Viability of wild rice in Montana environments
by Mark David Reller

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Agricultural Engineering
Montana State University
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Abstract:
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Montana contains regions with climates and conditions similar to those in Idaho where stands are established. The intent of this research was to determine if stands capable of supporting commercial harvest or improving wildlife habitat could be established in Montana. Research procedures included planting three varieties of wild rice seed in diverse sites and searching for existing stands.

After planting, sites were periodically observed to determine germination success, submergent growth, emergent growth and flowering. During this time interactions with wildlife and native plant competition were also noted. A commercial operation in Idaho was visited to obtain information on harvesting techniques, harvest equipment, curing, processing, storage, and marketing. Previously established stands were visited to observe plant growth, wildlife usage and site conditions.

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The research indicated that wild rice stands can be established in limited areas of Montana and that yields similar to those obtained by commercial growers elsewhere can be obtained. In addition wildlife such as ducks and muskrats used stands for food and cover.

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of a thesis submitted by

Mark David Reller

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ABSTRACT

Zizania Aquatica or Wild rice is an aquatic grass plant native to the Great Lakes region of the United States and Canada. Commercial stands have been established in this native region as well as in other parts of Canada and the United States, most notably in California and Idaho.

Montana contains regions with climates and conditions similar to those in Idaho where stands are established. The intent of this research was to determine if stands capable of supporting commercial harvest or improving wildlife habitat could be established in Montana. Research procedures included planting three varieties of wild rice seed in diverse sites and searching for existing stands.

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CHAPTER 1

INTRODUCTION

Alternative crops are gaining acceptance in Montana. Among the list of potential benefits alternative crops bring are profit and economic diversity. Wild rice (Zizania Aquatica) is one such crop. This "gourmet crop" brings a premium market price and utilizes lands not previously perceived as agriculturally valuable.

Wild rice can provide forage and cover sites for migratory waterfowl, fur-bearers, and even big game. Thus, the addition of wild rice to an ecosystem can also improve wildlife habitat.

Problem Statement

The primary goal of this research is to plant wild rice at several diverse Montana sites and observe first-season growth and subsequent stand establishment. The secondary goals are to investigate the plant's potential for commercial exploitation by reviewing commercial operations in other regions, and to investigate its potential for improving wildlife habitat.

Since wild rice is not native to Montana, numerous questions arise which cannot be fully answered given the scope and time frame of this research project. However, information gathered from planting test plots of wild rice and similar observations made in a Montana stand planted ten years ago, provide a starting point for accessing the potential viability of wild rice in Montana climates.

Objectives

The objectives of this study are to:

1.) Provide a review of important literature addressing the commercial production and processing of wild rice and to outline the process of commercial wild rice production and processing;

2.) Document the procedures and results of test plantings of wild rice in a diversity of Montana sites, and compare those results with locations in which wild rice has previously been established or is native;

3.) Provide general guidelines for individuals interested in stand establishment in Montana.

CHAPTER 2

LITERATURE REVIEW

Introduction

Native North American Indians of the Great Lakes region called wild rice "Manomin," which means "good berry." This grain was regarded as "food from the gods" and was used in religious ceremonies (Weir and Dale, 1960, p. 719). Such reverence is not surprising given the grain was a staple in their diet. Today, wild rice is popular among gourmet chefs because of its dark color and unique flavor.

Although many wild rice stands gleaned by Indians in centuries past are still producing grain today, the bulk of present-day production is from commercial paddies.

The Plant

Official Description

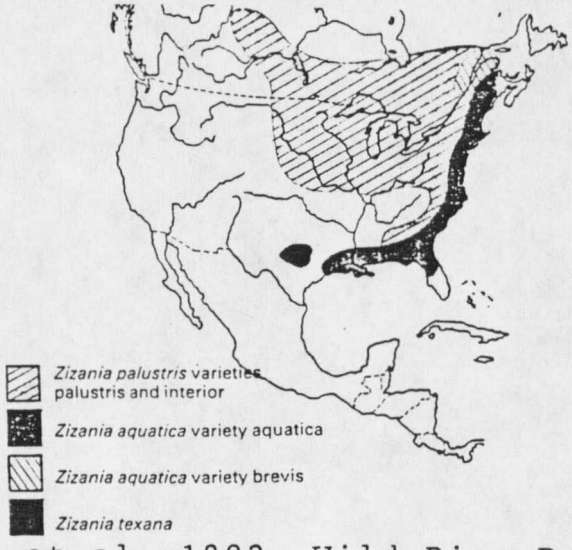
Through the centuries, wild rice has been called Mamonin, Indian rice, Canadian rice, squaw rice, water oats, blackbird oats, and marsh oats. Wild rice is the name most widely used today. (Oelke, 1982, p. 4). Wild rice is a member of the grass family and belongs to the genus Ziza-

nia. It is not related to common rice, which belongs to the genus Oryza and species Sativa L.

There are four species of wild rice, Zizania palustris L., Zizania aquatica L., Zizania texana, and Zizania latifolia. The geographic distribution of these species is illustrated in Figure 1. Zizania texana is found in a small area of Texas. Zizania aquatica grows in the St. Lawrence River, in eastern and southeastern U.S. coastal areas, and in Louisiana. Zizania palustris is the large seed type that grows in the great lakes region and is the only species harvested for food (Oelke et al. 1982, p. 4). Oelke's distinction between aquatica and palustris contradicts most

FIGURE 1

Natural Distribution of Wild Rice Varieties



Source: Oelke et al. 1982. Wild Rice Production in Minnesota. University of Minnesota Agricultural Extension Bulletin 464-1982, p. 6.

other authors. They refer to Zizania aquatica as the food-producing species which grows in the great lakes region and Canada (Chinsuwan 1981; Goel, et al. 1972 and 1970; Lund 1975). Only food-producing species are considered in this report.

In E. Oelke's description, Zizania palustris and Zizania aquatica are defined as annuals, while the others are perennials.

Life Cycle

The fruit of the wild plant is the caryopse a small, one-seeded, dry, indehiscent fruit fused with the seed in a single grain, and is similar to the kernel in cereal grain. The large endosperm is surrounded by a thin layer of pericarp and aleurone. The embryo at one end of the caryopsis contains a cotyledon that can extend the length of the caryopsis, a coleoptile that surrounds the terminal bud, and a coleorhiza that surrounds the primary root. The lemma and palea (hulls) remain on the seed during harvest but are removed during processing. The endosperm, pericarp, embryo, and hulls make up 77, 4, 4, and 14 percent of the seed, respectively (1% rounding error) (Oelke, et al., 1982, pp. 6-7). Figure 2 illustrates typical grain sizes.

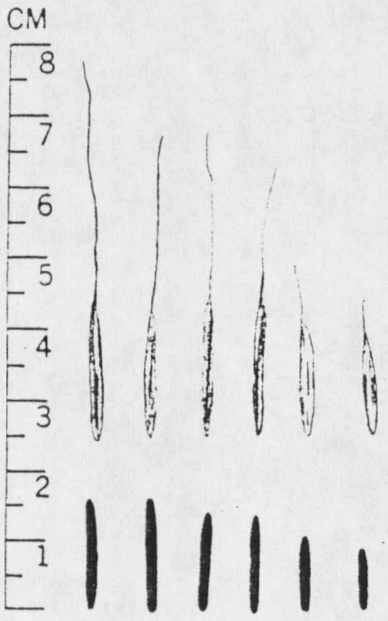
In autumn, mature wild rice seeds fall from the head of the plant and sink into the water (Weir and Dale, 1960, p.

719). The seeds require three to four months of dormant storage in cold water (35°F) before they will germinate (Oelke, et al., 1982, p. 15). In 1965 G.M. Simpson used the term "after-ripening" to describe the activity during this period and noted that after-ripening for 148 to 202 days brought about a considerable increase in the germination rate as well as an increase in the total germination percentage. He found this was true for constant temperature tests as well as for tests with diurnal temperature swings (Simpson, 1966, p. 3).

Tests with alternating temperature showed higher rates

FIGURE 2

Typical Wild Rice Grain Sizes



Wild rice seeds with hulls (lemma and palea) on (top), and with hulls removed (bottom). Source: Oelke, et al., 1982, p.6

of germination but similar total germination percentages (See Table 1). Alternating temperatures were intended to simulate a lake-edge environment, where diurnal fluctuations of water temperature occur as wind actions or water currents cause the thin layer of warm water to be replaced by colder, deeper layers.

Oelke, et al., (1982) reported that dormancy is caused by a tough, impermeable pericarp that is covered by a layer of wax and by an imbalance of growth promoters and inhibitors. The growth inhibitor, abscisic acid, was found to be

TABLE 1

Germination Percentage vs. Temperature

Constant temperature	Percent Germination 1 week	4 weeks	Alternating temperature	Percent Germination 1 week	4 weeks
°F			°F [a]		
42	0	2	42-68	5	67
46	0	20	42-86	16	51
50	0	54	46-72	31	80
55	8	76	46-82	27	65
59	24	72	50-75	35	79
64	34	84	50-79	37	73
68	52	62	55-75	50	77
72	40	60	55-79	53	75
75	58	66	59-72	51	80
79	50	54	59-82	52	69
82	26	32	64-68	38	71
86	6	6	64-86	41	55

[a] Temperature altered daily; 12 hours at each temp.
Source: E. A. Oelke, 1982, p. 15.

higher in dormant than in non-dormant seeds. Simpson's research verified the effect of low seed coat permeability on the dormancy period by breaking the seed coat with a needle. Seeds with altered seed coats germinated without a dormant period.

Svare (1960) concluded that the percentage germination of wild rice was higher at low oxygen levels (0.35-1 ppm.) than at high oxygen levels (6.0-8.0 ppm.), but that no further plant development occurred at oxygen levels below 1 ppm. Simpson (1965) reported that dormancy can be broken by subjecting the seed to low oxygen concentrations and to cold water. He noted that freezing did not harm the grains and that rice frozen solid in a deep-freeze between fall and spring had high germination rates and percentages. This was true so long as dehydration was prevented. Drying seed below 28% moisture content wet basis is not recommended (Oelke, et al., 1982, p. 15). The optimum pH range for germination is 6.0 to 8.0 (Simpson, 1965, p. 5).

Dormancy can also last for several years. For example, it is known that in wild rice beds where an unusual spring freshet has destroyed the crop for one year such that no additional grains are deposited, a heavy stand will still appear in the following year. This indicates that a considerable seed quantity has delayed germination for at least 18 months (Simpson, 1965, p. 8).

The first indication of germination in a wild rice seed is the coleoptile breaking through the pericarp. Seven to ten days later the primary root emerges through the pericarp (Oelke, et al. 1982, p. 7). After three weeks, the seedlings usually have three leaves but remain submerged. The first internode elongates as in corn and oats. Wild rice seedlings can emerge through three inches of flooded soil. The internode elongates very little if the seed germinates in water but in the absence of soil.

Adventitious roots occur at the first node and occasionally at the second and third nodes. A leaf sheath with a leaf blade is attached to each node above the coleoptile node (Oelke, 1982, p. 7). The terminal bud differentiates nodes and internodes and terminates in an inflorescence.

The submerged leaves have an inconspicuous mid-vein and multiple lateral veins. These leaves die after emergence. The next two leaves have waxy surfaces and float on the water surface. They have a well developed mid-vein, larger lateral veins, and are thicker than the submerged leaves. Numerous cellular hairs project from the upper epidermal layer of the floating leaves. These projections trap air bubbles which keeps the upper surface from wetting and allows the leaves to float (Weir and Dale, 1960, p. 724). Submergent and floating leaves vary in width from 0.25 to 0.375 inches and vary in length from 6 to 12 inches.

After two to three floating leaves are produced, the

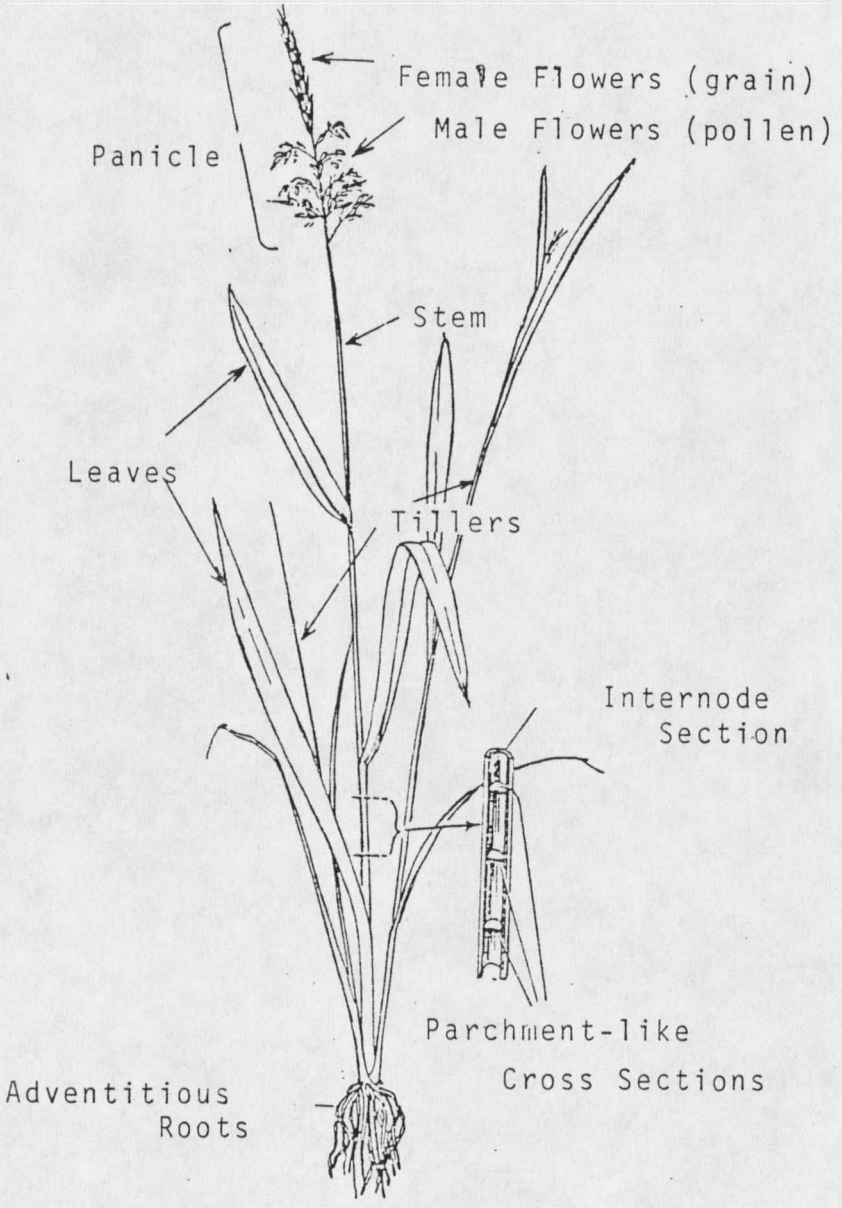
tips of the stiffer emergent leaves appear above the water. Although the upper surface is similar to the floating leaf blade, the emergent leaves grow much larger, varying in width from 0.75 inches to 1 inch and varying in length from 16 to 30 inches. The lower internodes of the plant are approximately 12 inches long, while the upper three to five internodes of the mature stem are 12 to 30 inches long. Internodes are hollow and are divided at regularly spaced intervals by thin, porous, parchment-like partitions. The stem diameter varies from 0.25 to 0.50 inch depending on the variety, plant density, fertility level, and water depth. The basal nodes of the main stem can produce up to 50 tillers per plant, many of which bear panicles. In fields with a plant population of four plants per square foot, plants will have three to six tillers (Oelke, 1982, p. 7). Typical plant heights range between 4.5 to 6.5 feet (Stucker, et al., 1986, p. 46). (See Figure 3 for a drawing of a mature wild rice plant.)

The shallow adventitious root system of the mature plant has a lateral spread reaching from 8 to 12 inches. The roots lack root hairs and are straight, spongy, and usually white although sometimes rust-tinged by iron deposits.

The transition from vegetative to floral growth is evident typically in mid June when the shoot apex shows

FIGURE 3

WILD RICE PLANT



Source: Oelke, et.al. (1978)

vigorous meristematic action. The monoecious panicle is 18 to 20 inches long with the female, seed-bearing portion being the upper 10 to 12 inches. The staminate (male) inflorescence has 12 to 15 branches that are 4 to 5 inches long. Each branch has 50 to 60 staminate florets with six stamens each enclosed by a lemma and palea. These stamens produce pollen which is dispersed by winds. The pistillate (female) inflorescence has 150 to 200 florets on branches that vary in length from 1 to 5 inches, with the upper branches being the shortest (Oelke, et al., 1982, p. 9). Each pistillate floret has only one caryopsis, and the glume are not developed. Thus, the harvested seeds are actually spikelets (Oelke, et al., 1982, p. 9).

Wild rice is usually cross-pollinated. Pistillate floretes emerge from the leaf sheath before the staminate florets. The stigmas are receptive to pollination for only three to four days; this period is generally before the stamens of the same plant shed pollen. Sometimes, however, transition florets (those between the pistillate and staminate) have both stigmas and anthers, allowing them to self-pollinate.

Fertilization is evident within 24 hours of pollination by a withering of the stigma. Two weeks later, the caryopsis is visible; four weeks after fertilization the plant is ready for harvest. Individual caryopses on a panicle mature at different rates; and 7 to 10 ten days are re-

quired for all to mature. When disturbed mature seeds shatter or drop from the panicle. Plant breeders have developed shatter-resistant varieties, thereby increasing harvest efficiencies. Weir and Dale (1960) provide an extremely detailed description of the development of the wild rice plant and compare its various development stages with those of Oryza (common rice). They concluded that although there are differences in both chromosome number and structure of the pollen sacs, studies of the embryo and emergent leaves do suggest a close relationship between the two genera.

History

Wild rice has been a staple in the diets of the Great Lakes region Indians for centuries. French trappers learned to eat the grain from these Indians (Winchell and Dahl, 1984, p. 4). They traded for processed rice and sold it to white communities during the late 1800's.

Today wild rice is harvested from naturally occurring stands or cultivated in paddies in Minnesota, California, Idaho, and Canada. (A more detailed chronology of wild rice history is contained in the appendix and is entitled "Historical Summary.")

Required Environment

Duck hunters and commercial entities have established wild rice stands in a wide variety of environments, from 53° north latitude in Canada to 39° north latitude in California. Because of this adaptability, classifying ideal wild rice growing conditions is difficult at best. The water, soil and climatic features of successful sites are listed in the following paragraphs.

Water

Water is one of the most fundamental growth factors for wild rice. Flow rate, depth, and water quality are important considerations, and must be addressed in detail.

Stoddard (1957) reports that wild rice beds appear to need "slowly" flowing water. "Slowly" is a relative term and no author specified a velocity. Weber and Simpson (1967) grew rice in test pots in which soil was kept at 60% of field capacity (i.e. zero water flow and zero water depth). Plants in these tests showed reduced dry weight, height, and grain yield. Goel, et al. (1970) also noted that wild rice seldom becomes established in land-locked stagnant waters or in swift-flowing streams. Oelke, et al. (1982) expressly states that continuous flow is not necessary, but that water should be added daily or as needed to

compensate for percolation, evaporation, and transpiration. They also note that evapotranspiration requirements for wild rice in Minnesota climates ranges from 24 to 30 acre-inches per year.

Water depth recommendations are common in the literature reviewed and are given as a range of depth. Commonly recommended water depths range between 6 inches and 4.5 feet. Oelke (1982) recommends an optimum depth of 13 inches and suggests a six inch minimum for any point in the field. He also states that water over 14 inches causes lodging. Weber and Simpson (1967) noted that in water depths less than 4 inches there was a tendency for the plant to form only aerial leaves. Emergence was reduced in non-flooded soils, although plants still grew to maturity and bore seed even when moisture was reduced to 80 percent of field capacity. This indicated the plant has the ability to mature under a wide range of moisture conditions.

Tests show that plants grown in water 12.6 inches deep had longer leaves and larger leaf areas than plants grown at shallower water depths. Since the yield of a plant can be correlated with leaf area, any set of environmental factors that influences leaf area will also affect yield. Plant height can also be correlated with water depth, and is greatest when water depths are near 12.6 inches (Thomas and Stewart, 1969, p. 1531).

Fluctuations in water depth are undesirable during the first 8 to 10 weeks of the growing season (Oelke, et al., 1982, p. 22). If water depths are dropped too rapidly during the submerged and floating leaf stage, then the leaves, sheaths, and stems are susceptible to breakage by wind and wave action. If water depths are raised during the early stages of growth, poor growth in the aerial stages results from increased growth and elongation of the submerged stages. The number of submerged leaves increases linearly with the amount of time the plant is submerged (Thomas and Stewart, 1969, p. 1525-1527).

Water levels should not be raised during the later stages of the growing season because buoyant rice stems and leaves can pull the roots out of loose, muck soil as levels rise (Stoddard, 1957, p. 8).

Commercial fields are often drained two to three weeks prior to harvest to allow harvest equipment access. During hot weather, care must be taken so that mineral soils do not dry out before plants are mature. Oelke, et al. (1982) recommend that the soils be kept saturated during the grain-filling period.

There are several important water quality factors that affect growth. Wild rice grows best in water with a total alkalinity between 40 ppm and 200 ppm. The water pH should range between 6.8 and 8.8 (Oelke, Fact Sheet #20, and Stoddard, 1957, p. 78). The recommended sulfate ion con-

centration is 10 ppm, but Oelke (1982) reports that experimental plots with sulfate concentrations up to 250 ppm grew normal plants. Simpson notes that the optimum carbonate ion concentration is near 40 mg/L. Oxygen levels below 1 ppm will allow germination, but will not sustain further plant development (Simpson, 1965).

Although water temperatures have been previously discussed for germination needs, the literature reviewed offered no recommendations regarding the optimum temperature for plant growth. Growth chamber tests were generally conducted at 20° C (Weber and Simpson, 1967).

Soil

Based on the literature reviewed, soil factors appear to be less limiting to plant development than water factors. Very little technical information is presented. Oelke, et al. (1982) does report that "nearly 90% of wild rice fields are developed on organic soils." Although he does not give a specific geographic reference, it is assumed he is referring to Minnesota. Much of Minnesota's wild rice is planted in peat soils. Oelke, et al. (1982) also states that it is difficult to establish wild rice in Minnesota's clay subsoils. A. G. Thomas's water depth experiments were done in soils consisting of 1 part loam, 1 part sand, and 1 part peat. Weber and Simpson's experiments were carried out

either in "muck" obtained from a lake bottom or in a prairie sandy loam. Oelke and Brun summarize soil requirements in a single paragraph;

> "Wild rice grows well on a wide range of soils from peat to clay. Soils in natural stands of wild rice often have low percentages of available potash and phosphate and a high organic matter content."

Soil nutrient factors are quantified by Oelke, et al. (1982) with fertilizer recommendations based on nutrient levels determined from soil tests. These values are listed in Table 2. Meyer and Bloom (1986) confirmed these fertilizer recommendations and also recommend specific forms of nitrogen to apply.

Urea is the recommended form of nitrogen to apply to wild rice. In moist and flooded soils, urea breaks down in a matter of days to ammonium (NH_4) which can be absorbed by wild rice roots (Meyer and Bloom, 1986 p. 22).

Nitrate, however, is an ineffective nutrient on flooded soils because it will be lost to denitrification, a process that converts nitrate to nitrogen gas. Denitrifying bacteria are generally aerobic, and utilize oxygen as a terminal electron acceptor. Terminal electron acceptors are atoms or compounds that serve as a sink for electrons given off in the oxidation of carbonaceous compounds. In the absence of oxygen, such as in flooded soils, denitrifying bacteria are able to utilize the nitrogen atom in nitrate as a terminal acceptor. Thus, the nitrate is converted either to nitric

oxide, nitrous oxide, or elemental nitrogen (Follet, et al. p. 40).

TABLE 2

Fertilizer Application Based on Soil Tests

Nitrogen

Status of field	Amount of nitrogen (N) to apply each year	
	Mineral Soils	Organic Soils
	pounds/acre	
1st year only	20	15
2nd year and older	40	30

Phosphorus

Phosphorus (P) soil test, (pounds/acre)	Amount of phosphate (P_2O_5) to apply
	pounds/acre
0-15	40
16-30	20
over 30	0

Potassium

Potassium (K) soil test, (pounds/acre)	Amount of potash (K_2O) to apply
	pounds/acre
0-100	60
101-200	40
201-300	20
over 300	0

Source: Oelke, et. al., 1982

Fertilizer should be placed at 6 to 8 inches deep in the soil and in rows 16 to 18 inches on center. This placement prevents denitrification and keeps nitrogen away from weeds and algae.

Flooded wild rice soils exhibit different biological and chemical reactions than are normally found in well aerated upland soils. Air is found in the interstitial pore spaces of upland soil. In flooded soils this air is replaced by water, and the root zone is anaerobic or near-anaerobic. In this environment, adaptive facultative anaerobes and true anaerobes dominate, although a thin layer of soil at the soil/water interface may support aerobic activity, with oxygen supplied by the water. The thickness of this aerobic layer is determined by a dynamic balance between the rate of oxygen supplied by the water and the oxygen consumption rate of organisms in the soil. In mineral soils this layer may be 0.25 to 0.5 inches thick and is usually brown with underlying layers of grayish brown to gray due to iron reduction. In organic soils, there often is no surface oxidized layer since reducing conditions can extend to the soil surface (Oelke, et al., 1982, p 18).

After nitrates and nitrites are reduced, manganese and iron are reduced to more soluble forms. Next, sulfate is reduced to sulfide, which is extremely toxic to plants (Oelke, 1982, p. 18).

Some authors suggest slowly moving water as optimum for wild rice beds. This may provide the mechanism by which oxygen and nitrogen are carried in by the water and toxins flushed out.

Soil temperatures affect the rate of bacterial activity. In early spring when soils are cool and germination occurs, reduction reactions may be near a standstill. These reactions increase by May, as soils warm and emergence occurs, and peak in mid to late July. Plants may germinate, begin to grow, and then be poisoned by toxins produced in reduction reactions.

Climate

Climate is another important factor to consider for wild rice establishment. In north central Minnesota, wild rice requires between 106 and 130 days to mature, depending upon variety and growing season temperatures. The plant requires approximately 2,900 growing degree days (base 40 ^{o}F) to mature (Oelke, et al. 1982, p. 9). Stages of plant development and accumulation of growing degree days (base 40 ^{o}F) are illustrated in Figure 4. This required growing period should not be confused with the frost-free period, because the first four weeks in a wild rice plant's life are aquatic submergent or floating leaf stages. During

those stages of growth the water temperature buffers the plant against air temperature extremes.

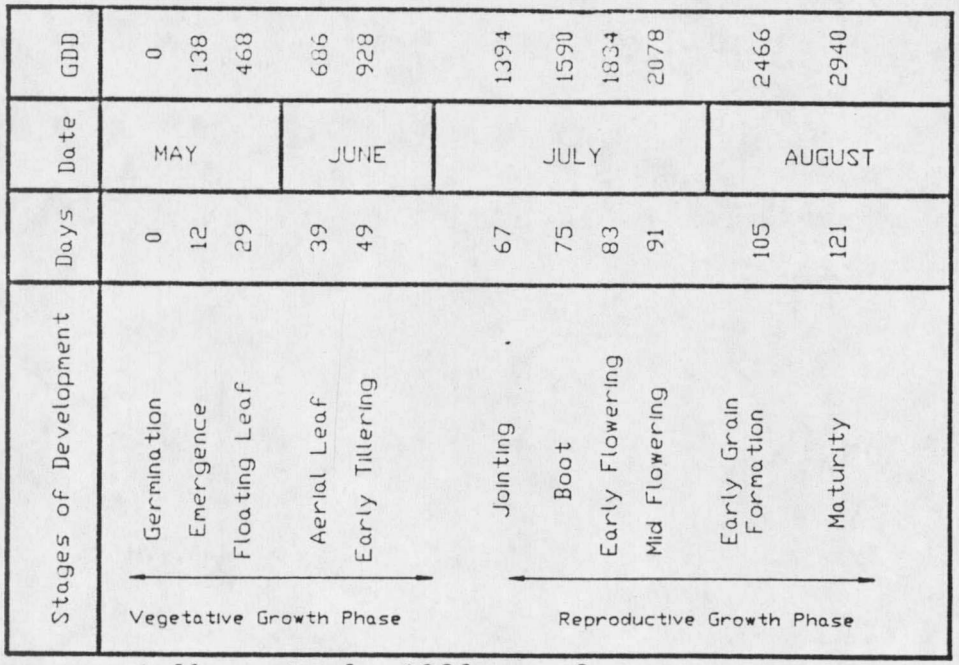
Short day-lengths tend to cause the plant to develop too rapidly (Winchell and Dahl, 1984, p. 19). When day length is less than 14 hours, the number of florets per panicle are reduced, thereby reducing yield.

Light levels used by researchers (Weber & Simpson (1967) and Thomas & Stewart (1969)) to grow normal healthy plants in experiments ranged from 69,000 to 89,000 ergs/cm^2/sec.

Rainfall in Minnesota climates can lead to moisture conditions that promote leaf diseases, while California growers are not plagued by this problem (Winchell and Dahl,

FIGURE 4

Stages of Development vs. Growing Degree Days



Source: Oelke, et al. 1982, p. 9.

1984, p. 19). Thus, in considering a potential wild rice site, it is reasonable to assume that rainfall distribution during the growing season should range between Minnesota (3 to 4 inches per month) and California (<1 inch per month). Idaho which averages 1 to 3 inches per month is also free of leaf diseases (Jeff Baker personal communication).

Jeff Baker of St. Maries Wild Rice in Idaho has suggested that equisetum or "mairstail", an aquatic plant common in Montana and Idaho, can be used as an indicator of environmental and climatic conditions conducive to wild rice growth. His experience in Idaho has shown that areas supporting stands of equisetum can readily be converted to wild rice stands. Montana Fish and Wildlife personnel have established stands of wild rice in areas that now support both wild rice and equisetum.

Commercial Processes

Commercial grain products are produced in a variety of geographic areas. While practices used for field preparation, planting, harvesting, etc. may be similar, regional differences exist. Wild rice is no exception, with farming practices as diverse as the locations in which it is harvested.

Regional differences among commercial wild rice operations can be roughly categorized as the Idaho method, the

Minnesota method, and the California method. Data for historical wild rice production from 1963 through 1985 is listed in Table 3.

The majority of Idaho's wild rice acreage is a stand in Benewah Lake. The remaining acreage is composed of stands established in 40 to 60 acre paddies built with small dikes. All stands are a shattering lake variety of wild rice. Herbicides are sometimes used on stands of weeds. No fertilizer is used and thinning is not practiced. Multiple passes by airboats are used to harvest the grain. Ineffi-

TABLE 3

Historical Wild Rice Production Data

(1,000 Processed Pounds)

	United States				Canada				
Year	Minn Lake	Minn. Cultivated	Cal. Cultivated	U.S. Total	Ontario	Manitoba	Saskat-chewan	Total Canada	Grand Total
1963	1286		0	1286	22		0	22	1308
1964	514		0	514	23		0	23	537
1965	435		0	435	12		0	12	447
1966	429		0	429	18		0	18	447
1967	1051		0	1051	225		0	226	1277
1968	524	36	0	560	126		0	126	686
1969	392	160	0	552	63		0	63	615
1970	489	364	0	853	26	60	1	87	940
1971	487	608	0	1095	121	200	9	330	1425
1972	414	1496	0	1910	481	240	22	743	2653
1973	406	1200	0	1606	57	251	5	313	1919
1974	400	1036	0	1436	4	55	9	68	1504
1975	200	1233	0	1433	41	57	17	115	1548
1976	800	1809	0	2609	501	141	39	681	3290
1977	437	1031	10	1478	414	462	34	910	2388
1978	220	1761	29	2010	68	190	24	282	2292
1979	304	2155	67	2526	131	239	60	430	2956
1980	1000	2320	230	3550	427	560	129	1115	4665
1981	400	2274	544	3218	301	181	205	687	3905
1982	440	2697	800	3937	75	166	208	449	4386
1983									
1984	450	3600	3690	7740				1009	8749
1985	60	4000	9600	13660				357	14017

Source: Winchell and Dahl (1984) and Nelson and Dahl (1985)

ciencies in the harvest process reseed the fields. Although most Idaho wild rice fields are never drained, some are drained for initial planting. Typical yields in Idaho are 400 pounds per acre (harvest weight) of long grain gourmet quality wild rice, with a finished yield of approximately 200 pounds per acre (dry weight).

Crop residue is left to decompose in the aquatic environment and crop rotation in not used. This method of wild rice management is also used in parts of Minnesota and Canada.

The Minnesota method has evolved around varieties of wild rice bred for shatter-resistance. Fields are drained before harvest to allow the soil to dry enough to support combine harvesters. Chemicals are used to control insects, fungi, and weeds. Inefficiencies in the harvest reseed the field. To maximize yields, thinning is used on second-year and older fields. Typical yields are 1000 or more pounds per acre (harvest weight with 40% moisture wet basis) of short grain, blend-quality wild rice. This also finishes to approximately 200 pounds per acre (dry weight). The finish rate is low due to immature kernels harvested by the combine. Crop residue is tilled into the soil after harvest. Fields are fallowed or used to grow rotation crops every three to five years.

The California method is adapted from the conventional rice (Oryza) industry. Many farmers here grow both wild rice and common rice. Shatter-resistant wild rice is combine-harvested from drained fields using common rice combines. The fields dry during winter and must be reseeded each growing season. This allows the growers to select a new variety each growing season, a luxury unique to the California method. Other regions must perform significant field maintenance in order to change varieties. The California method uses chemicals to control pests and fertilizers to supply nutrients. Typical yields are 1200 pounds per acre (harvest weight with 40% moisture wet basis) of blend-quality wild rice, which finishes to 575 pounds per acre (dry weight). Crop residue is incorporated into the soil with tillage after harvest.

The appendix details commercial field preparation and planting techniques in the section entitled "Field Preparation and Planting." Information on wild rice varieties and harvest techniques is in the appendix section entitled "Varieties and Harvest Techniques." The appendix also contains sections that address "Fall Tillage and Rotation Crops," "Commercial Processing," and "Diseases and Pests."

Wildlife

A major consideration in the establishment of wild rice is the resulting impact on wildlife habitat.

"Wildlife habitat" can be defined simply as natural environment of plants and animals. This environment must supply the plant or animal with all the food, cover, and reproductive sites necessary for survival. For wild rice, that environment must be aquatic for at least part of the year and is often covered with shallow water year round.

Aquatic ecosystems that can support wild rice are extremely complex systems. They interface land, water and air systems, thus they contain a diversity of life forms including birds, mammals, reptiles, fish, insects, invertebrates, bacteria, and fungi.

The term "wildlife" has a variety of definitions and is often used subjectively. A literal definition is those plants and animals which live in nature. Many people immediately think of commercially valuable wildlife, including ducks, geese, big game animals, fish and fur-bearers. All these creatures can be found in or on the perimeters of shallow aquatic ecosystems.

Oelke, et al. (1982) report that Minnesota wild rice fields serve as resting, foraging, nesting, and brood rearing sites for both resident and migratory water birds. They state that the data suggests a 20 acre commercial wild

rice field will often support one to two nesting pairs of ducks, a waterfowl production statistic that compares favorably with potholes, a prime duck-producing area. This information has been well known for many years, and many acres of wild rice have been introduced by duck hunters and wildlife agencies. Good duck and goose habitat also support many other types of plants, animals, invertebrates, and other life forms. For instance, the logo for St. Maries Wild Rice Company contains a Great Blue Heron, because it is frequently seen in Idaho wild rice fields.

Wild rice provides cover for the organisms which feed on it and for others. Skunk and raccoon forage successfully at the land water interface of wild rice stands, mink utilize the stands (Oelke, et al., 1982, p. 27), and bass are reported by St. Maries Wild Rice to be found extensively in boatways cleared through wild rice stands in Benewah Lake in Idaho.

Food Chain Effects

More than 35 species of shore birds and wading birds have been observed using wild rice fields. Many are resident birds that forage on the flooded fields, while several species nest on the dikes (Oelke, et al., 1982, p. 270). Twenty-six species of birds are known to feed on wild rice (Weir and Dale, 1960, p. 719). When the stomach contents of

8000 ducks in 200 different wild rice fields were analyzed, the concentration of wild rice grain was found to be second only to soft aquatics.

Grain consumption by ducks has been studied because of concern over the damage they cause conventional grain crops. Tests with barley, hard wheat, and durum wheat fed to groups of both caged and active mallards show that under extreme conditions such as freezing temperatures, consumption rates approach 200 grams/day (field weight of grain). A rate between 95 and 115 grams/day is more realistic during mid- August to early October when most crop damage occurs (Sugden 1979, p. 38). Wild rice is similar in protein and carbohydrates but lower in fat than wheat. Assuming similar consumption rates and that foraging mallards will recover 30% of grain lost to shatter and harvest inefficiency, then a one acre field with 500 pounds of lost grain would support 10 mallards for 34 days under extreme conditions (200 grams/day). At lower consumption rates (100 grams/day) that same acre would support 10 ducks for 68 days. For details on nutritional values of wild rice see the appendix section entitled "Nutrition."

How many ducks would be supported by an acre of wild rice planted solely for duck habitat? If it is assumed that one acre will yield 1800 pounds of wild rice (as obtained in test plots in Corvallis, Montana), that harvest weights

of wild rice are similar to field weights of conventional grains, and that the ducks will recover 30% of the grain, then under extreme conditions (200 grams/day consumption rate), one acre should support 10 ducks for 123 days.

Mammals will also feed on wild rice. Deer and moose have been observed in wild rice fields (Oelke, et al., 1982 p. 27), and muskrats are known to eat the grain and the plant. Crustaceans such as crayfish also browse on young wild rice plants. Estimates of consumption rates for these animals were not found in the literature reviewed.

On a microscopic scale, grazer and shredder organisms decompose vegetative matter produced by wild rice plants. "Grazer" and "shredder" are functional groupings used to describe the morphological and behavioral characteristics of water invertebrates (Vannote, et al., 1980, p. 132). Grazers or scrapers are adapted primarily for shearing attached algae from surfaces, while shredders utilize particulate organic matter such as leaf and stem litter, with a significant dependence on the associated microbial biomass. The food chain extends a few steps further as the shredders are consumed by predator organisms such as various insect larval stages. The insects and insect larva are in turn consumed by fish and birds.

Microclimate Effects

Microclimate affects which could result from stand establishment of wild rice include wave dissipation along shore lines, shading of the benthic region, and sediment trapping in flowing systems. Stands could also have thermal effects on the microclimate's air and water. Stagnation of water by stands could lead to increased water temperatures. This may be partially offset by the effects of shading. Warmer water temperatures could effect localized air temperatures.

The Niche Concept

The "niche concept" as defined by Nilsson (1985) is "the status of an organism in its community." Finding a species to fill a vacant niche in an ecosystem, which is not fully exploited by native species should be the main philosophy behind the introductions of exotics.

Since the overall effect of wild rice stand establishment is dependent on many components, it is difficult to accurately predict the result of its introduction. In the absence of detailed research, one can only speculate on potential individual component effects and try to predict overall results based on summation of the components, or make comparisons with similar introductions. Even when

predicted outcomes look favorable for habitat improvement, the term improvement must be carefully interpreted. Long-term as well as short-term effects must be carefully considered before introducing any non-native plant species into a wild ecosystem. The potential risks must be addressed, as the attempt to diversify and increase habitat can often have the opposite effect.

Nilsson (1985) discusses some of the potential outcomes of introducing exotics, suggesting that the potential results can include:

1) rejection of the introduced stock because there is no "vacant niche" or because predators graze down the population at early stages;

2) hybridization with very closely related stocks, formerly adapted to the ecosystem;

3) eradication of a stock that is either an "ecological homologue" or a very available prey; or

4) establishment within a "vacant niche" in the community, meaning it adapts to resources not fully exploited by other species, finally allowing it to survive as a member of the community.

Aquatic systems are complex because of multiple interactions that occur within them. Thus the successful introduction of a species within one ecosystem may not necessarily indicate the outcome in another "similar" ecosystem. For example, the introduced stock may or may not be eradicated

depending on levels of predation. A combination of lack of a vacant niche and predation may affect whether or not a native plant species is eradicated as a result of competition with wild rice.

Still, one method of assessing and reducing risk is by studying historically similar events. In the case of wild rice, there are many examples in Canada, California, and Idaho where the plant has been introduced into wild ecosystems.

Canadian officials in Saskatchewan introduced wild rice in the 1930's for wildfowl feed. By the 1980's the plant was not only feeding wildlife but commercial interests were harvesting up to 200,000 pounds annually (Winchell and Dahl, 1984).

In California and Minnesota, growers have learned that migratory waterfowl can cause economic losses. Also in California, where thousands of cultivated acres have been introduced, growers have found that wild rice does not become established in natural waterways or show a proclivity to regenerate (M. Westcott personal communication). In Minnesota, the natural stands must be protected by regulated harvests due to the fragility of the populations.

Duck hunters introduced the plant to Idaho in the 1940's, which led to a commercial stand in Benewah Lake. Fred Bear, manager of Heyburn State Park in the Idaho

Panhandle where Benewah Lake is located, summed up Idaho's experience with wild rice. "Wild rice is good for everyone, the fishermen, the hunters, the farmers, and now our lake restoration program, good for the taxpayers too, it's one of those rare everybody-wins situations," (Outlook '86).

Such enthusiasm must be tempered until as many factors as possible about the effects of wild rice introduction are assembled and analyzed to determine if introduction into a particular site will have positive or negative effects. Even then, judgment must be tempered when defining positive and negative effects. For example, the first stand established in Idaho was a boon for duck hunters, but without management it became a nuisance for boaters as it choked off boat channels and docks.

The Montana Department of Agriculture expressed no concern over attempting to establish stands and reported that permits are not required by state agencies to introduce non- native plants in Montana.

Care should also be taken to prevent the introduction of other new life forms that may be contained in wild rice seed, including weeds, insects or fungi.

CHAPTER 3

PROCEDURES

Wild Rice in Montana Climates

Official research on wild rice in Montana was initiated by Malvern Westcott in the spring of 1986 at the Western Agricultural Research Center in Corvallis, Montana, a Montana State University facility. Four 12′ x 12′ plots were created with border dikes in a field and supplied with water from a nearby irrigation ditch. Seeds were obtained from a Minnesota grower and from St. Maries Wild Rice Co. in Idaho, planted one inch deep in rows on 12" centers, and flooded the first week of May. Seeding rates approximated the 50 pounds per acre recommended by Minnesota growers (see "Field Preparation and Planting" in the Appendix of this report). The plots required periodic reflooding to maintain a water depth of 8 to 10 inches.

Plant growth was lush, with many plants over 6′ tall. Successive late August and early September hand harvests yielded 997 pounds per acre on an oven dry basis. This was converted to 40% moisture or 1667 pounds/acre (lb./ac.) in order to compare it with yield data for the same planting method at the Minnesota Agricultural Experiment Station in

Grand Rapids during the 1973-75 growing seasons. The Grand Rapids yield was 1676 lb./ac. These promising results spurred interest in further research.

Test plots were again planted by Westcott at the Western Ag. Research Center in Corvallis, Montana in 1987. Additional test plots were planted in several locations by the author. The research center plots closely resembled conditions that would exist if present agricultural lands were converted to cultivated wild rice production. The author's plots were intended to simulate conditions that would exist if wild swamp lands were converted to stands of wild rice.

Westcott provided the three wild rice varieties used in these experiments. They included a cultivated, non-shattering type, Minnesota Wild Rice (K-2) and two non-shattering types (NC-1 and EXP-4) developed for cultivated plots by the Nor Cal Company in California. In this report they are referred to as Minn., Nor Cal, and Experimental respectively.

The author established test plots in a diverse cross-section of western and southwestern Montana. Unfortunately, eastern Montana received no plots. Descriptions of the planting sites and procedures used are described in detail in the "Planting Notes" section of this chapter.

For reference, the sites have been named Dad's Dams, Cabin site, Mikes Moose Marsh, East Bay Flathead Lake, Scoonover Dike, Red Bluff Research Center, and the George

Kahrl Ranch. Stands established by the Forest Service in 1978 and 1986 were also monitored. These stands are referred to as Swan Lake and Spring Creek, respectively.

For the 1987 growing season the project included 12 bays of 144 square-feet each at the experiment station in Corvallis, 11 plots of 100 square-feet each in wild-type environments, and 4 plots of 100 square-feet each in cultivated environments located across Montana.

Planting Notes

The following paragraphs contain detailed descriptions of all plots except for those at the experiment station, and highlight seeding rates, seeding methods, varieties of rice planted, elevation, soil data, and plot specific information. Growing degree day data for weather stations near all sites is tabulated in Table 4, providing a comparison with selected sites in Minnesota and Idaho. This same data tabulated for those sites that produced mature plants is further illustrated as a bar chart in Figure 5. Table 5 provides departures from normal for average temperatures so that the 1987 growing season can be compared with other years. Important parameters for all Montana sites, excluding Corvallis, are summarized in Table 6. Table 7 compares precipitation distribution on a monthly

basis for those sites that produced mature plants in Montana with selected sites in Minnesota and Idaho. Figure 6 summarizes the same data in bar chart form. Table 8 lists water quality parameters for selected sites.

TABLE 4

Growing Degree Days Comparisons[a]

SITE	April	May	June	July	August	Sept.	Total
Swan Lake	-	437.5	591.9	670	572.2	455	2726.6
Pony	-	369	559.5	617	569.5	515.5	2630.5
Norris	-	544	736	798	751.5	649.5	3479
Cardwell	-	502	673.5	770	654	542	3141.5
Trout Creek	-	465	626	684.5	778	568.5	3122
Polson	-	559	733.5	835.5	771	623.5	3522.5
Scoonover	-	530.5	695	739	643	548	3155.5
Corvallis	-	539.5	687	786.5	698	572.5	3283.5
St. Maries	- [b]	566 [c]	575.5	838	794	632.5 [d]	3588
Aitkin	141 [b]	414 [c]	677	871	785	251 [d]	3139
Grand Rapids	127 [b]	380 [c]	635	816	734	231 [d]	2923
Itasca	111	375	645	833	759	213	2936

a ((Daily Max.+Daily Min.)/2)-40
b April values ave. of 1984, 1985, 1986 data
c May-Aug. values are normals for region
d Sept. values ave. of 1984, 1985, 1986 data
Source: Montana data from NOAA ISSN 0145-0395
Minnesota data from Oelke, et. al., 1986

TABLE 5

Average Temperature Departures from Normal

SITE	April	May	June	July	August	Sept.
Swan Lake	-					
Pony	-					
Norris	-	4.2	3.1	-4.2	-4.3	2.8
Cardwell	-					
Trout Creek	-	3	2.2	-2.9	1.9	2.5
Polson	-	5.4	0	-0.1	0	4
Scoonover	-					
Corvallis	-					
St. Maries	-					

Source: NOAA ISSN 0145-0395 (Montana 1987) NOTE: Period of record inadequate to determine departures for some sites.

TABLE 6

Site Summaries

SITE	SOIL	NO3-P-K % OM	WATER QUALITY TDS/SAR	OBSERVED GAS LEVEL	NATIVE VEGETATION	PLANTING METHOD	SEEDING RATE	WATER DEPTH Inches	OUTCOME	NOTES
Dad's Dams Trout Creek	Silt 8.8% sand 9.0% clay 82.2% silt	0.3-67.3-119 µg/g 14.75%	31/2.00	heavy	Presently unidentified emergents	Broadcast & Muck Spring	12 - 18 seeds/sq. ft.	10 - 28	no mature plants	cattle breach dam
Cabin Site Trout Creek	Silt Loam 15.4% sand 18% clay 66.6% silt	0.3-20.4-256 ppm 10.36%		Zero Previously unflooded	Buck brush and grasses	Rows Spring	1 - 3 seeds/inch rows 12' o.c.	8	no mature plants	plot failed to hold water
Mikes's Moose Marsh Trout Creek	Silt Loam 11.4% sand 16% clay 72.6% silt	0.2-49.4-79 µg/g 13%		light to moderate	Presently unidentified submergents	Broadcast & Muck Spring	12 - 18 seeds/ sq.ft.	12	no mature plants	drop in water table consumed by cattle, moose
East Bay Flathead A Polson	Silt Loam 24.4% sand 22% clay 53.6% silt	0.6-55.4-199 µg/g 15.25%		unflooded at time of planting	Hippuris Myriopyllum	Rows Spring	1 - 3 seeds/inch rows 12' o.c.	48	plants emerged but none matured	consumed by Muskrats
East Bay Flathead B Polson	Loam 45.4% sand 14% clay 40.4% silt	0.7-34.7-110 µg/g 10.82 %	228/1.27	light	Utricularia or Bladderwart Potamogetons	Broadcast & Muck Spring	25 - 30 seeds/sq.ft.	24	some matured	consumed by Muskrats
Scoonover Dike Allentown	Silty clay 13% sand 41% clay 46% silt	1.3-26.2-308 µg/g 4.55 %	96/1.51	light	Cattail Myriopyllum additional unidentified	Broadcast & Muck Spring	12 - 18 seds/sq.ft.	18 - 28	nearly all matured	plauged by Muskrats
Red Bluff Experiment Station Norris	Loam 31.4% sand 20% clay 48.6% silt	4.6-53.7-246 ppm 25.1 %	347/2.93	unflooded at time of planting	unidentified sedges	Rows Spring	1 - 3 seeds/inch rows 12' o.c.	2 - 6	some reached soft dough	early frost killed
G. Kahrl Ranch Willow Creek	Untested		332/3.20	moderate	Presently unidentified	Mudballs & Broadcast Spring	6 - 8 balls/sq.ft.	12 - 16	few emerged None matured	consumed by muskrats & geese
Swan River National Wildlife Refuge	Sandy loam 57% sand 7% clay 36% silt	0.9-6.2-76 µg/g 0.30 %		moderate	equisetum	Planted 1978 by Forest Service		18 - 24		Heavy use by ducks
Spring Creek Swan Lake	Silty loam 29% sand 17% clay 54% silt	1.1-25.8-82 µg/g 20.7%	165/0.32	High	equisetum	Broadcast from Airboat Fall	estimated @ 30 lb./ac.	18 - 24	healthy stand established	heavy use by muskrats

TABLE 7

Precipitation Comparisons (Inches)

Site	May 1987 Values Departure Greatest Day	June	July	August	Sept.
Montana					
Corvallis	1.4	1.55	1.88	.90	.10
	-	-	-	-	-
	.49	.37	.60	.22	.09
Cardwell	4.65	1.44	3.57	1.39	.43
	-	-	-	-	-
	1.16	.43	.82	.44	.38
Polson	1.64	1.80	2.16	1.31	.20
	-.43	-.38	1.10	.15	-1.02
	.68	.76	1.41	.80	.10
Swan Lake	2.62	2.74	4.87	2.22	1.07
	-	-	-	-	-
	-	1.0	2.92	-	-
		[b]			
Scoonover	1.64	.73	3.08	1.63	.3
	-	-	-	-	-
	.36	_	1.73	.99	.23
Idaho					
St. Maries	2.36	2.03	2.00	.77	.10
	.22	-.03	1.23	-.55	-1.21
	.92	.85	-	-	-
		[c]			
Minnesota	(normals)				
Aitikin	3.39	3.83	4.79	4.19	
Grand Rapids	3.16	3.79	4.12	3.38	
Itasca	2.80	4.33	3.34	3.47	

a NOAA ISSN 0145-0395 b
b Partial summary due to missing data
c Oelke, et. al., (1986)

FIGURE 5

Growing Degree Day Comparisons

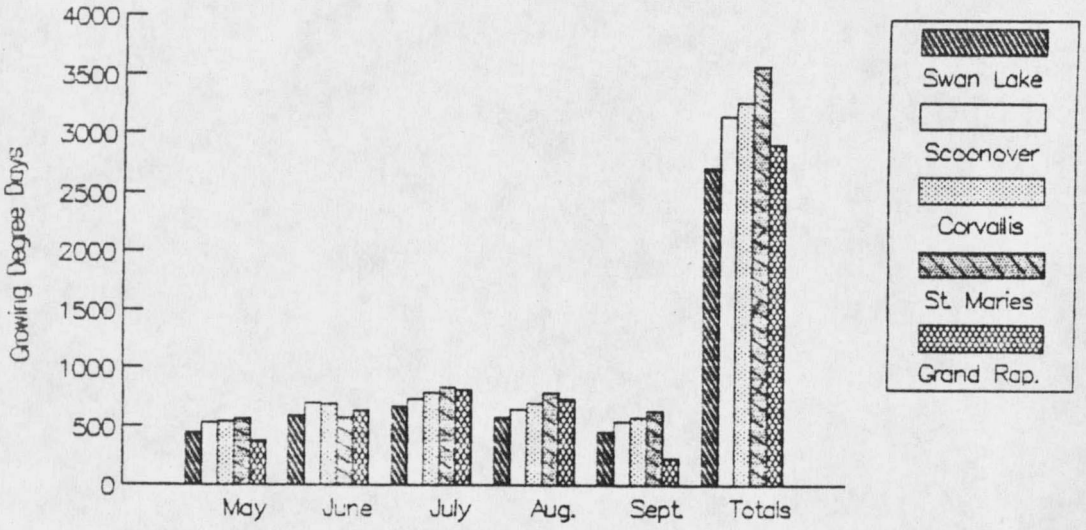


FIGURE 6

Precipitation Comparisons

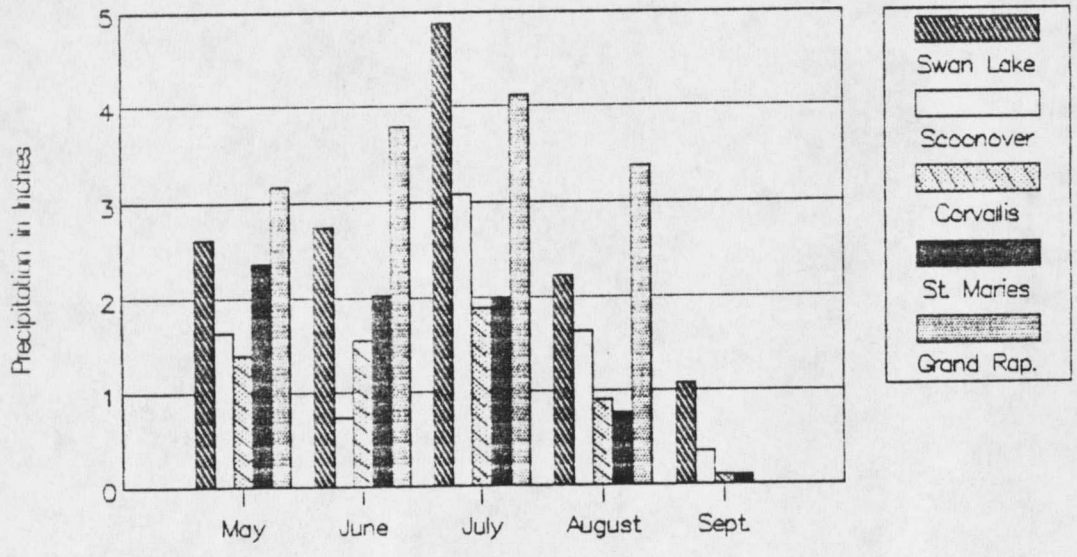


TABLE 8

Water Quality Analysis

Description of Sample	TDS mg/l	Na mg/l	Mg mg/l	Ca mg/l	Sulfate mg/l	pH	Hardness CaCo3 mg/l	SAR
Flathead Lake #2	228	7.3	20	46	7	6.25	200	1.27
Scoonover Dike	96	5.3	8.5	16	30	5.5	71	1.51
George Kahrl Ranch	332	20	18	60	60	5.5	230	3.20
Norris	347	20	23	70	30	6	270	2.93
Spring Creek	165	1.7	18	40	7	5.5	180	0.32
Dad's Dams	31	2	0.4	1.6	6	4	20	2.00

Source: Samples tested by MSU Chemistry Dept.
TDS = Total Dissolved Solids
SAR = Sodium-adsorbtion ratio = Na/((Ca + Mg)/2)**.5

Samples tested by Montana State University Chemistry Dept.
TDS = Total Dissolved Solids
SAR = Sodium-adsorbtion ratio = Na/((Ca+Mg)/2)**.5

Dad's Dams

Planting Date: Friday, May 8, 1987.

Location: Swamp Creek Drainage, Trout Creek, MT, Goat Peak Quadrangle 7.5-Minute Series, T25N R31W Section 20, Elevation = 2580'. (See Figure 7)

Description: "Dad's Dams" are located on land owned jointly by Glenn and Dale Reller near Trout Creek, Montana.

This planting site was an inactive beaver dam built an estimated 12-15 years ago and abandoned for at least the past six years. The site has two dams. The lower dam retains water over an area of approximately 2000 square-feet, with depths ranging from 4 in. to 4 ft. It has one outlet that drains into Swamp Creek and three inlets that drain from the upper dam.

The upper dam retains water over approximately 5000 square-feet with depths ranging from 2 in. to 3 ft. There are three outlets that drain into the lower dam and two inlets. One inlet drains spring fed active beaver ponds located 2000 feet up-stream. The other inlet is a branch channel of Swamp Creek that flows only during spring run-off.

Plots and Planting Procedure: The soil texture was 8.8% sand, 9.0% clay, and 82.2% silt, resulting in a textural class of silt. The NO3, P, & K values of the soil of 0.3 ug/g, 67.3 ug/g, and 119 ug/g respectively. Organic matter content of the soil was 14.75%. The soil was 10 inches to 2 ft. thick and was perched over gravel. The highly organic soil bubbles "swamp gasses" for one to three minutes when disturbed with a shovel or by walking. Water temperature at planting was 52 degrees Fahrenheit.

Plot "A" was 10'X 10' and was planted with a 3'X10' swath of the Minn. variety, followed by a 3'X10' swath of the Experimental variety, and finally a 3'X10' swath of the Nor Cal variety (from south to north). The soil was worked and mixed with a row hoe before planting to release as much gas as possible and to disturb the sparse native vegetation (unidentified submergents). The seed for each swath was broadcast by hand over the water and sank quickly. A 0.5 to 1 ft./sec. water velocity was observed. The

seed density over the bottom was 12 to 18 seeds per square foot. After broadcasting, the seed was stirred or "mucked" into the soil with a row hoe to a depth of 0.5 to 1 inch. The water depth varied over the long axis of the swath, starting at 10", increasing to 28" at the center, and then tapering to 10". The flow velocity was slightly higher in the deeper region. This depth pattern was common for the plot. Soil depth also varied in a similar pattern with 10+ inches of soil beneath the shallow water and 24+ inches beneath the deeper water.

Plot "B" was 10'X10' with an even water depth of 10 inches. Seed was again broadcast in swaths of 3'X10' but in a random order of Minn., Nor Cal, and Experimental (from north to south). Seed density was again 12 to 18 seeds per square-foot. Seeds were incorporated by walking repeatedly through the seed beds. High gas levels were observed during this process. The soil layer was observed to be 8 to 10 inches thick.

For lack of a large enough area the "C" plot was actually three "subplots" composed of 3'X10" swaths of each variety. The lone Minn. swath was in the inlet channel from the spring in silt 24+ inches deep and showed both high gas and high water flow. Seed was broadcasted into 13" of water and worked with a row hoe. The lone Experimental variety was broadcast into 6 to 8 inch deep water that showed medium gas levels when worked with a hoe. The soil

layer was firm and measured 3 to 6 inches deep. The lone Nor Cal was also in the spring inlet channel with a water depth of 16 inches and low gas levels.

A "D" plot was planted over a 10'X15' area. It consisted solely of Minn. broadcast at a density of 3 to 8 seeds per square foot, in water 2 to 3 feet deep. No working of the soil or incorporation of the seed was done but gas levels were suspected to be high.

Dad's dams are frequented by 1 to 2 mallard pairs.

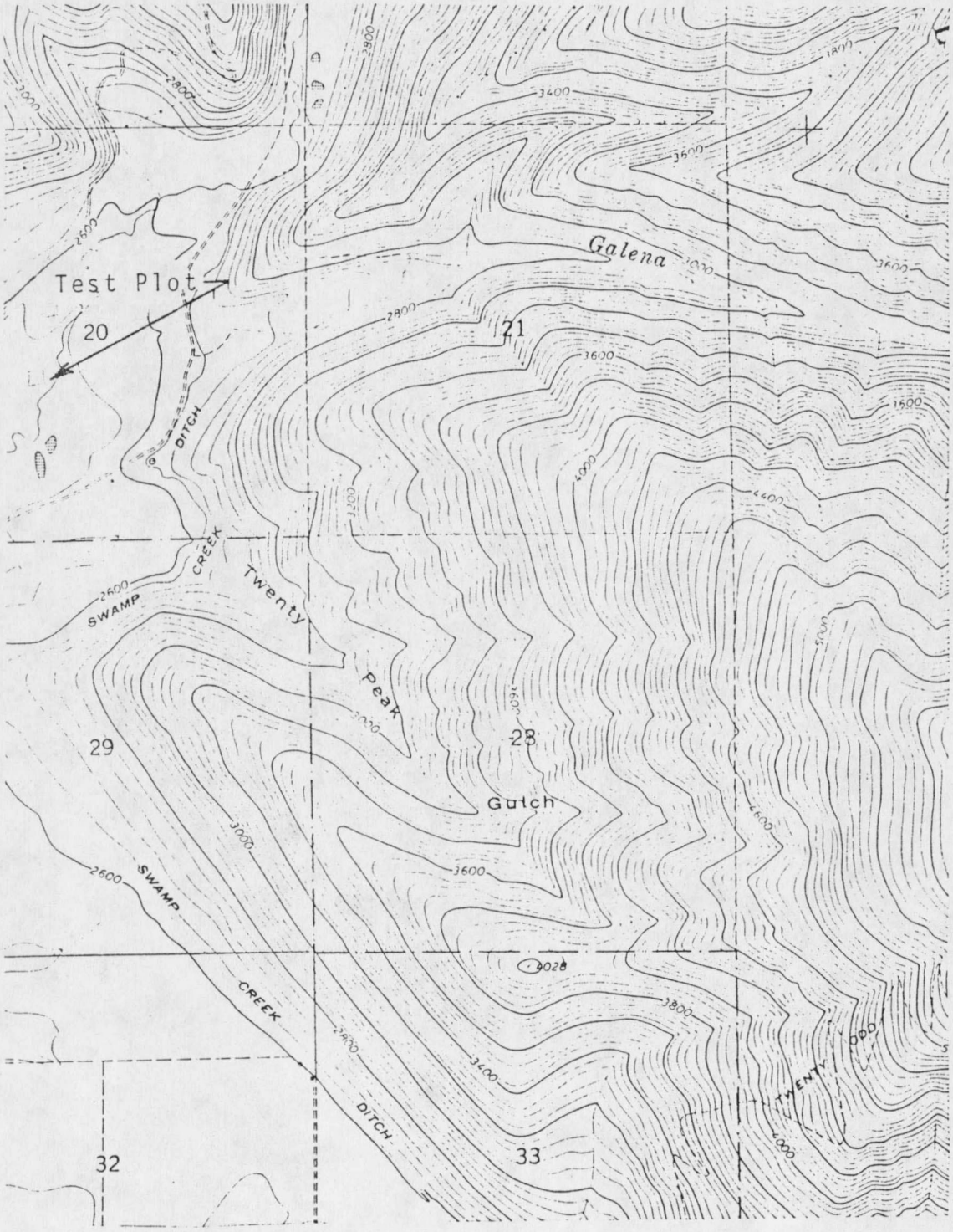
Results and Speculations for Dad's Dams: On June 28, the plots showed poor germination and plants were still either submerged or at the floating leaf stage. Many of the plants were covered with a light brown to clear film approaching 1/8 inch thick, which could either have been a fungal or bacterial growth, or a webbing created by the larval stages of midges. Inspection of the site two weeks later found the beaver dam damaged by open range cattle in the area and the plots drained. Although the breach was repaired it took an estimated 3 to 5 days to refill the dam and re-cover all the plots. Few plants survived the ordeal; those that did faltered and died over the course of the summer. None reached maturity. Additional factors that may have contributed to the failure on these plots include extremely high levels of "swamp gasses" formed by anaerobic decomposition of organic vegetation buried by dam silta-

tion. These "swamp gasses" could indicate extremely low oxygen levels and the existence of progressed reduction conditions, both of which lead to environments toxic to the young wild rice plants. Toxic sulfide concentrations can build up under reduced conditions. Seasonal temperature fluctuations that limit reduction reaction rates might explain how the plants were able to germinate and grow when temperatures were down and reduction reactions slow, but then died when temperatures and reduction reactions increased. This might also account for the sparse levels of other plant life present.

The pH level was 4, which is outside recommended limits and indicative of severe reducing conditions and the presence of H_2S. The soil structure was very fine; one had to be very careful walking in hip boots since what appeared to be 12 inches of water often turned out to be 36 inches of water and muck. Al Bruner of St. Maries Wild Rice Co. speculated that such an unstable soil condition would make it difficult for the plants to develop a healthy root system.

FIGURE 7

Excerpt from Goat Peak Quadrangle



Mike's Moose Marsh

Planting Date: Saturday, May 9, 1987.

Location: Swamp Creek Drainage, Trout Creek, MT, Goat Peak Quadrangle 7.5-Minute Series, T25N R31W Section 20, Elevation = 2580'. (See Figure 7)

Description: This site was planted on property owned by Mike Bombadill located nearly one-quarter mile down stream from Dad's Dams. The planting site was a depression in the ground surface, which is below the groundwater table. The surrounding area has many springs and marshy areas that are frequented by moose. The site had no surface inlet or outlet and covers approximately 600 square feet.

The water table on this property has been observed to vary directly with the level of Swamp Creek. In normal years the marsh is covered by 12 to 16 inches of water in May and decreases to less than one inch by late August. In dry years the marsh has been dry by early September.

Plots and Planting Procedure: A 10'X10' plot was created by hoeing and raking out the native vegetation. During this process swamp gasses were dislodged from the soil. This soil texture was 11.4% sand, 16% clay, and 72.6 % silt resulting in a textural class of silt loam, with NO3, P, and K values of 0.2 ug/g, 49.4 ug/g, and 79 ug/g respectively. Organic matter content of the soil was 13%. Seeds

were broadcast into replications of 3' X 10' and worked into the soil both with a row hoe and by walking through the seedbed. The seeding rate was 12 to 18 seeds per square foot. Water depth was 12". The order of the varieties, from west to east was Nor Cal, Minn. and Experimental. A second 10'X10' plot adjoined the first on its southern border and was planted by broadcasting the seed at the same rate into natural submergent and emergent vegetation. The vegetation consisted of clumps of heavy bladed grasses, fibrous mossy plants, and small broadleaf plants. The order of the varieties was the same and seed was worked into the soil by walking through the plot. Gas levels were light in both plots and no visible flow was observed. Water temperature was 48 degrees Fahrenheit.

Results and Speculations on Mikes Moose Marsh: Both plots germinated and reached the floating leaf stage by June 28. The summer of '87, however, received little precipitation and low available snowpack in the headwaters of Swamp Creek. By mid to late July the marsh was dry. Plants that continued to survive were consumed by moose and open range cattle. No plants achieved maturity.

Flathead Lake East Bay at Polson

Planting Date: Monday, May 11, 1987.

Location: Flathead Lake, Polson, MT, East Bay Quadrangle

7.5-Minute Series, T22N R19W Section 050, Elevation= 2890'. (See Figure 8)

Description: This plot was located on property controlled by the Confederated Salish and Kootenai Indian Tribes on the East Bay of Flathead Lake near Polson, Montana. Permission to plant the site was obtained from J. Loyd Jackson, the shoreline protection administrator.

The level of the lake is controlled by Kerr Dam, with a full pond level targeted for June 20 and lasting through October. When the lake is not full East Bay is bordered by a 150 acre mud flat and large expanses of cattail stands where migratory waterfowl nest. Two small streams drain into the area and create small pockets of standing water. When the lake is full the area is under 2 to 4 feet of water. Plot "A" was 10' x 10'. It was still unflooded when planted in May, although the soil was saturated. Native plants were cleared and the plot was planted in rows. Since the area is very prone to wave action an additional 3' X 10' area was planted in a protected cove of cattails.

Plots and Planting Procedure: The "A" plot was planted on the lake side of a band of cattails. The soil texture was 24.4% sand, 22% clay, and 53.6% silt resulting in a textural class of silt loam, with NO3, P, and K levels of 0.6 ug/g, 55.4 ug/g, and 199 ug/g respectively. The organic matter content of the soil was 15.25%. The plot was flooded with four feet of water when the lake filled, but at the

time of planting the plot was not yet covered. When working the site in hip boots it was common to sink to the knees in mud. The soil was saturated or near saturation and foot prints in the mud would fill with water in three to five minutes. The plot was cleared of native vegetation with a hoe and a 6" border was created about the perimeter with 2" layer of mud scraped from the plot. Native vegetation was identified by Shari Gregory, a tribal botanist, as Hippuris or Mairstail and Myriopyllum. The plot was divided into north and south halves and planted in rows. The north half was planted with the Minn. variety; the south half was planted with Nor Cal. The area is very prone to wind and waves when the lake is full. A 3'X10' replication of the Experimental variety was planted in a nearby "cove" or protected region formed naturally by the cattails. This site was also row-planted. The soil temperature in both plots was 61 degrees Fahrenheit.

The "B" plot had a soil texture of 45.4% sand, 14% clay, and 40.6% silt resulting in a textural class of loam, with NO_3, P, and K values of 0.7 ug/g, 34.7 ug/g, and 110 ug/g respectively. The organic matter content of the soil was 10.82%. The site is covered year-round with water from an in-flowing stream as previously mentioned. Cattails border three sides and a road borders the fourth. Water temperature was measured at 74 degrees Fahrenheit and soil temper-

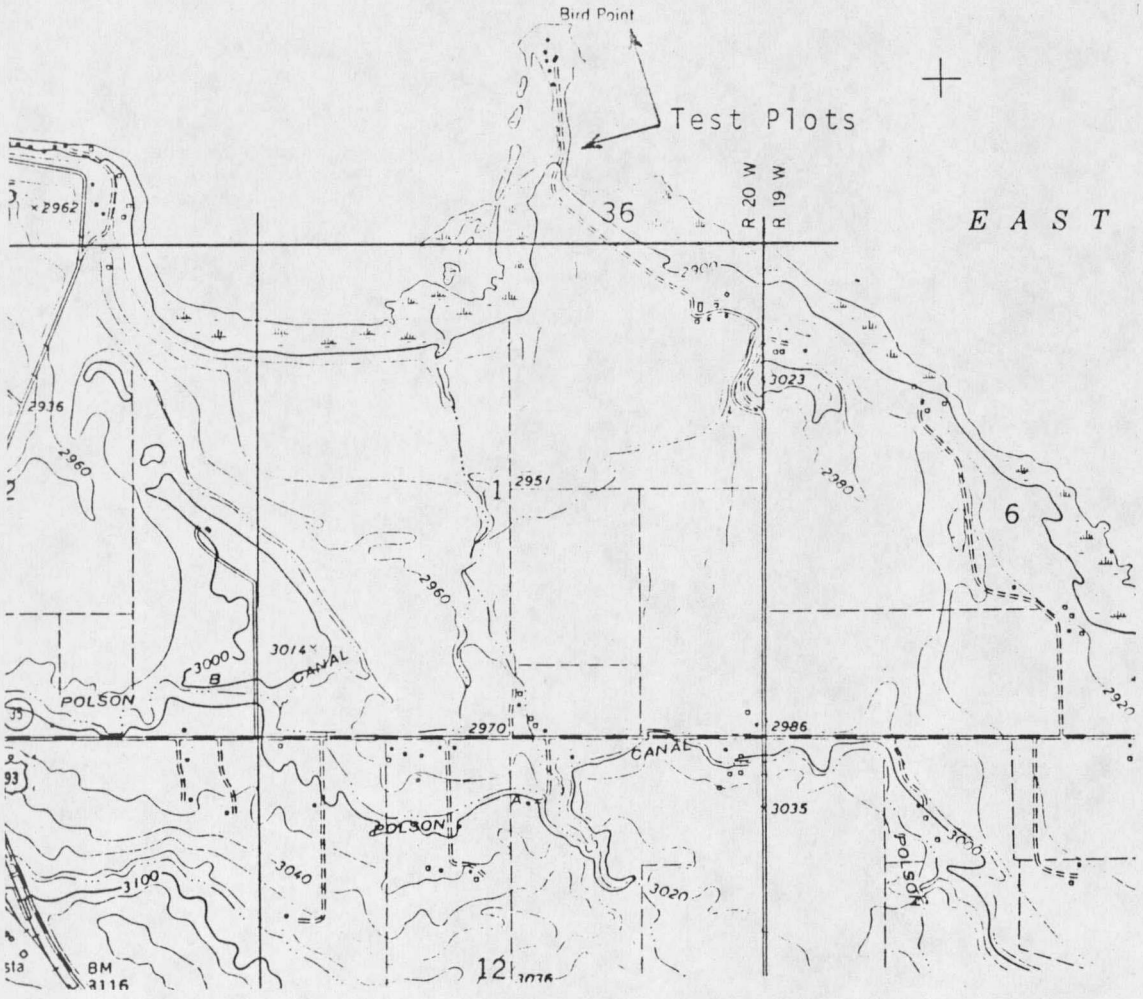
ature at 64 degrees Fahrenheit. A heavy cover of vegetation was scraped with a hoe to reduce competition. The seed was broadcast into 5'X10' replications of Wild and Nor Cal and worked into the soil with a row hoe. Seeding rates were 12 to 18 seeds per square foot. The vegetation was identified as Utricularia or Bladderwart, Potamogeton pectinatus or Sago pondweed, and Potamogeton pusillus. A second 10'X10' plot was the Minn. variety broadcast into the native plant cover. The seeding rate was increased to 25 to 30 seeds per square foot. At the time of planting the water was 10" deep but should reach 3' at full lake level.

Results and Speculations on Flathead Lake: When the plots were visited on June 27, the "A" plots were under 4' of water and distinct rows of plants in the floating leaf stage were visible. The "B" plot was under 3' of water and appeared as a dense stand of floating leaf stage plants in both the cleared and uncleared sites. When checked again in late July, the "A" plot had been completely eaten by muskrats. All that remained was plant stems one-quarter to one-half inch in diameter and protruding one-half to one inch above the water. The size of the stem implied that the plants had made it to the emergent stage. The "B" plots had plants 16" to 24" above the water with lush foliage, but had been thinned considerably by muskrats. By September 3 only scattered plants remained, but many of them were in

the soft dough stage. The sparse nature of the stand was attributed to persistent muskrat predation. Mature plants were 3′ to 5′ in height as measured from soil to top of plant. Follow-up visits in late August, 1988 and early September, 1989 revealed mature flowering plants. Although the stand was sparse, mature seed drift, or muskrats activity had spread the plant to areas other than the original plots. All plants were contained within a one acre area.

FIGURE 8

Excerpt from East Bay Quadrangle



Scoonover Dike

Date: Monday, May 11, 1987.

Location: Marsh Creek Drainage, Allentown, MT, Ft. Lonnah Quadrangle 7.5-Minute Series, T20N R19W Section 01, Elevation = 3020'. (See Figure 9)

Description: Scoonover Dike is a Ducks Unlimited project that was constructed in the winter of 1986 and filled in spring of 1987. It is managed by the National Bison Range headquartered nearby at Moise. Permission to plant the site was obtained from Jon Malcom, Director of the National Bison Range. The $48,000 project created a 26 acre pond with several islands and was intended to create and enhance waterfowl nesting habitat. The water depth ranges from 1' to 7' deep. The morning of planting Malcom, counted for management purposes 40 nesting pairs of ducks, and 40 feeding pairs of non-breeding ducks, and 12 geese.

Plots and Planting procedures: Plot "A" was located in 12 to 18 inches of water. Existing plants on the site were sparse remnants of land plants including fine grasses and thistles that were dying as a result of being submerged. A 10'X10' plot was broadcast with the Minn. variety in the east half and Nor Cal in the west half, then worked with a hoe to incorporate the seed into the soil.

The "B" plot was located near the outlet in an area which had ponded water prior to building of the dike. It

was bordered on the south edge by a band of cattails and contained numerous submergent plant species. This native vegetation was hoed to reduce competition and seeds were broadcast at a rate of 12 to 18 seeds per square foot, with the Minn. variety in the west half and the Experimental variety in the east half. Seed was incorporated into the soil with a hoe and by walking through the area. Light amounts of swamp gasses were observed. The 10'X10' plot had a water depth gradient of 10" to 18". A 5'X10' plot was planted by broadcasting the Experimental variety into undisturbed native vegetation. Results from soil testing revealed a textural class of silty clay composed of 13% sand, 41% clay, and 46% silt. NO_3, P, and K values were 1.3, 26.2, and 308 ug/g respectively. The organic matter content of the soil was 4.55%. The water temperature was 72 degrees Fahrenheit at the time of planting.

Results and speculations Scoonover: When checked on June 27, the "A" plot was a mixture of floating leaf stage and emergent plants 10 to 20 inches above the water. In the "B" plot, all emergent plants had been clipped at the water surface by feeding muskrat or young geese. By August 6, plants in the "A" plot had begun to flower and reach the soft dough stage. The "A" plot, however, was now also being plagued by muskrats. The muskrats were building feeding stations in the plot by cutting plants and making a floating mat. When sufficient plant matter was in place the

muskrats would climb up out of the water and sit on the floating mat to sun and eat. A 3'x 3' feeding station was removed from the plot on August 6 and another on August 23. By September 3, the plot had been well thinned but still had a healthy stand ranging from plants in the soft dough stage to mature plants that had lost their seeds. Duck feathers and plants broken by birds were also visible in the plot. The flowering plants were readily visible among the cattails, providing a visual check on extent of seed drift during planting. Mature plants were found scattered over 100' of shoreline and competing favorably with cattails. It should be noted that the cattails were also in their first year stand establishment in this portion of pond.

The "B" plot recovered from the June muskrat feeding session and by September 3 appeared as a very consistent stand in the soft dough stage. It is speculated that submergent and floating leaf stage plants were not damaged during the feeding session and that an even age class of plants matured into the stand. A final inspection on September 18 found the Minn. variety had matured and shattered all grain before yield data could be obtained. The Nor Cal and Experimental varieties were still in the soft dough stage. In both plots on Scoonover Dike the California varieties were taller, slower to mature, and held male

florets longer. All varieties reached maturity and produced grain. All grain was released into the pond by natural mechanisms such as shatter, wind, birds, or animals.

Mature plant heights varied from 4' for the Minn. variety to over 9' for the Nor Cal and Experimental varieties. The results of tissue analysis are listed in Table 9.

Follow-up visits in 1988 and 1989 revealed only scattered individual plants. It appeared that the wild rice could not compete with the now established stand of cattails at the site.

TABLE 9

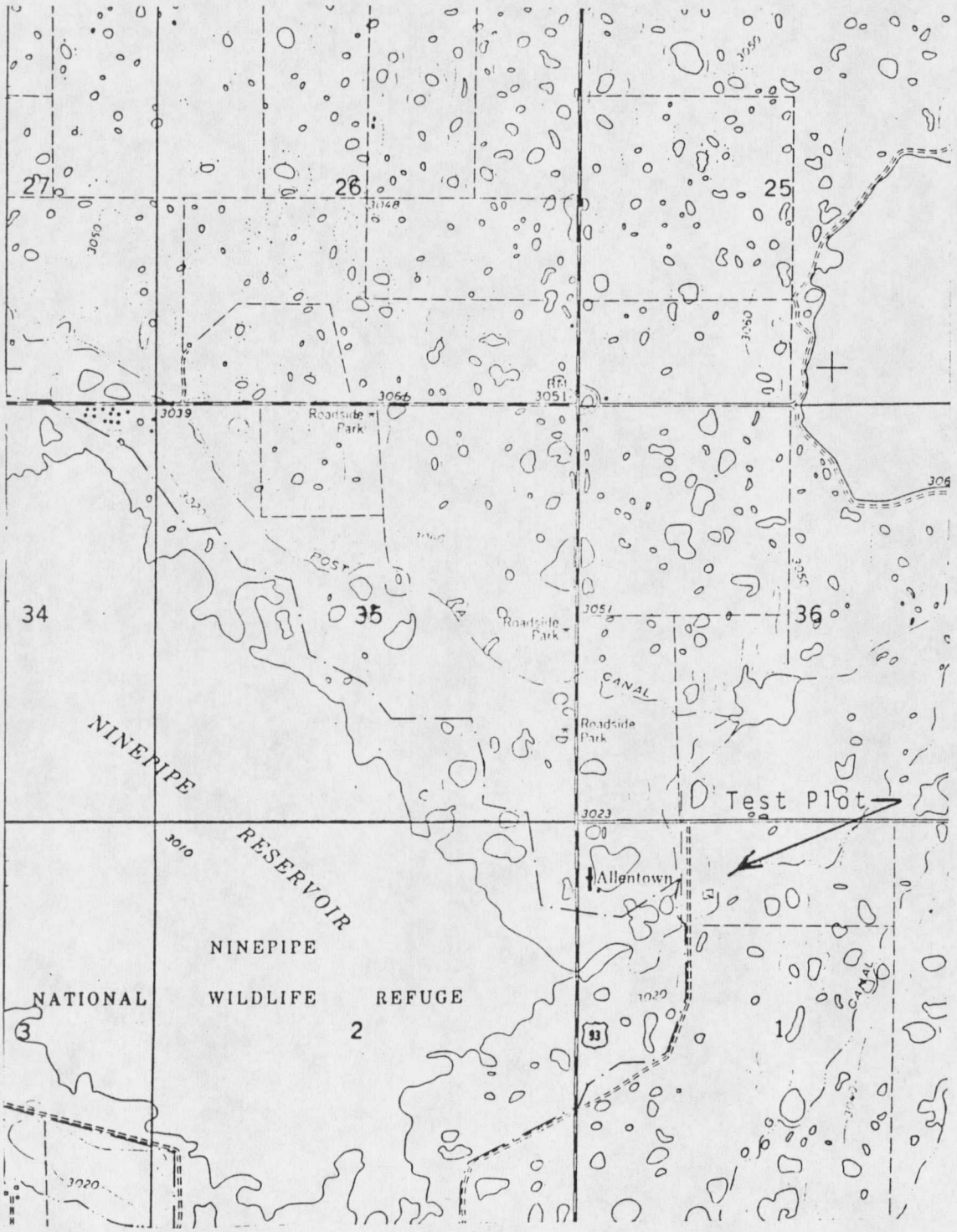
Wild Rice Tissue Analysis [a]

Tissue Sample Source	TKN %N	%P	%K	ug/g Fe	ug/g Mn
Scoonover "A"	1.03	0.20	0.14	648	613
Scoonover "B"	1.02	0.02	0.19	2185	671

[a] Tissue samples are from entire plants obtained from Scoonover Dike plots. Samples where oven dried and ground before testing. Plants were in soft dough stage of development. Testing was done at the Western Ag. Research Center in Corvallis, Montana.

FIGURE 9

Excerpt from Ft. Lonnah Quadrangle



Red Bluff Experiment Station

Planting Date: Tuesday, May 12, 1987.

Location: Warm Springs Creek Drainage, Norris, MT, Norris Quadrangle 7.5 Minute Series, T3S R1W Section 13, Elevation = 4789'. (See Figure 10)

Description: Plot six is located on land administered by Montana State University at the Red Bluff Research Center near Norris, Montana. Permission to plant the site was obtained from Art Linton, Animal and Range Science Department Head, and Eldon Ayers, Red Bluff Ranch Manager.

The planting site was located near the banks of Warm Springs Creek. A heavy bladed bunched grass, possibly a sedge, along with fine grasses were cleared from the site when the soil was still frozen in April. The site has a very high water table. After the soil had thawed, two 10'X10' plots were spaded to accelerate drying and remove root clumps. After several weeks the soil was dry enough to permit tilling. Border dikes were then built from 1"X10" lumber, wooden stakes, and soil. A 1.5" PVC pipeline was run 220 feet up to a small spring to bring water to the plots. The line runs directly into the "A" plot, where a standpipe overflow conveys water to the "B" plot. Water depths varied over time from 1" to 6" as a result of air pockets forming in the gravity line and floating organic matter clogging the stand pipe overflow. Thus, the "B" plot

water level fluctuated more dramatically. At times the water level was at less that one inch for up to three days; and for short periods it contained no standing water.

A fence was erected around the site to keep sheep, horses, and cattle from damaging the border dikes.

Sandhill cranes, mallards, muskrats, mink, beaver, and redtail hawks are common in the area.

Plots and Planting Procedure: The soil was 31.4% sand, 20% clay, and 48.6% silt for a textural class of loam. Organic matter content of the soil was 25.1%, the highest of all sites tested. Analysis revealed that the nutrient levels of NO3, P, and K were 4.6 ppm, 53.7 ppm, and 246 ppm respectively. Each of the two plots was rowed and planted with three rows of each variety. Rows were on one foot centers; thus, each plot contained one replication of each variety. The order of varieties, from west to east was Minn., Nor Cal, Experimental, Experimental, Nor Cal, and Minn.

Weather data for this site was not readily available. In Tables 4, 5, and 6 the nearby sites of Cardwell, Norris Power station, and Pony are listed. These sites form a rough triangle around the site.

Results and Speculations for Red Bluff: The plots were maintained weekly by "burping" the irrigation line to remove accumulated air bubbles and restore flow and by

checking water temperature. Inlet water from the spring was consistently 55 °Fahrenheit. The "A" plot varied in response to weather patterns. On cloudy days the water temperature was usually 3 to 10 degrees cooler than air temperature. On sunny days the temperature was generally 10 to 20 degrees warmer than the air. A similar pattern was observed in the "B" plot, except the temperatures were generally 5 to 10 degrees warmer than the "A" plot. The highest temperature recorded was 105 °Fahrenheit and occurred in the lower pond when the air temperature was 85 °Fahrenheit.

By July 16, the plants in both plots were 18 to 24 inches tall. The lower plot showed the most vigorous growth, while in the upper plot the plants displayed a yellowish tinge. American Pondweed and Blue-green Algae appeared between the rows of wild rice plants. At this time intruders began feeding on the lower plot. Assuming that the intruders were ducks or geese, bird netting was placed over both plots. The next weekly inspection revealed that muskrats were entering the plots from Warm Spring Creek and feeding on the tender young rice stalks. On July 28, permission from the Department of Fish, Wildlife and Parks was obtained to protect the plots by setting traps. Two muskrats were caught in the first 24 hours; two more were caught the next week. A mink was inadvertently trapped during the third week. While trapping stopped the depreda-

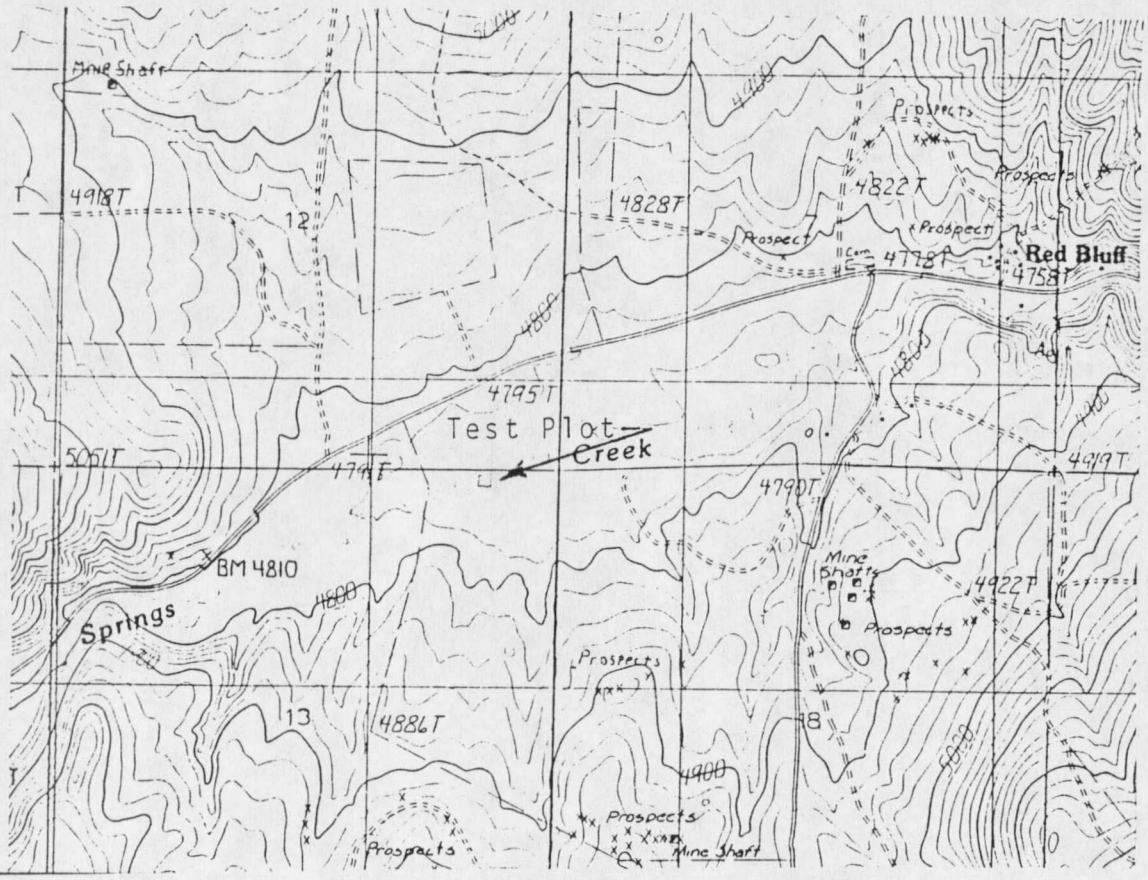
tion, an early frost in mid August killed all remaining plants just as flowering was beginning to occur in the Nor Cal and Experimental varieties, and as soft dough stages were beginning to occur in the Minn. variety.

Plant height reached 3 to 3.5 feet. Trapping was stopped after the frost; and by mid September, the muskrats had resumed feeding in the dead standing plants.

Plants located in approximately a 2' radius from the inlet appeared more healthy and vigorous during all stages of growth.

FIGURE 10

Excerpt from Norris Quadrangle



George Kahrl Ranch

Planting Date: Tuesday, May 26, 1987.

Location: Jefferson River Drainage, Willow Creek, MT, Three Forks SE Quadrangle 7.5-Minute Series, T1N R1E Section 05, Elevation = 4100'. (See Figure 11)

Description: The Jefferson River borders the ranch and several sloughs from the river reach out into the Cottonwood covered bottom land. One major slough and a small branching finger of the Jefferson were chosen as planting sites. Permission to plant was not gained until nearly two weeks after the aforementioned plots had been planted. As a result of the late planting date, much of the seed had sprouted in the cooler where it had been stored.

Muskrats and mallards were spotted during planting.

Plots and Planting Procedures: The slough showed signs of a small flow (< 1 cfs), but current was negligible along the shoreline area that was planted. In the "A" plot, a 2'X12' area near the shore was cleared of native vegetation with rakes and hoes. Water depth was 12 to 16 inches. The bottom sloped rapidly, necessitating a narrow plot. The soil was black to blackish-gray, silty, and organic and released light amounts of gasses when worked. No soil samples were analyzed for this site. During storage the Nor Cal variety had produced sprouts 2 to 4 inches long with visible root systems, a stem, and the first leaf set.

Three hundred of these seedlings were planted in the plot by packing the root cluster in a 1.5" diameter ball made from mud on the site. These were then hand placed firmly on the bottom at a density of 6 to 8 plants per square foot in water 12 to 16 inches deep.

The "B" plot was also a shoreline plot. A 5'X10' area was cleared and broadcast-planted with the Experimental variety then worked with a rake. The "C" plot was similar in size and planting method, but was planted with the Minn. variety. The soil at the "C" site, however, was a thin layer of silt over a gravel bottom.

The other region planted at the Kahrl Ranch was the river branch site which had the strongest current of all sites planted. The fast-flowing regions (estimated to be 2+ feet per second) had very sandy bottoms with silt deposits along the edges. A small island supported native plants of the sedge type. The Minn. variety was broadcast along the edges of the island for 30'. At the time of planting the seed was 50% germinated seeds and sank much slower than in previous plantings. A 10'X10' plot was cleared of sedges with hoes and rakes. Nor Cal was then broadcast and incorporated with a hoe. Sprouts were also planted by hand directly into the mud.

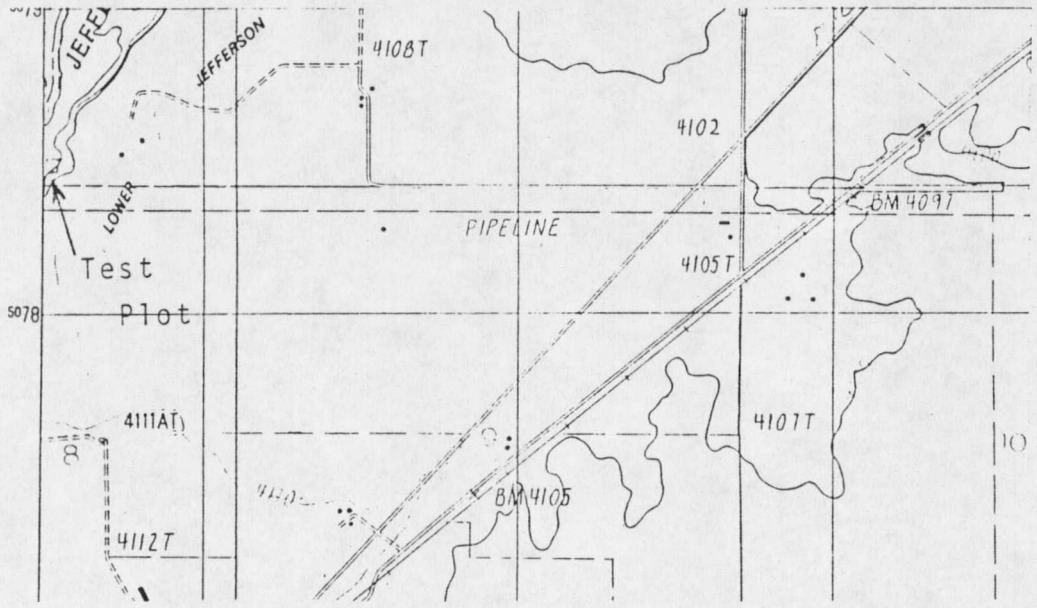
Results and Speculations for Kahrl Ranch: A mid-June inspection of the plots in both the slough and the river branch revealed plants in the floating leaf stage. By

July, the slough plants planted by the mud ball technique had emerged only to be consumed by muskrats. The broadcast plants had met a similar fate. Other plants in both slough plots continued to grow in the submerged stage but were plagued by the same clear to light brown film that appeared in Dad's Dams. These plants died before emergence from the water. Remnants of some submergent wild rice plants were found that contained only root wads and a short length of stem that appeared to have been bitten or clipped off. This may have been the result of crayfish feedings.

All plants in the river branch died when a heavy irrigation period drained the river branch for two weeks. Although a second sprouting occurred when the branch refilled, all plants failed to achieve maturity.

FIGURE 11

Excerpt from Three Forks SE Quadrangle



Swan River National Wildlife Range

Planting Date: Two stands were established by U. S. Forest Service personnel in 1978. A third site was planted by Fish and Wildlife personnel in the fall of 1986.

Location: Swan River at the mouth on Swan Lake, Swan Lake MT, Yew Creek Quadrangle 7.5-Minute Series, T25N R18W Section 16, Elevation = 3066' (See Figure 12). Spring Creek at the mouth on Swan Lake, Swan Lake MT, Swan Lake Quadrangle 7.5-Minute Series, T25N R18W Section 23, Elevation = 3700' (See Figure 13).

Description: The Forest Service stands were located in Swan Lake on a delta at the mouth of Swan River and in sloughs upstream and off the river. The planting method used to establish these stands is unknown. The Fish and Wildlife stand was located in Spring Creek as it enters Swan Lake. The stand was established by broadcasting seed from an air boat.

Results and Speculation for Swan Lake Sites: This was the most encouraging site in Montana, located on the Swan River National Wildlife Range near the town of Swan Lake, Montana. Three sites total approximately two acres.

In the 1978 the Forest Service planted two stands which today are estimated at just over one and one-half acres combined. Over the years, the stands have been self-seeding and stable in size. Plant density was 2 plants per square

foot in the delta stand and 12 plants per square foot in the slough stand. Water depth in the delta stand varied from 1 to 3 feet when observed during September of 1987. Water depth in the slough stand varied from 2 to 4 feet when observed during the same time period.

In October of 1986, the Dept. of Fish, Wildlife & Parks planted 30 pounds of seed acquired from St. Maries Wild Rice Co. under an arrangement partially funded by the Cooperative Extension Service in Kalispell. The seed was broadcast from an airboat into a stand of equisetum with no prior seedbed preparation. Water depth varied from one to two feet. During a site visit on September 17, an area estimated as 375 feet by 30 feet or just over one-quarter acre was dominated by wild rice plants. Plant maturity ranged from soft dough stage to just shattering to fully shattered. The site was located on a series of dikes on Spring Creek built in the late 1920's as a commercial muskrat farm. Although the farm was abandoned in the mid 1930's, evidence of muskrats was very visible in the rice stands. A conservative estimate is that one-half of the wild rice plants that emerged were eaten or destroyed by the muskrats.

Soil samples for the Swan River area plots indicated the Spring Creek site was a silty loam containing 29% sand, 17% clay, and 54% silt. NO3, P, and K levels tested as 1.1, 25.8, and 82 ug/g respectively. The organic matter content

of the soil was 20.7%. The NO3, P, and K levels and organic matter content at the Swan Lake plots were 0.9, 6.2, 76 ug/g and 0.30% respectively. The soil was a sandy loam with 57% sand, 7% clay, and 36% silt. Moderate to high amounts of gasses were released when the soil was disturbed. Results of water quality samples are listed in Table 16.

Plant heights varied from 6 to 8 feet tall when measured from the root ball to the top of the plant.

The Swan River stands had the highest flow of water passing though the stand relative to all other tested plots which produced plants. The delta plot received water flow from the river as it diffused out over the delta. The Spring Creek stand was located along the slow moving stream as it passed though a marsh region. A 1'x 1'x 1' test hole was dug next to the stand. Soil removed from the hole was saturated and the hole filled with water in 2.5 minutes. When the water in the hole was stirred and muddied, a visible flow profile developed and the water cleared in less than 2 minutes, indicating a significant groundwater flow through the region.

Waterfowl and Blackbirds have been consistently seen in the stands and utilize the wild rice both for cover and as a food source. Honey bees were also prevalent.

FIGURE 12

Excerpt from Yew Creek Quadrangle

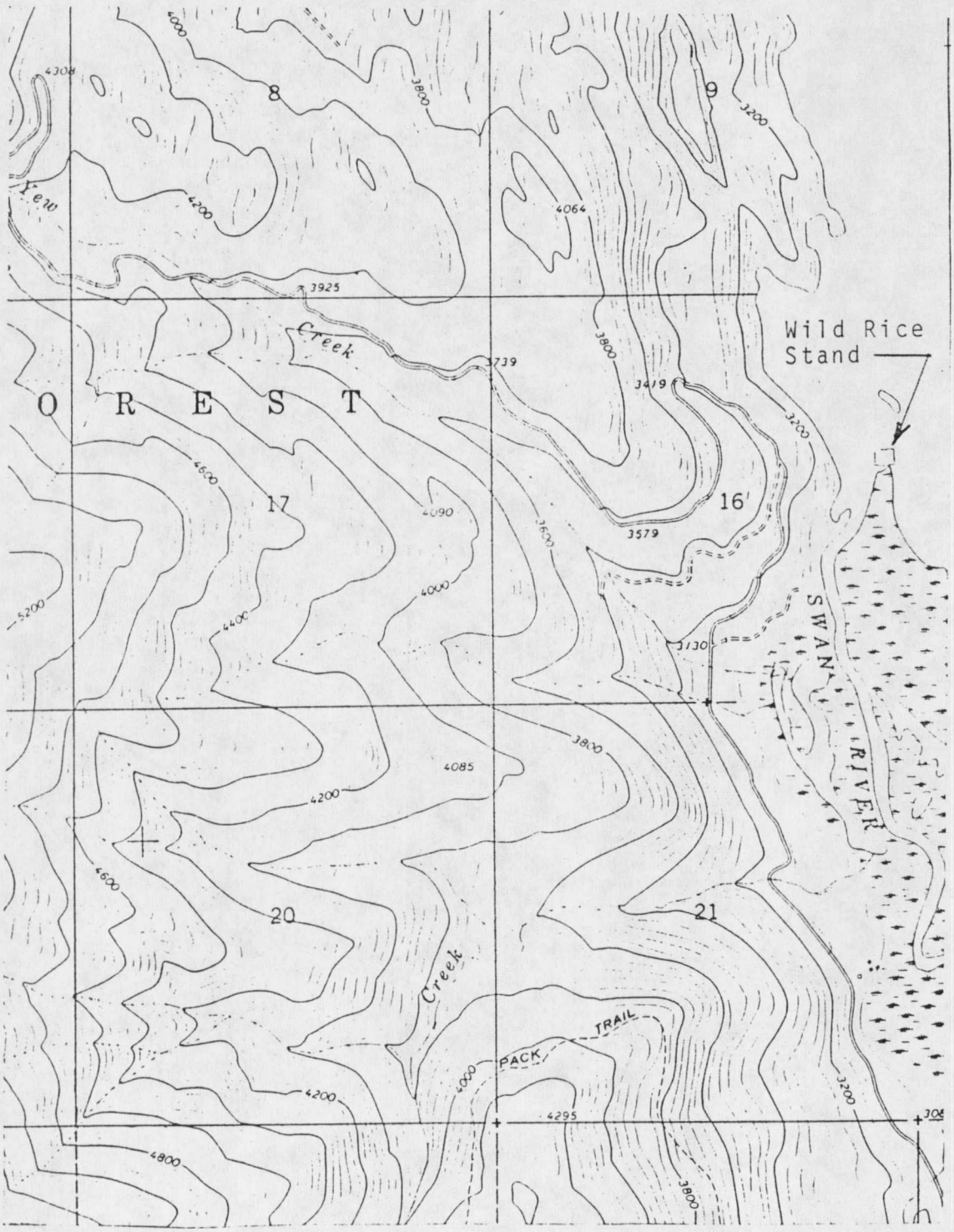
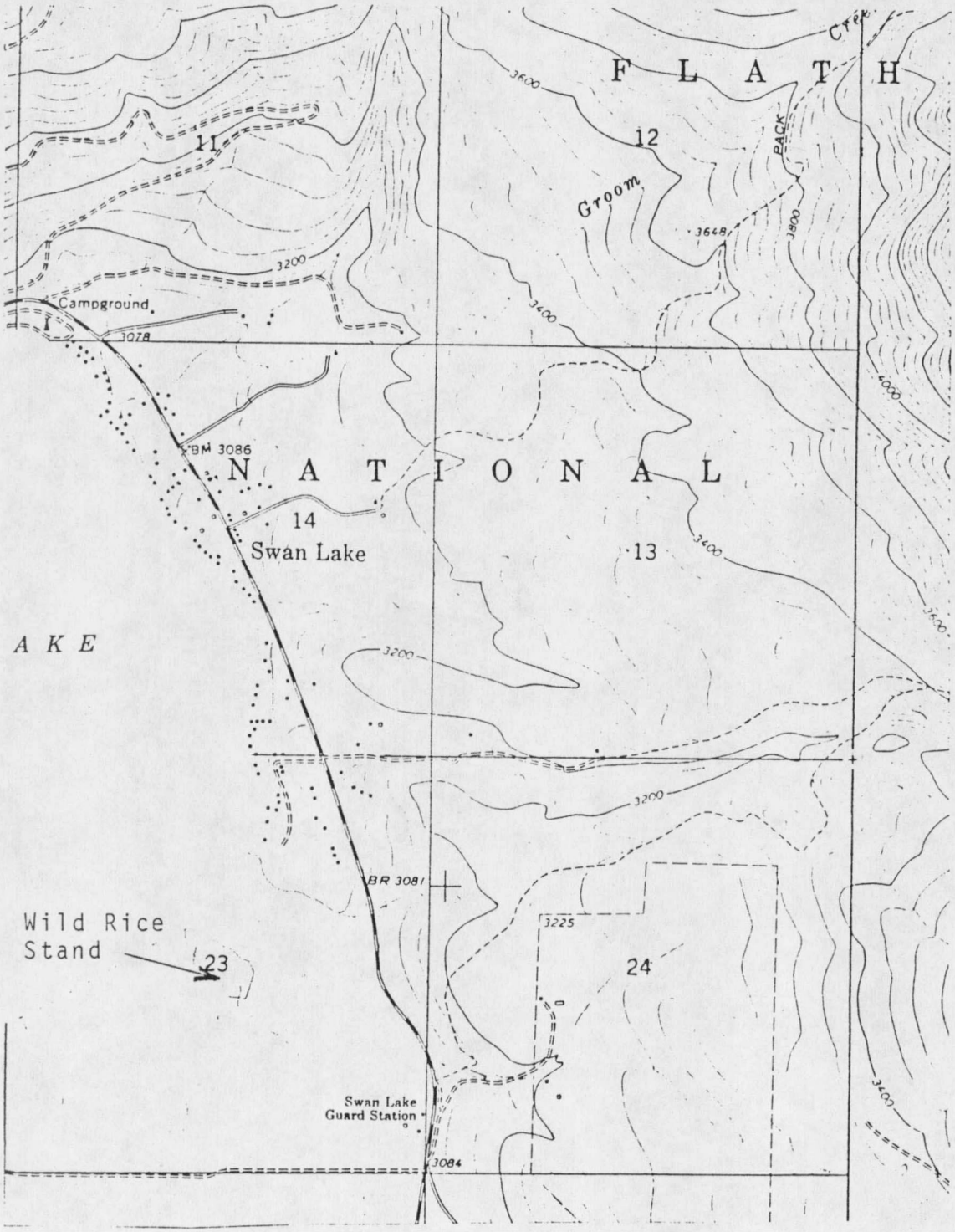


FIGURE 13

Excerpt from Swan Lake Quadrangle



CHAPTER 4

RESULTS AND DISCUSSION

It has been demonstrated that wild rice will grow to maturity in at least four Montana sites. These sites, in order of importance, are Swan Lake with twelve growing seasons, the Western Agricultural Research Station (WARC) with two growing seasons, the east bay of Flathead Lake with three growing seasons and Scoonover Dike with one growing season. The Red Bluff Experiment Station also grew plants to near maturity but succumbed to a frost in August. Site parameters for all sites where listed in Table 6.

Commercial Viability

Yield In Montana Climates

The Western Agricultural Research Center plots provided the only current data on yield potential for wild rice under Montana growing conditions. Plants were multi-pass harvested by hand by Research Center personnel for two growing seasons. Malvern Westcott, Director of the project, estimated that these harvest techniques recovered 50 to 80 percent of the actual yield. The lower percentage pertains to fertilized plots and the higher figure to unfertilized

plots. No explanation was available for the discrepancy in recovery percentages. The highest yields were obtained from the Minnesota variety K- 2. With fertilization the 1987 crop produced up to 1800 pounds per acre (harvest weight estimated at 50% moisture).

The Scoonover Dike plots were by far the most lush and dense stands in the State. Many plants were over 9' tall with thick, healthy looking foliage. Plant densities were 10 to 15 plants per square foot. Unfortunately, the location of these plots prevented daily monitoring and thus harvesting was not possible. Observations of the WARC plots and the other successful Montana plots suggest that the Scoonover Dike plots would have provided similar if not higher yields than those at the Research Center. The Swan Lake stands had lower plant densities and would likely have shown lower yields if tested. Flathead lake produced only a few mature plants as a result of muskrat predation; speculations on yield, therefore, cannot be made.

The yield data from Montana test plots compares favorably with other commercial areas. California produces approximately 1200 unprocessed pounds per acre while Minnesota approaches 1000 pounds per acre (Nelson and Dahl, 1986, p. 90). Idaho produces approximately 400 pounds per acre. Assuming 50% moisture at harvest and 40% conversion to finished product, 1800 pounds of harvested rice would finish to 360 pounds of saleable product.

Suggested Harvest Techniques

Harvest techniques applicable to Montana include both multiple-pass and single-pass methods. Single pass hoppers appear best suited to undrainable paddies or paddies with irregular bottom contours and obstacles. Multiple-pass equipment with track or wheel-drive systems could be used in drainable paddies. Single-pass harvest operations require well drained paddies and firm soils, but more importantly they require wild rice varieties with even maturation and nonshattering characteristics.

Because Montana has a well established grain industry, combines that could be converted to wild rice harvesting should be readily available in Montana. Single-pass equipment would likely have to be custom built. (See the Appendix section entitled "Varieties and Harvesting" for additional information on harvesting equipment.)

Processing and Marketing

Currently, processing and packaging facilities are unavailable in Montana. However, such facilities in Idaho are presently operating under capacity (Jeff Baker, personal communication 1987) and have the potential to process Montana grain. Interstate transportation of harvested grain is not uncommon; for example some of California's

wild rice is shipped to Minnesota for processing (Nelson and Dahl, 1986, p. 91). In light of the relative distances involved, Minnesota firms might also be considered as potential processors.

Markets within Montana could likely be developed for the gourmet varieties of wild rice. The blend varieties would require large food processing firms, which are located out of state. Broken and low-grade wild rice could be ground in-state and sold as wild rice flour.

Additional Considerations

No state permit is required to import or grow wild rice. However, water and farm chemicals are controlled by the State of Montana.

Wild rice grown in Minnesota climates uses nearly 30 acre-inches of water per year. This is comparable to alfalfa in high consumptive-use areas in Montana (Montana Irrigation Guide, SCS). While water consumption may be similar for the two crops, water management techniques are very different. The State may require extensive water use permitting before allowing development of wild rice operations. The state also has the authority to prevent the use of chemicals that may contaminate surface or ground waters. Thus the use of wild rice field chemicals such as Malathion, Dithane M-45, and 2,4-D should not be used without first consulting the proper authorities.

Potential Areas For Wild Rice Development

To date, a very limited number of sites have been tested for suitability of wild rice production. However, several sites appear promising. The Bitterroot, Swan, Mission, and Flathead Valleys all exhibit adequate soils, climate, and water requirements to grow wild rice. In addition, they are located less than 200 miles from St. Maries, Idaho, where wild rice has been successfully cultivated and processed for the past several years. These valleys seem to be a logical place to attempt commercial wild rice establishment.

Other sites in Montana should not be discounted. In an effort to speculate on Montana sites where wild rice might successfully be cultivated, a map was created with the aid of a computer program. This software is entitled by the acronym MAPS, which stands for Montana Agricultural Potentials System. It was developed by scientists with the Montana Agricultural Experiment Station at Montana State University. The system consists of a large data base of Montana climatic and geographic variables. A list of these variables is found in Table 10. The state is divided into 8-square mile divisions and cataloged for characteristics including precipitation, growing degree days, elevation, etc. The program operator may specify a single or combina-

tion of variables. Areas with the specified variable will be plotted on a Montana map. Among the software's advertised practical applications are selecting areas to grow a specific crop varieties based on performance under similar conditions elsewhere in Montana, and mapping wildlife habitat areas.

A map (Figure 14) was generated to identify areas that might sustain wild rice. The map shows the results of plotting three combinations of variables with the MAPS program. The first combination is designated by a colon {:} in each 8-square mile block which successfully met the three criteria. Those criteria were:

1) slope was restricted to 2% or less,

2) growing degree days exceeded a threshold of 1400 base 50 ^{o}Fahrenheit, and

3) the mean date of the first fall freeze is September 12th or later.

The slash symbol {/} designates those area which met the three criteria plus were restricted to soils similar to those soils that grew wild rice previously in Montana or fit the same description (SCS Montana Soils Map). The final symbol {x} signifies the area that met the four preceding criteria plus was restricted to a climax vegetation indicating marsh or willow-type ecosystems.

When this map was compared to maps plotting the individual variables, it was evident that the slope limitation

TABLE 10

Montana Agricultural Potentials System
Base Maps Available as of November, 1987

Precipitation	(average annual, in inches)
Precipitation, April 1 to July 31	(percent of average annual)
Precipitation, May 1 to July 31	(percent of average annual)
24 Hour Peak Precipitation	(50-year 24 hour peaks, in inches)
Snowfall	(average annual, in inches)
R-Factor	(rainfall intensity/Universal Soil Loss Equation)
Potential Evapotranspiration and Mean Date When Lilacs Begin to Bloom	(average annual in inches)
Frost Free Season	(average length in days)
First Freeze	(average date)
Last Freeze	(average date)
Growing Degree Days	(13 classes mapped, 0 to >3,000 growing degree days per year)
Chinooks	(number of strong chinooks per 100 years)
Landownership	(private, Forest Service, BLM, state, etc.)
Landuse (Land Cover)	(e.g. forest, range, dryland crops)
Consumptive Use of Water	(e.g. high, moderate, low)
Irrigated Land - Yellowstone Drainage	(percent irrigated)
Average (Mid-range) Elevation	(in feet)
Highest Elevation	(in feet)
Lowest Elevation	(in feet)
Slope	(expressed in percent)
Geology	(generalized geology, 24 classes mapped)
Soils	(136 map units, associations of great groups)
Climax Vegetation	(62 map units)
Counties	(FIPS Code Number)
Soil Depth Classes	(soil mapping units from shallow to deep)
Mean Annual Soil Temperature	(Arkley equation)
Latitude	(in decimal degrees, ie., 45.15°)
Longitude	(in decimal degrees)
Relief	(elevation differences within each cell)
Predominant Aspect	(eight compass points and level; ie., E, SE, S)
Precipitation, April 1 to July 31	(average in inches)
Precipitation, Aug. 1 to March 31	(average in inches)
Maximum Temperature - July*	(average in degrees F)
Minimum Temperature - July*	(average in degress F)
Maximum Temperature - Jan.	(average in degrees F)
Minimum Temperature - Jan.	(average in degrees F)

* Maximum and minimum temperature maps for every month are being developed.

eliminated large areas from consideration. The slope value for each 8 square-mile division was estimated in two different ways. One method takes the maximum and minimum elevation for the region and assumes that they occur at a diagonal distance from one another. The difference of these two elevations divided by the diagonal distance was used as the slope. The second method uses slopes developed from SCS soils maps. Overall, the two methods compare favorably yet extreme regional differences exist. The Bitterroot Valley is one example where climatic and soil restrictions were met, but where the site was excluded by the slope limitation. This could explain why areas of known successful cultivation such as the Mission and Swan Valleys were excluded. Still, the map provides insight into other areas that may have potential for stand establishment or wild rice development. With the slope limitation in mind, areas neighboring those marked might also be suitable.

Only one 8 square-mile unit met all five criteria. That unit is located just north of Three Forks. This area also contained many units that met the first four criteria. The Helena Valley contained the remainder of the sites that met the first four criteria. All other sites met only the three criteria. With the exception of the units on Flathead Lake, all sites are east of the Continental Divide and

are virtually (Red Bluff and George Kahrl Ranch are east of the Divide) untested for wild rice potential. Many of these sites, however, are located near agricultural communities that might possess the equipment and expertise needed to successfully raise and market wild rice.

The hot dry summers east of the Divide might lend well to cropping systems similar to those used in California, which employ annual seeding and high plant densities. Spring runoff could be used to fill paddies, as is done in Minnesota. This practice makes efficient use of water when it is most available. Water will still be required during the early and mid portions of the growing season to account for evapotranspiration and seepage losses. Draining of paddies could provide water for late season irrigation of hay crops.

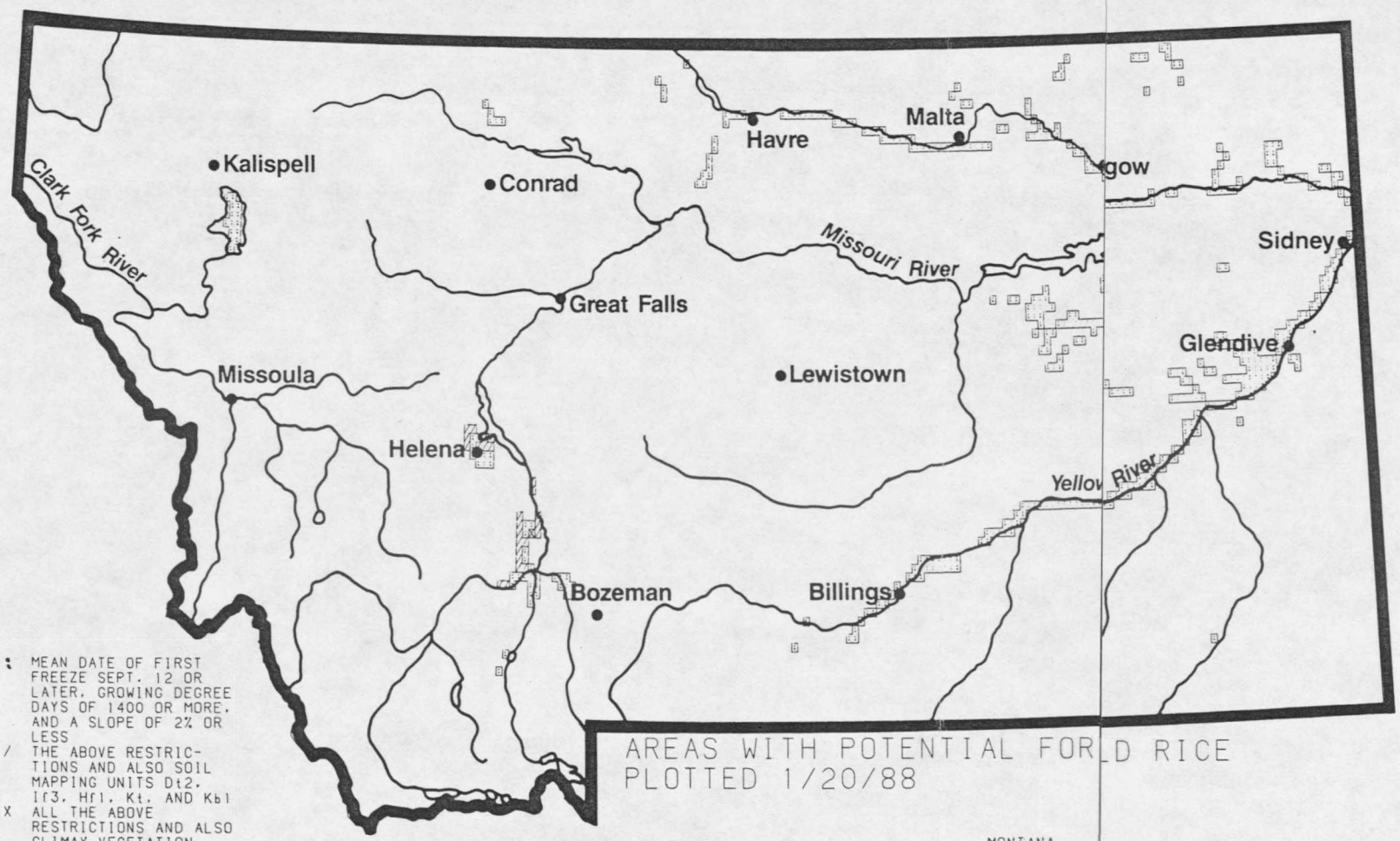
Wildlife Habitat Improvement

The history of wild rice is rich with successful introductions of the plant in the name of wildlife habitat improvement, most notably in Canada and Idaho where the introduction of wild rice for waterfowl eventually lead to its commercial development.

In Montana, personnel working on behalf of the Swan River National Wildlife Range have successfully established two small stands and a third looks promising. Several

FIGURE 14

Montana Areas With Potential For Wild Rice



species of ducks heavily utilize the stands for foraging, cover, nesting, and brood-rearing (Ray Washtac, Manager of the Swan River National Wildlife Range, 1987, personal communication). Other birds such as the Great Blue Heron have been observed feeding in the stands. Fur-bearing animals such as muskrats and mink also utilize the stands for food and cover.

Benewah Lake in Idaho supports a bass sport fishery. Boat channels mowed in the wild rice stands are reported to be a favorite spot for local bass fisherman (Jeff Baker, St. Maries Wild Rice, 1987, personal communication). Minnesota wild rice paddies serve as nesting and feeding areas for several varieties of birds. Raccoons, skunks, and mink forage on the dikes and ditches (Oelke, et al. 1982, p. 27). Moose and deer are seen in the wild rice fields there as well.

Stand establishment could potentially be used as a tool to reclaim land damaged by construction or mining activities. Stands would create a food source for birds and wildlife mentioned above, plus provide biomass for utilization lower in the food chain.

In summary, a large variety of wildlife will utilize wild rice stands. Whether the introduction of wild rice will actually "improve" habitat in Montana has not been answered.

Stand Establishment

Presently, an estimated two acres of established wild rice stands exist in Montana. The majority of those stands are contained near Swan Lake. Plots planted in Flathead Lake continued to survive and produce seed though the 1989 growing season in spite of heavy predation by muskrats.

Westcott reports that a private land-owner near Corvallis has acquired 50 lb. of St. Maries seed and planted it for the 1988 growing season. Westcott also plans to work with the administrators of the Lee Metcalf Wildlife Refuge near Stevensville to establish a stand of unspecified size.

CHAPTER 5

SUMMARY AND CONCLUSIONS

Summary

Wild rice is a non-native, annual grass that has been introduced to Montana. In one isolated area the plant has survived for 12 years in a wild environment. Several other diverse environments have shown a potential to support wild rice stands.

Data collected from existing stands, successful test plots, and failed test plots in Montana has provided a basis for evaluating other Montana sites for their wild rice growing potential (See Table 6). In addition, a literature review has drawn information from the experiences of growers and researchers in other regions where wild rice has been successfully grown, which can also help evaluate a site's climate, soils, water, and potential pitfalls.

Preliminary indications are that Montana has the ability to produce yields of wild rice that are competitive, at least on a weight-per-acre basis, with other successful commercial wild rice operations. Additional information must still be collected to determine if commercial operations are economically feasible in Montana. The Costs of

land acquisition, field preparation, dike construction, equipment acquisition, equipment conversion, and water management systems need to be determined for Montana. These costs will vary from site to site. Processing facilities must also be found that will contract to finish or contract to purchase raw harvested grain.

Montana markets and export markets must be determined and cultivated before extensive production is initiated.

Water rights acquisition could cause extensive time delays for growers attempting to build and operate wild rice paddies in Montana. This is a result of the State's water rights process and the unfamiliarity of water rights administrators with wild rice operations.

Waterfowl appear to be the most obvious benefactors of wild rice stand establishment. The initial introduction of wild rice in Montana at Swan Lake was intended to enhance waterfowl habitat and appears successful. Canada and Idaho also have had positive results from stands introduced for waterfowl.

In Montana test plots, wild rice exhibited the ability to compete successfully with native submergents and emergents. Predation by muskrats is a factor that must be considered when attempting to establish small stands.

Managers of wildlife areas should be made aware that wild rice has been used successfully in Montana and other areas to provide forage and cover for waterfowl.

Further Research

Research concerning wild rice in Montana climates has to date provided only basic information. While it has proved that the plant will grow to maturity in several sites in Montana, limited yield data has been obtained for only for one site. Additional test plots and attempts at stand establishment are warranted before large scale commercial ventures are launched.

Future studies should examine yield potential in greater detail. Statistical studies should be designed and implemented to determine yield variance within each variety. In conjunction with these studies, data could be collected pertaining to nutrient balances in wild rice stands. Biological activities in the benthic regions and water column in wild stands could also be monitored. Thermal effects could be monitored in the water column as well. A range of evapotranspiration rates should be determined for Montana climates.

The map created by the MAPS software package could be useful in determining potential sites for further research. These sites might provide insight on the plants tolerance to salt or alkali soils which are common in eastern Montana.

Properties of the straw and chaff produced by wild rice could also be investigated in order to find ways to utilize all the biomass from the plant. For example, future test plots should include wetlands developed for reclamation of mined areas. The wild rice biomass might provide a substantial substrate for microorganisms that remove metals from mine seepage, or they may provide organic matter for metal adsorption (Skousen and Sencindiver, 1989, p. 25)

Wild rice paddies could also be used as water management tools. Their ability to remove the peaks from inflow hydrographs on reservoirs should be investigated. This could be a benefit to power generation operations and irrigators. If paddies located upstream from reservoirs are filled during the spring runoff, then less water would be required to be spilled from the reservoir. Groundwater recharge from paddies could supply baseflow into waterways, making water available to reservoirs at a later date. August drainage of paddies to prepare for harvest would also supply water for power generation or irrigation of other crops.

The potential adverse effects of wild rice must also be investigated. For example: Will August drainage of paddies cause thermal pollution problems? What adverse effects will result from the use of chemicals in wild rice operations? Given the warm, still, standing water in paddies will insect problems ensue? Will chemicals used for pest

control effect water quality or upset biological balances in aquatic systems?

Biological studies could determine the habitat potential before and after wild rice introduction in wild systems as well as in commercial paddies. This would help determine whether wild rice will improve wildlife habitat.

Wild rice will grow in some areas of Montana. Limited yield data compares favorably with established commercial stands in other areas. Wildlife have been observed to utilize the plant and its grain for food and cover. Introductions in other regions of North America have had successful results from both a commercial and wildlife improvement aspect. Large scale introductions in Montana should be delayed until small scale introductions can be more closely scrutinized.

LITERATURE CITED

Anderson, R. A. 1975. Wild Rice: Nutritional Review. Cereal Chemistry 53(6):949-955.

Boedicker, J. J., Schertz, C. E., and Lueders, M. C. 1983. A Water Separator for Combine Discharge Sample Analysis in Wild Rice Harvest Research. ASAE Transactions Vol. 27, pp 979-982.

Elliott, W. A. and Oelke, E. A. New Era For Wild Rice. Crops and Soils Magazine, Date Unknown

Chinsuwan, W. and Schertz, C. E. 1980. Evaluation of Wild Rice Stripping. ASAE Transactions Vol. 24, pp 63-67.

Fassett, N. C. 1924. A Study of the Genus Zizania.Rhodora Vol. 26, No. 308, pp 153-160.

Fassett, N. C. 1954. A Note of the Varieties of Zizania Aquatica L. Rhodora 26:153-160.

Follet, R. H., Murphy, L. S., and Donahue, R. L., 1981. Fertilizers and Soil Amendments. Englewood Cliffs, N.J.: Prentice-Hall.

Goel, M. C., Blanca, L. G., Marth, E. H., Stuiber, D. A., Lund, D. B., Lindsay, R. C., and Brickbauer, E. 1970. Microbiology of Raw and Processed Wild Rice. J. Milk Food Technol. 33:571-574.

Goel, M. C., Marth, E. H., Stuiber, D. A., Lund, D. B., and Lindsay, R. C. 1972. Changes in the Microflora of Wild Rice During Curing by Fermentation. J. Mild Food Technol. 35(6):385-391.

Halstead, E. H., and Vicario, B. T. 1969. Effects of Ultrasonics on the Germination of Wild Rice. Can. J. Bot. 47:1638-1640

London, 1986. Best in the West, Outlook '86 Magazine

Lund, D. B., Lindsay, R. C., Stuiber, D. A., Johnson, C. E., and Marth, E. H. 1975. Drying and Hulling Characteristics of Wild Rice. Cereal Foods World 20 (3):150-154.

Lund, D. B., Heidemann, R., Lindsay, R. C., Johnson, C. E., Marth, E. H., and Stuiber, D. A. 1975. Extended Storage of Wild Rice. ASAE Transactions Vol. 19, pp 332-340.

Meyer, M. and Bloom, P. 1986, Fertilizing Wild Rice and Speculations Concerning Silica. Minnesota Wild Rice Research 1986, University of Minnesota Agricultural Experiment Station Miscellaneous Publication 41--1987 pp. 22-26.

Nelson, R.N. and Dahl, R.P. 1985, Wild Rice Market Shows Vigorous Growth. University of Minnesota Agricultural Experiment Station Publication #649.

Nilsson, N. A. 1985. The Niche Concept and the Introduction of Exotics. Report #62, Institute of Freshwater Research, Drottningholm, Sweden.

Oelke, E. A. 1977. Harvesting Wild Rice Grown as a Field Crop. Ag. Extension Service University of Minnesota Extension Folder 344-1977.

Oelke, E. A. and Brun, W. A. Date Unknown. Paddy Production of Wild Rice. Ag. Extension Service University of Minnesota Agronomy Fact Sheet No. 20.

Oelke, E. A. and Elliott, W. A. 1978. Seeding Time, Method, and Rate for Wild Rice Grown as a Field Crop. Ag. Extension Service University of Minnesota Agronomy Fact Sheet No. 33-1978.

Oelke, E. A., Elliott, W. A., Kernkamp, M. F., and Noetzel, D. 1972. Commercial Production of Wild Rice. Ag. Extension Service University of Minnesota Extension Folder 284.

Oelke, Ervin A., Grava, J., Noetzel, D., Barron, D., Percich, J., Shertz, C., Strait, J., and Strucker, R. 1982, Wild Rice Production in Minnesota. University of Minnesota Agricultural Extension Service Bulletin 464-1982.

Oelke, E. A., McClellan, M., Leif, J., and Clay, S. 1986, Wild Rice Production Research-1986. University of Minnesota Agricultural Extension Service Miscellaneous Publication 41--1987.

Perich, J.A., Huot, C., Johnson, D., and Schanke, M. 1987. Wild Rice Disease Research - 1986. Minnesota Wild Rice Research 1986, University of Minnesota Agricultural Experiment Station Miscellaneous Publication 41--1987 pp. 56-84.

Robbins, G. S., Pomeranz, Y., and Briggle, L.W. 1971 Amino Acid Composition of Oat Groats. J. Agr. Food Chem. 19:536 (1971)

Schachi, H. 1986. Marketing Plan Puts Reins on State's Wild Rice Crop. San Fransisco Chronicle July 1, 1986.

Schertz, C. E., Boedicker, J. J., and Chinsuwan W. 1979. Equipment and Procedures for Combine Seperation Studies on Wild Rice. ASAE Transactions Vol. 23, pp 309-311.

Shih, S. F., Rahi, G. S., and Harrison, D. S. 1981. Evapotranspiration Studies on Rice in Relation to Water Use Efficiency. ASAE Transactions Vol. 25, pp 702-712.

Simpson, G. M. 1965. A Study of Germination in the Seed of Wild Rice (Zizania Aquatica). Can. J. Bot. 44:1-9.

Skousen, J. and Sencindiver, J. 1989 Latest Word on Wet lands. Division of Plant and Soil Sciences, West Virginia University.

Stoddard, C. H. 1957. Utilization of Waste Swamplands for Wild Rice Production. Land Econ. 33(1):77-80.

Stucker, R. E., Linkert, G.L., Wandrey, G.G., and Page, N.J. 1986. Wild Rice Breeding. Minnesota Wild Rice Research 1986, University of Minnesota Agricultural Experiment Station Miscellaneous Publication 41--1987 pp. 27-55.

Sugden, L. G. 1979. Grain Consumption By Mallards. The Wildlife Society Bulletin, Vol. 7, No. 1, Spring 1979.

Svare, C. W. 1960. The effects of various oxygen levels on germination and early development of wild rice. Minn. Dept. Conserv. Div. Game Fish Sect. Res. Planning Game Invest. Rept. No. 3.

Thomas, A. G. and Stewart, J. M. 1969. The Effects of Different Water Depths on the Growth of Wild Rice. Can. J. Bot. 47:1525-1531.

Vannote, R. L., Minshall G. W., Cummins, K. W., Sedell, J. R., and Cushing C. E. 1980. The River Continuum Concept. Can. J. Fish. Aquat. Sci. 37: 130-137.

Weber, R. P. and Simpson, G. M. 1967. Influence of Water on Wild Rice (Zizania Aquatica L.) Grown in a Prairie Soil. Can. J. Plant Sci. 47:657-663.

Wier, C. E., and Dale, H. M. 1960. A Developmental Study of Wild Rice, Zizania Aquatica L. Can. J. Bot. 38:719-739.

Winchell, E. H. and Dahl, R. P. 1984. Wild Rice Production, Prices, and Marketing. University of Minnesota Agricultural Experiment Station Miscellaneous Publication 29-1984.

APPENDICES

APPENDIX A

HISTORICAL SUMMARY

For untold centuries the North American Indians used primitive canoes to harvest wild rice, the staple of their simple diets. The slender stems of the mature plants were carefully bent over the sides of the canoe such that the grain-laden heads hung over the bottom of the canoe. A stick was then used to strike the heads and release the seeds into boat. Once a canoe was filled with grain, the harvest team returned to shore, where the wet grain was spread in the sun to dry. A good stand could be harvested many times because of the uneven ripening process.

Once the rice was sun dried it was parched over fires in small batches. After parching the Indians used crude threshing techniques to remove the hulls. The rice was then stored and cooked as needed throughout the year.

When French trappers and traders entered into what is now northern Minnesota and southern Ontario, wild rice was among the first items traded (Winchell and Dahl, 1984, p. 4). Commercial channels of trade began to develop at the turn of the century as white settlement encroached on northern Minnesota. Traders bought only processed wild rice from the Indians and sold it to local white communi-

ties or shipped it south for distribution in Minneapolis, Minnesota and communities in Wisconsin. Records show a Minneapolis firm sold 3,000 pounds of wild rice in 1899. About that same time a major rice trader named Frank Vance of Grand Rapids, Michigan reportedly averaged sales of five to six tons per year (Winchell and Dahl, 1984, p. 5).

Throughout the first half of the 1900's, Minnesota became the hub of the wild rice industry. Canadian wild rice which had been formerly handled by fur trading firms such as the Hudson's Bay Company, was being purchased by American firms who marketed the product out of Minnesota (Winchell and Dahl, 1984, p. 5). By the early 1920's, processing plants were built and provided a market for harvesters. The elimination of hand processing became nearly universal and was a turning point for the growing industry.

Due to their cyclical nature, wild rice stands produce good yields only one year in four (Winchell and Dahl, 1984, p. 3). Wind storms, pests, and diseases also had the potential to dramatically affect yields. Prices fluctuated in response to large shifts in supply from one year to the next, while the demand was relatively stable. Speculators who successfully exploited these price changes made substantial profits. Their strategy was to assemble large inventories in bumper crop years when prices were low and

sell at high prices during the following lesser crop years. Prices stabilized somewhat as the number of wild rice speculators increased, but fluctuations still remained (Winchell and Dahl, 1984, p. 5).

The lure of profit stimulated experimentation, and during the 1950's wild rice was grown under cultivated conditions in Minnesota.

Early attempts to cultivate wild rice met with mixed success. In many cases, crops would succeed in the first years but fail in subsequent years. Mechanized harvesting was difficult as a result of the uneven maturation of seeds on the panicle. Machine harvests were inefficient and required multiple passes over the fields because of shattering. Between passes, disturbances from birds or wind would spill grain into the water and render it unavailable for harvest.

Two events occurred in the early 1960's that laid the foundation for today's wild rice industry. In 1963, Dr. Paul Yagyu and Erwin Brooks, who were with the Department of Agronomy and Plant Genetics at the University of Minnesota, found plants with some shatter resistance in a field owned by Algot Johnson. These plants had a tendency to hold their seeds longer than lake varieties used by other growers. Encouraged by this trait, the seeds of this "non-shattering" variety were increased under controlled conditions by researchers. By 1968, enough seeds of the new

variety were available to plant 20 acres on land owned by Algot Johnson and the variety was named "Johnson". Subsequently, this "shatter-resistance" trait was found in other grower's fields and in natural lake stands. Growers could now use single-pass mechanized harvest and achieve acceptable yields. Although "non-shattering" is an accepted terminology, "shatter resistance" is more descriptive. Seeds in non-shattering varieties still fall off if not harvested soon after the maturity stage called "40% dark seed" (Oelke, et al., 1982, p. 12).

The second early-1960's event that stimulated the industry was a major marketing event. Uncle Ben's introduced a wild rice and traditional rice blend that was well received in the marketplace. A routine crop failure in 1965 forced Uncle Ben's to purchase 80% of the world's wild rice to meet the requirements of its new product. Not only was the purchase expensive, it signaled a constraint on expansion of what appeared to be a profitable product (Winchell and Dahl, 1984, p. 6). Uncle Ben's turned its attention to cultivated wild rice as a potentially more reliable supply. In 1967, contracts were signed with three growers in the Waskish area of Minnesota. To demonstrate commitment to the new industry, Uncle Ben's hired an agronomist to assist the contracted growers and continued research in cultivated wild rice for the next ten years. Although the success of

the 1967 contracts was partially due to ideal growing conditions that season, they drew considerable attention from local growers and investors.

The State of Minnesota quickly recognized the potential of the new industry to benefit the State, and in 1969 and 1971 provided funding for wild rice research to the University of Minnesota's Agricultural Experiment Station. Research at the University of Minnesota continues today.

By 1985, Minnesota had an estimated 25,000 acres of wild rice paddies and produced an estimated 4 million processed pounds. Production centers are located primarily in north central Minnesota near Aitkin, Clearbrook, Grand Rapids, and Waskish.

Minnesota regulates collection of lake wild rice. A permit is required and collection techniques, dates, and times are restricted. Much of the lake wild rice, 35 to 40 percent, is harvested on Indian reservations. This is attributed to historical negotiations for reservation boundaries, which requested that the important wild rice beds be included since wild rice was a staple Indian food (Winchell and Dahl, 1984, p. 10). Approximately five percent of the lake wild rice is taken from three of the state's federal wildlife refuges.

Minnesota is not alone in the wild rice industry. As early as the mid 1960's, growers in the Sacramento Valley area of northern California began experimenting with the

plant. In 1977, California produced 10,000 processed pounds of wild rice. Six California counties now grow wild rice: Shasta, Modoc, Siskiyou, Lassen, Mendocino, and Lake counties. These counties are outlined in Figure 15. Land previously used to grow common rice was easily converted to wild rice production (Schachi, 1986). In the early to mid 1980's, the market value of common rice was $0.63 per pound (harvest weight), while the market value of wild rice was $0.75 to $0.80 per pound (harvest weight). Growers saw no significant additional cost to shift from one crop to the other. Paddies and combine harvesting equipment can service either crop; thus, many farmers grow both crops (Winchell and Dahl, 1984, p. 19).

In contrast to Minnesota's relatively steady industry growth, California saw an explosion of production capability in the mid 1980's. In 1985 it replaced Minnesota as the leading state in wild rice production. Many growers were forced to leave the industry after a tremendous crop in 1986 caused a collapse in wild rice prices. Much of the 1986 crop was still in warehouses by December of 1987.

Numerous factors allowed California to achieve industry leadership. Leaf diseases, which plague Minnesota growers, are much less a problem in California. This is attributed to the low humidity, absence of rainfall, and sunny weather that prevails in California during the growing season

FIGURE 15

Wild rice Production Areas in California



Source: Winchell and Dahl 1984, p. 19

(Winchell and Dahl, 1984, p. 19). Annual re-seeding is required in California's dryer climate because paddies go dry in winter causing seeds to lose viability. Although annual seeding is expensive, up to $200 per acre, it prevents the annual decline in yield that Minnesota growers experience as volunteer plants in succeeding years cause crowding. Annual seeding also allows growers to quickly change to new varieties as they are developed. The seed market expanded sales potential and contributed to the rapid growth of the California wild rice industry.

The California Wild Rice Program was formed to do research, advertise and promote sales, service quality control, and attempt market stabilization. It operates

under the authority of the Director of Food and Agriculture of the State of California (Androus, 1987, personal comm.). Idaho has a fledgling wild rice industry whose origins can be attributed to duck hunters who introduced the plant to enhance waterfowl habitat. Seed was obtained from Minnesota sometime in the mid 1940's and planted in Benewah Lake located south of Coeur D' Alene in the Idaho Panhandle. The lake variety of wild rice they chose thrived and spread so vigorously that it restricted use of boat channels and docks (London 1986, Outlook '86, p. 87). In 1982, officials of Heyburn State Park where Benewah Lake is located contracted to have the boat channels opened and the rice harvested to stop the spread. St. Maries Wild Rice Company was formed to accomplish these objectives. A processing plant was built and additional acreage was planted. St. Maries is the sole company in Idaho's wild rice industry.

Canada is also a major producer of wild rice (See Table 3). The provinces of Manitoba, Saskatchewan, and Ontario are the production regions of Canada's wild rice industry.

Manitoba's contribution comes primarily from native stands of lake wild rice, which are administered through the province's Department of Natural Resources. The agency follows a policy that allows Manitobans to obtain leases granting exclusive harvesting privileges, and issues permits for development activities such as seeding and water

control (Winchell and Dahl, 1984, p. 11). Many of the stands are leased exclusively to Indians.

Ontario's production is entirely from natural bodies of water. Ontario has the least developed wild rice production sector of the three Canadian provinces. (Winchell and Dahl, 1984, p. 14).

Saskatchewan, unlike Manitoba and Ontario, originally had no harvestable stands of wild rice. The introduction of wild rice there dates back to the 1930's when conservation officials planted it for waterfowl feed.

The northern-most stands of wild rice are located in Saskatchewan (Winchell and Dahl, 1984, p. 12). Harvesting is again controlled by the provincial government, which requires leases to seed and harvest lakes. No other development, such as the use of chemicals for weed or pest control, construction of water level controls, docks or other structures is permitted.

APPENDIX B

FIELD PREPARATION AND PLANTING

Land converted to wild rice production requires some working to make the environment suitable for plant growth and development or to allow for access of harvest equipment. Natural stands of wild rice as found in Minnesota and Canada require no field preparation; stands are simply located and harvested.

When stands are to be established in an existing aquatic environment, little can be done to work the soil. Many stands have been established by duck hunters in this type of environment. In Idaho's Benewah Lake for example, seeds were simply broadcast into the water and allowed to compete with native plant species. St. Maries Wild Rice Co. of St. Maries, ID, has established stands by broadcast seeding at a seeding rate of 50 lb./ac. from airboats.

To reduce competition from native plants, especially ecquisetum, St. Maries developed underwater mowing equipment to cut back native vegetation. The company mows a site several times during the summer, then broadcasts seed into the mowed region from an airboat in the fall. The mowing appears to stress the native vegetation and the wild rice obtains a competitive edge the following growing season.

When it is possible to drain an aquatic system, the soil is plowed by conventional machinery. Next, seeds are broadcast with a fertilizer spreader at a rate of 50 lb./ac. The field is then harrowed and flooded. Except in California or unless varieties are changed, seeding is generally a one time operation, although segments of a field may need periodic maintenance seeding.

Oelke, et al., (1982) reports that in Minnesota, wild rice growers clear brush and small trees in winter by shearing with a bulldozer, then pile them for burning and burn them the following summer. After the soil is worked, a grower makes detailed topographic surveys to determine contour lines for dikes. Dikes are then constructed using standard engineering practices such as those recommended by the Soil Conservation Service (SCS). Dikes should first be seeded with bluegrass to retard erosion and weed growth. Bluegrass is recommended since it is not considered a weed in wild rice fields and does not serve as an alternate host for wild rice diseases (Oelke, et al., 1982, p. 11). Ditches are often placed around the perimeter of the field to promote rapid drainage before harvest. Such ditches require routine maintenance to keep them fully operational. Irrigation systems should be able to flood a field in 7 to 10 days (Oelke, et al., 1982, p. 11).

Before seeding new fields with wild rice, especially fields with peat soils, small grains such as oats are grown

for one to two years. This initial cropping without flooding provides a base of decomposed vegetation and results in fewer problems with floating peat when the fields are flooded (Oelke, et al., 1982, p. 15).

Wild rice seed can be obtained from several seed growers in the U.S. Certified seed is available from Minnesota growers and should be weed and disease free. St. Maries Wild Rice Co. will also supply seed if contacted during the harvest season (late August through mid September). They recommend soaking seed obtained from any source in a Malathion solution to kill insect larva and eggs (Jeff Baker, personal communication). Seed should also be cleaned by an air or gravity cleaner to remove weed seeds (Oelke, et al., 1982 P. 15). Seed should never be allowed to dry to less than 28% moisture or germination will be severely reduced (Oelke, et al., 1986, p. 15). High quality seed should exhibit 70% or better germination over 21 days (Oelke, et al., 1982, p. 15).

Seeding can be done either in the fall or in the spring. Fall seeding has the advantage of eliminating winter storage and handling costs. In addition, fall seeding is desirable since fields will usually be dry and accessible to equipment. Dry-planted fall fields, however, may require flooding or irrigation to ensure the moisture conditions necessary to maintain seed viability.

Spring seeding should be completed as early as possible, before seeds begin to sprout. Experiments in Grand Rapids indicated that seeding after June 1 was too late to allow the crop to mature in Minnesota climates.

Spring seeding requires the seed be stored in water over the winter. A common seed storage practice is to place seed in livestock tanks filled with water, or in 50 gallon drums perforated to allow water circulation and placed in flowing water. St. Maries uses plastic mesh bags placed in a river. To ensure optimum germination, the storage water should not be allowed to freeze and in nonflowing situations, it should be changed every three to four weeks (Oelke, et al., 1982, p. 15). Mud or silt should not be allowed to cover the seed during storage.

Three techniques are used to plant wild rice seed. One method uses a grain drill. Drilling is often done to 1 inch depths in rows 12 inches on center. Oats are sometimes mixed at 2 pounds of oats per 1 pound of wild rice seed to allow uniform seed flow through the equipment. A second method is to broadcast seed onto the soil with a fertilizer spreader and then incorporate the seed into the soil with a harrow to a depth of 1 to 3 inches. Thirdly, seed is broadcast onto the water surface from an airplane or air boat.

Seeding rates are determined by seed quality. Germination of commercially obtained seed may range from 15 to 95

percent and moisture may vary from 35 to 50 percent. Of the seeds that germinate, approximately 60% will establish plants when the seed is broadcast and followed by shallow incorporation into the soil. (Oelke, et al., 1982, p. 17). In light of these variations in seed quality and seed weight it is difficult to determine a precise seeding rate that will apply to all situations. First time growers should start by planting 40 to 50 pounds of seed at 50% moisture per acre. Experience and observation will help determine optimum planting rates for individual fields.

Oelke suggests for Minnesota growers a target plant population of four plants per square foot. This density provides for high yields, reduces incidence of leaf diseases, and minimizes lodging (Oelke, et al., 1982, p. 16).

Second-year and older fields planted with either shattering or non-shattering varieties tend to reseed themselves from seed drop prior to harvest and from inefficiencies in the harvest process. This reseeding can be up to 1000 pounds per acre (Oelke, et al., 1982, p. 17). Thus a stand may require thinning in subsequent years.

To thin wild rice fields, airboats are fitted with a series of V-shaped knives spaced 6 to 8 inches apart on a toolbar attached to the rear of the boat. During the plants floating leaf stage, the boat pulls the knife assembly through the fields at speeds up to 35 miles per hour.

The knives cut off young wild rice plants and weeds at the soil surface. Sometimes it is necessary to thin the fields in two directions (Oelke, et al., 1982, p. 17). St. Maries Wild Rice Co. in Idaho tried field thinning with a similar device in test fields, but found that increases in yield did not justify the additional expense incurred by the thinning operation.

California growers use the same fields and methods developed for domestic rice. Reseeding is required annually due to winter drying of the fields. Typical seeding rates are 80 to 100 pounds per acre (moisture content unknown) (Winchell and Dahl, 1984, p. 19). Since no seed carry-over is experienced, plant densities can be controlled with seeding rates and no thinning is required.

APPENDIX C

VARIETIES AND HARVESTING

Varieties of wild rice are selected by growers based on their intended market and on the harvest methods available.

Wild rice blended with traditional white or brown rice accounts for nearly 70 percent of the wild rice sales, with pure wild rice sales accounting for the remaining 30 percent. As a result, plant breeding has focused on developing strains suitable to blending. Seed length is major concern. Stucker, et al., (1986) explain:

> "Shorter seed is preferred in blends with white rice since the more uniform seed length allows for better texture, a more consistent cooking time and a higher proportion of wild rice kernels in a given blend. Pure wild, on the other hand, is more appealing and marketable to the retail consumer if it is long seeded. Current commercial cultivars have medium seed length and because of the need for shorter seed in the increasingly important blend market, wild rice growers and processors have encouraged wild rice breeders to develop short-seed cultivars."

Plant height is also important to plant breeders and growers. Taller plants produce more straw residue and are more susceptible to wind damage.

The final quality considered in variety selection is resistance to shattering, which affects the method of harvest used and the efficiency of harvest. Pure wild strains tend to shatter or drop seeds at the slightest disturbance as the individual caryopses ripen. Harvesting from these plants requires multiple collection passes over the field, with care taken to inflict as little damage on the plant as possible. Non-shattering varieties remain on the panicle longer and can be harvested by combines.

Stucker reports that testing for seed retention on the plant is a subjective evaluation. He describes the test as an upward stripping motion on a panicle grasped loosely by a closed hand. He also mentions a tensile strength meter, but dismisses it due to its inability to be used on all wild rice families. Testing for seed retention is complicated by the different maturing rates of plants within the same field. Immature seeds adhere more tightly on the panicle than do ripe seeds.

Non-shattering varieties currently available include Johnson, M1, M3, K2, Netum, and Norcal. Johnson was the first variety with some shattering resistance. It is tall, matures late, and has wide leaves with panicle color ranging from pale green to purple. Seed was increased by Algot

Johnson and was first made available in 1969. M1 and M3 were introduced by Manomin Development Co. M1, released in 1970, has some shatter resistance, is medium height, and has medium to late maturity. Leaves are medium width and panicle color is mostly purple. M3 was developed in 1974, and has some shatter resistance, is medium height, and has medium to late maturity, with leaves of medium width and panicles with a variety of colors. K2 was developed by Kosbau Bros. in 1972. It is medium height and has early to medium maturity, with leaves of medium width and purple panicles. Netum was developed by the Minnesota Agricultural Experiment Station and released in 1978. Plant height is medium, maturity is early, leaves are medium to narrow, and panicle colors vary from pale green to purple. All of the aforementioned varieties originated in Minnesota (Oelke, et al., 1982 p. 13).

To quantify early or late maturity Oelke tabulated heading and harvest dates for the five varieties in two Minnesota locations. Yield data is also included. These tables are reproduced in Table 11.

Excluding K2, the four varieties just described were acquired by Nor-Cal Wild Rice Co. of Woodland, California. After 4 to 10 years of breeding work in California, Nor-Cal released NC-1 with improved shatter resistance. NC-1 was further selectively bred for decreased seed size (the

TABLE 11

Heading and Harvest Dates of Wild Rice Varieties in Minn.

Variety	Excelsior Plots Heading	Harvest	Grand Rapids Plots Heading	Harvest	Average Yield
	July	August	July	Aug/Sept.	#/ac.
Netum	16	21	17	25	1348
K2	24	23	22	29	1614
M1	25	28	25	5	1534
M3	25	27	23	5	1750
Johnson	27	28	24	5	1485

Source: Oelke, et. al., (1982) NOTE: Average yields for Grand Rapids, Excelsior, and Clearbrook for 1978 and 1979 growing seasons. Plants per square foot ranged from 1.4 to 3.4. Panicles per square foot ranged from 7 to 9.6. Yields at 40% grain moisture.

primary objective), shorter plant height, and earliness. Results from this program included Exp-4 which exhibited 25 percent smaller seeds, 30 cm shorter plants, and 5 days earlier flowering than NC-1. Exp-5, another Nor-Cal product, is 10 to 14 days earlier than NC-1 (Ken Foster, President of Nor-Cal, personal communication).

Converting fields to new wild rice varieties is difficult in many areas because the seeds survive in the soil for several years (Oelke, et al., 1982 p. 32). Several methods are available, however, to aid conversion of a paddy to a new variety. When fall tillage is omitted and paddies are left unflooded, seeds on the surface will dry

out and lose viability. The following spring the field is flooded to allow germination of the surviving seed. After four to six weeks the field is drained, dried, and tilled to eliminate volunteer wild rice plants. A short season crop such as buckwheat could be planted after tillage. This procedure is repeated twice. A second method is to plow in the fall to bury most of the seed to a depth of 20 to 24 inches which prevents emergence. This technique has been used to switch to a new variety in just one season, but is limited to soil profiles which permit such deep tillage.

Once a variety has been selected, obtained, planted, and grown to maturity it is harvested. Shattering varieties, or wild type lake stands, are still harvested by the canoe and flail method in parts of Minnesota and Canada. In Minnesota this is the only method allowed by their recreational permitting process (Winchell and Dahl, 1984, p. 10). This is still considered a commercial harvesting technique since many individuals sell harvested grain to commercial processors. Lake stands in Canada and stands controlled by St. Maries Wild Rice in Idaho use air boats with specially designed hoppers to collect the ripe wild rice.

In Idaho, the airboats have a hopper mounted on the front that is constructed of sheet aluminum, aluminum tubing, PVC tubing and screening. As it is pushed through the field, the hopper strikes on the stem and bends stems over, causing the grain head to strike the PVC tubing

resulting in most of the mature seeds being shattered or released from the head. The screen directs the flying seed into the hopper. The hopper has a capacity of 300 lb. of harvested rice and can be filled in 5 to 10 minutes under ideal conditions. Thus, a 40 ac. field can be harvested in about six to eight hours. Since the rice matures at different rates on an individual plant, and maturation date varies from plant to plant, a field must be harvested every three to five days over the course of the three week harvest season. The harvest boat is powered by a 125 hp, aluminum block, Buick V8 engine turning a 66" propeller. Rice is removed from the hopper by hand and transferred to pickup trucks to be hauled to the processing plant (Jeff Baker, personal communication).

Schertz (1977) estimated that 95 percent of the wild rice acreage in Northern Minnesota, Manitoba, and Wisconsin, is harvested with direct-cut grain combines. The remaining acreage is cut with specially designed multiple-pass harvesters. Separation losses have been found to be 10 to 35 percent of net yield. High separation losses are believed to be associated with the high moisture content (40 to 45 percent moisture wet basis [Mwb]-grain, 70 to 75 percent Mwb- straw) of the crop at harvest. Losses are thought to be equally distributed between the losses at the sieve and losses at the straw walkers. Losses are also

attributed to the uneven ripening characteristics of wild rice and the presence of green stalks at harvest.

During wild rice harvest the soil is extremely wet and the track systems of combines must be modified. Wild rice is a poor sod-former and the stubble provides little support. Much wild rice is grown on organic soils that have lost most of their fiber strength from tillage.

Combine support systems range from conventional half-track systems and guide wheels to full-track systems with 45 inch pads bolted to each track shoe. While half track systems are available as standard attachments for many combines, the conversion to a full track system is a major operation. Oelke, et al., (1982) summarizes the situation:

> "The conversion to a full-track system is a major undertaking. In this system, the rear of the combine is carried on a walking beam instead of guide wheels. The walking beam, in turn, is supported on the channel frames of the two tracks. The original combine steering system is not adequate with a full-track system because there are no guide wheels and the brakes designed for the wheel unit are not capable of satisfactorily turning a full-track system. Braking of one axle of a differential speeds up the other side putting additional strain on all drive components.
>
> For most conversions to full-track, the differential spider gears of the combine are welded solid and steering clutches are installed in both the left and right drive shafts. These have been installed so that the conventional steering of the combine controls the clutches and the conventional brakes of the combine control the brakes. Installation of these steering clutches requires widening the tread, but allows use of wider pads on the tracks.
>
> The preferred situation is to have access to a combination of full-track and half-track machines. This permits use of the half-track to open fields and

harvest on firmer areas while having the full-track's capability to harvest where half-tracks are unable to operate."

A large diameter reel is needed in order for the reel bats to enter the crop without pushing the crop forward. These reels are seven or more feet in diameter (Oelke, et al., 1982 p. 30).

Draper extensions are used between the sickle and the cross-auger because of the height of wild rice plants. This provides a space for the plants to fall when entering the cross-auger, and this helps provide uniform feeding into the combine.

Most combines used in wild rice harvesting have a spike-tooth cylinder and concave. Spike-tooth cylinders are especially effective in processing heavy clumps of crop material. Rasp bar cylinders are especially effective in separating a large percentage of grain through the concave rather than passing it to the walkers for separation. Rasp bar cylinders leave straw in large pieces and make it easier to separate straw and grain on the walkers and sieves. Tests show that the rasp bar system can thresh the grain without increasing discharge losses, as compared to the spike tooth combines in wild rice (Oelke, et al., 1982, p. 30).

Many combine grain heads do not have an adequate divide point to handle a wild rice crop without modification. The problem manifests as stem hairpin and subsequent

accumulation of straw on the end of the header. Different divide points are added such as a large, pointed harpoon like divider. If the crop is lodged excessively, a bow type of divider is used to depress the crop at the end of the sickle instead of trying to pull it apart (Oelke, et al., 1982 p. 30).

There are several combine adjustments and operations which are important. Reel height should be adjusted such that it just sweeps the crop back into the draper extension. Excessive insertion of the reel bats into the crop will cause hairpinning of the straw over the reel bats. It increases the opportunity for the tall heads to be contacted by the reel structural members, thus leading to shatter losses. It will also increase the chances of pushing forward stems as the bat enters the crop. The height of the cut should be low enough to harvest most of the grain but high enough to reduce the amount of straw entering the combine.

Peripheral speed of the reel should generally be 1.25 to 1.75 times the travel speed of the combine. The speed or the aggressiveness of the cylinder and its closeness to the concave should be only enough to thresh the kernels. Excessive aggressiveness leads to breakup of the straw and reduces the capability of the walkers and sieves to separate grain from straw.

Air setting adjustments are critical for separating grain and straw on the sieves. Too much air blows the lighter kernels out the rear of the machine. Too little air permits chaff material to accumulate with the clean grain. Air passages should be periodically checked for collection of chaff material that may cause plugging.

Multiple-pass harvesters do not cut the grain head from the stem. Instead, they use finger-like troughs mounted on a special chassis. The troughs are spaced to allow the stems of the plant to pass between them as the machine moves forward, much like a comb moves through hair. A reel with bats rotates over the trough and gently knocks mature kernels from the panicles. The stems then bend and pass beneath the chassis. Immature kernels are left to mature and be collected on subsequent passes, usually in two to three days. The harvester is driven in the same path on later harvests so that the least number of plants are destroyed. The final pass may utilize a conventional wild rice combine.

APPENDIX D

FALL TILLAGE AND ROTATION CROPS

Fall tillage and crop rotation vary from region to region much like harvest techniques vary.

In Idaho, no fall tillage or crop rotation is practiced. After harvest is completed, the fields are generally left flooded and plant residue is left to decompose in the aquatic environment.

In California, the paddies are drained before harvest. After harvest operations are complete, the plant residue is tilled into the soil to decompose. Some growers rotate common rice into wild rice fields based on speculations concerning wild rice market prices.

Oelke, et al., (1982) recommends incorporating plant residue into the soil or burning to reduce leaf diseases the following year. Since wet weather often prevents burning, tillage is a common practice. Tillage also aids in weed control, especially cattails. It serves as a seedbed preparation and can help incorporate fertilizer. Fall plowing or use of a rotovator in second-year and older fields can reduce thinning needs. Oelke notes that many Minnesota growers keep fields fallow during the third year, while still maintaining ditches and dikes.

In fields that allow sufficient drainage, rotation crops are planted during the third year. Common rotation crops are buckwheat, rye, wheat, mustard, and forage grasses for seed production. While barley grows well, it is susceptible to brown spot disease; thus it is not recommended as a rotation crop (Oelke, et al., 1982, p. 32).

APPENDIX E

DISEASE AND PESTS

Wild rice plants are subject to many diseases, plagued by various pests, and face competition with several varieties of weeds.

Although wild rice is not closely related to common rice, they share common diseases by the same pathogens (Oelke, et al., 1982, p. 27).

The most serious disease affecting field-grown wild rice is Brown Spot. The disease is caused by the fungi Bipolaris oryzae and Bipolaris Sorokiniana. Since both fungi may cause similar symptoms and both can be found on infected plants, these two fungi are presently considered to cause Brown Spot disease (Oelke, et al., 1982, p. 27).

These fungi can survive on wild or domestic grasses, on wild rice stubble, and have also been found in wild rice seed. Infectious fungal spores are produced in the spring and are transported by wind. To date, all varieties of wild rice at all stages of growth are susceptible to the disease. Environmental conditions affect the severity of the disease, which is most damaging when day temperatures are 77^{o} to 95^{o} Fahrenheit and night temperatures are above 68^{o} Fahrenheit. Relative humidity of more than 89% and the

presence of free water on leaf surfaces for 11 to 16 hours also favor infection (Oelke, et al., 1982, p. 27). Diseased plants have oval brown spots with yellow edges. In early disease stages, these spots are approximately the size of sesame seeds. As the disease progresses, individual spots grow together, forming large brown diseased areas that cover leaves, leaf sheaths, and panicles. In advanced stages, the stems may break. Yield losses may vary from slight to total plant destruction. Disease control methods employ sanitation, chemicals or both. In the sanitation method crop residue is incorporated into the soil and fields are seeded with clean seed. Brown spot resistant rotation crops or fallow are other sanitation methods. Non-host plants must be used on dikes or border areas for this to be effective. In Minnesota chemical control practices include the protectant fungicide Mancozeb (Dithan M-45) at 2 pounds per acre, applied four times at 7 to 10 day intervals during flowering and grain filling stages (Oelke, et al., 1982 p. 28). Use of this chemical may not be approved in other areas; thus, users outside of Minnesota should check with local authorities before applying any chemical. Propiconazol or Tilt™ has been used in Minnesota studies with promising results but has not been approved for general use (Percich, et al., 1987, p. 56).

Stem Rot is another fungi affecting field-grown wild rice. Sclerotium sp. and Helminthosporium sigmoidium Cav. may cause this disease. Both fungi produce dark structures called sclerotia which appear in the leaf sheaths and stems. The sclerotia either survive in infected plant debris or float in water, and may be deposited on the soil surface during paddy drainage. In the spring, the fungi germinate and produce infective spores (conidia) that are wind or water borne. Symptoms of this disease appear as small, oval, purple lesions that initially develop on stems at water level or on floating leaves. This eventually leads to brittle stems and lodging. Since no effective chemical control is currently available, sanitation measures as described for Brown Spot are the only available control methods.

Stem Smut, caused by the fungus Entyloma lineatum, has been reported to cause economically serious yield reductions in managed natural stands in Canada, but has not proven a serious problem in cultivated fields (Oelke, et al., 1982, p. 28). Symptoms of this disease appear on mature plants as glossy black lesions on the heads, culms, and stems. The head lesions can girdle the stem and reduce seed production. Spores are produced in the lesions and released to the air for dispersal.

Ergot is a disease rare in Minnesota's cultivated fields but does occur in natural stands. It is caused by the

fungus Claviceps zizaniae. The overwintering structures, called sclerotia, can survive for years. During flowering, the sclerotia germinate and produce wind-borne ascospores that infect wild rice flowers. Hard, dark sclerotia are formed in place of grain. These may be harmful if consumed; however, they are larger than healthy kernels and can easily be removed. No control is practiced except removal of sclerotia from the grain before consumption (Oelke, et al., 1982, p. 28).

Bacterial Leaf Streak is found in most natural stands and cultivated fields. Yield losses have not yet been determined for this disease caused by the bacterium Pseudomonas syringae. Its symptoms are leaf lesions characterized by long, narrow, dark-green, water-soaked streaks that extend the length of the leaf blade. This water-soaked tissue eventually turns brown or black and may be covered with a glistening crust of bacterial exudate. No control methods are practiced against Bacterial Leaf Streak (Oelke, et al., 1982, p. 28).

Weeds common to Minnesota wild rice cultivation are Common Waterplantain, Cattail, Burreed, Common Arrowhead, Cursed Crowfoot, Water Starwort, and Small Pondweed (Oelke, et al., 1982, p. 23).

Common Waterplantain is the most serious threat to cultivated stands. One plant per square foot can result in

a yield reduction of 43% (Percich, et al., 1987, p. 68). Leaves from the plant emerge from root stocks before wild rice leaves emerge, thus forming a dense canopy that shades and kills some wild rice plants and reduces tillering in others. Tests done by Percich, et al., used microbial herbicides with some success to control this weed.

Cattail serve as overwintering sites for some pests but can be controlled with fall tillage. Common Arrowhead, Cursed Crowfoot, and Water Starwort, because they share wild rice habitat, reduce stand density and yield.

Oelke recommends applying 2,4-D (amine) at .25 pounds per acre for weed control in wild rice. Higher concentrations can damage wild rice. The chemical should be applied when the wild rice is in the tillering stage of growth as later application can be injurious. Spot-spraying areas of dense weed infestations is preferred over spraying the entire field.

Algae can reduce wild rice stands if an algae mat forms before the wild rice plant emerges. Applying copper sulfate at 15 pounds per acre helps control this problem. Multiple treatments may be necessary for complete control (Oelke, et al., 1982, p. 24).

Numerous insects and other pests plague wild rice. The wild rice worm or Apamea apamiformis is common in cultivated fields. Oelke, et al. (1982) describes the life cycle and control of wild rice worm in the following quote.

"Both harvesters and processors find the crawling larvae in harvested wild rice. Adult moths begin to appear in late June and early July when wild rice begins to flower. They mostly feed on milkweed blooms after emergence, which continues through August.

The female moth lays from 2 to more than 150 pearly white eggs per wild rice floret. The eggs are inserted past the stigma, which extrudes between the lemma and palea (hulls) of the floret. Egg laying is continuous over four to six weeks so that larval growth stages from early instars to nearly fully developed larvae are present. The early larval stages feed within the hulls and then eat their way through the hulls either before or shortly after the first molt. The infested florets do not form seeds. be carried by the wind to other plants. This is called ballooning.

After larvae become established in the panicle, they feed mostly on the wild rice kernels but also on male florets. During the feeding process, they create a webbing that is coated with white excrement.

There may be as many as eight larvae stages. Many larvae reaching the seventh stage show a strong tendency to migrate and bore into either wild rice stems or stems of other plants bordering the fields. The winter is passed in the seventh stage and the final larval molt occurs in the spring. Pupation takes place in early June and lasts approximately three weeks.

Wild rice worm control has been successful with several insecticides; however only malathion at 1 pound of active ingredient per acre is labeled. Malathion should be applied 14 to 21 days after eggs become visible in the hulls. One larva per plant will reduce yields by 11 percent."

Another pest common to wild rice is the Midge. Midges in the families Chironomidae and Dixidae use the flooded fields for larval development. Crictopus is a midge in the Dixidae family that has caused severe damage to first-year fields (Oelke, et al., 1982, p. 25). The adult is a small, delicate, mosquito-like fly that lacks scales on its wings and does not have functional mouth parts. Most growers do

not see it because it is so small and inconspicuous. It lays eggs in gelatinous masses in moist soil, which hatch when the field is flooded. Larvae spin a delicate but tough webbing, which they attach to submergent young wild rice plants. Larval feeding consists of both scraping up algae and abrading the leaf margins. Infected leaves often curl and do not emerge from the water. Midges can be detected by inspecting for frayed leaf edges, curling of leaves, and mud covered webbing. Malathion is used in first year fields to control their population. Second-year stands and older fields often have enormous numbers of midge larvae, but high plant populations make control unnecessary (Oelke, et al., 1982, p. 26).

Other insect pests are Rice Water Weevils, Rice Leafminer, and Rice Stem Maggot. Although wild rice hosts some phase of these insects life cycles, they seldom cause yield reductions.

Orconectes virilis or Crayfish have also been observed to cause stand reduction. It is likely that runoff waters used to fill paddies in the spring carry the crayfish to the fields. Once established, they are able to overwinter in drained fields by drilling into the mud and creating a burrow, where reproduction takes place. Crayfish reduce yield primarily by consuming the young plants. They are not a major problem on an industry-wide basis (Oelke, et al., 1982, p. 26).

Blackbirds, however, are a major problem. Depredation of wild rice by blackbirds begins when the first kernels are in the milk stage. The bird squeezes the hulls and forces the soft kernel out through the split between the hulls. As the crop matures, the bird feeds on the entire seed. During the shattering stages of development, blackbird feeding dislodges large amounts of grain, which spills into the water. Many methods have been tried to reduce blackbird damage including shooting, alarm records, continuous over-flight with aircraft, and even chemical conditioning. The chemical Methiocarb has been investigated as a bird repellent. It causes illness and induces conditioned aversion, though its effectiveness is limited (Oelke, et al., 1982, p. 27).

Mammals such as raccoon, mink, and skunk forage for food on dikes and in ditches. Deer and moose have been seen in wild rice fields. Although large mammals do cause damage, the magnitude is seldom economically important (Oelke, et al., 1982, p. 27). Muskrats can be a problem in several aspects. They may damage dikes by burrowing activities. They also feed on wild rice plants in all emergent stages of growth. In addition muskrats cut down many other plants and pile them together in the water to build floating platforms or feeding stations. This activity appears to destroy more plants than actual feeding (personal obser-

vation). St. Maries reported trapping 200 muskrats from a 40 acre field in one season, and speculated that a similar number would be taken the following year. Fields that are drained during winter have few problems with muskrats.

APPENDIX F

PROCESSING

Freshly harvested mature wild rice kernels must be processed to make them suitable for marketing. Processing may involve, separation of immature kernels, fermentation, parching, dehulling, scarification, cleaning, grading, and packaging.

Oelke, et al., (1982) describes a machine developed by the University of Minnesota Agricultural Engineering Department that separates immature kernels from combined wild rice seed. The machine separates three fractions designated as heavy, medium, and light. The heavy portion consists of stages of maturity, while the light fraction is mostly small diameter immature kernels. The yield of finished wild rice from the heavy fraction extracted by the separator was approximately 50% of the harvest weight and 60% of the total finished product. The balance was composed of the medium fraction. The light fraction yield was so low it was uneconomical to process and was discarded. Such separation machines are not used in all wild rice processing.

Fermentation is a universal processing operation. Fermentation or curing is a chemical and biological process

involving heat, respiration, moisture transfer, and activity by a large number of microorganisms. Most processors consider fermentation necessary for color and flavor development plus hull degradation (Oelke, et al., 1982. p. 34)(Goel, et al. 1972, p. 385). Wild rice fermentation is accomplished by placing freshly harvested grain on concrete slabs in piles or windrows, that typically are 18 to 24 inches deep (Goel, et al., 1972, p. 385). In larger operations the piles or windrows are turned daily by special machines; in small processing firms, they are turned by hand. This is done to promote aeration of the curing rice. Water is added daily at an approximate rate of one gallon per 100 pounds of wild rice to reduce excessive drying and to prevent temperature build-up which encourages the growth of molds. Moisture levels should be kept above 30% moisture wet basis not only to limit mold growth but to prevent a defect called "white centers" from developing after subsequent high temperature drying (Lund, et al., 1976, p. 332). Mold growth can lead to undesirable earthy flavors in the finished product (Lund, et al., 1976, p. 336).

Goel, et al., (1972) reported that microorganisms are present both on the outside of wild rice hulls and the outside of grains, with the larger number appearing on the outside of the hulls. He tested fermenting and parched wild rice for various kinds of microorganisms. His findings are summarized in Table 12. The aerobic bacteria count was

found to increase during fermentation, as was the psychrotrophic bacterial count, while the coliform count was erratic. Mold counts were also erratic. Yeasts, if present, could not be counted because of excessive mold growth on plates.

Fermentation periods of one week are common and desirable. During this period the color of the kernels darkens, hulling efficiency increases, and kernel fragility decreases. (Lund, et al., 1976, p. 336). Kernel fragility is expressed as the fraction of whole kernels in recovered usable wild rice solids. Wild rice is often fermented up to three weeks as a result of lack of processing capacity (Oelke, et al., 1982, p. 35). Usable rice solids tend to decrease as fermentation times increase beyond 30 days (Lund, et al., 1976, p. 334-335).

The next step in wild rice processing is parching. Parching wild rice serves several functions: it conditions the rice for hulling, reduces the moisture content for stability during storage, produces a toasted flavor, and gelatinizes the starch (Lund, et al., 1975, p. 151).

A variety of methods have been used to dry wild rice. Indians traditionally sun-dried the grain. Large metal pots over open fires have been used to parch rice. Modern wild rice processors use wood or gas heat to parch the grain in large rotating drums with paddles that mix the drying rice

TABLE 12

Kinds of Micro-organisms and Frequency of Isolation From Fermenting and Parched Wild Rice

Source and Kind of Microorganism	Fermenting wild rice	Parched wild rice
	(No. specific kind/ total isolates)	
From plate count agar (30 °C)		
Gram-positive rods	5/27	17/25
Gram-negative rods	14/27	6/25
Gram-positive cocci	8/27	2/25
Bacillus species	0/27	15/25
Corynebacterium species	0/27	2/25
Lactobacillus species	2/27	0/27
Leuconostoc species	3/27	0/27
From plate count agar (7 °C)		
	[b]	[b]
Pseudomonas species	23	3
Pigmented Pseudomonas species	8/23	0/3
From violet red bile agar		
Escherichia coli	2/44	1/6
Enterobacter aerogenes	5/44	1/6
Intermediates	37/44	4/6
From KF agar		
Streptococcus faecium	14/35	7/11
Streptococcus faecalis	6/35	1/11
Other streptococci	15/35	3/11
From acidified potato dextrose agar		
Aspergillus species	5/16	2/10
Penicillium species	2/16	3/10
Mucor species	8/16	5/10
Rhizopus species	1/16	0/16

Source: Goel, et. al., (1972)

(Lund, et al., 1975, p. 150). These devices resemble concrete mixers. Some modern parchers use air heated to 250 ^{o}Fahrenheit and passed through a rotating drum to parch rice. Oelke, et al., (1982) states that a typical batch rotary drum parcher is 4 feet in diameter and 6 to 8 feet long. Propane burners heat the exterior surface and heat is transferred through the drum to the wild rice as the drum rotates. Another system uses continuous parchers. In continuous systems the rice is fed into a series of drums up to 30 feet long. These drums are augured or inclined such that rice slowly progresses through the drum as it rotates and passes from one drum to the next. Parching is complete when the rice is discharged from the last drum.

Parching or drying reduces the moisture content of wild rice from 35-50% (moisture wet basis) to 7-12% (moisture wet basis). Common drying times are from one to two hours (Lund, et al., 1975 p. 150). Jeff Baker of St. Maries Wild Rice in Idaho likened parching control times and temperatures to the art of a fine brewmaster.

When wild rice is dried at temperatures below the gelatinization temperature (62 to 65 ^{o}C) a defect known as "white centers" occurs. Low initial moisture contents (25% moisture wet basis) also lead to this condition (Lund, et al., 1975 p. 152). White centers indicate the presence of starch granules, the gelatinization of which requires both high temperature and moisture. It has been implied that

white centers result from excessive mold growth during fermentation. Actually, both white centers and mold are related to moisture content. Extensive mold growth will occur if the moisture in curing (fermenting) wild rice drops below about 30 percent moisture wet basis. If this rice is then parched without soaking to increase the moisture above 30 percent moisture wet basis, white*p+6X centers will occur. Although the two factors appear to be related, no direct cause-and-effect relationship has been established (Lund, et al., 1975, p. 152). Drying wild rice too rapidly or at temperatures greater than 300°Fahrenheit will cause another defect called "hollow centers". This is undesirable because affected kernels are more fragile and reduce usable yields (Lund, et al., 1975 p. 152).

High drying temperatures can also scorch rice kernels and cause a burned flavor. Successful parching should provide a slightly nutty or toasted flavor to the rice. Several qualitative observations have been made on the reationships between drying conditions and flavor of wild rice (Lund, et al., 1975, p. 152). At air temperatures below 175 °Fahrenheit, the green-tea or earthy flavor of wild rice can be preserved and the toasted flavors will not develop. At air temperatures above 212 °Fahrenheit, toasted flavors are imparted and the intensity of the flavor is dependent on the temperature. Contact time of rice with the

heated surfaces of industrial dryers is very important in determining flavor. Contact times above 10 seconds at 400°Fahrenheit may result in burned or scorched wild rice.

Temperatures during parching affect the kernel fragility; fragile kernels may break during hulling and subsequent cleaning, grading, and packaging. Thus, improper drying may be reflected as low hulling efficiencies.

Following parching, wild rice kernels are allowed to cool before they are hulled. The traditional hulling method used by Indians was the wild rice dance. The twisting motion of their feet on the rice loosened and removed the hulls. Rice was also rubbed together by hand to loosen and remove hulls (Lund, et al., 1975 p. 150).

The first mechanical hullers were barrel hullers, which used an enclosed barrel with rotating paddles or rubber flails which knock the hulls from the kernel. This process was difficult to control and caused excessive damage to the kernels. Commercial wild rice operations have acquired hulling machines from the conventional rice industry. These hullers are composed of two rotating rubber cylinders operating at different RPM, which impart a scuffing action to the rice. The grain is fed by conveyers to the rollers, which transfer hulled kernels and hulls onto another conveyer that passes under vacuum ducts which remove the lighter hulls from the mixture.

Factors that affect hulling efficiency are length of fermentation time, moisture content of the rice when hulled, and parching temperatures. The percentage of hulls is listed as a function of kernel maturity in Table 13.

TABLE 13

Characteristics of Wild Rice at Different Maturities

Degree of Maturity *	Bulk Density g/cm^3	Bulk Density lb/ft^3	Moisture % w.b.	Hulls and Chaff %
1	0.50	31.2	26	20.1
2	0.41	25.6	28	21.6
3	0.36	22.5	33	22.5
4	0.32	20.0	39	34.6
5	0.24	15.0	58	61.3
6	0.19	11.9	68	81.9

Source: Lund, et. al., (1976)

* SCALE: 1 = Mature fraction characterized by predominately black kernels;
6 = very immature, characterized by mainly unfilled hulls and small, milky, green kernels.

This percentage decreases as fermentation time is increased (Lund, et. al,. 1975 p. 153), because active microbial fermentation degrades hull material and causes it to become fragile. Thus removing hulls requires less mechanical force. Huller settings must take into account fermentation time as well as kernel size.

The fraction of unhulled rice passing through the huller increases as the moisture content of the rice increases (Lund, et al., 1973, p. 154). This increased hulling efficiency is attributed to drier hulls becoming loosened from the kernel.

Some processors include an additional step called scarification, which involves removing the outer black coat from the kernel after hulling. This minimizes cooking time, which is desirable when wild rice is blended with conventional rice, (Goel, et al., 1970, p. 571). Oelke, et al., (1982) describes a typical scarifier as a continuous-flow device consisting of a cylindrical container with a shaft running down the longitudinal axis. Extending from the shaft are several rubber paddles. The axis of the scarifier is tipped slightly down in the direction of flow. The degree of scarification is controlled by the inclination of the scarifier and by the speed and clearance of the rubber paddles. Apparently, the outer coating of the kernel is removed by abrasion as the product passes through the device.

Grading equipment sorts the rice according to length and girth. The length-grader has a rotating cylinder with closely spaced indents. As the cylinder rotates, rice kernels of less than a specified length are carried in the indents to a higher elevation, then dropped into a trough and discharged from the grader. Kernels longer than the

indents are discharged from the opposite end of the grader. The girth or diameter-grading machine is located directly below the length-grader. It uses a cylindrical sieve with slotted openings. Kernels passing through the slotted openings are classified as "B" grade, while those retained are "A" grade. Broken kernels are also removed by both machines for use in soups or for grinding into wild rice flour.

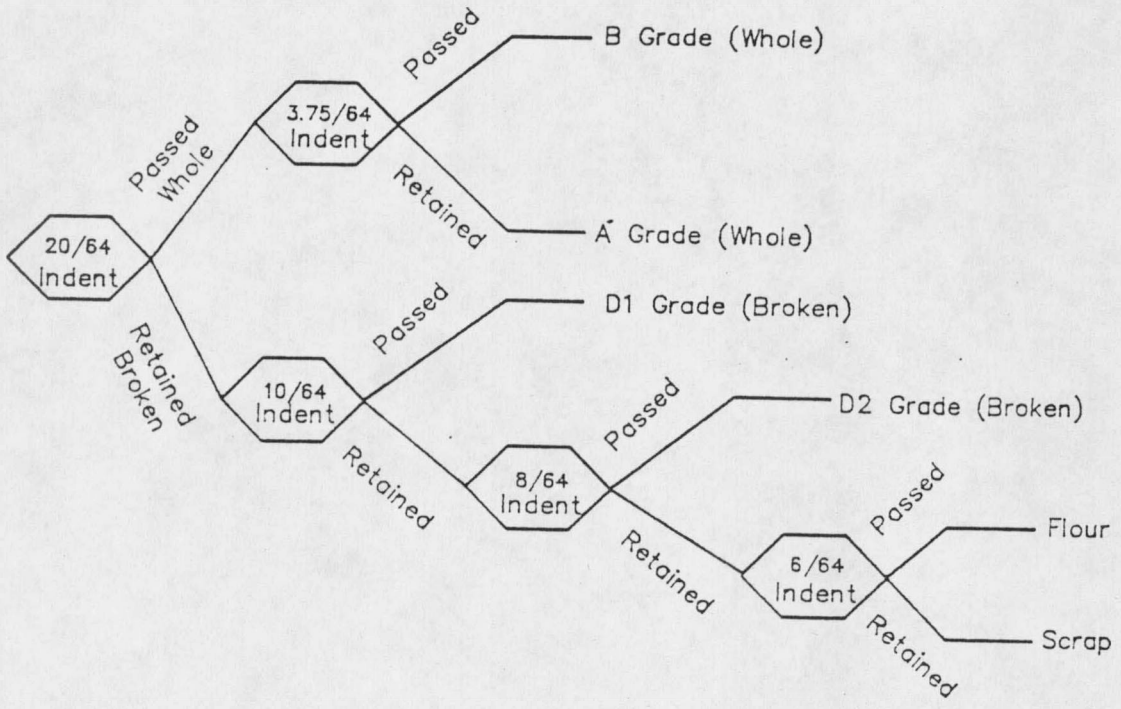
Grading schemes are not yet universal to the industry. In fact, some processors use no grading criteria at all (Winchell and Dahl, 1984, p. 25). Figure 16 shows a typical grading system, which results from the use of a rotating cylinder indent grader.

From the grading equipment the kernels are conveyed to a gravity table, which separates unhulled kernels, small rocks, and wild rice kernels by vibrating the rice over an inclined screen as air is forced up through the mixture. Unhulled kernels are returned to the huller, rocks are discarded, dust and husks are vacuumed off, and wild rice is sacked into 100 lb. sacks.

There are several cleaning stages in wild rice processing. Grain and straw are separated during combine operations, as discussed in the appendix entitled "Varieties and Harvesting." Large magnets are often placed above conveyers to remove metal fragments that may have contaminated wild

FIGURE 16

Wild Rice Grading System



Source: Oelke et al. 1982, p. 36.

rice during harvest and handling. Various types of aspirating devices are used between the huller and the subsequent processing equipment. Weed seeds are removed at the first grading. Small pebbles are removed by the gravity separator.

Characteristics of wild rice at different maturities were listed in Table 13. As the grain matures, the bulk density increases and the moisture content decreases. Mature kernels have lower percentages of hulls and chaff.

Large processing plants in Minnesota process grain supplied by local, Canadian, and even California growers. Some processors purchase grain on contract before planting has began. In California, processors may require growers on contract to stagger planting dates, allowing processors to handle large amounts of wild rice without excess processing capacity. In addition, damage to wild rice incurred during extended storage is minimized (Winchell and Dahl, 1984, p. 22). Other processors operate on a custom basis. Fees in such operations are generally charged on a per pound of finished product basis, creating incentives to achieve high finishing percentages. Assuming a finishing rate of 40 percent per pound of green wild rice, processing charges varied in 1983 from 18.5 cents to 85 cents per processed pound (Winchell and Dahl, 1984, p. 23). This wide range of processing fees is due to differences in processing plant size and transportation costs.

Lake wild rice is commonly believed to have a higher finishing rate than cultivated wild rice because only mature kernels are harvested, while combine operations acquire a percentage of immature kernels. Processor reports gave average finishing percentages of 40% for lake

rice and 38% for cultivated wild rice, indicating that the difference is only minor (Winchell and Dahl, 1984, p. 23).

APPENDIX G

MARKETING

Processors play an important role in marketing wild rice. Much of Canada's and Minnesota's wild rice is purchased from harvesters or growers by a processor who then sells it to industrial buyers, retailers, and other firms (Winchell and Dahl, 1984, p. 24). Processors tend to concentrate sales in regions known to be receptive to wild rice. Surplus stocks are often sold at discounted prices in Minnesota, making premium prices difficult to obtain in that region. Attempts to introduce wild rice products in areas unfamiliar with the grain have met with mixed success (Winchell and Dahl, 1984, p. 25). Typically processors have found market development difficult and expensive. In addition, processors have developed regions for marketing wild rice only to have a competitor move in and undercut prices.

Wholesalers also market wild rice, purchasing the grain from processors or growers and arranging for custom processing. Independent growers also market wild rice directly to consumers.

Cooperatives also share in the w*p+4Xild rice marketing arena. In 1982, 62% of Minnesota's cultivated wild rice was

marketed through two Minnesota cooperatives, Minnesota Rice Growers (MRG) and United Wild Rice Inc. (United).

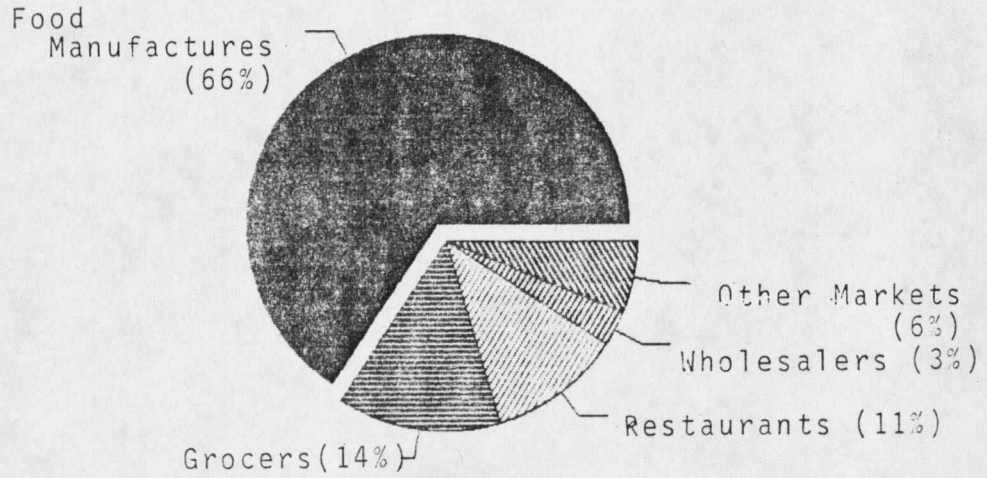
Marketing support organizations that do not directly sell wild rice engage in promotional activities and work toward better cooperation within the industry (Winchell and Dahl, 1984, p. 26).

Market outlets are dominated by industrial buyers, who account for approximately two-thirds of all wild rice sold (Winchell and Dahl, 1984, p. 28). Industrial buyers, such as Uncle Ben's Co. prepare, package, and market blends of wild rice and lo*p+1Xng grain rice. Wild rice blends are also offered by several other firms, including Minute Rice, Comet, M.J.B., and Rice-a-Roni. Blends typically contain only about 15% wild rice (Winchell and Dahl, 1984, p. 29). Another industrial buyer is a cornish game hen processor who pre-stuffs the birds with wild rice. The other one-third of sales can be attributed to grocers, restaurants, direct sales to consumers, and others. Sales by market are illustrated in Figure 17.

Long grain wild rice continues to be the preferred kernel size in the pure wild rice trade. Some restaurants, however, prefer to use broken wild rice for soups*p+6X and stuffings because it is available at a discounted price.

FIGURE 17

Wild Rice Sales by Market Outlet, 1982 Crop Year



Source: Nelson and Dahl, 1985, p. 4.

Winchell and Dahl (1984) summarize the spatial and temporal distribution of wild rice sales:

> "Urban consumers are more aware of wild rice than rural consumers. Sales of blends are also higher in urban areas. This is partially due to the gourmet image of wild rice and the tendency for gourmet foods to be popular in metropolitan areas. Several other factors reinforce this tendency, however. In the more sparsely populated rural areas, advertising costs per consumer are too high to merit extensive marketing. Rural consumers are less aggressively courted by the food industry in general, and this includes wild rice blend products. Secondly, shelf space is more limited in rural areas; since wild rice blends often have slow turnover relative to other

> food items, they frequently are not stocked by retailers.
>
> The popularity of wild rice blends differs markedly by region. The east and west coasts are major wild rice markets, as is the Chicago area (including Minneapolis and St. Paul). Additional areas of consumption are retirement communities of Florida and Arizona that have transplanted residents from the more traditional wild rice areas.
>
> Wild rice consumption continues to be associated with holiday meals. About 60 percent of blended wild rice sales are made during the Thanksgiving, Christmas, and Easter holidays, and advertising campaigns are generally timed for these heavy consumption periods. The blend market is split between the retail grocery trade, which accounts for about 85 percent of total blend sales, and restaurant trade. The pure wild rice market exhibits seasonal and geographic sales trends similar to those of packaged blend markets. Consumer purchases of pure wild rice are markedly higher in Minnesota than elsewhere due to the greater familiarity and lower prices. Minnesota consumers also buy a substantial amount of wild rice for shipment out of state as gifts."

Wild rice prices vary with the market in which the rice is sold. Prices are established through a two-tier process (Nelson and Dahl, 1985, p. 5). In the early spring, large food manufacturers such as Uncle Ben's negotiate pre-priced contracts with large sellers, locking prices for much of the production year. These pre-priced contracts are generally only available to growers who are members of marketing cooperatives and to large processors. The remaining wild rice is priced after contracts are fulfilled. Because many contracts are filled in the months following harvest rather than at harvest, the supply and demand situation for the residual wild rice may not clarify until six months after harvest. The general unorganized nature of

the industry and resulting absence of reliable price and quantity information tends to extend this period of uncertainty. Many independent growers, forced to sell in the residual market, must wait for prices to be determined and incur increased storage and handling costs. To an extent the industry has been the victim of its own history, where wild rice speculators relied on secrecy and even false and misleading market information to ensure exploitation of production and price variability (Nelson and Dahl, 1985, p. 5). Even though market conditions have changed with the introduction of cultivated wild rice, distrust continues to impede progress and cooperation in the industry.

The actual size of wild rice markets can be estimated by inspecting historical production trends. These figures for the U.S. and Canada were listed in Table 3 and are summarized in Figure 18. Nelson and Dahl (1985) reported that the market demand expanded at a vigorous rate of 26 percent per annum between 1982 and 1984. Then, in 1985, California production increased dramatically and prices fell (see Figure 18). The 1986 crop resulted in a tremendous nationwide surplus (Melvin Androus, Manager California Wild Rice Program, 1987, personal communication). Production had finally exceeded demand, resulting in a dramatic reduction of acreage in California, from 16,000 acres in 1986 to 7000 acres in 1987.

Wild rice wholesale prices for the period 1968 to 1986 are plotted in Figure 19.

The profitability of wild rice, as with any commodity, is what ultimately will determine its fate as a commercial crop. Profitability varies from region to region due to variations in yield and production costs. Minnesota has relatively low yields (188 finished pounds per acre) but also has low production costs. California, in contrast, has high yields (576 finished pounds per acre) but has higher production costs (Nelson and Dahl, 1986, p. 88-89). Table 14 illustrates these production cost differences. The

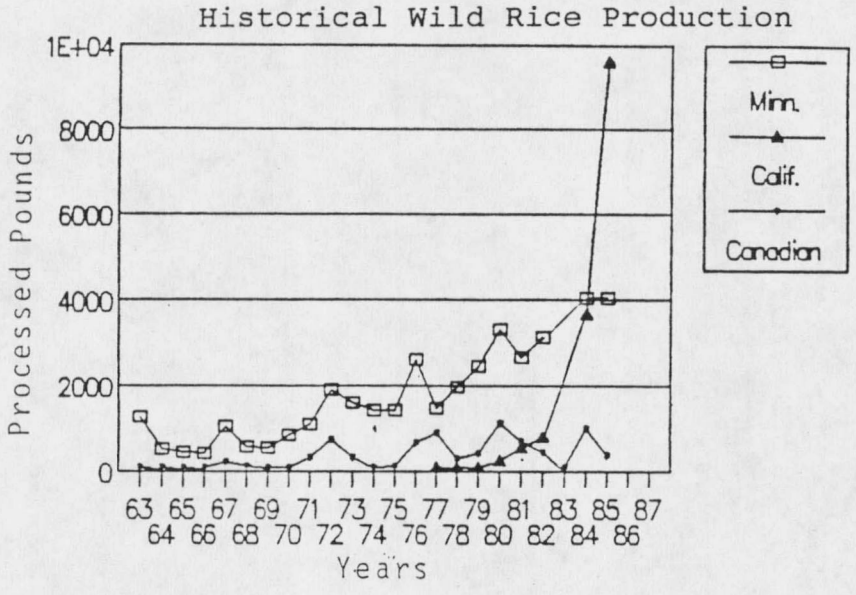
TABLE 14

Wild Rice Production Cost, Minnesota vs. California

	MINNESOTA	CALIFORNIA
	Cost/acre	
Field Prep.	$ 31.76	$ 39.41
Planting Costs	154.20	308.00
Growing Costs	70.95	99.71
Harvest Costs	151.88	55.83
Other Costs	50.62	68.46
Total Costs		
Year 1	$ 456.68	$ 571.39
Year 2	352.31	571.39
Year 3	400.23	571.39

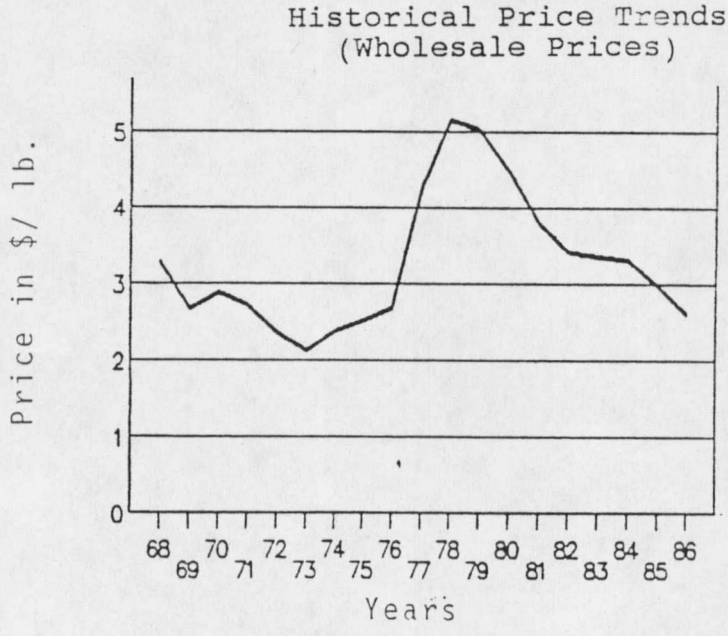
Source: Nelson and Dahl, (1986). NOTE: Costs where estimated by formula and/or by survey information collected from the industry in 1985 and are not presented as a standard to be met, maintained, or exceeded.

FIGURE 18



Source: Nelson and Dahl (1985)

FIGURE 19



Source: Nelson and Dahl (1986)

costs to Minnesota growers varies since fields are planted only once and then thinned, while California fields require annual reseeding. The bottom line cost per processed pound reveals California's competitive edge. California's cost is $0.99 per processed pound while Minnesota's total production cost is $2.43 per processed pound for the first year's production from a newly seeded field. In years two and three, when production comes from volunteer seed, Minnesota's total production cost is $1.83 and $2.13, respectively (Nelson and Dahl, 1986, p. 90).

California's dry climate gives it a yield advantage as it prevents the development of fungi, particularly the brown spot fungus. This climatic advantage also allows California growers to plant denser stands which, in Minnesota, produce a greater incidence of fungal disease. In addition, annual reseeding in California allows growers to readily take advantage of improved varieties.

Minnesota growers survive in the market place primarily because they receive higher prices for processed wild rice than California growers. In the 1985/1986 marketing year, Minnesota growers received prices ranging from $2.45 to $3.10 per processed pound, while California growers received prices ranging from $2.00 to $2.75 per processed pound. This price difference is partially attributable to

often transport unprocessed wild rice to Minnesota for processing and marketing (Nelson and Dahl, 1986, p. 91).

St. Maries Wild Rice is in a unique position, as the only wild rice firm in Idaho. It operates as grower, processor, marketer, and seed seller. In recent years, the operation has expanded to purchasing unprocessed or green grain from a network of six to eight contract growers. The price paid for green grain in 1987 was $0.65 per pound, down from over $1.00 per pound paid in previous years. Typical yields are approximately 400 pounds per acre harvest weight.

Jeff Baker of St. Maries estimated that their market mix consisted of 50% brokers, 20% restaurants, 20% mail order, and 10% retail shops. Seed sales are minimal, but still demand a reasonable return of $3.00 per pound green weight at harvest. Mail order and retail sales receive up to $8.00 per pound. The firm has invested an estimated $200,000 in structures, processing equipment, harvest equipment, and dike construction. With approximately 250 acres in production at 400 lbs. per acre, 100,000 pounds of green weight is available for processing. To bolster sales in the area, St. Maries has wild rice cook offs and tastings. Much like Minnesota, the locals take pride in the local industry.

APPENDIX H

NUTRITION

Wild rice, like most cereals, is not a complete food. It does, however, have some desirable nutritional attributes. Its composition has been compared with regular rice, hard red winter wheat, corn, and oats. Table 15 lists these nutritional similarities. Wild rice is second only to oats in protein content. The fat content is relatively low when compared to the other cereals; polished white rice is lower in fat because the bran and germ are removed. Ash values for wild rice are essentially comparable to the other grains, with the exception of polished white rice. Wild rice contains approximately the same quantity of crude fiber as brown rice and oats, but half that of wheat and corn. Its total carbohydrate content is slightly less than that of regular rice, but slightly greater than the other cereals listed. In all, wild rice compares very favorably in nutritive value with cereals commonly consumed today (Anderson, 1975, p. 951).

The protein contents of rice from both lake varieties and cultivated paddies has been tested at the University of Minnesota. As would be expected given the linked origins of the plant, very little variation was noted (Anderson,

1975, p. 950). A comparison of the percentages of essential amino acids in wild rice and other cereal grains is shown in Table 16. Acceptable levels of lysine and methio-

TABLE 15

Approximate Composition of Wild Rice and Other Selected Cereal Products

Compontent %	WILD RICE	BROWN RICE	POLISHED WHITE RICE	OATS	HARD RED WINTER WHEAT	CORN
Moisture	7.9-11.2	12.0	12.0	8.3	12.5	13.8
Protein	12.4-15.0	7.5	7.5	14.2	12.3	8.9
Fat	0.5-0.8	1.9	1.9	7.4	1.8	3.9
Ash	1.2-1.4	1.2	1.2	1.9	1.7	1.2
Crude fiber	0.6-1.1	0.9	0.3	1.2	2.3	2.0
Total Carbohydrate	72.3-75.3	77.4	80.4	68.2	71.7	72.2

Source: Anderson, (1976)

TABLE 16

Essential Amino Acids in Wild Rice and Other Cereals (Percentage of Protein)

Amino Acid	WILD RICE	POLISHED WHITE RICE	OATS	WHEAT	FAO PATTERN
Isoleucine	4.4	4.6	4.0	3.5	4.0
Leucine	7.4	8.0	8.3	6.8	7.0
Lysine	4.6	3.5	4.2	2.4	5.5
Methionine and Cystine	3.3	2.9	3.1	2.2	3.5
Phenylalanine and Tryrosine	9.1	10.1	9.9	8.0	6.0
Threononine	3.2	3.5	3.2	2.4	4.0
Valine	7.0	6.5	5.8	4.4	5.0

Source: Anderson, (1976)
a Methionine only

nine are present in wild rice, with lysine levels exceeding those of white rice, oats, and wheat (Anderson, 1975 p. 952). The lysine value of 4.6% protein in wild rice is about the same as is usually found in whole grain, high - lysine corn. Robbins, et al.,(1971) used SLTM values (sum of lysine, threonine, and methionine contents) to establish an indication of nutritional quality for oat protein. Similar calculations reported by Anderson for wild rice showed an SLTM value ranging from 10.5 to 11.1, which is slightly higher than that for oat groats at 10.0, and much higher that the 7.3 value for whole wheat.

Nearly 75% of wild rice composition is carbohydrates. (See Table 13). This includes starch, sugars, and all other carbohydrate substances. The sugar content drops after processing from a range of 1.8 to 2.7% sugar in raw wild rice to 1% for processed wild rice. Starch content varies from 60% to 65% of the carbohydrates. The caloric value for wild rice is 353 cal/100 grams, which is in the same range as most cereal grains (Anderson, 1975, p. 952).

The fat content of wild rice is quite low, approximately 1% by hexane extraction. Anderson reported that analysis of these extractions revealed that linoleic and linolenic acids make up more than 65% of the total fatty acid of the hexane-extracted lipid of wild rice. Linoleic acid is a fatty acid considered an essential human nutrient. These

acids are highly susceptible to oxidation and are probably responsible for the rancid odors that develop when wild rice is stored for long periods (Anderson, 1975, p. 953).

The mineral composition of wild rice compares favorably with that of the common cereals, oats, wheat, and corn (Anderson, 1975, p. 954). The mineral composition of several grains is compared in Table 17.

The vitamin content of wild rice is listed along with other cereals in Table 18. Wild rice is an excellent source of the B vitamins, thiamine, riboflavin, and niacin but like most cereals contains no vitamin A or C (Anderson, 1975, p. 954).

TABLE 17

Minerals in Wild Rice and Other Selecte Cereals
(mg/100g)

Mineral	WILD RICE	BROWN RICE	POLISHED WHITE RICE	OATS	HARD RED WINTER WHEAT	CORN
Calc	17-22	32	24	53	46	22
Iron	4.2	1.6	0.8	4.5	3.4	2.1
Magnesium	80-161	...	28	144	160	147
Potassium	55-344	214	92	352	370	284
Phosphorus	298-400	221	94	405	354	268
Zinc	3.3-6.5	...	1.3	3.4	3.4	2.1

Source: Anderson, (1975)

TABLE 18

Vitamin Content of Wild Rice and Other Selected Cereals

Vitamin		WILD RICE	BROWN RICE	POLISHED WHITE RICE	OATS	HARD RED WINTER WHEAT	CORN
Vitamin A,	I.U.	0	0	0	0	0	490
Thiamine,	mg/100g	0.45	0.34	0.07	0.60	0.52	0.37
Riboflavin,	mg/100g	0.63	0.05	0.03	0.14	0.12	0.12
Niacin,	mg/100g	6.2	4.7	1.6	1.0	4.3	2.2
Vitamin C,	mg/100g	0	0	0	0	0	0

Source: Anderson, (1975)

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