Integrating agronomic management practices with waterfowl populations in rice fields: opportunities and mutual benefits.

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ABSTRACT

Rice production in California is largely concentrated in the Sacramento Valley. Prior to converting the land into rice production, the valley was largely composed of interconnected wetlands which were inundated in the winter months when most of the rainfall occurs. Numerous duck, goose, swan, and shorebird species winter in the Sacramento Valley as they migrate each fall from the northern regions of the western part of the USA and Canada. Following the conversion of the wetlands into rice production areas during the early part of the 20th century, the winter habitat for waterfowl was significantly altered.

California rice production is considered to be one of the most productive in the world and grain yield of 12 tones per ha are no exception. High grain yields are always associated with high residue yields as the harvest index for rice remains close to 0.5. Whereas in the early days, residues were burnt in the fall or spring, new regulations will reduce the acreage that can be burned to 25 % of the total acreage used for rice production. As off-site use for rice straw remains limited, an on site disposal method is often the only option left for farmers . To accelerate the decomposition process of the residue, almost half of the total acreage used for rice production in California is reflooded during the winter months. Once the straw is dispersed across the field in the fall, the fields are flooded in late October or early November and drained again in early spring to allow preparations for seeding.

By providing alternative habitat during the winter months, the rice fields are attracting large number of waterbirds which use the fields, principally to forage and roost. When large number of birds visit the rice field, the extra disturbance they induce may lead to an increase in the rate of decomposition of the rice straw. Early findings from an enclosure study suggest that indeed decomposition was enhanced by waterfowl. Because waterfowl forage not only on rice seeds but also on seeds from weeds (moist-soil plants) that were present in the rice fields, the size of the seed bank of weeds may also be affected by the waterfowl population. If indeed proven to be correct, a reduction in weed herbicide use could also be anticipated. Along similar lines, the invertebrate population in the soil would also be dependent on the size of the waterbird populations that visit the winter-flooded fields. The impact of a reduced invertebrate population on nutrient cycling remains unknown.

Fully integrating agronomic rice practices with waterbird biology remains a largely unexplored area. Whereas rice management practices or the ecology of wildlife in rice fields have been studied independently from each other, a research project that fully integrate the two components remains largely a new area of interdisciplinary research . Conducting such an integrated research project on rice production and waterfowl, however, will have its

challenges. For example, the classical agronomic research design will have to be replaced with a design that can verify how the frequency of waterfowl visits to the rice fields has an impact on agronomic significant parameters such as rate of decomposition of the rice residue, the occurrence of seeds and even grain yield.

An interdisciplinary research project with participation of agronomists, soil scientists and wildlife biologists is initiated in 1999. A large landscape-scale driven project has been designed that will quantify and make predictions about the mutual benefits of producing rice in association with the waterfowl population. This field study will be used as a case study to assess the mutual benefits of waterfowl populations and agronomic practices.

APPROACH

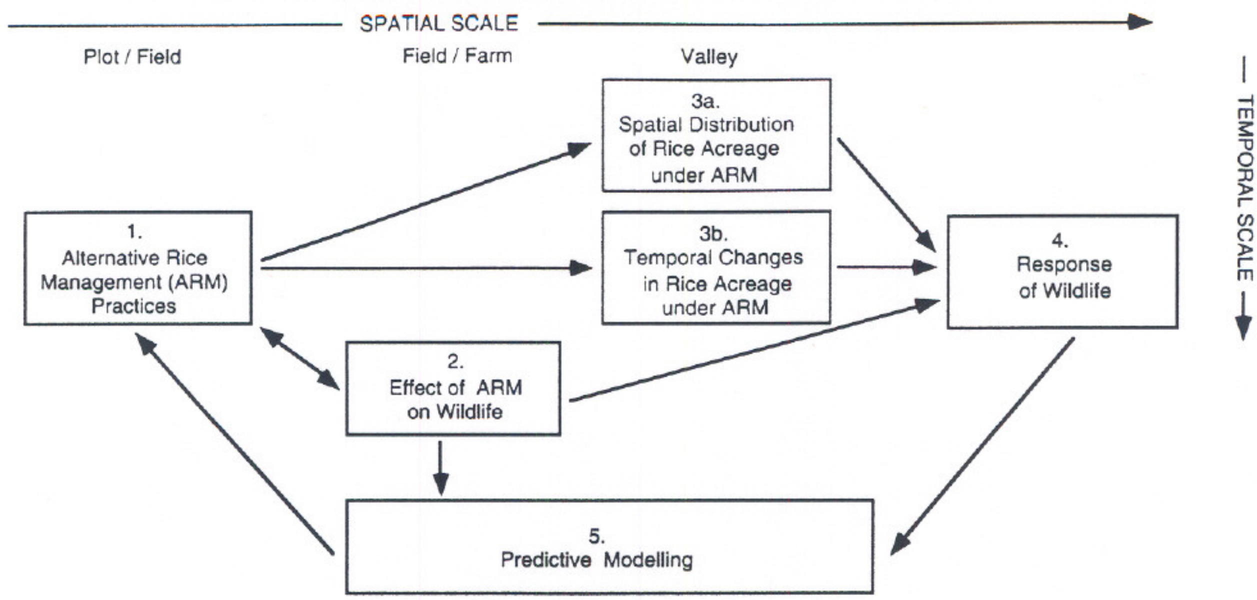
Recent changes in the way that California's rice fields are managed have altered fundamentally the habitat available to wildlife. The Rice Straw Burning Act, which reduces the rice acreage that can be burned each year, has increased use of alternative straw disposal methods such as flooding rice fields, often in conjunction with some form of straw manipulation (rolled, baled, disked or chopped). New developments in harvest technology (e.g., stripper header harvesters) have added further to the variety of rice management practices currently operating in California.

Efforts to evaluate agronomic efficiency of alternative rice management (ARM) practices have generally proceeded independently of efforts to evaluate the benefit of those practices to wildlife. Initial efforts from 1992-98 were supported by the California Energy Commission, Bureau of Reclamation, Ducks Unlimited, and the Central Valley Habitat Joint Venture. The latter group recognized that the priority of funding should be, in order, to studies of: (1) agronomy, (2) waterfowl ecology, (3) water issues, (4) other species impacts (such as shorebirds, endangered species, or anadromous fish). Agronomic concerns focus on issues such as the impact of winter flooding and high straw loads on nutrient availability, carbon buildup, and weed, disease and insect pests. Wildlife concerns, in contrast, focus on the value of ricefields as foraging or roosting habitat and on the potential impact of rice management practices on the quality of this habitat. Recently, there has been growing recognition of the value of ricelands to waterbirds and cooperative ventures between rice growers and wildlife agencies and organizations are increasing. However, a fully integrated effort to develop management plans that maximize the value of ARM to both farmers and wildlife will be needed.

An interdisciplinary research program to evaluate the factors limiting rice production and waterbird sustainability in California seeks to integrate both agronomic and natural resource functions of alternative rice management practices. The research comprises 5 components with linkages as indicated below.

Component 1. ARM and Rice Production.

Rice producers in California are faced with recently imposed legislative changes in production practices. Alternative rice residue management practices that incorporate rice straw into paddy soils and winter flooding are currently being adopted in CA due to the legislative restriction of open-field burning mandated by the California Rice Straw Burning Reduction Act (AB 1378, 1991). These changes may alter the sustainability of rice production unless producers are able to adequately manage for N in soil with continuous flooding and incorporated rice residues. Nitrogen use optimization must achieve both efficient utilization of fertilizer N inputs and soil organic N. The influence of the soil organic fraction on soil fertility in rice cropping systems is rarely considered; yet soil



organic matter (SOM) has been identified as the single most important indicator of soil quality in agricultural systems (NRC, 1993). Previous studies indicate that soil organic N is the most important source of plant-available N for rice in CA, representing 50-80% of total N assimilated by the crop (Broadbent, 1979; Mikkelsen, 1987). The effect of plant residues and winter flooding on N immobilization into organic fractions of rice systems has received little attention, especially in California. The implementation of residue incorporation with winter flooding has been found to reduce straw waste for seedbed preparation and provide needed habitat for migratory waterfowl. Incorporation of 9-10 Mg ha^{-1} of rice straw each year to soils with virtually continuous flooding may alter the composition and nature of SOM fractions; this in turn may have important agronomic implications with respect to N availability by affecting the rate of N sequestration by SOM.

The immobilization of N into soil organic matter represents a substantial sink for fertilizer and crop residue N inputs in terrestrial soils. Field trials, using the stable isotope ^{15}N, have shown that from 20-40% of fertilizer N remains behind in organic forms after the growing season in temperate-zone agricultural soils (Kelley and Stevenson, 1996). The organic N stabilized in humic fractions generally resists microbial attack and is not readily available for plant uptake (Stevenson, 1994). The long-term availability of the immobilized N is not often determined because of the lack of adequate methodology. In California, rice cropping systems have begun to utilize residue incorporation and winter flooding management on a routine basis. These changes in management have prompted the need for an understanding of the role of soil organic matter in regulating the immobilization and mineralization of N in submerged soils, and the improvement of N-use efficiency in rice.

Soils continuously cropped to rice and flooded have been shown to differ in soil organic matter composition and N availability compared to soils that have had fewer annual crops and longer aerated, fallow periods. Rice yield declines have been seen in several long-term experiments with continuously flooded double- and triple-cropped rice in the tropics. These yield depressions have been attributed to a declining effective-N supply while total soil N and C levels were maintained or increased (Cassman et al., 1995). Organic components of soils subjected to long-term, intensive rice culture were higher in total soil N, phenolic compounds, humic acid-N and had a greater proportion of total soil organic N as humic-acid-N than those soils that were less intensively cropped and flooded (Olk et al., 1996). In California, residue incorporation and winter flooding may similarly increase phenolic accumulation and N sequestration into humic materials and result in lower N-use efficiency of added fertilizer N.

Component 2. ARM and Wildlife

Harvested rice fields in the Sacramento Valley provide the bulk of food resources for large populations of wintering ducks, geese, and swans, even with the presence of tens of thousands of acres of managed wetlands on national wildlife refuges, state wildlife areas, and private duck clubs. Good estimates of the amount of rice remaining in conventionally harvested fields are available (Miller 1987, Miller et al. 1989), but estimates for the newer strip-harvested fields are only preliminary. In either case, little is known about the efficiency with which waterfowl forage in the different rice habitats available, and thus the usable proportion of rice seed in harvested fields is not known. A certain percentage may be unavailable because of the presence of straw which covers seeds and makes discovery and consumption by waterfowl difficult. Furthermore, the proportion unavailable may vary by rice treatment type. For example, some fields are left conventionally harvested (standing stubble) or strip-harvested (standing straw) with no additional treatment; some stripped fields are swathed or mowed, and either harvest type may be chopped or baled; many fields are disked/plowed and many are still burned. All of these treatments may be left dry or flooded. Thus, waterfowl have a variety of rice field habitat types to chose from, and foraging efficiency may vary in each making certain treatments more valuable for waterfowl management purposes (Day and Colwell, 1998).

Reciprocal benefits to rice growers of attracting waterfowl also needs further investigation. Research on small study plots in California indicated that waterfowl activity significantly reduced both the amount and the average diameter of surface straw residues in flooded rice fields (Bird et al. 1998 a,b). C, N, and lignin concentrations in the surface straw residue were also reduced on plots with duck activity, as were densities of invertebrates. These results suggest that considerable agronomic benefits may result for growers through attracting foraging water fowl.

Component 3: ARM and its Spatial Distribution.

Resource agencies, agricultural interests, conservation organizations and local governments require up-to-date information on the location and extent of seasonally flooded rice fields and wetlands for use in planning and evaluating land use actions and impacts to wildlife (Kempka et al., 1996, Andree et al., 1998). However, the highly variable nature of seasonally flooded habitat for wildlife makes it difficult to quantify and monitor. Flooded habitat changes in response to precipitation, management decisions, availability of water and agricultural markets. Differences are observed between years as well as within a single fall/winter season (Spell et al., 1995).

Component 4: ARM and the Response of Waterfowl.

Despite loss of over 90% of California's wetlands since the turn of the century, about 60% of Pacific Flyway and 18% of North American waterfowl winter in the Central Valley; millions more migrate through or nest there (U.S. Fish and Wildlife Service [USFWS] 1978, Gilmer et al., 1982, Canadian Wildlife Service and USFWS, 1986). The amount, distribution and quality of waterfowl habitat in the Central Valley has changed drastically during the last decade because of changing agricultural practices and habitat conservation efforts of the CVHJV and others. For example, the acreage of rice fields flooded after harvest in the Sacramento Valley increased 250% (60,000 to 150,000 acres) between 1985 and 1995 due to efforts of farmers and other conservationists to replace rice-straw burning with an economical and wildlife-friendly alternative. Waterfowl sanctuary in the Sacramento Valley provided by flooded rice fields increased nearly 700% (6,000 to 40,000 acres) during the same period because much of this additional flooded acreage was not hunted (CVHJV Technical Committee 1996). In contrast, flooded cropland habitat important to waterfowl declined about 50% in the San Joaquin Valley due to efforts to reduce water use and agricultural wastewater (Barnum and Euliss, 1991). Managed wetland acreage increased 36% in the Sacramento Valley (49,021 to 66,675 acres) but only 9% in the northern San Joaquin Valley (66,207 to 72,207 acres) during 1985-95 (CVHJV Technical Committee 1996).

Managers will need current information on waterfowl distribution, movement patterns and habitat use throughout the wintering period to understand how waterfowl have responded to habitat changes and to estimate the acreage, distribution and flooding regimes of habitats needed to support waterfowl populations in each Central Valley basin. For instance, to estimate waterfowl use-days and habitat requirements in each basin (USFWS 1978) when the desired Central Valley wintering populations of 4.7 million ducks and 865,000 geese and swans are reached (CVHJV Implementation Board 1990), CVHJV planners assumed that waterfowl distribution would remain like that observed during 1973-77 midwinter surveys, and that waterfowl populations in each basin would gradually buildup during fall, peak at the midwinter count in early January, and then gradually decline to desired summer breeding levels (Heitmeyer, 1989a). CVHJV goals for wetland and agricultural habitats in each basin were then developed assuming waterfowl would increase their use of wetlands as wetland habitat was increased (Heitmeyer, 1989a). Once in place assumptions regarding waterfowl distribution, movements and habitat use should be evaluated. Managers can then determine whether habitat goals and management strategies of the CVHJV and other programs need to be modified to ensure long-term viability of conservation programs and wildlife populations they support.

When fully implemented, the CVHJV will affect activities on 950,000 acres of wetlands and agricultural lands in the Central Valley at a capital cost of more than $528 million and an annual cost of about $38 million (CVHJV Implementation Board 1990). It is crucial that farmers and managers of conservation programs such as the CVHJV have the information necessary to understand how wildlife respond to landscape-scale changes so that their large investments provide the maximum sustained benefit for our natural resources.

Component 5: ARM and Predicting the Impact on Rice Production and Waterfowl Population.

Recent studies have indicated that the implementation of alternative rice management practices may have important benefits for waterbird conservation (Elphick ,1998; Elphick and Oring, 1998). To date, however, research on the relationships between waterbirds and rice field management have been hampered in two ways. First, most research has been descriptive in nature. It is important to move into the realm of prediction, by using mathematical models that blend ecological theory with practical information obtained in the field, to estimate what will happen under different management scenarios. The second limitation on current knowledge has been that different investigators have worked largely in isolation, coming together only occasionally at meetings to discuss their research. By integrating our modeling research with studies of agronomy and waterbird behavior, we will be in a position to address effectively the concerns of farmers, wildlife managers and conservation biologists, and to develop recommendations for how best rice can be managed to satisfy all interested parties.

Through rigorously designed large-scale surveys and experimental manipulations flooded fields support significantly greater densities of 24 species of water birds than fields left unflooded (Elphick, 1998; Elphick and Oring, 1998). Many of these species are thought to have undergone significant declines due to the conversion of Central Valley wetlands to agricultural lands (e.g., Heitmeyer et al., 1989). Results indicate that agricultural flooding may provide the key to reversing these declines in water bird populations.

Research to date has focused on understanding how the management of individual fields influence bird use. This information is useful for directing management at a local scale. And needed to provide an accurate picture of the large-scale consequences of different management options.

Studying large-scale questions is difficult without enormous resources and considerable inconvenience to landowners. Given the information available, the most effective way to address these problems is through modeling. A modeling approach allows the integration of the results from various studies to assess the effects of different management regimes without having to conduct the large-scale experiments that would otherwise be necessary. Once the modeling is complete field tests should be conducted to validate the modeling results.

The modeling approach should explicitly incorporate spatial and temporal scale. Most agronomic analysis, of necessity, take place at a small spatial scale, usually experimental field plots. However, wildlife responses typically occur at considerably larger scales, usually field or valley-wide. Studies will be integrated at the plot level with studies of changing rice management practices at the valley level. By examining wildlife response to both field level management practices and valley-wide changes in the extent and location of rice acreage under ARM, the impact of alternative rice management practices on wildlife at both small and large spatial scales will become known.

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