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Uncovering the spatial dynamics of wild rice lakes, harvesters and management across Great Lakes landscapes for shared regional conservation

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ABSTRACT

Sustainable conservation and management of valued resources and ecosystem services relies on understanding the dynamics of the socio-ecological system. In the case of wild rice, a cherished food resource of Northern Great Lakes landscapes, the dynamics involve (a) a changing distribution of wild rice lakes, (b) changing harvester population and demographics, and (c) different management overlays. Together these factors influence harvester choices and opportunities and create unexpected spatial dynamics between people and the lakes they harvest. In this paper we examine first, the regional distribution and characteristics of wild rice lakes through compilation of multi-agency data, geospatial analysis, license sales and harvest surveys. Second, we identify patterns of harvest in the region through six case study lakes and examine the decision-making models used to open lakes for harvest. Gathered together these various forms of knowledge and collected data sets inform our understanding of the social–ecological systems involving wild rice (*Zizania palustris*). Watersheds with wild rice have declined by 32% since the early 1900s, and are now primarily limited to northern Minnesota and Wisconsin. Across case studies wild rice harvesters tend to gather wild rice close to where they live or learned to harvest and 50% have more than 20 years experience. Some wild rice lakes draw harvesters from greater distances and in higher numbers. Models for managing the harvest of wild rice range from 'gather when ripe' by state entities to a more hands-on posting by reservation committees specifying hours and days of harvest on a lake by lake basis. The social–ecological system around wild rice is a complex mosaic of multiple management jurisdictions, culturally diverse people, and an ecological system that is not well understood and potentially declining in extent. Defining the context of harvest within the spatially connected landscape and across multiple management systems is a first step in developing a shared framework of governance for the sustainability of wild rice landscapes.

1. Introduction

Conservation approaches in the U.S. focused on wild harvested products, such as berries, boughs, mushrooms and wild rice, have emerged as a specific area of interest within the forestry community (Emery, 2001; Love and Jones, 1995). Research on the development of community-based forestry initiatives and more participatory and integrative research involving communities of gatherers, natural resources, and management institutions has been conducted by Bailey (2002), Baker and Kusel (2003) and Ballard (2004). Issues of access and availability, and the identification of harvest strategies and participants are explored in salal (*Gaultheria shallon*) gathering in the Pacific Northwest, where non-residents were the primary harvesters acting on a commercial scale (Ballard, 2004). Crane (2010) points to the role of culture within social–ecological systems and the way cultures can frame resource degradation perspectives differently, as is the case between the Marka and Fulani agropastoralists and soil-fertility decline n the West African Sahel. The cultural connection to wild rice for the indigenous Ojibwe frames their perspective on wild rice management differently than non-Ojibwe.

Euro-American entry into wild rice harvest and management in the Upper Great Lakes Region has played a significant role in creating the social–ecological system that exists today. Harvesting of wild rice (*Zizania palustris*) has evolved from subsistence gathering (pre-European contact), to use as a trade item (fur trade era, mid 18th century), and finally to a blend of supplemental use and commodities income involving both Native American and non-Native populations. Regulation of harvest has also transitioned from local governance on individual lakes to mixed management ranging in scale from tribal self-governance across reservation lakes to state wide policies (Jenks, 1900; Vennum, 1988). This mix of tribal governance, state resource management, spatially

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overlapping jurisdictions and culturally diverse harvesters exists with limited coordination and a lack of vision towards sustainability.

The social–ecological system of wild rice landscapes have become increasingly complex and the question of whether or not wild rice populations are stable or declining is unknown (Rodriguez, 1999). Adaptive governance, as described by Folke et al. (2005) provides a perspective from which to explore the development of a more resilient system, one not yet in existence. Information on wild rice distribution is limited, making it difficult to identify current trends. Data that is available remains dispersed among multiple government and tribal agencies, limiting our understanding of population dynamics. Relationships between harvesters and the lakes they harvest are undocumented and influenced by the multiple scales of regulation found across the harvesting region. Conservation strategies for wild rice are not yet formalized, and little effort has been directed towards creating a structure or model for attempting to do so. Traditional ecological knowledge systems as described by Berkes (1999) could inform practices of resource use and management for wild rice, as these systems still exist but have not been adopted or examined alongside scientific resource management. This paper will focus on research conducted to reveal the intricacies of the linked social–ecological system of wild rice harvest and management across cultural and ecological boundaries.

2. Background

Jenks (1900) used the term 'wild rice district' to describe the glaciated alluvial region of Wisconsin and Minnesota, USA. This region contains many low gradient streams connecting numerous lakes – often with substrates of mucky, organic sediments – that support one of the few remaining concentrations of natural wild rice growth in the world (Ontaria, Canada being the other). Estimates of wild rice abundance today range from a minimum of 26,000 ha in Minnesota under favorable growing conditions to less than half that for Wisconsin (David, GLIFWC, personal communication; Jenks, 1900; Meeker, 1996; Minnesota DNR, 2008). Precise area is difficult to assess due to the annual nature of this grass, its wide fluctuation in production from year to year, and limited data.

We make a distinction here between wild rice growing in lakes and streams and the wild rice found most commonly in retail stores around the United States and in a variety of consumer rice blend products. In the 1950s development of a commercial variety of wild rice, cultivated in paddies, led to a commercial market that now produces over 23 million pounds a year, accounting for roughly 98% of the market crop (Kuiken, 2007). The states of California and Minnesota have been the primary producers of domesticated *Zizania* since the 1980s (Oelke, 2007). This rice is a cultivar grown in constructed paddies on private lands and not to be confused with the wild harvested wild rice, which is a state public resource. Annual harvest of *wild* wild rice, more difficult to quantify, is estimated through harvest surveys to be roughly half a million pounds (Davidson-Hunt and O'Flaherty, 2007; MN DNR, 2008). Sold primarily by individuals and difficult to track, wild harvested wild rice can sell for double the price of cultivated.

Our study focuses solely on wild rice growing on public waters (lakes and streams) across the Northern Great Lakes Region within the U.S., and which is regulated as a state resource and harvested by traditional (hand-harvest) methods.

2.1. Wild rice ecology

Growth and development of wild rice, particularly in Canada, has been studied by Dore et al. (1969), Lee (1986,1987), and Thomas and Stewart (1969). Wild rice is an annual plant, which grows from seed in rivers and lakes with soft organic bottoms. Optimum recorded water depths for wild rice range from 0.3 to 0.6 m (Aiken et al., 1988) with plants occasionally growing in water depths up to 1 m (Moyle, 1944). Water depth year-to-year and fluctuating water levels during the growing season impact wild rice development and often affect production from year to year. During early growth, when the plants are floating on the water and the roots are shallow, wild rice is most susceptible to uprooting (Aiken et al., 1988; Vennum, 1988). High water levels in a given year can often drown out a rice bed, while drought conditions may increase production but make harvesting the seed difficult. Wild rice is a monoecious plant that is wind pollinated. The tiny white female flowers emerge first on the stem, while the male flowers are still encased in the sheath, reducing the possibility of self-fertilization. Once fertilized, wild rice seed matures from the top of the stem downward over a period of 10–14 days, shattering from the plant when ripe and anchoring in the sediment close to the parent plant (Fannucchi et al., 1986; Moyle, 1944).

Once distributed across the eastern half of the United States, habitat for wild rice was reduced significantly with Euro-American settlement in the late 1800s and early 1900s (Meeker, 1993; Rogosin, 1954; Vennum, 1988). Wild rice provides important feeding and resting areas for waterfowl on their seasonal migration and is utilized by a variety of mammals, fish and invertebrates (Huseby et al., 2001; Moyle, 1944; Stoudt, 1944). As early as 1890, hunting clubs, recognizing the lure of wild rice for migrating waterfowl, bought and planted wild rice seed in local lakes (Jenks, 1900). Changes in hydrology (dams, road crossings), climate change and invasive species threaten today's wild rice region, now confined primarily to the northern, less populated areas of Minnesota and Wisconsin (Jennings et al., 2003; Minnesota DNR, 2008). In recent years, Minnesota's Department of Natural Resources has seen a doubling of requests by shoreland owners for permits to remove wild rice (2002 through 2006). Increased development along shallow lakes, and increased motorized recreational use on lakes that harbor shallow bays of wild rice will continue to reduce wild rice habitat (Radomski and Goeman, 2001; Tynan, 2001).

Harvesters, duck hunters and resource managers have more recently influenced abundance and distribution of wild rice through manipulation of water levels and sowing of seeds (David, 2000; Doolittle, 2000; Vennum, 1988). These changes in use, population and regulation have made the dynamics between harvesters, wild rice lakes and management less decipherable.

2.2. Cultural use

Seeds of the aquatic wild rice plant have been utilized as food for more than a thousand years (Huber, 2000; Jenks, 1900; Valppu, 2000). Wild rice is harvested each fall using a canoe and hand-held sticks, in much the same way the Native American Ojibwe people gathered it prior to European settlement. Oral traditions within the Ojibwe culture describe a historic migration of the people westward to where 'food grows on the water.' This food, wild rice, or *manoomin* (Ojibwe) is considered a gift from the creator to the Ojibwe and continues to be an important element in traditional ceremonies and customs (LaDuke, 2003; Regguinti, 1992). Ojibwe of the region consider wild rice to be a foundational aspect of their identity as a people (Vennum, 1988; LaDuke, 2005).

As late as the early 1900s, the Ojibwe camped on the shores of the wild rice lakes, gathering, parching (drying) and cleaning their rice. Elders, older members of their community respected for their experience and knowledge, would determine when the wild rice was ripe on a particular lake, open the lake to harvest and watch over the gathering. As the boats move through the rice, ripe seed shatters as the stems are bent over and the rice heads are knocked

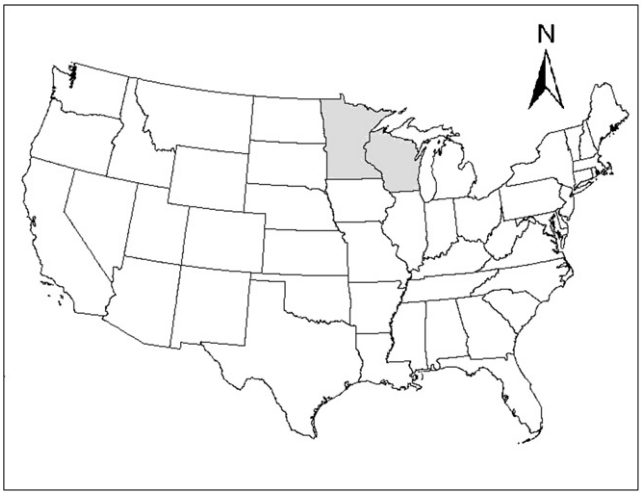

Fig. 1. Area of study: Minnesota and Wisconsin.

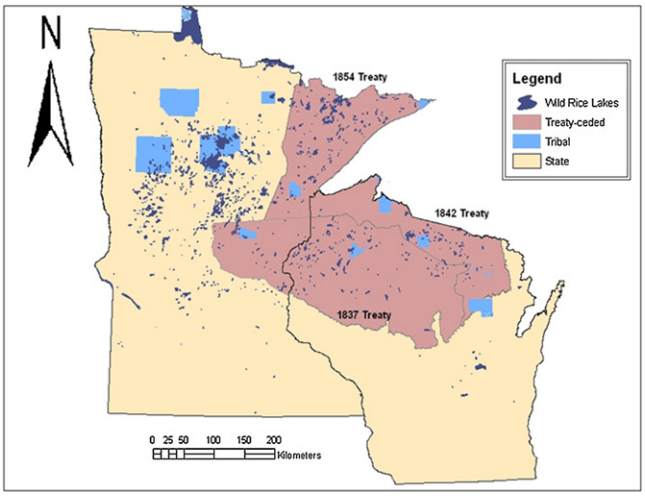

Fig. 2. Wild rice distribution across state, tribal and treaty ceded lands in Minnesota and Wisconsin.

with sticks. Harvesting in this manner sends wild rice seed into both the canoe and the water, where enough falls to germinate a crop for next season. Individuals who did not follow the guidance of the elders in regards to where and when to harvest were likely to have their canoes taken from them and any rice they had gathered, dumped on the lake bottom (Kegg, 2002; Vennum, 1988). Harvesters now rarely camp and most have the ability to drive from lake to lake looking for ripe wild rice.

State license sales for harvesting wild rice in Minnesota peaked at 16,000 in the late 1960s, just prior to the commercial production of cultivated wild rice. An average of 2000 state licenses for the hand-harvest of wild rice on public waters were sold each year from 2000 to 2009, based on license sales in Minnesota and Wisconsin, the only states in the U.S. that regulate wild rice harvest (Minnesota and Wisconsin DNR) (Fig. 1). Estimated tribal participation in Minnesota is 3000 harvesters (Minnesota DNR, 2008); Wisconsin numbers are unknown. Both tribal and non-tribal members have expressed concern regarding the decline in participation, especially by youth (Mertens, 2004; Minnesota DNR, 1998).

2.3. Jurisdiction and management

Authority to regulate and manage the harvest of natural wild rice primarily rests within state and tribal institutions across the Upper Great Lakes Region in the United States (U.S.). Both Minnesota and Wisconsin delegate that authority to their respective Departments of Natural Resources (Minnesota Statute 84.15 and Wisconsin Statute 29.607). Tribal governments in Minnesota and Wisconsin maintain jurisdiction over harvest of wild rice within reservation boundaries. Treaty agreements between some tribes and the U.S. government reserve harvesting rights for those tribal members within the territories ceded, independent of state regulation (Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and 1854 Treaty Authority) (Fig. 2).

Current management for wild rice consists of *manipulating the resource,* through water level management (dams and beavers) or seeding of lakes; and *regulating harvesters*, requiring licenses and controlling days and hours of harvest. Wisconsin management efforts involve re-seeding lakes where appropriate as determined by historical records and/or current habitat status (David, GLIFWC, personal communication). This re-seeding is done by purchasing freshly harvested wild rice from those gathering it off lakes and streams, and then re-distributing it on selected lakes with potential habitat. Seeding is not always successful, but in areas where it is, harvestable rice stands are restored to the resource base. Anecdotal evidence suggests that wild rice has always been re-distributed to ensure harvesting opportunities for families (Vennum, 1988). Ducks Unlimited partners with the Minnesota Department of Natural Resources to control beaver and water levels on approximately 100 wild rice lakes (of an estimated 970 lakes) across the state, promoting wild rice growth for enhanced waterfowl production (Landwehr, 2004; Schneider, 2007).

The matter of opening lakes for harvest is perhaps the most contentious aspect of wild rice management across the entire ricing region. Tribal management allows for committee and resource staff to make decisions regarding the opening of particular beds of wild rice, even within the same lake. Treaty ceded lakes in Wisconsin that are date regulated (not all of them are) are posted open for harvest through a decision between the local conservation officer and a tribal representative (David, GLIFWC, personal communication). Minnesota also practiced co-management for opening of Big Rice lake, within the 1854 Treaty Authority area in 2005, but the state later backed out and refused to set a posting date in 2006, leaving it open based on 'ripeness' (Vogt, 1854 Treaty Authority, personal communication). State lakes in Minnesota are 'open when ripe' meaning that harvest may occur once the seeds are mature. As it stands now, the 'open when ripe' law is unenforceable as there is no definition of ripeness from which to make a charge, since rice kernels ripen over a period of days and weeks, even on the same stalk.

Access to lakes for harvest is governed by a harvester's tribal affiliation and/or residency (Minnesota DNR, 2011) Harvesters in Wisconsin can travel to Minnesota and purchase a non-resident harvesting license; however Minnesota harvesters cannot cross over to Wisconsin to harvest, unless they are harvesting under a treaty-ceded permit due to tribal registration (GLIFWC 2011). Harvesters may sometimes cross management jurisdictions while gathering a season's harvest. Costs of licenses and restrictions on harvesting also vary across jurisdictional lines, impacting harvesters differently. Multiple agencies with dissimilar regulations and licensing requirements make it extremely difficult, if not impossible, to gather regional harvester data to inform wild rice management.

3. Problem situation and approach

The dynamics of the wild rice landscape have changed dramatically over the past century. Harvesters of wild rice now include those outside of the traditional culture (Ojibwe) and little is known

about either group's use of the landscape or their relationship with the lakes they harvest on. How far will they travel, why do they choose certain lakes, and how many lakes do they harvest? Limited spatial information is available on wild rice lakes, making it difficult to identify trends in distribution that could inform land use, development, and regional conservation decisions. Multiple regulating governments, limited fiscal resources, and issues of distrust have been a deterrent to development of a regional wild rice perspective.

At the time of this study, geospatial data on the distribution and abundance of wild rice across Minnesota and Wisconsin was limited. Minnesota DNR had a GIS point layer to designate wild rice lakes within their inventory set, a database with estimated presence of wild rice based on phone and mail surveys of area wildlife biologists (Geisen, MDNR, personal communication). This dataset, although extensive, incorporated data from as early as 1941, over representing the current distribution of wild rice in Minnesota. GLIFWC monitors a subset of their wild rice lakes, located primarily in Wisconsin, through aerial surveys each fall and uses harvester surveys at the end of the season to document harvest. However, there has yet to be a consistent region-wide spatial record from which to measure temporal change in distribution.

Monitoring distribution of wild rice on a regional scale is complicated by the annual nature of this native grass and the changing water levels of aquatic systems, which influence its growth from year to year (Aiken et al., 1988; Vennum, 1988). Satellite imagery suitable for identifying some plant groups has not yet proven cost or labor effective for regional monitoring. The Leech Lake Band of Ojibwe working with Cincinnati University, Ohio mapped wild rice using remotely sensed data (Landsat 7 data) in 1999. They were successful in estimating abundance within the boundaries of the reservation, an area just over 2590 km^2, but a lack of funding restricted the project to one year (Bailey et al., 2001). Aerial photography, currently used to monitor individual lakes in some areas, is effective on a finer scale where rice beds are known to occur and ground truth visits are feasible, but is not viable across a study region that encompasses more than 32 million hectares.

Therefore, to capture the spatial and socio-ecological drivers of this wild rice landscape we asked two main questions:

- How are wild rice lakes distributed across ecological and management boundaries?
- What are the spatial and temporal dynamics between wild rice harvesters and the lakes they harvest?

Understanding the dynamics of a resource base spread across multiple management regimes and harvested by a diverse and widely distributed community requires an approach that integrates both social and landscape methods. The underlying premise of this research is that a dynamic coupled human–nature approach is needed to understand and sustain this regionally significant resource – wild rice. In the face of limited funds and limited data, cooperative action between the users of the resource (harvesters) and resource managers across the rice-growing region is essential to building a regional approach for wild rice conservation.

Within this context, we examined characteristics of the wild rice landscape to identify patterns and relationships between wild rice lakes, harvesters of wild rice, and management regimes. These patterns and relationships were then synthesized to capture patterns of wild rice harvest across the region. We applied geographically explicit narratives, combining spatial and traditional and contemporary ecological knowledge, to help us understand social–ecological relationships and inform conservation planning. In this case, creating spatial narratives of wild rice harvest provided a tool to develop a shared sense of stewardship among harvesters across the broader wild rice landscape – something previously lacking. The concept of the spatial narrative tool is developed further in Silbernagel (2005) and Price et al. (this issue).

4. Methods

We report three primary analyses: (1) Regional characteristics: geospatial analysis of the relationships between wild rice lakes, management regimes and wild rice harvest across the study region; (2) Patterns of harvest: analysis of harvester use and spatial relationships to wild rice lakes through case studies, landing site visits and in-depth interviews; (3) Decision making regarding the opening of harvest: visits with managers and committees.

4.1. Regional characteristics

The distribution of wild rice lakes across the landscape forms the base upon which management and harvesting of wild rice is examined. Wild rice growth on individual lakes can vary so extensively that estimated coverage in hectares was not attempted. Moreover, wild rice also grows in rivers and streams throughout the region, and these data sets were not included in this study. We related current distribution of wild rice lakes across the region to spatial data representing both ecological and sociological units (watersheds, ecoregions, zipcodes, and states).

4.1.1. Wild rice lakes inventory

The Minnesota DNR Shallow Lakes data set is the most comprehensive list of wild rice lakes available to us. Information within this database was compiled from multiple sources, including questionnaires, lake vegetation surveys, personal observations, and waterfowl management projects, spanning 66 years (Geisen, MDNR, personal communication). Data showing confirmation of wild rice from 1996 to 2006 were used to define a baseline dataset from which to compare future decline or expansion of wild rice. Further refinement of this data set included permit requests and harvester surveys. Removal of wild rice along shorelines in Minnesota requires an Aquatic Plant Management permit (APM) with approval requiring an on-site visit to observe the vegetation. APM permits provide more recent observation data (1999–2006) for nearly 300 lakes in the wild rice data set and added an additional 78 lakes to the total. A 2006 survey of wild rice harvest license buyers provided updated data on lakes that had been harvested that year, and these lakes were also added to the eleven-year data set. Finally, the 1854 Treaty Authority has been conducting surveys of lakes in the treaty-ceded territory for several years, and their lakes with wild rice were added to update the distribution baseline.

Wisconsin's wild rice lake inventory comes from information received through harvest surveys and aerial monitoring by GLIFWC. In addition, a recent inventory using herbarium specimens and field notes documenting the presence of wild rice (compiled by J. Sundance through the University of Wisconsin – Green bay) became available for use. Our research combines all data sets, Minnesota and Wisconsin, into one regional baseline of wild rice distribution for the years 1996–2006.

4.1.2. Watersheds

Wild rice, with an affinity for flowing water, is most often associated with streams and lakes on flowages, systems that are commonly managed using watershed approaches. Mapping wild rice at this level meets several objectives: (1) the watershed unit is large enough to be discernable at a scale useful for management; (2) data are of the adequate resolution for identifying whether or not wild rice is present, and (3) mapping at this scale allows for quantitative measuring without jeopardizing local knowledge issues surrounding traditional harvest lakes. Watershed polygons for Minnesota are based on the Natural Resource Conservation

Table 1
Experience (years harvested) and age began harvesting, across harvesting population ($N = 147$).

Lake	Harvester experience		
	N	Avg. age began harvesting (range)	Avg. years harvested (range)
State (Minnesota)			
Upper rice	13	23 (8–46)	15 (1–49)
Mallard	46	20 (6–48)	23 (1–58)
Ceded territory			
Big rice	17	20 (9–36)	25 (1–55)
Clam	25	29 (10–58)	16 (1–47)
Tribal			
Mud	37	14 (8–38)	19 (1–35)
Rice	9	12 (9–16)	44 (20–72)
Total/Avg.	147	20	22

Service Watershed Boundary Dataset, based on a 1:24,000 scale and consistent with aggregated minor watersheds as designated by the Minnesota DNR ($N = 931$). The layer for Wisconsin is based on the Department of Natural Resources watershed designation, approximately equivalent to Hydrologic Unit Code (HUC) "Watershed" (Level 5, 10-digit Hydrologic Unit Hierarchy (HUC)) ($N = 334$) (Wisconsin DNR, 2010).

4.1.3. Ecoregions

Defining the distribution of wild rice lakes across ecological boundaries is consistent with current resource management strategies and provides a tool for conservation planning. Based on the National Hierarchical Framework of Ecological Units (Bailey, 1995; Cleland et al., 1997), ecological units, varying in size, are layered over the base wild rice lakes base map to assess distribution as related to biotic and environmental factors. Distribution was assessed at the Province and Section level, associated with major climate zones, biomes and native vegetation and at the section and subsection level, smaller areas more closely tied to glacial deposits, regional or local climate, and surface topography.

4.1.4. Jurisdictional boundaries

We obtained GIS layers for jurisdictional boundaries through the respective state natural resource agencies and tribal authorities. These included: Wisconsin and Minnesota Departments of Natural Resources (Minnesota Statute 84.15 and Wisconsin Statute 29.607), and two treaty-ceded authorities, (Great Lakes Indian Fish and Wildlife Commission (GLIFWC) and 1854 Treaty Authority). Layers represented two states, three treaty-ceded territories and thirteen tribal reservations. Primary use of these layers was to estimate the percent of wild rice lakes under each jurisdiction. Treaty-ceded boundaries are estimates only.

4.1.5. Harvesting community

Harvester distribution was also mapped in relation to wild rice lake distribution using residence data (zipcodes) obtained from the sale of state harvesting licenses. Regional data represents those purchasing state harvesting licenses in 2005 and 2006, and was obtained from the Minnesota DNR and GLIFWC. A significant limitation of this data set is its potential to under-represent Ojibwe harvesters. In Minnesota and Wisconsin tribal members from Ojibwe/Chippewa bands affiliated with either GLIFWC or the 1854 Treaty Authority are permitted to harvest under off-reservation permits and are not required to possess a state license as long as they are harvesting on ceded territory (1837, 1842 and 1854) or reservation land. This effectively eliminates most of the Wisconsin tribal harvesters from being accounted for in state harvest license sales since more than 90% of wild rice lakes occur within treaty ceded lands and reservations. Reservation licensing information was requested but not provided due to concerns from the wild rice committee regarding potential misuse of data once it was published.

4.2. Patterns of harvest

Harvester movement and regional use of the landscape was informed through case studies, lake landing surveys and interview data, combined with spatial analysis. Individual harvest patterns, if known, were used to describe and explore relationships between lakes and harvesters. In this section the use of case studies involving six lakes, site visits to each lake during harvest, and follow-up interviews with harvesters provided the basis for this data.

4.2.1. Case study lakes

We selected lakes based on management regime (state, tribal or treaty ceded) and history of active rice gathering. A total of six lakes, two from each management regime, were selected with the assistance of local managers and visited both in 2005 and 2006 during the harvest season. Upper Rice Lake (Clearwater County, MN) and Mallard Lake (Aitkin County, MN) were identified as good candidates for state lakes based on heavy use (Mallard) and increased management for wild rice production (Upper Rice). No state lakes were chosen in Wisconsin as nearly all wild rice lakes occur within treaty ceded areas or reservations. Big Rice Lake (St. Louis County, MN) and Clam Lake (Burnett County, WI) were identified as primary wild rice lakes within the 1854 Treaty Authority and GLIFWC, respectively. Finally, tribally managed lakes were identified; Rice Lake (Forest County, WI–Sokaogon Chippewa Band) and Mud Lake (Cass County, MN – Leech Lake Band of Ojibwe). We approached each band through the appropriate natural resource department and requested permission to conduct the study within reservation lands. In both cases we received permission from the tribal council. Each of the lakes identified were considered to be well known and heavily utilized by harvesters, independent of their size (Table 1).

4.2.2. Landing surveys

Using lakes to identify harvesters, rather than license sales, allowed us to look at relationships that exist between harvesters and the lakes they utilize for wild rice gathering. We spoke with all harvesters at a landing either before they went out on the water or very shortly after they came back in to the landing. Information requested included: age they began harvesting, total years harvesting, and zip code of residence. Zip codes provided a geospatial connection to examine distance traveled to harvest wild rice. If harvesters participated at the landing we asked if they would consider being contacted for a follow-up interview.

4.2.3. Interviews

After harvest season we conducted interviews, most often in harvester's homes. The interviews consisted of a set of harvest

questions for that year (total pounds harvested, number of years harvested, who processed), followed by a series of questions exploring first experiences harvesting wild rice, current practices, reasons for harvesting and descriptions of the lake and any changes noted, both in the lake and in gathering wild rice over the years. Recent aerial photographs of each lake were used in the interview to provide a visual reminder when participants described harvest on the lake. Participants responded enthusiastically to the photos, pointing out where they had accessed lakes and recalling the conditions of the rice in various parts of the lake. Interviews typically lasted an hour and were audio-recorded.

4.2.4. Synthesis

Defining the wild rice landscape through a series of maps or a synopsis of interviews only tells part of the story. Through the integration of spatial, visual, narrative, and qualitative data, we created a sequence of spatial narratives around wild rice harvest, unifying the different forms of knowledge produced in this research. These spatial narratives were then used both for identifying a community of harvesters, linked through place, and as a tool for communicating research findings. The spatial narrative concept is elaborated further in Price et al. (this issue) as a tool in scenario building and landscape modeling with expert knowledge.

For each case study lake we composed a spatial narrative layout that included components such as: a location map, aerial photograph of the lake, ground-level photo images, harvester demographics, harvest data, and quotes of personal experiences from harvesters. We brought these narrative layouts (beyond the scope of this paper) to harvester community meetings to generate conversations around shared regional conservation.

4.3. Decision making for the opening of harvest

To gain insight into how wild rice lakes are opened for harvest we participated in management meetings for each of the jurisdictions and went along on a wild rice check in areas where that was occurring. Feedback on whether or not the opening date was appropriate was provided unsolicited from harvesters during the majority of interviews and landing visits.

5. Results

5.1. Regional characteristics: distribution of wild rice lakes and harvesters

5.1.1. Wild rice lakes distribution

Wild rice lakes are found in greatest abundance in the northern half of Minnesota and Wisconsin. Based upon this study, 1203 lakes contained wild rice from 1996 to 2006, varying in abundance from a fringe of plants along the lake edge to harvestable stands covering the entire lake. Distribution of wild rice across watersheds and ecoregions was established using our 1996–2006 wild rice lakes dataset.

A total of 328 watersheds were identified with wild rice, roughly 25% of all watersheds within Minnesota and Wisconsin. Comparing this data with the pre-1996 data set, watersheds with wild rice have declined 32 percent since the early 1900s (Fig. 3a).

Following the more recent classifications into ecoregions by Bailey (1995), the study area falls primarily within the Laurentian Mixed Forest Province, an area largely dominated by mixed hardwood and coniferous forest to the north, and to the south a transition zone to the eastern deciduous forest and prairie parklands. Although wild rice once grew outside of this region, the current distribution appears to fall within this ecological province.

The majority (82%) of wild rice lakes in MN and WI fall within the Laurentian Mixed Forest Province. Within this province, we see a

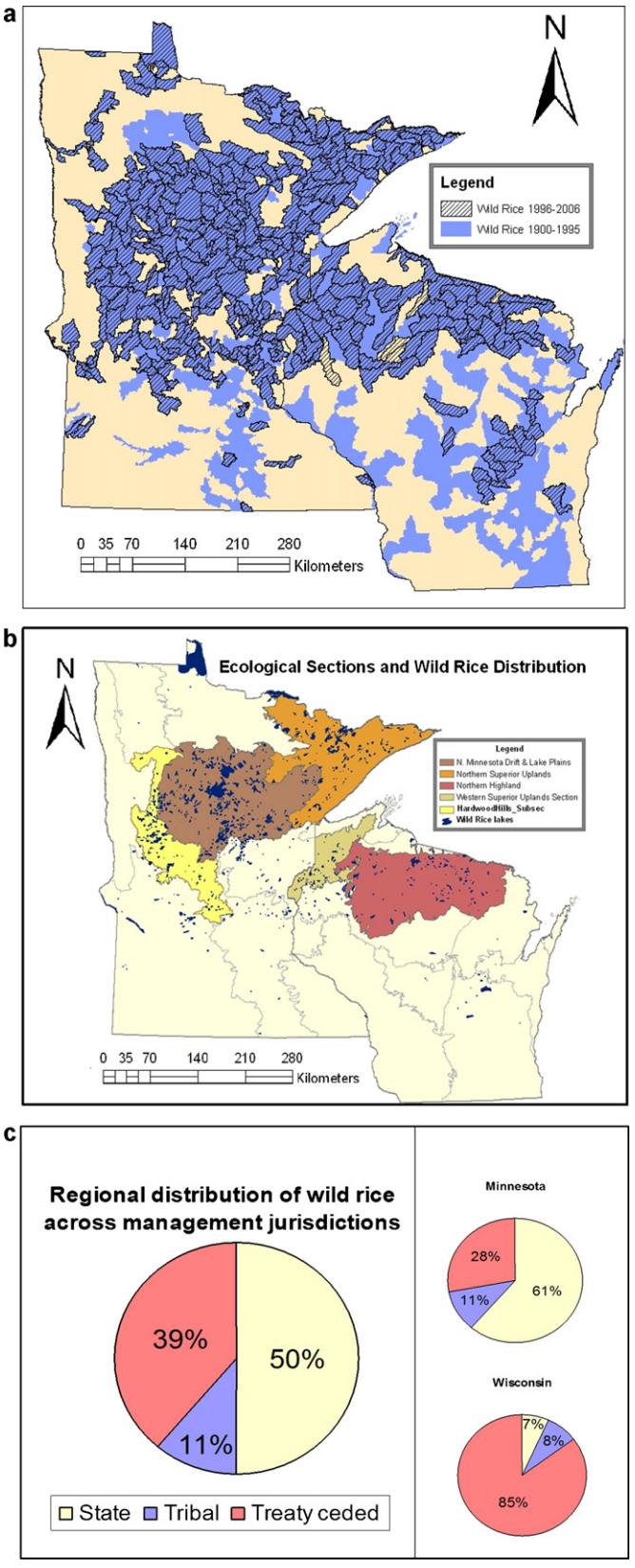

Fig. 3. (a) Change in watersheds with wild rice from historic to known current. Minnesota data from MN DNR. Wisconsin data from GLIFWC and Juniper Sundance (http://www.uwgb.edu/biodiversity/zizania/index.htm). (b) Wild rice lake distribution across ecological provinces and sections. (c) Distribution of wild rice lakes across management regimes.

concentration of wild rice lakes in the Northern Minnesota Drift and Lake Plains Section in Minnesota, extending through the Northern Superior Uplands (Fig. 3b). These two sections hold 70 percent of the known wild rice lakes. In Wisconsin 78 percent of known wild rice lakes fall within the Western Superior Uplands and Northern Highland Sections.

Regional analysis of lake distribution within the three jurisdictions show that state and treaty ceded jurisdictions each retain 50 and 39 percent of the total, respectively, while tribal reservations manage 11 percent (Fig. 3c). In Wisconsin, where nearly all of the wild rice lakes fall within treaty ceded territory (85%), GLIFWC (tribally affiliated) has primary jurisdiction. State and tribal authorities split the remaining 15 percent at seven and eight percent, respectively. Minnesota, conversely, maintains state management over 61 percent of wild rice lakes, with treaty authorities and tribal governments having 28 and 11 percent, respectively. An important point to recognize is that the percentages refer to the *number of lakes*, not the percent of wild rice acreage. Several of the largest beds of wild rice beds are found on large lakes within reservations.

5.1.2. Harvesting community

Harvesters of wild rice tend to live near where wild rice grows, as demonstrated by mapping zip codes of those who purchased seasonal wild rice licenses in 2005 and 2006 (Fig. 4a) The highest density of licenses sold were in zip codes within the wild rice range. Seasonal license sales in Minnesota nearly doubled from 2005 to 2006 (735 and 1396, respectively), as a result of poor rice production in 2005 and a better rice crop in 2006. Wisconsin maintained relatively stable numbers, selling 585 licenses in 2005 and 659 in 2006. Minnesota has both a daily license and a seasonal license, along with a non-resident license. To provide comparable numbers, only seasonal license data was used for this data set.

Age and gender demographics were also collected from license sales data, providing a look at a 'typical' state-licensed wild rice harvester. The average harvester is male, near the age of 48. While women do purchase state licenses and harvest, their numbers were few (17%). Licenses are not required for those under age 16 in both states, and in Wisconsin, those over the age of 65 also need not purchase a license.

Harvesting *experience* averaged 22 years, ranging from several first year harvesters to an Ojibwe elder who had harvested for 72 years. Average experience varied little between state and tribal harvesters (20 and 23 years, respectively), although it did vary between lakes (Fig. 4b). Rice lake was statistically different ($p < .0002$) than the others. Just over half of the harvesters in the study (51%) reported harvesting 21 years or more while 26% report five or less years of experience (Table 1).

Age began harvesting was significantly different between tribal and state harvesters ($p < .0001$), and between harvesters from each study lake ($p < .0001$) (Fig. 4c). Tribal harvesters began at an average age of 15 and state harvesters at 23 years. This number appears to be rising. A Minnesota DNR survey of harvesters in 2006 reported an average age of 31 years for beginning harvesting (Norrgard et al., 2007).

Comparing 'experience harvesting' (years) with 'age began harvesting', we found an interesting dynamic among harvesters in our study. Harvesters with less than five years experience (23% of total, $n = 32$) began harvesting, on average, at 25 years of age while harvesters with 35 years experience or more (25% of total, $n = 33$) started harvesting wild rice on average, at age 14. This difference is significant ($p < .00001$). These numbers suggest that today fewer youth may be harvesting and that harvesters in general are entering the rice beds at an older age, a trend supported by Wisconsin surveys (Davidson-Hunt and O'Flaherty, 2007).

Table 2
Average distance between zipcode of residence and lake harvested for each study lake.

Lake	Distance traveled			
	N	# of zip codes	Avg. distance (km)	Stdev
State (Minnesota)				
Upper rice	13	8	45	81
Mallard	46	23	106	79
Ceded territory				
Big Rice	17	7	68	95
Clam	25	8	20	17
Tribal				
Mud	37	8	38	14
Rice	9	1	5	0
Total/Avg.	147	55	58	

5.2. Patterns of harvest: spatial dynamics between harvesters and wild rice lakes

Site visits were made in August and September, resulting in 203 contacts and 147 useable responses, a 72 percent participation rate. Forty percent of those responding to on-site surveys ($n = 58$) were tribal harvesters, while sixty percent were state/non-tribal harvesters ($n = 89$). Interview participants came from this contact set and the resulting follow-up interviews involved 16 tribal harvesters and 33 state/non-tribal harvesters ($n = 49$).

Harvesters tend to live relatively close to the wild rice lakes they harvest, but will travel for an opportunity to harvest 'premium' wild rice. Distance between harvester zip code of residence and lake harvested averaged 58 km ($N = 147$), with a minimum average distance of 5 km for Rice Lake harvesters and a maximum average distance of 106 km for Mallard Lake (Table 2). Mallard Lake shows a distinct draw for harvesters from across the region, pulling in harvesters from the greatest distances and at the highest numbers (Fig. 5a). Follow-up interviews identified Mallard rice as being considered "premium" by both harvesters and buyers and commanding a higher price on the local markets due to its size and flavor.

Harvesters from state lakes averaged more than double the distance of travel (93 km) than those harvesters on treaty ceded (39 km) or reservation lakes (32 km). Again, Mallard, a state lake, was a large influence and on the opposite end of the spectrum was Rice Lake, a reservation lake, where most residents live within sight of the lake itself. Distance traveled maps for Big Rice (treaty-ceded) and Mud Lake (tribal) are also presented (Fig. 5b–d). The long commuters for Big Rice were people who grew up in the Ely area and then moved down to the cities (Minneapolis/St. Paul) for work, returning each fall to participate in the harvest.

Results from interviews shed more light on the variance in travel. Mallard Lake in Aitkin County, Minnesota, draws harvesters from distances in excess of 200 km. Harvest totals from this lake were highest among all study lakes, with total harvest in excess of 3000 lbs (1351 kg, $n = 10$), more than 1000 lbs (450 kg) higher than any other lake. Harvesters describe the rice as "premium," "healthiest, biggest heads" and "longer kernel. . .sought after." Individuals harvesting wild rice on Mallard also harvested on more lakes than other harvesters and harvested over 1000 lbs per person, on average, for the season (Fig. 6). Individual harvest amounts for the season ranged from a minimum of 20 lbs (9 kg) and a maximum of 2000 lbs (909 kg), giving an average of 512 lbs (233 kg) per person. Compared to surveys by the Minnesota Department of Natural Resources and GLIFWC, this average is high. GLIFWC's average in 2006 was 107 pounds, while 79 percent of respondents to the DNR survey reported harvesting less than 500 lbs of wild rice in 2006.

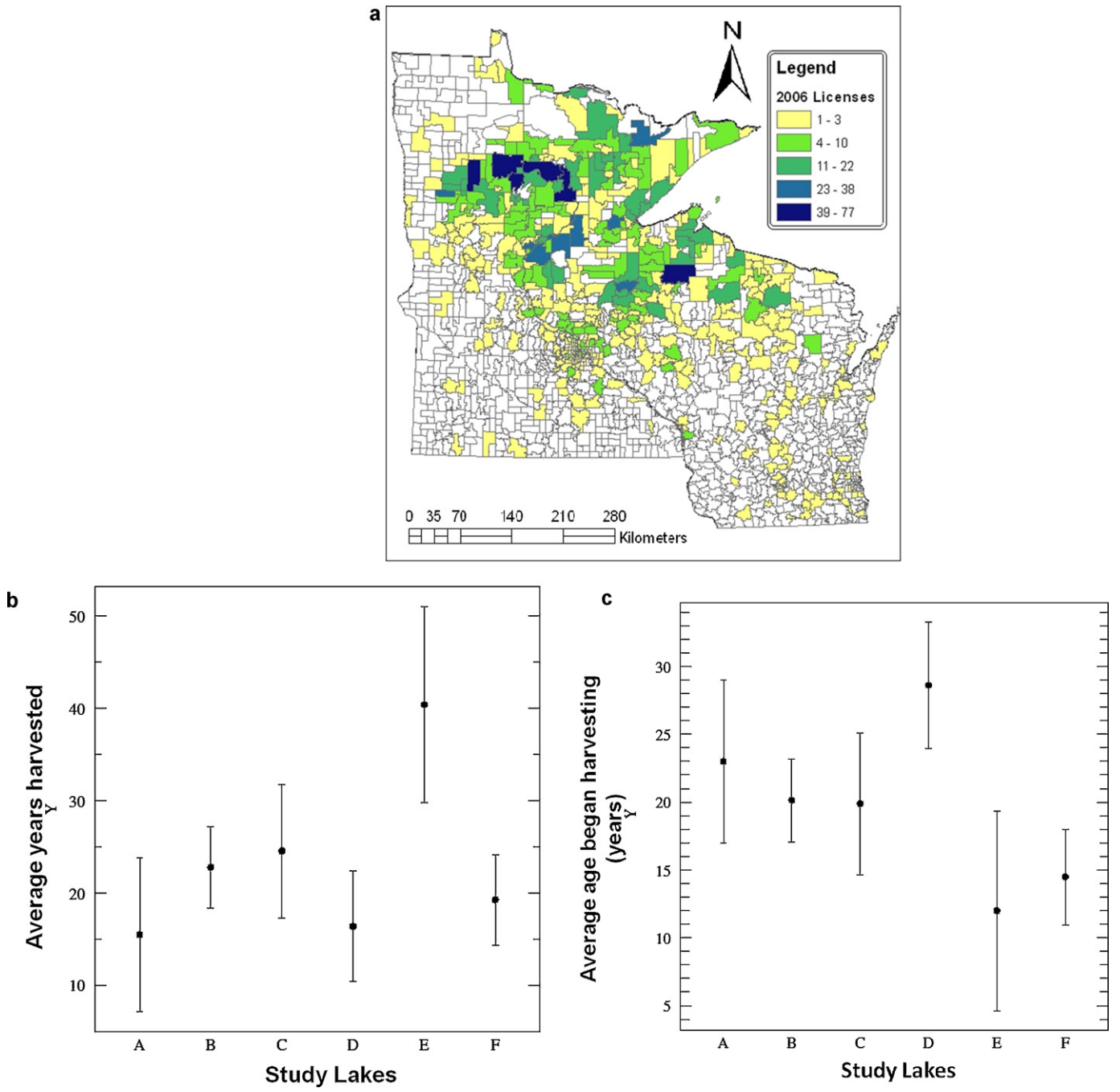

Fig. 4. (a) License sales for 2005 and 2006 combined, by zipcode. (b) Average experience harvesting wild rice by study lake: *State lakes* (A) Upper Rice; (B) Mallard; *Treaty ceded lakes* (C) Big Rice; (D) Clam; *Tribal Lakes* (E) Rice; (F) Mud. (c) Average age began harvesting by study lake: *State lakes* (A) Upper Rice; (B) Mallard; *Treaty ceded lakes* (C) Big Rice; (D) Clam; *Tribal Lakes* (E) Rice; (F) Mud.

5.3. Decision making for the opening of harvest

The decision to open a lake for wild rice harvest is often tied up in where it lays within the region. In the broadest sense, the season for harvesting wild rice typically runs from early to mid-August through late September. Officially in Minnesota regulations state that wild rice can be harvested from August 15 through September 30th and that "The harvest of "green" (unripe) wild rice is unlawful" (Minnesota DNR, 2011). The decision as to when a lake is ready for harvest is then left in the hands of the harvester. This 'one size fits all' opening date has the benefit of spreading out harvesters across many lakes.

On reservations and on date-regulated lakes in Wisconsin lakes are posted open for harvesting according to the recommendations of a representative from the state and a local tribal authority or by committee. In Wisconsin this accounts for less than half of the lakes harvested (52 out of roughly 125). The other non-date regulated Wisconsin lakes are open when ripe. Reservation lakes, such as Mud (Leech Lake Reservation) and Rice Lake (Mole Lake Sokaogon Reservation) are opened by committee. In both cases the committee has the option to open all or part of the rice lakes, and to even close them down for a day or two, or limit harvesting hours. Posting lakes open does tend to concentrate harvesters as they often want to be the first ones on the lake. The Leech Lake wild rice committee

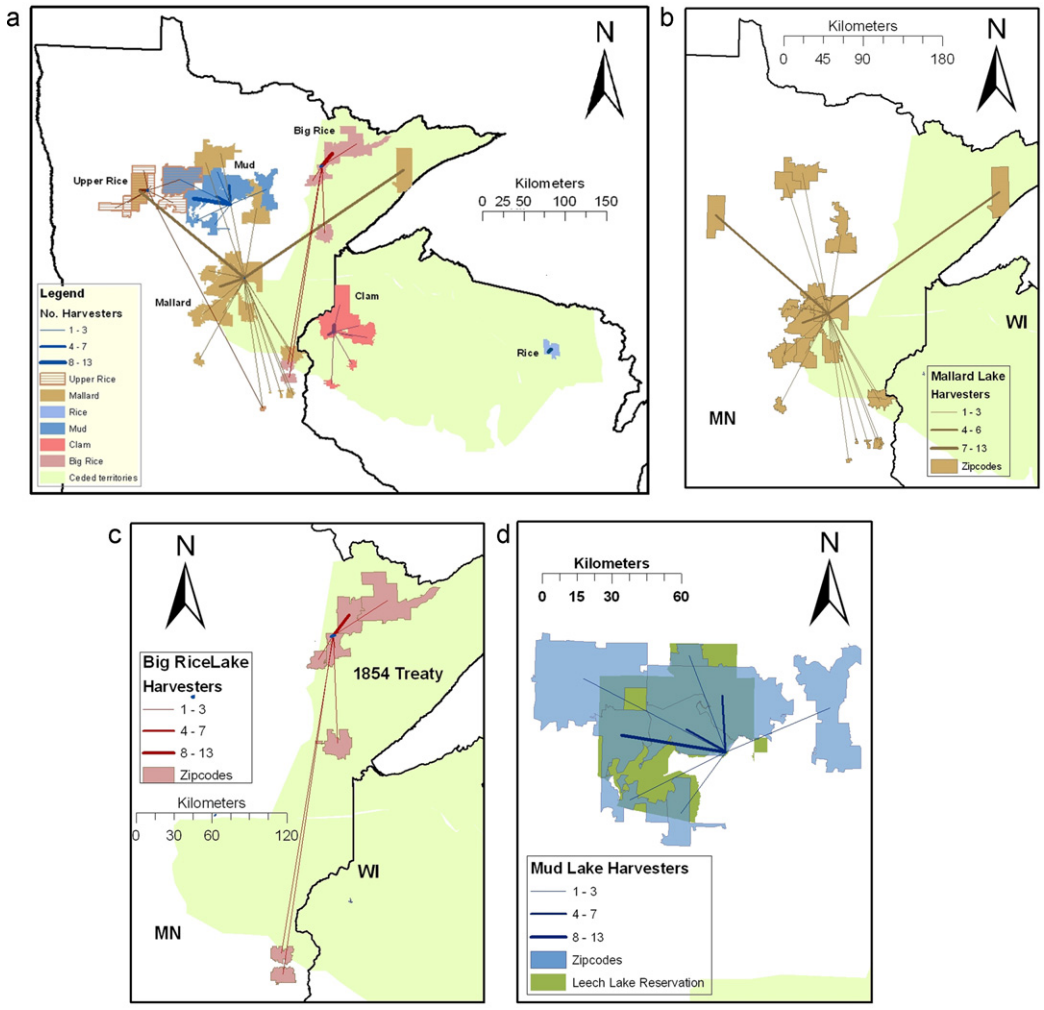

Fig. 5. Comparative distances from lake harvested to center of zipcode of residence for harvesters. Thickness of lines represents number of harvesters traveling from a particular zip code area to a wild rice lake. (a) Six study lakes, (b) Mallard Lake, Minnesota, (c) Big Rice Lake, Minnesota, (d) Mud Lake, Minnesota.

reduced this risk by not opening any beds until they had at least two different ones ripe, to spread out the harvesters.

Opening of rice beds in multi-jurisdictional waters can become an area of conflict and difficult enforcement. Border lakes, such as Natures Lake on the northern border of the Leech Lake reservation is split north and south, with the north end under state jurisdiction and the south end under tribal. Harvester conflicts arise due to the fact that non-tribal harvesters ricing on the north end disregard the tribal opening and harvest under the state rule of 'harvest when ripe,' often going out on the lake up to a week before the band is ready to post it open. Big Rice Lake, in St. Louis County, was posted open in 2005 for harvest by a committee including the Minnesota DNR, 1854 Treaty Authority and members of the Bois Forte and Grand Portage Bands of Ojibwe. With posting the bands can limit harvest by opening the lake to harvesters only every other day for the first week, as occurred in 2005. This is sometimes done to give the lakes a 'rest' from boat activity. In 2006 the Minnesota DNR decided not to allow posting on this state lake, which lies within the 1854 ceded territory, based upon a decision from upper management. Posting of lakes is a topic that will always draw a response from harvesters.

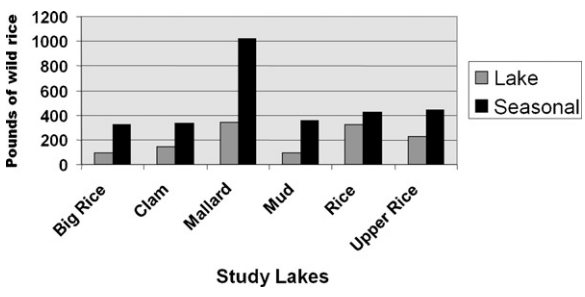

Fig. 6. Harvest averages by lake and season for people harvesting on study lakes.

6. Discussion

Wild rice distribution since 1900, based on watersheds, shows a 32 percent decline, primarily in the southern, more urbanized reaches of the wild rice landscape. Little is known about the causes of these declines as loss of wild rice is seldom documented. Aquatic plant management permit applications for wild rice removal and seasonal housing trends, which both show an increase in areas of wild rice growth, suggest that continued interaction between lakeshore owners and wild rice will only grow – to the detriment of the wild rice. On-going monitoring of wild rice abundance and area, conducted by both treaty-ceded organizations, shows potential for establishing a regional monitoring framework, but funding is a critical limiting factor. Trends and patterns occurring with wild rice on lakes outside of those directly managed remain unknown and undocumented.

The distribution of wild rice across jurisdictional units, particularly at the regional level, requires a cooperative approach if wild rice is to be maintained on the landscape. No formal coordination currently exists to address and identify the larger regional perspective of wild rice distribution, but co-management as implemented by GLIFWC and the 1854 Treaty Authority provide potential frameworks for creating a viable regional approach. Community-based conservation models are already in use across North America, recognizing both the unique knowledge and connections communities have to their surroundings and the importance of non-timber forest products to local economies (Baker and Kusel, 2003; Berkes and Folke, 1998; Davidson-Hunt and O'Flaherty, 2007).

Access to wild rice is most limited on reservations, where Ojibwe bands may restrict harvest to enrolled band members only. In light of the distribution of wild rice across management units, this restricted access affects only a relative few wild rice lakes. A much larger access issue to watch as it develops is the ability of non-residents to harvest wild rice in Minnesota. With nearly four times the number of wild rice waters than Wisconsin, Minnesota began to allow non-resident harvest of wild rice in 2004. Discussions with harvesters and managers overall suggest harvesting pressure is low as compared to thirty years ago.

The harvesting community, involving participants from both indigenous and Euro-American cultures, is an untapped resource. Harvesters on four of the six study lakes had 20 or more years of association with their individual wild rice lake, a knowledge source that should not be discounted. This association between harvester and lake reflects the potential wealth of local knowledge harvesters may have in regards to production and harvest on a particular lake over time, knowledge that may inform our understanding of wild rice landscapes. Similar long-term relationships are documented by Emery (2001) with harvesters of special forest products in Michigan.

Harvesters tend to harvest close to home, or the lakes they began on. This connection to local lakes and the average experience of 20 years for over half of all harvesters interviewed lays the groundwork for development of a community-based approach for wild rice. Local management regimes, such as the Sokaogon Mole Lake Band of Chippewa, operate on a level that currently involves wild rice harvesters participating in management and regulation decisions through established frameworks. The Leech Lake Band of Ojibwe, with a more extended area of management, still is able to involve harvesters in monitoring and assessment of wild rice through Advisory Committees and with input from the Tribal Council. But as the extent of the region and management reaches the state level, the connection is lost between harvester, management and individual lakes.

Conflicts between harvesters and between harvesters and management are often associated with decisions to begin harvesting, whether through posting or 'harvest when ripe' on state lakes. Holding lakes closed can run the risk of losing ripe rice should a storm, with winds and rain, knock the mature rice off the stalk. Going in early to a lake is considered to be detrimental to the plants and could impact further development of the grain. The range of views is influenced by the abundance of wild rice available to harvesters in the northern regions.

We confronted several challenges in this process that should be recognized when considering use of the resulting distribution maps. First, a consistent definition of "wild rice lake" does not exist across the region. How much wild rice must grow in a lake for the lake to be considered a wild rice lake? Lakes vary in their abundance and area of wild rice, from a fringe population to hundreds of hectares and both are included in existing data sets. Another challenge is the fluctuating nature of wild rice populations on any one water body. How often must a lake sustain wild rice (in years) to be considered a wild rice lake, and conversely, how long can a lake continue to be considered a wild rice lake without producing any growth? Additional research focused on a subset of lakes with limited or varying production is needed to address these questions. Finally, stream and river wild rice is not represented in this data set because methods for defining reach or location of rice along a waterway has hindered collection and as with the lake data sets, varied in their implementation across management jurisdictions.

7. Conclusions

Long-term sustainability of our endemic wild rice landscape is uncertain. Those who harvest wild rice understand the dynamics of this natural resource and value its presence on the landscape. Harvesting numbers appear to be declining however, and harvesters are aging. We cannot afford to discount the experience harvesters have, nor can we continue to look only at individual lake management.

Across cultures the introduction of youth to harvesting wild rice, and the participation of families appears to be quite low. Those interviewed often suggested that they had a difficult time getting their kids to harvest wild rice with them. The average age to begin harvesting is trending upward. Creating opportunities for families to learn about this traditional activity should be considered when looking at recruitment from a natural resource use perspective.

Those involved in the management of wild rice and the people who harvest this natural grain have limited opportunities to converse on a local or regional level about issues affecting this resource. GLIFWC holds an annual meeting consisting of DNR staff, tribal representatives and a few interested guests (trappers, wild rice harvesters) primarily to discuss the previous year's management efforts. Minnesota meets with tribal and state staff, and sometimes trappers, on a project-by-project basis, but does not hold an organized session for wild rice harvesters at a state level. No formal organization representing traditional hand-harvesters of wild rice exists within the wild rice region, making it difficult for harvesters to raise issues and engage in discussions with natural resource staff. Development of a community-based organization for wild rice management requires creating a co-management structure that shares responsibility and management power while creating a framework that builds trust and encourages stewardship and learning (Berkes, 2004). This is a challenge in a social–ecological system that includes harvesters with differing worldviews, cultural traditions and a history of strained relations and conflict around wild rice (Berde and Wild Ricing, 1980; LaDuke, 2005; Walker and Doerfler, 2007).

Identifying characteristics of wild rice distribution, harvest and management across multiple jurisdictions provides a beginning from which to build potential systems for addressing a shared regional conservation approach to wild rice and other social–ecological systems. Managers and harvesters have shown an interest in working towards a regional perspective, but were limited in organization and communication. This research greatly expanded communication among harvesters and managers and brought communities of the wild rice region together. In light of the significance of wild rice as both a cultural and natural resource in the Northern Great Lakes Region it is imperative that cooperative strategies be found to consistently monitor and assess the dynamics of this regional socio–ecological system.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ecolmodel.2011.09.015.

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