, clearly marked out for each squaw the right to harvest. At full maturity the bundles of panicles were completely sheared off and put in the canoe; or they were bent over the side of the canoe and the bound-in grains were released. An adaptation of this bundling method has recently been devised and patented (United States Patent 3111799) by J. M. Schmit and H. L. Andrews in Minnesota. Instead of being bound, the heads are enclosed in a polyethylene bag.

The Indian method of hulling and separating the kernels was simple but practical. The freshly harvested grain had first to be dried, so it was spread out sparsely on skins or bark, or on an expanse of flat rock in the sun, stirred from time to time, and covered when protection from rain was necessary. The dried harvest could then be stored without fear of rotting and kept until it was convenient to parch it.

For parching, a moderate amount of the grain, not more than half a bushel or so, was put into a bark basket or large bowl hung over an open fire. The grain had to be stirred constantly to prevent it from burning. It is said that the heat applied was just sufficient to swell the starch grains and force apart the tightly closed hulls. After the seed cooled, it was placed in a shallow hole on hard ground and "danced" under foot. The material so threshed was tossed into the wind, and by this simple method the grain was separated from the chaff and dirt.

Methods of parching, hulling, and winnowing, and the kind of rude equipment differed between tribes. Manufactured utensils were introduced by the white men and, as they soon became easily available, the methods used were modified somewhat. A very full account of all aspects of the wild-rice harvest as practiced by the Ojibway in Minnesota has been written by the German ethnologist Eva Lips (1956).

FRONTISPIECE.—Indians preparing rice for food.

1

1. A Mississagua squaw parching wild rice by stirring over a slow fire. Near Harwood, Rice Lake, Ontario.

2

2. "Dancing" wild rice to separate the grain from the hulls. Near Harwood.

3

3. Winnowing wild rice. Near Harwood, Rice Lake, Ontario.

—Adapted from photographic postcards.

Indians preparing wild-rice for food. This page appeared in Wild Rice *by Miss Faith Fyles, Department of Agriculture Bulletin No. 42, 1920.*

Processed wild-rice. Upper: *A retail product of good quality; most of the grains are whole and plump, and on most of them the pericarp is intact.* Middle: *Grain as finished by the Indians in southeastern Manitoba; the grain is clean and wholesome, but broken and heavily scarred.* Lower: *A sample of select quality as exhibited by Jack Wade, Lac du Bonnet, Man. (× about 2.5).*

Rice, Oryza sativa. *Three stages in the processing of cultivated rice of the cultivar Bluebonnet 50, extensively grown in the southern United States.* Upper: *The grain as harvested, with hulls still on (× 3).* Middle: *The grain, from which hulls have been removed by threshing, but with the brownish pericarp still intact (× 3).* Lower: *Polished kernels, from which the pericarp and germ have been removed. The rice is ready for the retail market (× 3).*

CURRENT METHODS OF HARVESTING AND PROCESSING

All the wild-rice sold today comes from untended stands that grow in streams and other waterways. There have been attempts to control the supply and level of the water, or to create new impoundments in localities where this is possible, but cultivation in a paddy has been done only on an experimental scale. Most of the grain is still harvested by hand from canoes. The operation of harvesting, however, is conducted on a much larger scale than formerly, and, in some regions, it follows a well-organized plan.

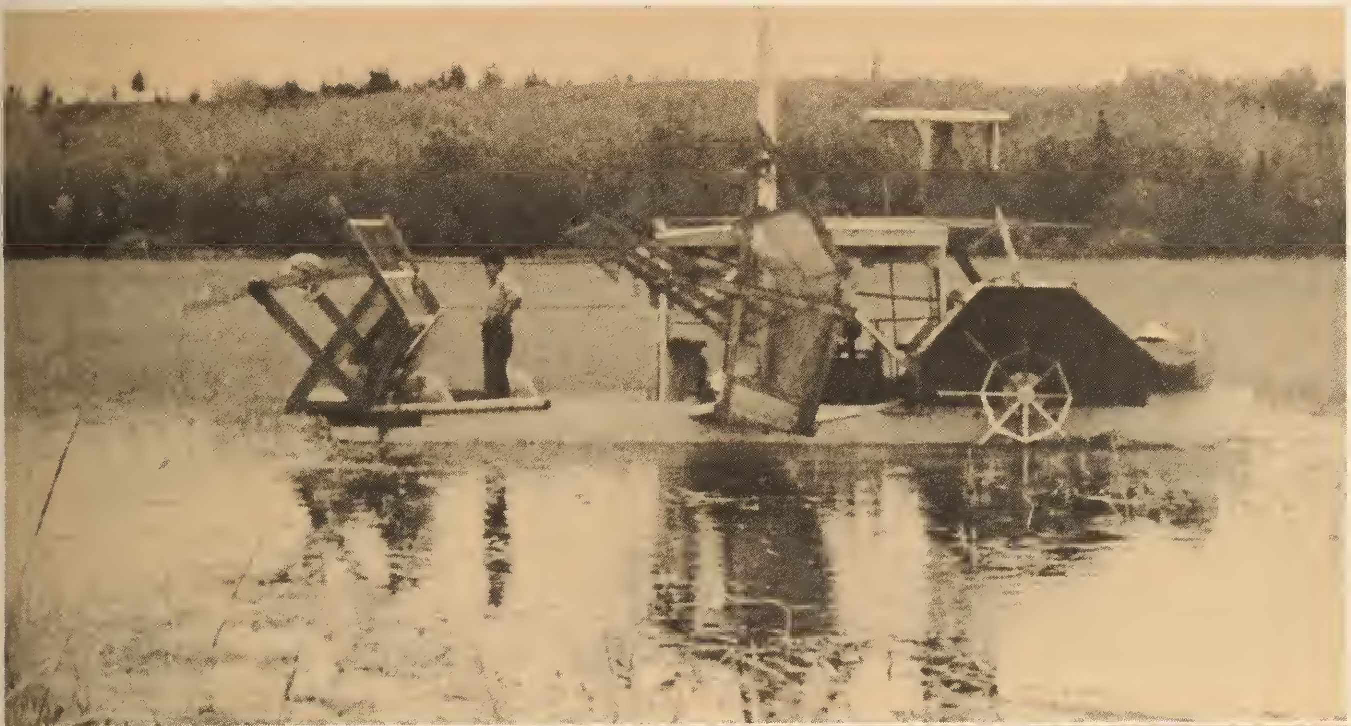
In Manitoba, the chief area of production in Canada, the office of the provincial Lands Branch in Winnipeg issues licenses giving contractors the rights for harvesting the rice on designated blocks, or concessions, of crown land. Besides the basic license fee, each contracting agent pays an annually fixed royalty to the government for each pound of "green" rice harvested.

Among the people who take part in the harvest are Indians from the nearby reserves, local trappers and lumbermen, and landed settlers who have familiarity with wilderness operations. The agent pays a fixed price, set by the government, to the harvesters on delivery of the green rice at his gathering wharf. To ensure fairness to the gatherers, a starting date is set for the harvest and no one person is allowed to enter the fields before this time. Broad stands are subdivided into strips and assigned to each pair of harvesters. By such regulations, the harvesting of immature grain is discouraged, losses are kept to a minimum, and the pick is more uniform and predictable. It is usually not necessary to make any special provision to replenish the beds because an adequate number of grains fall into the water. On account of the remoteness of some concessions, the agent often provides modest facilities to accommodate or transport itinerant harvesters and he may also supply modern aluminum canoes, which are clean and of light weight. Use of row boats is discouraged and motor boats are not allowed on the smaller wild-rice lakes.

The use of mechanical devices for harvesting is prohibited on crown lands in Manitoba, and in the adjoining states of Minnesota and Wisconsin. On privately owned land, of which there is actually very little in the best wild-rice country, such restriction cannot be applied. On Indian reserves it is the Indian agent who supervises all operations, and he ensures that only bona fide members of his reservation participate. A full account of the activities and methods associated with harvesting and processing of wild-rice is given by Steeves (1952).

The machines used by private harvesters have been constructed, sometimes invented, by the operators themselves. Some might be classed as contraptions rather than machines and they often incorporate features or mechanical devices that show much ingenuity and enterprise. One popular and very successful type consists of a reel of horizontally revolving arms, much like those of the grain binder, mounted on the front of a 'scow.' It is actually a sturdy platform built across slender-bodied floats and driven by a separate gasoline motor, not the one that propels the craft through the water. Sometimes additional reels are mounted in such a way that they extend from the sides. The speed of the reels can be controlled independently, so that they may not necessarily move at the rate of progress of the craft. The revolving arms gently sweep in the heads, and the ripe grains, which flip off, are caught on a fine mesh screen from which they can be scooped up and bagged. The construction of the first harvester of this type is credited to the late H. B. Williams, widely known as "Mister Wild-rice," who operated the Williams Wild-rice Farm at Pointe du Bois in a remote part of eastern Manitoba. It is reported that with the machine Mr. Williams could harvest as much as 500 pounds per hour if the crop was good, and, in stands too thin for profitable harvesting by canoe his harvester could still be used to considerable advantage. Indeed, the machine was often not put into use until after the prime crop had been selectively gathered by hand.

Another machine devised on a quite



Mechanized harvesting of wild-rice. Upper: *The harvester developed by H. B. Williams at Lac du Bois, Man. Rotating flails beat the ripe grains onto a fine-wire screen as the scow, mounted on two slender floats, is propelled through the rice beds.* (Photo by National Film Board) Lower: *Z. Durand of Winnipeg and the harvester he invented. Tapered aluminum scoops catch the grains and direct them to a long collecting trough mounted across the skiff. Oscillating rods jiggle the wild-rice stems as the craft moves through the beds.* (Photo by National Film Board)

Green rice harvested in remote parts of Manitoba is flown into clearing points by airplane. A Norseman ties up at Riverton to discharge its cargo. (Photo by National Film Board)

different plan is that built by Mr. Z. Durand, a resident of Winnipeg. It consists of a number of slender metal scoops with vibrating rods, placed in a series in front of a long gathering trough, and all mounted across an outboard-driven skiff. The principal involved in this and other similar machines is basically the same as the aboriginal method, a technique for shaking off the ripe grains gently and catching them before they fall into the water, at the same time allowing for the stems to remain undamaged for further ripening.

The freshly harvested green rice is always somewhat wet and must be cared for quickly; otherwise, biological heating and molding will set in. The water comes directly from the harvesting operation, but it is also contributed by exudation from the green hulls, bits of stems, and grains that are not completely ripe. Moist starch and other foods from broken or squashed grains provide a rich medium for microorganisms, bacteria, yeasts, and molds. Rapid shipment by motor transport, railway express, and even aircraft is necessary to get this perishable material to the processing plants. Finely woven burlap bags or cotton sacks are the containers in general use for shipment, but if the crop is heavy and comes on quickly, almost any kind of nonreturnable container finds its use. The crop, of course, cannot be stooked or handled in bulk fashion like the field cereals.

The green rice is spread out in as shallow a layer as possible on a large storage floor for drying. This process of drying is generally spoken of as curing, a term that might seem to imply the imparting of some added, or mellowing, advantage. Actually the first purpose of curing is to air and dry the grain mass to prevent souring and decay. This drying, which takes a few days to effect by the means now in use, fulfills another purpose in allowing immature grains to pass into a riper stage of maturity. Many soft grains become firm and turn a characteristic dark brown or black during this period. Drying could be hastened by artificial methods, but there is good purpose in having it done gradually. At the present time, the grain is simply turned over or stirred by pitchforks at least once a day, and the layer is moved progressively forward on the floor towards the parching ovens.

The parching ovens are cylindrical structures that rotate over an open fire. They generally handle about a bushel of wild-rice at a time. Formerly, the ovens were made from empty oil drums and turned by a hand crank.

The purpose of parching is to drive off all residual traces of water from the surface of the hulls and, also, to remove some of the moisture from within the kernels themselves. As long as water issues from the ovens in the form of a visible vapor the operator knows that the material is not suitably dry. Care must be taken not to overheat the grains, to cook them, or cause them to pop. The agitation by rotation must therefore be continuous, and if the heat is not applied too strongly and the load is not too heavy, the temperature inside the oven should not rise excessively until after the water is vaporized. After being dumped from the ovens the warm grain becomes perfectly dry on cooling, and it can be poured easily into hampers. The kernels are now firm and hard, and they lie more or less loosely

Bags of green rice received at a processing plant in Winnipeg are first emptied onto a long pavement. The grain is then forked over and spread to dry, before it goes to the parching ovens in the shed beyond.

within their hulls; extraneous leaf and twig fragments are bone dry, and all caterpillars are dead and shriveled. The material is ready to go straight to the huller–cleaner, or it may be held in storage in this dry state. It is quite conceivable that the whole parching process could be put on an automatic system with thermally controlled, continuous-flowing equipment. The needs and future of this still embryonic industry first require economic appraisal.

Wild-rice in a casserole prepared for the table. (Photo by Canada Department of Agriculture)

The hulling of the grain is done in large cylindrical containers about the same size and shape as the parching ovens, and like them, originally constructed from empty 45-gallon gasoline drums. The hullers, however, are mounted in a stationary position and the axle, to which flails covered with pieces of rubber-garden hose are attached, rotates by motor power. Practice determines the proper speed of the flails. As the kernels shell out quite readily, the threshing must not be done so harshly that the seeds will be broken. This dehulling is the same process, and based on the same principle, as the beating or dancing of the rice originally performed by the Indians, and the same as the one that occurs in the modern farm threshing machine. Although there is always some breakage of the long kernels, the proportion can be kept to a minimum by careful handling. A jet of air forced into the huller during threshing carries out the empty hulls and any light extraneous matter, and the smooth kernels are left clean.

The dehulled grain then passes over vibrating sieves, and finally it flows out on a broad moving belt for inspection on its way to the bagging bin. Small or broken grains passing the sieves, though of inferior quality, are saved and marketed in other than choice table form. It is only the large, plump, unbroken, and unscratched kernels that are preferred for the culinary market. The brown-black pericarp gives the distinctive appearance and character to the wild-rice and the aim is to keep it unscarred. The graded grain is put up in clean 100-pound bags for bulk shipment, or directly into small display packages of 8 ounces for the retail trade. Precooked, canned, or ready-mixed products are also available.

COMMERCIAL PRODUCTION

Processed wild-rice has been offered for sale for several decades. Demand continues to increase, but no complete statistics on the quantities produced or the amounts consumed domestically or exported, or market conditions have ever been regularly and officially kept. For the past several years, however, the Lands Branch of the Manitoba Department of Mines and National Resources, has kept records of the licenses issued and of the royalties returned from the crown-land concessions over which the Branch has jurisdiction. The figures given in Table 1 (page 76) are from this source. The weights are for freshly harvested green rice, the state in which the grain is accepted at the concessions, and not for the processed product. The figures fall short of the complete totals for the annual harvest, because they do not include the portions kept by the Indians for their own use or what has been reserved for reseeding, or smaller amounts disposed of in other ways. The records for the Whiteshell Provincial Forest are tabulated separately. The Whiteshell Provincial Forest has always been the chief producing area in Manitoba, and it represents a unit area on which the trend from year to year can better be traced.

The Manitoba figures do not, of course, include green wild-rice that has come into the province from the neighboring Ontario. There are no processing plants in Ontario and the harvest from this province is shipped directly to the Winnipeg area or to Minnesota, where there are processing outlets situated at about equal distances. The amount of wild-rice harvested annually in western Ontario might be twice that of Manitoba. The amount produced in other parts of Canada is insignificant in proportion and it does not seem to get into the commercial market. The good quality of the western Ontario grain puts it much in demand.

Figures for the amount of wild-rice exported from Canada are given in Table 2 (page 77). The records do not distinguish between green rice and processed wild-rice, both forms being exported. Almost all the exported wild-rice goes to the United States, and as far as known, all of it is shipped from points in Manitoba and in Ontario west of Lake Superior. The main market for the finished product is in the large cities of the United States, but small lots are sent to

TABLE 1 POUNDS OF GREEN WILD-RICE HARVESTED IN MANITOBA, 1945–1968

Year	Manitoba total	Whiteshell Provincial Forest
1945	no record	48,000
1946	no record	86,755
1947	no record	40,400
1948	no record	no harvest
1949	334,792	243,000
1950	132,136	75,361
1951	136,037	177,156
1952	112,749	197,461
1953	29,261	22,661
1954	48,841	6,113
1955	60,609	1,659
1956	488,353	61,619
1957	88,605	54,994
1958	267,253	141,578
1959	5,000	2,208
1960	267,641	64,677
1961	325,000	120,392
1962	105,000	2,799
1963	140,566	40,247
1964	233,397	66,490
1965	23,662	3,662
1966	120,547	5,194
1967	593,000	180,000
1968	200,000	107,000

Source: Lands Branch, Manitoba Department of Mines and Natural Resources.

centers in other parts of the world where a table delicacy is in demand. It is interesting that some of the product marketed in Eastern Canada is packaged in the United States.

A rather exhaustive inquiry into the statistics of production was made some years ago by Steeves (1952). His sources of information provided data that, understandably, are fragmentary and confusing, but from his cautious interpretation much indicative information may be derived. For example, a decade ago twice as much wild-rice was produced in the United States as in Canada, mainly in Minnesota and Wisconsin. In recent years, the Canadian processing and packaging plants have come into fuller operation and it can be expected that the industry will expand substantially as time goes on. Many wild stands, particularly those remote from the now-established processing centers, are extensive and are exploited either not at all or only partially.

For many years there used to be an active harvesting industry at Rice Lake in central southern Ontario, mainly for the sale of planting seed, but this business has now been discontinued, reputedly because of the gradual reduction in the productivity of the local beds. Elsewhere throughout the country some seed is gathered by private individuals and by conservation bodies for the purpose of planting new stands, usually locally, but no record can be kept of the extent of this activity. Certain specialty seed firms in the United States, particularly in Wisconsin, widely advertize in sportsmen's journals and outdoors magazines, so their seed finds a popular market, even within the wild-rice growing areas of Canada. In general, the processors of finished wild-rice are not interested in this smaller enterprise of the sale of viable seed, because of the special problems of storage and transportation.

TABLE 2 AMOUNT AND VALUE OF WILD-RICE EXPORTED FROM CANADA, 1952–1968

Year	Amount exported (pounds)	Value (dollars)
1952	305,819	345,690
1953	296,403	282,797
1954	57,268	76,863
1955	188,154	157,450
1956	211,929	282,445
1957	48,283	103,199
1958	453,403	532,234
1959	261,130	303,199
1960	233,222	322,028
1961	486,271	457,420
1962	183,542	308,897
1963	119,596	181,893
1964	235,296	448,741
1965	67,152	181,450
1966	77,472	427,000
1967	404,772	872,000
1968	198,704	499,000

Source: Trade of Canada, Exports by Commodities, Dominion Bureau of Statistics.

RECOMMENDATIONS FOR PLANTING, STORAGE, AND CULTIVATION

The following suggestions are directed to those who wish to extend an existing stand or to establish a new stand in an untested area. The recommendations already given by various writers have been taken into consideration as far as possible. However, the agronomic aspects of practical and economic production are quite speculative, because no extensive base of experience is available.

PLANTING

Seed gathered fresh can be planted the same day or within a few days by simply scattering it on the water. Ripe grains sink rapidly and lodge in a natural position for germination. Seed that has been held in dry storage for several days, however, should be soaked in water so that any air that has entered the hulls will be dissipated and the scattered grains will not float away. The seed should also be stirred in the water so that poor and empty spikelets, which rise to the top, can be skimmed off and discarded. Seed can be kept in water for a fairly long time. However, the water must be kept cold and changed from time to time to prevent fermentation caused by smashed grains and debris.

A steady boat or raft is the best vehicle to use when sowing because the seed can be scattered more widely and uniformly from a standing position. A canoe may be too insecure for effective large-scale planting. Seed can also be planted by a person wading in the shallow water if the bottom is firm enough, or the seed may be thrown from the shore if the water's edge is accessible. The grains will carry quite a distance if flung with force by hand. Embedding them in mud balls, a practice often recommended, is not very effective. Large-scale plantings in remote wilderness areas have been accomplished by aircraft.

Because of the present scarcity and expense of viable seed, the amount used needs to be kept to a minimum. If wild-rice is being tried for the first time and it is not certain whether it will be successful or not, it is best to make light plantings in several likely areas. Certain discouragement and financial loss may result if a large planting should fail to establish. A rate of about 20 pounds of wet seed to the acre is suggested for trial plantings. If sown in the fall, the seeds will germinate the next spring, and the results will be seen that summer. If conditions prove favorable, the plants should produce adequate grains to reseed the bottom for a full crop the next year. The grower should therefore wait for the second year before he comes to a conclusion about how dense a stand the habitat will support.

Wild-rice does not spread readily to other areas and it is slow to expand its stands. Consequently, if the initial planting was localized or patchy, an effort should be made to fill up the gaps by supplementary plantings. Heavy seeding seldom accomplishes comparable results. As in any crop, there is a maximum yield that can be expected from a unit area, and though heavier seeding may produce more individual stems, the total yield cannot be increased beyond this maximum. When many plants grow close together, they are more slender and usually only single-stalked; hence, they produce no more seed than the few well-spaced, abundantly tillered plants that result from a sparse seeding.

An existing stand could be expanded by following proper procedures.

SITE

In summary, the following are preferred sites:

where the water in early summer will be about 1 inch to 2 feet deep but no deeper;

where there is a circulation of water, that is, in streams or rivers, or in lakes at the mouth of entering streams;

places where there is no competition from other plants;

where the bottom soil is "open" in the ecological sense, that is, in soil of deltaic deposits, flood-eroded beaches, drowned land, and especially, soft silty bottoms;

on a cultivated bottom, that is, one that has been stirred up or harrowed to drag out aquatic plants and to open up a seed bed.

Avoid cattail swamps, marshes, tree-shaded shorelines, and waters where there is a bottom layer of vegetation. Also avoid a location where there are strong winds or high waves, or where plants will be battered by drifting logs or boat traffic.

SHIPPING SEED FOR PLANTING

If planting is to be done in the fall, which is the logical and most practical time, certain precautions for gathering and shipping the seed should be taken. Fully stalk-matured seed is much preferred, but the difficulties of obtaining it are great because of the uneven ripening of the grains and the shedding of the ripest ones. Harvest the grain when it is dry and keep it from getting wet. Under usual harvesting and weather conditions, however, these requirements are often hard to fulfill. Do not attempt to sort the grain by flotation before shipping, but leave this operation until just before planting. The reason for leaving the grain dry for shipment is to prevent the growth of molds and bacteria, and to prevent heating of the seed lot, which would damage the living germs. Dry ripe grains hold their viability quite well for a few weeks in the fall, but immature grains do not. According to the experience of some collectors, drying seed grain in the sun reduces the viability quite rapidly, probably because the surface on which the drying is done becomes excessively hot.

At all times, of course, be careful to prevent mechanical injury to the grains. Even when the stalk is mature, the grains of wild-rice are still a bit soft and easily crushed if stepped on or handled carelessly. No advantage is gained by removing the hulls before planting.

Seed lots may be shipped in any container, but since air transport is often used, lightweight cartons or packages are more economical. If for any reason the seed has to be shipped moist, or if it has to be held for more than a couple of weeks before planting, it should be distributed thinly in sphagnum moss or sawdust and kept cool, even refrigerated to just above the freezing point, to prevent fermentation and heating.

WINTER STORAGE AND SPRING SHIPMENT

There is some advantage to spring planting, but it is slight. There is less danger of the seed being destroyed by bottom-feeding birds and insects in the fall and winter, and less danger of its being buried too deeply by spring sediments. It is often more convenient to seed in the spring, so the ways of keeping the seed viable over winter have to be taken into account.

For winter storage, the seed should be placed between layers of mud or sphagnum moss, or ordinary garden soil or sand as long as the grains are layered. This stratified seed is placed in wooden boxes or flats, and sunk in water. The water can be held in barrels left outside and in the shade during the fall, but the water should be changed periodically before freeze-up. The containers can also be submerged in a pond or stream, but in this case their tops should be covered with fine-mesh wire to prevent loss of contents and depredations by animals.

The method formerly used by suppliers at Keene on Rice Lake took advantage of a local ample supply of spring water. The grain was put in large underground reservoirs, specially constructed and connected so as to be supplied with a strong flow of cold water. When the seed was dumped into the reservoir of water, the empty husks, debris, and insects were carried off by the overflowing water. During the winter, the reservoirs seldom froze completely over, although the water was very cold. The grains, however, tended to germinate as springtime approached and they had to be disposed of quickly at that time.

With modern methods of refrigeration,

Low-lying land might be converted into a paddy field by breaking, leveling, and dyking.

large quantities of seed may be kept in a wet condition in cold-storage rooms without serious loss of viability. Temperatures just above the freezing point, between 30° and 35° F, seem to be best, but solid freezing brought on gradually does no apparent harm. Some molding on the surface of the mass may take place if cold-storage conditions are not quite right.

For shipment, the seed is placed in sphagnum moss in strong burlap bags, usually protected by a loose wooden crate, and kept saturated. Because of the soggy nature of the contents, shipment of the crate by railway express is required. Small quantities sent airmail must be in drip-proof containers. The temperature during shipment should be kept as low as possible, because germination could take place rapidly at this time of year. It is almost impossible to handle sprouted seed because the slender seedlings soon become entangled in a very fragile mass.

CULTIVATION

Apparently, there has not yet been any serious attempt to grow wild-rice as an agricultural crop. However, it may be possible to do this as long as the special requirements of the plant are understood and provided. A higher yield and better quality of grain than that of natural stands could at least be anticipated. Whether the procedure would be economically feasible is still to be determined.

It would be expected that cultural practices such as those applied to the rice crop in the southern United States and other parts of the warm-temperature world could also be applied to wild-rice. Planting would have to be modified to take account of the strong dormancy of seed, and harvesting would need to be modified to catch the readily shattering grain.

Low-lying land, particularly if situated beside an adequate supply of natural water, might be converted to a paddy field by breaking, leveling, and dyking. Cultivation areas would be immediately seeded in mid-September, and a layer of water let in. The water would lie all winter and be maintained the next spring and into early summer at a suitable and uniform depth. If the water level were gradually lowered from about 6 inches or 1 foot in June to a few inches during July, and to complete surface drainage in August, the land would be firm enough to harvest by suitably designed machinery. Further drying of the land after harvest would allow the soil to attain a condition adequate for weed eradication and preparation of a new seedbed. The busy time would then be from mid-August to the end of September. The Canadian farmer with a certain amount of machinery, the usual know-how, and some suitably situated land could probably make a success of growing this specialty crop.

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