BIOLOGICAL, CHEMICAL AND PHYSICAL RELATIONSHIPS OF WILD RICE, *Zizania aquatica* L., IN NORTHWESTERN ONTARIO AND NORTHEASTERN MINNESOTA

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Peter Ferguson Lee

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That afternoon there was a party of tourists at the Terrace and looking down in the water among the empty beer cans and dead barracudas a woman saw a great long white spine with a huge tail at the end that lifted and swung with the tide while the east wind blew a heavy steady sea outside the entrance to the harbour.

"What's that?" she asked a waiter and pointed to the long backbone of the great fish that was now just garbage waiting to go out with the tide.

"Tiburon," the waiter said. "Eshark." He was meaning to explain what had happened.

"I didn't know sharks had such handsome, beautifully formed tails."

"I didn't either," her male companion said.

Up the road, in his shack, the old man was sleeping again. He was still sleeping on his face and the boy was sitting by him watching him. The old man was dreaming about the lions.

Ernest Hemingway

from The Old Man and the Sea

ABSTRACT

Large natural stands of wild rice, *Zizania aquatica* L., were examined in northeastern Minnesota and northwestern Ontario in terms of their biological, chemical, and physical characteristics.

The growth of wild rice during the 1976 and 1977 growing seasons was quantified at four sampling sites on the Mississippi River near the Clay Boswell Steam Electric Station at Cohasset, Minnesota. Cluster analysis was used to illustrate the intercorrelations and seasonal trends which existed among the water and sediment chemical variables. All biological, chemical, and physical variables were corrected for any time dependency and discriminant analysis isolated those factors which could separate the four sampling sites. A wild rice growth model was derived by combining (i) a time independent equation formed from a multiple regression analysis of the time corrected biological, chemical, and physical variables isolated as being significant in the discriminant analysis versus the time corrected dry weights per wild rice plant; and (ii) a time dependent equation formed by fitting a logistic equation to the overall mean weights per wild rice plant at the four sampling sites.

Seasonal changes in nutrient concentrations were monitored during 1976 and 1977 in the wild rice roots, leaves, stems, and heads at the four sampling stations near the Clay Boswell

Steam Electric Station. A time independent analysis of variance was performed on the 1976 leaf elemental concentrations to isolate those elements which were statistically different among the four sites. These isolated elements were only poorly correlated to the concentrations of the corresponding nutrients in the sediment, and the variances seemed to be a result of luxury consumption. In order to explain the similar elemental concentrations at the four sampling sites, a model was derived based on the presumption of a constant rate of absorption of the elements per unit weight. Theoretically, the model could describe the types of seasonal trends observed for many of the elements, but using actual data, good fits were obtained only after the aerial leaf stage had been reached. It was thought that the poor fits prior to this phenological stage could be due to either sampling error, differences in phenological development within each station, or absorption by the leaves as well as the roots.

The major commercial stands in the study region were examined in terms of their geographical distribution and ecological relationships. The northern limit of the rice stands was at approximately 150 growing-days. Frequency distributions were determined for seed length, number of seeds per head, density of wild rice heads per m^2, and the weight per wild rice plant. Seed lengths tended to be shorter in the more southern latitudes. Frequency distributions and cluster

analysis relationships were determined for the water chemical variables, pH, iron, sulfate, conductivity, total alkalinity, magnesium, calcium and potassium; and the sediment chemical variables, pH, loss on ignition, conductivity, calcium, magnesium, phosphorus, potassium, nitrogen, iron, zinc and manganese. The frequency distributions of the leaf concentrations of iron, manganese, zinc, calcium, magnesium, and phosphorus were determined. Only poor correlations were found between the concentrations of elements in the leaf tissue and the concentrations of the corresponding element in the sediments.

Discriminant analysis was used to categorize lakes planted with wild rice in northwestern Ontario in terms of their potential to produce commercial crops. Variables included in the discriminant functions were pH and dissolved iron in the water, extinction of photosynthetically active light in the water, available calcium, zinc, and phosphorus in the sediments, and the suitability of the sediment for root anchorage. In terms of individual plant performance, photosynthetically active light was negatively correlated with head weight ratio. The role of the other variables seemed to involve deficiencies of micronutrients primarily through the formation of ferric hydroxide complexes.

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INTRODUCTION

The largest natural stands of wild rice, *Zizania aquatica* L., in North America are found in northwestern Ontario, northeastern Minnesota and eastern Manitoba. The harvest from these stands has long played an important role in this region. For hundreds of years it provided a needed source of nourishment to the native people of the region (McAndrews, 1969) and early European settlers to the area are known to have traded with the Indians for supplies of wild rice (Jenks, 1901).

Today, wild rice in these natural stands is important for its economic stimulus. In good crop years, total harvests reach as high as 4 million pounds (unprocessed) which, at 1978 prices of $2.00 per pound, inject approximately 8 million dollars into the local economy at the primary level alone. The corresponding retail value of the crop is upwards of 15 million dollars. These figures seem impressive. However, the importance of these natural stands, to the Canadian wild rice industry, is diminishing slowly as a result of the increasing development of wild rice paddy culture in Minnesota.

Paddy culture was introduced into Minnesota in the late 1960's. Primarily due to the admirable three-way communication link which existed among the American wild rice industry, the state and federal governments, and the academic community, a multi-million dollar industry has been built. Long term research requirements were early identified and the

development of shatter-resistant wild rice, and control practices for diseases and insects have allowed paddy growers to achieve significant, sustainable yields. Harvests from the paddies are now in the neighbourhood of 5 million pounds annually, and although this figure changes somewhat from year to year, it does not exhibit the severe fluctuations in yields that are characteristic of the natural stands.

The impact of paddy culture on the Canadian wild rice industry has been rather severe. The American companies are now able to assure themselves of a steady supply and thus have a distinct advantage in marketing the finished product. In the past two years their efforts have been directed towards crushing the Canadian wild rice industry by paying exorbitant prices for any natural stand production, thereby cutting off the Canadian industries only supply source. It is therefore evident that if the natural stands of wild rice are to be a viable component of the Canadian wild rice industry, then management practices must be found which will allow the industry to achieve sustainable and profitable yields.

Unfortunately, the management of freshwater wetlands is still only a "state of the art" technique based on our present knowledge of these systems which is lacking in such areas as productivity, decomposition, hydrology and nutrient cycling (Wetzel, 1978). Furthermore, in managing any wetlands, consideration should be given as to how any single management technique may affect the total wetland environment (Stearn, 1978). Therefore, in terms of studying wild rice in natural waters, the

approach should be an "holistic" one, which examines the interactions of all biological, chemical and physical factors affecting the growth of the plant.

The basic objective was to try and gain a better understanding of how wild rice relates to its immediate environment with the ultimate view of applying this knowledge to increasing the production of the natural stands of wild rice in Canada. It was decided to approach this overall objective by dividing the examination of interacting factors influencing the growth of wild rice into two major parts with each part in itself being subdivided once.

Firstly, the growth of wild rice was studied in detail at a site with potential extremes in growing conditions, namely a thermal power generating station. The problem of seasonal changes in environmental factors at five sampling stations near the power station was corrected for, and, using discriminant analysis - an among groups multivariate technique - the factors were isolated and used to model the growth of wild rice.

A specific problem of plant-environmental interactions was not being able to correlate the concentration of an element in plant tissue with the corresponding element in the sediment or soil. This problem arose directly out of the first study and the two hypotheses of Klopatek (1978) were assessed for their potential to explain this phenomenon. In the case of wild rice, the second hypothesis, namely that concentration

of elements in plant tissue were independent of the concentrations of the same elements in the sediment or soil, appeared to offer the most likely explanation. A theoretical model was derived to offer support for the second hypothesis.

The second part of the objective examined the regional distribution of factors which influence the growth of wild rice. Specifically the biological, chemical and physical components of the environment of wild rice were investigated throughout northwestern Ontario and northeastern Minnesota in order to gain some measure of environmental ranges within existing commercial stands of wild rice.

Finally, the growth performance of wild rice plantings in various lakes, previously without wild rice, was studied with a view to deriving recommendations for the management of this resource. Based upon plant density, each lake planted with wild rice was categorized into one of three groups. Discriminant analysis was used to isolate those biological, chemical and physical factors which varied among the three groups and these isolated factors were assessed for their possible effect on the growth of wild rice.

CHAPTER 1

A STUDY OF AMONG SITE VARIANCE IN THE GROWTH OF WILD RICE, *Zizania aquatica* L., NEAR A THERMAL POWER GENERATING STATION AT COHASSET, MINNESOTA

INTRODUCTION

The growth of plants is a function of the biological, chemical and physical properties of the surrounding environment. Biological factors which may affect the growth of aquatic macrophytes are disease (Klotzli, 1970), grazing (Wetzel, 1975) and inter- and intraspecific plant competition (Hutchinson, 1975). According to the literature both disease and grazing are negligible in terms of affecting aquatic plant production. The spatial distributions of the individual species are generally attributed to the physiological requirements of the species but examples of direct plant competition have been documented between *Glyceria* spp and *Phragmites communis* (Buttery *et al*, 1965), and *Chara* spp and various rooted angiosperms (Wohlschlag, 1950). Kadlec and Wentz (1974) listed the aquatic perennials, *Eichornia crassipes*, *Trapa natans*, *Phragmites communis*, *Typha latifolia* and *Hibiscus* spp, as problem species adapted for rapid dispersal and increased competitive ability. Intraspecific competition, causing the dry weights of individual plants to decrease as plant density increases, is well known for crop plants (Milthorpe and Moorby, 1974) but has been seldom studied in aquatic macrophytes. Bernatowicz and Pieczynska (1965) observed a negative relationship between plant density and the weights of stems of *Phragmites communis*. Lind and Cottam (1969) found *Myriophyllum exalbescens* to weigh less in sampling plots with greater density.

The varying concentrations of chemical factors can influence the growth and production of macrophytes. Misra (1938), recorded that the growth of *Potamogeton perfoliatus* was dependent upon the sediment type in which it grew. Similar variations of growth rates with different sediment types were observed for *Lobelia dortmanna* and *Ruppia mortima* (Moyle, 1945), *Phragmites communis* (Pearsall and Gorham, 1956), *Myriophyllum exalbescens* (Mulligan and Barnowski, 1969), *Ceratophyllum demersum* (Denny, 1972) and *Potamogeton pectinatus* (Kollman and Wali, 1976). Some studies related the distribution and production of aquatic plants to water chemistry (Moyle, 1945; Casey and Downing, 1976), although it appeared that many aquatic plants obtain their nutrients from both water and sediment (Bristow and Whitcombe, 1971; Denny, 1972).

Physical factors known to affect the growth of aquatic macrophytes are water depths, currents, and waves (Sculthorpe, 1967; Hynes, 1972), light (Pearsall and Hewitt, 1933; Sculthorpe, 1967; Spence and Chrystal, 1970), and temperature (Sculthorpe, 1967).

In general, the majority of the above studies concentrated on only one aspect of the environment which affected the growth performance of the particular macrophyte being examined. This approach is quite simplified since in a complex natural system no one factor acts independently of other factors. An increasing number of studies are now being done, which, through the use of multivariate statistics, quantify the wetland habitat by examining a large number of environmental factors simultaneously (Walker and Coupland, 1970;

Walker and Wehrhahn, 1971; Auclair *et al*, 1976; Johnson, 1977). The multivariate approach has provided a useful, more realistic interpretation of within and among group spatial variations of the natural environment. Unfortunately many environmental factors also exhibit seasonal as well as spatial variations, which, simply as a result of changes due to time, cause the variances of these factors to become so large that multivariate methods can no longer be applied with any degree of accuracy.

During 1976 and 1977, the growth of wild rice, *Zizania aquatica* L., was quantified according to the statistical differences in the biological, chemical and physical factors at different sampling locations near a thermal power generating station. Such power plants provide ideal settings for studies of among group variations since they generally produce distinct differences in the natural environment within a relatively small area and thus allow sampling to be completed during the same time frame. The objectives of this study were; (i) to identify any seasonal trends and statistical intercorrelations of the variables thought to influence the growth of wild rice at different sampling stations, (ii) to devise a technique which would remove any seasonal time-dependency trends in the variables so that discriminant analysis, a multivariate among groups statistical technique, could be used to isolate those variables which differed among the sampling stations; and (iii) to derive a mathematical model, which included these isolated variables, for the seasonal growth of wild rice at the sampling stations.