WILD RICE IN EAST CENTRAL MINNESOTA

I. Water, sediment, and plant nutrient relationships on three wild rice marshes.

II. The effects of traditional wild rice harvesting in a wild rice marsh.

by

Genevieve T. Fannucchi

A Thesis

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

in Natural Resources

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

December 1983

APPROVED BY THE GRADUATE COMMITTEE OF:

Lyle E. Nauman

Dr. Lyle E. Nauman, Committee Chairman
Professor of Wildlife

James W. Hardin

Dr. James W. Hardin
Associate Professor of Wildlife

Dr. R. David Hillier
Associate Professor of Biology

PREFACE

This thesis is written in the format of two papers intended for publication in various scientific journals. Each paper deals with different aspects of research on wild rice (*Zizania aquatica*) marshes in east central Minnesota. The research was conducted in the summer and fall of 1980 and 1981. The primary objectives of the study were to: (1) determine some of the chemical aspects of wild rice marshes; and (2) assess the impacts of traditional wild rice harvesting on a wild rice marsh. Material not intended for publication is found in the Appendix.

Funding for this project was provided by the U.S Department of the Interior - U.S. Fish and Wildlife Service contract no. 14-16-0009-80-028.

ACKNOWLEDGEMENTS

I wish to thank my major professor, Dr. Lyle E. Nauman and the members of my graduate committee, Dr. James Hardin and Dr. R. David Hillier for their editorial comments and assistance throughout this project. I also thank the personnel at the Sherburne National Wildlife Refuge, especially R. Papike, P. Dunham, and P. Larson. Special thanks goes to my field coordinator and friend R. Joarnt, refuge biologist. Thanks also to R. Towne, for his assistance in getting this project started; to R. Sharpe, for his comments and suggestions during the development of this study; to R. Libertus, Minnesota Wild Rice Commissioner, for his assistance and enthusiasm throughout the project; to Dr. E. A. Oelke, University of Minnesota Extension, for his conversations about cultivated wild rice systems; to L. Stout and all the wild harvesters whose cooperation and concern made the harvest impact assessment possible; to the UWSP Environmental Task Force crew for their assistance with water chemistry analysis; to R. Kilcoyne and K. P. Weinmann for their help in securing project equipment; and to my typists J. Humke and C. Pingle. Lastly I would like to thank my research partner, W. Fannucchi, without whose help this project could not have been completed.

TABLE OF CONTENTS

LIST OF TABLES

PART I.

PART II.

LIST OF FIGURES

PART I.

PART II.

LIST OF APPENDICES

WATER, SEDIMENT AND PLANT NUTRIENT RELATIONSHIPS ON THREE WILD RICE MARSHES

GENEVIEVE T. FANNUCCHI, College of Natural Resources, University of Wisconsin - Stevens Point, WI. 54481
WILLIAM A. FANNUCCHI, College of Natural Resources, University of Wisconsin - Stevens Point, WI. 54481
LYLE E. NAUMAN, College of Natural Resources, University of Wisconsin - Stevens Point, WI. 54481

Abstract: Three wild rice (Zizania aquatica) marshes were investigated during 1980 and 1981 in the Sherburne National Wildlife Refuge. The study sites show 3 points along a continuum of wild rice abundance, from bumper stand to failure. Lake Josephine and Orrock Lake represented the end points on the continuum, having a dense stand (52 stems/m^2 in 1980, and 49 stems/m^2 in 1981), and a poor stand (<1 stem/m^2 in 1980 and 1981), respectively. Johnson Slough represented an intermediate point, with a moderate stand (18 stems/m^2 in 1980, 14 stems/m^2 in 1981). Water, sediment, and plant tissue parameters were analyzed to determine if a similar continuum relationship was reflected in these parameters. Water analysis showed significant differences ($p \leq 0.05$) among study sites for alkalinity, total hardness (1980 and 1981), iron (1980), and sulfates (1981). Sediment analysis showed significant differences ($p \leq 0.05$) for boron and NH_4-N (1980). Sediment boron and iron, although not following the continuum relationship in 1981, were also significantly different ($p \leq 0.05$). Plant tissue analysis (1981) showed boron to be significant ($p \leq 0.05$). It also showed a higher nutrient uptake of Mn and Fe, when compared to other available micronutrients. The water, sediment, and plant tissue analyses from these study areas indicate a possible iron-wild rice relationship. Continued study, however is needed to verify the importance of iron to the wild rice plant.

Past studies have indicated that certain basic physical and chemical conditions are required for naturally occurring wild rice stands (Moyle 1944, Lawrence 1951, Steeves 1952). According to Moyle (1944), the most important single factor affecting wild rice growth is water chemistry. The best wild rice stands generally occur in lakes having a pH of 6.8 to 8.8 (Stoddard 1960). Wild rice tolerates a wide range of alkalinity (5-250 ppm) but is not found in waters high in sulfate salts (Moyle 1967). Large stands are not found where sulfate concentrations exceed 10 ppm and wild rice is totally absent where they are greater than 50 ppm (Moyle 1944, 1967).

Little is known about the sediment nutrient components required by natural stands of wild rice. Limited testing, done by Stoddard (1960), shows low percentages of available potash and phosphate, and high amounts of organic matter are present in wild rice lake sediments. Soft alluvial soils seem to be best for rice growth in Northwestern Ontario (Lee 1976). Kenora district studies in Canada indicate that highest rice densities occurred on silty or organic sites over a hard mineral bottom (Gideon 1972). According to Rogosin (1951), wild rice grows best on a substratum of deep, (at least 45 cm) soft, mucky soil, and does not readily establish itself on a hard mineral bottom, such as sand. Other studies indicate that under anoxic conditions, sediment production of ferrous sulfide may impede growth (Zingle 1969 as cited in Gideon 1972).

Limited studies on nutrient uptake of wild rice stands have been conducted in Canada. Concentrations of potassium, calcium, magnesium, and copper were found to be quite similar in roots, stems, leaves, and heads (Lee 1977). Canadian values for phosphorous, potassium, calcium, and copper content in wild rice are well within the range of concentrations found in other aquatic plants (Hutchinson 1975). However, Lee (1977) noted that wild rice plants exhibited a strong uptake of iron, and to a lesser extent, managanese, and that large concentrations of iron may be essential for normal growth of wild rice.

Few studies have investigated the waters and sediments of natural wild rice areas. Little experimental work has been done on the nutrient uptake of naturally occurring wild rice plants. The purpose of this study was to examine the water, sediment, and plant nutrient relationships on 3 wild rice marshes in central Minnesota.

STUDY AREA

Primary study areas included Lake Josephine (59 ha, 14 ha rice stand), a shallow water marsh within the St. Francis River basin, the northern section of Johnson Slough (26 ha, 11 ha rice stand), and Orrock Lake (101.4 ha, 1 ha rice stand), both within the Snake River basin (Fig 1). The study sites are located on the Sherburne National Wildlife Refuge, Sherburne County, Minnesota. Refuge narratives state that extensive drainage caused by a 1920's ditch system and the invasion of carp (*Cyrinus carpio*) into the lakes and streams of the St. Francis River basin in the early 1940's may have severely damaged wild rice habitat.

METHODS

Water samples were randomly collected in the northern and southern sections of the rice beds in Lake Josephine and Johnson Slough.

Samples were also taken along the eastern shoreline, in the center, and in the west bay of Orrock Lake. Water quality was sampled 4 times throughout the 1980 field season, mid-June through October, and twice monthly during the same period in 1981. Dissolved oxygen was determined on site using the azide modification method (American Public Health Association 1976). Parameters sampled included: pH, conductivity, alkalinity, total hardness, TKN, total phosphorous, SO_4, and iron. Samples were analyzed at the Environmental Task Force Laboratory, - UWSP - using procedures outlined in Standard Methods-14th edition (American Public Health Association 1976).

Lake bottom samples were collected in late October (both years) from each study site. Each wild rice bed was divided into 2 ha sampling units. Rice beds were completely sampled on Lake Josephine and Johnson Slough. Eight random sampling units were selected on Orrock Lake. From each sampling unit, 6, 5 cm diameter cores were combined to form a composite sample which was frozen for later analysis. A total of 20 composite bottom samples were analyzed each year.

Sediment samples were analyzed both years for pH, organic matter, P, K, Ca, Mg, B, Mn, Zn, S, NH_4-N, NO_2-NO_3-N, and Cl. Sediment iron levels were determined in 1981 only. Samples were analyzed by the UW-Extension Soil and Forage Analysis Laboratories at both Marshfield and Madison, Wisconsin using soil analysis procedures based on the Wisconsin Procedures for Soil Testing (Liegel et al. 1980).

Plant tissue was collected prior to flowering from each study site during 1981. Nine random sample sites (N=4 Lake Josephine, N=2 Johnson Slough and N=3 Orrock Lake) were selected. Twenty flag leaves per site were removed and air dried. Plant nutrient concentrations were determined for N, P, K, Ca, Mg, S, Zn, B, Mn, Fe, AL, Na, and NO_3-N. Samples were analyzed at the Soil and Plant Analysis Laboratory - Madison, Wisconsin using the Wisconsin Procedures for Plant Analysis (Liegel et al. 1980).

To determine if any statistically significant differences existed among study sites, all water, sediment and nutrient analyses were subjected to a 1-way analysis of variance (Johnson 1976). The Scheffe post hoc test (Hays 1963) was also applied to the variables when a significant difference ($p \leq 0.05$) was found among variables.

The wild rice density of each study site was determined during July 1980 and 1981. Transects were established across the width of each wild rice bed. Two 0.1 m^2 rectangular sample plots (Daubenmire 1959) were examined every 30 m. Similar methods were used by Whigham and Simpson (1977) to estimate seeding densities of 8 wild rice populations in New Jersey.

RESULTS AND DISCUSSION

The study sites were selected to show a range of wild rice abundance or continuum from dense stand to failure. Lake Josephine, Johnson Slough, and Orrock Lake represent a dense, moderate, and sparse rice stand, respectively. The average rice density in Lake Josephine was 52 stems/m^2 in 1980 (N=236) and 49 stems/m^2 in 1981 (N=216). Johnson Slough averaged 18 stems/m^2 in 1980 (N=132) and 14 stems/m^2 in 1981 (N=126). Orrock averaged less than 1 stem/m^2 during 1980 (N=16) and 1981 (N=48). Samples were taken primarily in Orrock's west bay since wild rice was most dense in this section of the lake during both years.

Lake Josephine and Orrock Lake represent extremes on the range of wild rice abundance in the study areas and Johnson Slough the midpoint. Water, sediment, and plant tissue parameters were selected for analysis when they showed a similar continuum relationship. It is likely that variables which occur in the greatest or least amount on a bed with a successful crop, and also have respectively low or high values on a lake with no crop might exert a significant influence on rice growth. This argument may be further strengthened if the parameters for a moderate crop are intermediate between the 2 extremes.

Water Analysis

The average pH of the 3 study areas ranged from 8.6 to 9.0 in 1980, and 7.8 to 9.3 in 1981 (Table 1). Significant statistical differences ($p \leq 0.05$) which reflected the range of abundance or the continuum relationship indicated previously, occurred between study areas for alkalinity, total hardness, and iron during 1980. During 1981 only alkalinity, total hardness, and sulfates showed this relationship. In all cases, Lake Josephine and Orrock Lake represent 2 extremes (highest or lowest concentrations) and Johnson Slough is intermediate.

According to Moyle (1944), Stoddard (1957), and Gideon (1972), both alkalinity (1980-1981) and sulfate (1981) levels are within the generally accepted range of values for successful rice crops. Although the level of iron was not significant ($p \leq 0.05$) in 1981, Lake Josephine had the highest concentration (0.98 ppm), Johnson Slough the intermediate (0.79 ppm), and Orrock Lake the lowest (0.74 ppm).

It is unclear at the present time how alkalinity and total hardness might affect wild rice growth. It is known that wild rice stands can tolerate a wide range of carbonates (Gideon 1972). In fact, Minnesota wild rice grows best in waters with carbonate levels of over 40 ppm (Rogosin 1954). The average alkalinity levels during the entire study period (Table 1) were within the tolerance limits outlined by Moyle (1944).

As previously mentioned, wild rice is generally intolerant of high sulfate concentrations (Gideon 1972, Moyle 1944). According to Gideon (1972), the best wild rice areas have sulfate concentrations of less than 10 ppm. Sulfate ion concentrations were low during 1980, averaging less than 0.05 ppm for all study sites and from 1.35 to 3.63 ppm in 1981 (Table 1).

According to Wetzel (1975), the typical range of total iron found in oxygenated surface waters of pH 5 to 8 is about 50 to 200 ugl^{-1}, (or 0.05-0.2 ppm) but higher iron levels may occur in certain alkaline closed lakes rich in organic matter. The higher iron levels of the study areas may reflect this. Nevertheless, Lake Josephine, which had a bumper rice crop in 1980, had the highest average concentration of iron, while Orrock Lake, which had a crop failure, had the lowest concentration. Johnson Slough, with a moderate stand of rice, had intermediate iron concentrations (Table 1). Community structure may also help to explain the higher iron contents of the study waters. According to Oborn and Hem (1962), some water emergent, soil rooted plants such as cattail (<u>Typha latifolia</u>), permit a blanketing effect on water by allowing the growth of submerged aquatics beneath them. This blanketing can decrease oxygen levels and eventually affect the redox potential (Oborn and Hem 1962). During most of its growth, wild rice is an emergent soil rooted plant found in association with many submersed aquatics (Moyle 1944, Rogosin 1954). During the study period all 3 wild rice beds had an accompanying dense mat of submersed aquatics beneath them. This blanket effect may have influenced the chemical equilibria of the water resulting in a higher dissolved iron concentration.

The importance of nutrients in the water for the growth of wild rice is unknown. Lee (1976) suggests that since the early floating leaf stage of rice is similar to other submergent and floating vegetation, wild rice may, at this time, obtain most of its required nutrients from the water rather than through its root system.

Sediment Analysis

Wild rice can grow in a variety of lake and river bottoms. Dore (1969) reports that wild rice can grow in mud, sand, or gravel. However in most cases, wild rice is found in soft-textured sediments such as muck or silt (Ferren 1977, Moyle 1967).

The relative roles of the sediments in wild rice nutrient uptake are unknown. However, in studies relating wild rice growth to N, P and K uptake, Grava and Raisanen (1978) found that the majority of the nutrient elements was supplied by the sediments. The total nutrient requirements of wild rice have not been determined. According to Grava (1973), the nutrient requirements of wild rice may differ from upland crops because of the submersed conditions under which it grows (Grava 1973). In an unflooded upland crop soil, oxygen is available for micro-organisms and plant roots. When a soil is flooded this situation changes. Aerobic organisms quickly utilize the remaining dissolved oxygen present and create an anaerobic environment. This lack of oxygen promotes a reduced condition allowing reduced forms of nutrients to become more available to plants. According to Grava (1973), this situation exists in flooded paddies of field grown wild rice.

Sediment analysis results for 1980 and 1981 can be found in Table 2. Using ANOVA analysis, only boron and NH_4-N showed a significant ($p \leq 0.05$) continuum relationship in 1980. In both cases, Scheffe post hoc analysis showed concentrations in Lake Josephine to be significantly lower ($p \leq 0.05$) than Orrock Lake, but not significantly different from Johnson Slough. However, Johnson Slough's boron and NH_4-N concentrations were intermediate between the other 2 lakes. Boron, although significant ($p \leq 0.05$) in 1981, did not show the continuum relationship. Instead, boron concentration was greatest in Johnson and about equal in both Lake Josephine and Orrock Lake (Table 2).

Stiles (1961) reported that grasses absorb less boron than other plants. Monocots also tend to have a lower requirement for boron than dicots (Hewitt 1963). Boyd and Walley's (1972) studies on Typha latifolia and Juncus effusus found no significant correlation between concentrations of boron in soils and in plant tissue. However, in their study, standing crops of cattail increased with increasing levels of soil boron. Cultivated rice (Oryza sativa) has a low boron content (Hirai 1950). In fact, Hirai's (1950) studies indicate that in properly managed paddies of cultivated rice, the supply of boron often exceeds the demand.

Although wild rice is not an ancestor of cultivated rice, it resembles cultivated rice, in that, it grows under submersed conditions. Comparisons between the 2 species, based solely on the known submersed soil conditions of cultivated rice, may help to understand the virtually unknown wild rice sediment conditions.

Most cultivated rice soils in the world are nitrogen deficient (Patnaik 1978). It is also known that in submersed soils ammonia is the major form of nitrogen available to cultivated rice (Ponnamperuma 1964). However, it seems unlikely that either boron or NH_4-N had an effect on wild rice abundance during 1980. In both cases, the lakes with the best crops had the lowest concentration of both boron and NH_4-N (Table 2).

Iron, although not fitting into the soil continuum pattern was significant ($p \leq 0.05$) in 1981. The average iron concentration in the sediment of Lake Josephine was 23 kg/ha, while in Johnson it was 2856 kg/ha, and in Orrock 2497 kg/ha (Table 2). If wild rice does utilize iron from lake sediments, perhaps an area containing an abundant crop could eventually deplete soil iron reserves, and thereby effect the redox potential. According to Patrick and Mahapatra (1968:328), when a soil is flooded and depleted of oxygen, the reduction of oxidized inorganic compounds occurs in the following order, "nitrate and managanic manganese compounds are reduced first; next the ferric compounds are reduced to the ferrous form and finally sulfate is reduced to sulfide." Studies by Takai et al. (1956) show that ferrous iron begins to appear in the soil at Eh values of +50 millivolts, and that sulfide occurs at -230 millivolts.

Soil reduction does not appear to be harmful to cultivated rice except at extremely low redox potentials, i.e. Eh levels low enough for sulfide to form (Connell and Patrick 1968). Iron is important in preventing low redox levels (Jeffery 1961). Most cultivated rice soils contain a high concentration of ferric oxide, and it is believed that this element is important in maintaining an Eh level that prevents the excessive formation of sulfate (Patrick and Reddy 1978).

Although the average concentrations of sulfates were within the accepted limits for wild rice growth in Lake Josephine's waters, they increased during 1981 (Table 1). Lake Josephine's sediment iron content was also low (23 kg/ha) when compared to the other study sites (Table 2). Hydrogen sulfide, at concentrations as low as 0.1 ppm, has been found to be toxic in cultivated rice culture solutions (Ponnamperuma 1964). In some cultivated paddy rice soils hydrogen sulfide inhibits the uptake of water and nutrients, and may cause root-rot (Vamos 1958). According to Ponnamperuma (1964), this problem arises only on bleached sandy soils and muck soils low in active iron. Mitsui (1955) and Desai et al. (1957) have shown that toxic levels of H_2S will not become a problem in most soils due to the formation of FeS. However, when large excesses of sulfides are formed, or the soil is deficient in iron, toxic levels are achieved (Harter 1966).

If comparisons can be made between cultivated rice and wild rice systems, perhaps the limited amount of iron in Lake Josephine's sediments may eventually become inadequate and fail to maintain an Eh level that prevents the excessive formation of sulfate. If sulfur fails to be fixed (i.e. as FeS) and precipitated, as occurs under normal anerobic conditions, sulfates may be released and eventually inhibit the growth of wild rice.

Plant Analysis

Studies conducted by Lee (1977) and Grava (1973) indicate that rice plant tissue contains a high amount of Fe and Mn when compared to other available plant micronutrients. Plant tissue analysis from this study also show a higher nutrient uptake of Mn and Fe, when compared to other available micronutrients (Table 3). However, both elements are within the range of normal internal dry tissue concentrations considered adequate for higher plants (Salisbury and Ross 1978).

Only boron showed significant statistical differences ($p \leq 0.05$), between study sites and fit into the proposed abundance continuum. Boron content was lowest in Lake Josephine's wild rice, averaging 9.7 ppm and greatest in Orrock, averaging 13.3 ppm (Table 3).

Boron content of these wild rice plants may simply be reflective of the boron content of the sediments. Orrock Lake had both the greatest concentration of boron in its sediments and in its rice plants (Table 3). This finding agrees with studies conducted by Boyd and Walley (1972) on cattail and _J. effusus_. In their studies, plants from sites low in boron contained less boron than plants from sites high in boron.

The accumulation of elements from soils by vegetation is complex (Boyd and Hess 1970). Water depth, soil type, pH, etc. probably interact with nutrient levels to influence boron uptake. In fact, Boyd and Walley (1972) indicated that phosphorous is more likely to be a more limiting factor for fresh-water plants than boron. Calcium levels are also known to influence boron uptake (Hewitt 1963). Data on the accumulation of boron in native aquatic vegetation is scarce. However, boron is a proven essential micronutrient for higher plants (Salisbury and Ross 1978)

In this study, the results of plant, sediment, and water analyses were used to understand differences in wild rice production. Significance was attached to those parameters which fit a range of abundance pattern, from bumper crop to failure. The water, sediment, and plant tissue content of the study areas may indicate a possible iron-wild rice relationship.

In flooded calcareous and sodic soils, it is known that cultivated rice may suffer from iron deficiencies (Randahawa et al. 1978). It is also known that cultivated rice has a higher apparent iron requirement than other plants (Lin 1946). According to Oelke, (pers. comm.) iron increases the foliar strength of lab raised wild rice plants and the application of iron chelate improves seedling growth. Continued study however, is needed to verify the importance of iron to the wild rice plant. Quantitative tissue analysis should be performed for aquatics such as wild rice. Such studies might reveal results applicable to native wild rice areas.

LITERATURE CITED

American Public Health Association. 1976. Standard methods for examination of water and wastewater Wash., D.C. 1193pp.

Boyd, C. E. and L. W. Hess. 1970. Factors influencing shoot production and mineral nutrient levels in Typha latifolia. Ecology 55:296-300.

__________ and W. W. Walley. 1972. Studies of the biogeochemistry of boron. 1. Concentrations in surface waters, rainfall, and aquatic plants. Amer. Midl. Nat. 88:1-14.

Connell, W. E. and W. H. Patrick. Jr. 1968. Sulfate reduction in soil: effects of redox potential and pH. Science 159:86-87.

Daubenmire. R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-65.

Desai, A. D., T. S. Rao and L. R. Hirikerur. 1957. Drainage for rice fields - sulfide toxicity. J. Indian Soc. Soil Sci. 5:155-161.

Dore, W. G. 1969. The wild rice plant. Can. Dep. Agric. Plant Res. Inst. Publ. No. 1393. 82pp.

Ferren, W. R. 1977. Habitat, morphology and phenology of southern wild rice (Zizania aquatica L.) from the Wading River in New Jersey. Bull. Torrey Bot. Club 104:392-396.

Gideon, M. M. 1972. Ecology of wild rice plants in the Kenora forest district of Ontario. Minist. Nat. Resour. Ontario, Canada. 70pp.

Grava, J. 1973. Plant nutrients in flooded soils. Fourth Ann. Wild Rice Symp. Bemidgi, Minn. 11pp.

________ and K. A. Raisanen. 1978. Growth and nutrient accumulation and distribution in wild rice. Agron. J. 70:1077-1081.

Harter, R. D. 1966. The effect of water level on soil chemistry and plant growth of the Magee Marsh Wildlife Area. Ohio Game Monogr. 2. 36pp.

Hays, W. L. 1963. Statistics. Holt, Rhinehart and Winston, Inc. New York, N.Y. 719pp.

Hewitt, E. J. 1963. The essential nutrient elements: requirements and interactions in plants. Pages 137-360 in F. C. Steward ed. Plant physiology. Academic Press, New York, N.Y.

Hirai, K. 1950. Scientific consideration of boron in view of soil and manure. Kyushu Univ. Lab. Manure Sci. Rept. 1.

Hutchinson. G. E. 1975. Vol. 3. Limnological Botany. John Wiley, New York, N.Y. 660pp.

Johnson, E. 1976. Elementary statistics. Duxbury Press. North Scituate, Mass. 550pp.

Jeffery, J. W. O. 1961. Defining the state of reduction of a paddy soil. J. Soil Sci. 12:172-179.

Lawrence, D. 1951. Wild rice. Minnesota Nat. 2:24-25.

Lee, P. F. 1975. Water levels as they relate to the production of wild rice (Zizania aquatica L.) on Lake of the Woods. Wild Rice Project. Ontario Minist. of Nat. Resour. 8pp.

________ 1976. Northwestern Ontario wild rice management plan. Ontario Minist. Nat. Resour. 59pp.

________ 1977. Growth performance and selection criteria for waters artificially seeded with wild rice in Northwestern Ontario. Wetland Developing and Consulting Co., LTD. 51pp.

Liegel, E. A., C. R. Simpson and E. E. Schulte. 1980. Wisconsin procedure for soil testing, plant analysis, and feed and forage analysis. Univ. Wis. Madison, Wisconsin. 51pp.

Lin, C. K. 1946. Effect of oxygen and sodium thioglycollate on the growth of rice. Plant Physiol. 21:304-318.

Moyle, J. B. 1944. Minnesota wild rice. J. Wildl. Manage. 8:177-184.

________ 1967. Wild rice-some notes, comments and problems. Minn. Dept. Cons. Div. Game and Fish. Spec. Publ. No. 47. 10pp.

Mitsui, S. 1955. Inorganic nutrition fertilization and soil amelioration for lowland rice. Tokendo Ltd. Tokyo, Japan.

Oborn, E. T. and J. D. Hem 1962. Some effects on the larger types of aquatic vegetation on iron content of water. Geol. Survey Water-Supply Paper 1459-I pp. 237-268.

Patrick, W. H. Jr. and I. C. Mahapatra. 1968. Transformation and availability to rice of nitrogen and phosphorous in waterlogged soils. Adv. Agron. 20:323-359.

____________ and C. N. Reddy. 1978. Chemical changes in rice soils. Pages 361-379 in Soils and rice. International Rice Research Institute. Los Banos, Philippines.

Patnaik, S. 1978. Natural sources of nutrients in rice soils. Pages 501-518. in Soils and Rice. International Rice Research Institute. Los Banos, Philippines.

Ponnamperuma, F. N. 1964. Dynamic aspects of flooded soils and the nutrition of the rice plant. Pages 295-328. in Nutrition of the rice plant. International Rice Research Institute. Los Banos, Philippines.

Randhawa, N. S., M. J. Sinha and P. N. Takkar. 1978. Micronutrients. Pages 581-603. in Soils and rice. International Rice Research Institute. Los Banos, Philippines.

Rogosin, A. 1951. An ecological life history of wild rice. Univ. Minn., St. Paul. Minn, Dep. Bot. 29pp.

_________ 1954. An ecological life history of wild rice. Division of Game and Fish-Fisheries Research Unit. Minn. Dep. Conserv., St. Paul, Minn. 15pp.

Salisbury, F. B., and C. W. Ross. 1978. Plant physiology. Wadsworth Publishing Co. Inc. Belmont, Calif. 422pp.

Steeves, T. A. 1952. Wild rice-Indian food and a modern delicacy. Econ. Bot. 62:107-142.

Stiles, W. 1961. Trace elements in plants. Cambridge Univ. Press. Cambridge, Mass. 249pp.

Stoddard, C. H. 1957. Utilization of swamplands for wild rice production: a progress report. J. of Soil and Water Conserv. 12:135-138.

_________ 1960. Wild rice production from new wetlands. Trans. North Amer. Wildl. and Nat. Resour. Conf. pp144-153.

Takai, Y., T. Koyama and T. Kamura. 1956. Microbial metabolism in reduction process of paddy soil. Part 1. Soil Plant Food. Tokyo, Japan 2:63-66.

Vamos, R. 1958. Inhibition of sulfate reduction in paddy soils. Nature 182:1688.

Wetzel, R. G. 1975. Limnology. W. B. Saunders Co., Philadelphia, PA. 743pp.

Whigham, D. and R. Simpson. 1977. Growth, mortality and biomass partitioning in freshwater tidal wetland populations of wild rice (Zizania aquatica var. aquatica) Bull. Torrey Bot. Club. 104:347-351.

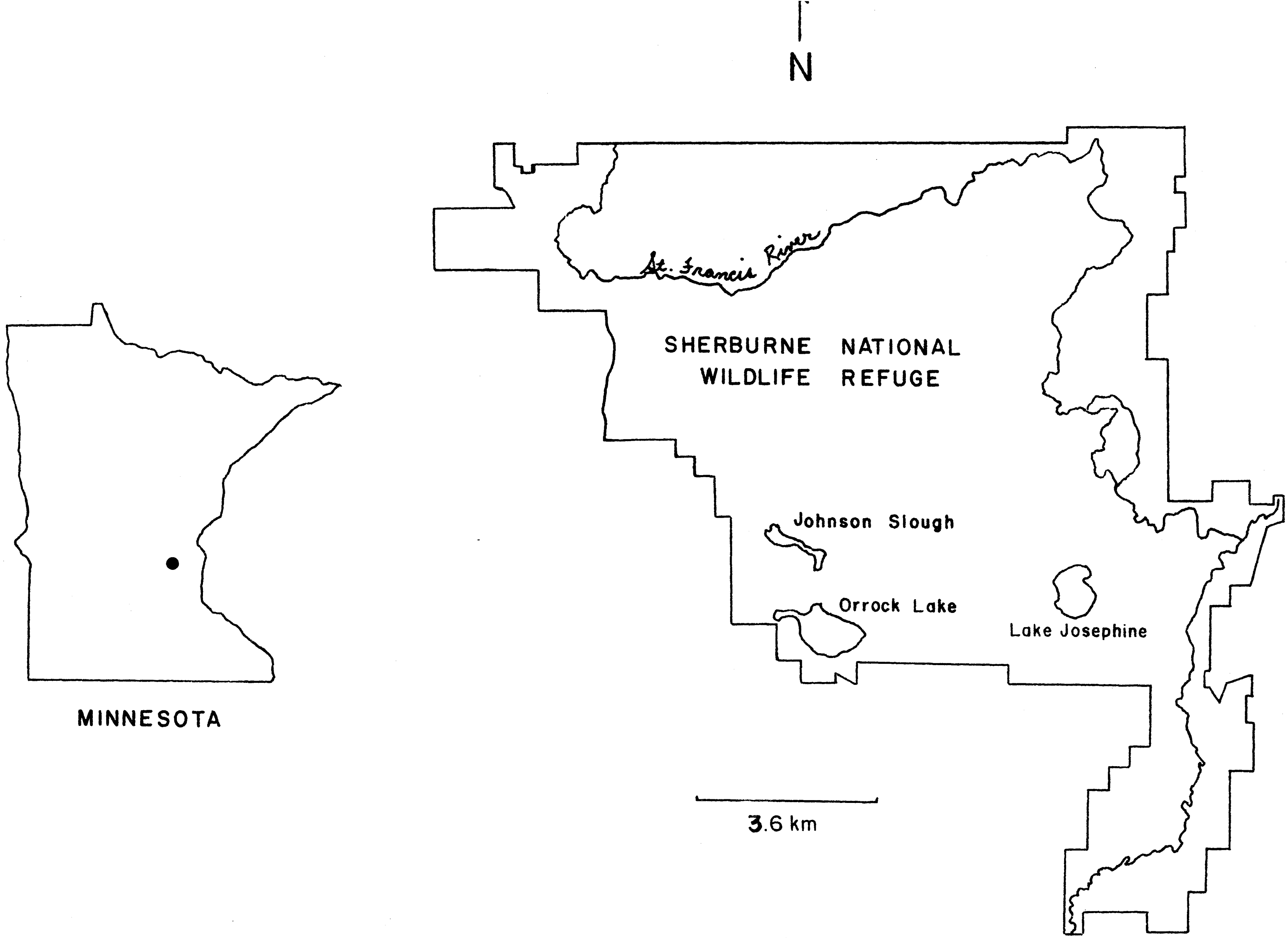

Fig. 1. Location of the 3 primary study sites on the Sherburne National Wildlife Refuge.

Table 1. Chemical characteristics of water collected from Lake Josephine, Johnson Slough, and Orrock Lake, Sherburne National Wildlife Refuge, June-October 1980-1981.

	Location					
	Josephine		Johnson		Orrock	
Parameter[a]	1980	1981	1980	1981	1980	1981
pH	8.95	7.85	9.0	7.87	8.67	9.37
	---- ppm ----		---- ppm ----		---- ppm ----	
alkalinity	155[b]	150[c]	113[b]	144[c]	107	90[c]
total hardness	164[b]	158[c]	121[b]	150[c]	116	93[c]
SO4	<0.04	3.63[c]	<0.05	2.56[c]	<0.05	1.35[c]
Fe	1.35[b]	0.98	0.46[b]	0.79	0.27[b]	0.74
	N=12	N=20	N=16	N=20	N=20	N=30

[a]All significant differences show a range of abundance relationship - i.e. Lake Josephine and Orrock Lake represent 2 end points, and Johnson Slough is intermediate.

[b]($p \leq 0.05$) 1980

[c]($p \leq 0.05$) 1981

Table 2. Chemical characteristics of sediments collected from Lake Josephine, Johnson Slough, and Orrock Lake, Sherburne National Wildlife Refuge, October 1980 and 1981.

		Location					
		Josephine		Johnson		Orrock	
Parameter	Measurement Unit	1980	1981	1980	1981	1980	1981
pH	-	7.0	7.7	6.1	6.1	6.7	7.6
O.M.	kg/ha	327	280	296	280	297	280
B	ppm	1.5[a,b]	1.2[c]	1.7[a]	1.8[c]	2.0[a,b]	1.3[c]
NH_4-N	ppm	48.2[a,b]	22.6	53.8[a]	19.9	96.3[a,b]	22.7
Fe	ppm	-	23[c]	-	2856[c]	-	2497[c]
		N=7	N=7	N=5	N=5	N=8	N=8

[a]Denotes significant difference ($p \leq 0.05$) as determined by ANOVA analysis and also shows a range of abundance relationship - i.e. Lake Josephine and Orrock Lake represent 2 end points, and Johnson Slough is intermediate.

[b]Denotes significant difference ($p \leq 0.05$) as determined by Scheffe post-hoc analysis.

[c]Denotes significant difference ($p \leq 0.05$) as determined by ANOVA analysis, however no continuum relationship exists.

Table 3. Plant nutrient concentrations from Lake Josephine, Johnson Slough, and Orrock Lake, Sherburne National Wildlife Refuge, 23 July-4 August 1981.

Nutrients	Josephine	Location Johnson	Orrock
N ($\bar{x}$ % dry wt)	4.03	4.14	4.41
P	0.37	0.37	0.39
K	1.68	1.78	1.83
Ca	0.57	0.57	0.65
Mg	0.12	0.11	0.15
S	0.26	0.28	0.29
Na	0.05	0.07	0.12
B ($\bar{x}$ ppm)	8.9[a]	9.7[a]	13.3[a]
Mn	230	156	133
Fe	154	254	171
Cu	3.05	2.90	3.20
Al	68.5	68.2	85.4
Zn	14	18	16
	N=80	N=40	N=60

[a]Denotes significant difference ($p \leq 0.05$) and shows a range of abundance relationship - i.e. Lake Josephine and Orrock Lake represent 2 extremes, and Johnson Slough is intermediate.

THE EFFECTS OF TRADITIONAL WILD RICE HARVESTING ON A WILD RICE MARSH

GENEVIEVE T. FANNUCCHI, College of Natural Resources, University of Wisconsin - Stevens Point, WI. 54481
WILLIAM A. FANNUCCHI, College of Natural Resources, University of Wisconsin - Stevens Point, WI. 54481
LYLE E. NAUMAN, College of Natural Resources, University of Wisconsin - Stevens Point, WI. 54481

Abstract: The effects of traditional hand harvesting on a wild rice (*Zizania aquatica*) bed was studied. Based on stem density measurements Lake Josephine was divided into 2 equal sections. Hand harvesting was limited to 1 section during 1980 and 1981. A comparison between 1980 and 1981 seed production shows a 37% or greater decline in the number of seeds/head, the average number of seeds harvested, and the estimated number of seeds available for germination and wildlife consumption throughout the marsh. Increases were seen in the average weight of seeds/100 and the estimated number of non-viable seeds in the marsh. The average number of seeds/head prior to harvest showed no significant difference ($p \leq 0.01$) between the 2 marsh sections during 1980 and 1981. The average number of seeds/head from each section, compared between years, were significantly lower (t test, $p \leq 0.01$) throughout the marsh in 1981. During both years the amount of wild rice removed by harvesting represented a small percentage of the wild rice available. In 1980, 14% of the available wild rice (harvest section) was removed. In 1981, 10% was harvested. Based on seed production estimates, the hand harvesting of wild rice on Lake Josephine appears to have had no severe impact on future stand reseeding.

Wild rice grows throughout the eastern half of the United States and adjoining portions of Canada (Hitchcock 1971). According to Libertus (1981), when water levels are favorable, a possible 12,100 ha containing 200-400 harvestable stands of natural wild rice, exist in Minnesota. In northwestern Ontario, when conditions are favorable, an estimated 10,700 ha of wild rice exist (Lee 1976).

Wild rice is a native North American plant valued both as a waterfowl food and as a lucrative agricultural crop (Moyle 1944, Neilson 1964, Stoddard 1957). An estimated 1,135,000 kg of native Minnesota wild rice was harvested in 1980, having a potential value of $11,250,000.00 (Libertus 1981). In Canada, the 1973 value of unprocessed rice from just the Lake of the Woods (Ontario) was estimated at $1,000,000 (Lee 1976).

Extensive harvesting of wild rice has been carried on for 300 to 500 years by the Algonquian and Sioux tribes (Edman 1969). According to Moyle (1942, 1967), some Minnesota stands have existed for more than 300 years and have been harvested for over 100 years. Despite the long history of wild rice harvesting, concern about the effects of traditional harvesting on wild rice beds dates back to Jenks (1898), who maintained that it was necessary to constantly reseed stands to prevent their extermination by harvesters. Moyle (1942) has stated that traditional wild rice harvesting, as practiced by native Americans has had little or no effect on wild rice stands. Lawerence (1951) states that the traditional method of harvesting neither endangers the crop nor interferes with the nutrition of waterfowl.

Various authors have estimated the percent of wild rice actually taken by hand harvesting. Dore (1969) estimates that 50% of the grain is taken, the remainder falling back into the water to become seed for next years stand. According to Moyle (1944), as little as 10% of the crop maybe taken by hand harvesting. Lawerence (1951) hypothesizes that not more than 20% of the crop is harvested.

Little experimental work has been done to quantify the production of a natural wild rice stand. The effects of harvesting on the reseeding potential of a rice bed, the percent of seed actually taken by traditional harvesting, and the percent of seed left for wildlife usage has not been determined.

In recent years a conflict has arisen as to whether to preserve the wild rice resource on the Sherburne National Wildlife Refuge (Minnesota) for the exclusive use by wildlife, or to allow harvesting of this valuable crop. The following paper presents a limited quantitative look at the impacts of traditional wild rice harvesting on a natural wild rice stand, and attempts to determine whether hand harvesting has an effect on the following years stand.

STUDY AREA

The study was conducted on Lake Josephine, a 59 ha shallow water marsh located on the Sherburne National Wildlife Refuge, Sherburne Co., Minnesota. Water control structures exist both to the north of the lake and at the lake's outlet. A 14 ha wild rice stand exists on Lake Josephine, surrounded by a predominantly cattail (*Typha latifolia*) mat.

METHODS

Wild rice density in Lake Josephine was determined during July 1980 and 1981. Thirteen transects were established across the width of the wild rice bed. Two $0.1m^2$ rectangular sample plots (Daubenmire 1959) were examined every 30 meters to determine both density and vegetative cover (N=236, 1980; N=219, 1981). Similar methods were used by Whigham and Simpson (1977), on 8 populations of wild rice in New Jersey.

One of the principal causes of wild rice stand failure is high water levels during May and June (Moyle 1944). In order to eliminate such problems, Lake Josephine was maintained at an average depth of 58 cm during the study period. Preferred water levels for wild rice range from 30-92 cm (Moyle 1944).

To evaluate the effects of hand harvesting, Lake Josephine was divided into 2 equal portions. Based on 1980 density measurements, a harvest and a non-harvest section, having similar densities, was established (Fig. 1). The dividing boundary consisted of 26 3 m posts spaced at approximately 30.5 m intervals. The posts were connected by streamered fishing line.

To assess harvesting impact on the amount of seed potentially available for germination and wildlife consumption, seed heads were removed from 80 $0.1m^2$ sample plots during 1980 and 1981. Each year 20 sample plots per section were examined prior to and immediately after the final harvest was completed. Seed head sample sites were located near accessible boundary posts. Samples were taken 3.5 m from each post. The number of seeds/head, the amount of development per head and general seed head conditions, were determined for each sample.

Six harvests were conducted in 1980 from 29 August-14 September, and 4 harvests during 1981 from 6 September-15 September. Experienced rice harvesters using traditional methods (Dore 1969, Hofstrand 1970, Steeves 1952, Sokolov 1981), harvested from 1000 to 1400 h, with 2 to 4 day resting intervals between harvests. Rice boat densities varied from 1 boat/1.9 ha to 1 boat/4.3 ha. All "green" (unprocessed) rice removed was weighed at the field site.

To assess wild rice seed production during 1980 and 1981, the following parameters needed to be determined:

1. the average number of seeds/head
2. the average weight of seeds/100
3. the average number of stems/m^2
4. the average number of seeds/m^2
5. the estimated number of seeds in the marsh
6. the estimated number seeds/section
7. the estimated number of non-viable seeds/section
8. the estimated number of seeds available for harvest
9. the estimated number of seeds harvested
10. the estimated number of seeds available for germination and wildlife consumption/section

Seed head samples (N=1360, 1980; N=1067, 1981) were used to determine the average number of seeds/head. Seeds were individually counted and the number of non-viable seeds per head, (i.e. ergot (*Claviceps zizaniae*) infected, depredated, sterile and partially developed) per sample was recorded. The number of viable seeds, (i.e. fully developed, hard and green), was also recorded. Seed weight/100 seeds (N=186, 1980; N=124, 1981) including hulls and awns was determined after each harvest. Sample size was calculated using a formula for sampling intensity without presampling $n=(s/s_x)^2$ (Freese 1963). The average number of stems/m^2 was determined using the density techniques previously mentioned. Equations used to determine parameters 5-10 can be found in Table 1.

To determine the effects of harvesting on Lake Josephine's rice stand, the average number of seeds/head collected prior to harvest during both years were computed. A t-test and pooled t (Johnson 1976) were used to determine if any statistical difference existed between sections, and between years for each section. The average number of non-viable seeds/head collected post harvest during the study, were also computed using the same statistical tests. Non-viable seeds/head were analyzed to see if causes other than harvesting could have influenced yields.

RESULTS AND DISCUSSION

Refuge narratives indicate that no wild rice existed in Lake Josephine during 1979. The past occurrence of wild rice on Lake Josephine is irregular (Table 2). This however, is not unusual for a wild rice bed. According to Moyle (1942), although the rice crop exhibits no regular cyclic behavior, it fails on the average once every 3 or 4 years. Bumper crops are not recorded as occurring in successive years (Moyle 1942).

Bumper crops (i.e. high yields) did not occur in Lake Josephine during both 1980 and 1981. Although the number of stems/m^2 were not significantly different ($p \leq 0.01$) during the study period, the average number of seeds/head and the amount of rice harvested declined. The causes of yield reduction in years following a bumper crop of wild rice may involve overseeding and lodging. Moyle (1942) suggests that overseeding and excessive production of straw, from a dense stand of wild rice, may reduce the following years crop. Many of Lake Josephine's 1981 rice seedlings were shallowly rooted in the previous years rice straw. As they grew, toppling or lodging occurred. According to Larson and Maranville (1977), lodging decreases the yields of many small grains. It is known that lodging, which occurs prior to heading in wheat (*Triticum aestivum*), reduces the kernel number per spike (Laude and Pauli 1956).

Density measurements alone are not an effective means of determining the potential yield of wild rice. According to Black and Aase (1982), grain yield is based on the number of heads/unit area, the number of kernels/head, and kernel weight. Calculations used to estimate the 1980 and 1981 seed production of rice in Lake Josephine were based on the average number of stems/m^2, the average number of seeds/head, and the average weight of seeds/100. A comparison between 1980 and 1981 seed production shows a 37% or greater decline in the number of seeds/head, the average number of seeds/m^2, the estimated number of seeds harvested, and the estimated number of seeds available for germination and wildlife consumption throughout the marsh (Table 3). The areas not impacted by wild rice harvesting also showed a seed decline (Table 3). Increases were seen in the average weight of seeds/100 and the estimated number of non-viable seeds in the marsh (Table 3).

The average number of seeds/head prior to harvest showed no significant difference ($p \leq 0.01$) between the 2 marsh sections during 1980 and 1981 (Table 4). However, yield and the average number of seeds/head declined throughout the marsh in 1981 (Table 3); and when seed head production from each section was compared between years, the average number of seeds/head was significantly lower ($p \leq 0.01$) in 1981 (Table 4). The decrease in seed production in Lake Josephine during 1981 was not due to harvesting, since the yield on each side remained relatively equal. Based on seed production estimates, the hand harvesting of wild rice on Lake Josephine does not reduce subsequent stands. During both years the amount of rice removed by harvesting, represented only a small percentage of the rice available. In 1980, 14% of the available wild rice (harvest section) was removed (Table 5). In 1981, 10% was harvested (Table 5).

Competition for nutrients due to high natural seeding rates, may prove to be more important than impacts due to traditional harvesting. According to Rogosin (1958), high seeding densities may create competition for available nutrients and light, ultimately inhibiting the rate of growth and grain filling of wild rice. Estimated seeding densities from 1980 were high, averaging 2181 kg/ha. A seeding rate of 98 kg/ha of quality wild rice seed is recommended for paddy or field cropped wild rice (Oelke and Elliott 1978). Grain yields of cultivated rice (*Oryza sativa*) have been shown to be adversely affected by seeding rates of 135-303 kg/ha (Wells and Faw 1978). In fact, they state that in dense populations of cultivated rice, excessive growth prior to anthesis limits grain yield, because of competition for the remaining available nutrients.

The following year's rice stand can also be affected by the number of non-viable seeds produced, since these seeds are unlikely to germinate. The estimated number of non-viable seeds/section increased 19% in the harvest section and 45% in the non-harvest section during the study period (Table 3). Post harvest analysis of the average number of non-viable seeds/head showed no significant difference ($p \leq 0.01$) between the 2 marsh sections during 1980, however, non-harvest sections were significantly different between years ($p \leq 0.01$) (Table 4). The number of partially developed post harvest grains increased 29%, and the amount of sterile grains increased 33% in the non-harvest section from 1980 to 1981 (Table 4). Although the harvest section showed no change either year (Table 4), both sections may actually be more similar than they appear, since hand harvesting dislodged non-viable seeds.

All pistillate florets do not produce viable grains. In fact, 80% grain sterility has been recorded in some Canadian wild rice areas (Dore 1969). Floret sterility may be associated with pollination and fertilization problems due to weather, or to the late season production of secondary panicles (Dore 1969). According to Sata and Takohashi (1971), as cited in Evans and Wardlaw (1976), high temperatures shorten the duration of grain filling in cultivated rice to such a point that grain yields are reduced, and carbohydrate reserves are left in the plant. However, a confident answer to what causes grains to suddenly stop growing doesn't exist for any cereal (Evans and Wardlaw 1976).

Although seeding density, competition for nutrients, grain condition, and temperature may effect wild rice yields, actual yield is determined during harvest. Accurately estimating the proper time for harvesting natural stands of wild rice is a judgement call, and opinions often differ. According to Neilsen (1964), harvesting should commence when the green kernels are fairly firm and ripened black kernels exist on the top of the spike. Maximum yield of processed field grown wild rice occurs when 35-40 percent of the kernels are dark rather than green in color (Oelke et al. 1982).

Wild rice seed heads ripen over a 10 day period, with grains falling as they ripen (Moyle 1944). Stands are usually hand-harvested several times during the ricing period. A 1 to 2 day resting interval usually occurs between harvests, allowing the remaining grains to ripen. Dore (1969) states that prematurely shed seeds generally do not germinate.

Harvesting must coincide with maximum seed head ripening to insure that the bed is reseeded with viable seeds. If a rice bed is continuously harvested before adequate seed head ripening has occurred, over a period of years, the germination of that rice stand may be adversely affected. Steeves (1952) states that prior to the establishment of the Commissioner of Conservation in Minnesota, rice stands began to decline. According to Steeves (1952), as wild rice harvesting became more profitable, competition for the grain increased and harvesters went into the rice beds too early. The grains which fell during the harvest, normally serving for reseeding, were not ripe enough to germinate (Steeves 1952).

Although wild rice harvesting did not seem to effect seed bed germination in Lake Josephine, not all native stands should be harvested. Distinctions should be made between the wild rice harvest and the wild rice resource. Proper wild rice management should insure the continuance of the resource. Since wild rice is an annual, its persistance depends on yearly reseeding. Properly timed harvesting should result in the adequate reseeding of a stand with viable seed. Hand harvesting should be allowed on healthy stands of wild rice. Newly seeded areas, poorly germinating beds or stands in which lodging is severe should not be opened to harvesting. Sufficient grain for bed reseeding will be produced during the years when hand harvesting is not conducted.

LITERATURE CITED

Black, A. L. and J. K. Aase. 1982. Yield component comparisons between USA and USSR winter wheat cultivars. Agron. J. 74:436-441.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33:43-65.

Dore, W. G. 1969. The wild rice plant. Can. Dep. Agric. Plant Res. Inst. Publ. No. 1393. 82pp.

Edman, F. R. 1969. A study of wild rice in Minnesota. Minn. Res. Comm. Rep. Upper Great Lakes Regional Commission. 56pp.

Evans, L. T. and I. F. Wardlaw. 1976. Aspects of the comparative physiology of grain yield in cereals. Adv. Agron. 28:301-359.

Fresse, F. 1963. A guidebook for statistical transients. Southern Forest Exp. Sta. U. S. Dep. Agric. 77pp.

Hitchcock, A. S. 1971. Manual of the grasses of the United States. Dover Publications Inc., New York, N.Y. 1051pp.

Hofstrand, R. H. 1970. Wild ricing. Nat. Hist. 79:50-55.

Jenks, A. E. 1898. The wild rice gatherers of the upper lakes. Ann. Rep. Bur. of Am. Ethology (Smithsonian Inst.) 19:1019-1131.

Johnson, R. R. 1976. Elementary statistics. Wadsworth Publ. Co., Inc., Belmont, Calif. 550pp.

Larson, J. C. and J. W. Maranville. 1977. Alterations of yield, test weight and protein in lodged grain sorghum. Agron. J. 69:629-630.

Laude, H. H. and A. W. Pauli. 1956. Influence of lodging on yield and other characteristics of winter wheat. Agron. J. 48:452-455.

Lawerence, D. 1951. Wild rice. Minnesota Nat. 2:24-25.

Lee, P. F. 1976. Northwestern Ontario wild rice management plan. Ontario Minist. Nat. Resour. 59pp.

Libertus, R. 1981. Wild rice. Minnesota DNR Commissioners Rep. 2pp.

Moyle, J. B. 1942. The 1941 Minnesota wild rice crop. Fisheries Res. Invest. Rep. No. 40. Bureau of Fisheries Res. Div. of Fish and Game. 59pp.

__________ 1944. Minnesota wild rice. J. Wildl. Manage. 8:177-751.

__________ 1967. Wild rice - some notes, comments and problems. Minn. Dept. Conserv. Div. Game and Fish. Spec. Publ. No. 47. 10pp.

Neilson, J. D. 1964. Wild rice identification and propagation in Northern Saskatchewan. Agricultural Rep. 3371. Prince Albert, Saskatchewan. 13pp.

Oelke, E. A. and W. A. Elliott. 1978. Seeding time, method and rate for wild rice grown as a field crop. Agron. Fact Sheet No. 33 Agric. Ext. Serv. Univ. Minn. 2pp.

__________, J. Grava, D. Noetzel, D. Barron, J. Percich, C. Schertz, J. Strait, R. Stucker. 1982. Wild rice production in Minnesota. Univ. Minn. Agric. Ext. Bull. 464. 38pp.

Rogosin, A. 1958. Wild rice growth and production in relation to water level, seeding density and fertilizer application in northern Minnesota, a progress report. Dept. of Botany. Univ. Minn., Minneapolis. 13pp.

Sokolov, R. 1981. The taming of the grain. Nat. Hist. 90(1):98-102.

Steeves, T. A. 1952. Wild rice - Indian food and a modern delicacy. Econ. Bot. 62:107-142.

Stoddard, C. H. 1957. Utilization of swamplands for wild rice production: a progress report. J. Soil and Water Conserv. 33:135-138.

Wells, B. R. and W. F. Faw. 1978. Short-statured rice response to seeding and N rates. Agron. J. 70:477-480.

Whigham, D. and R. Simpson. 1977. Growth, mortality and biomass partitioning in freshwater wetland populations of wild rice (Zizania aquatica var. aquatica). Bull. Torrey Bot. Club 104:347-351.

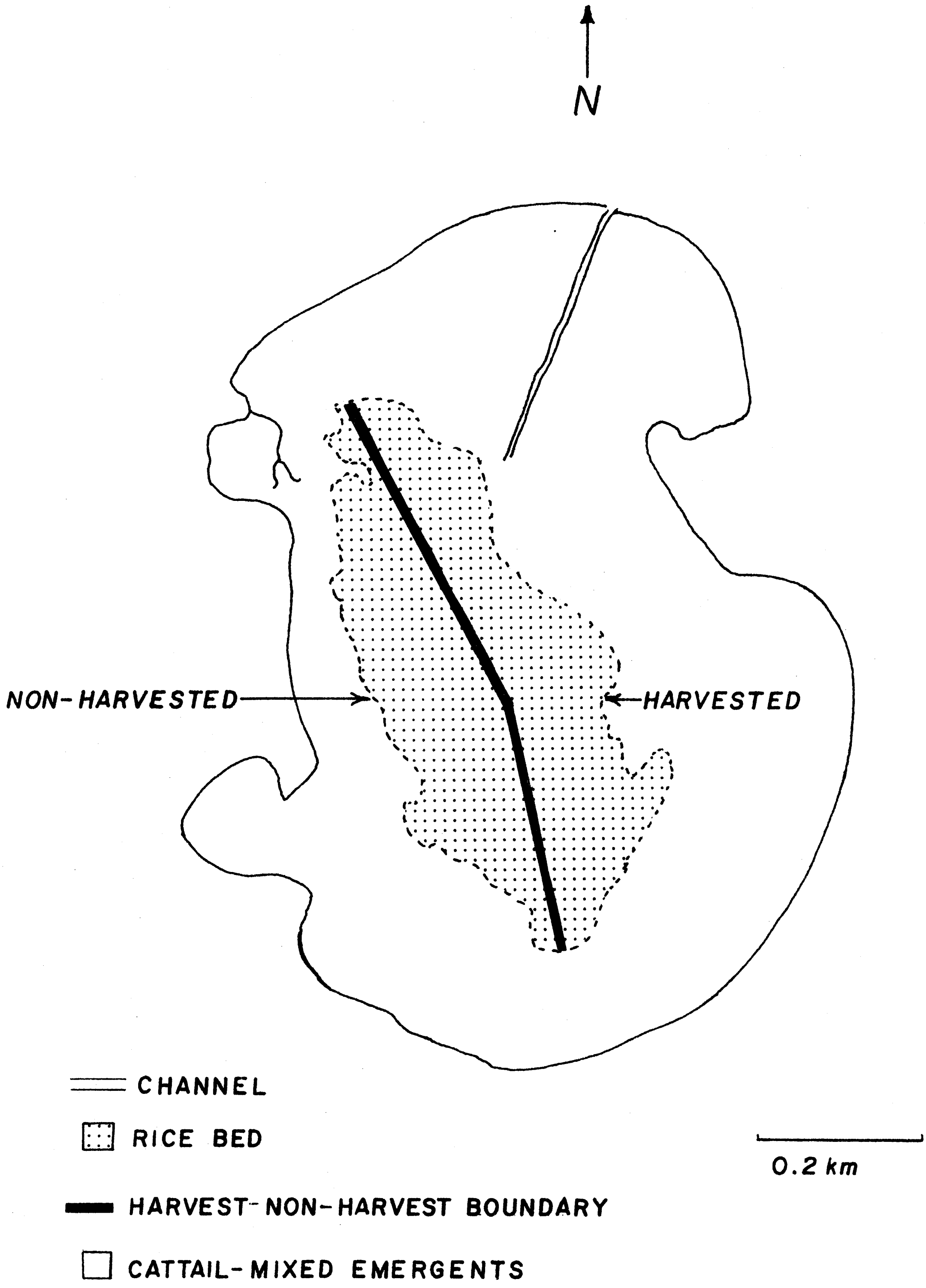

Fig. 1. Location of harvest/non-harvest sections on Lake Josephine, Sherburne National Wildlife Refuge - Fall 1980-1981.

Table 1. Equations used to assess wild rice seed production in Lake Josephine, Sherburne National Wildlife Refuge, 1980 and 1981.

1.	(5)[a]	(m^2 in Lake Josephine) x (average number of stems/m^2) = average number of stems in Lake Josephine (average number of stems in Lake Josephine) x (average number of seed/stem or head) = estimated number of seeds in Lake Josephine
2.	(6)	estimated number of seeds/section = (estimated number of seeds in Lake Josephine) / 2
3.	(7)	(% of non-viable seeds/section) x (estimated number of seeds/section) = estimated number of non-viable seeds/section
4.	(8)	(estimated number of seeds/section) - (estimated number of non-viable seeds/section) = estimated number of seeds available/section
5.	(9)	(total harvested weight) / (average weight of seeds/100) = the estimated number of seeds harvested
6.	(10)	the estimated number of seeds available for germination and wildlife consumption/section = (the estimated number of seeds available for harvest) - [(the estimated number of non-viable seeds/section + the estimated number of seeds harvested (only applicable to the Harvest Section))]

[a]Number in parenthesis refers to parameter indicated in paper.

Table 2. Past occurrence of wild rice on Lake Josephine, Sherburne National Wildlife Refuge, 1965-1981.

Year	Condition of wild rice stand
1965[a]	no rice
1966	average
1967	poor
1968	heavy
1969	good[b]
1970	no rice
1971	good
1972	no rice
1973	present
1974	present
1975	--[c]
1976	--
1977	sparse
1978	scattered along edges
1979	--
1980[d]	52 stems/m^2
1981[d]	49 stems/m^2

[a]Data from 1965-1979 based on subjective estimates obtained from refuge narrative reports.

[b]Seed heads did not fill out, so what appeared good was an average to poor crop.

[c]- Indicates no record.

[d]Data from present study.

Table 3. Seed production of wild rice on Lake Sherburne National Wildlife Refuge, 1980 and 1981.[a]

	Year 1980	1981	% Change
Number of seeds/head[b]	140	88	(-)37
Weight of seeds/100[c]	2.99 gm	3.50 gm	(+)15
Number of stems/m^2	52	49	(-) 6
Number of seeds/m^2	7280	4312	(-)43
Number of seeds in Lake Josephine	*1.1×10^9/31,413 kg	6.2×10^8/21,779 kg	(-)31
Number of seeds/section[d]	5.2×10^8/15,706 kg	3.1×10^8/10,899 kg	(-)31
Number of non-viable seeds/section[e]			
HARVEST	4.7×10^7/1413 kg	5.0×10^7/1743 kg	(+)19
NON-HARVEST	4.2×10^7/1256 kg	6.6×10^7/2288 kg	(+)45
Number of seeds available/section			
HARVEST	4.8×10^8/14,293 kg	2.6×10^8/9155 kg	(-)36
NON-HARVEST	4.8×10^8/14,450 kg	2.5×10^8/8610 kg	(-)40
Number of seeds harvested	6.4×10^7/1922 kg	2.5×10^7/874 kg	(-)55

Table 3. cont.

	Year		
	1980	1981	% Change
Number of seeds available for germination and wildlife consumption/section HARVEST	3.7×10^8/10,957 kg	1.9×10^8/6537 kg	(-)40
NON-HARVEST	4.4×10^8/13,194 kg	1.8×10^8/6321 kg	(-)52

[a]Based on the average number of seeds collected both prior to and post harvest, unless stated otherwise.

[b]N=1360, 1980: N=1067, 1981.

[c]Based on seed samples (N=186, 1980; N=124, 1981) collected after each harvest.

[d]Both sections assumed equal, based on 1980 density.

[e]Based on the average % of sterile, depredated, ergot infected and partially developed seeds examined post harvest/section.

*Values for the numbers of seeds represented in scientific notation have been rounded.

Table 4. Wild rice seed head analysis on Lake Josephine, Sherburne National Wildlife Refuge, 1980 and 1981.

Year(s)	Sections	Ave. # of seeds/head[a]	Ave. # of non-viable seeds/head[b]	Ave. # of partially developed seeds/head[b]	Ave. # of sterile seeds/head[b]
1980	Harvest/ Non-harvest	130/153	12/13	9/10	3/2
1981	Harvest/ Non-harvest	92/77	14/23*	9/14	3/6
1980/ 1981	Non-harvest/ Non-harvest	153/77*	13/23*	10/14	2/6
1980/ 1981	Harvest/ Harvest	130/92*	12/14	9/9	3/3

[a]Based on prior to harvest seeds heads: N = 772; 1980, N = 526; 1981.

[b]Based on post harvest seeds heads: N = 588; 1980, N = 541; 1981.

*Significant difference ($p \leq 0.01$).

Table 5. Percent utilization of wild rice per harvested/non-harvested sections and throughout Lake Josephine on the Sherburne National Wildlife Refuge, 1980 and 1981.

Year	Section	% Harvested	% of non-viable diseased or depredated seed[a]	% available for germination and wildlife consumption
1980	Harvest	14	9	84
	Non-harvest	--	8	92
	Throughout the marsh	7	9	84
1981	Harvest	10	16	74
	Non-harvest	--	21	79
	Throughout the marsh	5	19	76

[a]Based on analysis of post harvest seeds and determined for each section separately.

APPENDICES

Appendix A. Water gauge readings for Lake Josephine, Sherburne National Wildlife Refuge, 1980.

Date	Water level[a] (m)
22 July	0.591
24 July	0.591
29 July	0.591
2 August	0.582
7 August	0.670
8 August	0.755
14 August	0.731
19 August	0.822
22 August	0.844
25 August	0.853
1 September	0.932
24 September	1.024
26 September	0.920
6 October	0.701
11 October	0.667
15 October	0.652
26 October	0.649
31 October	0.673
1 November	0.641

[a]0.00 gauge reading = 290.81 m above mean sea level.

Appendix B. Water gauge readings for Johnson Slough, Sherburne National Wildlife Refuge, 1980.

Date	Water level (m)
29 June	2.63
17 July	2.54
3 August	2.45
11 August	2.53
27 August	2.54
7 September	2.57
9 October	2.64
10 October	2.64

Appendix C. Water gauge readings for Orrock Lake, Sherburne National Wildlife Refuge, 1979-1980.

Year	Date	Water level[a] (m)
1979	8 June	2.96
	10 July	2.98
	26 July	2.85
	21 August	2.89
	18 September	2.91
	3 October	2.88
	17 October	2.85
	29 October	2.89
1980	5 June	2.95
	8 June	2.93
	14 June	2.90
	25 June	2.79
	23 July	2.70
	29 July	2.69
	18 August	2.74
	28 August	2.74
	31 August	2.76
	11 September	2.84
	25 September	2.84
	1 October	2.85
	7 October	2.85
	15 October	2.85
	27 October	2.85
	31 October	2.84

[a]0.00 gauge reading = 293.81 m above mean sea level.

Appendix D. Water gauge readings for Lake Josephine, Sherburne National Wildlife Refuge, 1981.

Date	Water level[a] (m)
3 June	0.725
4 June	0.725
10 June	0.744
14 June	0.914
15 June	0.920
16 June	0.877
19 June	0.780
24 June	0.829
27 June	0.822
2 July	0.792
7 July	0.908
28 July	0.822
10 August	0.810
17 August	0.786
23 August	0.774
25 August	0.841
27 August	0.896
5 September	0.990
6 September	0.990
8 September	0.774
13 September	0.932
16 October	0.569
19 October	0.609
25 October	0.566
28 October	0.566

[a]0.00 gauge reading = 290.81 m above mean sea level.

Appendix E. Water gauge readings for Johnson Slough, Sherburne National Wildlife Refuge, 1981.

Date	Water level (m)
11 June	3.38
16 June	3.57
26 June	3.56
10 July	3.47
16 July	3.57
22 July	3.53
24 July	3.53
29 July	3.51
4 August	3.51
17 August	3.52
21 August	3.51
27 August	3.58
3 October	3.54
6 October	3.46
14 October	3.54

Appendix F. Water gauge readings for Orrock Lake, Sherburne National Wildlife Refuge, 1981.

Date	Water level[a] (m)
4 June	2.60
8 June	2.60
9 June	2.60
10 June	2.61
16 June	2.72
26 June	2.73
3 July	2.68
9 July	2.63
17 July	2.68
24 July	2.65
27 July	2.62
13 August	2.60
28 August	2.62
30 August	2.62
18 September	2.56
24 September	2.56
4 October	2.56
13 October	2.60
23 October	2.63
28 October	2.63
31 October	2.62

[a]0.00 gauge reading = 293.81 m above sea level.

Appendix G. Secchi disk readings from Orrock Lake, Sherburne National Wildlife Refuge, 4 June 1980.

Station	Secchi disk transparency[a] (cm)	Water depth (cm)
1[b]	45.0	97.0
2[b]	61.0	70.0
3[b]	63.0	90.0
4	78.5	84.0
5	73.5	105.0
6	73.5	88.0
7[c]	60.0	84.0
8	63.5	100.0
9	56.5	100.0
10	57.5	96.0
11	67.5	105.0
12	64.5	111.0
13	65.0	110.0
14	73.5	87.0
15	51.0	82.0
16	61.0	105.0
17	71.0	115.0
18[c]	62.5	116.0
19	69.5	104.0
20	65.5	109.0
21	61.0	100.0
22	56.0	102.0
23	57.0	107.0
24	56.0	89.0
25	53.0	97.5
26	50.0	107.5
27	49.0	110.0
28	49.0	91.5
29	53.0	118.5
30	58.5	93.5
31	49.0	99.5
32	45.5	102.0
33	52.5	98.0
34	48.0	92.0
35	57.0	101.5
36	46.0	104.0

[a]Zone of light penetration down to approximately 5% of the solar radiation reaching the surface.
[b]East bay.
[c]West bay.

Lack of notation indicates remainder of lake.

Appendix G. (continued).

Station	Secchi disk transparency[a] (cm)	Water depth (cm)
37	46.0	105.5
38	52.0	95.0
39	49.5	122.0
40	51.0	116.0
41	51.5	100.0
42	52.5	80.0
43	46.0	112.0

Appendix H. Water quality data collected from 3 sample points on Lake Josephine, Sherburne National Wildlife Refuge, 30 June-21 October 1980.

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Reactive P	Total P	NH_4	NO_2-NO_3	TKN	SO_4	Fe
			ppm									
30 June												
1	7.95	230	133	145	10.20	0.030	0.125	0.08	<0.02	2.04	<0.5	-[a]
2	9.52	150	84	98	10.00	0.010	0.050	0.02	<0.02	1.60	<0.5	-
3	9.85	149	86	99	10.20	0.130	0.235	0.02	<0.02	1.96	<0.5	-
5 Aug.												
1	7.21	234	130	146	10.20	0.040	0.065[b]	0.14	<0.05	1.52[b]	0.5[b]	-
2	7.05	244	140	146	0.5[b]	0.031	0.730[b]	0.26	<0.05	>4.00[b]	5.0[b]	-
3	7.04	345	188	204	2.6[b]	0.032	1.00[b]	0.15	<0.05	>4.00[b]	9.5[b]	-
7 Sept.												
1	7.34	203	176	186	5.4	0.032	0.130	0.04	<0.02	1.58	<0.5	1.10
2	7.66	97	169	184	7.2	0.015	0.070	0.02	<0.02	1.56	<0.5	0.7
3	7.44	290	154	164	6.1	0.010	0.080	0.01	<0.02	1.52	<0.5	0.55
21 Oct.												
1	7.43	361	188	188	11.82	0.007	0.165	0.08	0.02	4.20	<0.5	2.85
2	7.71	371	194	194	12.83	0.020	0.165	1.32	0.02	4.48	<0.5	1.75
3	7.87	400	212	210	12.12	0.020	0.140	0.86	0.02	3.68	<0.5	1.15

[a]Parameter not sampled.
[b]Data questionable due to high amounts of particulate matter in samples.

Appendix I. Water quality data collected from 4 sample points on Johnson Sough, Sherburne National Wildlife Refuge 30 June-21 October 1980.

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Reactive P	Total P	NH_4	NO_2-NO_3	TKN	SO_4	Fe
			ppm									
30 June												
1	7.33	165	95	103	13.67	0.005	0.025	0.12	<0.02	1.10	<0.5	-[a]
2	9.09	145	97	91	10.40	0.002	0.025	0.04	<0.02	1.16	<0.5	-
3	9.75	128	75	83	9.33	0.002	0.020	0.06	<0.02	1.12	<0.5	-
4	9.76	124	73	82	11.53	0.002	0.025	0.04	<0.02	1.14	<0.5	-
5 Aug.												
1	7.50	216	120	126	8.90	0.010[b]	0.295[b]	0.04	<0.05	>2.00[b]	7.6[b]	-
2	9.26	165	70	114	10.60	0.080[b]	0.330[b]	0.13	<0.05	>4.00[b]	0.5	-
3	9.03	158	104	104	9.20	0.012[b]	0.165[b]	0.10	<0.05	3.04[b]	<0.5	-
4	8.38	200	102	126	7.50	0.038[b]	0.135[b]	0.11	<0.05	>2.00[b]	<0.5	-
7 Sept.												
1	7.35	214	114	123	6.30	0.002	0.035	0.01	<0.02	1.08	<0.5	0.40
2	7.45	265	136	142	5.80	0.002	0.035	0.03	<0.02	1.10	<0.5	0.30
3	7.66	220	136	147	6.70	0.002	0.040	0.01	<0.02	1.10	<0.5	0.20
4	7.47	233	139	145	4.60	0.002	0.050	0.04	<0.02	1.18	<0.5	0.50

[a]Parameter not sampled.
[b]Data questionable due to high amounts of particulate matter in samples.

Appendix I. (continued).

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Reactive P	Total P	NH_4	NO_2-NO_3	TKN	SO_4	Fe
			ppm									
21 Oct.												
1	7.87	248	134	130	9.90	0.005	0.015	0.02	<0.02	0.96	<0.5	0.40
2	7.77	252	136	133	9.90	0.002	0.015	0.02	<0.02	1.00	<0.5	0.45
3	7.86	262	140	140	9.90	0.007	0.015	0.06	0.02	1.04	<0.5	0.70
4	7.90	268	142	142	10.40	0.005	0.025	0.02	<0.02	1.10	<0.5	0.80

Appendix J. Water quality data collected from 5 sample points on Orrock Lake, Sherburne National Wildlife Refuge 30 June-21 October 1981.

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Reactive P	Total P	NH_4	NO_2-NO_3	TKN	SO_4	Fe
			ppm									
30 June												
1	8.45	185	104	108	9.38	<0.002	0.035	0.02	<0.02	1.12	<0.5	-[a]
2	8.94	170	94	99	7.29	<0.002	0.035	0.02	<0.02	1.12	<0.5	-
3	9.23	148	80	85	10.00	0.050	0.100	0.02	<0.02	1.18	<0.5	-
4	8.60	175	102	106	11.02	0.005	0.040	0.06	<0.02	1.12	<0.5	-
5	8.70	168	102	105	4.28	0.002	0.030	0.06	<0.02	1.08	<0.5	-
5 Aug.												
1	7.93	263	140	144	7.00	0.010[b]	0.125[b]	0.07	<0.05	1.60[b]	0.5	-
2	7.95	225	112	160	7.50	0.010[b]	0.055[b]	0.05	<0.05	1.56[b]	0.5	-
3	9.47	137	72	92	10.70	0.073[b]	0.915[b]	0.08	<0.05	>4.00[b]	<0.5	-
4	8.00	253	130	130	6.90	0.10[b]	0.260[b]	0.10	<0.05	2.02[b]	<0.5	-
5	7.94	253	130	148	7.00	0.010[b]	0.040[b]	0.13	<0.05	1.24[b]	<0.5	-
7 Sept.												
1	8.59	195	102	126	9.10	0.002	0.030	0.04	<0.02	1.12	<0.5	0.05
2	7.88	160	84	97	5.80	0.002	0.025	0.03	<0.02	0.94	<0.5	0.15
3	8.64	151	74	80	5.80	0.015	0.090	0.04	<0.02	1.28	<0.5	0.80
4	8.80	184	94	103	9.40	0.002	0.025	0.04	<0.02	1.04	<0.5	0.05
5	8.33	198	98	108	7.70	0.002	0.030	0.01	<0.02	0.94	0.5	0.05

[a]Parameter not sampled.
[b]Data questionable due to high amounts of particulate matter in samples.

Appendix J. (continued).

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Reactive P	Total P	NH_4	NO_2-NO_3	TKN	SO_4	Fe
			ppm									
21 Oct.												
1	8.06	245	126	124	11.21	0.002	0.030	0.02	<0.02	1.14	<0.5	0.15
2	8.20	253	124	124	11.61	0.002	0.025	0.02	<0.02	1.12	<0.5	0.25
3	7.68	242	124	124	8.99	0.007	0.035	0.02	0.02	1.48	<0.5	0.80
4	8.20	240	124	124	11.21	0.005	0.025	0.02	<0.02	1.10	<0.5	0.15
5	8.32	240	124	124	11.62	0.007	0.025	0.02	<0.02	1.04	<0.5	0.25

Appendix K. Water quality data collected from 2 sample points on Lake Josephine, Sherburne National Wildlife Refuge, 8 June-19 October 1981.

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Total P	TKN	SO_4	Fe	K	Ca Hardness
			ppm								
8 June											
1	7.63	229	114	116	3.90	0.075	1.52	-[a]	2.00	-	75
2	7.83	204	106	107	4.25	0.050	1.32	-	1.40	-	68
23 June											
1	7.91	260	129	135	9.10	0.062	1.27	-	1.25	-	99
2	7.63	262	127	133	9.90	0.045	1.12	-	1.00	-	101
6 July											
1	8.66	210	112	119	12.40	0.048	1.03	4	0.56	-	88
2	8.54	225	116	121	10.90	0.034	1.01	3	0.71	-	88
20 July											
1	7.72	244	119	136	10.60	0.060	1.22	3	0.28	-	98
2	7.40	277	138	156	5.40	0.105	1.56	2	0.42	-	116
3 August											
1	7.51	268	134	142	5.10	0.035	1.70	2	0.32	-	106
2	7.34	288	142	150	3.50	0.040	1.38	3	0.55	-	112

[a]Parameter not sampled.

Appendix K. (continued).

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Total P	TKN	SO_4	Fe	K	Ca Hardness
			ppm								
17 August											
1	7.29	291	190	206	6.53	0.055	1.10	3	1.24	-	162
2	7.31	272	178	190	5.34	0.050	0.92	3	1.65	-	150
2 September											
1	7.21	312	162	176	4.30	0.083	1.50	4	1.48	1.50	-
2	7.23	305	160	174	3.80	0.058	1.39	4	1.08	1.30	-
14 September											
1	7.45	324	152	164	6.90	0.050	1.20	5	1.10	1.30	-
2	7.40	335	158	170	4.30	0.040	1.26	6	1.20	1.10	-
28 September											
1	7.54	395	188	186	6.10	0.050	1.14	4	1.36	2.00	-
2	7.54	397	196	202	6.30	0.040	0.88	2	0.94	0.90	-
19 October											
1	7.66	365	189	189	6.50	0.030	1.12	4	0.62	1.40	-
2	7.46	355	185	187	4.50	0.035	1.21	6	0.51	1.40	-

Appendix L. Water quality data collected from 2 sample points on Johnson Slough, Sherburne National Wildlife Refuge, 8 June-19 October 1981.

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Total P	TKN	SO_4	Fe	K	Ca Hardness
			ppm								
8 June											
1	8.18	252	132	135	8.00	0.045	1.44	-[a]	0.04	-	94
2	7.86	260	136	137	6.40	0.045	2.12	-	0.05	-	98
23 June											
1	7.54	260	129	135	6.64	0.032	0.85	-	1.15	-	97
2	7.91	225	109	114	8.80	0.015	0.73	-	0.53	-	80
6 July											
1	7.85	252	134	137	9.70	0.041	0.83	2	0.93	-	102
2	8.51	214	114	115	11.40	0.034	0.79	1	0.25	-	84
20 July											
1	8.10	238	121	136	8.70	0.040	0.94	1	0.25	-	96
2	7.82	235	117	130	8.60	0.050	1.20	1	0.20	-	92
3 August											
1	7.50	295	152	158	7.60	0.062	1.26	2	0.32	-	116
2	7.70	268	140	146	6.20	0.032	1.08	1	0.22	-	106

[a]Parameter not sampled.

Appendix L. (continued).

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Total P	TKN	SO_4	Fe	K	Ca Hardness
			ppm								
17 August											
1	7.20	290	186	194	3.76	0.040	1.16	4	2.46	-	144
2	7.40	250	160	163	3.66	0.025	1.04	3	2.10	-	124
2 September											
1	7.24	305	160	172	2.50	0.050	1.13	3	2.44	0.80	-
2	7.65	290	154	164	6.20	0.034	1.02	3	0.40	0.70	-
14 September											
1	7.50	342	164	172	5.00	0.048	1.10	4	1.10	0.60	-
2	7.60	326	158	163	5.40	0.030	0.88	4	0.75	0.60	-
28 September											
1	7.90	326	166	169	8.60	0.037	0.92	4	0.68	0.60	-
2	8.00	319	164	163	9.00	0.025	0.96	3	0.62	0.80	-
19 October											
1	7.80	270	146	144	8.30	0.022	0.80	3	0.30	0.60	-
2	7.90	280	145	148	9.10	0.020	0.72	2	0.24	0.60	-

Appendix M. Water quality data collected from 3 sample points on Orrock Lake, Sherburne National Wildlife Refuge, 8 June-19 October 1981.

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Total P	TKN	SO_4	Fe	K	Ca Hardness
			ppm								
8 June											
1	9.4	140	78	79	9.1	0.045	2.0	-	0.25	-[a]	45
2	9.0	170	92	92	9.1	0.035	1.2	-	0.25	-	64
3	10.3	154	98	101	7.2	0.085	1.7	-	1.50	-	77
23 June											
1	10.0	122	61	67	13.5	0.012	0.3	-	0.20	-	31
2	9.5	154	83	85	12.7	0.045	0.8	-	1.25	-	58
3	9.9	152	83	92	12.7	0.105	0.6	-	1.55	-	62
6 July											
1	9.8	124	67	68	9.6	0.025	0.8	1.0	0.42	-	42
2	9.6	138	70	70	9.5	0.046	1.2	2.0	0.92	-	44
3	7.4	226	110	117	2.5	0.283	1.6	2.0	4.20	-	90
20 July											
1	8.0	176	87	96	7.0	0.050	1.3	1.0	0.45	-	64
2	9.0	145	68	80	9.2	0.040	1.1	1.0	0.19	-	50
3	7.5	200	98	108	3.2	0.190	1.3	3.0	1.39	-	78

[a]Parameter not sampled.

Appendix M. (continued).

	ph	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Total P	TKN	SO_4	Fe	K	Ca Hardness
			ppm								
3 August											
1	8.4	170	94	96	8.3	0.030	1.1	1.0	0.30	-	64
2	9.0	144	76	82	8.5	0.035	1.1	1.0	0.30	-	50
3	7.7	198	106	108	4.4	0.125	1.4	2.0	1.40	-	76
17 August											
1	9.1	114	72	80	8.1	0.03	1.2	1.5	0.35	-	44
2	9.5	107	70	70	8.2	0.02	1.0	1.0	0.40	-	40
3	8.3	155	92	98	5.6	0.125	1.3	3.5	1.66	-	70
2 September											
1	8.4	162	84	90	8.5	0.075	1.9	0.4	0.11	1.0	-
2	8.3	165	88	92	8.5	0.025	1.0	0.6	0.10	1.0	-
3	8.6	175	94	100	8.8	0.080	1.5	0.5	0.60	2.0	-
14 September											
1	8.5	182	86	92	7.9	0.020	0.9	0.5	0.18	2.0	-
2	8.3	189	90	94	6.4	0.045	1.0	0.7	0.30	2.0	-
3	9.8	144	74	78	12.2	0.118	1.4	0.6	1.12	3.0	-

Appendix M. (continued).

	pH	Conductivity (umhos/cm)	Alkalinity	Total Hardness	Dissolved Oxygen	Total P	TKN	SO_4	Fe	K	Ca Hardness
			ppm								
28 September											
1	8.3	225	110	110	9.9	0.025	1.0	1.0	0.24	0.8	-
2	8.7	218	104	104	11.2	0.027	1.0	1.0	0.32	0.9	-
3	8.6	231	122	116	12.0	0.065	1.1	1.0	1.14	0.8	-
19 October											
1	8.1	214	113	112	9.6	0.020	0.9	1.0	0.14	0.9	-
2	8.3	218	113	112	10.7	0.030	0.9	2.0	0.41	1.0	-
3	8.3	215	111	112	10.8	0.032	0.8	3.0	0.49	1.0	-

Appendix N. Chemical composition of wild rice (*Zizania aquatica*) flag leaf samples removed from 3 stands of wild rice, Sherburne National Wildlife Refuge, 23 July-4 August 1981.

	Percentage of dry weight							Dry weight (ppm)					
Location	N	P	K	Ca	Mg	S	Na	Zn	B	Mn	Fe	Cu	Al
Josephine (N=80)													
1	3.82	0.33	1.60	0.50	0.11	0.26	0.03	13	9.2	206	132	3.5	68.3
2	4.18	0.39	1.90	0.49	0.12	0.27	0.07	13	8.2	174	147	2.3	68.4
3	4.11	0.37	1.34	0.62	0.13	0.28	0.04	17	9.1	198	129	4.1	68.4
4	4.01	0.39	1.88	0.67	0.15	0.26	0.07	12	8.9	342	206	2.3	69.0
Johnson (N=40)													
1	4.38	0.38	1.98	0.50	0.10	0.28	0.03	18	9.5	150	251	2.4	68.2
2	3.90	0.35	1.59	0.63	0.11	0.27	0.11	18	10.0	161	257	3.3	68.2
Orrock (N=60)													
1	4.62	0.45	1.84	0.52	0.13	0.29	0.26	19	13.7	106	231	4.8	119.0
2	4.29	0.36	1.70	0.73	0.14	0.28	0.04	14	11.7	151	129	2.4	69.3
3	4.34	0.36	1.96	0.71	0.17	0.30	0.05	15	14.3	142	154	2.4	68.0

Appendix O. Results of sediment samples taken on Lake Josephine, Johnson Slough, and Orrock Lake, Sherburne National Wildlife Refuge, October 1980.

	pH	SMP	O.M.[a]	P	K	Ca	Mg	B	Mn	S	Sol. Salts	Na	Zn	Cl[b]	NH_4-N	NO_3 NO_2 N
				ppm							umhos/cm.	ppm				
Josephine																
1	7.0	--[c]	314	0.5	28	1650	500	1.2	15	3.0	100	70	0.25		41.59	8.58
2	6.9	--	314	0.5	23	1900	450	1.8	18	4.0	110	140	0.25		44.34	13.74
3	7.0	--	269	0.5	23	1900	425	1.5	21	3.5	100	140	0.25		62.66	14.19
4	7.0	--	269	0.5	20	1875	475	1.4	20	4.5	110	150	0.25	25.5	47.12	12.41
5	7.1	--	269	0.5	15	1875	500	1.5	14	3.5	100	160	0.25		26.71	8.81
6	7.0	--	269	0.5	15	1800	375	2.0	15	6.5	90	110	0.25		56.90	9.58
7	7.1	--	269	0.5	18	1875	475	1.2	15	8.5	90	120	-[d]		58.24	11.08
Johnson																
8	6.5	6.9	314	0.5	13	1700	225	1.6	30	2.5	80	105	18.2		38.20	9.80
9	6.4	6.5	314	0.5	20	1850	375	1.6	50	1.0	90	135	18.5		60.57	10.45
10	5.7	6.4	269	0.5	13	1650	250	1.5	75	1.5	80	85	18.5	21.0	52.10	10.08
11	5.7	6.0	314	0.5	15	1700	350	2.0	85	2.5	80	120	22.0		70.20	10.30
12	5.6	5.9	269	0.5	20	1600	275	1.6	65	3.0	70	160	14.5		47.90	8.81

[a]Metric tons/ha.
[b]Composite sample analysis.
[c]Value could not be determined.
[d]Parameter not sampled.

Appendix O. (continued).

	pH	SMP	O.M.[a]	P	K	Ca	Mg	B	Mn	S	Sol. Salts	Na	Zn	Cl[b]	NH_4-N	NO_3 NO_2 N
				ppm							umhos/cm.	ppm				
Orrock																
13	6.5	6.5	269	0.5	20	1800	450	2.0	25	1.5	100	140	8.0		165.10	14.01
14	6.9	--	314	0.5	13	1900	475	1.9	15	2.5	90	155	3.3		75.12	10.63
15	6.7	6.7	314	0.5	38	1850	550	1.5	18	3.5	100	160	2.8		122.40	11.24
16	6.7	6.8	314	0.5	20	1850	425	2.7	25	1.5	125	165	7.8	22.5	82.90	9.88
17	6.8	6.8	314	0.5	20	1800	375	2.0	30	1.5	100	110	8.0		85.95	8.83
18	6.6	6.7	269	0.5	15	1650	275	2.0	22	1.5	90	98	-		62.75	9.52
19	6.9	--	314	0.5	18	1750	450	2.0	13	3.5	90	123	-		107.30	15.26
20	7.0	--	269	0.5	23	1800	525	2.1	9	4.5	100	160	1.8		68.60	11.79

Appendix P. Results of sediment samples taken on Lake Josephine, Johnson Slough, and Orrock Lake, Sherburne National Wildlife Refuge, October 1981.

	pH	SMP	O.M.[a]	P	K	Ca	Mg	B	Mn	S	Sol. Salts	Na	Zn	Cl	NH_4-N	NO_3 NO_2 N
				ppm							umhos/cm.	ppm				
Josephine																
1	7.8	--[b]	280	0.5	19.0	6000	340	1.4	9.5	51.5	34	65	0.5	2.5	31.5	31.5
2	7.8	--	280	0.5	21.5	6225	360	0.9	7.0	40.0	35	65	0.5	1.5	36.0	53.0
3	7.8	--	280	0.5	14.0	5400	325	1.3	7.5	16.25	28	60	0.5	1.5	23.0	1.0
4	7.8	--	280	0.5	11.5	5625	325	1.5	6.5	4.5	26	55	0.75	2.0	7.5	4.5
5	7.8	--	280	0.5	14.5	5850	340	1.4	5.0	47.75	34	55	0.5	1.5	15.5	0.5
6	7.7	--	280	0.5	16.5	5625	300	1.05	5.5	57.5	33	60	0.5	2.0	23.5	4.0
7	7.7	--	280	0.5	13.0	5400	260	1.1	5.5	20.75	27	60	0.5	2.0	21.5	7.0
Johnson																
8	6.2	7.2	280	1.0	20.0	4650	360	1.8	55.5	24.25	25	60	18.75	2.5	21.5	2.5
9	6.3	7.1	280	1.5	18.5	4500	345	1.95	68.5	20.00	21	60	16.00	2.0	12.5	<0.5
10	5.9	6.7	280	2.0	22.5	3375	345	2.00	73.0	17.5	15	70	14.00	2.0	18.5	5.0
11	6.2	6.9	280	2.0	27.5	4350	360	1.8	87.0	20.5	24	65	16.75	3.5	28.0	5.0
12	6.0	6.7	280	2.5	15.5	3750	310	1.7	58.5	15.0	20	65	16.00	3.0	19.0	4.0

[a]Metric tons/ha.
[b]Value could not be determined.

Appendix P. (continued).

	pH	SMP	O.M.[a]	P	K	Ca	Mg	B	Mn	S	Sol. Salts	Na	Zn	Cl	NH_4-N	NO_3 NO_2 N
				ppm							umhos/cm.	ppm				
Orrock																
13	7.2	--	280	2.0	20.5	6000	425	1.0	32.0	21.75	32	70	7.5	3.0	19.0	12.5
14	7.5	--	280	0.5	19.0	6750	410	1.3	11.0	53.25	38	35	.75	3.0	23	11.5
15	7.6	--	280	0.5	17.0	6825	390	1.6	9.5	23.00	33	75	3.75	2.0	35.5	<0.5
16	7.5	--	280	1.0	16.0	6375	340	1.4	12.5	54.00	41	70	5.25	2.5	10.5	8.0
17	7.6	--	280	1.0	17.5	6000	350	1.55	22.0	37.5	38	65	37.50	1.5	19.0	3.0
18	7.8	--	280	1.5	29.0	5850	360	1.4	17.5	22.25	31	70	7.25	3.0	17.0	5.5
19	7.9	--	280	0.5	15.0	5100	260	1.05	25.0	13.25	33	60	5.25	2.0	22.0	6.5
20	7.9	--	280	0.5	29.5	6750	425	1.40	15.0	17.00	33	75	3.25	1.5	35.5	23.5

Appendix P. (continued).

	% dry matter	exchangeable K	Fe
		--------- ppm ---------	
Josephine			
1	21.2	32.5	20
2	19.5	32.5	20
3	14.4	22.5	20
4	14.4	20.0	15
5	18.7	20.0	15
6	19.5	25.0	25
7	19.4	22.5	45
Johnson			
8	15.2	30.0	3102.5
9	16.9	30.0	2805
10	18.4	70.0	2210
11	16.3	37.5	3782.5
12	14.8	20.0	2380

Appendix P. (continued).

	% dry matter	exchangeable K	Fe
		ppm	
Orrock			
13	13.5	35.0	>4250
14	16.3	35.0	765
15	18.8	35.0	1955
16	16.3	30.0	2295
17	14.1	32.5	4037.5
18	13.3	45.0	3017.5
19	13.5	25	2635
20	18.6	47.5	1020

Appendix Q. Vegetation analysis of 3 wild rice beds on the Sherburne National Wildlife Refuge, 11-23 July 1980.

Rice Bed		Lake Josephine		Johnson Slough		Orrock Lake (West Bay)	
Location	State	Minnesota		Minnesota		Minnesota	
	Township	34 N		34 N		34 N	
	Range	27 W		27 & 28 W		27 W	
	Section	3 & 10		6 & 1		7	
Species		% Cover	% Frequency	% Cover	% Frequency	% Cover	% Frequency
Brasenia schreberi		-[a]	-	+[b]	+	-	-
Ceratophyllum demersum		0.3	7	+	+	38.0	100.0
Cyanophyceae		2.1	25	-	-	-	-
Eleocharis spp.		-	-	0.03	2	-	-
Lemna minor		0.4	11	-	-	-	-
Najas flexilis		45.0	97	55.0	80	1.0	38.0
Nuphar variegatum		+	+	+	+	-	-
Nymphaea odorata		0.5	3	0.2	2	-	-
Phalaris arundinacea		0.02	1	-	-	-	-
Potamogeton berchtoldi		24.0	65	18.0	68	11.0	75.0
Potamogeton gramineus		+	+	+	+	-	-
Potamogeton natans		+	+	+	+	-	-
Potamogeton zosteriformis		+	+	+	+	-	-
Sagittaria latifolia		0.06	3	-	-	-	-
Sparganium eurycarpum		0.02	1	-	-	-	-
Unknown		0.02	1	-	-	-	-
Utricularia vulgaris		0.3	3	2.0	8	-	-
Zizania aquatica		12.0	96	4.3	89	7	88.0
		n=236		n=132		n=16	

[a]Species not encountered
[b]Species occurred in the bed without sufficient abundance to be encountered in the plots.

Appendix R. Vegetation analysis of 3 wild rice beds on the Sherburne National Wildlife Refuge, 10 July-4 August 1981.

Rice Bed		Lake Josephine		Johnson Slough		Orrock Lake (West Bay)		Orrock (Lake Proper)	
Location	State	Minnesota		Minnesota		Minnesota		Minnesota	
	Township	34 N		34 N		34 N		34 N	
	Range	27 W		27 & 28 W		27 W		27 W	
	Section	3 & 10		6 & 1		7		7	
Species		% Cover	% Frequency	% Cover	% Frequency	% Cover	% Frequency	% Cover	% Frequency
Brasenia schreberi		-[a]	-	+[b]	+	-	-	-	-
Ceratophyllum demersum		16	62	8	26	93	100	14	15
Chara vulgaris		2	1	-	-	-	-	-	-
Cyanophyceae		5	5	15	3	37	4	25	6
Eleocharis spp.		-	-	+	+	-	-	-	-
Lemna minor		4	55	2	2	6	13	-	-
Leersia orizoides		-	-	-	-	2	4	-	-
Lysimachia thyrsiflora		2	1	-	-	2	4	-	-
Myriophyllum spiatum		2	1	-	-	-	-	-	-
Najas flexilis		22	55	26	47	-	-	52	100
Nuphar variegatum		+	+	+	+	-	-	15	3
Nymphaea odorata		+	+	37	3	26	8	33	41
Phalaris arundinacea		+	+	-	-	-	-	-	-
Potamogeton berchtoldi		47	88	23	11	2	8	-	-
Potamogeton longiligulatus		-	-	23	44	-	-	-	-

[a]Species not encountered.
[b]Species occurred in the bed without sufficient abundance to be encountered in the plots.

Appendix R. (continued).

Rice Bed		Lake Josephine		Johnson Slough		Orrock Lake (West Bay)		Orrock (Lake Proper)	
Location	State	Minnesota		Minnesota		Minnesota		Minnesota	
	Township	34 N		34 N		34 N		34 N	
	Range	27 W		27 & 28 W		27 W		27 W	
	Section	3 & 10		6 & 1		7		7	
Species		% Cover	% Frequency	% Cover	% Frequency	% Cover	% Frequency	% Cover	% Frequency
Potamogeton zosteriformis		12	23	13	29	15	8	17	65
Sagittaria latifolia		+	+	+	+	-	-	+	+
Sparganium eurycarpum		2	1	-	-	-	-	-	-
Spirodela polyrhiza		3	4	+	+	-	-	-	-
Unknown		2	1	-	-	-	-	-	-
Utricularia vulgaris		20	11	10	8	2	4	2	3
Zizania aquatica		15	100	9	78	5	20	11	29
Zizania aquatica (debris)		15	72	20	10	-	-	-	-
		N=216		N=126		N=48		N=68	

Appendix S. Sampling intensity and general conditions of wild rice beds on 3 study sites at the Sherburne National Wildlife Refuge 11-23 July 1980, and 10 July-4 August 1981.

Location	Lake Josephine	Johnson Slough	Orrock Lake
N	236/219[a]	132/126	16/116
Average number of stems/m^2	52/49	18/14	<1/ <1
S.D.	3.99/2.96	1.43/0.89	1.81/1.42
Var.	15.92/8.77	2.04/0.79	3.28/2.01
Sampling intensity	16 samples/ha/15 samples/ha	11 samples/ha/11 samples/ha	12.4 samples/ha/45
Total wild rice area	14.45 ha	11.70 ha	1.29 ha/2.58 ha
% damage visible on rice plant[b]	none observed/30	53.8/60	29/67
% in blossom	7/0.9	0.01/0	0/12

[a]1980/1981.
[b]Damage included plants eaten by birds and/or mammals, insect depredation, and ergot infestation.

Appendix T. Percent occurrence, average density rating, and mean density rating for stratified random samples of submerged aquatics in Orrock Lake, Sherburne National Wildlife Refuge, 5-7 October 1980.

Location	West Bay N=4			North Bay N=4			Lake Proper N=42		
Area (open water only)	9.27 ha			9.3 ha			62.58 ha		
Sample number[a]	1,2,3,4			9,10,11,12,15			5,6,7,8,10,13,14...50		
Species	% occurrence	average[b] sample density rating	mean density rating all samples taken with this section	% occurrence	average sample denisty rating	mean density rating all samples taken with this section	% occurrence	average sample density rating	mean density rating for all samples taken with this section
Ceratophyllum demersum	100	3.25	3.25	-[c]	-	-	4	3.00	0.142
Chara vulgaris	-	-	-	-	-	-	16	3.42	0.571
Najas flexilis	-	-	-	75	2.66	2.00	50	1.80	0.904
Nitella spp.	-	-	-	-	-	-	4	1.00	0.047
Nuphar variegatum	-	-	-	-	-	-	26	1.81	0.476
Nymphaea odorata	50	1.00	.50	50	2.50	1.25	45	1.80	0.857

[a]See Appendix.
[b]Density rating of 4=heavy, 3=moderate, 2=scattered, 1=sparce.
[c]Species did not occur in random area sampled.

Appendix T. (continued).

Location Area (open water only)	West Bay N=4 9.27 ha			North Bay N=4 9.3 ha			Lake Proper N=42 62.58 ha		
Sample number[a]	1,2,3,4			1,10,11,12,15			5,6,7,8,10,13,14...50		
Species	% occurrence	average[b] sample density rating	mean density rating for all samples taken within this section	% occurrence	average sample density rating	mean density rating for all samples taken within this section	% occurrence	average sample density rating	mean density rating for all samples taken within this section
Potamogeton pectinatus	-	-	-	-	-	-	23	2.30	0.547
Potamogeton zosteriformis	75	2.00	1.50	75	2.66	2.00	40	2.35	0.952
Ruppia maritima	-	-	-	-	-	-	2	1.00	0.023
Scirpus acutus	-	-	-	-	-	-	19	3.00	0.571
Sparganium eurycarpum	-	-	-	-	-	-	2	1.00	0.023
Spirogyra	-	-	-	-	-	-	14	2.16	0.309
Utricularia vulgaris	25	1.00	0.50	50	1.50	0.50	33	1.85	0.619
Zizania aquatica	100	2.00	2.00	25	1.00	0.25	2	1.00	0.023

Appendix U. Wild rice head and seed analysis, prior to and post harvest, on Lake Josephine, Sherburne National Wildlife Refuge 1980.

	Prior to Harvest				Post Harvest			
	Harvest Section		Unharvested Section		Harvest Section		Unharvested Section	
		%		%		%		%
Total number of heads examined	387	-	331	-	289	-	299	-
Number of tight full heads	362	94	287	87	152	53	200	67
Number of crow-foot heads	25	6	44	11	137	47	99	33
Total number of seeds examined	46,286	96	47,979	96	7,271	18	10,685	21
Total number of pedicels without seed	2,020	4	2,076	4	34,115	82	38,577	79
Total number of seeds on heads	48,306	-	50,025	-	41,386	-	49,162	-
Average number of seeds per head	125	-	130	-	143	-	164	-

Appendix V. Wild rice head and seed analysis, prior to and post harvest on Lake Josephine, Sherburne National Wildlife Refuge 1981.

	Prior to Harvest				Post Harvest			
	Harvest Section		Unharvested Section		Harvest Section		Unharvested Section	
		%		%		%		%
Total number of heads examined	250	-	276	-	276	-	265	-
Number of tight full heads	225	90	240	87	213	77	201	76
Number of crow-foot heads	25	10	36	13	63	23	64	24
Total number of seeds examined	22,076	98	20,441	96	4,009	18	6,796	25
Total number of pedicels without seed	529	2	846	4	18,842	82	20,502	75
Total number of seeds on heads	22,605	-	21,287	-	22,851	-	27,298	-
Average number of seeds per head	90	-	77	-	83	-	103	-

Appendix W. Condition of examined seeds, prior to and post harvest, from Lake Josephine, Sherburne National Wildlife Refuge 1980.

	Prior to Harvest				Post Harvest			
	Harvest Section		Unharvested Section		Harvest Section		Unharvested Section	
		%		%		%		%
Number of undeveloped seeds examined	44,450	96.0	45,197	94.28	823	11.13	607	5.7
Average number of undeveloped seeds per head	115	-	117	-	2.84	-	2.03	-
Number of fully developed seeds examined	1,779	3.88	2,668	5.5	3,693	50.8	6,929	65
Average number of fully developed seeds per head	4	-	7	-	13	-	23	-
Number of depredated seeds examined	47	0.1	76	0.2	123	2	123	1
Average number of depredations per head	0.121	-	0.197	-	0.43	-	0.411	-

Appendix W. (continued).

	Prior to Harvest				Post Harvest			
	Harvested Section		Unharvested Section		Harvested Section		Unharvested Section	
Number of seeds infected with ergot	10	0.02	8	0.02	5	0.07	5	0.05
Average number of ergot infections per head	0.03	-	0.02	-	0.02	-	0.016	-
Number of partially developed seeds[a]	-	-	-	-	2,627	36	3,021	28.25
Average number of partially developed seeds per head[a]	-	-	-	-	9	-	10	-

[a]Data only applicable to post-harvest seed heads.

Appendix X. Condition of examined seeds, prior to and post harvest from Lake Josephine, Sherburne National Wildlife Refuge 1981.

	Prior to Harvest				Post Harvest			
	Harvest Section		Unharvested Section		Harvest Section		Unharvested Section	
		%		%		%		%
Number of undeveloped seeds examined	21,507	97.4	20,167	98.6	844	21	1,575	23.2
Average number of undeveloped seeds per head	86	-	73	-	3.05	-	5.94	-
Number of fully developed seeds examined	454	2.0	206	1.0	439	11	1,190	18.0
Average number of fully developed seeds per head	2	-	1	-	1.59	-	4.49	-
Number of depredated seeds examined	114	0.5	68	0.3	183	4.6	325	4.78
Average number of depredations per head	0.45	-	0.24	-	0.66	-	1.22	-

Appendix X. (continued).

	Prior to Harvest				Post Harvest			
	Harvest Section		Unharvested Section		Harvest Section		Unharvested Section	
Number of seeds infected with ergot	1	-	0	-	7	0.20	1	0.02
Average number of ergot infections per head	0.4	-	0	-	0.025	-	0.007	-
Number of partially developed seeds[a]	-	-	-	-	2,536	63.2	3,[illegible]4	54
Average number of partially developed seeds per head[a]	-	-	-	-	9	-	14	-

[a]Data only applicable to post-harvest seed heads.

Appendix Y. Number of invertebrates per wild rice (Zizania aquatica) plant from 3 wild rice marshes, Sherburne National Wildlife Refuge, June-September 1981.

	Josephine				Johnson				Orrock			
	June	July	Aug	Sept	June	July	Aug	Sept	June	July	Aug	Sept
Amphipoda												
Hyalella azteca	-[a]	1.0	0.8	-	0.6	0.4	0.3	1.6	-	0.8	6.3	0
Arachnida	-	0	0	-	0	0	0	0	-	0	0.3	0.2
Chironomidae	-	1.9	0.8	-	19.0	19.5	27.0	3.0	-	3.8	0.6	0.3
Coleoptera												
Curculionidae	-	0	0	-	0	0.1	0	0.1	-	0	0	0
Unknown	-	0.1	0	-	0.1	0	0	0	-	0	0	0
Hemiptura												
Gerridae sp	-	0.1	0	-	0	0	0	0	-	0	0	0
Mesovelia sp	-	0	0	-	0	0	0.3	0.1	-	0	0	0
Plea striola	-	0	0	-	0	0	0	0	-	0.2	0	0
Unknown	-	0.1	0	-	0	0	0	0	-	0	0	0
Hirudinea	-	4.0	0.8	-	1.7	3.8	9.3	1.3	-	3.4	7.6	0.6
Lepidoptera												
Apamea apamiformis	-	0	0.3	-	0	0	0	0	-	0.2	0	0

Appendix Y. (continued).

	Josephine				Johnson				Orrock			
	June	July	Aug	Sept	June	July	Aug	Sept	June	July	Aug	Sept
Mollusca												
Gyraulus sp.	-	2.1	1.4	-	0.1	2.1	2.0	0.3	-	4.8	0.6	1.3
Heliosoma sp	-	0.4	0.1	-	0	0	0	0	-	0	0	0
Physa sp	-	0.3	0.4	-	0.4	0.2	0	0.2	-	0	0	0.2
Sphaerium sp	-	0.1	0	-	0	0	0	0	-	0	0	0
Valvata sp	-	0.3	0.1	-	0	0	0	0	-	0	0	0
Tricoptera												
Oecetis sp	-	0	0	-	0	0	0.3	0	-	0.2	0.3	0
	-	N=13	N=7	-	N=10	N=7	N=3	N=6	-	N=5	N=3	N=6

[a]No samples taken.

Appendix Z. Amount of wild rice harvested from Lake Josephine, Sherburne National Wildlife Refuge, 1980 and 1981.

Date	Weight of Green Rice kg	% Recovered After Processing	Weight of Processed Rice kg
29 Aug	269.43	34	91.60
1 Sept	504.63	38	191.75
5 Sept/6 Sept[a]	220.44/330.22	36.5/38	80.46/125.48
8 Sept/8 Sept	444.07/216.82	39/37	173.18/80.22
11 Sept/11 Sept	249.48/216.82	37[b]/40	92.30/86.72
14 Sept/15 Sept	234.05/110.22	37[b]/39	86.59/42.98
Total	1922.10/874.08		715.88/335.40

[a]1980/1981.
[b]% recovered is based on the average rates reported from 29 August-8 September 1980.

Appendix AA. Economic value of harvested wild rice from Lake Josephine, Sherburne National Wildlife Refuge, 1980 and 1981.

Date	Price/kg Paid To Harvesters	Total Weight Harvested (kg)	Harvester's Pay
29 Aug	$1.10	269.43	$296.37
1 Sept	1.10	504.63	555.09
5 Sept/6 Sept[a]	1.32/2.64	220.44/330.22	290.98/873.60
8 Sept/8 Sept	1.32/2.64	444.07/216.82	586.17/572.48
11 Sept/11 Sept	1.32/2.64	249.48/216.82	329.31/572.48
14 Sept	1.76/2.64	234.05/110.22	411.92/291.60
Total		1922.10/874.08	$2469.84/$2310.16

[a]1980/1981.

Appendix BB. Harvested seed weights with hulls and awns on Lake Josephine, Sherburn National Wildlife Refuge, 1980 and 1981.

Date	N	Average weight/100 seeds (gm)	S.D.	Variance	% Undeveloped	% Depredated
29 Aug	5000	3.1	0.3	0.1	14.0	0.9
1 Sept	5000	2.9	0.2	0.1	11.4	1.9
5 Sept/6 Sept[a]	5000/3100	3.0/3.5	0.1/0.3	0.02/0.1	15.9/9.5	2.1/6.8
8 Sept/8 Sept	3100/3100	3.0/3.3	0.1/0.4	0.01/0.1	13.9/6.2	3.7/3.5
11 Sept/11 Sept	3100/3100	3.0/3.7	0.1/0.3	0.01/0.1	16.1/12.8	3.2/4.4
14 Sept/15 Sept	3100/3100	3.0/3.5	0.1/0.3	0.01/0.1	12.0/16.7	3.8/7.8

[a]1980/1981.

Appendix CC. Size of harvested wild rice in Lake Josephine, Sherburne National Wildlife Refuge, 1980 and 1981.

Date	N	Average seed size (mm)	S.D.	Variance
29 Aug	200	13.1	1.8	3.2
1 Sept	182	13.1	1.8	3.1
5 Sept/6 Sept[a]	182/182	12.7/14.2	1.7/2.11	2.9/4.48
8 Sept/8 Sept	182/182	12.5/14.7	1.8/1.94	3.2/3.78
11 Sept/11 Sept	182/182	12.1/14.1	1.7/2.13	2.3/4.54
14 Sept/15 Sept	182/182	11.3/13.84	1.5/2.03	2.3/4.15

[a]1980/1981.